Stormwater Assessment Pilot Study in the Wai'ula'ula Watershed, West Hawai'i

<u>Volume 3</u>

Comparison of Typical Past Practices and a Proposed New Approach

Photo courtesy of USDA NRCS

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Executive Summary

Evaluating the effect of a proposed action on stormwater runoff is a required part of conducting Environmental Impact Assessments (EA or EIS) in Hawaiʻi. Assessment practices used in the last thirty years in Hawaiʻi were documented in the ***Stormwater Impact Assessment Project*** (Department of Geography and Environmental Studies and PBR Hawaiʻi, 2011), which was a precursor to the current study. In the current study, we have identified a specific approach for stormwater assessment that represents a typical past practice. We then applied this method to hypothetical future developments in the Waiʻulaʻula watershed in West Hawaiʻi. Results so obtained were compared to results obtained using a state-of-the-art quantitative modeling study, which is described Volume Two of this report. To place this work in context, we have reviewed existing studies and placed the hypothetical proposed development in the context of State and County general plans. In recognition of the limitations of past practices, the ***Stormwater Impact Assessment Project*** recommended a new method of stormwater assessment. We applied the "proposed new" method to hypothetical new developments in the Waiʻulaʻula watershed. In evaluating the effectiveness of this assessment process, emphasis was placed on *post*-construction impacts, because existing federal regulations require mitigation measures that adequately address construction-related impacts.

It is clear that typical past assessment practices lack the depth and scope needed to fully disclose anticipated impacts. In comparison, the proposed new method has the following advantages:

1) fuller disclosure of site conditions and watershed context;
2) incentives to incorporate green design elements, including a variety of low impact development best management practices (BMPs);
3) recognition that mitigation efforts are especially important for ecologically sensitive or impaired watersheds;
4) promotion of quantitative techniques for determining the effectiveness of mitigation measures; and
5) gives explicit consideration to TMDL load targets.

The following limitations of the proposed new method are noted:

1) Secondary and cumulative impacts are not explicitly addressed;
2) The narrow focus on Clean Water Act regulatory concerns neglects stream channel condition and impacts to pollution abatement functions of wetlands and riparian areas;
3) In certain categories of watersheds, the proposed method does not require the developer to propose and evaluate post-construction BMPs early in the process; and
4) The recommended methods of assessing watershed stress can be unrealistic in some watersheds.

Both qualitative analysis and quantitative modeling can be used in stormwater assessment. Both have their respective strengths, and one is not a substitution for the other. Cost is likely to discourage the routine application of models in the preparation of EIS.

Table of Contents

List of Tables and Figures

I. Purpose and Scope of Study

Evaluating the effect of a proposed action on stormwater runoff is a required part of the environmental assessment process in Hawaiʻi. Assessment practices used over the last thirty years in Hawaiʻi were documented in the ***Year-1 Stormwater Impact Assessment Project*** (Department of Geography and Environmental Studies and PBR Hawaiʻi, 2011), which was a precursor to the current study. The purpose of the current study was to both evaluate the effectiveness of past assessment practices and evaluate a new assessment method proposed in the ***Year-1 Stormwater Impact Assessment Project.*** To evaluate these two methods we applied them to hypothetical future developments in the Waiʻulaʻula watershed in West Hawaiʻi. The emphasis was on mitigation of post-construction impacts because existing federal regulations ensure satisfactory mitigation of impacts during the construction period. Results obtained using past assessment practices were compared to results obtained using a state-of-the-art quantitative modeling study, which is described in Volume Two of this report. Application of the proposed assessment method required the use of models to estimate the effectiveness of the proposed mitigation measures. To assist in the interpretation of results, we have reviewed existing studies and placed the hypothetical proposed development in the context of State and County general plans.

Section II of this Volume provides the context and background information on the Waiʻulaʻula watershed and Section III provides a description of the hypothetical proposed developments used for the analysis in this study. Sections IV and V of this Volume describe the application of the past and proposed methods and evaluate their ability to fully disclose direct, secondary, and cumulative impacts. Strengths and limitations of the methods are discussed. Recommendations for improvements in stormwater assessment methodologies are included in Volume One of this report.

II. Context and Background Information for the Wai'ula'ula Watershed

II.1 Existing Land Use Designations and Development Patterns

The Hawaiʻi Land Use Law (Chapter 205, HRS) places all lands in the State into four districts: Urban, Agricultural, Rural and Conservation. Lands in the Conservation District are managed by the State, and the jurisdiction over Rural and Agricultural Districts is shared by the State Land Use Commission (LUC) and counties. The counties have sole jurisdiction over lands designated as Urban.

Currently, 69.4% of the Waiʻulaʻula watershed is designated Conservation. Lands in the Conservation District, primarily in the upper reaches of the watershed, are managed by the Department of Land and Natural Resources (DLNR). Conservation lands in the Waiʻulaʻula watershed include the Kohala Watershed Forest Reserve and Puʻu o ʻUmi Natural Area Reserve. These lands are regulated for the purposes of conserving, protecting, and preserving the important natural resources of the State through appropriate management and use to promote their long-term sustainability and public health, safety, and welfare. Use of Conservation District lands requires a Conservation District Use Permit (CDUP) issued by DLNR. Changing land use designation from Conservation requires action by the LUC. There will be no changes to Conservation lands under "development" scenarios in the Pilot Study.

Just over 21% (21.2%) of the Waiʻulaʻula watershed is currently designated for Agriculture use. While State statute outlines permitted uses of higher productivity (*i.e.*, quality) lands, it also delegates responsibility for zoning within the Agriculture District to the counties. Under county ordinance, Hawaiʻi County has further subdivided the agricultural land designation into subzones, based on permitted uses (agriculture, family agriculture, intensive agriculture, etc.). For lands delineated as "important agricultural lands" or of greater than 15 acres, changing land use designation from Agriculture requires action by the LUC. The County Council has authority to make changes to land use district boundaries for land areas of 15 acres or less that are not designated "important agricultural lands."

The Hawaiʻi County General Plan (Hawaiʻi County 2005) assigns two types of agricultural lands in the Waiʻulaʻula watershed. The first, "important agricultural lands," are those with better potential for sustained high agricultural yields because of soil type, climate, topography, or other factors. These prime agricultural lands in the Waiʻulaʻula watershed are concentrated in the more *mauka* parts of the watershed, including the Lālāmilo Farm Lots and a band of grazing land on the slopes of Kohala Mountain. The remaining lands in the Waiʻulaʻula watershed are designated "extensive agriculture," which are lands that are not capable of producing sustained, high agricultural yields without the intensive application of modern farming methods and technologies due to certain physical constraints such as soil composition, slope, machine tillability and climate. These include the drier grasslands in the lower watershed, currently used for seasonal grazing.

While Chapter 205, HRS, also delegates responsibility for zoning within the Rural District to the counties, it specifies that only the following uses are permitted within Rural Districts: low density residential (minimum lot size is one-half acre); agriculture; golf courses, golf driving ranges and golf-related facilities; and public, quasi-public, and public utility facilities. Rural lands currently account for 0.5% of the land use designation within the Waiʻulaʻula watershed. For land areas of greater than 15 acres, changing land use designation from Rural requires action by the LUC. As a result of the legal decision regarding the Hokulia development in South Kona[1], it is anticipated that large-lot, suburban development previously permitted in the Waiʻulaʻula watershed on agricultural lands will now require LUC approval for a district boundary amendment to reclassify lands from Agricultural to Rural.

Management of lands within the Urban District is delegated entirely to the county, and uses are controlled by the county zoning code. In Hawaiʻi County, the Zoning Code (Chapter 25, HCC) lists the permitted uses within each zone, as well as the required setbacks, height limits, parking areas for commercial developments, and other controls. While there is little urban or suburban development within the Waiʻulaʻula watershed at this time, the County's Land Use Pattern Allocation Guide (LUPAG) map shows substantial areas designated for urban and suburban expansion. These areas will require a change in land use district classification, shifting management jurisdiction for these lands completely to the County.

Much of the land in the Waiʻulaʻula watershed designated in the Hawaiʻi County General Plan for future low-density urban development, urban expansion, rural development, and industrial use is currently designated Agriculture.[2] To change land areas of 15 acres or less from Agriculture to Urban or Rural designations will require enactment of an ordinance by the Hawaiʻi County Council. Changes greater than 15 acres will require action by the State's Land Use Commission.

II.2 Future Land Use based on the Hawaiʻi County General Plan

Generally, all development within the County must conform to the policies outlined in its General Plan (Hawaiʻi County 2005) and specific community development plans. The county general plan provides a coordinated set of guidelines for decision-making regarding future growth and development and protection of natural and cultural resources. The plan is given the effect of law through adoption by the County Council.

As a policy document, Hawaiʻi County's General Plan provides the legal basis for all subdivision, zoning, and related ordinances and will guide revisions to the county code. It also includes Land Use Pattern Allocation Guide (LUPAG) maps by district that show conservation, agricultural, rural, resort and urban areas, urban expansion areas, and open areas. These serve to guide the location, type, and intensity of different land uses. Generally, future developments must be consistent with the LUPAG map. According to the General Plan

> [t]here are no universal standards for determining the amount of land needed in the future for each land use or activity located within an area. Estimates can be made, however, of the future land use acreage allocation for each use. The land use pattern is a broad, flexible design intended to guide the direction and quality of future developments in a coordinated and rational manner. (Hawaiʻi County 2005; p. 14-7)

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[1] Circuit Court Judge Ibarra ruled in 2003 that Hokulia was an urban project being built illegally on agriculturally-designated lands. He based this conclusion on his findings that the State Land Use Law (Chapter 205, HRS) requires that housing on agricultural lands be related to agricultural use and such agriculture must be economically viable.

[2] The exception is the land *makai* of Queen Kaʻahumanu Highway, which is currently designated Urban.

In the Waiʻulaʻula watershed, the LUPAG identifies areas of urban expansion, rural and low density urban development, industrial use, and resort development. These are described in the Hawaiʻi County General Plan as follows:

> Low Density: Residential, with ancillary community and public uses, and neighborhood and convenience-type commercial uses; overall residential density may be up to six units per acre.
>
> Resort Node: These areas include a mix of visitor-related uses such as hotels, condominium-hotels (condominiums developed and/or operated as hotels), single family and multiple family residential units, golf courses and other typical resort recreational facilities, resort commercial complexes and other support services. Only Major Resort Areas are identified as Resort Nodes on the LUPAG Map.
>
> Urban Expansion Area: Allows for a mix of high density, medium density, low density, industrial, industrial-commercial and/or open designations in areas where new settlements may be desirable, but where the specific settlement pattern and mix of uses have not yet been determined.
>
> Industrial Area: These areas include uses such as manufacturing and processing, wholesaling, large storage and transportation facilities, light industrial and industrial-commercial uses.
>
> Rural: This category includes existing subdivisions in the State Land Use Agricultural and Rural districts that have a significant residential component. Typical lot sizes vary from 9,000-square feet to two acres. These subdivisions may contain small farms, wooded areas, and open fields as well as residences. Allowable uses within these areas, with appropriate zoning, may include commercial facilities that serve the residential and agricultural uses in the area, and community and public facilities. The Rural designation does not necessarily mean that these areas should be further subdivided to smaller lots. Most lack the infrastructure necessary to allow further subdivision. (Hawaiʻi County 2005, p. 14-7 to 14-8)

As noted above, much of the land in the Waiʻulaʻula watershed designated in the Hawaiʻi County General Plan for future low-density urban development, urban expansion, rural development, and industrial use is currently designated Agriculture. Changing these lands to different uses will require action by the Hawaiʻi Land Use Commission or Hawaiʻi County Council, depending on acreage.

The Hawaiʻi County General Plan calls for the development of community development plans to be adopted by the County Council. The South Kohala Community Development Plan (CDP) was developed with significant community input and adopted by the Council on November 20, 2008. It provides a long-term plan with a planning horizon to year 2020, consistent with the General Plan. Its purposes are to identify the community's priority issues and develop policies and action programs to address those issues.

The South Kohala District, which includes the Waiʻulaʻula watershed, has experienced rapid growth over the past two decades, and it is projected that the current population of the district could almost double by 2020 if current trends continue. The community voiced concern that levels of infrastructure and public facilities did not keep pace with population growth. Therefore, the CDP makes issues of housing and infrastructure to accommodate the growth of vital importance. According to the South Kohala CDP (Hawaiʻi County 2008), "future development pressures will inevitably impact … 'extensive agricultural' lands to be developed for other uses besides agriculture" (p. 25). At the same time, it includes a policy to encourage and promote LEED (Leadership in Energy and Environmental Design) standards for building and neighborhood design (U.S. Green Building Council 2005) by providing incentives for projects that achieve a LEED certification level of "Silver" or higher (p. 52). The CDP also notes that there may need to be some future policy aimed at moderating future population growth.

The South Kohala CDP identifies District-wide policies that address the following priority land use issues: preserve culture/sense of place; traffic and transportation; affordable housing; emergency preparedness; and environmental stewardship and sustainability. It specifically identifies a sub-policy for the District that directs the County to develop or collaborate with other agencies and organizations to develop watershed management programs for the district, as well as water quality monitoring (Hawaiʻi County 2008; p. 52).

The South Kohala CDP includes a Waimea Town Plan, providing general guidelines for the long-range future of Waimea Town. Among the recommendations that are relevant to the Waiʻulaʻula watershed are the following:

Strategy 2.1 The County should carefully evaluate and condition, as appropriate, any rezoning that would negatively impact important agricultural lands or culturally, visually and environmentally important open space or resources in Waimea.

Strategy 2.2 Work with Parker Ranch to phase the "Parker 2020" Development.

Strategy 2.3 Revise the County subdivision regulations and Planning Department policies and enforcement procedures to ensure that agricultural subdivisions are created for agricultural purposes and are not used for rural residential purposes without rezoning.

Strategy 2.4 Amend the County of Hawaiʻi's General Plan "LUPAG" map by reducing the acreage of "Low Density Urban" land in Waimea Town.

Strategy 2.5 Develop a secondary commercial center on the east end of town.

Strategy 3.1 Protect Important Agricultural Lands.

Strategy 4.1 Develop a Waimea Affordable Housing Program.

Strategy 4.2 Encourage policies that would provide more affordable rental units in Waimea.

Strategy 5.1 Plan, design, and construct walkways and bikeways within the existing rights of way of the main Waimea Roads: Kawaihae Road and Mamalahoa Highway.

Strategy 5.5 Implement short-term traffic mitigation improvements in and around Waimea Town Center.

Strategy 5.7 Design and construct the Lālāmilo connector road.

Strategy 5.8 Work with the State Department of Transportation to resolve the best alignment for the proposed Waimea/Kawaihae Road bypass highway.

The South Kohala CDP summarizes planned development projects in the Waimea area. These include: Department of Hawaiian Homeland's (DHHL) Lālāmilo Residential project which proposes 442 houses on 160 acres adjacent to both Waikoloa and Keanuʻiʻomanō streams, along with a community center, parks, general agriculture, preservation area (19.1 acres), and open space areas (44.5 acres); Parker Ranch's Waimea Town Center (2020) Plan, which calls for 750 new homes, rezoning of 37.66 acres to multiple-family residential, and increasing commercial lands by about 104 acres; and Waimea Parkside, a 40-lot subdivision on 9.18 acres in Waimea town across Lindsey Road from the park. Mauna Kea Resort is tentatively planning to develop a golf course and 135 large acreage residential lots with associated infrastructure and commercial use on its ʻŌuli 2 property near the bottom of the watershed.

II.3 Existing Environmental and Natural Resources Studies

Existing studies relevant to the Waiʻulaʻula watershed were identified and used to evaluate the status and trends of the watershed and associated ecosystems.

MKSWCD (2011) compiles and summarizes existing information about the land uses, resources and conditions of the Waiʻulaʻula watershed. The 17,000-acre watershed supports a variety of land and water uses, ranging from agriculture to urban to commercial to conservation. The natural environment at the top of the watershed contains significant native ecosystems; however, the remainder of the watershed has been altered by substantial human activity over centuries.

The primary streams within the Waiʻulaʻula watershed are Waikoloa and Keanuʻiʻomanō streams, which converge at about 1,400-ft. elevation to become Waiʻulaʻula stream. According to MKSWCD (2011), Keanuʻiʻomanō originates from two smaller intermittent tributaries, Waiʻaka (which becomes Lanikepu Stream) and Haleʻaha, as well as Kohākōhau stream, which is considered perennial. Other small intermittent streams join Keanuʻiʻomanō and Kohākōhau. Waikoloa stream has no tributaries and is considered perennial in the upper sections and intermittent in the lower reaches (CWRM 1990).

USGS has gauges on Waikoloa (USGS gauge number 16758000) and Kohākōhau (gauge number 16756100) streams, which provide real time data on streamflow via the Internet. These gauges are located at the 3,460-ft. and 3,470-ft elevations respectively. According to MKSWCD (2011),

> The average or "mean" annual daily flow at Waikoloa and Kohākōhau, the only streams that are currently gauged, is 9.12 cubic feet per second (cfs) (5.89 million gallons per day (mgd)) and 9.82 cfs (6.35 mgd), respectively[3]. However, this mean flow likely occurs only 20-30% of the time (Rick Fontaine, pers. comm.). It is probably more revealing to look at the median flow on the flow duration curves for these streams. The median daily discharge for Waikoloa

[3] Average ("mean") annual discharge for Waikoloa (data from 1948-2009) ranges from 3.87 cfs (1962) to 15.3 cfs (1998). Average annual discharge for Kohākōhau (data from 1999-2009) ranges from 4.51 cfs (2008) to 14.0 cfs (1999).

> stream is 4.3 cfs (2.78 mgd) and for Kohākōhau stream 2.2 cfs (1.42 mgd) (Oki 2007). Even this level of flow requires it to have rained recently (Rick Fontaine, pers. comm.). (p. 20)

Maximum instantaneous flow recorded at Waikoloa Stream was 3,410 cfs in November 1979. Data available for Kohākōhau Stream since 1998 indicate a maximum instantaneous flow of 1,860 cfs recorded in March 2004.

Because streamwater is withdrawn from both Waikoloa and Kohākōhau streams below the gauges, it is difficult to determine average streamflows in lower elevations. Hawai'i County Department of Water Supply (DWS) relies on the streams within the Wai'ula'ula watershed for its primary sources of water in the Waimea area, through its diversions of Waikoloa and Kohākōhau streams. Currently, an average of 1.427 million gallons per day of water is diverted from these streams (DWS 2006).

The *Rainfall Atlas of Hawai'i* (Giambelluca *et al.* 2011) provides isohyets maps which can be used for estimating rainfall across a watershed. Annual rainfall in the Wai'ula'ula watershed ranges from 120 inches in the upper elevations to less than 10 inches at the coast.

Flooding has been a chronic problem in the Waimea area. Flooding of downtown Waimea and of roads crossing streams has been a particular concern. The Federal Emergency Management Agency (FEMA) has developed Flood Insurance Rate Maps (FIRMs) for Hawai'i Island, including the Wai'ula'ula watershed. Areas along Waikoloa, Keanu'i'omanō, and Lanikepu streams in Waimea fall within Zone A, as well as along Wai'ula'ula stream at the coast. According to MKSWCD (2011), Zone A is the flood insurance rate zone that corresponds to the 1% annual chance floodplains that are determined in the Flood Insurance Study (FIS) by approximate methods of analysis. This translates into the 100-year floodplain. There is one small area within Waimea town that falls into Zone X500. Zone X500 corresponds to the 500-year floodplain.

Nance (2002) prepared a drainage analysis for the DHHL Lālāmilo Residential Project EIS to establish more accurate probable limits of flood inundation for Keanu'i'omanō, Lanikepu and Waikoloa streams. The analysis concluded that

> [f]or Lanikepu and Keanu'i'omanō Streams, the areas subject to inundation by the 100-year flood are considerably narrower than shown on FEMA Panel 155166 0164D. Waikoloa Stream's inundated area, with the single exception where the flow splits into two channels, is also relatively narrow. The drainage analysis determined that the capacities of the stream channels are generally sufficient to contain most of the flood waters. (DHHL 2002, pp. 4-10 to 4-13)

The Natural Resources Conservation Service (NRCS) developed an *Engineering Report for the Waimea Nature Park* in 2004, which provides detailed hydrologic and hydraulic analyses of the stream reach through the park (NRCS 2004). The hydraulic analysis determines the peak flood discharge rates at identified stream locations for various storm intensities, associated with recurrence intervals.

There are both native and alien aquatic species established in the streams of the Wai'ula'ula watershed (MKSWCD 2011). DLNR's Division of Aquatic Resources (DAR) conducts periodic surveys of the biota in Hawai'i's streams. Its Freshwater Database contains survey data from the State's perennial and intermittent streams, compiled from a variety of sources. The database identifies native and exotic species of fish, crustaceans, mollusks, insects, and algae, and notes the elevation at which the data were collected. The data date back to the 1960s. Data for the streams in the Waiʻulaʻula watershed were collected in 1968, 1990, 1992, 1994, 1999-2001.

Englund (2010) observed 4 of the 5 native stream fish species in various locations throughout the watershed, from the 2,700-ft. elevation to the Waiʻulaʻula estuary[4]. He notes that "[t]his indicates that native fish traverse long stretches of intermittent stream channels during periods of flowing water, using the ephemeral stream habitat as an access corridor to the headwater regions of upper Keanuʻiʻomanō Stream" (p. 11). Permanent stream pools (that likely receive groundwater input) in the drier parts of the watershed provide habitat for these species during their migration.

The presence or absence of aquatic species is often used as an indicator of stream and watershed health. Englund *et al.* (2007) found that endemic Hawaiian aquatic insects are better bio-indicators for Hawaiian stream health than the native stream macrofauna, because of their more specific habitat requirements (Englund 2010). In the Waiʻulaʻula watershed, Englund (2010) collected a total of 23 species of aquatic insects, of which 65% were native and 35% were introduced species. He noted that "[t]he relatively high 65% overall native aquatic insect biodiversity found within the entire Waiʻulaʻula watershed is comparable to other high quality streams" (p. 12). In the upper reaches of Keanuʻiʻomanō, Waikoloa, and Kohākōhau streams, native species are even more dominant, maintaining an exceptionally high diversity "equaling any high quality stream found in the Hawaiian archipelago" (Englund 2010, p. 12).

As part of the Waiʻulaʻula watershed management plan development process, the Mauna Kea Soil and Water Conservation District compiled existing water quality data and collected new data (MKSWCD 2011). The following information is taken directly from MKSWCD (2011):

> Autosamplers were used to collect stormwater runoff in three locations. Water was analyzed for nutrient and suspended sediment concentrations. At the Marine Dam site (where Waikoloa stream exits the high-elevation forest), the stream has relatively low concentrations of nitrate, ammonia, and orthophosphate (PO4). At the sampling site downstream of Waimea Town (Sandalwood site), ammonia concentrations doubled, total phosphorus concentrations (TP) more than doubled, and nitrate concentrations quadrupled, compared to the Marine Dam site. The average nitrate concentration just barely exceeded the water quality standard. The TP concentration was nearly twice the allowable amount. At the sampling site near the mouth of the watershed, total nitrogen was high, with measured concentrations nearly twice what is allowed by State water quality standards.

Nine samples of urban storm runoff were collected by taking grab samples of flowing water in parking lots, storm water running off roads, or from pipes that collect parking lot/road runoff. All sites were located in Waimea, and samples were collected between November 2008 and April 2009. Based on this limited amount of data, it appears likely that runoff from high use paved areas exceeds water quality criteria for sediment (by a factor of five), total phosphorus (by a factor of four), total nitrogen (by a factor of three) and

[4] Englund's (2010) survey found *Lentipes concolor* (ʻoʻopu alamoʻo), *Awaous guamensis* (ʻoʻopu nākea), *Eleotris sandwicensis* (ʻoʻopu ʻakupa), and *Stenogobius hawaiiensis* (ʻoʻopu naniha). The fifth native species, *Sicyopterus stimpsoni* (ʻoʻopu nōpili), was observed previously in the 1992 DAR survey.

nitrate (measured values were only slightly greater than the standard). These results are not surprising, as urban storm runoff is usually high in sediment and nutrients.

During the period July 2006 through April 2008, the Department of Health (DOH) made frequent measurements of water quality at a number of coastal sites. Measurements in the nearshore waters of Kawaihae Bay at Waiʻulaʻula were taken on 33 separate days. Comparison of measurements against the water quality standards shows that the Bay has too much ammonia (concentrations are 2.8 times more than what is allowed) and too much chlorophyll (concentrations are double what is allowed). The high chlorophyll levels indicate that there is too much algae. It is likely the high ammonia levels are contributing to high excess algae. Because ammonia is rapidly converted to nitrate in the presence of oxygen, it is likely that the source of the ammonia is nearby. The measured nitrate and total nitrogen concentrations are near the standard. Total phosphorus concentrations are slightly above the standard.

As part of the development of the Waiʻulaʻula watershed management plan, MKSWCD (2011) also estimated pollutant loads within the watershed. “Loads” are the total amount of a pollutant that is exported from a watershed. Loads are usually measured in pounds (of Nitrogen, Phosphorus, or Sediment) per year. Annual loads were estimated for the watershed using NOAA’s Nonpoint Source Pollution and Erosion Comparison Tool (N-SPECT) model. The model’s estimate of sediment concentration (TSS) was about 20% higher than the measured concentration at the Marine Dam autosampler and more than double the measured concentration at the lower edge of the town of Waimea. It is possible that NSPECT under-estimated the amount of sediment that is re-deposited a short distance from where it was eroded. Or, it is possible that some of the RUSLE/MUSLE coefficients are not appropriate to Hawaiʻi. On an average annual basis, the model predicts that the nitrogen load from the watershed is approximately 23,000 kg or 1.4 kg/acre/year, while the predicted phosphorus load is 2,176 kg or 0.129 kg/acre/year (Gaut 2009). When compared to other watersheds in Hawaiʻi, N-SPECT produced reasonable estimates of nitrogen and phosphorus loads; however, the limited water quality data collected by autosamplers within the Waiʻulaʻula watershed suggest these estimates may be high (Gaut 2009).

III. Description of Hypothetical Proposed Developments

III.1 Location and Proposed Uses

This study examines the possible impact of development in areas of the Wai‘ula‘ula watershed that are currently undeveloped but slated for future development under the Hawai‘i County General Plan and Land Use Pattern Allocation Guide (LUPAG). Fourteen parcels meeting this description were identified, including one resort parcel, one rural parcel, one industrial parcel, six small parcels slated for low density urban use, and four slated for urban expansion.[5] Seven parcels were singled out for analysis using past assessment methods (Table 1 and Figure 1). These included the resort, rural, and industrial parcels, two low-density urban parcels (one with high rainfall and one with low rainfall), and two urban expansion parcels (one with high rainfall and one with low rainfall).

Table 1. Study parcels that will be "developed" and analyzed for stormwater impacts.

Parcel	LUPAG designation	Acres	Climate and location
2	Resort	31.93	Dry, near coast
3	Rural	249.25	Dry, low elevation
5	Low density urban	56.41	Near Waimea, wetter and steeper than parcel 9
9	Low density urban	55.20	Near Waimea, drier than parcel 5
11	Urban expansion	159.02	Dry, low elevation
12	Urban expansion	199.79	Wet, near Waimea
14	Industrial	192.85	Dry, flat ground, several miles from Waimea

[5] See Section 3.1 of Volume Two for the methods used to identify and delineate parcels.

III.2 "Business as Usual" Development Parameters

In recent years, a number of new developments have been proposed for West Hawaiʻi. These include the ʻOʻoma, Keahuolū, ʻĀina Leʻa, Lālāmilo, and Kaloko Makai projects[6]. Data from the Environmental Impact Statements (EIS) for these projects were used to estimate realistic development parameters for the hypothetical developments.

In the aforementioned five proposed developments, the percentage of land within the projects that was designated for open space ranged from 1% to 34% (average 14.4%). The percentage of land designated for commercial activities ranged from 1% to 12% (average 4.4%). The percentage of land designated for residential lots ranged from 65% to 84% (average 72%). Within the residential zone, the housing density ranged from 2.7 to 8.6 units per acre (average 5.9). These data were used to estimate development parameters for each of the LUPAG designations found in the Waiʻulaʻula Watersheds "proposed" (hypothetical) developments.

Table 2. Land use within each LUPAG category.
Values are estimates based on similar developments proposed in West Hawaiʻi.

LUPAG Designation	% area open space	% area commercial activities	% area industry	% area residential lots	Housing density in residential area (units/acre)
Rural	10	0	0	90	2
Resort	25	5	0	70	7
Low density urban	20	1	0	79	5
Urban expansion	5	20	0	75	10
Industrial	0	50	50	0	N/A

[6] EIS can be obtained from http://hawaii.gov/health/environmental/oeqc/index.html/. The projects examined for this study are all in Hawaiʻi County. They are: The Villages of ʻĀina Leʻa, Waikoloa, South Kohala District (2010); ʻOʻoma Beachside Village, North Kona (2009); the Keahuolū Affordable Housing Project, Kailua-Kona, North Kona (2008); Lālāmilo Residential Lots and Commercial Industrial Mixed Uses (2002); and Kaloko Makai, Kaloko and Kohanaiki, North Kona (2011).

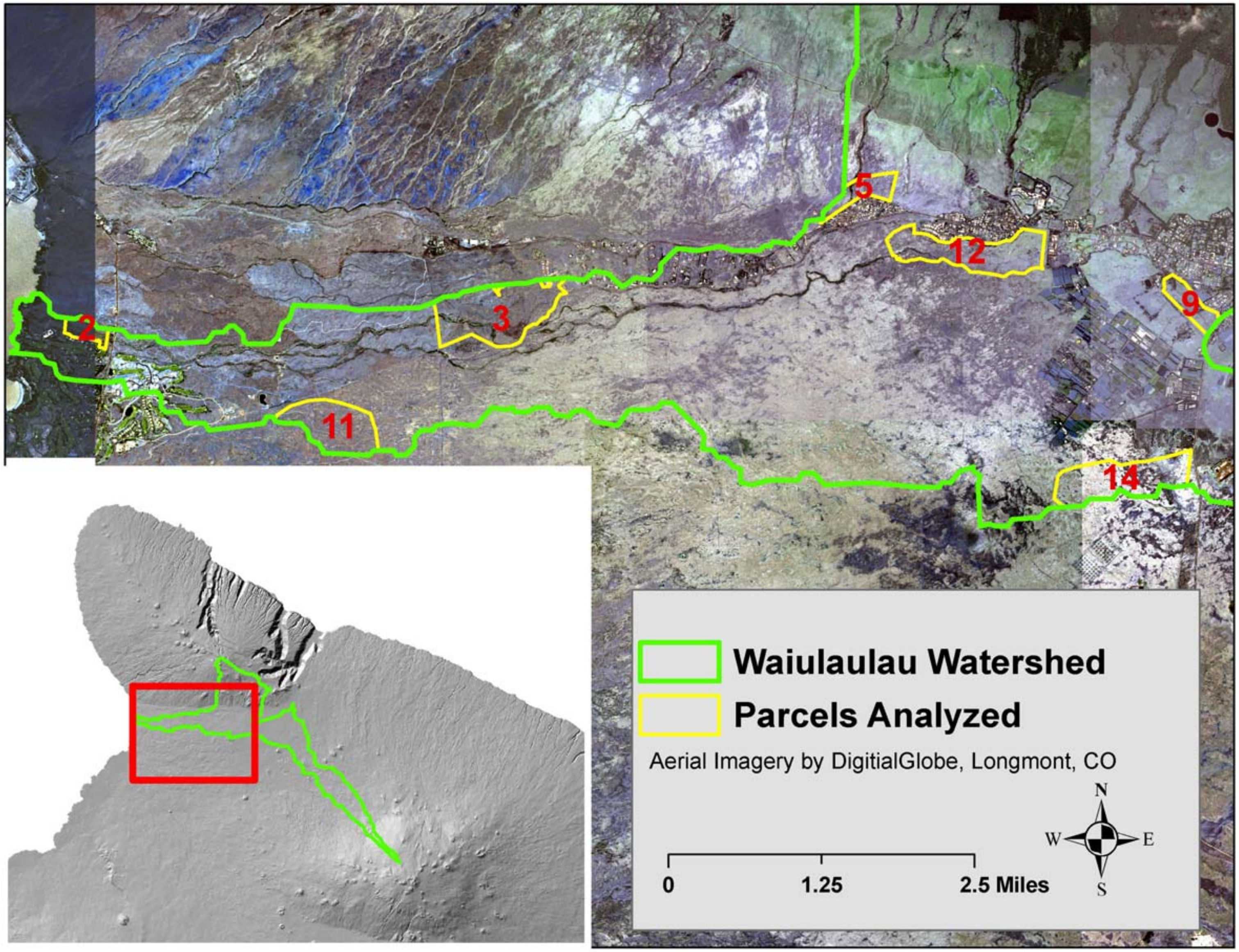


Figure 1. Parcels analyzed using the Typical Past Practice.

In most actual developments, there are several levels of residential density. For example, there could be multi-family housing and single family housing, or low-density and high-density residential neighborhoods. The range of densities is important when calculating percent impervious area. For the purpose of this study, therefore, it was assumed that resort and urban developments have a mix of higher density and lower density lots (Table 3). Values in Table 3 were selected to reflect likely future development patterns and be consistent with the average residential densities shown in Table 2, which are based on similar developments proposed in West Hawaiʻi during the last 10 years.

Table 3. Development parameters for each LUPAG category.
Values are estimates based on similar development proposed in West Hawaiʻi.

LUPAG Designation	% area low-density residential lots	Housing density low-density neighborhoods (units/acre)	% area high-density residential lots	Housing density high-density neighborhoods (units/acre)
Rural	90	2	0	no high-density housing
Resort	40	5	30	10
Low density urban	50	4	29	7
Urban expansion	50	8	25	14

Washburn *et al.* (2010) have developed guidance on percent impervious area for various land uses and residential densities (Table 4 and following discussion). Their methods have been adopted by several organizations, including the California Office of Environmental Health Hazard Assessment (http://www.oehha.ca.gov/ecotox/isc072208.html). For residential neighborhoods, the percent impervious surface is given by $-23.04 + 49.61\ \mathbf{DU}^{0.2196}$, where **DU** is units per acre.

Table 4. Impervious area for different land uses.
See text for values appropriate to residential development.

Land Use	% impervious surface
Commercial (retail and ≤ 25% offices)	86
Industry (assuming 50-50 mix of heavy and light industry)	86
Open spaces	2

The final development parameters for each parcel (Table 5) were calculated by combining information from Tables 1, 2, 3, and 4.

Table 5. Development parameters for each parcel.

Parcel	LUPAG	Total Acres	Commercial Acres	Residential Units	% Impervious Area
2	Resort	31.9	1.6	160	42
3	Rural	249.3	0	449	31
5	Low density urban	56.4	0.6	227	39
9	Low density urban	55.2	0.6	223	39
11	Urban expansion	159.0	31.8	1193	61
12	Urban expansion	199.8	40.0	1499	61
14	Industrial*	192.9	-	0	86

* The industrial parcel is assumed to be a 50-50 mix of light industry and heavy industry.

III.3 Alternative Development Parameters

Low Impact Development (LID) is defined as a more sustainable land development pattern than the conventional method currently used in most areas. It incorporates a suite of landscaping and design techniques known as "Better Site Design" that attempt to maintain the natural, pre-development hydrology of a site and the surrounding watershed. According to Horsley Witten Group (2006), the goals of LID include:

- "Prevent environmental impacts rather than having to mitigate for them;
- Manage water (quantity and quality) as close to the source as possible and minimize the use of large or regional collection and conveyance;
- Preserve natural areas, native vegetation and reduce the impact on watershed hydrology;
- Use natural drainage pathways as a framework for site design;
- Utilize less complex, non-structural methods for stormwater/wastewater management that are lower cost and lower maintenance than conventional structural controls; and
- Create a multifunctional landscape." (p. 1-2)

Stormwater LID practices and techniques fall within three categories: preservation of natural features and conservation design; reduction of impervious cover; and utilization of natural features and source control for stormwater management. LID practices selected for the alternative scenario in the Waiʻulaʻula parcels include:

- Bioretention and rain gardens
- Minimize site disturbance / reduce clearing/grading
- Minimize site impervious area
- Minimize right-of-way impervious surface
- Cluster development
- Stormwater dry well cartridge filtration
- Preservation of buffers
- Vegetated buffer / filter strips
- Open vegetated channels
- Infiltration trenches
- Permeable paving

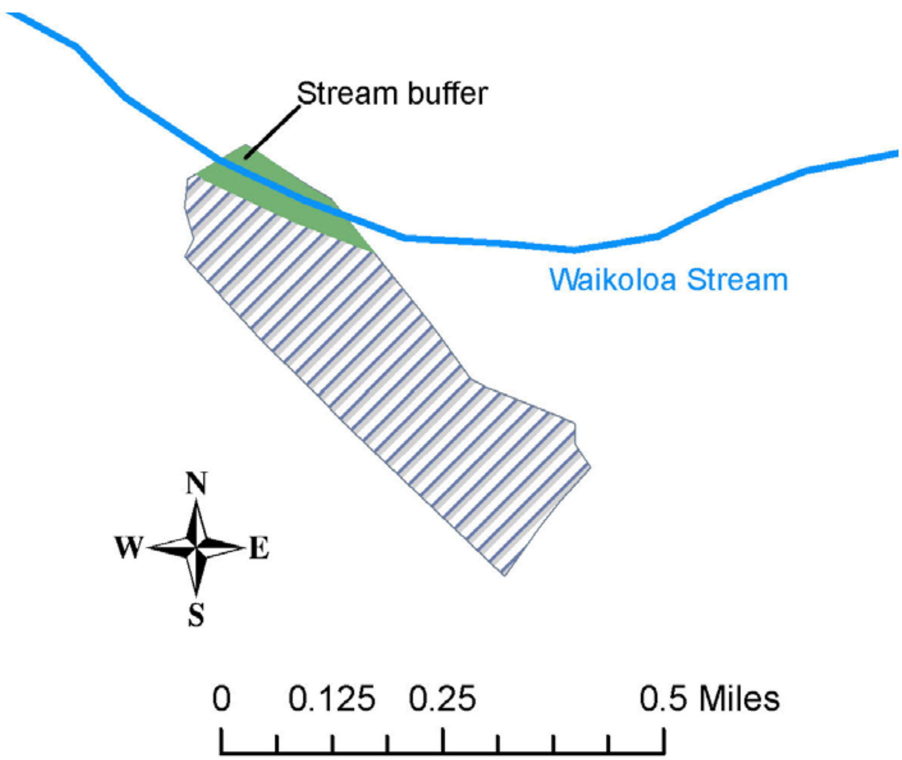


Figure 2. Stream buffer (45 m per side) at Parcel 9 (a low density development).

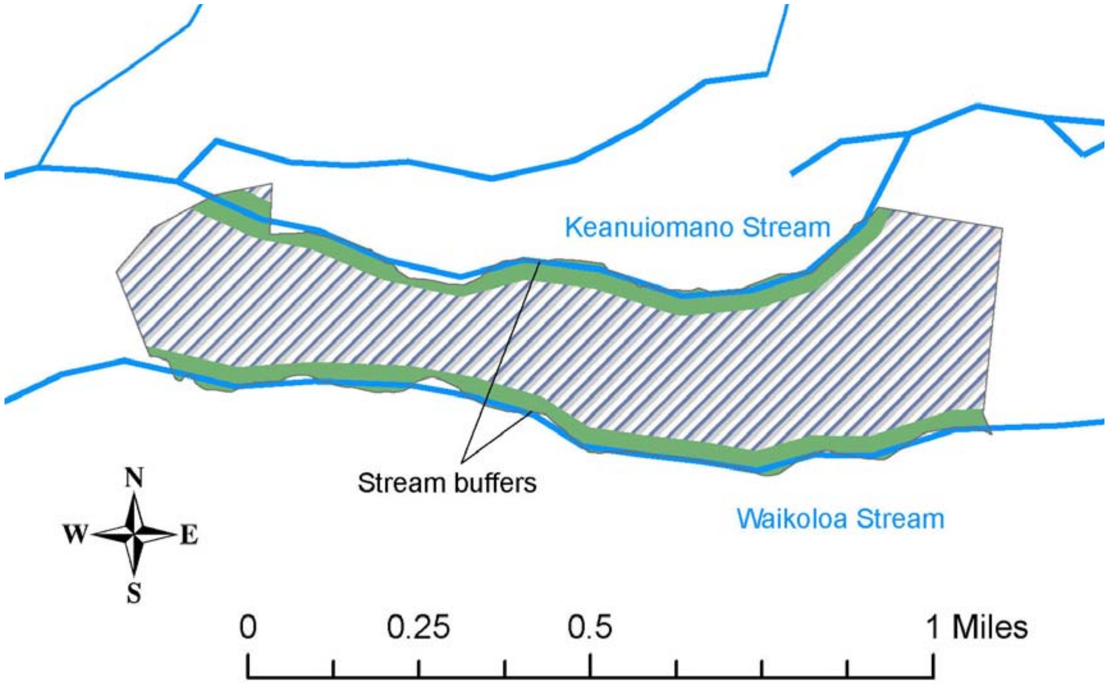


Figure 3. Stream buffer (45 m per side) in Parcel 12 (a high intensity development).

IV. Stormwater Assessment (Typical Past Practice)

IV.1 Method

In the past, EIS have employed a variety of approaches to assessing the impacts of proposed developments on stormwater. Assessment practices used in the last thirty years in Hawaiʻi were documented in ***Final Report Stormwater Impact Assessment Project*** (Department of Geography and Environmental Studies and PBR Hawaiʻi, 2011), hereafter referred to as the ***Year-1 Report***. The ***Year-1 Report*** concluded that there is no standard stormwater assessment procedure. Some EIS made no attempt at assessment at all, while the others varied in scope. In spite of the diversity of past approaches, there were certain elements that were employed more often than not. These frequently-employed elements can be considered to constitute a "Typical Past Practice" for stormwater assessment (Box 1). Steps 1-6 and 8-9 of the Typical Past Practice (Box 1) are assessment tools that were employed by at least 50% of the EIS examined in the ***Year-1-Report***. For cumulative impacts[7], however, there was such a broad range in the depth of analysis that no single method could be considered typical. We therefore considered the Typical Past Practice for assessing cumulative impacts (Step 7 of Box 1) to be the method that was at the median in terms of depth of analysis (half of EIS used more detailed analyses and half used less detailed analyses).

The Typical Past Practice for stormwater assessment (Box 1) has three components: (1) compilation of relevant data, (2) general discussion of likely impacts, and (3) proposals for mitigating impacts. The Typical Past Practice is fairly limited in scope and does not quantify impacts.

[7] Cumulative impacts are defined as those that arise from the sum of all past, present, and reasonably foreseeable future actions. Cumulative impacts can arise from individually minor but collectively significant actions taking place over a period of years.

Box 1. Steps in assessing stormwater impacts (typical past practice).

A. Compilation of Relevant Data

1. **Rainfall.** Average annual or median rainfall at the location of the proposed development.
2. **Topographic slope.**
3. **Soil type.**
4. **Soil erodibility.**
5. **FEMA flood hazard zones within the proposed development.**

B. Discussion or Assessment

6. **Discuss anticipated construction-related erosion impacts.**
7. **Identify whether or not there is a potential for cumulative impacts.** **“**Identification” is in a very general sense and does not extend as far as discussion or analysis.

C. Identification of Proposed Mitigation Actions

8. **Description of proposed mitigation measures intended to reduce construction-related erosion.** This may take the form of commitments to use standard best management practices.
9. **Description of proposed mitigation measures intended to reduce post-construction erosion.** As an example, mitigation measures might include building sediment collection basins, planting vegetation, or placing non-development buffers around natural drainage features.

IV.2 Results

Part A. Compilation of Data

Table 6. Descriptive data for parcels slated for future development

Parcel	Rainfall [1] (Inches/year)	Average Topographic Slope (deg)	Soil Type[2]	Soil Erodibility Classification[3]	FEMA flood hazard zones[4]
2	10.5	4.4	Kawaihae extremely stony very sandy loam (KNC)	Potentially highly erodible	A, X
3	18.0	4.4	KNC (47%) and PVD (53%)	Potentially highly erodible	X
5	41.8	8.1	Waimea very fine sandy loam (WMC)	Potentially highly erodible	X
9	27.6	1.3	Waimea very fine sandy loam (WMC)	Potentially highly erodible	A, X
11	13.2	4.1	Kawaihae extremely stony very sandy loam (KNC)	Potentially highly erodible	X
12	35.7	3.9	Waimea very fine sandy loam (WMC)	Potentially highly erodible	A, X
14	15.0	1.4	Pu'u Pa extremely stony very fine sandy loam (PVD)	Potentially highly erodible	X

[1] *Annual: Rainfall Atlas of Hawai'i (Giambelluca et al. 2011)*

[2] *From Natural Resources Conservation Service (NRCS) SSURGO database and maps (Soil Survey Staff, 2007).*

[3] *Classification of soil erodibility from water. From NRCS SSURGO database and maps (Soil Survey Staff, 2007).*

[4] *Flood hazard zone A "is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by approximate methods" and zone X "is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, and to areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees" (Digital Flood Insurance Rate Map).*

B. Discussion or Assessment

Anticipated construction-related erosion impacts

Urban developments can have a negative impact on the hydrology and water quality of a watershed, including increased runoff volumes and pollutant loadings. During construction, vegetative cover is stripped from the land and cut and fill activities that enhance the development potential of the land occur. This large scale grading, grubbing and earthwork leave bare soil exposed to wind and rain erosion. Stock-piling of construction material and fill onsite can also contribute sediment to water bodies within the watershed in the event of high winds or rain events. In areas of low rainfall, developers are often surprised when a major storm event catches them unprepared. Construction activities can also alter an area's hydrology and natural drainage features by increasing slopes, creating new and modifying existing channels and conveyances, and damaging protective riparian buffers.

Hydrological changes to a watershed are magnified after construction is completed. Impervious surfaces, such as roads, parking lots, sidewalks, and rooftops, decrease the infiltration capacity of the ground and result in greater volumes of runoff, increased potential for flooding, and greater runoff velocity during storms due to the combined effects of higher peak discharge, rapid time of concentration, and the smoother hydraulic surfaces that occur as a result of development (EPA 1993). The types of pollutants in runoff also change following development. Whereas sediment may be the primary pollutant from an undeveloped landscape, in urban or suburban areas, pollutants also include nutrients (fertilizers), pesticides, heavy metals, petroleum hydrocarbons, and pathogens.

The majority of parcels slated for development in the Waiʻulaʻula watershed are adjacent to or upslope of stream channels, making conveyance of construction and post-development runoff a potentially significant impact on watershed resources.

Identify whether or not there is a potential for cumulative impacts

With multiple large developments already proposed for the Waiʻulaʻula watershed and other watershed areas slated for urban and suburban expansion under the County's LUPAG, there is significant potential for cumulative impacts on water quality and watershed health. Each new development increases the overall imperviousness of the watershed. Developments planned and permitted without regard to their incremental effects when added to other past, present, and reasonably foreseeable future projects may result in unintended but serious environmental effects.

C. Identification of Proposed Mitigation Actions

Proposed mitigation measures intended to reduce construction-related erosion and runoff

According to Chapter 10, Hawaiʻi County Code, grading and erosion control plans must be prepared and approved before a permit is issued for a development project. These plans must include existing and proposed contours, erosion and sediment control measures, limits of grading providing proper setbacks from the property lines, location of any structures or easements, and any drainage patterns or devices. For construction activities, including clearing, grading, and excavation, that result in the disturbance of one or more acres of total land area, a National Pollutant Discharge Elimination System (NPDES) permit from the Hawaiʻi Department of Health is required. A County grading permit is required for any grading and grubbing work before a NPDES permit can be issued. The grading permit allows the grading, while the NPDES permit regulates stormwater runoff from the construction site.

In Hawaiʻi County, all urban developments (with very few exceptions) have been mandated to maintain pre-development runoff conditions. Pre- and post-development runoffs are calculated using the County

“Storm Drainage Standard.” The minimum criteria used for runoff calculations are a 1-hour, 10-year storm event. This requirement inhibits conveyance of development runoff into natural drainage systems.

These permit processes require, as permit conditions, a commitment to use standard best management practices to control erosion and stormwater discharges. Construction site erosion and sediment control management practices include:

– schedule projects so clearing and grading are done during the time of minimum erosion potential;
– stage construction;
– clear only areas essential for construction;
– locate potential nonpoint pollutant sources away from steep slopes, water bodies, and critical areas;
– protect natural vegetation;
– cover or stabilize topsoil stockpiles;
– use wind erosion controls;
– intercept runoff above disturbed areas and convey it to a suitable outlet, such as a sediment basin;
– establish vegetative cover on disturbed areas as quickly as possible;
– establish sediment basins or sediments traps;
– use filter fabric fence, straw bales, or other barriers to detain to filter construction runoff.

Proposed mitigation measures intended to reduce post-construction runoff and erosion

As noted above, Hawaiʻi County requires most urban developments to maintain pre-development runoff conditions after construction has been completed and the site is permanently stabilized. This is commonly done in Hawaiʻi County through the use of dry wells to capture runoff from roadways and other impervious surfaces. Other possible mitigation measures include:

– infiltration basins or trenches;
– vegetated filter strips;
– grassed swales;
– planted vegetation;
– non-development buffers around natural drainage features;
– porous pavement and permeable surfaces;
– concrete grid pavement;
– constructed wetlands.

IV.3 Comparison with N-SPECT Assessment

In a separate study, NOAA's Nonpoint-Source Pollution and Erosion Comparison Tool (N-SPECT) model was used to quantify the impact of proposed development on runoff for the 24-hour 2-year design storm and associated loads of total nitrogen and total phosphorus. N-SPECT was also used to predict changes to average annual soil erosion, calculated using the Revised Universal Soil Loss Equation (RUSLE). Key results are summarized below for the seven study parcels. Refer to Volume Two for more details.

N-SPECT predicts that development will *decrease* soil erosion (Table 7). Erosion will not be discussed further in this section.

According to the N-SPECT model, most parcels slated for development under resort, rural, or low density urban designations will see increased runoff and nutrient loads (Table 7). These increases are an order of magnitude lower, however, than increases predicted for parcels designated for urban expansion or industrial development. The model predicts that development of parcels slated for "urban expansion" will increase runoff and nutrient loads by at least 400%. Similar results are obtained for the industrial parcel. While these increases are locally significant, they are nonetheless small in the context of the entire 17,000 acre Wai'ula'ula watershed. For example, development increases the nitrogen load of parcel 12 by 423%. This amount of increase represents only 2.2% of the nitrogen load for the entire watershed, however. In the absence of a TMDL, it is difficult to judge whether 2.2% is significant. Similar interpretation issues arise when evaluating cumulative impacts of development.

N-SPECT can be used to predict how runoff volume and nutrient loads will change if the watershed is fully developed according to Hawai'i County's LUPAG (Figure 2). The "full build out" scenario in Figure 2 represents fourteen "proposed" developments that include most of the land that is currently undeveloped but slated for future development. (The fourteen developments include but are not limited to the seven that are the focus of this study.) There is some difficulty in interpreting the modeling results because we do not have guidance on how much extra runoff (or load) is too much. A TMDL is required to address significance, and the Wai'ula'ula watershed does not have a TMDL. On the other hand, N-SPECT *does* provide interesting estimates of runoff/loads/erosion originating from non-urbanized portions of the watershed (mostly forested lands within the conservation district or grazing lands within the agricultural district). According to N-SPECT, at full build-out non-urbanized lands will contribute 85% of the watershed's runoff, 70% of the watershed's total phosphorus load, 80% of the watershed's total nitrogen load, and 94% of soil erosion. (These are values for the 2-year storm except for soil erosion, which is on an average annual basis).

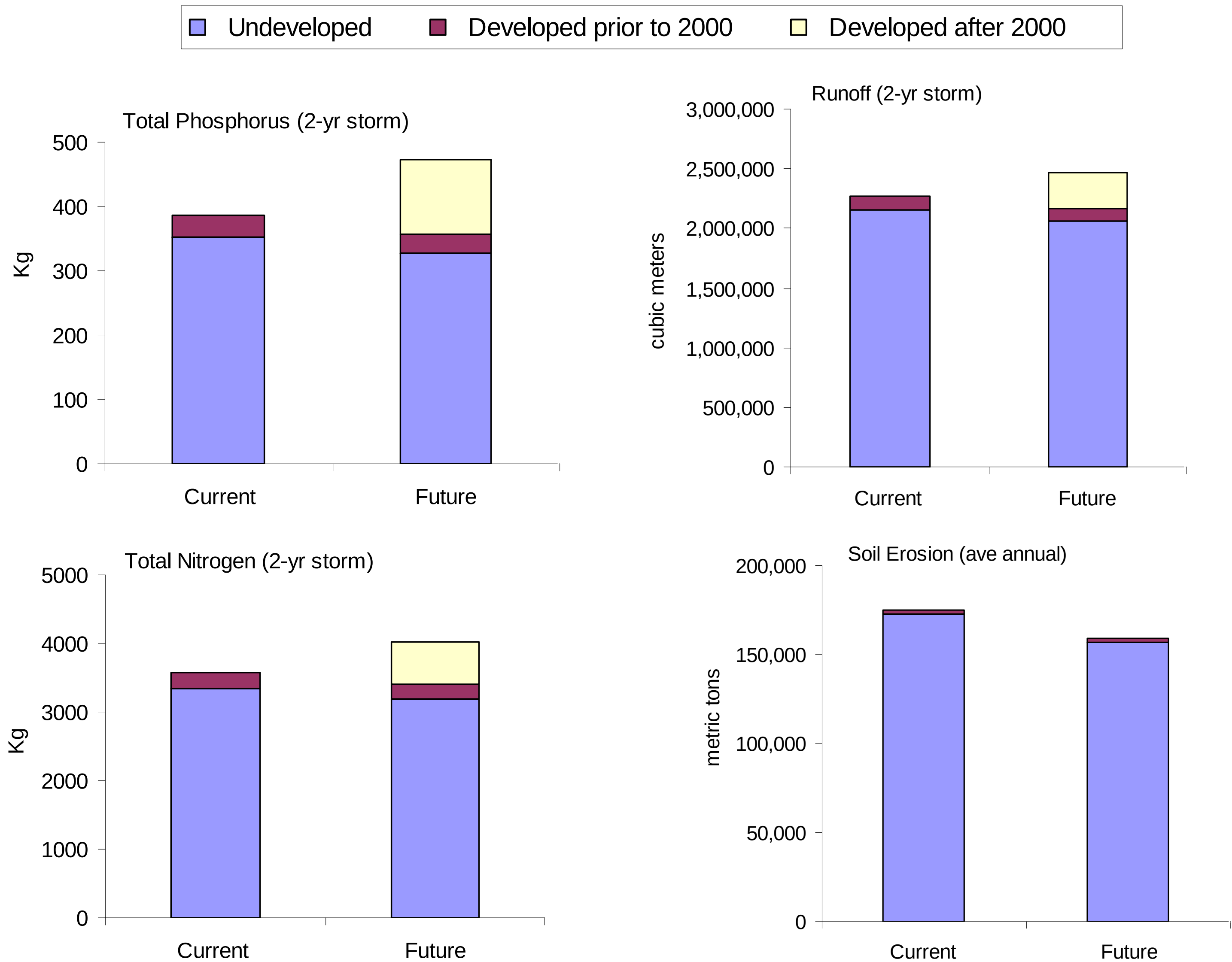
The qualitative assessment methods used in the past are complementary to quantitative assessment methods such as the N-SPECT model. For example, the typical past practice will identify the presence of a regulatory 100-year floodplain or soils that have been classified as highly erodible. The qualitative assessment measures used in the past also include proposing mitigation measures. Notably, N-SPECT is not designed to evaluate the effectiveness of proposed mitigation measures.

Table 7. Direct impacts estimated from the N-SPECT model.

Change in load is the change in load resulting from development of that parcel. The local percent change is based on the change in load divided by the pre-development load for that parcel. The change as a percentage of the watershed load is based on the change in load divided by the pre-development load for the entire 17,000 acre watershed. The “pre-development” load includes areas already developed as of 2000.

Parcel	LUPAG	Total Nitrogen 2-yr 24-hr event			Total Phosphorus 2-yr 24hr event			Runoff 2-yr 24-hr event			RUSLE Soil Erosion Average Annual		
		Change in Load (g)	Local Change (%)	Change as % of Watershed load	Change in Load (g)	Local change %	Change as % of Watershed Load	Change in Load (m^3)	Local Change (%)	Change as % of Watershed	Change in Load (kg/yr)	Local Change (%)	Change as % of Watershed Load
2	Resort	1,165	64	0.0	87	40	0.0	509	43	0.0	-138,312	-76	-0.1
3	Rural	7,755	54	0.2	471	26	0.1	-1,393	-10	-0.1	-7,321,510	-84	-4.0
5	Low density urban	3,915	34	0.1	-147	-8	0.0	1,728	25	0.1	-859,383	-82	-0.5
9	Low density urban	3,884	84	0.1	31	4	0.0	2,749	136	0.1	4,802	31	0.0
11	Urban Expansion	50,810	687	1.4	10,898	768	2.9	23,122	750	1.0	-198,818	-96	-0.1
12	Urban Expansion	76,559	423	2.2	16,900	542	4.4	33,988	394	1.5	-776,991	-97	-0.4
14	Industrial	55,001	>1,000	1.5	11,654	>1,000	3.1	24,730	>1,000	1.1	-25,696	-99	0.0

Figure 4. **Cumulative impacts resulting from full build out**. The land cover data are current to the year 2000. Lands to be developed after the year 2000 include--but are not limited to--parcels 2, 3, 5, 8, 11, 12, and 14.



IV.4 Adequacy of Typical Past Practice

The typical past practice appears to be adequate with respect to identifying and mitigating construction-related impacts.

The typical past practice identifies actions that will mitigate post-construction stormwater impacts. It does not, however, quantify impacts (either with or without mitigation) nor evaluate their significance.

The typical past practice *mentions* cumulative impacts but does not quantify, analyze, or discuss them. This is not adequate.

The typical past practice is narrow in scope. It does not address secondary impacts such as groundwater contamination resulting from dry wells. Nor does it address the possible impacts to aquatic, riparian, or coastal habitats either within the proposed development or in affected downstream areas.

V. Stormwater Assessment (Proposed New Method)

V.1 Description of Proposed New Method

V.1.1 Background

In the first year of this project, recommendations for how to assess the impacts of new development on stormwater were set forth in the ***Final Report Stormwater Impact Assessment Project*** (Department of Geography and Environmental Studies and PBR Hawaiʻi, 2011), hereafter referred to as the ***Year-1 Report***. The year-1 recommendations were concise and, in some cases, interwoven with background material. Therefore, one purpose of the following section is to clarify the recommendations and provide explicit and detailed instructions that would be helpful to anyone implementing the ***Year-1 Report*** assessment methodology. Further, the detailed instructions include information about how to acquire data needed for implementation of the assessment methodology.

The ***Year-1 Report*** combines recommendations for assessment with recommendations for remediation. Development of remediation plans is an important product of the environmental assessment process. The current report, however, focuses on assessment. One outcome of the proposed assessment methodology is a determination of whether the watershed is impaired, sensitive, or neither. Recommendations for mitigation actions vary according to the category into which the watershed falls.

The proposed methodology in the ***Year-1 Report*** is reproduced verbatim in Appendix A. While the wording of the proposed methodology implies that "cumulative" impacts are being assessed, the methodology does not, in fact, distinguish between the impacts of the proposed development and the impacts of either past actions or reasonably foreseeable future actions. It appears, therefore, that the proposed methodology addresses only direct impacts and does not address cumulative impacts taking place over a period of time. The portion of the ***Year-1 Report*** that discusses cumulative impacts is reproduced in Appendix B. The ***Year-1 Report*** does not contain a section discussing indirect impacts. It does, however, suggest that mitigation measures for impaired watersheds should consider pollutants carried by groundwater.

Both the ***Year-1 Report*** and the current report are geographically restricted to the State of Hawaiʻi.

V.1.2 Interpretation of Proposed Methodology

<u>Step 1:</u>

Collect the background information that is pertinent to developing a stormwater pollution prevention plan (SWPPP) for a NPDES permit

The following are specified as the minimum information required for this step:

- Identification of the watershed or sub-watershed
- Watershed area
- Proximity of streams
- Land uses within the watershed
- Rainfall intensity
- Land cover
- Hydrological soils group

Sources of data that can be used to obtain this background information are listed in Table 8.

Development of a stormwater pollution prevention plan for a NPDES permit should involve additional data and assessment beyond that listed in the ***Year-1 Report*** for step 1. For example, it could include (p. 7 of ***Year-1 Report***):

- Identification of potential pollutant sources resulting from construction activities
- Identification of nearby wetlands and nearshore waters and assessing whether they–or any other sensitive resources–should be protected
- Presence of contaminated soils
- Percentage of impervious area before and after construction
- Runoff coefficient before and after construction
- Identification of features affecting erosion, namely
  - Slopes and slope lengths
  - Soil types and presence of highly erodible soils
  - Rainfall seasonality

Inclusion of such information and assessments would be at the discretion of the organization conducting the stormwater assessment. Sometimes an EIS is prepared before the full details of a proposed development, for example percent of impervious area, are known.

Table 8. Minimum background information required by proposed method.

Parameter	Data needs and comments	Availability*
Watershed boundaries and watershed area	Must delineate watershed from topographic maps or GIS analysis of DEMs.	USGS topographic maps are widely available. DEMs are available from the US Geological Survey
Rainfall intensity	Data are available online from Precipitation Frequency Data Server. Return interval and storm duration not specified by proposed method.	NOAA Atlas 14 Precipitation Frequency Data Server available online at http://hdsc.nws.noaa.gov/hdsc/pfds/
Streams	DLNR Division of Aquatic Resources (DAR) data, derived from the USGS Digital Line Graphs and CWRM Hawaiʻi Stream Assessment Database is available in GIS format. It may be easier to discover the streams by examining USGS 7 ½ minute topographic maps, but data on paper maps may not be as comprehensive as DAR GIS data.	State GIS website (listed under "stream" or "darstreams") USGS 7 ½ minute topographic maps are widely available
Hydrologic Soil Group	Standard parameter of soil data provided by the Natural Resources Conservation Service (NRCS) soil data.	1. State GIS website has NRCS SSURGO data in GIS format. It can be difficult to use. 2. NRCS Web Soil Survey (Soil Survey Staff, 2011) is available at http://websoilsurvey.nrcs.usda.gov
Land cover	The proposed methodology suggests using NOAA's C-CAP land cover data. Other data sets that can be used are LULC (Land Use and Land Cover) and GAP land cover data (USGS 2011).	C-CAP data is available from the NOAA Coastal Services Center <http://www.csc.noaa.gov>. High resolution data are available for some islands. Links to some of the C-CAP data are on the State GIS website.

* The State GIS website <http://hawaii.gov/dbedt/gis> is maintained by the Office of Planning, Department of Business, Economic Development and Tourism of the State of Hawaiʻi.

Step 2

Determine if the watershed drains into an impaired receiving water or has been identified as high priority for restoration

"Impaired waters" are defined as those that are too polluted or otherwise degraded to meet the Hawaiʻi water quality standards. The federal Clean Water Act requires states to regularly describe overall status of water quality statewide and submit a list of waters that do not meet state water quality standards[8]. The most-recent document and list developed by the Hawaii Department of Health is entitled ***2006 State of Hawaii Water Quality Monitoring and Assessment Report: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to Sections 303(D) and 305(B), Clean Water Act (P.L. 97-117)***, better known as the Section 303(d) list. This list documents 209 marine waters and 93 inland freshwater perennial streams that do not currently meet state water quality standards. Once listed, some waterbodies are not subjected to future monitoring. In these cases, the waterbody remains listed because it is unknown if it is still impaired. Impairment should be determined according to whether the impacted streams—or their receiving waters—are on the most recent Section 303(d) list.

Restoration priority is based on the Hawaiʻi Watershed Prioritization Process (HWPP), where the 580 Hawaiian watersheds were listed from 1 – 580 in order of restoration priority, based on four broad classes of criteria: stressors, sensitive areas, assets, and indicators. A list of these (as of 2011 and with restoration priorities ranked) can be found in the ***Year-1 Report*** (Department of Geography and Environmental studies and PBR Hawaiʻi 2011).

If the watershed is not impaired or is not a high priority for restoration, go to step 4.

Otherwise, go to step 3.

[8] State water quality standards are the measures the state uses to evaluate the physical, chemical and biological health of its waters.

Step 3

Assessments Required for LEED Certification
(Impaired Watersheds or High Priority for Restoration)

Propose onsite mitigation measures to reduce pollutant generation between pre-and post-development that would be eligible to meet LEED-NC SS 6.1 and 6.2 credits, as well as comply with a TMDL allocation[9] if available. Mitigation measures should address, at a minimum, the pollutant with TMDL allocations, but should consider other potential sources generated by the various land uses within the watershed as well as pollutants transported by groundwater.

The following assessments are required in order to demonstrate eligibility for LEED 6.1 and 6.2 credits[10]:

- Pre- and post-development peak discharge and runoff volumes for the 1-yr 24-hr storm and the 2-yr 24-hr storm.[11]
  - If the site is $\leq$ 50% impervious before development the developer selects one of the following two choices:
    - Implement a management plan that prevents the post-development discharge/volume from exceeding the pre-development discharge/volume. Meeting this standard will require mitigation measures such as bioretention, permeable pavements, vegetated roofs, or rainwater harvesting. [6.1 credit]
    - Implement a management plan that protects the stream channel from erosion.
  - If the site is > 50% impervious before development, the post-development discharge should be at least 25% lower than the pre-development discharge. Meeting this standard will require mitigation measures such as bioretention, permeable pavements, vegetated roofs, or rainwater harvesting. [6.1 credit]
- Average annual total suspended solids (TSS) load[12] for two scenarios: post-development without a stormwater treatment system, and post-development with a stormwater treatment system. Note that LEEDS has a preference for basing loads on field monitoring, but collecting field data will be impractical and very expensive.

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[9] A TMDL is a calculation of the maximum amount of a pollutant that a waterbody can receive and still meet water quality standards, and an allocation of that load among the various sources of that pollutant.

[10] There are some discrepancies between assessments outlined on p. 18-19 of the LEEDS manual published by the US Green Building Council (2005) and the LEEDS-motivated assessments described on p. 26 of the ***Year-1 Report***. We have used the assessment guidelines in the LEEDS manual.

[11] Discharge has units of cubic feet per second, whereas runoff volume has units of cubic feet. The 1-year storm does not make sense in hydrologic statistics but is mentioned nevertheless in the LEEDS documentation.

[12] Loads have units of mass per time and represent the total amount of pollutant that exits a watershed in a given length of time.

- The stormwater treatment system must remove 80% of the average annual post-development TSS. [6.2 credit] Meeting this standard would normally entail using BMPs to reduce impervious cover, promote infiltration, and capturing and treating runoff.

In the event that the watershed in which the development is proposed has a Total Maximum Daily Load (TMDL) prepared by DOH, then it will likely provide specific load allocations for pollutants that are causing a waterbody to be impaired or threatened (most likely Total Suspended Sediments (TSS), Total Nitrogen (TN) and/or Total Phosphorus (TP)). In these cases, additional assessments of pre-development and post-development pollutant loads may be necessary.

Data required to perform assessments for impaired watersheds would include:

- Rainfall for the 1-yr 24 hr and 2-yr 24-hr design storms;
- Percent impervious area prior to development;
- TMDL (available from DOH) if one exists;
- Observational or modeling data that can be used to estimate post-development TSS loads;
- Data required to compute runoff volumes and peak discharges for design storms. The exact data required will vary according to the model used. Commonly used models include
    - The rational method (discharge only)
    - The SCS CN model (runoff volumes only)
    - The TR-55 model (runoff volumes and discharge)
    - The RUSLE and MUSLE models (erosion)

Optionally, the following data could also be procured:

- Identification of possible pollutants beside the ones for which impairment has been identified. Identification of possible sources of these pollutants.
- Identification of possible pollutants entering groundwater.

After meeting both LEED-NC SS 6.1 and 6.2, go to step 6.

Step 4

Determine if the watershed drains into "sensitive" receiving waters

The sensitivity of the receiving waters to these pollutants depends on flushing capacity, habitat quality, or beneficial designated use. Based on these factors, sensitive receiving waters include:

Designated beneficial use and/or habitat quality:
- Class AA marine waters or Class 1 inland waters;
- Coastal reserves;

Exceptional habitat quality:
- Coral reefs;
- High quality perennial streams;

Low flushing capacity or high freshwater input:
- Embayments;
- Anchialine ponds;
- Low-salinity nearshore coastal waters.

The ***Year-1 Report*** (Department of Geography and Environmental Studies and PBR Hawaiʻi 2011) contains information that is useful in identifying if a watershed drains into sensitive receiving waters. The more sensitive Hawaiian watersheds are identified in the ***Year-1 Report***, but it is not clear what criteria were used for categorization. For information on water classifications, refer to Appendix C.

Table 9. Source of factors influencing sensitivity of coastal waters.

Sensitivity Source	**Information Source**
Coral Reefs	State GIS website Listed under "Coral Reefs"
Stream habitat and quality	See "Watershed Health" in the ***Year-1 Report***
Low salinity coastal waters	List not available as of 12/2/11
Embayments	See "Embayments" in the ***Year-1 Report***
Anchialine ponds	http://www.hawaiiecoregionplan.info/anchpoolNC.html

If the watershed is not sensitive, go to step 7.

Step 5

Determine if receiving waters are already stressed. (Sensitive Watersheds Only)

If the watershed is sensitive, determine if the receiving waters are already stressed by doing a watershed plan (E.3) or a rapid assessment model (E.4). If a Section 319 watershed plan exists it can be found at http://hawaii.gov/health/environmental/water/cleanwater/prc/grants.html.

The proposed new method suggests the following possibilities for rapid assessment models: the Rational Method, TR-55, RUSLE, MUSLE, the Simple Method, and the salinity gradient method. With the exception of the salinity gradient method[13], these models are described in Appendix D, along with the data needed for their implementation.

If the receiving waters are not stressed, propose on- and/or offsite mitigation that results in no net increase in average annual runoff amount, peak discharge, erosion, and loads of total nitrogen and total phosphorus[14] (step 6).

If the receiving waters are stressed, propose on- and/or offsite mitigation measures to reduce pollutant loads[15] (step 6). The amount of the reduction is not specified.

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[13] There is a reference made to the salinity gradient method on page 28 of the ***Year 1 report***, but the document does not specify how to use this to determine if the receiving waters are stressed. The ***Year-1 report*** does not provide a reference for the salinity gradient method nor describe it.

[14] The ***Year-1 Report*** merely states “no net increase.” This is interpreted to mean no net increase in average annual loads of sediment, total nitrogen and total phosphorus. What is left open is whether there should be an assessment of runoff volume and peak discharge and whether there should be an assessment for design storms (for example the 24-hour, 100-year storm).

[15] The ***Year-1 report*** specifies reduction in “pollutant load.” This is interpreted to mean no net increase in average annual loads of sediment, total nitrogen, and total phosphorus. What is left open is whether there should be an assessment of runoff volume and peak discharge and whether there should be an assessment for design storms (for example the 24-hour, 100-year storm).

Step 6
Mitigation measures for watersheds

Development projects in watersheds that are impaired, a high priority for restoration, or sensitive and stressed should propose mitigation measures that result in reduction of stormwater loads. Projects in watersheds that are sensitive but not already stressed should propose mitigation measures that result in no net increase of stormwater loads. This is functionally-equivalent to the smallest possible reduction, however. See footnotes on previous page for a discussion of what "reduction in stormwater loads" means.

Examples of on-site and offsite mitigation measures are:

Site Design Measures:

- Narrower roads
- Clustered lot layouts
- Green roofs
- Rain harvesting
- Rain gardens
- Permeable pavement
- Riparian buffers

Stormwater Control Measures:

- Vegetated swales
- Infiltration facilities
- Stormwater wetlands
- Stormwater ponds
- Filtering systems

There are several different models that could be used to asses net increase in runoff and pollutant loads. Commonly used models include:

- The rational method (discharge only)
- The SCS CN model (runoff volumes only)
- The TR-55 model (runoff volumes and discharge)
- The RUSLE and MUSLE models (erosion)

Step 7
Comply with applicable NPDES and Grading Permit requirements.

All projects must comply with NPDES and Grading Permit requirements. These requirements will vary according to the nature of the project.

V.2 Application of Proposed Method to the Wai'ula'ula Watershed

V.2.1 Overview

Under the proposed method, the rigor of the analysis is determined by whether or not the watershed is sensitive, stressed, or impaired. As will be shown below, the Wai'ula'ula watershed is a sensitive and stressed watershed. For this kind of watershed and in the absence of a TMDL, there are two main parts in the proposed method. The first is compiling and analyzing qualitative data. The second is making quantitative assessments of whether or not the proposed mitigation measures reduce stormwater loads. The quantitative assessment is detailed and time consuming, thus only two sites were selected for detailed analysis (Figure 5). For the analysis we selected sites that have stream channels and different types of development, namely low density urban and urban expansion. This arrangement allows us to examine the types of development that are most likely to occur in this watershed. To avoid confounding the analysis, the selected parcels have similar climates.

Under the proposed method for sensitive stressed watersheds, proposed mitigation measures should result in a net decrease in stormwater loads. This is interpreted to mean that in comparison to pre-development conditions, the mitigated development will have lower peak flows, runoff volume, nutrient loads, and sediment loads. Because federal regulations already require that adequate mitigation measures be employed during the construction period, construction BMPs were not examined in this study.

N-SPECT modeling results presented in Volume Two of this report indicate that, on average, development *decreases* soil erosion by 72% for low density urban development and 92% for urban expansion development. Simply, soil that is covered by pavement or buildings cannot erode. In parcel 12, N-SPECT predicted that high intensity development would result in a 97% decrease in average annual soil erosion. The effect of mitigation measures on soil erosion was, therefore, not analyzed in parcel 12. Parcel 9, however, is one of the few sites that showed an increase in soil erosion as a result of low-intensity development. We have, therefore, modeled the effect of BMPs on soil erosion in parcel 9.

For the quantitative analysis of BMP effectiveness, three mitigation scenarios were evaluated: 1) no mitigation, 2) "business as usual" mitigation measures (BAU), 3) "innovative BMPs" (IBMP), and 4) IBMP plus dry wells. Prior to running these scenarios it was necessary to determine loads under baseline (existing, pre-development) conditions.

For reasons discussed previously, the 2-year, 24-hr storm event was used to evaluate post-construction impacts on runoff volume , peak flows, and loads of total phosphorus and total nitrogen. N-SPECT was used to evaluate runoff volume, nutrient loads, and average annual erosion using the RUSLE option. The TR-55 model was used to evaluate peak flows.

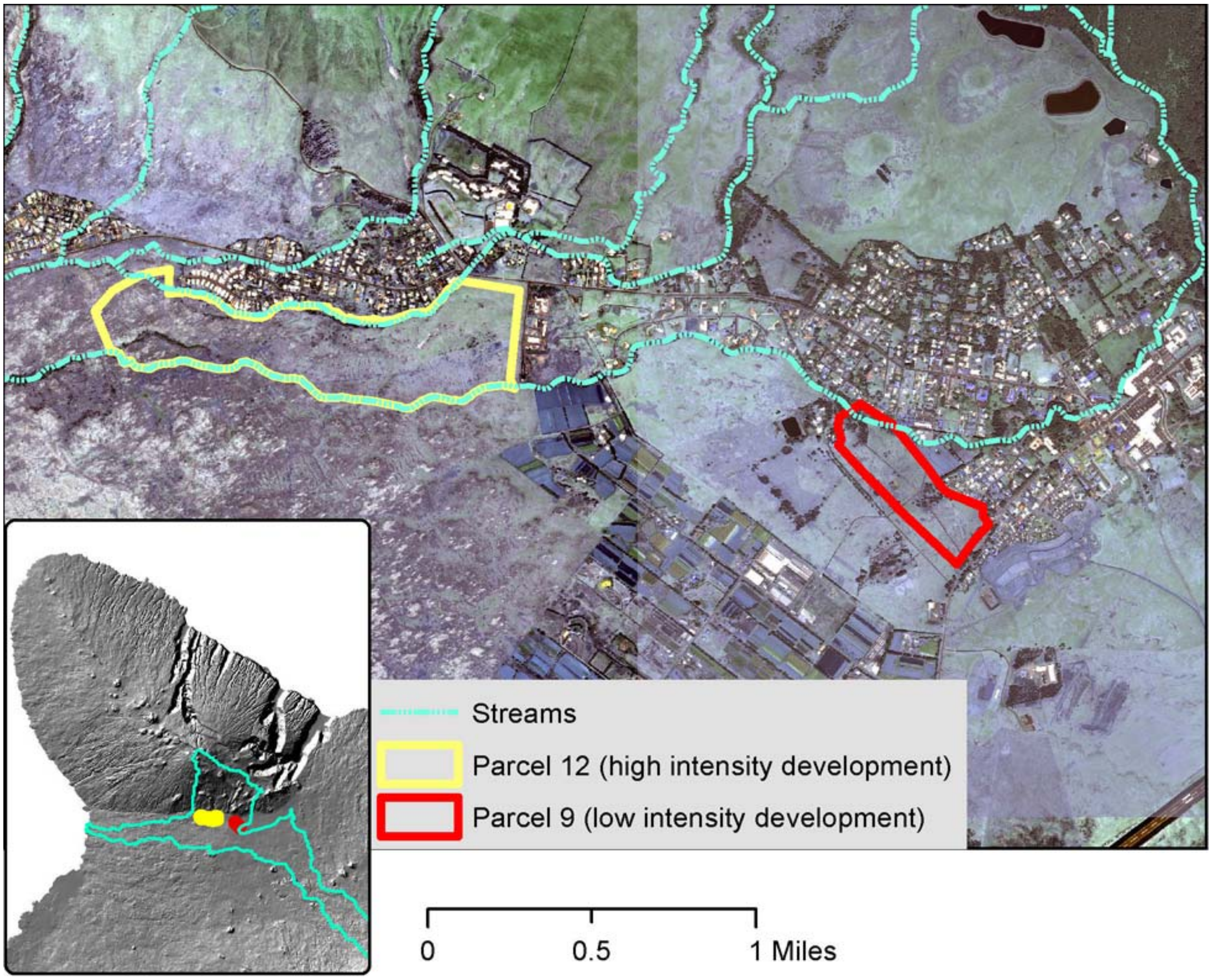

Figure 5. Parcels analyzed using the proposed new method from the *Year-1 Report.*

V.2.2 Background Information

Step 1 of the proposed method requires the following background information:

- Identification of the watershed or sub-watershed
- Watershed area
- Proximity of streams
- Land uses within the watershed
- Rainfall intensity
- Land cover
- Hydrological soils group

Both parcels 9 and 12 are located within the middle-upper portion of the Wai'ula'ula watershed (Figure 5). Tables 10-13 provide basic descriptive data including area, slope, rainfall, soil type, and hydrologic soil group. Rainfall is seasonal with 37% falling in the eight-month drier summer period and 63% falling during the winter rainy season[16].

Existing land use data are shown in Tables 14-15. There are two major sources of land use data (C-CAP and GAP), so data are provided for each. Both indicate that the dominant pre-existing land cover is grassland. Parcel 12 is currently grazed intensely by cattle. Parcel 9 is currently grazed less-intensively by horses.

Keanu’i’omanō stream flows for 1.76 km along the north boundary of parcel 12. Waikoloa stream flows for 2.05 km along the southern boundary of Parcel 12 and also flows for a short distance (0.20 km) through the northern tip of parcel 9. Both streams have been classified by DLNR's Division of Aquatic Resources (DAR) as perennial, although in reality they are currently intermittent within the parcels because the streams are dammed upstream (for diversion of water for the community’s potable water supply). Keanu’i’omanō (DAR stream code 8-5-03.055) and Waikoloa (DAR stream code 8-5-03.055) are the primary tributaries to Wai’ula’ula stream. Another potential area of development impact is wetlands. According to the National Wetland Inventory, there are no wetlands in parcels 9 and 12, nor are there wetlands downstream of the parcels.

The proposed method allows for additional background information beyond the required minimum. Below, we list additional data from publically-available sources, but not additional data that requires field investigations or interviews with local experts:

- Soils in both parcels have been classified by NRCS as potentially highly erodible by water.
- Regulatory floodplain maps show flood zones A and X in both parcels.[17]
- Topographic slopes are described in Table 12.
- Post-construction impervious area is shown in Table 11. Pre-development impervious area is close to zero.

[16] Data from weather station Kamuela 192.2, which receives about 41.5 inches of rain annually.

[17] *Flood hazard zone A “is the flood insurance rate zone that corresponds to the 100-year floodplains that are determined in the FIS by approximate methods” and zone X “is the flood insurance rate zone that corresponds to areas outside the 500-year floodplain, areas within the 500-year floodplain, and to areas of 100-year flooding where average depths are less than 1 foot, areas of 100-year flooding where the contributing drainage area is less than 1 square mile, and areas protected from the 100-year flood by levees” (Digital Flood Insurance Rate Map).*

Table 10. Description of parcels that were assessed using the proposed new method.

Parcel ID	Area (km^2)	Area (acres)	LUPAG Designation (Future Development)	Streams	Dominant Existing Land Cover
9	0.22	55.	low density urban	The Waikoloa stream flows through the parcel for a short distance.	Grassland
12	0.81	200.	urban expansion	Bordered on the north by Keanu'i'omanō Stream and bordered on the south by the Waikoloa Stream	Grassland

Table 11. Development parameters for parcels 9 and 12.
See section III.2 for information on how these data were estimated.

Parcel	LUPAG	% area in commercial development	Residential Units	% Impervious Area (BAU)	% Impervious Area (IBMP)
9	Low density urban	1. %	223	39	31%
12	Urban expansion	20. %	1499	61	49%

Table 12. Climate, topography, and soils for parcels 9 and 12.

Parcel	Rainfall [1] (Inches/yr)	Average Topographic Slope (deg)	Slope lengths (average in ft)	Soil Type [2]	Soil Erodibility Classification [3]	Hydrologic Soil Group [2]
9	27.6	1.3	200	Waimea very fine sandy loam (WMC)	Potentially highly erodible	B
12	35.7	3.9	500	Waimea very fine sandy loam (WMC)	Potentially highly erodible	B

[1] *Annual: Rainfall Atlas of Hawaiʻi (Giambelluca et al. 2011)*

[2] *From Natural NRCS SSURGO database and maps (Soil Survey Staff, 2007).*

[3] *Classification of soil erodibility from water. From NRCS SSURGO database and maps (Soil Survey Staff, 2007).*

Table 13. Rainfall intensity.

Parcel	*Storm Events*		
	10yr/1hr	2yr/24hr	100yr/24hr
9	1.56 inches	2.96 inches	9.10 inches
12	1.55 inches	3.01 inches	9.16 inches

Table 14. Pre-development land cover associated with each site (based on C-CAP).

C-CAP Land Cover	Parcel 9 (% of total)	Parcel 12 (% of total)
Grassland	65.6	74.3
Evergreen forest	5.7	3.7
Scrub/Shrub	19.8	11.1
Low Intensity Developed	4.0	7.2
Bare Land	0.0	3.2
High intensity developed	4.5	0.3
Cultivated Land	0.4	0.1

Table 15. Pre-development land cover associated with each site (based on GAP).

Gap Land Cover	Site 12 (% of total)	Site 12 (% of total)
High Intensity Developed	3.0	0.6
Low Intensity Developed	3.0	7.7
Alien Grassland	94.1	89.3
Uncharacterized Open-Sparse Vegetation	0.0	2.4

V.2.3 Qualitative Analysis

Step 2: Determine if the watershed drains into an impaired water or has been identified as high priority for restoration

The Wai'ula'ula watershed does not contain any surface waters identified as impaired by the State of Hawai'i, nor has it been identified as a high priority for restoration by the Hawai'i Watershed Prioritization Process (June 2009). However, it has been identified as a watershed in need of protection by that same process.

In the state of Hawai'i, minimum water quality standards (Chapter 11-54, HAR) are established by the Department of Health under the provisions of the Clean Water Act. These standards are intended to protect designated uses of streams and marine waters.

Section 303(d) of the Clean Water Act requires states to regularly publish a list of impaired waters: water bodies (both freshwater and marine) that do not meet these state water quality standards, even after the application of technology-based effluent limitations. States are also required to obtain and review all existing and readily-available water quality data and compare these data against the State's water quality standards and, after applying listing criteria, determine the level of impairment for that waterbody. The most recent Section 303(d) list for Hawai'i contains information compiled in 2006. No surface waters (stream or marine) in the Wai'ula'ula watershed are listed as impaired.

In 2009, the Hawai'i Coastal Zone Management (CZM) Program undertook an effort to identify priority watersheds where watershed plan development and implementation would be targeted. GIS was used to overlay data layers representing different criteria in order to determine priority watersheds for restoration and protection. In the model, classes of criteria represented stressors, sensitive areas, assets, and indicators. Stressors are properties of a watershed that could potentially lead to water quality impairment. Sensitive areas are those likely to be harmed by polluted runoff. Assets are properties which would serve to protect a watershed from disturbances. Indicators show those watersheds that are already recognized as in need of restoration.

This effort resulted in a ranking of all watersheds in Hawai'i from 1 (worse) to 580 (better) and a table listing the top 50 watersheds in need of restoration and the top 50 in need of protection (23 needed both protection and restoration, 27 restoration only, and 27 protection only). The Wai'ula'ula watershed was listed in this table as a watershed in need of protection.

Step 3: Conduct assessments required for LEED certification (impaired watersheds only).

This step was skipped for the Wai'ula'ula watershed because it is not an impaired watershed.

Step 4: Determine if watershed drains into "sensitive" receiving waters.

For the reasons described below, the Wai'ula'ula watershed is categorized as "sensitive."

Hawai'i has water quality standards for marine and fresh waters. Significant portions of both marine and fresh waters in the Wai'ula'ula watershed fall within the more protective classifications described below. In addition, the receiving marine waters provide habitat for coral reefs and fisheries resources and the receiving stream waters are home to native insects and migratory fish species. Bioassessments conducted by Englund and described below indicate that the streams within the Wai'ula'ula watershed are of the highest quality in terms of stream health and biodiversity. For these reasons, it has been determined that the watershed drains into sensitive receiving waters.

The receiving marine waters immediately offshore of the Waiʻulaʻula watershed are classified as AA (south of Waiʻulaʻula Point) and A (north of Waiʻulaʻula Point). The outlet of Waiʻulaʻula Stream is immediately south of Waiʻulaʻula Point, so the receiving waters at the stream outlet are classified as AA. The objective of “class AA, marine waters” is that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practical, the wilderness character of class AA waters shall be protected.

All inland fresh waters are classified in Chapter 11-54, HAR, based on their ecological characteristics and other natural criteria as flowing waters (*e.g.*, streams), standing waters (*e.g.*, lakes and reservoirs), and wetlands. These waters are further classified for the purposes of applying water quality standards and selecting appropriate quality parameters and uses to be protected in these waters.

Three stream classifications can be found in the Waiʻulaʻula watershed. Streams within the Puʻu o ʻUmi Natural Area Reserve are Class 1(a). Streams within the Conservation District but outside of Puʻu o ʻUmi NAR are Class 1(b). All other areas of the watershed are Class 2. Note that a single stream can have different classifications in different reaches.

Class 1 inland waters are to remain in their natural state as nearly as possible with an absolute minimum of pollution from any human-caused source. Waste discharge into these waters is prohibited. The uses to be protected in class 1(a) waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other non-degrading uses. The additional uses to be protected in class 1(b) waters are domestic water supplies and food processing. Class 2 inland waters are to be protected for recreational purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping and navigation. Class 2 waters shall not act as receiving waters for any discharge that has not received the best degree of treatment or control.

Aquatic species play extremely important ecological roles within the watershed. Their presence or absence is often used as an indicator of stream and watershed health. In the Waiʻulaʻula watershed, surveys of Waikoloa and Keanuʻiʻomanō streams conducted in 1992 by DLNR's Division of Aquatic Resources (DAR), in 2002 by Bishop Museum's Hawaiʻi Biological Survey (HBS), and in 2010 by R.A. Englund revealed a wide array of native endemic and indigenous aquatic fishes and macro-invertebrates.

Englund (2010) observed 4 of the 5 native stream fish species in various locations throughout the watershed. *Lentipes concolor* (ʻoʻopu alamoʻo) was detected in Keanuʻiʻomanō Stream at the 2,700-ft. elevation. Englund notes that “[this] indicates that native fish traverse long stretches of intermittent stream channels during periods of flowing water, using the ephemeral stream habitat as an access corridor to the headwater regions of upper Keanuʻiʻomanō Stream” (p. 11). *Awaous guamensis* (ʻoʻopu nākea) was also common in the lower Waiʻulaʻula Stream. *Eleotris sandwicensis* (ʻoʻopu ʻakupa) and *Stenogobius Hawaiiensis* (ʻoʻopu naniha) were found in the Waiʻulaʻula estuary. While *Sicyopterus stimpsoni* (ʻoʻopu nōpili) was not found during Englund’s recent survey, it was observed in previous studies (1992 DAR survey). None of the native fish species have been Federally listed as endangered, though the ʻoʻopu alamoʻo is considered a potential candidate (Loope 1998).

Englund *et al.* (2007) found that "endemic Hawaiian aquatic insects are better bio-indicators for Hawaiian stream health as compared to the native stream macrofauna (fish, crustaceans, mollusks) because aquatic insects have more specific stream habitat requirements" (Englund 2010, p. 11). Englund (2010) collected a total of 23 species of aquatic insects in the Waiʻulaʻula watershed, of which 65% were native and 35% were introduced species. According to Englund (2010), "[the] relatively high 65% overall native aquatic insect biodiversity found within the entire Waiʻulaʻula watershed is comparable to other high quality streams" (p. 12). In the upper reaches of Keanuʻiʻomanō, Waikoloa, and Kohākōhau streams, native species are even more dominant, maintaining an exceptionally high diversity "equaling any high quality stream found in the Hawaiian archipelago" (Englund 2010, p. 12).

Step 5: Determine if receiving waters are already stressed (sensitive watersheds only)

A watershed management plan was developed for the Wai'ula'ula watershed (MKSWCD 2011). Water quality monitoring conducted as part of the plan's development indicates that the watershed's receiving waters, while general good, are becoming stressed.

Table 16 lists nutrient and sediment standards applicable to the marine waters immediately offshore of the Wai'ula'ula watershed (both A and AA waters).

Table 16. Open coastal waters water quality criteria.

Parameter	Geometric mean not to exceed this value
Total Dissolved Nitrogen*	0.10 mg/L
Ammonia Nitrogen (NH_4)	0.0025 mg/L-N
Nitrate + Nitrite Nitrogen*	0.0045 mg/L-N
Total Dissolved Phosphorous*	0.0125 mg/L
Phosphate*	0.005 mg/L
Chlorophyll a	0.30 ug/L
Turbidity	0.10 N.T.U.

*If salinity is less than or equal to 32 parts per thousand, this parameter shall be related to salinity using a regression equation specified in Section 11-54-6, HAR, pages 47-48.

During the period of July 2006 through April 2008, DOH made frequent measurements of water quality at a number of coastal sites. Measurements in the nearshore waters of Kawaihae Bay at Waiʻulaʻula were taken on 33 separate days. Comparison of these measurements against the water quality standards shows that the Bay has too much ammonia (concentrations are 2.8 times more than what is allowed) and too much chlorophyll (concentrations are double what is allowed). The high chlorophyll levels indicate that there is too much algae; and it is likely the high ammonia levels are contributing to high excess algae. Because ammonia is rapidly converted to nitrate in the presence of oxygen, it is likely that the source of the ammonia is nearby. The measured nitrate and total nitrogen concentrations are near the standard. Total phosphorus concentrations are slightly above the standard.

Table 17 lists water quality standards applicable to streams.

Table 17. Water quality criteria for streams.

Parameter	Geometric mean not to exceed the given value	Not to exceed the given value more than ten percent of the time	Not to exceed the given value more than two percent of the time
Total Nitrogen (mg /L)	0.250* 0.180**	0.520* 0.380**	0.800* 0.600**
Nitrate + Nitrite (mg/L-N)	0.070* 0.030**	0.180* 0.090**	0.300* 0.170**
Total Phosphorous (mg/L-P)	0.050* 0.030**	0.100* 0.060**	0.150* 0.080**
Total Suspended Solids (mg/L)	20.0* 10.0**	50.0* 30.0**	80.0* 55.0**
Turbidity (N.T.U.)	5.0* 2.0**	15.0* 5.5**	25.0* 10.0**

*standard applicable during rainy (wet) season of November 1 through April 30
**standard applicable during dry season of May 1 through October 31

Autosamplers were used to collect stormwater runoff in three locations. Samples were analyzed for nutrient and suspended sediment concentrations. At the Marine Dam site (where Waikoloa stream exits the high-elevation forest), the stream had relatively low concentrations of nitrate, ammonia, and orthophosphate (PO_4). At the sampling site downstream of Waimea Town (Sandalwood site), ammonia concentrations doubled, total phosphorus concentrations (TP) more than doubled, and nitrate concentrations quadrupled. The average nitrate concentration just barely exceeded the water quality standard. The TP concentration was nearly twice the allowable amount. At the sampling site near the mouth of the watershed, total nitrogen was high, with measured concentrations nearly twice what is allowed by State water quality standards.

Nine samples of urban stormwater runoff were collected by taking grab samples of flowing water in parking lots, storm water running off roads, or from pipes that collect parking lot/road runoff. All sites were located in Waimea, and samples were collected between November 2008 and April 2009. Based on this limited amount of data, it appears likely that runoff from high-use paved areas exceeds water quality criteria for sediment (by a factor of five), total phosphorus (by a factor of four), total nitrogen (by a factor of three) and nitrate (measured values are only slightly greater than the standard). These results are not surprising as urban stormwater runoff is usually high in sediment and nutrients.

Step 6: Identify mitigation measures for watershed

Changes to proposed mitigation measures are described below in section V.2.4.

Step 7: Comply with applicable NPDES and grading permit requirements.

This step is normally addressed after an EIS is drafted and the project has been approved. The implementation of specific permit requirements is outlined during the more-detailed design phase undertaken during project siting, construction, and post-construction activities.

V.2.4 Proposed Mitigation Actions

Under the proposed method for sensitive stressed watersheds, mitigation measures should be designed so that they result in decreased stormwater loads (represented by peak flows, runoff volume, nutrient loads, and sediment loads at the boundary of the parcel).

In Hawai‘i County, dry wells are the standard mitigation measure. They capture stormwater runoff from impervious areas at a maximum disposal rate of 6 cubic-feet-per-second of water per dry well (Kuba 2005). When runoff is captured, nutrients and sediment carried by the runoff are also captured. Dry wells, therefore, constitute the “business as usual” mitigation scenario and are also necessarily part of the suite of mitigation practices hereby referred to as the “innovative best management practices (IBMP)" scenario.

The following additional mitigation measures are proposed for the IBMP scenario:

Parcel 9 (low-intensity development)

- Establish 45-meter wide riparian buffer along the southern side of Waikoloa stream (0.2 km in length) to trap sediment entrained in runoff from developed areas. (See Figure 2 on p. 20)
- Minimize impervious areas by using permeable paving, where practicable, and minimizing street widths.
- Direct runoff from roofs and driveways into rain gardens and other forms of bioretention and away from the stream channel.

Parcel 12 (high-intensity development)

- Establish 45-meter wide riparian buffer along the southern side of Keanu’i’omanō stream (1.76 km in length) and the northern side of Waikoloa stream (2.05 km in length) to trap sediment entrained in runoff from developed areas. (See Figure 3 on p. 21)
- Use cluster development to concentrate development in smaller areas so that the remaining land can be preserved as natural buffers to protect environmentally-sensitive areas, including stream channels and steeper slopes.
- Minimize impervious areas by using permeable paving, where practicable, and minimizing street widths.
- Direct runoff from roofs, driveways and parking areas into rain gardens and other forms of bioretention and away from the stream channels.
- Use stormwater dry well cartridge filtration on dry wells receiving runoff from parking areas.

V.2.5 Use of N-SPECT to Evaluate Effectiveness of Mitigation Efforts

Methods for runoff and nutrient loads

Unmitigated impacts of runoff and loads of total phosphorus and total nitrogen were determined by estimating the post-development loads (without mitigation impacts) and subtracting the pre-development loads. All N-SPECT runs were performed for the two-year 24-hour storm event. Pre-development loads were estimated using N-SPECT default parameter values for the existing C-CAP land cover. Two methods were used to calculate unmitigated post-development loads:

> *Method 1: Default N-SPECT Curve Numbers.* The normal way that N-SPECT treats new development is to change all of the C-CAP land cover within a proposed development polygon to either the "low intensity developed" category or the "high intensity developed" category.
>
> *Method 2: Impervious area.* The post-development percent impervious area was calculated based on housing density, open space, and commercial footage (see table 5 in section II.2). Parcel 12 (high intensity urban expansion) has more impervious area than parcel 9 (low density urban). Within each parcel, a random assortment of cells was selected to represent the post-development percent impervious area. Within the impervious area, Curve Numbers were set to the value that produces 100% runoff and 0% infiltration, and pollutant coefficients (nutrient concentrations) were set to the default values for high intensity development. N-SPECT simulations were then conducted with new parameter values inside the impervious areas and the original C-CAP parameter values outside the impervious area.

Most of the IBMPs function to reduce impervious area. To model these IBMP, the amount of post-development impervious area was reduced by 20%. N-SPECT was then run using method 2 (impervious area) described above, only with a smaller amount of impervious area. The benefit of the IBMPs that reduce impervious area can be seen by comparison of loads with full impervious area and loads with reduced impervious area.

Riparian buffer strips were another proposed IBMP. Within each parcel, buffers of 45 m were created around streams. Within these buffers, the land cover class was changed to "Scrub/Shrub". The difference between the developed parcel (with the stream buffer) minus the baseline was used to quantify the potential effects of stream buffers.

The BAU mitigation calls for dry wells that capture all runoff from impervious areas. To model dry wells, the impervious cells were assigned Curve Numbers that produce 0% runoff and 100% infiltration. This results in no runoff from the areas served by dry wells. When there is no runoff there is no nutrient loading; therefore, nutrient loads were reduced accordingly. N-SPECT assumes that nutrient concentrations are constant regardless of the amount of runoff. Under the IBMP scenario, dry wells were also employed but they serviced a smaller area because there was less impervious area.

Results for runoff and nutrient loads (2-year storm)

Table 18 shows that unmitigated development increases runoff and nutrient loads by several hundred percent. The impacts of the various mitigation measures, expressed as load reductions, are shown in Table 19. Dry wells achieve a significant reduction in runoff volume and nutrient loads. The riparian buffers are the least effective according to model predictions, but the model under-estimates the effectiveness of buffers in intercepting pollutant-laden runoff from upslope areas. Most of the IBMP serve to reduce impervious area, which by itself is insufficient to reach target load reductions. To reach load reduction targets, dry wells must be used in addition to innovative measures that reduce impervious area.

At parcel 9 (low-intensity development), both BAU and IBMP mitigation scenarios reduced runoff and nutrient loads to well-below existing conditions (Table 20). These reductions were about 200% lower than existing loads if one estimated unmitigated loads using N-SPECT default values or about 45% lower if one used the impervious area method to estimate unmitigated loads. The IBMP mitigation measures were slightly more effective than the BAU mitigation measures, but both were more than adequate. In parcel 12 (high intensity development), both BAU and IBMP mitigation measures reduced runoff and nitrogen loads below existing loads. This reduction was about 20% below existing loads if N-SPECT defaults were used to estimate existing loads and about 60% if the impervious area method was used. BAU and IBMP mitigation measures were essentially equivalent in their effectiveness. The situation was different, however, for loads of total phosphorus in parcel 9.

If N-SPECT defaults were used to estimate unmitigated loads, then the BAU mitigation measures did not reduce parcel 9 post-development loads below existing loads. In contrast, the IBMP mitigation measures did, if only by a small amount (1% reduction). If, however, the impervious area method was used to calculate existing loads, both BAU and IBMP scenarios reached load reduction targets. If the impervious area method was used to estimate unmitigated loads, then both BAU and IBMP mitigation scenarios were more than adequate. The difference between the two methods of estimating unmitigated loads does complicate interpretation of modeling results. The conservative interpretation of these results, however, is that the BAU mitigation scenario may not be enough and other measures, perhaps a riparian buffer, should be employed.

Table 18. Impact of unmitigated development, calculated using the 2-year storm.

“Before” refers to existing pre-development conditions and “after” refers to after unmitigated development. The “N-SPECT default” method calculates post-development loads based on placing the entire parcel into N-SPECT’s “high intensity developed” (parcel 12) or “low intensity developed” (parcel 9) categories. The impervious area method increases runoff only in the impervious areas; nutrient loads within the impervious area are calculated using default pollutant parameters for “high intensity development." The impervious method does not change parameters outside of the impervious area.

Site	Method	Runoff (m^3)			Total Phosphorus (g)			Total Nitrogen (g)		
		Before	After	% change	Before	After	% change	Before	After	% change
9	N-SPECT defaults	2,129	5,216	+145	901	939	+4	4,852	9,232	+90
9	impervious area	2,129	7,608	+257	901	3,520	+291	4,852	16,934	+249
12	N-SPECT defaults	8,923	44,491	+399	3,130	20,911	+568	18,367	98,771	+438
12	impervious area	8,923	41,043	+360	3,130	18,910	+504	18,367	90,544	+393

Table 19. Load reductions from various Best Management Practices, calculated using the 2-year storm.

Parcel	BMP	Reduction in Runoff (m^3)	Reduction in Total Phosphorus (g)	Reduction in Total Nitrogen (g)
9	BAU dry well	6,455	3,034	14,331
9	Stream buffer	279	103	584
9	Reduce impervious area	814	387	1,784
9	Reduce impervious area and use dry wells	5,466	2,569	12,134
12	BAU dry well	37,630	17,686	83,539
12	Stream buffer	1,484	546	3,027
12	Reduce impervious area	6,388	3,499	15,462
12	Reduce impervious area and use dry wells	35,709	17,280	80,556

Table 20. Changes in loads for the two mitigation scenarios (BAU and IBMP).

Values in the table are the changes in loads resulting from *mitigated* development. Changes were calculated as mitigated loads minus pre-development (existing) loads. Values in parentheses are the percent change from existing pre-development conditions.

Parcel	BMP scenario	Change in runoff m^3 **(%)**	Change in Total Phosphorus load g **(%)**	Change in Total Nitrogen load g **(%)**
Calculated with pre-development loads estimated with default N-SPECT parameters				
9	BAU	-3,368 **(-158%)**	-2,996 **(-332%)**	-9,951 **(-205)**
9	IBMP + dry wells	-3,863 **(-181%)**	-3,077 **(-342%)**	-10,781 **(-222%)**
12	BAU	-2,062 **(-23%)**	+95 **(+3%)**	-3,135 **(-17%)**
12	IBMP + dry wells	-1,625 **(-18%)**	-45 **(-1%)**	-3,179 **(-17%)**
Calculated with pre-development loads estimated using the impervious area				
9	BAU	-976 **(-46%)**	-415 **(-46%)**	-2,249 **(-46)**
9	IBMP + dry wells	-1,471 **(-69%)**	-496 **(-55%)**	-3,079 **(-63%)**
12	BAU	-5,510 **(-62%)**	-1,906 **(-61%)**	-11,362 **(-61%)**
12	IBMP + dry wells	-5,073 **(-57%)**	-2,046 **(-65%)**	-11,406 **(-62%)**

Methods for Soil Erosion

In N-SPECT, the RUSLE method for calculating soil erosion is different from the method for calculating runoff and nutrient loads. In RUSLE, rainfall kinetic energy is a key parameter; rainfall amount and Curve Numbers are not parameters. RUSLE assumes that soil is dislodged by intense rainfall and erosion is proportional to parameters reflecting land use, vegetation, and quality of land management. In N-SPECT, this parameter varies with C-CAP land use category. RUSLE output consists of average annual erosion minus the small amount of sediment that is re-deposited prior to leaving the parcel.

To estimate unmitigated loads in parcel 9, N-SPECT/RUSLE was run first with existing C-CAP land use and then with post-development land use (low intensity development). There are a small number of cells whose existing land use is high-intensity development. These in-holdings were not changed to low-intensity because existing development would not be re-developed.

The impact of unmitigated development was calculated as post-development loads minus existing pre-development loads. To estimate load reductions from dry wells, it was assumed that no erosion occurred within the impervious areas (39% of parcel for BAU and 31% for IBMP) because soil that is covered by pavement or buildings cannot erode. To estimate load reductions from the riparian buffer strip (an IBMP) land cover within the buffer was changed to scrub/shrub, which is the vegetation category that has the least erosion.

Results for Soil Erosion

Impacts of development, with and without mitigation, are shown in Table 21. There are no results for parcel 12 because previous analysis showed that this parcel's high-intensity development resulted in a *reduction* of erosion. Thus, mitigation was not needed in parcel 12. In parcel 9, the BAU mitigation measures result in post-development loads that are 8% smaller than existing loads. The proposed IBMP mitigation measures, however, result in post-development loads that are 8% *larger* than existing loads. This is not sufficient.

In order to achieve satisfactory load reductions in the IBMP scenario, two additional mitigation measures were added to the original measures. The first consists of conserving the few small areas of evergreen forest by dedicating them to pocket parks. The second measure consists of re-grading 25% of the residential area so that hillslope lengths are 50% shorter than existing lengths. The shorter hillslopes result in shallower and slower sheetflow and flow in rills. Addition of these two measures resulted in post-development loads that are 8% smaller than existing loads.

Table 21. Impact of mitigation on average annual soil erosion in parcel 9, estimated with RUSLE.

Scenario	Result Numbers are in kg of eroded soil, not including the small amount that is re-deposited before leaving the parcel.
Load reductions	
BAU dry wells	6.04[1]
IBMP dry wells (reduced impervious area)	1.91[1]
Stream buffer	1.74
Forest parks	0.42
Re-grading	2.30
Impact of development (post-development loads minus existing loads)	
Without mitigation	+4.84 (31% increase)
BAU	-1.20 (8% decrease)
IBMP originally proposed (reduced impervious area + dry wells + stream buffer)	+ 1.20 (8% increase)
IBMP originally proposed plus two additional ones (reduced impervious area + dry wells + stream buffer + forest park + re-grading)	-1.25 (8% decrease)

[1] The IBMP scenario has 20% less impervious area than the BAU scenario. It would be logical to expect a 20% reduction would result in a 20% reduction in the benefit of the dry wells, not a 68% reduction. It appears, however, that those specific areas that were changed from impervious to pervious happened to be areas with higher than usual rates of erosion. It would be possible to deliberately place the impervious areas in high impact zones where the benefits of paving would be greatest. This option was not evaluated, however.

V.2.6 Use of TR-55 to Evaluate Mitigation of Peak Flows

The TR-55 model (USDA/SCS 1986) estimates peak discharge in a two-step process: runoff volume is calculated using SCS Curve Numbers (CN) and then runoff is routed through a series of planes and channels in order to obtain the discharge hydrograph and peak flow. Routing is performed using unit hydrograph techniques with area and time of concentration as major parameters. The user must configure the watershed as a series of planes (hillslopes) and channels. Each plane and channel has an area, slope, and length; additionally, channels have a cross-sectional shape. The model has routines for calculating the time of concentration from the aforementioned data. It also has default CN values for a given hydrologic soil group and land use/land cover category. Users may enter custom land uses with their custom Curve Numbers. Details of application of TR-55 to parcels 9 and 12 are found in appendix E. The only aspect of the model application that needs to be discussed here is the need to break each parcel into several sub-basins. This is because each parcel lies cross-wise across several drainages so that surface runoff exits the parcel at multiple locations. It was thus necessary to model each sub-basin separately. The goal of mitigation is to ensure that for each sub-basin the mitigated peak flow (the maximum instantaneous discharge in ft^3/s) at the parcel boundary is less than the original pre-development peak discharge.

Several scenarios were modeled with TR-55: a) existing undeveloped conditions, b) unmitigated development, c) development with dry wells (BAU), and d) development with innovative BMPs. Simulations were for the 2-year 24-hour storm. For each of these scenarios, Curve Numbers were selected as follows:

- Simulations for undeveloped conditions were obtained based on current C-CAP land use classifications. Simulations for unmitigated development were based on a breakdown of the post-development percentage of land in open, commercial, and residential uses. Refer to section III.2 for an explanation of how these percentages were derived and values obtained for each parcel. Curve Numbers for open land were set to those for urban grass in good condition; Curve Numbers for commercial areas were set to default values for the commercial category; and custom Curve Numbers for residential areas were based on the percent impervious area which was in turn based on housing density (see section III.2).

- The BAU simulations were based on the assumption that all runoff from impervious areas flows into drywells. See section III.2 for impervious area calculations. Curve Numbers for pervious areas were based on Curve Numbers for urban grass in good condition.

- In the IBMP scenario, dry wells were used in conjunction with other mitigation measures that reduced the amount of impervious surfaces by 20% (in comparison to the BAU scenario). Curve Numbers for pervious surfaces were set to those for urban grass in good condition.

Results indicate that dry wells (BAU scenario) are highly-effective in reducing peak discharges below pre-development values (Tables 22 and 23). Innovative BMPs also reduced peak discharges to below pre-development levels, but the reductions were not as large because there was less impervious area.

Table 22. Effectiveness of mitigation measures for peak discharge for the 2-year, 24-hour storm.

Numbers in the table are the percent reduction in peak discharge (sum across sub-areas) compared to pre-development values

	Mitigation Option	
Parcel	*Business as Usual*	*Innovative BMP*
12 (high intensity development)	67%	54%
9 (low intensity development)	39%	29%

Table 23. Peak discharge (cfs) for the 2-year 24-hour storm under various mitigation scenarios.

Parcel	Sub-basin	Pre-development	Unmitigated Development	Business as Usual Mitigation	Innovative BMP
12	1	16.2	21.8	5.3	7.1
	2	7.9	52.0	2.7	3.4
	3	11.9	89.7	3.9	6.0
9	1	1.4	11.5	1.2	1.4
	2	1.2	9.3	1.0	1.1
	3	2.6	11.1	1.2	1.4
	4	1.1	7.0	0.7	0.9
	5	1.5	7.5	0.8	0.9

V.2.7 Summary of Findings

The parcels slated for possible development are largely undeveloped grasslands that are adjacent to existing developed areas. They are located in the middle-upper reaches of the large Waiʻulaʻula watershed in an area of moderate rainfall (25-35 inches per year). Dammed perennial streams flow intermittently across or adjacent to the parcels slated for development. The stream system of which these are a part have a high ecological value insofar as all native freshwater fish species are found in them. There is also a diverse population of native aquatic insects.

The Waiʻulaʻula watershed does not contain any surface waters identified as impaired by the State of Hawaiʻi, nor has it been identified as a high priority for restoration. It has been identified as a watershed in need of protection. The receiving waters are categorized as “stressed” because of reduced water quality in Waikoloa Stream as it passes through Waimea town and in nearshore coastal waters near the stream outfall. In summary, the watershed is categorized as sensitive and stressed, but not impaired. It is, therefore, recommended that mitigation measures reduce post-development stormwater loads to below those for existing conditions. Towards that end, two sets of mitigation actions were proposed. In the “business as usual” (BAU) scenario, dry wells capture all runoff from impervious areas[18]. In the “innovative best management practices” (IBMP) scenario, there are a variety of measures for reducing impervious area and promoting infiltration close to the source of runoff. Dry wells are employed in the IBMP to capture runoff from a reduced impervious area.

<u>Quantitative Evaluation of Stormwater Loads</u>

The N-SPECT model was used to evaluate stormwater loads under existing, unmitigated post-development and mitigated post-development conditions. Both the BAU and IBMP mitigation scenarios reduce post-development runoff and total nitrogen loads to well below existing loads. In large measure, this is because dry wells are extremely effective. For total phosphorus (TP) loads in parcel 9, BAU and IBMP are more than sufficient to reduce loads to below those for existing conditions. In parcel 12, however, BAU mitigation may not be sufficient to meet TP load reduction targets. IBMP mitigations are marginally better and do reduce post-development TP loads to below existing conditions. In summary, proposed mitigation efforts are more than sufficient, with the possible exception of the BAU scenario in parcel 12. This suggests that additional measures targeted at phosphorus loads should be considered.

In many cases, the impact of high-intensity development on soil erosion is positive. Soil that is covered by pavement or buildings cannot erode. In parcel 9, however, unmitigated low-intensity development is predicted to increase erosion. Models predict that load reduction targets can be met with BAU mitigation but not with the proposed IBMP. This prompted the proposal of additional mitigation measures that, when combined with the original IBMP measures, were sufficient to reduce erosion below existing levels.

N-SPECT is not capable of estimating peak discharges, which must be reduced below pre-development levels. The TR-55 model was, therefore, used to evaluate peak flows. Results indicate that dry wells are highly effective and reduce peak discharges below pre-development values. The reduction for BAU was greater than the reduction for IBMPs, which deliberately reduce impervious area.

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[18] “As a general rule, dry wells on the Island of Hawaiʻi are designed to accommodate a flow rate no more than 6 ft^3/s” (Kuba 2005). It is unclear if dry wells are engineered to accommodate a specific amount of flow generated by a specific catchment area and recurrence interval.

Concluding Remarks

Parcels 9 and 12 differ in that the former is slated for low-intensity development and has a very short length of stream running through it and the latter is slated for high-intensity development and has a considerable amount of stream frontage. In terms of application of the proposed method and in terms of results, however, there is not much difference between the two parcels. The only possible exception is that in the high-intensity parcel it was difficult to reach load reduction targets for total phosphorus.

Without modeling, it is difficult to predict if proposed mitigation actions are sufficient. On the other hand, loads estimated by models are only as good as model assumptions and accuracy of parameter values. Further, even if the models provide realistic estimates of load reductions, the recommended BMPs will only be effective if they are properly designed, constructed, and maintained. It is notable that, in some cases, results of the modeling forced a reconsideration of proposed mitigation measures.

The real purpose of applying the proposed method to the hypothetical developments is to determine if the proposed method is feasible to implement and effective at disclosing impacts. These issues will be addressed in the next section.

V.3 Adequacy of the Proposed Method

Feasibility of Applying the Proposed Method

The difficulty in applying the proposed method will depend on whether the watershed is sensitive or not, stressed or not, impaired or not, and whether or not it has a TMDL[19]. Watersheds for which a TMDL has been developed may be easier to work with because extensive data collection and analyses have already been conducted prior to the preparation of an EIS. The Waiʻulaʻula watershed is stressed (but not impaired), sensitive, and does not have a TMDL. This meant that extensive analysis was required by the proposed method. In our experience, it was possible to apply the proposed method to the Waiʻulaʻula watershed. Two factors greatly facilitated this. First, a watershed plan exists. Second, a pollutant load model had already been developed (refer to Volume Two of this report). Without the watershed plan and existing model application, it would have been very difficult to fully apply the proposed method. As it was, application was time-consuming, especially the step in which load reductions were predicted for each of the various BMPs.

Adequacy of the Proposed Method

In comparison with past assessment practices, the proposed new method has the following advantages:

1) fuller disclosure of site conditions;
2) places the stormwater impacts in the context of the watershed;
3) incentives to incorporate green design elements, including a variety of best management practices;
4) recognition that mitigation efforts are especially important for ecologically-sensitive or impaired watersheds;
5) promotion of the use of quantitative techniques for determining the effectiveness of mitigation measures;
6) TMDL load targets, in areas with existing TMDLs, are given explicit consideration. This ensures that the impact of the project does not exceed the ability of the watershed to absorb loads.

The following limitations of the proposed new method are noted:

1) Secondary and cumulative impacts are not explicitly addressed;
2) The narrow focus on Clean Water Act regulatory concerns neglects certain other related considerations such as stream channel condition and the effects on the pollution abatement functions of wetlands and riparian areas;
3) In watersheds that are neither ecologically-sensitive nor currently impaired, the proposed method does not require the developer to propose and evaluate post-construction BMPs. Post-construction BMPs will eventually be required when the project reaches the stage of county permits, but it would be better to consider them early in the process during preparation of an EIS.

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[19] The total maximum daily load (TMDL) is an estimate of the amount of given pollutant that can enter a given stream or receiving waters (in a given amount of time) without exceeding water quality criterion. The maximum allowable load is typically allocated between different uses, for example, contributions from sewage treatment plants, agriculture, and urban stormwater runoff. The TMDL is a non-binding management measure within the Clean Water Act.

4) The modeling tools underestimate the load reduction from stream buffers. This is because they do not recognize that buffers trap sediment and particulate nutrients that originate uphill from the buffer. Riparian buffers have other important benefits, such as stabilizing streambanks, preserving important habitats, and providing recreation.
5) The link between stormwater impacts and flood hazards is not explicit. These two topics are typically covered in separate chapters of an EIS. In addition, County drainage design requirements are not incorporated into the analysis.
6) The methods to determine if a watershed is stressed are unrealistic. Watershed plans are too great an effort and the rapid assessment models do not measure the gap between where the watershed is and where is should be.

Step 5 of the proposed method recommends several alternatives for determining whether or not a sensitive watershed is stressed. These alternatives include preparing a watershed plan or applying a rapid assessment model. The specific rapid assessment models mentioned in the ***Year-1 Stormwater Impact Assessment Project*** are described in Appendix D. If a watershed plan already exists it should certainly be consulted. If one does not exist, however, it is not always practical to prepare one during the environmental assessment process just to determine whether a sensitive watershed is stressed. Watershed plans are expensive (~$100,000-200,000) and require local capacity and community buy-in. Further, it takes time to prepare one (~1-3 years), so it may not fit into the time-frame for preparation of an EIS. The rapid assessment models are not necessarily a good solution either. These models can provide quantitative estimates of runoff, peak flows, and pollutant loads. Unless there is a TMDL, however, it can be difficult to interpret results in the absence of watershed-specific criteria of stress.

Rapid assessment models can also be used to evaluate the effectiveness of proposed mitigation measures. In this context, the models can be used to calculate percent load reduction so there is little difficulty in evaluating the significance of results. Nevertheless, there are a number of drawbacks to these models:

1) The models recommended by the ***Year-1 Stormwater Impact Assessment Project*** were not designed to estimate load reductions for specific mitigation measures. Applying them for this purpose is not straightforward.
2) Estimates are only as reliable as parameter values and model assumptions.
3) Applying the models is time-consuming and, therefore, expensive.

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Appendix A: Year-1 "Proposed Methodology"

for Assessing Impacts of Development on Stormwater

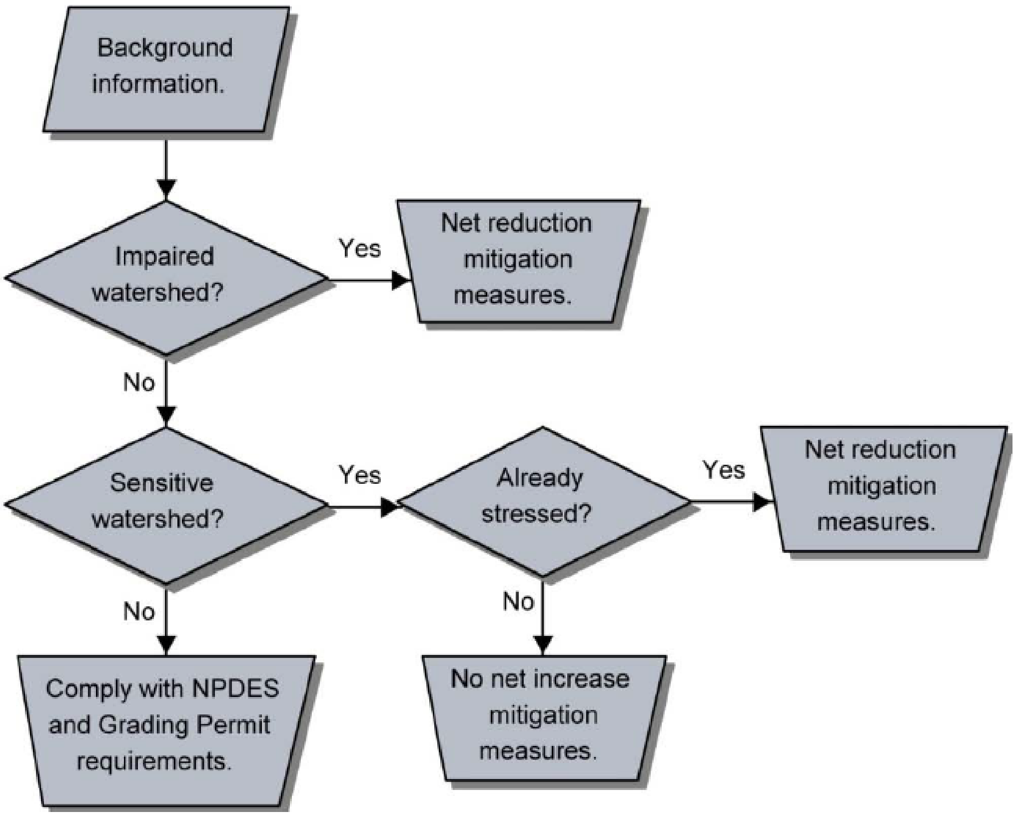
Taken directly from the report authored by the Department of Geography and Environmental Studies and PBR Hawaiʻi (2011). For additional information see section V.1.1.

Synthesis-- Recommended EIS Stormwater Cumulative Impact Methodology

Applying the above concepts, the recommended steps to analyze cumulative stormwater impacts are as follows (see Figure 9):

1. *Background Information.* Provide background information pertinent to the development of a pollution prevention plan for a NPDES Permit including:
    - Identification of the watershed;
    - Watershed area;
    - Proximity of streams;
    - Land uses within the watershed;
    - Rainfall intensity;
    - Hydrological soils group.
2. *Impaired Watershed.* Does the watershed drain into an impaired receiving water or identified as high priority for restoration? If yes, then propose onsite mitigation measures to reduce pollutant generation between pre-and post-development that would be eligible to meet LEED-NC SS 6.1 and 6.2 credits, as well as comply with a TMDL allocation if available. Mitigation measures should address as a minimum the pollutant with TMDL allocations, but should consider other potential sources generated by the various land uses within the watershed and pollutants transported by groundwater;
3. *Sensitive Watershed.* If not impaired, does the watershed drain into a "sensitive" receiving water? If yes, determine if the receiving waters are already stressed through a watershed plan, rapid assessment model, or salinity gradient method.
    - If stressed, propose on- or offsite mitigation measures to reduce pollutant loads through onsite and/or offsite measures.
    - If not stressed, propose on- or offsite mitigation measures that result in no net increase.
4. If not impaired or sensitive, comply with applicable NPDES and Grading Permit requirements. Projects in impaired or sensitive watersheds must also comply with applicable NPDES and grading permits in addition to heightened mitigation measures identified in previous steps.

Figure 10. Proposed Stormwater Cumulative Impact Assessment Steps



Appendix B: Year-1 Report Discussion of Cumulative Impacts

Taken directly from Department of Geography and Environmental Studies and PBR Hawai'i (2011). See comments in third paragraph of page 31 or section V.1.1. about "cumulative" impact methodology.

Proposed Methodology for Stormwater Cumulative Impact Assessment

The proposed methodology for stormwater cumulative impact assessment has the following objectives:

- Meet state of the art guidance on cumulative impact analyses;
- Match the level of analysis to the potential sensitivity of the watershed;
- Where rigorous analysis is merited, use the best available knowledge on watersheds where available, and suggest rapid assessment methods where not available;
- Distinguish and integrate the different geographic scales of analysis—the project site direct impacts as distinguished from the cumulative regional watershed impacts to estimate the proportionate impact of the project;
- Encourage mitigation measures that are consistent with and have the potential to earn credits under green building programs such as LEED;
- Provide useful base information and guidance to subsequent design-phase permits.

State of the Art Guidance on Cumulative Impact Analysis

Based on a recent study on Hawaii's EIS system, there is a definite need for guidance: "Cumulative effects assessment is neither well understood nor well implemented and is not integrated with the planning process" (University of Hawaii, 2010, p. 85). Recognizing the nascent state of knowledge to address cumulative impacts from over ten years ago, the Council on Environmental Quality (Council on Environmental Quality, 1997) and EPA (U.S. Environmental Protection Agency, 1999) sought to provide guidance on cumulative impacts. Based on these guidance documents, a cumulative impact methodology should address the following:

- Identification of Impacted Resources. "Cumulative effects need to be analyzed in terms of the specific resource, ecosystem, or human community being affected." (Council on Environmental Quality, 1997, p. 8). For stormwater, the impacted resources include the the inland and marine waters that should be protected or restored to be fishable and swimmable.
- Definition of Geographic Boundaries. "Cumulative effects on a given resource, ecosystem, or human community are rarely aligned with political or administrative boundaries. . . Cumulative effects on natural systems must use natural ecological boundaries . . ." (Council on Environmental Quality, 1997, p. 8). For stormwater, the natural geographic boundary is the watershed, which is discussed further below.
- Determining Past, Present, and Reasonably Foreseeable Future Actions. "Cumulative effects are caused by the aggregate of past, present, and reasonably foreseeable future actions. " (Council on Environmental Quality, 1997, p. 8). For stormwater, land uses are indicators of nonpoint pollution sources. Land cover data sets provide past and present land uses, while land use designations (e.g., State Land Use districts, county zoning) provide an indication of reasonably foreseeable future pollutant sources.
- Establishing Baseline Condition and Thresholds. "Each affected resource, ecosystem, and human community must be analyzed in terms of its capacity to accommodate additional effects, based on its own time and space parameters." (Council on Environmental Quality, 1997, p. 8). For stormwater, although the water quality standards provide a reference

Appendix C: Classification of Water Bodies

Based on Section 11-54-3, HAR, as described by the State of Hawaiʻi Department of Health.

(http://hawaii.gov/health/environmental/env-planning/wqm/050708Meeting/supportdocs.pdf)

Inland Waters

Class 1	It is the objective of class 1 waters that these waters remain in their natural state as nearly as possible with an absolute minimum of pollution from any human caused source. To the extent possible, the wilderness character of these areas shall be protected. Waste discharge into these water is prohibited. Any conduct which results in a demonstrable increase in the levels of point or nonpoint source contamination in class 1 waters is prohibited.
Class 1a	The uses to be protected in class 1.a. waters are scientific and educational purposes, protection of native breeding stock, baseline references from which human-caused changes can be measured, compatible recreation, aesthetic enjoyment, and other non-degrading uses which are compatible with the protection of the ecosystems associated with waters of this class.
Class 1b	The uses to be protected in class 1.b. waters are domestic water supplies, food processing, protection of native breeding stock, the support and propagation of aquatic life, baseline references from which human-caused changes can be measured, scientific and education purposes, compatible recreation and aesthetic enjoyment.
Class 2	The objective of class 2 waters is to protect their use for recreation purposes, the support and propagation of aquatic life, agricultural and industrial water supplies, shipping, and navigation. The uses to be protected in the class of waters are all uses compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment or control compatible with the criteria established for this class. No new treated sewage discharges shall be permitted within estuaries.

Marine Waters

Class AA	It is the objective of class AA waters that these waters remain in their natural pristine state as nearly as possible with an absolute minimum of pollution or alteration of water quality from any human-caused source or actions. To the extent practicable, the wilderness character of these areas shall be protected. No zones of mixing shall be permitted in this class. The uses to be protected in this class of waters are oceanographic research, the support and propagation of shellfish and other marine life, conservation of coral reefs and wilderness areas, compatible recreation, and aesthetic enjoyment.
Class A	It is the objective of class A waters that their use for recreational purposes and aesthetic enjoyment be protected. Any other use shall be permitted as long as it is compatible with the protection and propagation of fish, shellfish, and wildlife, and with recreation in and on these waters. These waters shall not act as receiving waters for any discharge which has not received the best degree of treatment of control compatible with the criteria established for this class. No new industrial discharges shall be permitted within embayments (with exceptions as noted by rule).

Marine Bottom Ecosystems

Class I	It is the objective of class I marine bottom ecosystems that they remain as nearly as possible in their natural pristine state with an absolute minimum of pollution from any human-induced source. Uses of marine bottom ecosystems in this class are passive human uses without intervention or alteration, allowing the perpetuation and preservation of the marine bottom in a most natural state, such as for non-consumptive scientific research (demonstration, observation or monitoring only), non-consumptive education, aesthetic enjoyment, passive activities, and preservation.
Class II	It is the objective of class II marine bottom ecosystems that their use for protection including propagation of fish, shellfish, and wildlife, and for recreational purposes no be limited in any way. The uses to be protected in this class of marine bottom ecosystems are all uses compatible with the protection

Appendix D: Assessment Models Mentioned by the Proposed Method

For sensitive watersheds, the proposed new method recommends determining if the receiving waters are already stressed by doing a watershed plan (E.3) or one of the a rapid assessment model listed below.

MUSLE (for design storms) and RUSLE (for average annual). These are used to model soil erosion and are included within N-SPECT.

Data Required	**Source**
Rainfall erosivity	Contact state NRCS office or check Office of Planning GIS website (data may be added in the future)
Soil erodibility (water k-factor)	State of Hawaiʻi GIS website http://hawaii.gov/dbedt/gis/soils.htm or NRCS Soil Data Mart
L and S topographic factors	Derive from topographic data
Supporting practices and cover management factors	Renard et al. 1997
Runoff volume and peak flow rate (MUSLE only)	Varies. Already coded in N-SPECT version or use CN model and TR-55 for stand-alone applications

N-SPECT. An analysis tool developed for ArcGIS 9.2 and 9.3 by NOAA. It calculates erosion, pollutant loads, and runoff volume.

Data Requirements	**Source**
Land cover	C-CAP or GAP State of Hawai‘i GIS website http://hawaii.gov/dbedt/gis/download.htm
Rainfall/precipitation	Rainfall Atlas of Hawai‘i http://rainfall.geography.hawaii.edu/downloads.html
Soil hydrologic group and erodibility k factor	State of Hawai‘i GIS website http://hawaii.gov/dbedt/gis/soils.htm
Pollutant coefficients	Standard coefficients come with N-SPECT program
Raining days	Must be estimated by user; no guidance on how to do so.
Rainfall erosivity	NRCS
DEM topography	Widely available; standard dataset from USGS

Rational Method. It calculates peak discharge in using the formula $Q_p = C\,i\,A$.

Data Required
Rainfall intensity i (in/hr)
Drainage area A (acres)
Land cover runoff coefficient C

SCS CN Model. Runoff depth (effective rainfall depth) is a function of total rainfall depth and an abstraction parameter, CN (Curve Number). CN is a function of hydrologic soil group, land use, ground surface condition, and antecedent moisture condition.

Simple Method. This method estimates pollutant loads under the assumption that pollutant concentrations are constant across time. Concentration is multiplied by runoff volume which must be calculated independently. N-SPECT offers the choice of calculating sediment loads either with the simple method or using RUSLE.

Data Required
Runoff volume
Pollutant concentration
Area

TR-55. This is considered more accurate than the Rational Method (see 5.4.1.2 for this) for larger watersheds and can be modified to fit future scenarios. The data required are time of concentration, drainage area, rainfall distribution, 24-hr rainfall, a pond and swamp adjustment factor, and SCS Curve Numbers (USDA 1986).

Data Required
Topography (maps or DEM) is used to delineate sub-basins, determine spatial configuration of runoff zones, and derive slopes and length
Roughness values and channel geometry
Design storm rainfall
Pond and swamp adjustment factor
Land use designation (varies spatially and is used to derive Curve Numbers or can enter custom CN)

Appendix E: Modeling Peak Discharge with the TR-55 Model

Introduction

The TR-55 model (USDA/SCS 1986) estimates peak discharge in a two-step process: runoff volume is calculated using SCS Curve Numbers (CN) and then runoff is routed through a series of planes and channels in order to obtain the discharge hydrograph and peak flow. The user provides the amount of storm rainfall and the temporal distribution of rain, selecting from two types. Routing is performed using unit hydrograph techniques with area and the time of concentration as major parameters. The user must configure the watershed as a series of planes (hillslopes) and channels. Each plane and channel has an area, slope, and length; additionally, channels have a cross-sectional shape. The model has routines for calculating the time of concentration from the aforementioned data. It also has default CN values for a given hydrologic soil group and land use/land cover category.

The Muskingum-Cunge reach routing procedure is used to calculate the effect of channels and Storage-Indication is used to calculate the effects of structures. In applications to Wai'ula'ula developments, all the sub-basins were very small, resulting in time of concentration values that were very small. In this case, TR-55 sets the time of concentration to the minimum value of 0.1 hours.

Model users will wish to consult the following resources:

USDA, Natural Resources Conservation Service (NRCS). 2009. Small Watershed Hydrology: WinTR-55 User Guide. January 2009. ftp://ftp.wcc.nrcs.usda.gov/wntsc/H&H/WinTR55/WinTR55UserGuide.pdf

USDA, Natural Resources Conservation Service (NRCS). 2009. WinTR-55 (Version 1.00.09) [Software]. http://www.nrcs.usda.gov/wps/portal/nrcs/detailfull/national/water/quality/?&cid=stelprdb1042901

Required Input Data

Non-GIS data
- Rainfall distribution (Type I for Hawai'i)
- Rainfall for 2-year 24-hour storm
- SCS Curve Numbers for C-CAP categories

GIS data
- DEM
- C-CAP land use categories
- Hydrological soil group (B for both parcels)

Project user-input data
- User (person creating the analysis)
- State
- County
- Project name
- Project subtitle
- Dimensionless Unit Hydrograph (if not standard)
- Storm Data Source
- Sub-area Entry and Summary

Sub-area Description
Sub-area Flows to Reach/Outlet
Area (ac. or sq. mi.)
Weighted Curve Number (CN) (calculated when land use is input)
Time of concentration (TCU) (can be manually input rather than calculated)

Application of TR-55 to Parcels 9 and 12

The first step was to pre-process topographic data in ArcMap. This involved creating Flow Direction and Flow Accumulation rasters from the DEM. Next, the Basin Tool was used to delineate sub-basins within each parcel. This was necessary because the parcels lie cross-wise across drainages. To simplify matters, very small sub-basins along the edge of the parcels were consolidated into a larger sub-basin. The Zonal Statistics tool was used to obtain values of C-CAP categories within each sub-basin. On the basis of topography, the sub-basins were divided into hillslopes (represented as rectangular planes) feeding into channels. Estimates of the channel and hillslope lengths and slopes were made using the Flow Accumulation raster and the Measure tool.

To set up the WinTR-55 model, one inputs land cover areas in the appropriate soil group (B) for both parcels. C-CAP categories and their comparable WinTR-55 classifications are shown in Table 24. The results of this process are shown in Table 25.

Table 24. C-CAP to WinTR-55 land cover conversion table.

C-CAP	WinTR-55	Curve Number (Hydrological Soil Group B)
High Intensity Development	Commercial	92
Low Intensity Development	¼ acre lots	75
Cultivated Land	Straight row, good	78
Grassland	Grassland, good	61
Forest	Woods, good	55
Shrub/Scrub	Brush, good	48
Bare Land	Bare soil	86

Table 25. Weighted Curve Numbers used in TR-55 simulations

Parcel	Sub-basin	Current (Pre-Development)	Unmitigated Development	Business as Usual	Innovative BMPs
12	1	62	64	85	79
12	8	62	83	85	79
12	20	62	83	85	79
9	101	59	76	78	74
9	102	59	76	79	75
9	103	62	76	79	75
9	104	61	60	79	75
9	105	61	76	79	75

Four scenarios were run for each sub-basin as follows:

Current, Pre-Development: Acreage of C-CAP land use categories was input into the WinTR-55 program using Table 24 to convert land cover classes to WinTR-55 classifications.

Unmitigated Development: Each parcel is a different mix of Open, Commercial, and Residential land uses (see Section II). Open land was categorized as "Urban grass, good," Commercial as Commercial, and Residential was a custom number based on the percent impervious area (see Section III).

Business As Usual (BAU): Assumes all runoff from impervious areas flows into drywells, as is the current practice for most of the Big Island. Non-impervious areas were modeled as "Urban grass, good," in WinTR-55.

Innovative Best Management Practices (IBMP): Assumes that the impervious area is 20% lower than in the BAU scenario. Pervious surfaces are modeled as "Urban grass, good" (same as BAU).

Figure 6: WinTR-55 Main Window with Inputs for Parcel 12 Sub-basin 20.

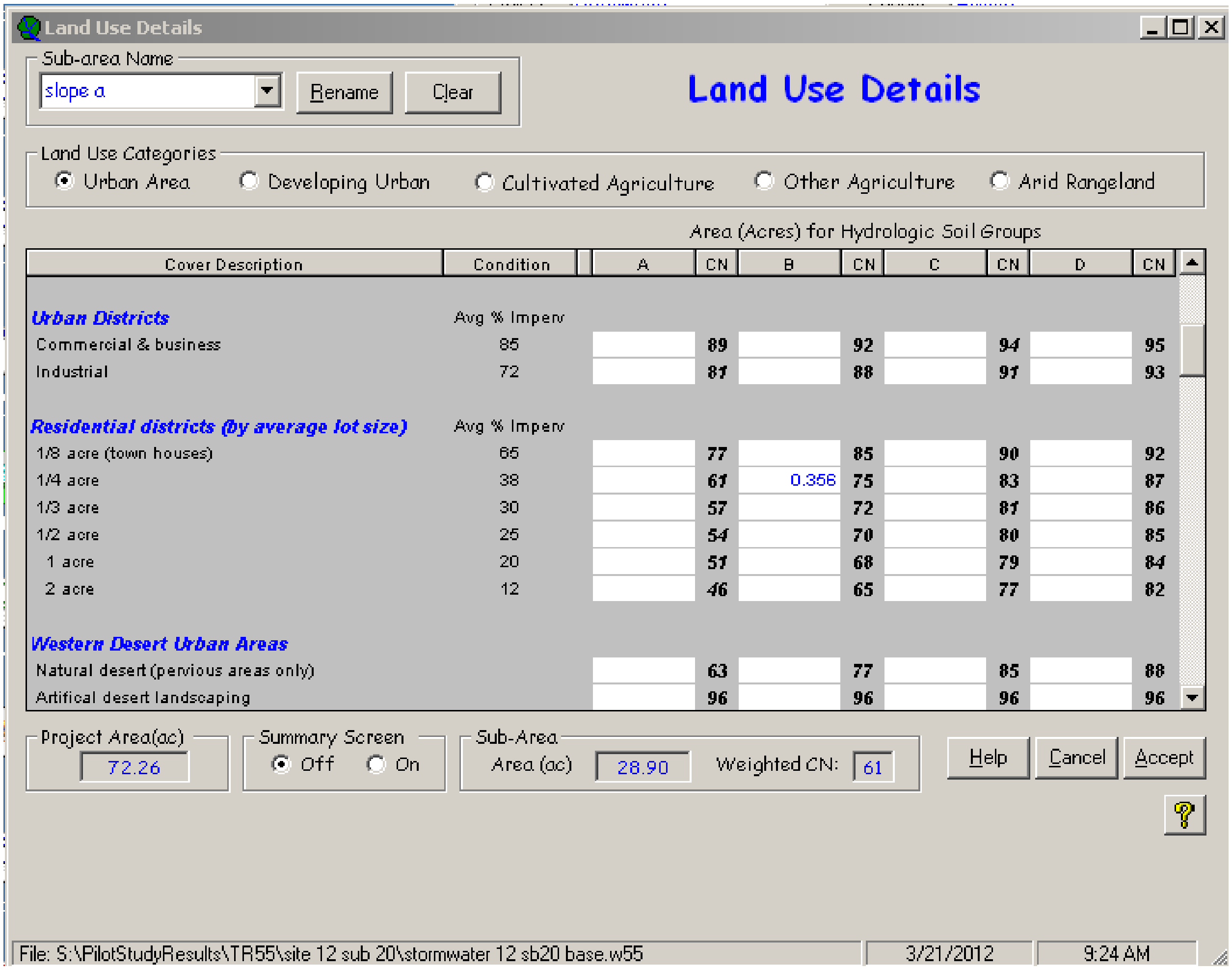
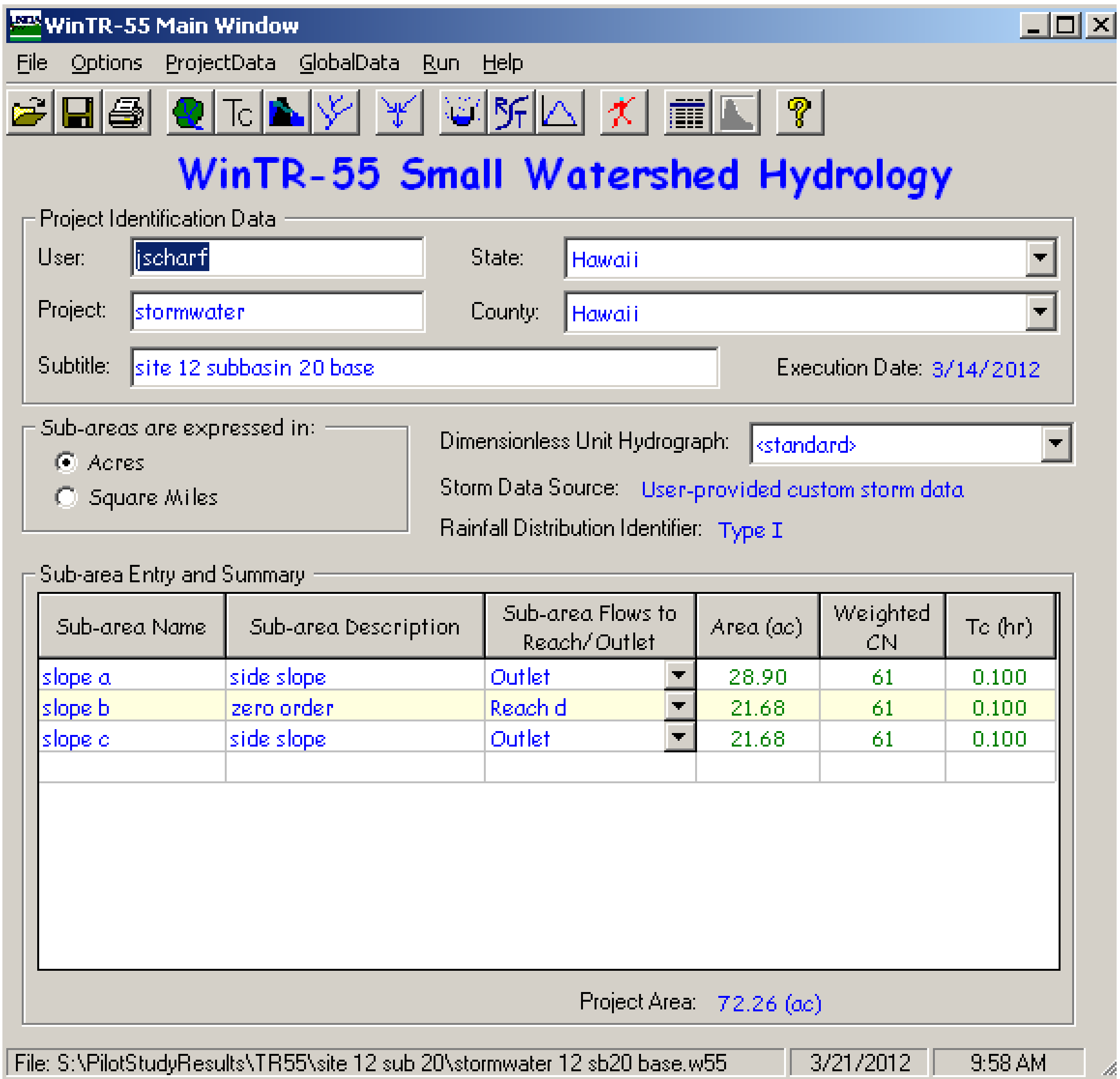


Figure 7: WinTR-55 Land Use Input Window.

It is important to match the Curve Numbers for a C-CAP land cover class to the appropriate cover description (see Tables 24 and 25).



Glossary

Baseflow. Streamflow that occurs in-between stormflow-generating rains. Baseflow is derived from groundwater discharge.

Best Management Practice (BMP). A specific action, process, method, or technology that is effective and practical for preventing or reducing pollution from nonpoint sources. Management practices are selected for appropriateness to the source, location, and climate.

Cumulative Impacts. Impacts that arise from the sum of all past, present, and reasonably foreseeable future actions. Cumulative impacts can arise from individually minor but collectively significant actions taking place over a period of years.

Design Storm. A hypothetical large rare rainstorm. Sometimes referred to as an "event". This concept is best understood as an example. Consider a location for which the 1-hour 10-year rainstorm is 2.4 inches. This storm delivers 2.4 inches of rain in one hour and has a 10-year recurrence interval. This means that in any given year there is a 1 in 10 chance that the largest 1-hour rainfall will exceed 2.4 inches.

Geographical Information System (GIS). A computer system for storing and analyzing geographically referenced (map-like) data.

Intermittent stream. A stream that carries water for months at a time but periodically ceases to flow when shallow groundwater is depleted. Intermittent streams differ from **ephemeral streams** in that ephemeral streams are not fed by groundwater and carry water only after rains.

Interrupted stream. A stream that carries water through much of its length but has sections of dry streambeds.

LEED refers to the Leadership in Energy and Environmental Design program, which provides developers with a framework for identifying and implementing practical and measurable green building design, construction, operations, and maintenance solutions (U.S. Green Building Council. 2005).

Loads refer to the amount of pollutant leaving a development or watershed in a specified amount of time. Typical units are kilograms per year or kilograms per storm event. Loads are relevant to the ecosystem in its entirety while concentrations (amount of pollutant in a unit volume of water) are relevant in terms of stress to individual organisms.

Losing Streams lose water to streambed infiltration. This means that it is possible for discharge to decrease in a downstream direction. Loads generated upstream may not reach the ocean. Note that a stream may be losing in some reaches and gaining in others.

Peak Flow. The maximum discharge experienced during a runoff event or during the course of year. A stream's discharge (synonym flow) is the amount of water flowing past a given point in a given amount of time. Units are volume of water per units time: typically cubic feet per second (cfs) or cubic meters per second (cms).

Perennial stream. A stream that carries water at all times. Perennial streams are fed both by stormwater runoff and by groundwater.

Raster. GIS data or models that represent a spatially continuous variable (e.g. land use or rainfall) as an equally-spaced grid of values.

Runoff. As used in this report, runoff is synonymous with stormwater and refers to water flowing over the ground or in streams in response to a hard rain. Runoff occurs during and immediately after a rainstorm. Occasionally this term is used to denote all water in streams, whether derived from "surface" runoff or from groundwater.

Secondary impacts. Impacts which are caused by an action and are later in time or farther removed in distance, but are still reasonably foreseeable. These indirect effects may include growth-inducing effects and other effects related to induced changes in the pattern of land use, population density or growth rate, and related effects on air and water and other natural systems, including ecosystems. (From Chapter 11-200, HAR)

Section 303(d) List. The federal Clean Water Act requires states to regularly describe overall status of water quality statewide and submit a list of waters that do not meet state water quality standards. The most-recent document and list developed by the Hawaii Department of Health is entitled ***2006 State of Hawaii Water Quality Monitoring and Assessment Report: Integrated Report to the U.S. Environmental Protection Agency and the U.S. Congress Pursuant to Sections 303(D) and 305(B), Clean Water Act (P.L. 97-117)***, better known as the Section 303(d) list.

Stormwater is water flowing over the ground or in channels immediately after a hard rain. Stormwater is contrasted with **baseflow**, which is derived from groundwater and comprises the small but steady streamflow in-between hard rains.

Stormwater Assessment. Prediction of the effect of an activity on stormwater. Effects could include changes to the amount runoff, changes to the timing and magnitude of peak flows, and initiation of streambank erosion. This term is most often used in the context of an Environmental Impact Statement.

Total Maximum Daily Load (TMDL). An estimate of the amount of given pollutant that can enter a given stream or receiving waters (in a given amount of time) without impairing water quality. The maximum allowable load is typically allocated between different uses, for example, contributions from sewage treatment plants, agriculture, and urban stormwater runoff. The TMDL is a non-binding management measure within the Clean Water Act, implemented by the Hawai'i Department of Health.

Total Nitrogen (TN). "Total" nitrogen refers to the sum of all forms of nitrogen, including particulate, dissolved, inorganic (e.g. nitrate), and organic (e.g. decomposed leaves) forms. Different forms of nitrogen have different levels of bioavailability, but nitrogen changes form readily so it is traditional to analyze all of them together.

Total Phosphorus (TP). “Total” phosphorus is the sum of all forms of phosphorus, including particulate, dissolved, inorganic (e.g. orthophosphate), and organic (e.g. decomposed leaves) forms. In streams a high percentage of phosphorus is in particulate form, so BMPs that reduce sediment loads are usually effective in reducing the amount of phosphorus that enters streams.

Total Suspended Solids (TSS). TSS concentration refers to the amount of sediment (either mineral or organic) in water and has units of mass of solids per unit volume of water.

Water Quality Standards. The criteria used by the State uses to evaluate whether its waters are healthy. Water quality standards address physical, chemical and biological aspects of water quality and set the bar for minimum acceptable quality.

Yield. Pollutant loads divided by the acreage of the area that generates the runoff. Yields have units of mass of pollutant per unit time per unit area. Yields are useful in comparing different geographic areas or examining spatial variations.