ALAN M. ARAKAWA
Mayor

KYLE K. GINOZA, P.E.
Director

MICHAEL M. MIYAMOTO
Deputy Director

JAN 2 3 2011

TRACY TAKAMINE, P.E.
Solid Waste Division

Wastewater Reclamation
Division

COUNTY OF MAUI
DEPARTMENT OF
ENVIRONMENTAL MANAGEMENT
2200 MAIN STREET, SUITE 100
WAILUKU, MAUI, HAWAII 96793

RECEIVED
'11 JAN -6 P1:26
OFF. OF ENVIRONMENTAL QUALITY CONTROL

January 3, 2011

Director
Office of Environmental Quality Control
State of Hawaii
235 South Beretania Street, Suite 702
Honolulu, Hawaii 96813

Dear Director:

SUBJECT: ENVIRONMENTAL ASSESSMENT/ENVIRONMENTAL IMPACT STATEMENT PREPARATION NOTICE FOR THE PROPOSED WAILUKU-KAHULUI WASTEWATER RECLAMATION FACILITY SHORELINE PROTECTION EXTENSION (TMK NO. (2) 3-8-001:188)

The County of Maui, Department of Environmental Management, the approving agency for the Environmental Assessment/Environmental Impact Statement Preparation Notice (EA/EISPN) for the subject project, requests publication of the subject document in the next issue of The Environmental Notice. Enclosed are the following items:

- One (1) copy in PDF format and a completed OEQC publication form on CD
- One (1) hardcopy of the EA/EISPN.

We have enclosed a completed OEQC Publication form and Project Summary, a CD (PDF) and one (1) copy of the EA/EISPN. Additionally, the EA/EISPN has been transmitted to the Wailuku Public Library and the Kahului Public Library by copy of this letter.

Please feel free to contact Mr. Mich Hirano, Munekiyo & Hiraga, Inc. at (808) 244-2015, should you have any questions.

Very truly yours,

Kyle Ginoza. P.E., Director
Department of Environmental Management

Enclosures
cc: Juan Rivera, Department of Environmental Management
Rob Sloop, Moffatt & Nichol
Mich Hirano, Munekiyo & Hiraga, Inc.
Wailuku Public Library (w/copy of EA/EISPN only)
Kahului Public Library (w/copy of EA/EISPN only)

Environmental Assessment/ Environmental Impact Statement Preparation Notice

PROPOSED WAILUKU-KAHULUI WASTEWATER RECLAMATION FACILITY SHORELINE PROTECTION EXTENSION

Prepared for:

County of Maui,
Department of Environmental Management

Accepting Authority:

County of Maui,
Department of Environmental Management

January 2011

Copyright © 2011,
by Munekiyo & Hiraga, Inc.

MUNEKIYO & HIRAGA, INC.

CONTENTS

Executive Summary . . . . . Page i

I. PROJECT OVERVIEW . . . . . Page 1

A. PROJECT LOCATION, EXISTING USE, AND OWNERSHIP . . . . . Page 1

B. HISTORICAL CONTEXT . . . . . Page 1
1. History of the Facility . . . . . Page 1
2. Central Maui Wastewater Reclamation Facility Study . . . . . Page 4
3. Maui County Council Action on the Study . . . . . Page 9

C. PROJECT NEED . . . . . Page 10

D. PROPOSED ACTION . . . . . Page 14

E. CONSTRUCTION METHODOLOGY . . . . . Page 14

F. CHAPTER 343, HAWAI'I REVISED STATUTES COMPLIANCE . . . Page 18

G. PERMITTING REQUIREMENTS . . . . . Page 20
1. Chapter 343, HRS, Environmental Impact Statement (EIS) . . . . . Page 20
2. Special Management Area (SMA) Use Permit and Shoreline Setback Variance (SSV) . . . . . Page 20
3. Conservation District Use Permit (CDUP) . . . . . Page 21
4. U.S. Department of the Army Permit . . . . . Page 21
5. Water Quality Certification . . . . . Page 21
6. Coastal Zone Management (CZM) Consistency Approval . . . . . Page 21

H. PROJECT COST AND IMPLEMENTATION SCHEDULE . . . . . Page 21

II. EXISTING ENVIRONMENT, POTENTIAL IMPACTS, AND MITIGATION MEASURES . . . . . Page 22

A. PHYSICAL ENVIRONMENT . . . . . Page 22
1. Surrounding Land Use . . . . . Page 22
2. Climate, Topography, and Soils . . . . . Page 23
3. Flood and Tsunami Hazard . . . . . Page 27
4. Coastal Processes . . . . . Page 29
5. Flora and Fauna . . . . . Page 31
6. Streams and Wetlands . . . . . Page 32

7. Nearshore Marine Environment . . . . . Page 32
8. Relative Sea Level Rise . . . . . Page 33
9. Historical and Archaeological Resources . . . . . Page 34
10. Cultural Assessment . . . . . Page 35
11. Air Quality . . . . . Page 36
12. Noise Characteristics . . . . . Page 37
13. Water Quality . . . . . Page 37
14. Scenic and Open Space Resources . . . . . Page 38

B. SOCIO-ECONOMIC ENVIRONMENT . . . . . Page 39
1. Population and Demographic . . . . . Page 39
2. Economy . . . . . Page 40

C. PUBLIC SERVICES . . . . . Page 41
1. Recreational Facilities . . . . . Page 41
2. Police and Fire Protection . . . . . Page 42
3. Solid Waste . . . . . Page 42
4. Medical Services . . . . . Page 43
5. Schools . . . . . Page 43

D. INFRASTRUCTURE . . . . . Page 44
1. Roadways . . . . . Page 44
2. Wastewater . . . . . Page 45
3. Water . . . . . Page 45
4. Drainage . . . . . Page 46
5. Electricity, Telephone, and Cable Television Systems . . . . . Page 46

E. CUMULATIVE AND SECONDARY IMPACTS . . . . . Page 47

III. RELATIONSHIP TO GOVERNMENTAL PLANS, POLICIES, AND CONTROLS . . . . . Page 49

A. STATE LAND USE DISTRICTS . . . . . Page 49

B. CONSERVATION DISTRICT USE ANALYSIS . . . . . Page 49

C. HAWAI'I STATE PLAN . . . . . Page 54

D. MAUI COUNTY GENERAL PLAN . . . . . Page 55

E. WAILUKU-KAHULUI COMMUNITY PLAN . . . . . Page 58

F. COUNTY ZONING . . . . . Page 59

G. COASTAL ZONE MANAGEMENT CONSIDERATIONS ..... Page 59
1. Recreational Resources ..... Page 60
2. Historical/Cultural Resources ..... Page 61
3. Scenic and Open Space Resources ..... Page 62
4. Coastal Ecosystem ..... Page 63
5. Economic Use ..... Page 64
6. Coastal Hazards ..... Page 65
7. Managing Development ..... Page 65
8. Public Participation ..... Page 66
9. Beach Protection ..... Page 67
10. Marine Resources ..... Page 67

H. SHORELINE SETBACK VARIANCE ..... Page 69

I. OTHER REGULATORY REQUIREMENTS ..... Page 72
1. Historical Shoreline Analysis of Coastal Erosion and Accretion Rates ..... Page 72
2. Shoreline Type ..... Page 72
3. Site Maps ..... Page 73
4. Beach Profiles ..... Page 73
5. Existing Walls ..... Page 73
6. Description of Improvements ..... Page 73
7. Coastal Hazard History ..... Page 73
8. Waves and Currents ..... Page 73
9. Sediment Movement ..... Page 74
10. Thirty-year Erosion Hazard ..... Page 74
11. Photographs ..... Page 74
12. Alternatives ..... Page 74
13. Professional Engineer Seal ..... Page 74

IV. SUMMARY OF UNAVOIDABLE ENVIRONMENTAL IMPACTS ..... Page 75

V. ALTERNATIVES TO THE PROPOSED ACTION ..... Page 76

A. ALTERNATIVES FOR CENTRAL MAUI'S WASTEWATER NEEDS ..... Page 76
1. Preferred Alternative ..... Page 76
2. Alternatives Considered ..... Page 76
3. Site Location Options ..... Page 79
4. Non-Structural Alternative ..... Page 79

B. ALTERNATIVES FOR SHORELINE PROTECTION AT THE EXISTING FACILITY ..... Page 80
1. Preferred Alternative ..... Page 80
2. Buried Revetment Alternative ..... Page 80

3. Beach Nourishment Alternatives ..... Page 80
4. Onsite Strategic Retreat of Facilities Alternative ..... Page 81
5. Other Alternatives ..... Page 81
6. No Action Alternative ..... Page 82
7. Deferred Action Alternative ..... Page 82

VI. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES ..... Page 83

VII. RELATIONSHIP BETWEEN THE SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY ..... Page 84

VIII. SIGNIFICANCE CRITERIA ASSESSMENT ..... Page 85

IX. LIST OF PERMITS AND APPROVALS ..... Page 89

X. AGENCIES AND ORGANIZATIONS TO BE CONSULTED IN THE PREPARATION OF THE DRAFT EIS ..... Page 90

XI. REFERENCES ..... Page i

F:\DATA\MoffattNichol\WK WWRF\EA EISPN.rpt.wpd

LIST OF FIGURES

Figure 1. Regional Location Map ..... Page 2
Figure 2. Property Location Map ..... Page 3
Figure 3. Aerial Photograph of Project Site and Surrounding Area ..... Page 5
Figure 4. Photographs of Existing Revetment ..... Page 6
Figure 5. Annual Erosion Hazard Rate Map ..... Page 12
Figure 6. Photographs of Shoreline Fronting the Facility ..... Page 13
Figure 7. Threatened Infrastructure at the Wailuku-Kahului Wastewater Reclamation Facility ..... Page 15
Figure 8. Proposed Revetment Site Plan ..... Page 16
Figure 9. Proposed Revetment Typical Cross-Section ..... Page 17
Figure 10. Soil Association Map ..... Page 24
Figure 11. Soil Classification Map ..... Page 26
Figure 12. Flood Insurance Rate Map ..... Page 28
Figure 13. State Land Use Designation ..... Page 50
Figure 14. Community Plan Designation ..... Page 53

LIST OF APPENDICES

Appendix A.	Conservation District Use Application Approval Letter for Existing Revetment
Appendix B.	Central Maui Wastewater Reclamation Facility Shoreline Evaluation Report
Appendix C.	Wailuku-Kahului WWRF Preliminary Engineering Report, Shoreline Erosion Control
Appendix D.	Maui County Council Resolution No. 06-12, "Accepting the Central Maui Wastewater Reclamation Facility Study and Concurring Recommendations and Long Term Plan"
Appendix E.	April 1, 2010 Letter from Department of Land and Natural Resources
Appendix F.	April 7, 2010 Letter from Office of Environmental Quality Control
Appendix G.	April 21, 2010 Letter from Office of the Mayor
Appendix H.	Letter Report on an Archaeological Field Inspection of Portions of the Central Maui Wastewater Reclamation Facility
Appendix H-1.	A General Archaeological Monitoring Plan for Scheduled Tsunami Improvements Project at the County of Maui Wastewater Treatment Plant at Kanaha, Wailuku Ahupua`a, Wailuku District, Maui Island
Appendix H-2.	State Historic Preservation Division Approval Letter of Monitoring Plan
Appendix I.	Certified Shoreline Survey

Executive Summary

Project Name:	Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension
Type of Document:	Environmental Assessment/Environmental Impact Statement Preparation Notice
Legal Authority:	Chapter 343, Hawai`i Revised Statutes
Agency Determination:	Environmental Impact Statement to be prepared
Applicable Environmental Assessment review "Trigger":	Use of County Lands and Funds Work within the State Land Use Conservation District Action within the Shoreline Setback Area
Location:	TMK: (2) 3-8-001:188 Kahului Island of Maui
Applicant:	Department of Environmental Management, County of Maui 2200 Main Street, Suite 200 Wailuku, Hawai`i 96793 Contact: Kyle Ginoza, Director Phone: (808) 270-8230
Accepting Authority:	Department of Environmental Management County of Maui 2200 Main Street, Suite 200 Wailuku, Hawai`i 96793 Contact: Kyle Ginoza, Director Phone: (808) 270-8230
Consultant:	Munekiyo & Hiraga, Inc. 305 High Street, Suite 104 Wailuku, Hawai`i 96793 Contact: Mich Hirano, AICP Phone: (808) 244-2015
Project Summary:	The applicant, the County of Maui, Department of Environmental Management, proposes to extend the existing shoreline protection at the Wailuku-Kahului Wastewater

Reclamation Facility (WKWWRF). The WKWWRF is located on a shore fronting parcel to the east of Kahului Harbor.

The shoreline seaward of the WKWWRF is experiencing erosion at an Annual Erosion Hazard Rate of -1.0 to -2.5 feet per year according to the County of Maui Shoreline Erosion maps. Erosion threatens several structures at the WKWWRF, including structures which cannot be moved.

Correspondence between the County of Maui and the U.S. Army Corps of Engineers (USACE) indicates that in 1978, the County of Maui requested that the USACE complete a feasibility study for providing emergency shoreline protection at the WKWWRF under Section 103A of the River and Harbor Act of 1962. The study cited erosion rates as high as 10 feet per year and concluded that the erosion had reached a critical state. It further recommended that a 1,500 foot long rock revetment be constructed along the entire seaward side of the WKWWRF. In 1979, USACE authorized the design and construction of the revetment under Section 14 of the Flood Control Act of 1946. At that time, Federal funding participation was limited to $250,000.00, and only 450 feet of the revetment were completed seaward of the holding pond. The Board of Land and Natural Resources (BLNR) approved the County's Conservation District Use Application (CDUA) for the 450-foot rock revetment in 1979. The present proposed project entails completing the revetment along the seaward side of the facility with an extension of 1,200 feet of new revetment to the west. Additional landward extensions will also be required at each end of the revetment to prevent flanking. The revetment will be constructed along the existing beach scarp. The crest of the new revetment will be between elevations of +10 to +13 feet Mean Lower Low Water (MLLW) and the toe of the revetment will be set at -3 feet MLLW. The crest elevation of the existing revetment will be raised to match the new revetment crest height to provide additional sea-level rise capacity. At the base of the revetment will be a layer of geotextile filter fabric, then a layer of bedding stone and two (2) layers of armor stone. There will be both excavation and fill required to prepare the slope for the new revetment. The alignment will be developed such that the cut and fill quantities will be as balanced as possible. Any required fill will be of beach-quality sand, and any additional sand will be placed on the

beach seaward of the revetment.

Construction will begin upon receipt of applicable permits and approvals, which is anticipated to be in early 2012. Anticipated cost is estimated to be approximately $4.2 million (2008 dollars). The project will be carried out in one (1) phase and it is anticipated to take twelve (12) months to complete .

I. PROJECT OVERVIEW

I. PROJECT OVERVIEW

A. PROJECT LOCATION, EXISTING USE, AND OWNERSHIP

The Wailuku-Kahului Wastewater Reclamation Facility (WKWWRF) is located on the northern coastline of the island of Maui at 281 Amala Place. See **Figure 1**. The WKWWRF site covers an area of 18.755 acres. The subject property is identified by Tax Map Key (2) 3-8-001:188. See **Figure 2**. The subject property is a shore fronting parcel and is surrounded by Kanaha Beach Park to the east, Amala Place to the south, the Kanaha Pond State Wildlife Sanctuary further south, and Kahului Harbor to the west. Access to the WKWWRF is provided by Amala Place.

The subject property is located in the State Land Use Conservation District. Lands within the Conservation District fall within the purview of the Department of Land and Natural Resources (DLNR). The subject property is designated for Public/Quasi-Public use in the Wailuku-Kahului Community Plan map. As part of the State Conservation District, there is no County zoning designation attached to the property.

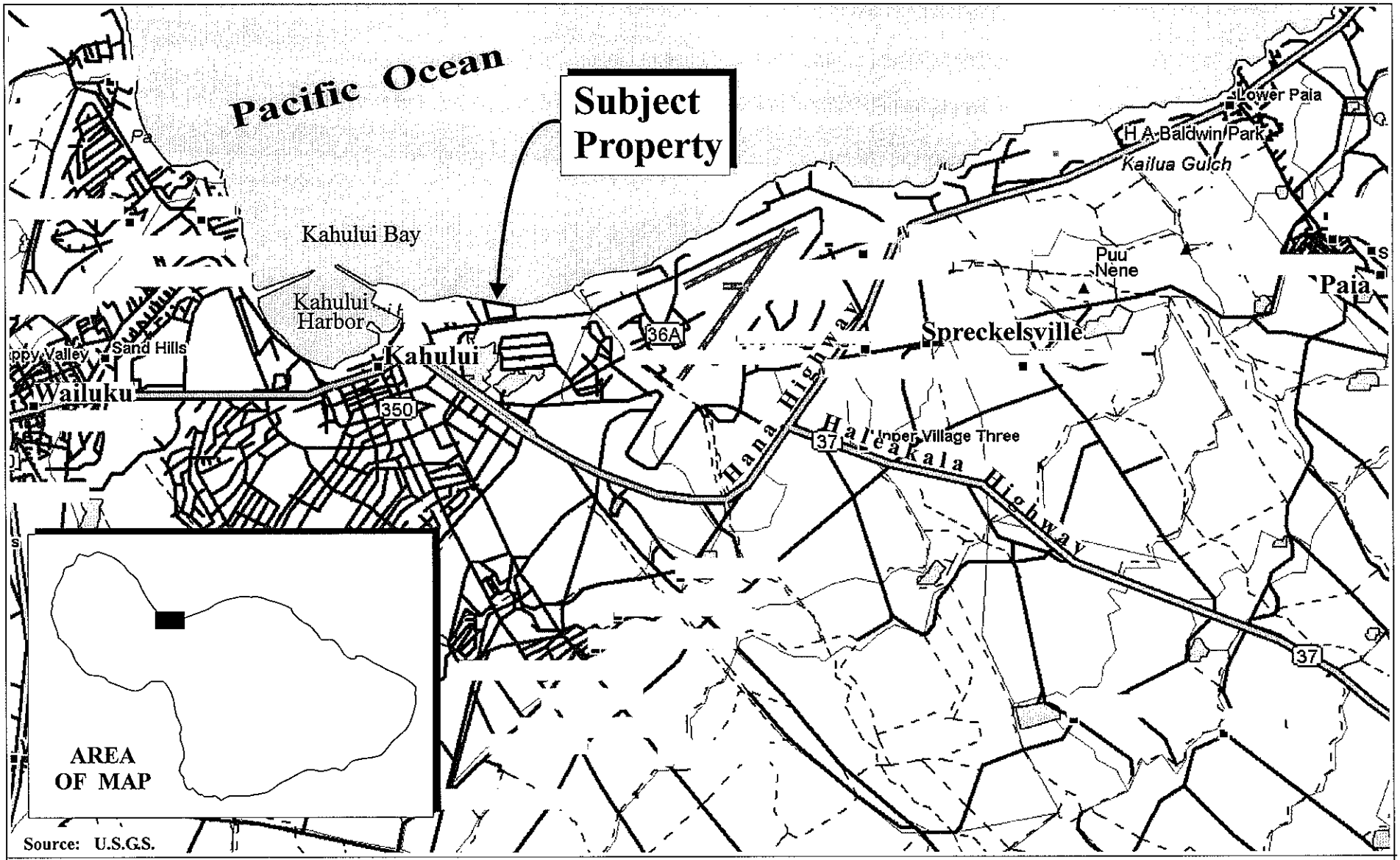
The WKWWRF provides secondary treatment of sewage and features an activated sludge biological treatment process, secondary clarification, and filtration. The principle solids treatment and handling processes are aerobic digestion and centrifuge dewatering. The final R-2 effluent is disposed of mostly via eight (8) gravity injection wells. The balance of the effluent (66.4 million gallons in FY 2009) is recycled for plant use, irrigation, and dust control.

The subject property is owned by the State of Hawai`i. On April 19, 1980, the Governor of the State of Hawai`i, through Executive Order No. 3006, set aside the subject property for sewage treatment purposes and vested control and management of the property with the County of Maui.

B. HISTORICAL CONTEXT

1. History of the Facility

The WKWWRF was constructed in 1973 to serve the Central Maui region, including the areas defined by the developed areas of Waiehu, Wailuku, Kahului, Spreckelsville, and Paia. The plant has an existing treatment capacity of 7.9 million



Source: U.S.G.S.

Figure 1 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

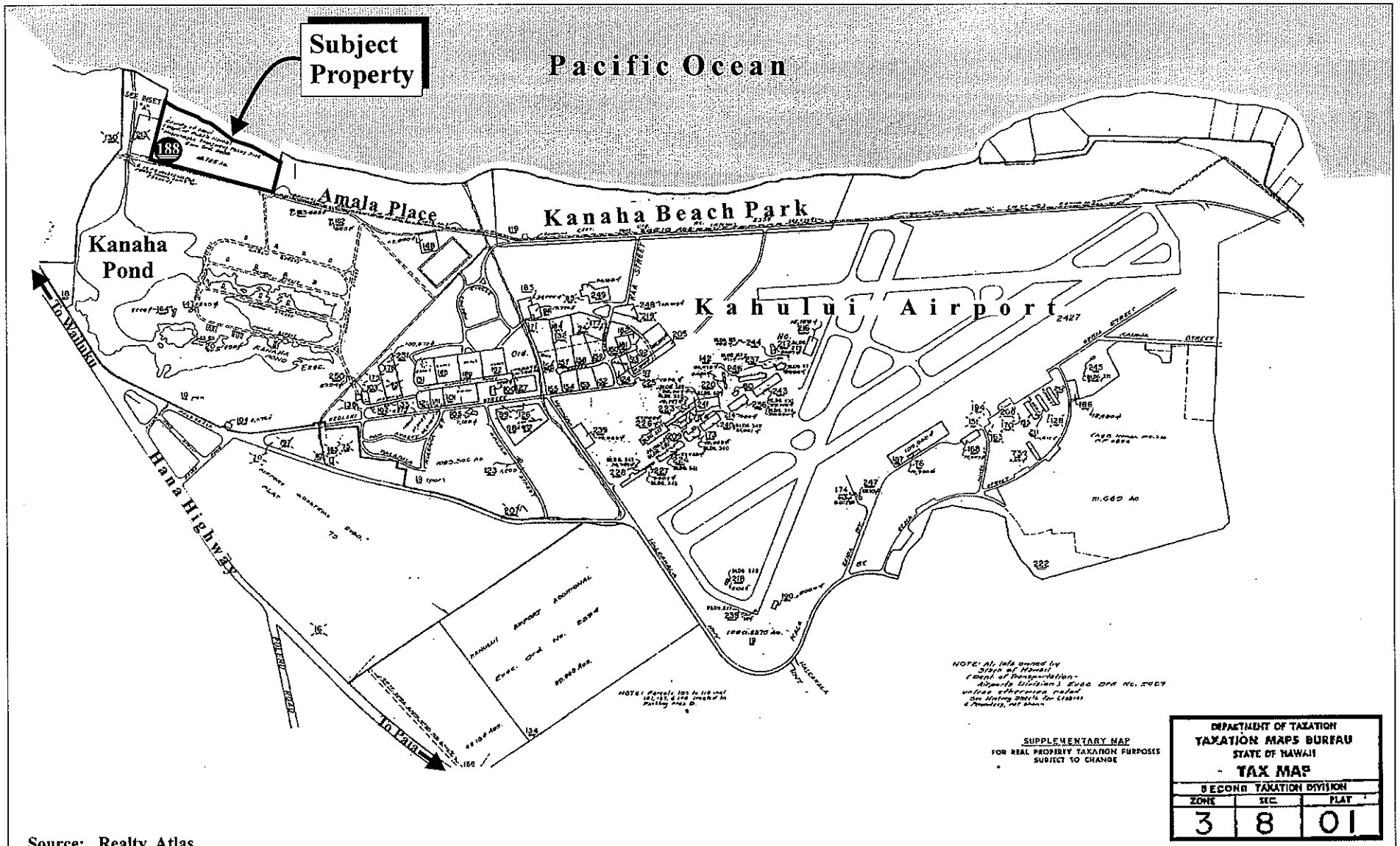
Regional Location Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\regionallocation



Source: Realty Atlas

Figure 2 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Property Location Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\propertyloca

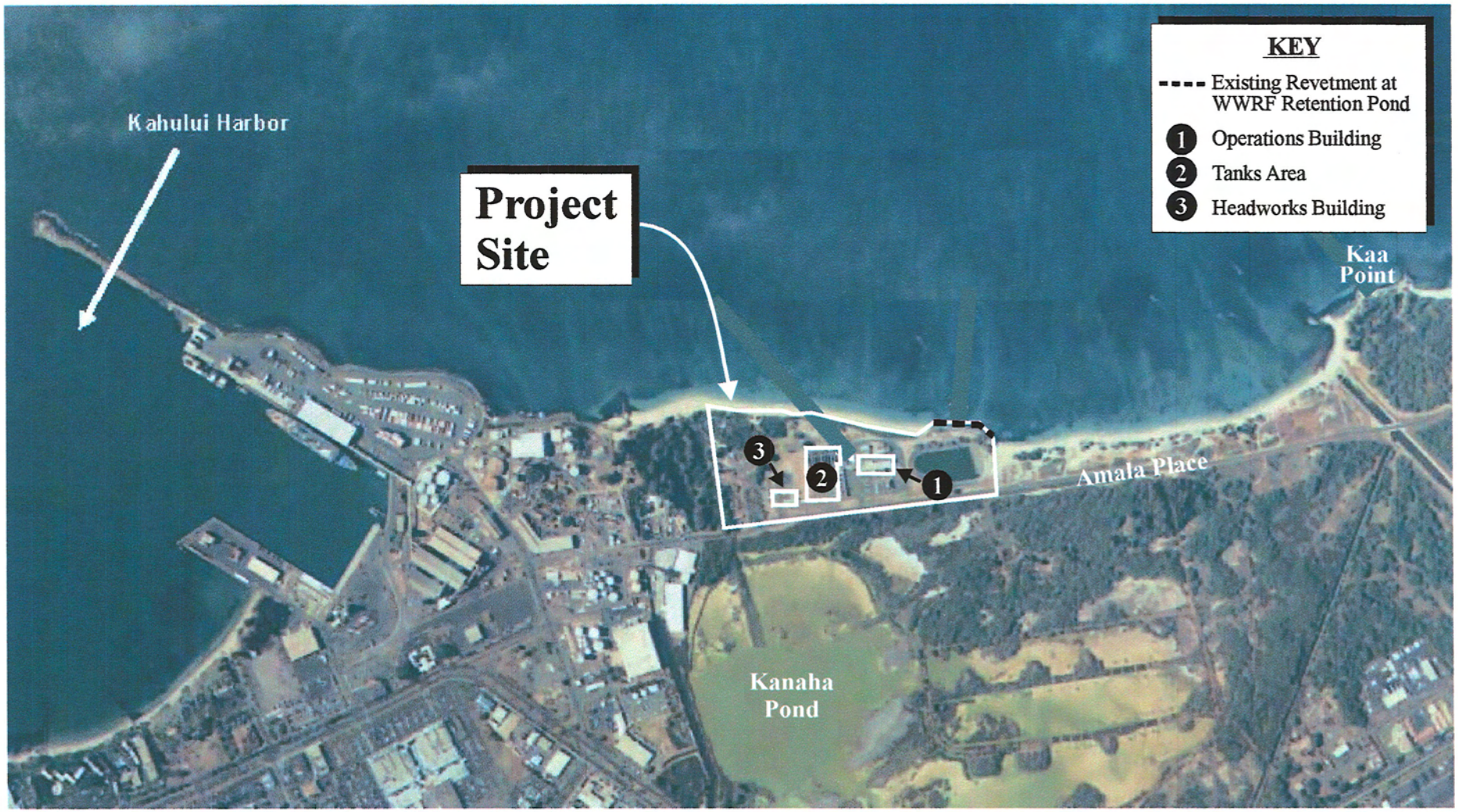
gallons per day (mgd) average dry-weather flow. According to projections, the facility will reach capacity around 2029 and will need plant upgrades and the currently proposed shoreline erosion protection measures to accommodate more growth of residents and businesses in the Central Maui service area.

Since its original construction, the plant has been upgraded to provide increased capacity as well as structural measures to protect the facility from tsunami and shoreline erosion hazards. In 1979, the U. S. Army Corps of Engineers (USACE) constructed 450 feet of a planned 1,500 foot-long revetment to provide emergency shoreline erosion protection. See **Figure 3** and **Figure 4**. The CDUA, File No. MA-7/28/78-1074, was approved prior to construction. See **Appendix "A"**. The existing retention pond is now used for emergency overflow and the processing of sewage is handled in the sludge holding tanks which are located above ground.

Improvements are currently in progress at the WKWWRF for tsunami protection. The tsunami protection measures include below grade structural reinforcement of the concrete slab foundation to prevent underscouring and wave action erosion of the shoreward side of the Operations Building. The Centrifuge Control Room will be relocated above the 100-year tsunami wave height. Refer to **Figure 3.** Improvements at the Tanks and Headworks Building include thickening of the slab below grade, addition of walls and flood doors at grade level, and reinforcing footings below the scourline to protect against wave action erosion. The tsunami protection work for the Operations Building and Centrifuge Control Room has been completed. Tsunami protection improvements for the Tanks and Headworks Building area are in the bidding and construction phase. These projects are separate and distinct from the scope of this shoreline protection project.

2. Central Maui Wastewater Reclamation Facility Study

In 2005, the County of Maui, Department of Environmental Management ("Applicant"), completed the Central Maui Wastewater Reclamation Facility (WWRF) Study (Study) to identify alternatives to meet the long-term wastewater infrastructure requirements (Austin, Tsutsumi & Associates, 2006). The three (3) main issues at the WKWWRF are available treatment capacity, shoreline erosion, and potential tsunami impacts. The Study included the following elements to address these issues and to develop alternative solutions:



Source: Moffatt and Nichol

Figure 3 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Aerial Photograph of Project Site and Surrounding Area

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\aerial photo

East Flank of Existing Revetment

West Flank of Existing Revetment

Source: Moffatt & Nichol

Figure 4 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Photographs of Existing Revetment

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

Moffatt\Nichol\WK WWRF\ExistingRevetmentPhotos

- Community Participation through an assembly of a Core Working Group (CWG), consisting of stakeholders and community members
- Existing Wastewater Infrastructure and Capacity
- Options for Effluent and Biosolids Disposal
- Shoreline Issues
- Wastewater Reclamation Facility Structural Issues
- Alternatives for Future Wastewater Infrastructure Needs
- Public Outreach
- Financial Plan

Twenty-one new capacity treatment alternatives were generated, considering multiple effluent disposal options for new capacity. Three (3) system wide demand-side management alternatives were also considered, which included the following: (1) Initiate a water conservation program; (2) Replace existing high-use water fixtures (e.g., toilets and showerheads); and (3) Expand the existing Infiltration and Inflow reduction program.

The County team ranked these options utilizing the pair-wise comparison approach, identifying the top ten (10) ranked alternatives for further evaluation. The evaluation criteria included cost, environmental impacts, reclamation potential, and other items. The No Build alternative was ranked last of the 21 alternatives. The three (3) demand-side management alternatives have all been implemented by the County.

After a thorough evaluation analysis, the highest ranked wastewater treatment concept alternative (Alternative 1) was to: *Expand the existing Wailuku/Kahului WWRF for future capacity, strengthen the WWRF for tsunami/erosion concerns, and utilize injection wells for effluent disposal.* The Study recommended the following plan.

- Implement Alternative 1 to protect the County's major financial investment in the existing facility by mitigating the tsunami impact risk and armoring the shoreline fronting the facility.
- Continue the Wastewater Reclamation Division's program to reduce Infiltration/Inflow into the wastewater collection system.

- The Wastewater Reclamation Division and the County Board of Water Supply should partner to implement a comprehensive water conservation program.

- Reconsider water reuse opportunities for Central Maui.

The Study notes in its recommendations that Alternative 1 has the least financial impact on the community and wastewater rate payers at a capital cost of $30 million or $8.68/billing cycle increase in sewer user fees. The alternatives to build a new Central Maui wastewater reclamation facility were estimated to cost in the range of $350 million to $475 million (2005 dollars).

The Central Maui WWRF Study included a Shoreline Evaluation Report, which reviewed potential alternatives for shoreline protection of the facility. See **Appendix "B"**. The Report considered multiple alternatives for shoreline protection. These included beach nourishment, beach nourishment augmented with sand retention structures, armor rock revetment, and other alternatives. The beach nourishment options included placing additional sand on the beach over two (2) different lengths. The beach nourishment augmented with sand retention structures would entail placing additional sand on the beach as well as construction of T-groin structures. The revetment options included an extension of the existing revetment, with or without the placement of additional sand over the structure. The other alternatives included coral rubble fill and a vertical seawall/revetment hybrid structure. A detailed description of these alternatives is provided in Chapter V of the EA/EISPN document.

These alternatives were evaluated based on the following nine (9) criteria.

- Construction Cost

- Maintenance Cost

- Public Access and Usage

- Design Life

- Regulatory Compliance

- Aesthetics

- Impacts to Kahului Harbor
- Environmental Impacts – Biology
- Environmental Impacts – Adjacent Shorelines

The criteria were weighted for importance and each alternative was assessed on its value for the criteria. Net present value costs were estimated over a 50-year project lifetime. Based on this evaluation, the first preferred alternative was the buried revetment, with an estimated total cost of $5.4 million. This was followed by an extension of the existing revetment, with an estimated total cost of $1.6 million. The revetment structure provides a last line of defense against severe storms and tsunamis.

In 2008, a more detailed analysis and revised costs were presented in the Preliminary Engineering Report for Shoreline Erosion Control. See **Appendix "C"**. The total cost for the buried revetment was estimated at $7.7 million for purchased sand and $11.7 million for dredged sand. The total cost for the revetment extension was estimated at $4.2 million (2008 dollars).

3. Maui County Council Action on the Study

The Maui County Council Public Works Committee met on January 9, 2006 to consider Resolution No. 06-12, "ACCEPTING THE CENTRAL MAUI WASTEWATER RECLAMATION FACILITY STUDY AND CONCURRING RECOMMENDATIONS AND LONG TERM PLAN". See **Appendix "D"**. The Committee met with the Director of Finance; the Deputy Director of Public Works and Environmental Management[1]; the Wastewater Reclamation Division Chief, Department of Public Works and Environmental Management; Deputy Corporation Counsel; and Study consultants. The Committee also accepted public testimony.

The Director of Finance responded to Committee questions about the County's ability to finance the various options considered by the Study. He stated that the original facility had been constructed with the assistance of State and Federal funds, but the current assessment concluded that no significant portion of future expenses

[1] In 2006, the functional responsibilities of the Department of Public Works and Environmental Management were split into two (2) departments: Department of Public Works and Department of Environmental Management. The Wastewater Reclamation Division is now within the Department of Environmental Management.

would be available external to the County. The Committee discussed the process used to involve the community in the Study, the Study's recommendation, and its adequacy. The Committee also reviewed the arguments in support of maintaining the facility in its current location, rather than relocating the facility. The Committee expressed a concern about determining whether the facility should be maintained at its current site or moved without full Council discussion. After discussing whether to refer the resolution to the Committee of the Whole, defer it to hold Council public hearings, or recommend adoption of the resolution, the Committee voted to recommend adoption of the resolution.

On February 17, 2008, the Maui County Council voted to adopt Resolution No. 06-12. The resolution states that shoreline erosion is one (1) of three (3) primary concerns regarding the future of the WKWWRF and that the "County of Maui must decide how it will meet its wastewater treatment and disposal needs for the Central Maui Region for the next 20 to 30 years". The resolution further states that the Council "accepts the Study" and concurs with the Department of Public Works and Environmental Management recommendations. This includes the recommendation to "mitigate shoreline erosion through the construction of shoreline erosion structures or beach nourishment". Refer to **Appendix "D"**.

C. PROJECT NEED

The need for shoreline erosion protection has been identified and documented by the County of Maui since the completion of the WKWWRF in 1976. From 1976 to 1978, the County of Maui and USACE worked together and evaluated the erosion at the site, performed a Feasibility Study, and designed a protective revetment. This resulted in the construction of the existing revetment and CDUA approval in 1979. The original intention was to protect the whole facility, but funding limitations reduced the actual constructed length to the most critical area at the time (450 feet).

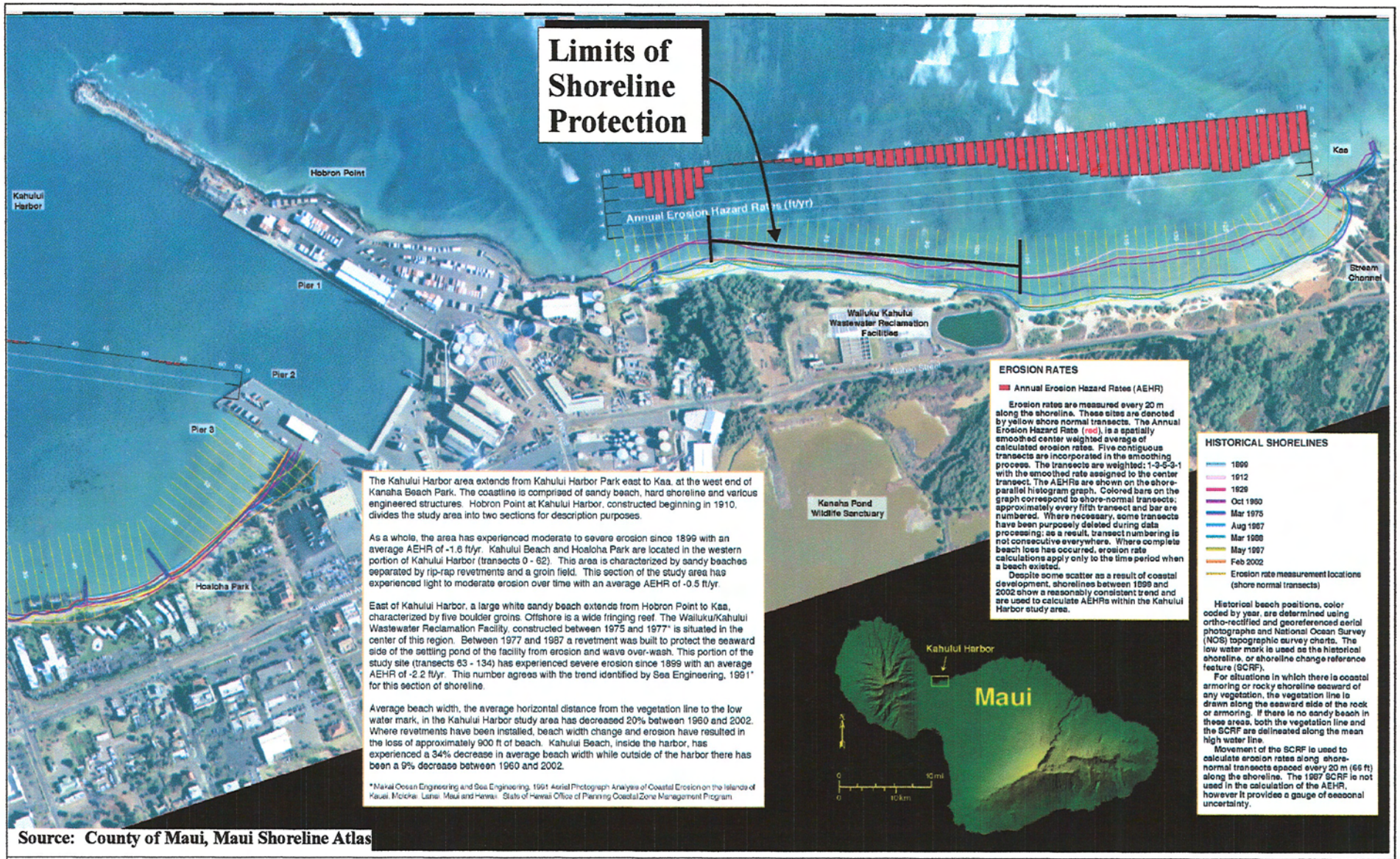
The Shoreline Evaluation Report included in the Central Maui WWRF Study delineated the shoreline erosion issues at the facility and potential causes of the erosion. Refer to **Appendix "B"**. The north shore of Maui has historically experienced erosion and resulting shoreline recession, including the stretch fronting the WKWWRF. The report discussed long-term shoreline changes over the 13,000-ft long beach extending east from Kahului Harbor towards Spreckelsville Beach. This stretch of beach is broken into a series of pocket beaches by manmade groins, natural lava points, and beachrock points. The report also

discussed changes in the shoreline from Kahului Harbor to Kaa Point, which is a subsection of the 13,000-ft beach, over shorter periods of time.

Much of the change in beach configuration is attributed to sand mining operations in the area from the early 1900's through the 1970's. Sand was mined for use as cement aggregate for construction and in the production of lime for sugar cane processing. Other natural potential contributors to shoreline erosion include relative sea level rise, elevated sea levels during storms, and changes in reef production of coralline sand. Man-induced influences other than sand mining include the structures and dredging practices of Kahului Harbor, WWII training exercises along the beach, and dune destruction. Refer to **Appendix "B"**.

Shoreline erosion in the area of the WKWWRF has been documented for over 100 years. The County of Maui Shoreline Erosion Maps were compiled using aerial photography and historic T-sheets. The erosion map including the WKWWRF shoreline indicates the extent of erosion for over 100 years. Refer to **Figure 4** and see **Figure 5**. The map indicates that the Annual Erosion Hazard Rate (AEHR) is between -1.0 and -2.5 feet per year (ft./yr.) directly in front of the WKWWRF. However, the existing revetment built in 1979 has halted further shoreline erosion for that particular section, which results in the AEHR being under-reported. Along the WKWWRF property, the average AEHR is -2.4 ft./yr. Review of past shoreline surveys indicates that the shoreline west of the existing revetment is eroding at a rate of up to -6.0 ft/yr (Brown and Caldwell, 2002). In addition to on-going erosion, there are seasonal shifts in the shoreline position ranging from 25 to 55 feet. These shifts increase the likelihood of erosion and property loss when the beach is narrow, typically in the winter months.

The 2007 certified shoreline and a 2002 site map of the WKWWRF from Brown and Caldwell were analyzed to determine when the first structures at the WKWWRF could be threatened if no additional protection is put in place based on the seasonal shoreline position shifts and annual erosion rates. See **Figure 6**. Although the County is studying options to reuse the treated wastewater, the existing injection wells continue to be necessary, therefore, protecting the shoreline will be necessary for the continued protection of the injection wells. The existing injection Well No. 2 is already at risk of damage based on the worst-case seasonal recession and erosion rates. The access road could be threatened in only one (1) year and the existing sludge holding tanks in as few as four (4) years. These structures could possibly be relocated within the WKWWRF property. However, the northeast corner of the chlorine contact tank and effluent meter is located approximately 120 feet from the existing fence line. The size of this structure and its position in the wastewater treatment cycle would



The Kahului Harbor area extends from Kahului Harbor Park east to Kaa, at the west end of Kanaha Beach Park. The coastline is comprised of sandy beach, hard shoreline and various engineered structures. Hobron Point at Kahului Harbor, constructed beginning in 1910, divides the study area into two sections for description purposes.

As a whole, the area has experienced moderate to severe erosion since 1899 with an average AEHR of -1.6 ft/yr. Kahului Beach and Hoaloha Park are located in the western portion of Kahului Harbor (transects 0 - 62). This area is characterized by sandy beaches separated by rip-rap revetments and a groin field. This section of the study area has experienced light to moderate erosion over time with an average AEHR of -0.5 ft/yr.

East of Kahului Harbor, a large white sandy beach extends from Hobron Point to Kaa, characterized by five boulder groins. Offshore is a wide fringing reef. The Wailuku/Kahului Wastewater Reclamation Facility, constructed between 1975 and 1977* is situated in the center of this region. Between 1977 and 1987 a revetment was built to protect the seaward side of the settling pond of the facility from erosion and wave over-wash. This portion of the study site (transects 63 - 134) has experienced severe erosion since 1899 with an average AEHR of -2.2 ft/yr. This number agrees with the trend identified by Sea Engineering, 1991* for this section of shoreline.

Average beach width, the average horizontal distance from the vegetation line to the low water mark, in the Kahului Harbor study area has decreased 20% between 1960 and 2002. Where revetments have been installed, beach width change and erosion have resulted in the loss of approximately 900 ft of beach. Kahului Beach, inside the harbor, has experienced a 34% decrease in average beach width while outside of the harbor there has been a 9% decrease between 1960 and 2002.

*Makai Ocean Engineering and Sea Engineering, 1991 Aerial Photograph Analyses of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. State of Hawaii Office of Planning Coastal Zone Management Program.

Source: County of Maui, Maui Shoreline Atlas

Figure 5 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Annual Erosion Hazard Rate Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol/WK WWRF/annualerosion

Looking West from the Existing Revetment, July 2004

Looking West from the Existing Revetment, March 2008

Source: Moffatt & Nichol

Figure 6 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Photographs of Shoreline Fronting the Facility

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

Moffatt\Nichol\WK WWRF\ShorelinePhotos

prohibit it from being relocated elsewhere on the property. With this distance, the chlorine contact tank and effluent meter could be threatened in as little as nine (9) years, using the worst-case seasonal recession and erosion rates. Refer to **Appendix "C".**

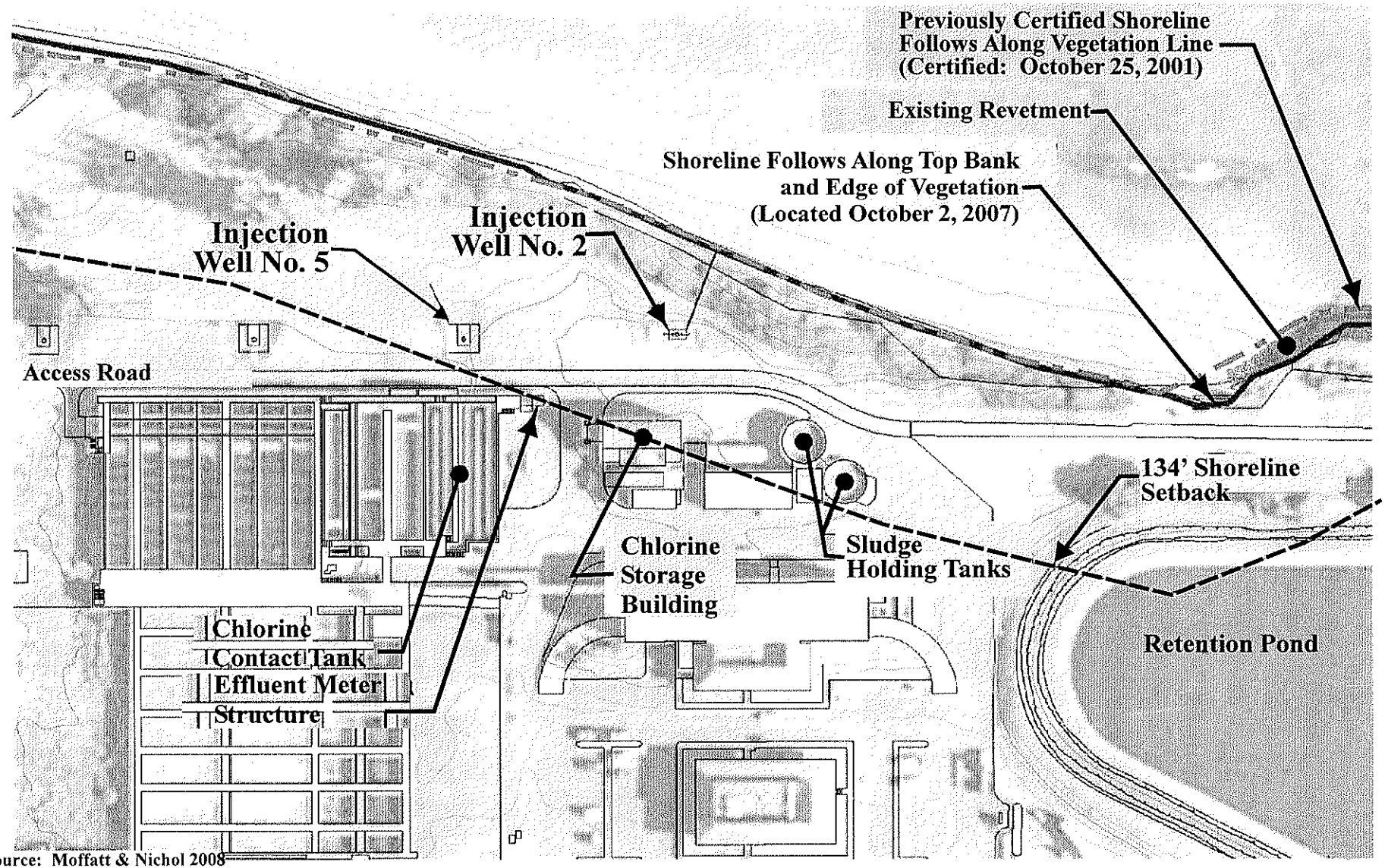
A large hurricane, tsunami, or increase in the rate of sea level rise could significantly reduce these time estimates. Given the unpredictability of future storms and tsunamis, as well as the typical time required to design, permit, and construct a shoreline protection project (three (3) to five (5) years), it was recommended that a shoreline protection alternative be selected and implemented as soon as possible. The no build alternative puts the facility at a high risk of damage due to erosion, which would threaten the facility's ability to meet the wastewater treatment needs of Central Maui, and presents a significant potential environmental hazard.

D. PROPOSED ACTION

The County of Maui, Department of Environmental Management, Wastewater Reclamation Division proposes to extend the existing shoreline protection at the WKWWRF, located in Kahului, Maui, Hawai'i. The proposed project consists of the construction of an approximately 1,200-ft. rock mound revetment extension to the west of the existing revetment with short landward returns to prevent flanking erosion. See **Figure 7**. The revetment would require approximately 15,000 tons of armor and under layer rock. The extension would be similar to the existing revetment, and would be constructed along the existing erosional beach scarp. See **Figure 8**. The crest of the new revetment will be between elevations of +10 to +13 feet Mean Lower Low Water (MLLW) and the toe of the revetment will be set at -3 feet MLLW. See **Figure 9**. The crest elevation of the existing revetment will be raised to match the new revetment crest height to provide additional sea-level rise capacity. At the base of the revetment will be a layer of geotextile filter fabric, then a layer of bedding stone and two (2) layers of armor stone. There will be both excavation and fill required to prepare the slope for the new revetment. The alignment will be developed such that the cut and fill quantities will be as balanced as possible. Any required fill will be of beach-quality sand, and any additional sand will be placed on the beach seaward of the revetment. Refer to **Figure 9**. This structure would be located within the Shoreline Setback Area.

E. CONSTRUCTION METHODOLOGY

The construction of the revetment will be performed using typical land-based equipment for rock/excavation work. It is anticipated that the contractor will mobilize, stage and access the



Source: Moffatt & Nichol 2008

Figure 7 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

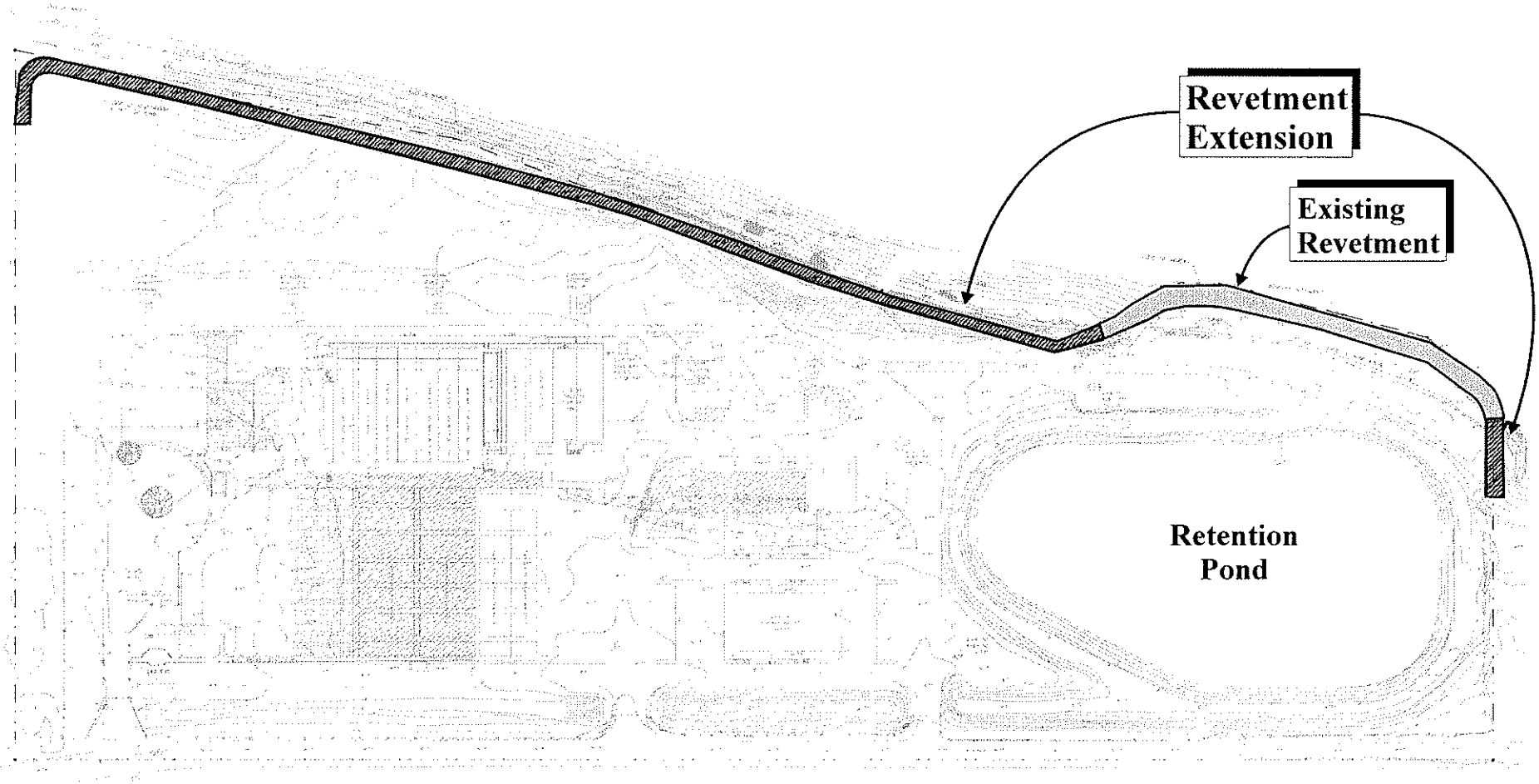
Threatened Infrastructure at the Wailuku-Kahului Wastewater Reclamation Facility

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol/WK WWRF/ThreatenedInfrastructure



Source: Moffatt & Nichol

Figure 8 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

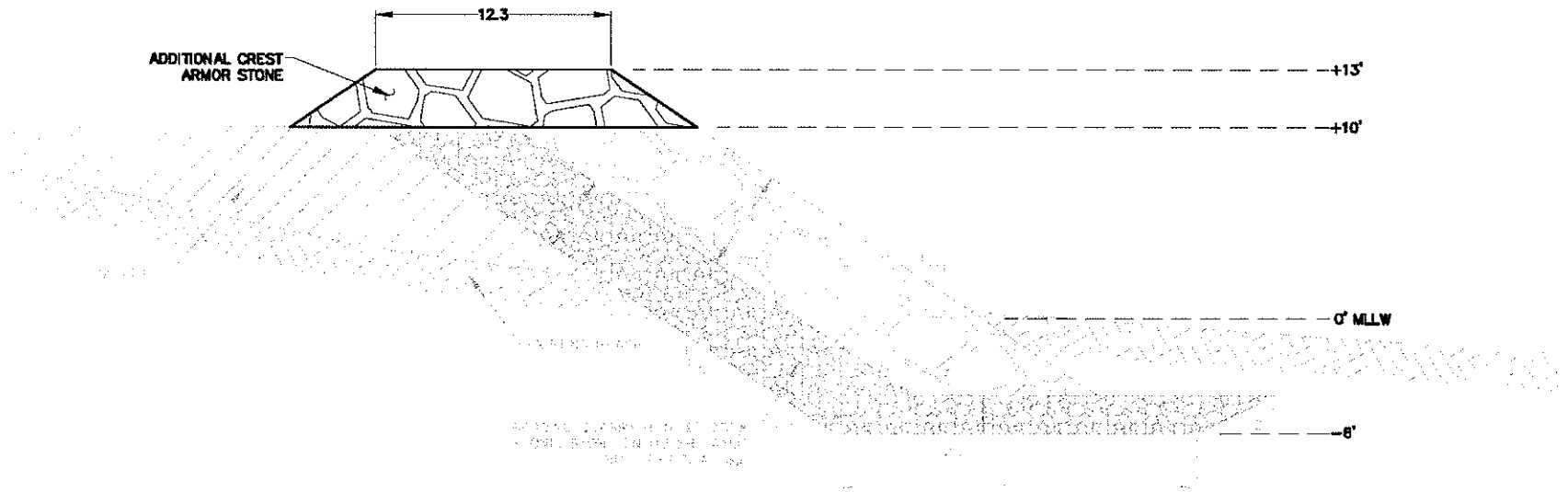
Proposed Revetment Site Plan

NOT TO SCALE

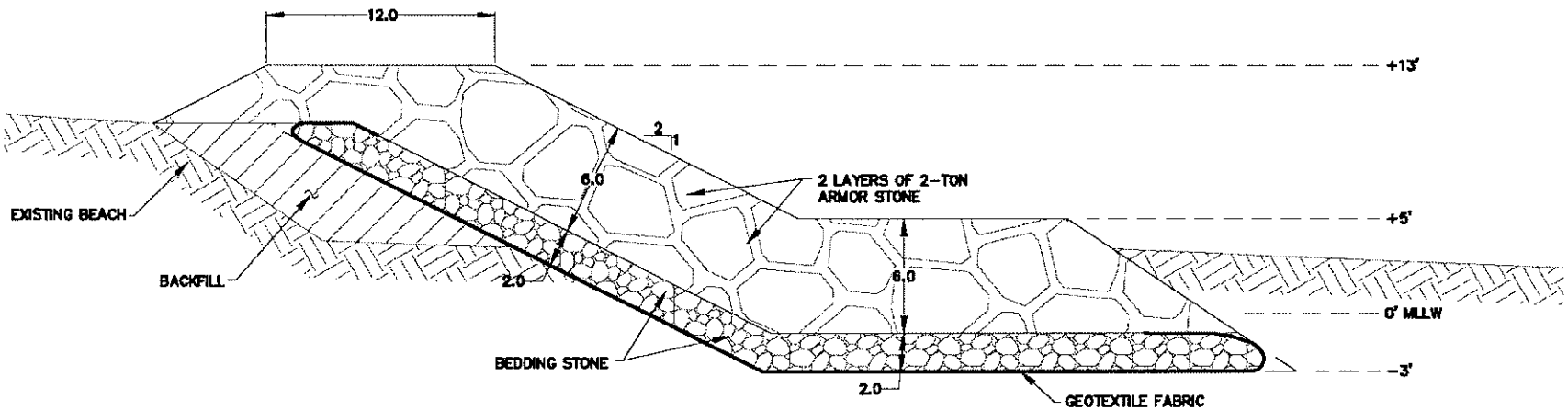
Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\RevetmentPlanView



Existing Revetment Improvements



New Revetment Extension

Source: Moffatt & Nichol

Figure 9 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Proposed Revetment Typical Cross-Section

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\TypicalRevetmentCross-Section

project site from the WKWWRF property.

The existing vegetation will be cleared and grubbed to the extent that is required for access and working space. All removed vegetation debris will be hauled off site and disposed of at an appropriate landfill or recycling location.

The slope of the embankment will be prepared with excavators and filter fabric will be placed by hand. The bedding stone, underlayer stone, and armor stone will be delivered to the site by rock hauling trucks, transported onsite by a front-end loader and placed with a backhoe excavator. Modifications to the existing revetment will be made from the top of the slope using an excavator.

A majority of the work will be performed from the top of the slope, but the contractor will be required to place excavators and similar machinery on the beach during favorable tide, wind, and wave conditions. Sand may need to be moved around to provide a level working pad for the equipment. When working on the beach, the contractor will provide appropriate signage and public safety measures. Disturbed areas in the vicinity of the project will be restored.

The onsite construction period is anticipated to be approximately 12 months.

F. CHAPTER 343, HAWAI'I REVISED STATUTES COMPLIANCE

The proposed project involves three (3) actions which trigger the environmental review process. They are the use of County lands and funds, work with the State Land Use Conservation District, and action within the Shoreline Setback Area. In accordance with Chapter 343, Hawai'i Revised Statutes (HRS), an Environmental Impact Statement (EIS) will be prepared to assess the project's impact. This Environmental Assessment/Environmental Impact Statement Preparation Notice (EA/EISPN) is prepared in accordance with Chapter 200 of Title 11, Department of Health Administrative Rules, Environmental Impact Statement Rules.

Potential accepting authorities include the County of Maui, Department of Environmental Management (DEM); the Maui County Planning Commission; or the State Department of Land and Natural Resources, Office of Conservation and Coastal Lands.

Due to the multiple jurisdictions involved the DEM, by letter dated March 10, 2010,

requested the Office of Environmental Quality Control's (OEQC) opinion as to whether the DEM could be the Accepting Authority based on the fact that the DEM has control and management of the property. The DEM also requested, by letter dated March 10, 2010, the Department of Land and Natural Resources (DLNR) concurrence with DEM being the Accepting Authority. By letter dated April 1, 2010, the DLNR concurred with DEM being the Accepting Authority. See **Appendix "E"**. By letter dated April 7, 2010, OEQC opined that since DEM has control of the property through an Executive Order, DEM can be the Accepting Authority. OEQC further stated that according to Section 11-200-4(a)(2), Hawaii Administrative Rules (HAR), whenever an agency proposes an action, the final authority to accept a statement is the mayor, or an authorized representative, of the respective county. See **Appendix "F"**. By letter dated April 21, 2010, Mayor, Charmaine Tavares designated the DEM as the mayor's authorized representative to process and accept the EIS for the project. See **Appendix "G"**.

Chapter 343, HRS, ensures that environmental concerns are given appropriate consideration in decision making along with economic and technical considerations. The EIS is a disclosure document identifying the potential environmental effects and mitigative measures necessary to minimize these effects.

As the mayor's authorized representative, the DEM has determined that there may be significant environmental impacts and an EIS is warranted for the project. This EA/EISPN has been filed with the OEQC for publication in the Environmental Bulletin (Bulletin) as public notification that an EIS is required for the project. Publication of the EA/EISPN initiates the thirty (30) day period where agencies, groups, or individuals may request to become a consulted party and to make written comments regarding the environmental effects of the proposed action. Substantive comments received shall be responded in writing and included in the Draft EIS.

Upon completion of the Draft EIS by DEM, the Draft EIS is filed with the OEQC for publication in the Bulletin notifying the agencies, groups, and individuals of the availability of the Draft EIS for review and comment. The period for public review and for submitting written comments commences from the date notice of availability of the Draft EIS is initially published in the Bulletin and shall continue for a period of forty-five (45) days. Any comments received after the forty-five (45) day period need not be considered or responded to.

Substantive comments received shall be responded in writing and included in the Final EIS.

A statement shall be deemed to be an acceptable document by the accepting authority or approving agency only if all of the following criteria are satisfied:

1. The procedures for assessment, consultation process, review, and the preparation and submission of the statement, have all been completed satisfactorily as specified in Chapter 343, HRS;

2. The content requirements described in Chapter 343, HRS, have been satisfied; and

3. Comments submitted during the review process have received responses satisfactory to the accepting authority, or approving agency, and have been incorporated in the statement.

The DEM shall file the Final EIS with the OEQC to complete the environmental review process. The Final EIS may be appealed through judicial review in the courts upon filing of an appeal within sixty (60) days of its notice in the Bulletin.

G. PERMITTING REQUIREMENTS

The following regulatory compliance and approvals will be required:

1. Chapter 343, HRS, Environmental Impact Statement (EIS)

Chapter 343, HRS is invoked due to three (3) triggers: the use of County lands and funds, work with the State Land Use Conservation District, and action within the Shoreline Setback Area.

Due to the sensitive marine environment and anticipated environmental impacts associated with the proposed action, an EIS is being prepared to assess the proposed action. This EA/EISPN will be reviewed by the Accepting Authority, Department of Environmental Management, for determination and concurrence.

2. Special Management Area (SMA) Use Permit and Shoreline Setback Variance (SSV)

The project is located within the County of Maui, Special Management Area (SMA) and the Shoreline Setback Area. As such, the SMA Use Permit and Shoreline Setback Variance (SSV) approvals are required from the Maui Planning Commission.

3. Conservation District Use Permit (CDUP)

The project is located within the State Land Use Conservation District. As such, a Conservation District Use Permit (CDUP) is required from the Board of Land and Natural Resources.

4. U.S. Department of the Army Permit

The project area affects the navigable waters of the U.S. which are under the jurisdiction of the U.S. Department of the Army. In accordance with Section 10 of the Rivers and Harbors Act of 1899 and Section 401 and Section 404 of the Clean Water Act, a U.S. Department of the Army Permit will be required for the proposed action.

5. Water Quality Certification

The project construction occurs within range of waters protected by Section 401 of the Clean Water Act. In accordance with the Act, a Section 401 Water Quality Certification will be required from the State of Hawai'i, Department of Health.

6. Coastal Zone Management (CZM) Consistency Approval

As previously noted, the project is located within the County SMA and involves federal permitting approval by the Department of the Army. As such, a Coastal Zone Management (CZM) Consistency Approval must be obtained from the State Department of Business, Economic Development, and Tourism, Office of Planning.

H. PROJECT COST AND IMPLEMENTATION SCHEDULE

Construction will begin upon receipt of applicable permits and approvals, which is anticipated to be in early 2012. The estimated cost for the revetment is approximately $4.2 million. The project will be carried out in one (1) phase and it is anticipated to take 12 months to complete.

II. EXISTING ENVIRONMENT, POTENTIAL IMPACTS, AND MITIGATION MEASURES

II. EXISTING ENVIRONMENT, POTENTIAL IMPACTS, AND MITIGATION MEASURES

A. PHYSICAL ENVIRONMENT

1. Surrounding Land Use

a. Existing Conditions

The project site is located in Kahului, the island of Maui's center of commerce. Kahului is home to Kahului Harbor, the island's only deep water port, and to the Kahului Airport, the second busiest airport in the State. With its proximity to the harbor and airport, the Kahului region has emerged as the focal point for heavy industrial, light industrial, and commercial activities and services, such as warehousing, baseyard operations, automotive sales and maintenance, and retailing for equipment and materials suppliers. The region is considered Central Maui's commercial retailing center with Queen Ka`ahumanu Center, Maui Mall, Kahului Shopping Center, and Maui Marketplace located within proximity of the project site.

Surrounding this commercial core is an expansive residential area comprised principally of single-family residential units. Residential uses encompass the area extending from Maui Memorial Medical Center to Pu`unene Avenue located to the west of the project site. The nearest residential areas to the project site are east of Pu`unene Avenue, located just over one (1) mile away and Spreckelsville to the east, located approximately 1.8 miles away.

The area immediately west of the WKWWRF is considered to be a heavy industrial area and includes oil tank farms, auto storage yards, warehouses, and a power plant. The port facilities at Kahului Harbor are located approximately 0.5 mile to the west of the WKWWRF. The Kahului Airport is located approximately one (1) mile east of the WKWWRF and Kanaha Beach Park is located to the east of the WKWWRF. The Kanaha Pond State Wildlife Sanctuary is located to the south across Amala Place. The WKWWRF site is bounded on the north by Kahului Bay.

b. Potential Impacts and Mitigation Measures

The project site is located in an area of heavy industrial uses related to Kahului Harbor and in proximity to the Kahului Airport as well as recreational uses related to beach activities and the Kanaha Pond Wildlife Sanctuary. The use of tall cranes during construction may require approval from the Federal Aviation Administration (FAA), due to the proximity of the WKWWRF to Kahului Airport. The WKWWRF has been in use since 1973 and is complementary to other public/quasi-public uses at the Kahului Harbor and Airport. The proposed project will provide protection for the WKWWRF from damage due to shoreline erosion and mitigate potential adverse impacts to surrounding land uses from erosion damage to the wastewater facility. It is anticipated that the shoreline protection will not adversely impact the character of the surrounding land uses.

2. Climate, Topography, and Soils

a. Existing Conditions

Like most areas of Hawai`i, Maui's climate is relatively uniform year-round. Characteristic of Hawai`i's climate, the project site experiences mild and uniform temperatures year round, moderate humidity, and a relatively consistent northeasterly tradewind. Variation in climate on the island is largely left to local terrain.

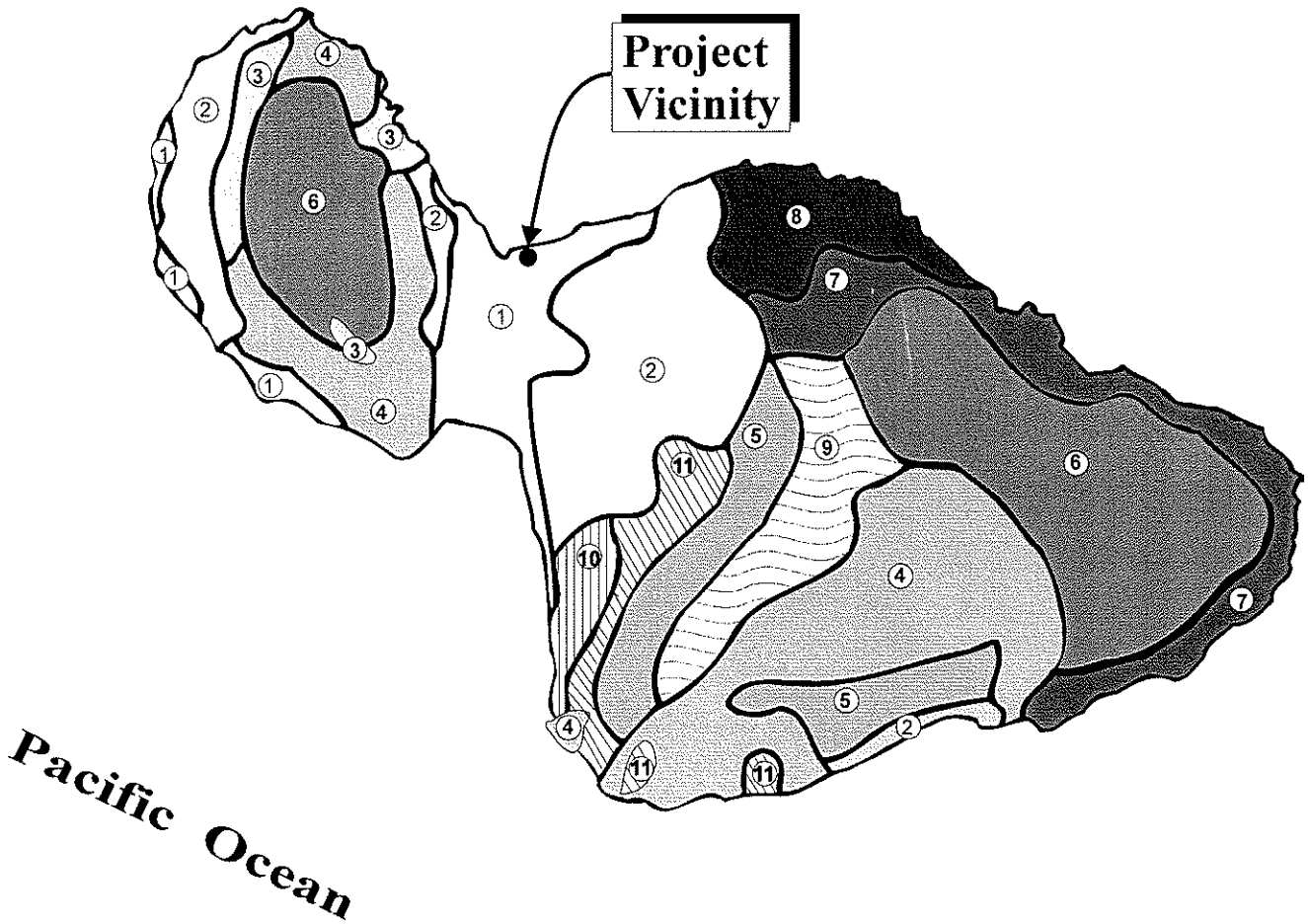
Average temperatures recorded at the neighboring Kahului Airport range from lows in the 70's to highs in the 80's. September is historically the warmest month, while February is the coolest. Rainfall in the area averaged approximately 19 inches in 2008 (Maui County Data Book, 2010). Winds in the Kahului region are predominantly out of the north-northeast and northeast.

The existing site is relatively flat and ranges in elevation from six (6) to ten (10) feet above mean sea level (msl) (Austin, Tsutsumi & Associates, Inc., 2006).

Underlying the project site is soil of the Pulehu-Ewa-Jaucas soil association. See **Figure 11**. This association occurs in basins and on alluvial fans and is

LEGEND

1. Pulehu-Ewa-Jaucas association
2. Waiakoa-Keahua-Molokai association
3. Honolua-Olelo association
4. Rock land-Rough mountainous land association
5. Puu Pa-Kula-Pane association
6. Hydrandepts-Tropaquods association
7. Hana-Makaalae-Kailua association
8. Pauwela-Haiku association
9. Laumaia-Kaipoipoi-Olinda association
10. Keawakapu-Makena association
11. Kamaole-Oanapuka association



Map Source: USDA Soil Conservation Service

Figure 10 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Soil Association Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\soils

characterized by well-drained and excessively drained soils that have a moderately-fine to coarse-textured subsoil or underlying material.

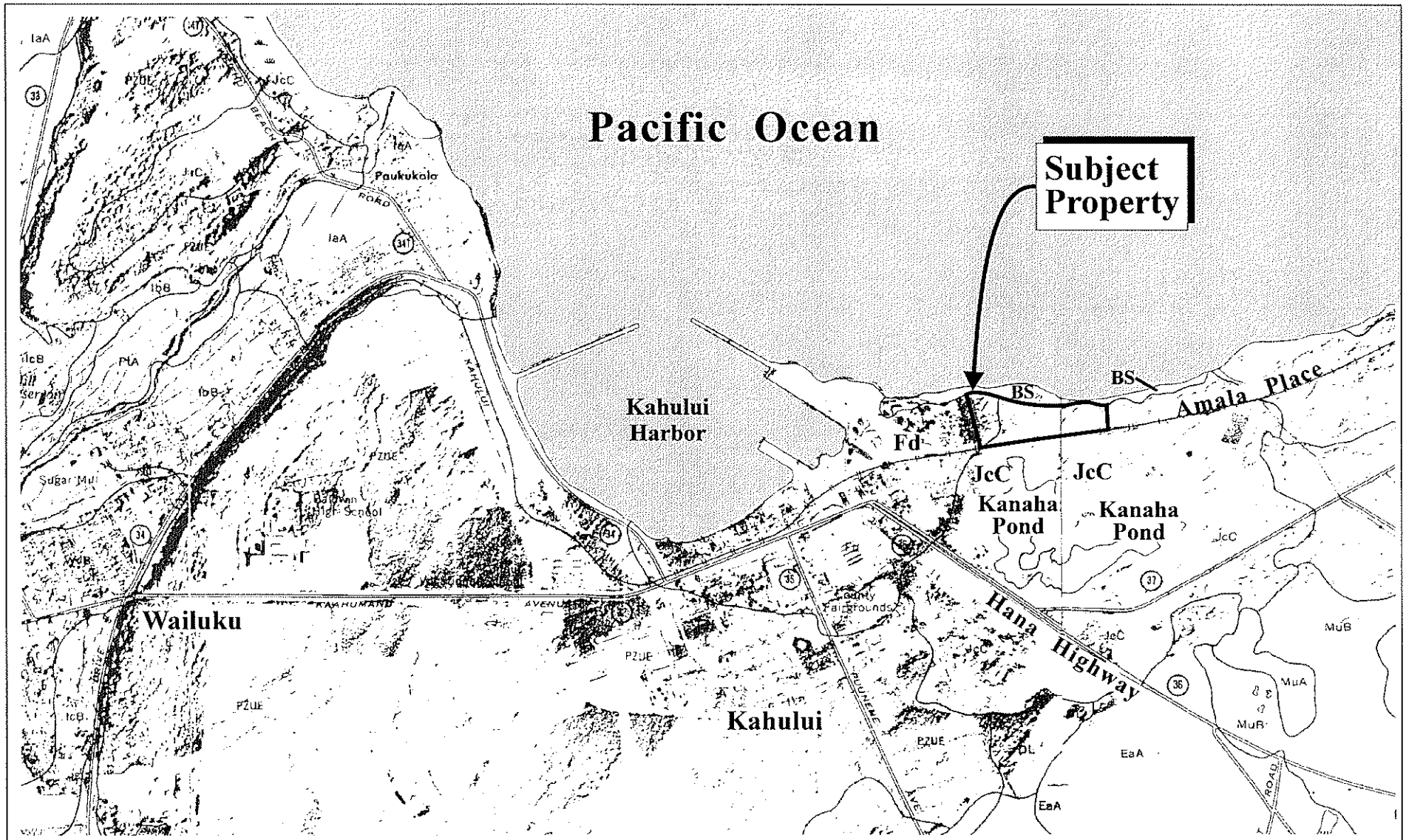
Specifically, the project site contains Jaucus sand, saline (JcC), 0 to 12 percent slope soils, Fill lands (Fd), and Beach soils (BS). See **Figure 11**. JcC soils occur near the ocean in areas where the water table is near the surface and salts have accumulated. This soil is used for pastures, wildlife habitat, and urban development. It is poorly drained in depressions but excessively drained on knolls. The Fd soils are located in the eastern portion of the parcel. Beach soils (BS) front the subject property.

The Detailed Land Classification-Island of Maui establishes a soil productivity rating ranging from "A" to "E", with "A" representing the highest level of productivity and "E" being very poor for agricultural production. This rating system is based on factors including machine tillability, stoniness, texture, clay properties, drainage, rainfall, elevation, and slope. The land underlying the project site is unclassified, as it is situated within an existing urbanized area.

In 1977, the State Department of Agriculture established a classification system for identifying Agricultural Lands of Importance to the State of Hawai`i (ALISH), primarily, but not exclusively, on the basis of soil characteristics. The three (3) classes of ALISH lands are: "prime", "unique", and "other important" agricultural land with the remaining non-classified lands designated as unclassified. The subject property is unclassified by the ALISH system, with no agricultural uses.

b. <u>Potential Impacts and Mitigation Measures</u>

The site is developed and the WKWWRF has been established on the site since 1973. The proposed revetment could have potential impacts on the sand soils. The rock mound revetment will change the topography of the site in the area along the fence line where it is constructed. Further study during the preparation of the Draft EIS will be carried out to determine potential impacts and mitigation measures. Mitigation alternatives investigated will include a program to monitor the beach width after the proposed action is completed to determine if the sand soils are being impacted. If the sand soils are lost as a result of the revetment, they could be replaced with other sands



Source: USDA, Soils Conservation Service

Figure 11 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Soil Classification Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\soilclass

suitable for this beach.

3. Flood and Tsunami Hazard

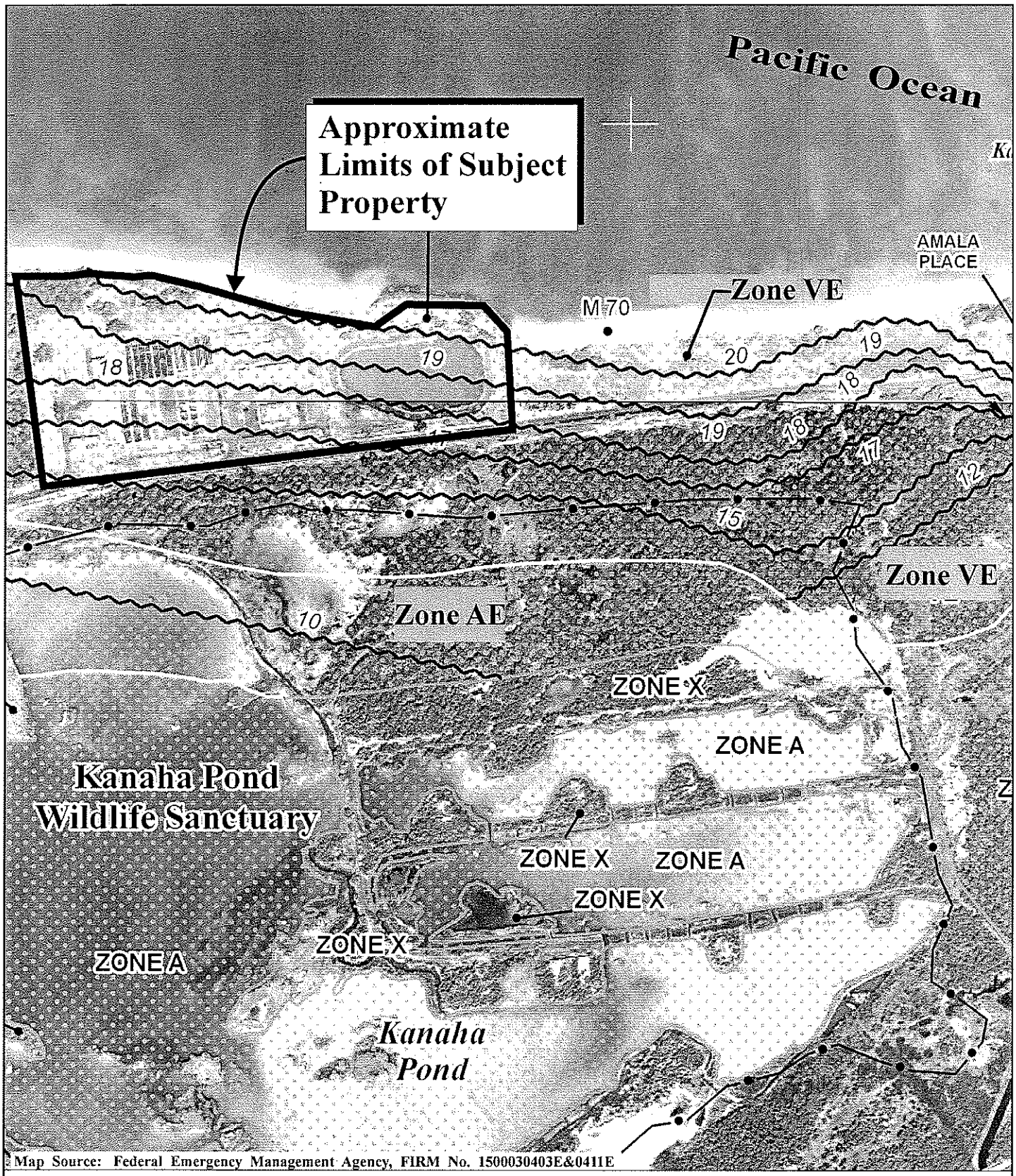
a. Existing Conditions

The project site is located within Flood Zone VE, with base flood elevations of 17 to 20 feet above mean sea level (msl), as established by the applicable Flood Insurance Rate Map (FIRM) for Maui County. See **Figure 12**. Flood Zone VE is a coastal flood zone with velocity hazard from wave action and determined base flood elevations. Regarding tsunami hazard, the tsunami evacuation map for the region produced by the State Civil Defense Agency indicates the tsunami evacuation area extends from the shoreline up to Keolani Place and Haleakala Highway. The project site is, therefore, situated within the tsunami evacuation area.

When a tsunami strikes, the maximum vertical height of the water in relation to sea level is referred to as run-up and the maximum horizontal distance is referred to as inundation. The Maui Mitigation Plan lists the greatest run-up experienced in Kahului as 12 feet (December 1860). The most destructive tsunami occurred in May 1960 when "*the waves washed inland for a distance of about 3,000 feet to ground elevations of about six (6) feet*". Refer to **Appendix "C"**.

The possibility will always exist that future tsunamis may be of greater destructive power than those previously recorded.

Structural tsunami protection improvements are currently in progress as a separate project at the WKWWRF. The tsunami protection measures were approved by the Department of Planning for a SMA Assessment (SMX 2008/0531) in 2008. The planned tsunami protection measures include below grade structural reinforcement of the concrete slab foundation to prevent underscouring and wave action erosion of the shoreward side of the Operations Building. The Centrifuge Control Room will be relocated above the 100-year tsunami wave height. Improvements at the Tanks and Headworks Building include thickening of the slab below grade, addition of walls and flood doors at grade level, and reinforcing footings below the scourline to protect against wave action erosion. The tsunami protection



Map Source: Federal Emergency Management Agency, FIRM No. 1500030403E&0411E

Figure 12 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension
Flood Insurance Rate Map

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\FIRM

work for the Operations Building and Centrifuge Control Room has been completed. Tsunami protection improvements for the Tanks and Headworks Building area are in the bidding and construction phase.

b. Potential Impacts and Mitigation Measures

The proposed revetment is specifically intended to provide additional protection against severe storms and tsunamis, helping to mitigate their impact. Without the shoreline protection measures, the beach would continue to erode and threaten the upland area, creating a greater potential flood and tsunami hazard at the site as well as loss of land. All vertical construction will be implemented in accordance with Maui County Code, Chapter 19.62 relating to Flood Hazard Areas, as applicable. Where required, standards of development set forth in Chapter 19.62 will be incorporated in the shoreline protection design.

4. Coastal Processes

a. Existing Conditions

The project site is bounded on the north by approximately 1,350 linear feet of shoreline. There is an existing 450-foot rock revetment on the east side of the property. The beach fronting the project site is part of the 13,000-foot long beach that extends east from Kahului Harbor towards Spreckelsville Beach. This beach is broken into a series of pocket beaches separated by manmade groins, natural beachrock, and lava points. Sand ranges in size from medium-sized grains to cobbles. The beaches in this area are primarily used by locals and visitors for world-class windsurfing, kitesurfing, as well as fishing and regular beach recreation.

There is a large fringe reef just offshore that extends for several miles along this beach. The reef is characterized by a wide crest (one-half (0.5) mile to one (1) mile in width) that extends from a shallow nearshore toe to depths ranging from 10 to 30 feet. Closer to Kahului Harbor, the reef is narrow or absent. Refer to **Appendix "B"** and **Appendix "C"**.

The coastline stretching from Kahului Harbor towards Spreckelsville Beach in the east experiences net longshore sediment transport in the east to west

direction. It appears very unlikely that the direction of net sediment transport would reverse to be east-directed. Refer to **Appendix"B"**. Historical sand mining in the area created a sediment deficit, and the significant effects of this are seen through the lack of sediment input from the upcoast beaches to the east. The net rate of longshore sediment transport in the WKWWRF littoral cell is currently estimated to be between 1,300 and 4,000 cubic yards per year from east to west. This rate is likely to continue into the future. Refer to **Appendix "B"**.

Erosion has occurred along a majority of the north shore, and is not a result of the existing revetment at the WKWWRF retention pond. The highest erosion rates along the WKWWRF occurred before the existing revetment was constructed. The largest contribution to the long term erosion of the north shore beaches is the removal of sand for lime production as well as cement manufacturing and aggregate. This permanent removal of sand from the littoral system has resulted in a deficit in the sediment budget and erosion over the length of beach from Kahului Harbor in the west to Baldwin Beach in the east. Refer to **Appendix "B"**.

The area has experienced moderate to severe erosion over the years. Along the WKWWRF property, the average AEHR is -2.4 ft/yr. Review of past shoreline surveys indicates that the shoreline west of the existing revetment is eroding at a rate of up to -6.0 ft/yr. In addition to ongoing erosion, there are seasonal shifts in the shoreline position ranging from 25 to 55 feet. Refer to **Figure 5**.

b. <u>Potential Impacts and Mitigation Measures</u>

The proposed project is intended to protect the shoreline fronting the WKWWRF from further erosion. It would protect the WKWWRF from threats posed by erosion, allowing the facility to continue serving Central Maui's wastewater needs into the future.

The proposed project may impact coastal processes in the area. The revetment may contribute to beach loss between the structure and the ocean. If the revetment acts as a groin, it may limit the transfer of sand from the beach area in the east to the beach west of the WKWWRF. On shorelines that experience net long term erosion or are subject to relative sea level rise,

the shorelines adjacent to hard structures can migrate landward, resulting in "passive erosion", which can limit lateral access to adjacent beaches (Griggs, 2005). Further study will explore the potential impact of the revetment on the beach directly in front of the structure as well as the potential impact on the adjacent shoreline. These potential impacts will be discussed in the Draft EIS. The beach width could be monitored after the proposed action is completed to determine if the beach is being impacted. Beach nourishment at the project site or updrift from the impacted beach as a possible mitigation alternative, if required, will be evaluated in the Draft EIS.

5. Flora and Fauna

a. Existing Conditions

The project is situated in an area that has been used for the WKWWRF site for 35 years. Plant life found in this area includes Guinea grass, buffelgrass, and Koa haole shrubs along with kiawe trees and some ornamental species of palms used in site landscaping.

Terrestrial fauna in the vicinity of the project site include introduced species, such as rats, feral cats, mongoose, and dogs. Avifauna typically found in this area include the mynah, spotted dove, zebra dove, barred dove, Japanese white-eye, cardinal and red-crested cardinal, gray francolin, house finch, chickens, nutmeg mannikin, African silverbill, chestnut mannikin, sparrow, and the kolea.

There are no known rare, threatened, or endangered species of flora and fauna located on the project site. However, it is noted that the adjacent Kanaha Pond Wildlife Sanctuary is home to the Hawaiian stilt and Hawaiian coot, which are both endangered endemic birds. The pond is also a critical habitat for the endangered Blackburn's sphinx moth.

b. Potential Impacts and Mitigation Measures

In the short term, the construction of the revetment and potential resulting beach loss could have potential impacts on organisms inhabiting the shoreline. While a terrestrial survey has been conducted over the WKWWRF grounds, an additional study will be carried out to characterize the flora and

fauna on the ocean side of the property. The proposed structure could, in the long term, provide additional habitat for crabs and juvenile fish. If it is determined that there will be an impact to the flora and fauna in the area, mitigation measures will be documented in the Draft EIS.

6. Streams and Wetlands

a. Existing Conditions

There are no streams or wetlands located within the project property boundaries, however, the Kanaha Pond Wildlife Sanctuary (KPWS) lies across Amala Place to the south of the WKWWRF. The pond is historically a natural pond thought to exist and be used by early Hawaiians. Since the early 1900's, it has served as a waterfowl refuge. Parts of the sanctuary were used as a disposal site for dredged material from the construction of the Kahului Harbor. In 1952, the site was designated as a wildlife sanctuary. In 1971, it was placed on the National Registry of Historical Natural Landmarks by the U.S. Department of the Interior, National Park Service (U.S. Army Corps of Engineers, 2003).

The KPWS is home to two (2) endangered endemic birds, the Hawaiian Stilt (Ae`o) and the Hawaiian coot, along with a number of other migratory species. The sanctuary is also designated as a critical habitat for the endangered Blackburn's sphinx moth (U. S. Army Corps of Engineers, 2003).

b. Potential Impacts and Mitigation Measures

The construction of the proposed revetment extension could provide protection to Kanaha Pond from wave overtopping. Potential impacts to Kanaha Pond from the proposed project will be evaluated and discussed in the Draft EIS.

7. Nearshore Marine Environment

a. Existing Conditions

There is a large fringe reef just offshore of the project site that extends for several miles along this beach. The reef is characterized by a wide crest (one-half (0.5) mile to one (1) mile in width) that extends from a shallow

nearshore toe to depths ranging from 10 to 30 feet. Refer to **Appendix "B"**. Closer to Kahului Harbor, the reef is narrow or absent. The National Oceanic and Atmospheric Administration (NOAA) (2007) recently completed a characterization of the geomorphology and biology of the nearshore regions around Maui. The biological coverage maps indicate that the area fronting the WKWWRF contains pavement, scattered coral and rock, and sand. In this sense, pavement is flat, solid carbonate rock that is often covered by a thin sand veneer.

b. Potential Impacts and Mitigation Measures

Short-term impacts from construction include the potential for increased turbidity of the coastal waters and excavation of sand to construct the revetment. A Best Management Practices (BMPs) plan will be prepared and included in the Draft EIS. If beach nourishment is implemented, the imported sediment characteristics will be matched to the native characteristics so that offshore migration of sand will be limited.

8. Relative Sea Level Rise

a. Existing Conditions

Relative sea level changes in the Hawaiian Islands are caused by rising sea levels, as a result of global warming and land subduction. Land subduction is caused by the plate movements of the islands. Globally, the msl has risen by 10 to 30 cm (4 to 12 inches) over the last century. Sea level is projected to rise twice this amount (2 feet) over the 21st Century (Fletcher, et al. 2002).

In the Hawaiian Islands, the long-term trend of sea level rise caused by land subduction decreases from the island of Hawai`i to the northwest (D. Jeon, 1995). Therefore, the island of Maui subsides faster than Oahu and Kauai, since it is located closer to Hawai`i. Tide gauge data from Kahului, Maui shows a relative sea level rise of 2.46 cm [±0.23] per decade (0.97 inches [±0.09] per decade).

Several studies indicate that future sea level rise may increase considerably (Fletcher, 1992 and Fletcher *et al.*, 2002). The median sea level increase on Maui is predicted to be 9.1 inches over the next 50 years and over 19 inches

over the next century.

More recent work by Fletcher (http://www.soest.hawaii.edu/coasts/sealevel/) indicates that a sea level rise of 40 inches by 2100 is "highly likely." The risk of sea level rise to Maui's critical infrastructure is highlighted in Norcross-Nu`u, Charles Fletcher, et al. 2008, *Bringing Sea-Level Rise Into Long-Range Planning Considerations on Maui, Hawaii*, where the WWRF facility is explicitly identified. In addition, the paper cites the potential for rates that range as high as 1.6m (63 inches) per century.

At the Kahului Beach area, the USGS profile data indicate the shoreline slope is approximately 10 feet horizontal to one foot vertical (Brown & Caldwell, 2002). With this slope, a one-inch change in sea level relates to a 9.7- inch change in the relative shoreline position per decade (approximately 0.081 feet per year, or 0.97 inches per year). Over time, wave heights and the erosive effects of storms could be enhanced because of the rising sea levels.

b. Potential Impacts and Mitigation Measures

The proposed project itself will not affect the sea level. However, rising sea level could potentially impact the shoreline fronting the facility and pose a further risk to the WKWWRF itself. The latest research from the University of Hawai`i Coastal Geology Group on sea level rise and coastal erosion will be reviewed as well as other reference material on this subject. The findings will be incorporated into the design of the crest elevation and width of the revetment.

9. Historical and Archaeological Resources

a. Existing Conditions

An archaeological field inspection was conducted on portions of the WKWWRF property in 2007 by Xamanek Researches, LLC for the tsunami protection project. See **Appendix "H"**. A wave cut bank was inspected near the boundary of the parcel closest to the shoreline. The inspection revealed previously disturbed sand, and no cultural materials were noted in the cut bank.

Sand dune deposits were noted in all the non-built areas of the subject property, as well as along Amala Place. Of note was adjacent Kanaha Pond which has traditional cultural value and is identified by the State Historic Preservation Inventory Site No. 50-50-05-1783.

b. Potential Impacts and Mitigation Measures

Due to the presence of sand deposits and the location of the project near the shoreline, construction of the proposed action would include precautionary archaeological monitoring. An archaeological monitoring plan was prepared and submitted to the State Historic Preservation Division (SHPD) for review and approval prior to ground disturbing activity for the proposed tsunami protection project. See **Appendix "H-1"**. The SHPD approved the Archaeological Monitoring Plan. See **Appendix "H-2"**. An updated Monitoring Plan will be prepared to cover the shoreline protection project at the WKWWRF and submitted to SHPD prior to any ground altering activity. If any historic or cultural resources are discovered, all construction activity will stop and coordination will be carried out with the appropriate agencies to mitigate potential adverse impacts.

10. Cultural Assessment

a. Settlement Patterns and Existing Conditions

The WKWWRF site is a developed property that has been heavily altered since it was constructed in 1973. The project site falls within the limits of what was once called Ka`a Lands, or Wailuku Commons, a region which covered about 24,000 acres between Wailuku and Pa`ia (Monsarratt, 1882). In 1882, Claus Spreckels acquired fee simple title to all of Wailuku ahupua`a, including the Commons (Kennedy et al., 1993). Later that year, Spreckels founded HC&S (Hawaiian Commercial and Sugar), and within a short time, developed a state-of-the-art sugar mill, as well as a support system of railways and irrigation ditches (Kennedy et al, 1993).

An 1882 map of Kahului Harbor (Monsarratt, 1882) shows the Commons as vacant land south of Kahului town, which was then a mixture of about 20 buildings and a wharf (Jackson, 1881). Around the same time, the area was described as *"a complete desert, a great, barren stretch of sand and dust*

*spread from Wailuku to Pa`ia, except for a little cattle grazing around the present location of Spreckelsville"* (Burns, 1991). An 1881 map by Jackson of the surrounding area shows "undulating sand hills" crossed only by dirt roads and the railroad line to Pa`ia, while a 1910 map by Shoemaker shows the seaward half of the area as "pasture".

In 1942, the U.S. Government annexed 3,800 acres at Pu`unene and Kahului for the construction of naval air stations. At Kahului, 1,350 acres were leased from HC&S for Naval Air Station Kahului (NASKA). Remnants of an old WWII pill box from Navy use of the area remain offshore in front of the treatment plant. In the early 1950's, NASKA was taken over by civilian authorities for public airport purposes. In recent decades, the Kahului Airport has expanded.

Traditional and customary native Hawaiian rights exercised in the area relate to access to beach and marine resources and access to the adjacent Kanaha Pond, a significant cultural resource. The proposed project will not limit, alter, or interfere with access to Kanaha Pond.

b. Potential Impacts and Mitigation Measures

In order to assess the potential cultural impact associated with the proposed project, interviews will be carried out with individuals familiar with the cultural practices in the area. A summary report of the cultural interviews will be presented in the Draft EIS.

In accordance with Section 6E-43.6, Hawai`i Revised Statutes, and Chapter 13-300, Hawai`i Administrative Rules, if any significant cultural deposits or human skeletal remains are encountered, work will stop in the immediate vicinity and the SHPD will be contacted. Specific protocols will be incorporated into the Archaeological Monitoring Plan.

11. Air Quality

a. Existing Conditions

Air quality in the Wailuku-Kahului region is considered good, as point sources (e.g., Maui Electric Power Plant, HC&S Mill) and non-point sources

(e.g., automobiles) of emissions do not generate problematic high concentrations of pollutants. The relatively high quality of air can also be attributed to the region's constant exposure to the trade winds which quickly disperse emissions.

b. Potential Impacts and Mitigation Measures

Short-term impacts on air quality may result from construction-related activities. BMPs will be implemented to minimize such impacts. In the long term, adverse impacts to air quality associated with the proposed project are not anticipated.

12. Noise Characteristics

a. Existing Conditions

Traffic noise generated by vehicles traveling along Hana Highway and Ka`ahumanu Avenue is a source of background noise in the vicinity of the plant. The predominant factor in noise quality is aircraft traffic utilizing the Kahului Airport. Ambient noise in the vicinity is also generated by wind and surf from the adjacent marine environment.

b. Potential Impacts and Mitigation Measures

Ambient noise conditions may be temporarily affected by construction activities in the short term. In the long term, adverse noise impacts associated with the proposed project are not anticipated.

13. Water Quality

a. Existing Conditions

The coastal nearshore waters fronting the project site are classified "Class A" waters according to the State Department of Health Water Quality Standards Map of the Island of Maui (October 1987). Pursuant to Hawai`i Administrative Rules (HAR) Chapter 11-54, 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. An assessment of the inshore and offshore water quality in the project area will be carried out and discussed in the Draft EIS. Water samples will be collected in and around the project site and an analysis will include, but not be limited to, temperature and salinity, dissolved oxygen, pH values, turbidity and suspended solids, nutrients and chlorophyll.

b. Potential Impacts and Mitigation Measures

Construction of the rock mound revetment and construction activities involving mechanical equipment in the vicinity of the shoreline can lead to turbidity during the construction period. Typically, this type of turbidity is short term, limited in spatial extent, and similar to the turbidity experienced in a high-wind event.

A water quality monitoring program will be implemented for the project. The program will include collection of baseline water quality data prior to the initiation of construction in order to measure any degradation of water quality that may be attributable to the construction activity.

Temporary increases in turbidity as a result of construction activities will cease once the project is completed. Further, the proposed rock mound revetment is anticipated to reduce the amount of sand sediment input into the marine environment currently resulting from beach erosion. More importantly, the revetment is designed to prevent erosion and damage that could lead to a large-scale release of sewage and/or treatment byproducts into the marine environment. Coordination with the State Department of Health, Clean Water Branch, will be undertaken to address applicable permitting requirements. The results of the water quality assessment may establish additional procedures to mitigate potential impacts to water quality. These measures will be incorporated in the Draft EIS.

14. Scenic and Open Space Resources

a. Existing Conditions

Scenic and open space resources to the south of the project site include the Kanaha Pond State Wildlife Sanctuary, and beyond, the West Maui

Mountains. Toward the east is Kanaha Beach Park, while the Pacific Ocean and a stretch of sandy beach lie to the north. The majority of undeveloped lands in the Central Maui isthmus is utilized for sugar cane cultivation. This agricultural use creates a vast expanse of sugar cane fields that establishes and dominates the open space character of the region. The sandy beach to the north and east of the project site also establishes the open space character along the coastline in the vicinity of the project site. There is a public beach access to the east of the subject property.

The site currently has a 450-ft rock revetment in front of the WKWWRF Retention Pond. This existing revetment has been in place for 30 years.

b. Potential Impacts and Mitigation Measures

The site is located in an area that is both industrial and natural. Public use of the shoreline in front of the WKWWRF, however, is limited relative to neighboring beaches. The public beach access to the east of the subject property will not be adversely impacted by the proposed project. Due to the existing revetment, a portion of the shoreline already has a rock structure and extension of the existing revetment would not adversely impact the visual and open space resources in the area. However, the construction of additional length to the revetment may reduce the beach area fronting the project site. Beach width can be monitored after the proposed action is completed to determine if beach nourishment is warranted. The Draft EIS will include discussion on mitigation measures such as beach nourishment and/or lateral shoreline access on top of the rock revetment.

B. SOCIO-ECONOMIC ENVIRONMENT

1. Population and Demographic

a. Existing Conditions

Maui County has experienced strong growth in recent years. The resident population has increased approximately 24 percent in the ten-year span from 1992 to 2002, from 108,585 in 1992 to 134,139 in 2002. Growth in the County is expected to continue with the resident population projected to increase to 151,300 by 2010 and 174,450 by 2020 (County of Maui, June

2006).

b. Potential Impacts and Mitigation Measures

The proposed project is not a direct generator of population, nor will it alter the demographic characteristics of the area. The WKWWRF will be better equipped to serve the long-term wastewater needs of Central Maui residents with shoreline protection. With these measures, it will also be able to provide its services without vulnerability to interruption or damage to the facility caused by erosion.

2. Economy

a. Existing Conditions

The Kahului region is the island's center of commerce. Combined with neighboring Wailuku, the region's economic character encompasses a broad range of commercial, service, and governmental activities. In addition, the region is surrounded by significant agricultural acreages, which include sugar cane fields. The vast expanse of agricultural land, managed by HC&S, is considered a key component of the local economy.

Visitor arrivals on the island of Maui were at 2,075,800 in 2008, with the vast majority arriving by air (Maui County Data Book, 2010).

The unemployment rate for Maui County and Maui Island were 7.8 and 7.6 percent respectively, in October 2010 (Hawaii Workforce Informer, 2010). The unemployment rate for the same period in October 2009 for Maui County and Maui Island were 8.7 and 8.5 percent, respectively.

Based on the Department of Environmental Management's Central Maui Wastewater Reclamation Facility Study (Austin, Tsutsumi & Associates, 2006), the demand for additional wastewater treatment capacity would be triggered in 2029, when the existing WKWWRF is projected to reach its design capacity of 7.9 MGD.

b. Potential Impacts and Mitigation Measures

Short-term economic benefits are expected as a result of project construction. Beyond the short-term effects, the proposed project will also have indirect positive impacts on the economy by protecting long-term wastewater handling capacity in the Central Maui Region. An anticipated additional positive impact resulting from project implementation is increased safety for the public due to the reduction of risk of damage to the WKWWRF from shoreline erosion. The revetment would also provide a last line of defense against a tsunami. The proposed action is the most cost-effective solution for the facility, and it does not place an undue burden on taxpayers, especially in comparison to alternatives that include relocating the facility.

C. PUBLIC SERVICES

1. Recreational Facilities

a. Existing Conditions

County recreational facilities are administered and maintained by the Department of Parks and Recreation. The Wailuku-Kahului region contains a network of recreational facilities comprised of mini-parks, as well as neighborhood and district parks. The region's seven (7) mini-parks are distributed uniformly throughout the area, while the region's eleven (11) neighborhood and three (3) district parks provide a wide range of facilities to meet the recreational needs of the community.

In the vicinity of the project site, a wide range of shoreline and ocean recreation activities such as boating, fishing, diving, surfing, canoeing, kayaking, picnicking, kitesurfing, and windsurfing are available at the Kahului Harbor and nearby beach parks. County parks in the vicinity include Kanaha Beach Park, Baldwin Beach Park, Hoaloha Park, Kahului Community Center, Keopuolani Park, and the War Memorial Sports Complex. The site is also within proximity of the State's Iao Valley Park.

b. Potential Impacts and Mitigation Measures

The shoreline fronting the facility has limited use by the public. The proposed project has potential impacts on the stretch of shoreline fronting the

facility as well as the adjacent shoreline. These include possible beach loss and loss of lateral access due to passive erosion. After construction is completed, beach width could be monitored to assess any impacts. Mitigation in the form of beach nourishment could maintain the recreational integrity of the area if significant impacts are observed. The results of the coastal shoreline process studies and potential impacts to coastal recreational resources will be further discussed in the Draft EIS.

2. Police and Fire Protection

a. Existing Conditions

Police protection for the Wailuku-Kahului region is provided from the Maui Police Department (MPD) headquarters in Wailuku, approximately 2.5 miles from the project site. The region is served by the Department's Central Maui patrol.

Fire prevention, suppression, and protection services for the Wailuku-Kahului region are provided by the Department of Fire and Public Safety's Wailuku Station, located in Wailuku Town about three (3) miles from the project site, and the department's Kahului Station, which is located on Dairy Road less than one (1) mile to the south of the subject property.

b. Potential Impacts and Mitigation Measures

The proposed project is limited in scope to provide shoreline erosion protection at the existing WKWWRF. It is not anticipated to have an adverse impact on police and fire services. The proposed structure will not extend existing service limits for emergency services.

3. Solid Waste

a. Existing Conditions

Single-family residential solid waste collection service is provided by the County of Maui on a regular basis. Residential solid waste collected by County crews is disposed of at the County's Central Maui Landfill, located four (4) miles southeast of the Kahului Airport. In addition to County-collected refuse, the Central Maui Landfill accepts commercial waste from

private collection companies. Refuse collection for the WKWWRF is provided by County refuse collection service.

b. Potential Impacts and Mitigation Measures

The proposed project is limited in scope to provide shoreline erosion protection at the existing WKWWRF. It is not anticipated to have an adverse impact on solid waste services. Construction waste will be minimal. Other excavated material will either be stockpiled onsite or trucked to the Maui Disposal construction waste site for disposal, as necessary.

4. Medical Services

a. Existing Conditions

Maui Memorial Medical Center, the only major medical facility on the island, services the Wailuku-Kahului region. Acute, general, and emergency care services are provided by the 231-bed facility. In addition, numerous privately operated medical/dental clinics and offices are located in the area to serve the region's residents.

b. Potential Impacts and Mitigation Measures

The proposed project is limited in scope to provide shoreline erosion protection at the WKWWRF. The proposed project is not anticipated to adversely impact medical services.

5. Schools

a. Existing Conditions

The Wailuku-Kahului region is served by the State Department of Education's public school system, as well as several privately operated schools accommodating elementary, intermediate, and high school students. Department of Education facilities in the Kahului area include Lihikai, Pomaika`i, and Kahului Elementary Schools (Grades K to 5), Maui Waena Intermediate School (Grades 6 to 8), and Maui High School (Grades 9 to 12). Existing facilities in the Wailuku area include Wailuku Elementary School (Grades K to 5), Iao Intermediate School (Grades 6 to 8), and Baldwin High

School (Grades 9 to 12).

b. Potential Impacts and Mitigation Measures

No impacts to existing schools and educational services are anticipated from the proposed action.

D. INFRASTRUCTURE

1. Roadways

a. Existing Conditions

The Wailuku-Kahului region is served by a roadway network which includes arterial, collector, and local roads. Major roadways in the vicinity of the project site include Hana Highway, Dairy Road, Keolani Place, and Hobron Avenue.

Access to the project site is provided by Amala Place via Hana Highway and Hobron Avenue through the Kahului Harbor industrial area.

In proximity of the project site, Hana Highway has an east-west orientation and functions as a four-lane, major divided State arterial highway which links East Maui and Central Maui. The posted speed limit on Hana Highway is 45 miles per hour (mph) at the approaches to the Dairy Road and Hobron Avenue intersections.

Amala Place is a two-lane, east-west County road that provides access to the Kanaha Pond State Wildlife Sanctuary and Kanaha Beach Park. The posted speed limit on Amala Place is 30 mph. The project site is located to the north of Amala Place.

b. Potential Impacts and Mitigation Measures

Traffic to and from the WKWWRF will, for the most part, be limited to vehicles of operations personnel and employees. Traffic resulting from these sources will be intermittent and is not anticipated to significantly impact existing traffic conditions along Hobron Avenue, Amala Place, or other area roadways. A construction traffic management plan will be prepared and

submitted to the Department of Public Works for review and approval during the permitting process, as applicable. Increased construction traffic will be short term and mitigated by the construction management plan. The proposed shoreline protection measures are not anticipated to increase traffic at the WKWWRF in the long term. The proposed project would provide a benefit in protecting Amala Place from wave overtopping.

2. Wastewater

a. Existing Conditions

Domestic wastewater generated in the Wailuku-Kahului region is conveyed to the WKWWRF. As previously mentioned, the design capacity of the facility is 7.9 million gallons per day (MGD). Cumulative wastewater flow currently allocated is approximately 6.6 MGD.

b. Potential Impacts and Mitigation Measures

The wastewater reclamation needs from the project site will be limited to existing fixtures and will be minimal. The proposed improvements will not increase wastewater flows. The Kaa and NASKA force mains run along Amala Place, but will not be affected by the proposed project. The proposed project will protect the WKWWRF site from shoreline erosion and result in the long-term viability of the facility to meet the wastewater processing requirements for Central Maui in an efficient and cost-effective manner. Taking action to protect the facility from shoreline erosion is critical, and the no action alternative is highly undesirable because it places the facility and the nearshore environment at a high risk of damage.

3. Water

a. Existing Conditions

Domestic water from the Wailuku-Kahului region is provided by the Department of Water Supply's (DWS') Central Maui Water System.

The project area is served by the DWS system. The source for this water is the Waihe`e wells that were developed by the Central Maui Source Joint Venture. The three (3) developed wells currently have a total capacity of 13.5

million gallons per day (MGD). The water storage tanks that serve the system for this area are located in Wailuku.

b. Potential Impacts and Mitigation Measures

The proposed shoreline protection structure is not anticipated to increase water demand at the project site. It is not located near the water source and would not have an impact on source water quality.

4. Drainage

a. Existing Conditions

Currently there are no drainage improvements at the project site. The existing site is generally flat and the total surface runoff generated from the site is approximately 39.03 cubic feet per second (cfs). The subject property can generally be broken into four (4) drainage areas. Runoff from a small portion of the subject property (approximately 1.23 cfs) currently sheetflows off the site in a northerly direction towards the shoreline. The runoff from the other drainage areas sheetflows over the property towards the existing roadway, Amala Place, and to the adjacent properties (SSFM, 2008).

b. Potential Impacts and Mitigation Measures

The revetment structure could affect the drainage capacity of the project site by creating a barrier to drainage flow. Further study will be carried out during the preparation of the Draft EIS to determine what, if any, impacts the structure would have on drainage at the project site and identifying mitigation measures as required.

5. Electricity, Telephone, and Cable Television Systems

a. Existing Conditions

Electrical, telephone, and cable television (CATV) services to the project site are available though Maui Electric Company, Hawaiian Telcom, and Oceanic Time Warner Cable, respectively.

b. Potential Impacts and Mitigation Measures

No impacts to the electrical, telephone, and CATV systems are anticipated from the proposed project.

E. CUMULATIVE AND SECONDARY IMPACTS

Cumulative impacts are defined as the impact on the environment which results from the incremental impact of an action when added to other past, present, and reasonably foreseeable future actions, regardless of what agency or person undertakes such other actions.

In order to assess the potential cumulative and secondary impacts related to the development of the proposed project, the Wailuku-Kahului Community Plan has been utilized as the basis for reasonably foreseeable future development in the region. The Community Plan reflects current and projected conditions in the Central Maui Region and sets forth goals, objectives, policies, and recommendations to guide the development of the region, as well as enhance its overall living environment.

There may be cumulative impacts of the proposed action which lead to beach loss and a reduced supply of sand for beaches downdrift from the project site. On shorelines that experience a net long term erosion or are subject to relative sea level rise, such as that fronting the WKWWRF, the shorelines adjacent to hard structures can migrate landward, resulting in "passive erosion". This can limit lateral access to the adjacent beaches (Griggs, 2005). These effects will be further studied and addressed in the Draft EIS.

Secondary impacts are those which have the potential to occur later in time or farther in distance, but are still reasonably foreseeable. They can be viewed as actions of others that are taken because of the presence of the project. Secondary impacts from highway projects, for example, can occur because they can induce development by removing one of the impediments to growth-transportation access.

The proposed project itself is not considered a generating component for the population, nor will it place additional burden upon infrastructure. The processing capacity of the WKWWRF will not increase as a result of the proposed improvements, although the project enables the planned expansion to move forward. Secondary impacts include a potential increase in the population of the Central Maui Region, as well as the effects of induced growth, which is facilitated by the additional capacity resulting from infrastructure improvements, such as the WKWWRF.

Long-term growth and development in the Central Maui Region are guided by the Wailuku-Kahului Community Plan. Conformance with the Community Plan, as well as any other State and County land use policies, plans, and controls involve the appropriate and adequate mitigation of impacts relating to a proposed action.

The tsunami protection phase for the Operations Building has been completed. Tsunami protection improvements for the clarifiers, aeration basins, chlorine contact chamber, sand filters, and Headworks Building are in the bidding and construction phase. The proposed action for shoreline protection in this document is separate and distinct from the tsunami protection improvements, and as such, has been separately assessed pursuant to Chapter 343, HRS.

III. RELATIONSHIP TO GOVERNMENTAL PLANS, POLICIES, AND CONTROLS

III. RELATIONSHIP TO GOVERNMENTAL PLANS, POLICIES, AND CONTROLS

A. STATE LAND USE DISTRICTS

Pursuant to Chapter 205, Hawai`i Revised Statutes (HRS), all lands in the State have been divided and placed into one (1) of four (4) land use districts by the State Land Use Commission. These land use districts have been designated "Urban", "Rural", "Agricultural", and "Conservation". The project site is located within the State "Conservation" district. See **Figure 13**. The existing wastewater reclamation facilities are covered under Conservation District Use Permit (CDUP) MA-3047. A CDUP, approved by the Board of Land and Natural Resources, will be required for the proposed extension of the revetment. Based on the Department of Land and Natural Resources (DLNR) Conservation Subzone map, the subject property falls within the "Limited" subzone. Pursuant to Hawai`i Revised Statutes Chapter 13-5-22 (P-6), permitted uses within the "Limited" subzone include:

> *Land uses undertaken by the State of Hawai`i or the counties to fulfill a mandated government function, activity, or service for public benefit and in accordance with public policy and the purpose of the conservation district.*

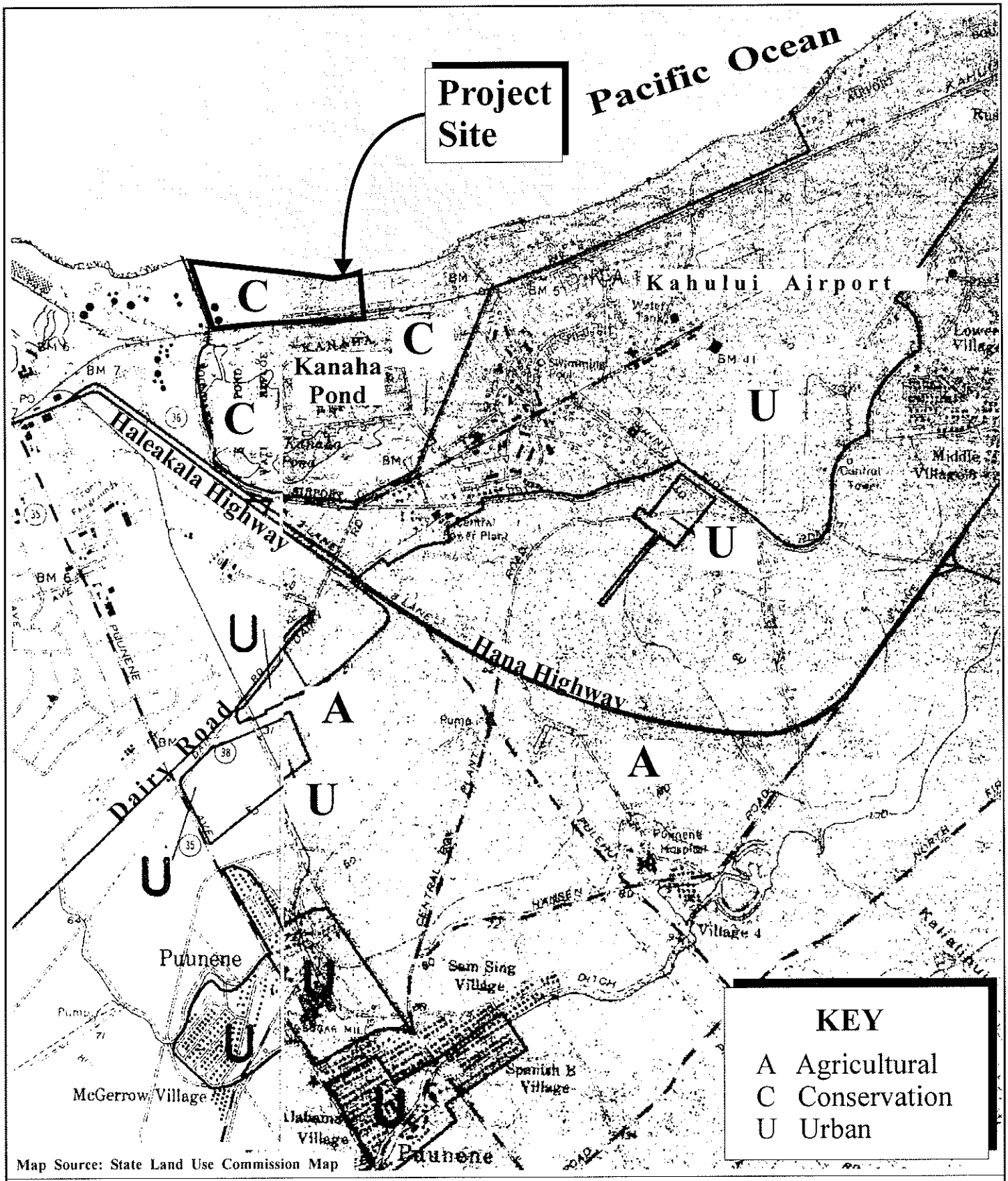
The proposed project meets the permitted uses definition in the "Limited" subzone.

B. CONSERVATION DISTRICT USE ANALYSIS

A Conservation District Use Application (CDUA) File No. MA-7/28/78-1074, was approved for the original revetment in 1979. Refer to **Appendix "A"**.

The subject project, which is an identified permitted use within the "Limited" subzone of the Conservation District, requires a Conservation District Use Permit from the Board of Land and Natural Resources (BLNR). Accordingly, a CDUA for the project will be prepared in accordance with HAR, Title 13.

Thus, with regard to the subject property's consistency with the purposes of the Conservation District, the following criteria are addressed below.



Map Source: State Land Use Commission Map

Figure 13 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension
State Land Use Designation

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\SLUD

1. **<u>The proposed land use is consistent with the purpose of the Conservation District:</u>**

The proposed project is consistent with the purposes of the Conservation District. The subject property is not located near a watershed area and will not, therefore, impact watersheds or water sources. The proposed project is part of an established land use since 1973 and is located within an industrial area and a recreational area. There is an existing revetment that was built in 1979. The extension of this revetment is consistent with the character of this area. Scenic resources and viewplanes will not be affected by the construction of the revetment.

Existing coastal access to the east of the subject property will be maintained. However, the project may result in passive erosion, limiting lateral access. Appropriate forms of mitigation will be explored, such as providing access over the revetment. The beach fronting the WKWWRF is not heavily used by the public, but the proposed action may result in beach loss directly seaward of the revetment. Mitigation alternatives, such as beach nourishment, will be explored during the EIS process. The beach width may also be monitored after the proposed action is completed to determine if beach nourishment may be required.

The proposed action will provide erosion control to protect the land on which the WKWWRF is located. Shoreline protection is critical to the continued operation of the facility, the ability to provide for Central Maui's wastewater needs, and the prevention of a potential large-scale environmental issue.

2. **<u>The proposed land use is consistent with the objectives of the subzone of the land on which the use will occur:</u>**

The proposed project is the continuation of an armor rock revetment as a shoreline protection measure within the "Limited" subzone of the Conservation District. Erosion control and other hazard prevention devices are permissible uses within the "Limited" subzone of the Conservation District. Erosion control is critical to the safety and integrity of the facility and its ability to meet Central Maui's wastewater treatment needs.

3. **The proposed land use complies with provisions and guidelines contained in Chapter 205A, HRS, entitled "Coastal Zone Management", where applicable:**

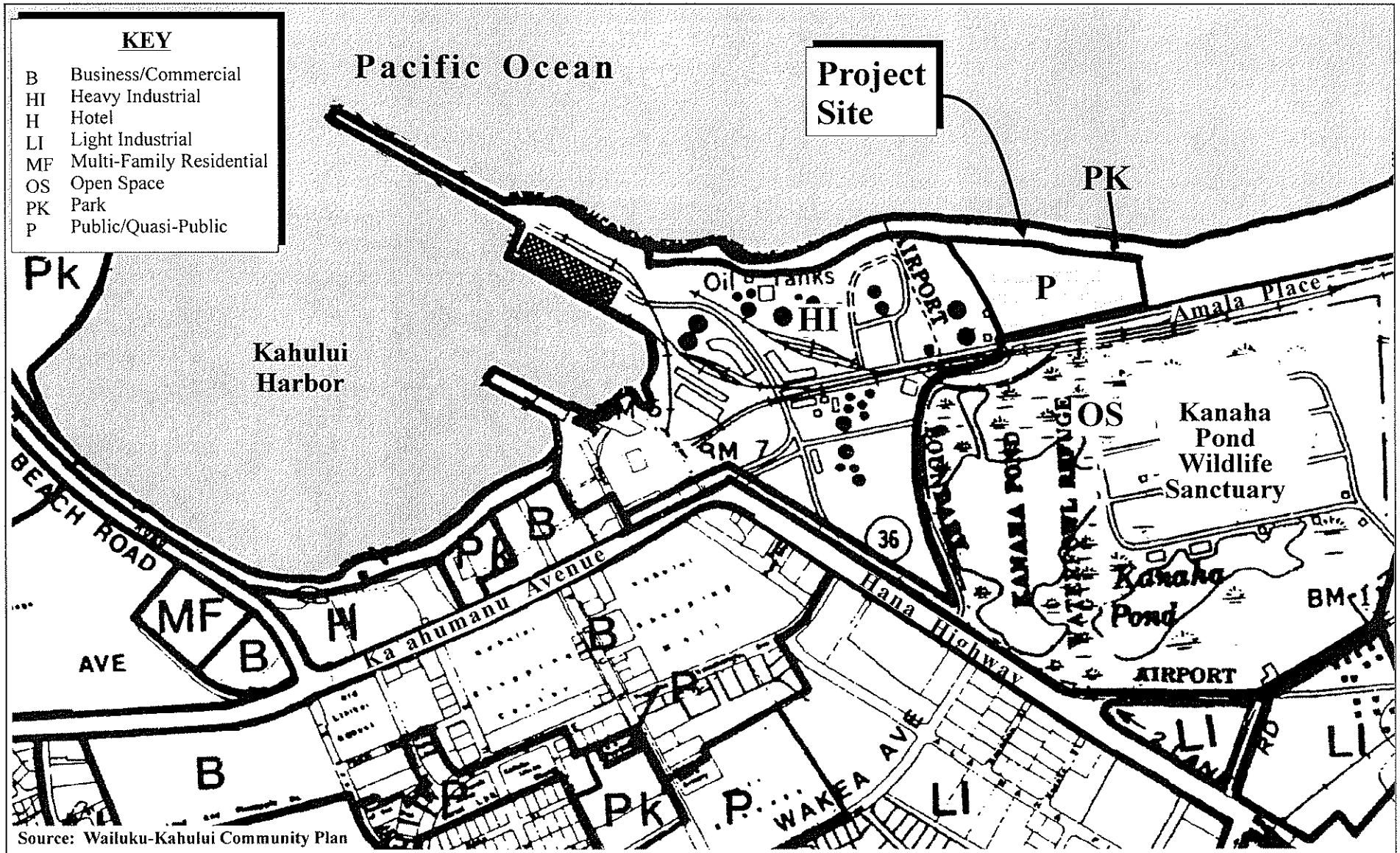
The subject project complies with provisions and guidelines in Chapter 205A, HRS. An application for a Special Management Area (SMA) Use Permit for the subject project will be prepared and submitted to the County of Maui, Department of Planning for processing. Issuance of SMA approval for the project is anticipated to occur at least 45 days prior to the 180-day expiration deadline on the CDUA.

4. **The proposed land use will not cause substantial adverse impacts to existing natural resources within the surrounding area:**

The strip of land designated for "Park" use on the Wailuku-Kahului Community Plan in front of the facility, where the existing beach is located, is currently threatened by erosion and relative sea level rise. See **Figure 14**. The proposed action is designed to prevent additional shoreline erosion in front of the WKWWRF. The proposed action may result in beach loss, passive erosion, and a decreased supply of sediment material for beaches downdrift. Mitigation alternatives will be further explored during the EIS process. BMPs relating to drainage and erosion control measures will be implemented to ensure that potential adverse impacts to existing natural resources in the area are appropriately mitigated during construction. Consequently, the proposed action is not anticipated to cause substantial adverse impact to local natural resources within the surrounding area, community, or region.

5. **The proposed land use, including buildings, structures, and facilities shall be compatible with the locality and surrounding areas, appropriate to physical conditions and capabilities of the specific parcel or parcels:**

The WKWWRF has been an established land use since 1973. The proposed action is limited in scope and scale, consisting of a previously identified extension to an existing revetment at the site. The proposed action is deemed a viable and cost-effective alternative in protecting the WKWWRF and its ability to provide for Central Maui's wastewater treatment needs. As the WKWWRF is located within an industrial area, and the beach fronting the facility has limited use by the public, the proposed construction is considered compatible with the surrounding area.



Source: Wailuku-Kahului Community Plan

Figure 14 Proposed Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Community Plan Designation

NOT TO SCALE

Prepared for: County of Maui, Department of Environmental Management

MUNEKIYO & HIRAGA, INC.

MoffattNichol\WK WWRF\CPLUD

6. **The existing physical and environmental aspects of the land, such as natural beauty and open space characteristics, will be preserved or improved upon, whichever is applicable:**

The proposed action includes the extension of an armor rock revetment between the existing revetment on the east side of the WKWWRF property and the industrial area to the west of the WKWWRF property. As such, it is aesthetically compatible with the existing nature of the area. The proposed action will not obstruct any viewplanes or impede upon open space characteristics. As a result, physical, open space, and environmental aspects of the land will not be adversely impacted.

7. **Subdivision of land will not be utilized to increase the intensity of land uses in the Conservation District:**

The subject project does not involve the subdivision of land nor does the applicant intend on subdividing the parcel in the future.

8. **The proposed land use will not be materially detrimental to public health, safety, and welfare:**

The proposed action is intended to maintain the functional integrity of the WKWWRF. No adverse impacts to public health, safety, and welfare are anticipated to result from the proposed project. The proposed shoreline protection will create a public benefit in protecting the capability of the WKWWRF to meet Central Maui's wastewater needs and safely contain wastewater before it is treated. BMPs will be utilized to ensure that potential impacts to neighboring properties are appropriately mitigated.

C. HAWAI`I STATE PLAN

Chapter 226, HRS, also known as the Hawai`i State Plan, is a long-range comprehensive plan which serves as a guide for the future long-term development of the State by identifying goals, objectives, policies, and priorities, as well as implementation mechanisms. The proposed action is in keeping with the following Hawai`i State Plan objectives and policies:

CHAPTER 226-13 PHYSICAL ENVIRONMENT – LAND, AIR, AND WATER QUALITY

Objective

1. Maintenance and pursuit of improved quality in Hawai`i's land, air, and water resources.

Policy

- Reduce the threat to life and property from erosion, flooding, tsunamis, hurricanes, earthquakes, volcanic eruptions, and other natural or man-induced hazards and disasters.

The proposed project protects the WKWWRF from the threat of erosion and the accompanying threat to the facility's ability to provide wastewater treatment services for Central Maui. It improves the reliability and safety of the facility, especially in the event of strong storm events or relative sea level rise which would increase the rate of erosion.

D. MAUI COUNTY GENERAL PLAN

As stated in the Maui County Charter the purpose of the general plan shall be to:

> *"indicate desired population and physical development patterns for each island within the county; shall address the unique problems and needs of each island and region within the county; shall explain the opportunities and the social, economic, and environmental consequences related to potential developments; and shall set forth the desired sequence, patterns, and characteristics of future developments. The general plan shall identify objectives to be achieved, and priorities, policies and implementing actions to be pursued with respect to population density, land use maps, land use regulations, transportation systems, public and community facility locations, water and sewage systems, visitor destinations, urban design and other matters related to development."*

Ordinance No. 3732 adopting the General Plan Countywide Policy Plan 2030 took effect on March 24, 2010. The following analysis of the project is provided in relationship to the Countywide Policy Plan 2030:

With regard to the Countywide Policy Plan, Section 2.80B.030 of the Maui County Code states the following:

The countywide policy plan shall provide broad policies and objectives which portray the desired direction of the County's future. The countywide policy plan shall include:

1. *A vision for the County;*

2. *A Statement of core themes or principles for the county; and*

3. *A list of countywide objectives and policies for population, land use, the environment, the economy, and housing.*

Core principles set forth in the Countywide Policy Plan are listed as follows:

1. Excellence in the stewardship of the natural environment and cultural resources;

2. Compassion for and understanding of others;

3. Respect for diversity;

4. Engagement and empowerment of Maui County residents;

5. Honor for all cultural traditions and histories;

6. Consideration of the contributions of past generations as well as the needs of future generations;

7. Commitment to self-sufficiency;

8. Wisdom and balance in decision making;

9. Thoughtful, island-appropriate innovation; and

10. Nurturance of the health and well-being of our families and our communities.

Congruent with these core principles, the Countywide Policy Plan identifies goals, objectives, policies and implementing actions for pertinent functional planning categories, which are identified as follows:

1. Natural environment

2. Local cultures and traditions

3. Education

4. Social and healthcare services

5. Housing opportunities for residents

6. Local economy

7. Parks and public facilities

8. Transportation options

9. Physical infrastructure

10. Sustainable land use and growth management

11. Good governance

With respect to the Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension Project, the following goals, objectives, policies and implementing actions are illustrative of the project's compliance with the Countywide Policy Plan:

Improve Physical Infrastructure

Goal:

Maui County's physical infrastructure will be maintained in optimum condition and will provide for and effectively serve the needs of the County through clean and sustainable technologies.

Objective: Improve waste-disposal practices and systems to be efficient, safe, and as environmentally sound as possible.

Policy: Pursue improvements and upgrades to existing wastewater and solid-waste systems consistent with current and future plans and the County's Capital Improvement Program.

Objective: Improve the planning and management of infrastructure systems.

Policies: Discourage the development of critical infrastructure systems within hazard zones and the tsunami-inundation zone to the extent practical.

Ensure that basic infrastructure needs can be met during a disaster.

The extension of the shoreline revetment will protect an existing major infrastructure facility from shoreline erosion and potential wave-generated hazards from storms and tsunamis to ensure the continued operation of waste-disposal services for the Central Maui region.

In summary, the Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension Project is consistent with the theme and principles of the Countywide Policy Plan.

E. WAILUKU-KAHULUI COMMUNITY PLAN

The project site is located in the Wailuku-Kahului Community Plan region which is one (1) of nine (9) Community Plan regions established in the County of Maui. Planning for each region is guided by the respective Community Plans, which are designed to implement the Maui County General Plan. Each Community Plan contains recommendations and standards which guide the sequencing, patterns, and characteristics of future development in the region.

Land use guidelines are set forth by the existing Wailuku-Kahului Community Plan Land Use Map. The WKWWRF site is designated for "Public/Quasi-Public" use by the Community Plan Land Use Map. The strip of land fronting the project site along the shoreline is designated for "Park" use. Refer to **Figure 14**. The proposed revetment would be constructed along the back portion of the beach, close to the existing fence line, and similar to the existing revetment.

The proposed action is in keeping with the following Wailuku-Kahului Community Plan (2002) objectives and policies:

INFRASTRUCTURE

Goal

Timely and environmentally sound planning, development, and maintenance of infrastructure systems which serve to protect and preserve the safety and health of the region's residents, commuters, and visitors through the provision of clean water, effective waste disposal and drainage systems, and efficient transportation systems which meet the needs of the community.

LIQUID AND SOLID WASTE

Objective and Policy

1. Coordinate sewer system improvement plans with future growth requirements, as defined in the Community Plan.

Implementing Action

3. Investigate the feasibility of constructing a wastewater treatment facility for the Central Maui area to service the future needs of population growth. Locations to be investigated include the airport area, the Pu`unene sugar mill area, and other areas east of Kuihelani Highway. Site conditions to be evaluated shall include, but not be limited to, potential odor problems with surrounding neighborhoods, corrosive environments, effluent disposal, groundwater contamination and project costs.

The Central Maui Wastewater Reclamation Facility Study recommended the use of the existing facility, taking measures to protect it from tsunamis and erosion after extensive review and investigation of the feasibility to relocate the facility. The proposed action is in keeping with this implementing action based on Maui County Council Resolution No. 06-12, "ACCEPTING THE CENTRAL MAUI WASTEWATER RECLAMATION FACILITY STUDY AND CONCURRING RECOMMENDATIONS AND LONG TERM PLAN". Refer to **Appendix "D"**.

F. COUNTY ZONING

As previously mentioned, the subject property also falls within the State Land Use Conservation District. Lands within the Conservation District fall within the purview of the Department of Land and Natural Resources. In this context, County zoning is not considered an active land use designation at the property. The proposed improvements will require a CDUP approval by the BLNR.

G. COASTAL ZONE MANAGEMENT CONSIDERATIONS

The subject property is located within the County of Maui's Special Management Area (SMA). Pursuant to Chapter 205A, HRS, and the Rules and Regulations of the Maui Planning Commission, actions proposed within the SMA are evaluated with respect to SMA objectives, policies, and guidelines. This section addresses the project's relationship to

applicable coastal zone management considerations, as set forth in Chapter 205A, HRS and the Rules and Regulations of the Maui Planning Commission.

1. Recreational Resources

Objective

Provide coastal recreational opportunities accessible to the public.

Policies

(A) Improve coordination and funding of coastal recreational planning and management; and

(B) Provide adequate, accessible, and diverse recreational opportunities in the coastal zone management area by:

(i) Protecting coastal resources uniquely suited for recreational activities that cannot be provided in other areas;

(ii) Requiring replacement of coastal resources having significant recreational value, including but not limited to surfing sites, fishponds, and sand beaches, when such resources will be unavoidably damaged by development; or requiring reasonable monetary compensation to the state for recreation when replacement is not feasible or desirable;

(iii) Providing and managing adequate public access, consistent with conservation of natural resources, to and along shorelines with recreational value;

(iv) Providing an adequate supply of shoreline parks and other recreational facilities suitable for public recreation;

(v) Ensuring public recreational use of county, state, and federally owned or controlled shoreline lands and waters having recreational value consistent with public safety standards and conservation of natural resources;

(vi) Adopting water quality standards and regulating point and non-point sources of pollution to protect, and where feasible, restore the recreational value of coastal waters;

(vii) Developing new shoreline recreational opportunities, where

appropriate, such as artificial lagoons, artificial beaches, and artificial reefs for surfing and fishing; and

(viii) Encouraging reasonable dedication of shoreline areas with recreational value for public use as part of discretionary approvals or permits by the land use commission, board of land and natural resources, and county authorities; and crediting such dedication against the requirements of Section 46-6, HRS.

Response: There is public shoreline access to the east of the subject property, but the beach directly seaward of the facility is not heavily used. The existing revetment itself is used for fishing. The access to the beach and to the revetment for fishing will not be impacted by the proposed project. The revetment may contribute to beach loss between the structure and the ocean. If the revetment acts as a groin, it may limit the transfer of sand from the beach area in the east to the beach west of the WKWWRF. On shorelines that experience net long-term erosion or are subject to relative sea level rise, the shorelines adjacent to hard structures can migrate landward, resulting in "passive erosion", which can limit lateral access to adjacent beaches (Griggs, 2005). Further study will explore the potential impact of the revetment on the beach directly in front of the structure as well as the potential impact on the adjacent shoreline. These potential impacts will be discussed in the Draft EIS. The beach width could be monitored after the proposed action is completed to determine if the beach is being impacted. Beach nourishment at the project site or updrift from the impacted beach as a possible mitigation alternative, as applicable, will be evaluated in the Draft EIS.

2. Historical/Cultural Resources

Objective

Protect, preserve, and, where desirable, restore those natural and manmade historic and prehistoric resources in the coastal zone management area that are significant in Hawaiian and American history and culture.

Policies

(A) Identify and analyze significant archaeological resources;

(B) Maximize information retention through preservation of remains and artifacts or salvage operations; and

(C) Support state goals for protection, restoration, interpretation, and display of historic resources.

Response: A cultural assessment will be performed to assess the potential impacts of the proposed action on cultural and historic properties and practices in the vicinity. The proposed action may result in passive erosion and a loss of lateral shoreline access. Beach nourishment as a mitigation option could offset passive erosion and the loss of lateral access, triggered if the beach width is lost. On the other hand, the proposed revetment could provide new opportunities for fishing in the area. Further discussion of these alternative forms of mitigation, as applicable, will be included in the Draft EIS.

3. Scenic and Open Space Resources

Objective

Protect, preserve, and, where desirable, restore or improve the quality of coastal scenic and open space resources.

Policies

(A) Identify valued scenic resources in the coastal zone management area;

(B) Ensure that new developments are compatible with their visual environment by designing and locating such developments to minimize the alteration of natural landforms and existing public views to and along the shoreline;

(C) Preserve, maintain, and, where desirable, improve and restore shoreline open space and scenic resources; and

(D) Encourage those developments which are not coastal dependent to locate in inland areas.

Response: The extension of the existing revetment is anticipated to have minimal adverse impacts to scenic and open space resources in the area. The proposed project site is bounded to the west by an industrial area and to the east by the existing revetment. Extension of the existing revetment is not anticipated to visually impair viewscapes and open space resources.

The beach area currently designated as "Park" land on the Wailuku-Kahului Community Plan seaward of the project site has the potential to disappear, but the

proposed revetment would halt further erosion of the land. Lateral access over the revetment could be provided to mitigate the potential loss of the beach fronting the project site. Monitoring the beach width could indicate if the beach is being lost after the proposed action is completed. Beach nourishment as a mitigation option would maintain the beach area. Placement of sand over the rock revetment could hide the rock and create the look of a natural beach. An assessment of these potential mitigation alternatives will be further discussed in the Draft EIS.

4. Coastal Ecosystem

Objective

Protect valuable coastal ecosystems, including reefs, from disruption and minimize adverse impacts on all coastal ecosystems.

Policies

(A) Exercise an overall conservation ethic, and practice stewardship in the protection, use, and development of marine and coastal resources;

(B) Improve the technical basis for natural resource management;

(C) Preserve valuable coastal ecosystems, including reefs, of significant biological or economic importance;

(D) Minimize disruption or degradation of coastal water ecosystems by effective regulation of stream diversions, channelization, and similar land and water uses, recognizing competing water needs; and

(E) Promote water quantity and quality planning and management practices that reflect the tolerance of fresh water and marine ecosystems and maintain and enhance water quality through the development and implementation of point and nonpoint source water pollution control measures.

Response: The revetment is designed to protect the WKWWRF from erosion and storm damage, reducing the risk of point source sewage discharges to the marine ecosystem. During construction, there is the potential for limited, temporary increases in turbidity in the nearshore waters, similar to that seen on windy days or during small storms. The area fronting the WKWWRF contains some scattered coral and rock formations, as well as carbonate rock pavement and sand. If beach nourishment mitigation is warranted, matching the nourishment and native sand

characteristics will help prevent the fill from migrating offshore. Additionally, the revetment can provide valuable nearshore hard-bottom habitat and has the potential to encourage juvenile fish recruitment offshore.

5. Economic Use

Objective

Provide public or private facilities and improvements important to the State's economy in suitable locations.

Policies

(A) Concentrate coastal dependent development in appropriate areas;

(B) Ensure that coastal dependent development such as harbors and ports, and coastal related development such as visitor facilities and energy generating facilities, are located, designed, and constructed to minimize adverse social, visual, and environmental impacts in the coastal zone management area; and

(C) Direct the location and expansion of coastal dependent developments to areas presently designated and used for such developments and permit reasonable long-term growth at such areas, and permit coastal dependent development outside of presently designated areas when:

(i) Use of presently designated locations is not feasible;

(ii) Adverse environmental effects are minimized; and

(iii) The development is important to the State's economy.

Response: The proposed action to protect the shoreline fronting the WKWWRF enables the continuing use of the site for wastewater treatment purposes. Plant relocation costs have been estimated to range between $350 million and $475 million (2005 dollars). Shoreline protection measures at the existing facility, in contrast, have been estimated to range between $4.2 million and $13.1 million (2008 dollars). Investing in measures to protect the existing facility from tsunamis and shoreline erosion threats is much more cost-effective and places significantly less burden on taxpayers than relocating the plant.

6. Coastal Hazards

Objective

Reduce hazard to life and property from tsunami, storm waves, stream flooding, erosion, subsidence, and pollution.

Policies

(A) Develop and communicate adequate information about storm wave, tsunami, flood, erosion, subsidence, and point and nonpoint source pollution hazards;

(B) Control development in areas subject to storm wave, tsunami, flood, erosion, hurricane, wind, subsidence, and point and nonpoint pollution hazards;

(C) Ensure that developments comply with requirements of the Federal Flood Insurance Program; and

(D) Prevent coastal flooding from inland projects.

Response: The purpose of the proposed action is to protect the WKWWRF from shoreline erosion and storm damage. The project site is located within Zone VE, an area of flooding due to wave velocity. It is also located in an area where severe erosion has been occurring over at least the past 100 years. Along the project site, the average AEHR is -2.4 ft/yr. Review of historic shoreline surveys indicates that the shoreline west of the existing revetment is eroding at a rate of up to -6.0 ft./yr and there is an additional seasonal shoreline shift of 25 to 55 feet. Refer to **Appendix "B"**. The revetment would also provide a degree of protection against tsunamis and allow for sea level rise. New construction shall comply with applicable provisions of Chapter 19.62, Flood Hazard Areas, of the Maui County Code.

7. Managing Development

Objective

Improve the development review process, communication, and public participation in the management of coastal resources and hazards.

Policies

(A) Use, implement, and enforce existing law effectively to the maximum extent

possible in managing present and future coastal zone development;

(B) Facilitate timely processing of applications for development permits and resolve overlapping of conflicting permit requirements; and

(C) Communicate the potential short and long-term impacts of proposed significant coastal developments early in their life cycle and in terms understandable to the public to facilitate public participation in the planning and review process.

Response: The proposed project will undergo public review and comment pursuant to Chapter 343, HRS. Public meetings and stakeholder meetings will be carried out during the EIS process. The project is also subject to a public hearing at the Maui County Planning Commission in connection with the project's SMA Use Permit and Shoreline Setback Variance (SSV) applications review and approval process, as well as a public notified review of the CDUP before the Board of Land and Natural Resources.

8. Public Participation

Objective

Stimulate public awareness, education, and participation in coastal management.

Policies

(A) Promote public involvement in coastal zone management processes;

(B) Disseminate information on coastal management issues by means of educational materials, published reports, staff contact, and public workshops for persons and organizations concerned with coastal issues, developments, and government activities; and

(C) Organize workshops, policy dialogues, and site-specific mediations to respond to coastal issues and conflicts.

Response: As discussed above, public awareness and participation for the project are facilitated through the Chapter 343, HRS, SMA Use Permit, SSV, and CDUP approval processes. In addition, there was an extensive public involvement element in the original Central Maui Wastewater Reclamation Facility Study in 2005.

9. Beach Protection

Objective

Protect beaches for public use and recreation.

Policies

(A) Locate new structures inland from the shoreline setback to conserve open space, minimize interference with natural shoreline processes, and minimize loss of improvements due to erosion;

(B) Prohibit construction of private erosion-protection structures seaward of the shoreline, except when they result in improved aesthetic and engineering solutions to erosion at the sites and do not interfere with existing recreational and waterline activities; and

(C) Minimize the construction of public erosion-protection structures seaward of the shoreline.

Response: The beach fronting the project site is designated as "Park" land on the Wailuku-Kahului Community Plan. This land will likely disappear due to erosion without any additional measures. The shoreline protection project is proposed so that no damage occurs to the WKWWRF and there is no loss of the "Public/Quasi-Public" land on which it is built. The construction of the proposed structure could lead to beach loss and loss of lateral access. These potential impacts will be further explored in the Draft EIS, along with mitigation alternatives such as beach nourishment and lateral access over the revetment structure. Beach width could be monitored, setting a determined width that would trigger corrective action, such as beach nourishment.

10. Marine Resources

Objective

Promote the protection, use, and development of marine and coastal resources to assure their sustainability.

Policies

(A) Ensure that the use and development of marine and coastal resources are

ecologically and environmentally sound and economically beneficial;

(B) Coordinate the management of marine and coastal resources and activities to improve effectiveness and efficiency;

(C) Assert and articulate the interests of the State as a partner with federal agencies in the sound management of ocean resources within the United States exclusive economic zone;

(D) Promote research, study, and understanding of ocean processes, marine life, and other ocean resources in order to acquire and inventory information necessary to understand how ocean development activities relate to and impact upon ocean and coastal resources; and

(E) Encourage research and development of new, innovative technologies for exploring, using, or protecting marine and coastal resources.

Response: The revetment is designed to protect the WKWWRF from erosion and storm damage, which reduces the risk of point source sewage discharges that would have a negative impact on marine resources. If beach nourishment mitigation is warranted, matching the nourishment and native sand characteristics would help prevent the fill from migrating. Additionally, the revetment can provide valuable nearshore hard-bottom habitat and has the potential to encourage juvenile fish recruitment and increase the value of the marine resources. The potential impacts of the proposed project on marine resources will be further studied in the Draft EIS process. During construction, there is the potential for limited, temporary increases in turbidity in the nearshore waters, similar to that seen on windy days or during small storms. A Best Management Practices (BMPs) plan will be developed as a part of the design plans and specifications to mitigate potential adverse impacts to coastal and marine resources during construction.

In addition to the foregoing objectives and policies, SMA permit review criteria pursuant to Act 224 (2005) provides that:

No special management area use permit or special management area minor permit shall be granted for structures that allow artificial light from floodlights, uplights, or spotlights used for decorative or aesthetic purposes when the light:

(1) Directly illuminates the shoreline and ocean waters; or

(2) Is directed to travel across property boundaries toward the shoreline and ocean waters.

Response: The proposed shoreline protection measure will not involve or result in direct illumination of the shoreline or ocean waters, nor direct light across property boundaries toward the shoreline.

H. SHORELINE SETBACK VARIANCE

A Shoreline Setback Variance (SSV) by the County of Maui will be required, as the entire proposed revetment structure would be located within the Shoreline Setback Area. A separate SSV application will be prepared and filed with the County of Maui, Department of Planning for review and approval by the Maui Planning Commission.

The following improvements are proposed within the shoreline setback:

1. Placement of armor stone to stabilize the shoreline slope.
2. Minor grading to prepare an even surface for the placement of the large boulders.
3. Placement of smaller rocks and geotextile fabric to prevent leaching of the backfill through the voids between the large boulders.

Application and approval criteria required for a Shoreline Setback Variance (SSV) are set forth in the "Shoreline Rules for the Maui Planning Commission", Chapter 203, Sections 14 and 15. A recent certified shoreline survey (June 2008) is included in **Appendix "F"**. The proposed actions within the shoreline setback have been analyzed with respect to these criteria, as discussed below.

1. A shoreline area variance may be granted for a structure or activity, if the commission finds that the proposed structure or activity is necessary for or ancillary to certain uses.

Response: The placement of the revetment along the shoreline to protect the functional integrity of the WKWWRF is deemed to be in the public interest. The proposed revetment and related improvements will stabilize shoreline conditions to ensure the continued long-term functional integrity of the WKWWRF. The proposed action has been chosen after extensive study of the feasibility of different options to meet Central Maui's wastewater needs. Refer to **Appendix "B"**. The proposed

shoreline protection is essential for maintaining public health and safety, and is the most cost-effective option.

2. **A structure or activity may be granted to a variance upon grounds of hardship if:**

   a. **The applicant would be deprived of reasonable use of land if required to fully comply with the shoreline setback rules.**

      Response: The proposed action within the shoreline setback is needed to protect the functional operations of the existing WKWWRF. The proposed action will provide protection to the shoreline and the WKWWRF from erosion, as well as an additional degree of protection from tsunamis. The Central Maui Wastewater Reclamation Facility Study concluded after much analysis that the best option to meet Central Maui's wastewater needs is to strengthen the existing facility to protect against tsunamis and shoreline erosion, and to expand it in the future for additional capacity. Given the existing critical infrastructure system being impacted and the threat to the shoreline within the shoreline setback, the applicant would be deprived of reasonable use of the land if these actions could not be implemented. Refer to **Appendix "B"**.

   b. **The applicant's proposal is due to unique circumstances and does not draw into question the reasonableness of the shoreline setback rules.**

      Response: The existing conditions of the property pose a unique circumstance which warrants the need for the proposed action. The original erosion control revetment for the facility was not completed due to financial constraints. The proposed revetment is necessary to maintain the functional viability of the WKWWRF. The proposed structure is aesthetically compatible with the nearby industrial area and the existing revetment on the east side of the WKWWRF property. In summary, the unique circumstances of rapid shoreline erosion affecting the subject property do not draw into question the reasonableness of the shoreline setback rules.

   c. **The proposal is the practical alternative which best conforms to the purpose of the shoreline setback rules.**

      Response: The existing portion of the revetment has demonstrated

favorable performance over its 30 year life, and it is the most economical alternative that meets the required standards, therefore, the proposed action represents a practical alternative which best conforms to the purpose of the shoreline setback rules. In particular, the proposed work will stabilize the location of the shoreline to enable continued functional operations of the WKWWRF; the proposed action will ensure public health and welfare; the proposed action will maintain the quality of scenic and open space resources fronting the subject property. The need for public lateral access over the revetment will be evaluated in the Draft EIS.

3. **Before granting a hardship variance, the commission must determine that the applicant's proposal is a reasonable use of the land.**

Response: The proposed actions are an extension of an existing erosion control revetment designed to stabilize conditions along the shoreline. The actions do not intensify the use of the shoreline with respect to the current conditions, nor do they pose a risk to individuals or to the public health and safety. The proposed actions are essential elements in allowing the WKWWRF to be functionally viable, while maintaining a context of reasonableness, as prescribed by the shoreline rules.

4. **For purposes of the shoreline rules, hardship shall not include economic hardship to the applicant; county zoning changes, planned development permits, cluster permits or subdivision approvals after June 16, 1989; any other permit or approval which may have been issued by the commission.**

Response: The proposed action is not being sought as relief to economic hardship to the applicant but is proposed to ensure public health and safety to the residents of Central Maui. The action is intended to stabilize conditions along the shoreline while ensuring the continued functional integrity of the WKWWRF.

5. **No variance shall be granted unless appropriate conditions are imposed.**

Response: The proposed actions comply with conditions relating to the provision of safe lateral access; minimization of risk to beach processes; minimization of risk relating to structural failure and loose rock and rubble; and minimization of impacts on public views to, from, and along the shoreline. The need for lateral access over the revetment structure will be evaluated in the Draft EIS. The revetment will be designed by a professional engineer licensed in the State of Hawai`i to ensure its structural integrity and structural soundness. The top of the revetment will be set at

+10 ft. to +13 ft. MLLW and is not anticipated to adversely impact views and scenic resources.

In summary, the proposed actions within the shoreline setback are considered necessary for the viable operation of the WKWWRF and the protection of the adjacent shoreline. The actions are in keeping with the purpose and criteria set forth in the shoreline rules.

I. OTHER REGULATORY REQUIREMENTS

As described in Chapter I, the proposed action will require a Department of the Army Permit, a Section 401 Water Quality Certification, and a Coastal Zone Management Consistency Approval. Coordination will be undertaken with the Department of the Army, Department of Health, and Office of Planning, respectively, to prepare and submit the required application submittals.

Additionally, the Office of Environmental Quality Control (OEQC) has published a Shoreline Hardening Policy and Environmental Assessment Guidelines. The Guidelines list thirteen (13) items that should be included with "any Environmental Assessment prepared in conjunction with an application to construct a seawall, revetment, or similar structure, or an activity that will alter in any way littoral processes affecting the shoreline" (OEQC, 1998). These items are listed below with a description of how they will be addressed in the Draft EIS for this project.

1. Historical Shoreline Analysis of Coastal Erosion and Accretion Rates

A historical shoreline analysis is included in the Shoreline Evaluation Report, found in **Appendix "B"**. This analysis includes long-term changes over the past 100 years as well as an analysis of changes over shorter periods of time.

2. Shoreline Type

A description of the nature of the affected shoreline, types of sand located on the shoreline, relationship between the shoreline and the reef, and historical information about the area are included in the WKWWRF Preliminary Engineering Report, Shoreline Erosion Control. Refer to **Appendix "C"**.

3. **Site Maps**

Aerial photographs of the project site and surrounding land uses, as well as erosion rate maps, property location maps, and site plans can be found in Chapter I of this EA/EISPN report.

4. **Beach Profiles**

USGS beach profile data is included in the WKWWRF Preliminary Engineering Report, Shoreline Erosion Control. Refer to **Appendix "C"**. The profile location closest to the project site is called "VKHL" and it is located near the western property line of the WKWWRF, close to Station 72 in the County Erosion Maps.

5. **Existing Walls**

There is an existing 450-ft revetment on the eastern side of the WKWWRF property, protecting the WKWWRF holding pond. This revetment was built by the USACE in 1979 under the authority of Section 14, Emergency Flood Control Act of 1946, as amended.

6. **Description of Improvements**

The description of the proposed improvement is found in Chapter I of this document and in **Appendix "C"**, the Preliminary Engineering Report. It discusses the structures on the WKWWRF property, including their location, an estimation of time until they are threatened by erosion, and the feasibility of relocating them.

7. **Coastal Hazard History**

A description of coastal hazards in the vicinity of the WKWWRF is contained in Chapter II of this document, as well as the Preliminary Engineering Report, found in **Appendix "C"**.

8. **Waves and Currents**

A summary of the wave climate that affects the WKWWRF is contained in Chapter II of this document, as well as the Shoreline Evaluation Report found in **Appendix "B"**.

9. Sediment Movement

A Sediment Budget Analysis is included in the WKWWRF Preliminary Engineering Report, Shoreline Erosion Control. Refer to **Appendix "C"**.

10. Thirty-year Erosion Hazard

The Maui Shoreline Erosion Maps used aerial photography and historic T-sheets to assess the extent of erosion over 100 years in and around the project site. Refer to **Figure 5** and **Figure 6**. The determination of the annual rate of erosion was based on this data.

11. Photographs

Photographs of the existing revetment and the site of the proposed revetment, an aerial map of erosion in the area, and an aerial rendering of the proposed revetment are included in Chapter I of this document.

12. Alternatives

The alternatives to both the relocation of the wastewater treatment facility and shoreline protection measures at the existing facility are detailed in Chapter V of this document. They are further detailed in the Preliminary Engineering Report found in **Appendix "C"**.

13. Professional Engineer Seal

The coastal engineering firm Moffatt & Nichol will prepare the project design drawings with the required Professional Engineer (P.E.) seal.

IV. SUMMARY OF UNAVOIDABLE ENVIRONMENTAL IMPACTS

IV. SUMMARY OF UNAVOIDABLE ENVIRONMENTAL IMPACTS

The proposed project will result in certain unavoidable construction-related environmental impacts as outlined in Chapter II.

In the short-term, construction associated with the project will generate noise impacts. These impacts will be limited to the immediate vicinity of the project construction areas. Sound attenuating construction equipment will be used, where practicable, to mitigate noise impacts caused by construction.

Unavoidable temporary air and water quality impacts will also arise as a result of construction activities, such as the generation of dust and other airborne pollutants. Appropriate BMPs will be incorporated in the construction process to mitigate adverse construction-related impacts.

In the long term, the proposed project may result in beach loss, a reduced supply of sand for beaches downdrift from the project site, and passive erosion. The likelihood and extent of these impacts will be studied and discussed in the Draft EIS. The Draft EIS will also discuss the exploration of mitigation alternatives. This will include the monitoring of beach width, possible implementation of beach nourishment to prevent beach loss and passive erosion, and/or providing lateral access over the revetment.

V. ALTERNATIVES TO THE PROPOSED ACTION

V. ALTERNATIVES TO THE PROPOSED ACTION

A. ALTERNATIVES FOR CENTRAL MAUI'S WASTEWATER NEEDS

The County of Maui, Department of Environmental Management has looked at a variety of options in providing for the wastewater needs of Central Maui for the next 20 to 30 years (Austin, Tsutsumi and Associates, 2006).

1. Preferred Alternative

The proposed development plan, outlined in Chapter I, Project Overview, represents the Preferred Alternative. This alternative, which entails shoreline protection to the existing WKWWRF, presents the most cost-effective and viable alternative since the capital infrastructure is already existent onsite. Even though various components of the WKWWRF will require upgrading as they approach the design capacity of 7.9 MGD by the year 2029, the proposed development plan was deemed to be the most cost-effective at a cost of approximately $4.2 million (2008 dollars).

2. Alternatives Considered

The Central Maui Wastewater Reclamation Facility Study (May 2006) identified five (5) core wastewater treatment facility concepts as a basis for project alternatives with multiple effluent disposal options resulting in 11 alternatives for initial consideration. The five (5) core wastewater treatment facility concepts studied included the following.

a. Expand the existing Wailuku/Kahului WWRF and fortify facility to protect against tsunamis and shoreline erosion.

b. Maintain the existing Wailuku/Kahului WWRF at its current capacity; fortify facility to protect against tsunamis and shoreline erosion and construct satellite WWRF(s) to meet future wastewater capacity demands.

c. Maintain the existing Wailuku/Kahului WWRF at its current capacity, fortify

facility to protect against tsunamis and shoreline erosion and require new development to install individual wastewater systems.

d. Construct a new Central Maui WWRF to treat existing and future wastewater flows. Phase out existing Wailuku/Kahului WWRF.

e. Construct a new Central Maui WWRF to meet future wastewater treatment demands and relocate the existing Wailuku/Kahului WWRF away from tsunami and shoreline erosion impacts.

The direct and indirect effluent disposal options selected for consideration included the following.

1. Injection wells

2. Deep ocean outfalls

3. Brackish groundwater recharge

4. Water recycling

The resulting evaluation ranking of the 11 alternatives studied are summarized in **Table 1**, below.

Table 1. Wastewater Treatment Concept Alternatives

Rank	Alternative	Effluent Disposal Method
1	Expand the existing Wailuku/Kahului WWRF and fortify facility to protect against tsunamis and shoreline erosion.	Injection wells
2	Construct a new Central Maui WWRF to treat existing and future wastewater flows. Phase out existing Wailuku/Kahului WWRF.	Brackish groundwater recharge
3	Construct a new Central Maui WWRF to treat existing and future wastewater flows. Phase out existing Wailuku/Kahului WWRF.	Water recycling
4	Construct a new Central Maui WWRF to treat existing and future wastewater flows. Phase out existing Wailuku/Kahului WWRF.	Injection wells
5	Construct a new Central Maui WWRF to meet future wastewater treatment demands and relocate the existing Wailuku/Kahului WWRF away from tsunami and shoreline erosion zones.	Brackish groundwater recharge
6	Construct a new Central Maui WWRF to meet future wastewater treatment demands and relocate the existing Wailuku/Kahului WWRF away from tsunami and shoreline erosion zones.	Water recycling
7	Expand the existing Wailuku/Kahului WWRF and fortify facility to protect against tsunamis and shoreline erosion.	Brackish groundwater recharge
8	Construct a new Central Maui WWRF to treat existing and future wastewater flows. Phase out existing Wailuku/Kahului WWRF.	Ocean outfall
9	Expand the existing Wailuku/Kahului WWRF and fortify facility to protect against tsunamis and shoreline erosion.	Ocean outfall
10	Construct a new Central Maui WWRF to meet future wastewater treatment needs and relocate the existing Wailuku/Kahului WWRF away from tsunami and shoreline erosion zones.	Injection wells
11	Expand the existing Wailuku/Kahului WWRF and fortify facility to protect against tsunamis and shoreline erosion.	Water recycling

Source: Austin, Tsutsumi & Associates, Inc. 2006.

3. Site Location Options

Conceptual Central Wastewater Reclamation Facility potential new site options considered in the study included the following:

a. Ke`opu`olani County Park

b. South of Kuihelani Highway, in the vicinity of Kuihelani Highway and Maui Lani Parkway in existing agricultural lands

c. Pu`unene Sugar Mill site

d. South of Kahului Airport, in the vicinity south of Old Haleakala Highway and Hana Highway approximately 0.5 mile from the WKWWRF.

e. Old Pu`unene Airport Site

The sites were selected based on proximity to developed lands, adjacent land uses, and potential for water recycling and/or brackish groundwater recharge. The costs of developing a new facility at these alternative site locations ranged from $350 million to $475 million (2005 dollars).

4. Non-Structural Alternative

In addition to the new capacity alternatives, three (3) water and wastewater demand management alternatives were considered as a means to provide additional wastewater system capacity through managing potable water usage or reducing Infiltration/Inflow (I/I) into the wastewater system. The three (3) non-structural alternatives included:

- Initiate a water conservation program
- Replace existing high-use water fixtures (toilets, showerheads)
- Expand the existing I/I reduction program

These alternatives have all been implemented by the County to some extent. However, they do not eliminate the long-term need to increase wastewater treatment capacity in the Central Maui region.

B. ALTERNATIVES FOR SHORELINE PROTECTION AT THE EXISTING FACILITY

The Draft EIS will contain a separate and distinct section addressing alternatives to the proposed action for shoreline protection at the existing WKWWRF site. The following discussion is a preliminary evaluation of alternatives considered for shoreline protection at the WKWWRF.

1. Preferred Alternative

The proposed alternative, outlined in Chapter I, entails a 1,200-ft. extension of the existing revetment to protect the shoreline fronting the wastewater facility. This is the most cost-effective and viable solution, making use of the capital infrastructure already in existence and placing the least burden on taxpayers. This alternative is estimated to cost approximately $4.2 million.

2. Buried Revetment Alternative

The "Buried Revetment" Alternative entails adding beach nourishment to the revetment extension alternative. This would require approximately 75,000 cubic yards of beach fill material to initially create an approximately 50-foot beach berm, followed by approximately 30,000 cubic yards every eight (8) years to maintain the project design width. This alternative is more expensive than the proposed alternative and would place an additional maintenance cost on the County of Maui. In addition, the availability of a viable source of beach quality sand on Maui is presently very limited, and looks to be even more limited in the future as demand increases. This alternative is estimated to cost between $7.7 and $11.7 million.

3. Beach Nourishment Alternatives

Two (2) alternatives utilizing beach nourishment were considered: a longer section covering 4,000 feet, and a shorter section covering 2,650 feet. (Measurements are approximate.) The 4,000-ft. alternative would require an initial 215,000 cubic yards of sand fill to create an 80-ft. wide berm, followed by an additional 85,000 cubic yards every ten years. This longer alternative is estimated to cost between $8.1 and $13.1 million. The 2,650-ft. alternative would require an initial 145,000 cubic yards of sand fill to create an 80-ft. wide berm, followed by an additional 55,000 cubic

yards every eight years. This shorter alternative is estimated to cost between $5.5 and $10.4 million. Both projects would require replenishment of the sand over the entire life of the project. Smaller beach nourishment projects typically have less success with retaining beach area over time. Both projects presented a higher cost and a continued financial obligation in the sand replacement for the foreseeable life of the plant. In addition, the availability of a viable source of beach quality sand on Maui is presently very limited, and looks to be even more limited in the future as demand increases.

4. Onsite Strategic Retreat of Facilities Alternative

Relocating the facilities at risk to other areas of the WKWWRF site was considered as an alternative. Due to the land requirements and costs of relocation, this alternative was rejected. Structures currently at the highest risk due to shoreline erosion, such as the existing injection Well No. 2, access road, and existing sludge holding tanks, could possibly be relocated. However, it is not feasible to relocate the chlorine contact tank and effluent meter, due to the size of this structure and its position in the wastewater treatment cycle. The cost of relocating the operations building is also prohibitive. Even if the most threatened structures were to be relocated, other parts of the facility would become threatened by erosion. Thus, relocation is not a cost-effective or permanent solution.

5. Other Alternatives

The use of coral rubble fill as beach nourishment was considered. It was deemed impractical and undesirable due to the lack of a sufficient source for the material locally. This method is also discouraged because coral rubble is a littoral material and should remain in the littoral zone.

The use of rock or geotextile groins was considered. It was deemed ineffective due to the high cost and low net longshore transport rates in the WKWWRF littoral cell. Shore-perpendicular structures such as groins are best used in locations with high rates of net longshore transport.

A vertical seawall and hybrid structure was also considered. It was not pursued because this type of structure is significantly more expensive. There is limited public use of the beach fronting the facility, and this type of structure is more beneficial

where the public benefits of retaining beach space far outweigh the costs of construction and maintenance.

6. No Action Alternative

The "no action" alternative would keep the facility at risk for shoreline erosion, which poses a threat to the integrity of the facility and its ability to keep operating. In addition, this alternative presents the highest environmental and financial risk. This alternative would not address the purpose and need for this project. Out of twenty-one (21) alternatives for meeting Central Maui's wastewater needs for the next 20 to 30 years, this option was ranked last and rejected.

7. Deferred Action Alternative

The "deferred action" alternative would have similar consequences to the "no action" alternative in terms of the near-term safety of the facility and its ability to provide for Central Maui's wastewater needs. As a result, this option was also rejected.

VI. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

VI. IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

The development of the proposed project would involve the commitment of County lands and funds to protect the WKWWRF. In addition, labor and material resources would be expended as part of the project's construction phase. Commitments of these resources are considered irreversible and irretrievable. These commitments, however, are also considered appropriate in the context of providing sufficient protection for the WKWWRF to satisfy the current and future wastewater treatment demands of the Central Maui Region. Beach loss without the appropriate beach nourishment may be an irretrievable commitment of recreational resources. The degree and potential loss of beach resources will be further studied in the Draft EIS.

VII. RELATIONSHIP BETWEEN THE SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

VII. RELATIONSHIP BETWEEN THE SHORT-TERM USES OF THE ENVIRONMENT AND THE MAINTENANCE AND ENHANCEMENT OF LONG-TERM PRODUCTIVITY

The functional integrity of the WKWWRF is currently threatened by erosion of the shoreline fronting the facility. The alternatives to build a new Central Maui wastewater reclamation facility were estimated to cost in the range of $350 million to $475 million (2005 dollars). With an estimated cost of approximately $4.2 million (2008 dollars), the proposed shoreline protection extension places much less burden on the taxpayers. The proposed shoreline protection is considered a much more cost-effective solution to provide reliable wastewater treatment capacity for the Central Maui service area into the future.

VIII. SIGNIFICANCE CRITERIA ASSESSMENT

VIII. SIGNIFICANCE CRITERIA ASSESSMENT

The "Significance Criteria", Section 12 of the Administrative Rules, Title 11, Chapter 200, "Environmental Impact Statement Rules", were reviewed and analyzed to determine whether the proposed project could have significant impacts to the environment. The following criteria and preliminary analysis are provided.

1. **Involves an irrevocable commitment to loss or destruction of any natural or cultural resource.**

   An archaeological field survey was previously conducted on the project site to determine if any historic properties will be affected. No cultural or historic resources were identified. An Archaeological Monitoring Plan will be prepared to monitor construction activity. A cultural impact assessment will be conducted to determine if there will be any significant impacts to cultural practices. The proposed action may result in beach loss, loss of lateral shoreline access, and other potential impacts on the surrounding area. These impacts will be further studied in preparation of the Draft EIS. Anticipated impacts could be mitigated by alternatives, such as providing lateral access and/or beach nourishment, which will also be studied during the preparation of the Draft EIS.

2. **Curtails the range of beneficial uses of the environment.**

   The proposed project's impact on the beneficial uses of the environment will be further studied during the EIS process, along with mitigation opportunities, as appropriate. The project is intended to protect the existing facility, which in turn, provides protection to environmental resources by limiting erosion and providing storm damage reduction.

3. **Conflicts with the state's long-term environmental policies or goals and guidelines as expressed in Chapter 344, HRS, and any revisions thereof and amendments thereto, court decisions, or executive orders.**

   The proposed project will be assessed following the regulations of the Environmental Impact Statement process established in Chapter 344, Hawai'i Revised Statutes (HRS) and Department of Health, Hawai'i Administrative Rules, Title 11 Chapter

200, Environmental Impact Statement Rules.

4. **Substantially affects the economic welfare, social welfare, and cultural practices of the community or State.**

The proposed project will directly benefit the local economy by providing construction and construction-related employment in the short term. The project will provide shoreline erosion protection to the WKWWRF to ensure the continued health and safety of Central Maui residents, as well as protect a significant investment by the County of Maui in a public facility. Impacts to cultural practices will be further studied in the EIS process. The proposed action could create new opportunities for practices such as fishing. The beach width could be monitored to determine if impacts are occurring after construction is completed and to trigger corrective action, if necessary. Beach nourishment as mitigation could also offset the impacts of the proposed project. The shoreline protection offered by the proposed project will ensure the long-term viability and protection of the WKWWRF and benefit the economic and social welfare of residents in Central Maui.

5. **Substantially affects public health.**

The proposed project is designed to benefit public health and safety by upgrading the performance integrity of the wastewater treatment and reclamation system. It also helps to safeguard public health by protecting the facility and mitigating potential water quality impacts.

6. **Involves substantial secondary impacts, such as population changes or effects on public facilities.**

There will be no adverse effect on public services, such as police, fire, medical, educational, and waste collection services. Moreover, the proposed project will not impact population parameters. The proposed action is a needed protection measure to ensure the long-term viability of the County of Maui's Central Maui wastewater system.

7. **Involves a substantial degradation of environmental quality.**

There will be short-term impacts related to dust, siltation, and noise generated during construction. These potential dust and noise impacts will be mitigated through utilization of appropriate BMPs. There may also be long-term impacts as previously

discussed. These impacts and mitigation alternatives will be evaluated in the Draft EIS.

8. **Is individually limited but cumulatively has considerable effect upon the environment or involves a commitment for larger actions.**

The proposed project may have long-term effects on the nature of the shoreline fronting the WKWWRF. These impacts and mitigation alternatives will be further evaluated in the Draft EIS.

9. **Substantially affects a rare, threatened, or endangered species, or its habitat.**

There are no known rare, threatened, or endangered species at the site of the proposed action. There will be further studies carried out in the marine environment during the EIS process to identify potential impacts to the marine environment and adjacent Kanaha Pond and identify appropriate mitigation, as required.

10. **Detrimentally affects air or water quality or ambient noise levels.**

Construction activities will result in short-term air quality, noise, and water quality impacts. Dust control measures, such as regular watering and sprinkling, and installation of dust screens will be implemented to minimize wind-blown emissions. Noise impacts will occur primarily from construction equipment. Equipment mufflers or other noise attenuating equipment, as well as proper equipment and vehicle maintenance, will be used during construction activities. Construction noise impacts will be mitigated through compliance with the provisions of the State of Hawai`i, Department of Health Administrative Rules Title 11, Chapter 46, "Community Noise Control". These rules require a noise permit if the noise levels from construction activities are expected to exceed the allowable levels set forth in the Chapter 46 rules. Water quality impacts will be mitigated by adherence to a BMP Plan which may include temporary berms which will channel runoff into temporary retention basins and prevent runoff from entering the marine environment. Water quality will also be monitored during construction.

11. **Affects or is likely to suffer damage by being located in an environmentally sensitive area such as a flood plain, tsunami zone, beach, erosion-prone area, geologically hazardous land, estuary, fresh water, or coastal waters.**

The project lands are currently wholly within Flood Zone VE, an area of flooding

with wave velocity. The project is also located within an area that is experiencing severe erosion. The project measures are designed to protect the wastewater treatment facility from damage due to erosion.

12. <u>Substantially affects scenic vistas and viewplanes identified in county or state plans or studies.</u>

The project site is located within an area that has an industrial character and is an extension of the existing erosion control revetment. The height of the proposed rock revetment will be at an elevation of +10 feet to +13 feet MLLW.

13. <u>Requires substantial energy consumption.</u>

The proposed project will involve a limited commitment of fuel for construction equipment, vehicles, and machinery during construction and maintenance activities.

The proposed improvements will not result in a substantive increase in energy consumption at the WKWWRF.

Due to the possibility of significant impacts, the proposed project will undergo an Environmental Impact Statement process, and the potential and extent of impacts will be assessed accordingly.

IX. LIST OF PERMITS AND APPROVALS

IX. LIST OF PERMITS AND APPROVALS

The following permits and approvals are anticipated to be needed for project implementation:

Federal Government

1. Section 404 of the Clean Water Act, U.S. Department of the Army Permit

State of Hawai`i

1. Hawai`i Revised Statutes, Chapter 343 Environmental Impact Statement
2. Conservation District Use Permit
3. Section 401 of the Clean Water Act, Water Quality Certification
4. National Pollutant Discharge Elimination System Permit
5. Coastal Zone Management Consistency Approval

County of Maui

1. Special Management Area Use Permit and Shoreline Setback Variance
2. Construction Permits
3. Flood Hazard Area Development Permit

X. AGENCIES AND ORGANIZATIONS TO BE CONSULTED IN THE PREPARATION OF THE DRAFT EIS

X. AGENCIES AND ORGANIZATIONS TO BE CONSULTED IN THE PREPARATION OF THE DRAFT EIS

1. Larry Yamamoto, State Conservationist
U.S. Department of Agriculture
Natural Resources Conservation Service
P.O. Box 50004
Honolulu, Hawaii 96850-0001

2. Ranae Ganske-Cerizo, Soil Conservationist
Natural Resources Conservation Service
U.S. Department of Agriculture
77 Hookele Street, Suite 202
Kahului, Hawaii 96732

3. Lt. Doug Jannusch, Commander
U. S. Coast Guard
Fourteenth Coast Guard District
300 Ala Moana Boulevard
Honolulu, Hawaii 96850-4982

4. George Young
Chief, Regulatory Branch
U.S. Department of the Army
U.S. Army Engineer District, Honolulu
Regulatory Branch
Building 230
Fort Shafter, Hawaii 96858-5440

cc: Dan Meyers

5. Wayne Nastri, Regional Administrator
U. S. Environmental Protection Agency
Region 9
75 Hawthorne Street
San Francisco, California 94105

6. Loyal Mehrhoff
Field Supervisor
U. S. Fish and Wildlife Service
300 Ala Moana Blvd., Rm. 3-122
Box 50088
Honolulu, Hawaii 96813

7. State Comptroller
Department of Accounting and General Services
1151 Punchbowl Street, #426
Honolulu, Hawaii 96813

8. Karen Seddon
Executive Director
Hawaii Housing Finance and Development Corporation
677 Queen Street
Honolulu, Hawaii 96813

9. Director
State of Hawaii
Department of Business, Economic Development & Tourism
P.O. Box 2359
Honolulu, Hawaii 96804

10. Superintendent
State of Hawaii
Department of Education
P.O. Box 2360
Honolulu, Hawaii 96804

11. Chairman
Department of Hawaiian Home Lands
P. O. Box 1879
Honolulu, Hawaii 96805

12. Director
State of Hawaii
Department of Health
919 Ala Moana Blvd., Room 300
Honolulu, Hawaii 96814

13. Alec Wong, P.E., Chief
Clean Water Branch
State of Hawaii
Department of Health
919 Ala Moana Blvd., Room 300
Honolulu, Hawaii 96814

14. Patti Kitkowski
Acting District Environmental Health
Program Chief
State of Hawaii
Department of Health
54 High Street
Wailuku, Hawaii 96793

15. Chairperson
State of Hawaii
Department of Land and Natural Resources
P. O. Box 621
Honolulu, Hawaii 96809

16. Administrator
State of Hawaii
Department of Land and Natural Resources
State Historic Preservation Division
601 Kamokila Blvd., Room 555
Kapolei, Hawaii 96707

17. Hinano Rodrigues
Department of Land and Natural Resources
State Historic Preservation Division
130 Mahalani Street
Wailuku, Hawaii 96793

18. Director
State of Hawaii
Department of Transportation
869 Punchbowl Street
Honolulu, Hawaii 96813

cc: Fred Cajigal

19. Major General Robert G.S. Lee, Director
Hawaii State Civil Defense
3949 Diamond Head Road
Honolulu, Hawaii 96816-4495

20. Director
Office Of Environmental Quality Control
235 S. Beretania Street, Suite 702
Honolulu, Hawaii 96813

21. Administrator
Office of Hawaiian Affairs
711 Kapiolani Boulevard, Suite 500
Honolulu, Hawaii 96813

22. Director
State of Hawaii
Office of Planning
P.O. Box 2359
Honolulu, Hawaii 96804

23. Dan Davidson, Executive Officer
State of Hawaii
State Land Use Commission
P.O. Box 2359
Honolulu, Hawaii 96804

24. Mayor
County of Maui
200 South High Street
Wailuku, Hawaii 96793

25. Director
County of Maui
Office of Economic Development
2200 Main Street, Suite 305
Wailuku, Hawaii 96793

26. Administrator
Maui Civil Defense Agency
200 South High Street
Wailuku, Hawaii 96793

27. Jeffrey A. Murray, Fire Chief
County of Maui
Department of Fire and Public Safety
200 Dairy Road
Kahului, Hawaii 96732

28. Director
County of Maui
Department of Housing and Human Concerns
One Main Plaza
2200 Main Street, Suite 546
Wailuku, Hawaii 96793

29. Director
County of Maui
Department of Parks and Recreation
700 Halia Nakoa Street, Unit 2
Wailuku, Hawaii 96793

30. Director
County of Maui
Department of Planning
250 South High Street
Wailuku, Hawaii 96793

31. Chairperson, **Maui Planning Commission**
c/o Department of Planning
County of Maui
250 South High Street
Wailuku, Hawaii 96793

32. Gary Yabuta, Chief
County of Maui
Police Department
55 Mahalani Street
Wailuku, Hawaii 96793

33. Director
County of Maui **NOTE: SEND 3 COPIES**
Department of Public Works
200 South High Street
Wailuku, Hawaii 96793

34. Director
County of Maui
Department of Transportation
200 South High Street
Wailuku, Hawaii 96793

35. Director
County of Maui
Department of Water Supply
200 South High Street
Wailuku, Hawaii 96793

36. Danny Mateo, Council Chair
Maui County Council
200 South High Street
Wailuku, Hawaii 96793

37. Councilmember Joseph Pontanilla
Maui County Council
200 South High Street
Wailuku, Hawaii 96793

38. Councilmember Mike Victorino
Maui County Council
200 South High Street
Wailuku, Hawaii 96793

39. **Hawaiian Telcom**
60 South Church Street
Wailuku, Hawaii 96793

40. Greg Kauhi, Manager, Customer Operations
Maui Electric Company, Ltd.
P.O. Box 398
Kahului, Hawaii 96733

41. **Kahului Regional Library**
90 School Street
Kahului, Hawaii 96732

42. **Wailuku Regional Library**
251 High Street
Wailuku, Hawaii 96793

43. **The Maui News**
100 Mahalani Street
Wailuku, Hawaii 96793

44. **UH Environmental Center**
Krauss Annex 19
2500 Dole Street
Honolulu, Hawaii 96822

XI. REFERENCES

XI. REFERENCES

Austin, Tsutsumi & Associates, Inc. 2006. Central Maui Wastewater Reclamation Facility Study. Report prepared for the County of Maui, Department of Public Works and Environmental Management, May 31, 2006.

Brown and Caldwell Consultants. 2002. Sheet 11, Drawing Number G9, from the Phase IIA Modifications of the Wailuku-Kahului Wastewater Reclamation Facility. Prepared for the County of Maui, Department of Public Works and Waste Management, Revision dated January 2002.

Burns, Irma. 1991. Maui's Mittee and the General. Ku Pa`a Inc., Honolulu.

County of Maui, 2030 General Plan - Countywide Policy Plan, March 2010.

County of Maui, Office of Economic Development, 2007 Maui County Data Book, December 2007.

County of Maui, Office of Economic Development, 2009 Maui County Data Book, March 2010.

County of Maui, Socio-Economical Forecast, The Economic Projections for the Maui County General Plan 2030, June 2006.

County of Maui, Wailuku-Kahului Community Plan, 2002.

Fletcher, C.H. 1992. Sea-level trends and physical consequences: applications to the U.S. Shore. *Earth-Science Reviews*, 33, 73-109.

Fletcher, C.H. 2008. Sea Level Rise Website. <http://www.soest.hawaii.edu/coasts/sealevel/>.

Fletcher, C.H., E.E. Grossman, B.M. Richmond, and A.E. Gibbs. 2002. Atlas of Natural Hazards in the Hawaiian Coastal Zone, Maui Section. Prepared in cooperation with University of Hawaii, State of Hawaii Office of Planning, and National Ocean and Atmospheric Administration, U.S.G.S Geologic Investigations Series I-2761, U.S. Government Printing Office.

Griggs, G.B. 2005. The Impacts of Coastal Armoring. *Shore & Beach* Vol. 73, No 1, Winter 2005.

Jackson, George E.G. 1881. Map of Kahului Harbor and Adjacent Coast Line, Maui. Hawaiian Government Survey. September.

Jeon, D. 1995. Sea Level Change and Coastal Erosion in the Pacific Islands. Ph.D. Dissertation, University of Hawaii, May 1995

Kanai, Warren. "Information Paper: Kanaha Pond Wildlife Sanctuary Restoration, Maui, Hawaii." 4 Nov. 2003. US Army Corps of Engineers, Honolulu District. <http://www.poh.usace.army.mil/CW/factsheets/I-HIMa-20031104EW0-Kana.pdf>.

Kennedy, J., P. Brennan, and S. Ireland. 1993. *Archaeological Inventory Survey with Subsurface Testing Report for a Property Located at TMK 3-8-01:119 (por.), Wailuku Ahupua`u, Wailuku District, Island of Mau,*. Prepared for Maui County Department of Parks and Recreation. Archaeological Consultants of Hawaii, Inc., Haleiwa, Hawaii.

Monsarratt, M. 1882. Map of a Portion of Wailuku, Maui.

Munekiyo & Hiraga, Inc., Unpublished Project Report for the Wailuku-Kahului Wastewater Reclamation Facility Tsunami Protection Draft Environmental Assessment, December 2008.

Norcross-Nu`u, Zoe, Charles Fletcher, Matthew Barbee, Ayesha Genz, and Bradley Romine. 2008. "Bringing Sea-Level Rise into Long-Range Planning Considerations on Maui, Hawaii."

Oceanit Laboratories, Inc. 1997. Coastal Protection and Beach Restoration Feasibility Study for Maui County. Prepared for the County of Maui, Planning Department, November 1997.

Shoemaker, H.I. 1910. Map of Sugar Plantation at Puunene, Maui, Owned by Hawaiian Commercial & Sugar Co.

"Shoreline Hardening Policy and Environmental Assessment Guidelines." Dec. 1998. Office of Environmental Quality Control. <http://oeqc.doh.hawaii.gov/Shared%20Documents/Environmental_Assessment_PrepKit/Other_Guidance_Documents/Guidelines-Shoreline-Hardening-Policy-and-Environmental-Assessment.pdf>.

SSFM International, Inc. Drainage Summary for Wailuku Kahului Wastewater Reclamation Facility Tsunami Protection Project, Unpublished Letter Report, December 16, 2008.

State of Hawaii, Department of Labor and Industrial Relations, Hawaii Workforce Informer, http://www.hiwi.org, December 2010.

State of Hawaii, HRS Chapter 226, Hawaii State Planning Act.

Tomonari-Tuggle, M.J. and D. Welch. 1995. *The Archaeology of Kahului Airport,* Prepared for Edward K. Noda and Associates. International Archaeological Research Institute, Inc., Honolulu, Hawaii.

APPENDIX A.

Conservation District Use Application Approval Letter for Existing Revetment

GEORGE R. ARIYOSHI
GOVERNOR OF HAWAII

STATE OF HAWAII

DEPARTMENT OF LAND AND NATURAL RESOURCES
DIVISION OF LAND MANAGEMENT
P. O. BOX 621
HONOLULU, HAWAII 96809

DIVISIONS:
CONVEYANCES
FISH AND GAME
FORESTRY
LAND MANAGEMENT
STATE PARKS
WATER AND LAND DEVELOPMENT

January 12, 1979

Board of Land and
Natural Resources
State of Hawaii
Honolulu, HI

Gentlemen:

MAUI

County of Maui Department of Public Works
Request for Right of Entry to Construct
Rock Revetment at Kahului, Maui, Hawaii

At its meeting of October 13, 1978 under agenda Item H-7, the Board approved a County of Maui Department of Public Works Conservation District Use Application for the construction of a 450 feet rock revetment on the beach area fronting the Kahului Wastewater Treatment Plant at Kahului, Maui, Hawaii, Tax Map Key 3-8-01:por. 19 and storage of construction equipment on portions of the adjoining proposed Kanaha Beach Park area in connection with this erosion control project subject to the following terms and conditions:

1. The applicant shall comply with applicable provisions of Section 6 of Departmental Regulation No. 4;

2. Inclusion of hold-harmless condition for all work to be awarded by contract;

3. That the applicant obtain appropriate authorization through the Division of Land Management, DLNR, for the use of State lands, since this approval is for the use of conservation lands only;

4. In the event that unanticipated historical or archaeological remains are encountered by the effectuation of the proposed use, the applicant shall immediately contact the Historic Preservation Office at 548-6408;

5. Precautionary measures shall be taken to prevent pollution of coastal waters by accidental spillage of petroleum products, debris, or other construction related products during construction;

6. No materials shall be placed on or taken from conservation districts outside the project area;

APPROVED BY THE BOARD OF
LAND AND NATURAL RESOURCES
AT ITS MEETING HELD ON
1/12/79

ITEM F-7

7. All areas disturbed by work and work related activities shall be restored to acceptable conditions;

8. Appropriate measures shall be taken to minimize inconveniences and hazards to neighboring residences and the public in general; and

9. That the studies made for the project be forwarded to the Division of Water and Land Development for review.

RECOMMENDATION:

That the Board authorize a right of entry to the subject areas to the County of Maui for construction of rock revetment and storage of equipment purposes, respectively, subject to the foregoing and such other terms and conditions as may be prescribed by the Chairman.

Respectfully submitted,

JAMES J. DETOR
Land Management Administrator

APPROVED FOR SUBMITTAL:

SUSUMU ONO, Chairman

APPENDIX B.

Central Maui Wastewater Reclamation Facility Shoreline Evaluation Report

Central Maui Wastewater Reclamation Facility

Shoreline Evaluation Report

Prepared for:

Austin, Tsutsumi & Associates, Inc.
501 Sumner Street, Suite 521
Honolulu, HI 96817

Prepared by:

Moffatt & Nichol
250 W. Wardlow Road
Long Beach, CA 90807

April 2005

M&N File: 5454

TABLE OF CONTENTS

I. INTRODUCTION 1
- A. Background 1
- B. Purpose and Scope 1

II. RELEVANT COASTAL PROCESSES AND CONDITIONS 2
- A. Water Levels 2
- B. Waves 2
  - 1. Wave Sources 3
  - 2. Wave Exposure at Maui's North Coast 4
- C. Wind 4
- D. Precipitation 4
- E. Typical Hawaiian Beach Characteristics 5

III. SITE DESCRIPTION 5
- A. Kahului-Wailuku WWRF 5
- B. Wailuku Wastewater Pump Station 9

IV. WAILUKU-KAHULUI WWRF SHORELINE CHANGES 12
- A. Long-Term Changes 12
- B. Shorter-Term and Current Shoreline Changes 14
  - 1. 1912-1929 and 1929-1960 14
  - 2. 1960-1975 and 1975-1987 15
  - 3. 1987-1997 and 1997-2002 16
  - 4. Recent Profile and Shoreline Survey Data 20

V. WAILUKU WWPS SHORELINE CHANGES 24
- A. Long-Term Changes 24
- B. Historic and Current Decadal Shoreline Changes 24
  - 1. 1912-1929 and 1929-1960 26
  - 2. 1960-1975 and 1975-1987 26
  - 3. 1987-1997 and 1997-2002 26

VI. POTENTIAL CAUSES OF EROSION 30
- A. Natural Influences 30
  - 1. Sea Level Rise 30
  - 2. Storms (Wave-induced flooding) 30
  - 3. Reefs 31
- B. Man-Induced Influences 31
  - 1. Kahului Harbor 31
  - 2. Sand Mining 31
  - 3. WWII Training Exercises 31
  - 4. Dune Destruction 32

VII. NO-PROJECT ALTERNATIVE 32
A. WWRF 32
B. WWPS 36

VIII. POTENTIAL PROJECT ALTERNATIVES AT THE WWRF 37
A. Alternative 1 - Beach Nourishment 37
1. Alternative 1A – 4,000-ft Long Beach Nourishment 38
2. Alternative 1B – 2,650-ft Long Beach Nourishment 41
3. Sand Sources 41
B. Alternative 2 - Beach Nourishment Augmented with Sand Retention Structures (T-Groins) 42
1. Sources of Armor and Nourishment Material 43
C. Alternative 3 - Armor Rock Revetment 45
1. Alternative 3A – Revetment Extension 45
2. Alternative 3B – Buried Revetment 45
D. Other Alternatives 48
1. Coral Rubble Fill 48
2. Vertical Seawall and Hybrid Structure 48
E. Potential Environmental Impacts 49
F. Regulatory Requirements 50
G. Cost Estimates 51

IX. POTENTIAL PROJECT ALTERNATIVES AT THE WWPS 53
A. Alternative 1 - New Revetment 53
B. Alternative 2 - Repair Rubble Revetment 54
C. Other Alternatives 54
1. Seawall 54
2. Beach Nourishment 54
D. Cost Estimates 54

X. RANKING CRITERIA 56

XI. SUMMARY AND CONCLUSIONS 60
A. Wailuku-Kahului WWRF 60
B. Wailuku WWPS 60
C. Recommended Future Studies 61
1. Sediment Budget Analysis 61
2. Investigation of Offshore Sand Sources 62

XII. REFERENCES 63

APPENDIX A. SITE PHOTOGRAPHS FROM SITE VISIT ON JULY 16, 2004.

APPENDIX B. COST ESTIMATE SUMMARY

LIST OF FIGURES

Figure 1. Aerial photograph of the coast from Kahului Harbor to Kaa 7
Figure 2. East flank of the revetment fronting the Wailuku-Kahului WWRF. 8
Figure 3. Looking West towards the Wailuku-Kahului WWRF revetment. 8
Figure 4. Looking East from the revetment at the Wailuku-Kahului WWRF 9
Figure 5. Aerial photograph of the coast at the Wailuku Wastewater Pump Station 10
Figure 6. Large escarpment fronting the WWPS property (fence). 11
Figure 7. Escarpment and shoreline looking northwest from WWPS 11
Figure 8. County of Maui Shoreline Erosion Map at the Wailuku-Kahului Wastewater Reclamation Facility. 13
Figure 9. Shoreline Change Rate from 1912-1929 and 1929-1960 at the WWRF 17
Figure 10. Shoreline Change Rate from 1960-1975 and 1975-1987 at the WWRF 18
Figure 11. Shoreline Change Rate from 1987-1997 and 1997-2002 at the WWRF 19
Figure 12. Location of the USGS profile transects on Maui's North Shore. 20
Figure 13. Winter profile data at VKHL from 1995 to 1999. 22
Figure 14. Summer profile data at VKHL from 1995 to 1999. 23
Figure 15. County of Maui Shoreline Erosion Map at the Wailuku Wastewater Pump Station. 25
Figure 16. Shoreline Change Rate from 1912-1929 and 1929-1960 at the WWPS. 27
Figure 17. Shoreline Change Rate from 1960-1975 and 1975-1988 at the WWPS. 28
Figure 18. Shoreline Change Rate from 1988-1997 and 1997-2002 at the WWPS. 29
Figure 19. Wailuku-Kahului Wastewater Reclamation Facility 34
Figure 20. Alt. 1A and 1B - Cross-section of beach nourishment at the WWRF site. 39
Figure 21. Plan view of the beach nourishment alternatives at the WWRF site. 40
Figure 22. Details of the T-Groin Structure 43
Figure 23. Plan view of site with T-Groins and Beach Nourishment. 44
Figure 24. Plan view of Revetment Alternative 46
Figure 25. Typical Revetment Cross-Section 47
Figure 26. Picture of a cobble nourishment project, City of Ventura in Southern California. 49

LIST OF TABLES

Table 1. Kahului Harbor Tidal Datums 2
Table 2. Average Monthly Rainfall at Kahului 4
Table 3. Calculation of Years until WWRF Structures are Threatened. 35
Table 4. Summary of WWRF Structures that may be Threatened. 36
Table 5. Approximate Present-Value Cost Estimates for the WWRF Alternatives 52
Table 6. Approximate Annualized Cost Estimates for the WWRF Alternatives 53
Table 7. Approximate Present-Value Cost estimates for the WWPS Alternatives 55
Table 8. Approximate Annualized Cost Estimates for the WWRF Alternatives 55
Table 9. Weighted Value of Evaluation Criteria 57
Table 10. WWRF Alternative Evaluation 58
Table 11. WWPS Alternative Evaluation 59

CENTRAL MAUI WASTEWATER RECLAMATION FACILITY
DRAFT
SHORELINE EVALUATION REPORT

I. INTRODUCTION

A. Background

The County of Maui owns and operates the Wailuku-Kahului Wastewater Reclamation Facility (WWRF). The facility has a design capacity of 7.9 million gallons per day (MGD) and it is estimated the facility will reach this capacity sometime in the future. The County will soon be making decisions on how the wastewater treatment needs can be met for the next 20 to 30 years. Alternatives need to be discussed which will provide for the future wastewater treatment needs of the County. Alternatives under consideration include relocating the facility, increasing the capacity of the current facility, or directing some of the future flows to another facility or facilities.

A critical constraint associated with the alternatives analysis is that many of the County's beaches are eroding, including the shoreline fronting the Kahului WWRF. There are concerns regarding the current erosional trends on the existing and any future plant expansions.

The Wailuku Wastewater Pump Station (WWPS) is also part of the County's wastewater collection system. This pump station is also located close to the shoreline, on the west side of Kahului Harbor. This shoreline has experienced historical shoreline recession and needs to be included in the shoreline evaluation.

B. Purpose and Scope

The purpose of this study is to quantify shoreline erosion trends, assess potential causes for erosion, and develop preliminary shoreline protection alternatives for the Kahului WWRF site and also at the WWPS. The study is based on existing and available data and studies relating to shoreline erosion, causes of erosion, and potential solutions.

The shoreline evaluation comprises the following tasks:

1. Quantify shoreline erosion;
2. Assess potential causes of erosion;
3. Develop solution alternatives; and
4. Concept development.

II. RELEVANT COASTAL PROCESSES AND CONDITIONS

Understanding the relevant coastal processes and conditions is important in assessing causes for erosion and shoreline change and also for assessing potential solutions for shoreline protection. This section outlines water levels, wave conditions, and climate conditions (wind and precipitation).

A. Water Levels

Tides in the Hawaiian Islands are semi-diurnal, with two high waters and two low waters each tidal day. The tidal range varies from tide to tide, thus the tides are considered to have a diurnal inequality. The mean tide range is approximately two feet, and the maximum annual tide range is approximately four feet. Tide data for Kahului Harbor is presented in Table 1 [1].

Table 1. Kahului Harbor Tidal Datums

Highest Observed Water Level (1/9/74)	3.70 feet
Mean Higher High Water (MHHW)	2.35 feet
Mean High Water (MHW)	1.97 feet
Mean Sea Level (MSL)	1.17 feet
Mean Tide Level (MTL)	1.16 feet
Hawaiian Geodetic Vertical Datum (HGVD)	0.90 feet
Mean Low Water (MLW)	0.35 feet
Mean Lower Low Water (MLLW)	0.00 feet
Lowest Observed Water Level (6/20/55)	-1.40 feet

In addition to normal short-term periodic fluctuations of the sea surface, there is also a progressive change in sea level. Various projections of future sea level rise resulting from global warming, given past and projected increases in atmospheric carbon dioxide and other "greenhouse" gases have been developed. There can also be a relative sea level rise that results from combinations of rising sea level and sinking land. This can be of particular importance in the Hawaiian Islands due to ongoing geologic and tectonic processes. Relative sea level rise measured at Kahului Harbor is approximately 1.2 inches per decade (University of Hawaii 1998).

B. Waves

Ocean waves are the critical driving force in the movement of beach sand along a shoreline. This section provides a brief summary of the wave climate along Maui's North coast.

[1] Obtained from <<http://co-ops.nos.noaa.gov/benchmarks/1615680.html>>

1. Wave Sources

Waves approaching the Hawaiian Islands may be represented by the following general types:

1. ***Northeast Trade Waves*** – These waves are generated by the northeasterly trade winds that prevail approximately 75 percent of the year. Northeast trade waves are characterized in deep water by wave heights of up to 20 feet and periods ranging from 5 to 12 seconds. They occur most frequently and are the largest during the months from April through November.

2. ***Kona Storm Waves*** – During the winter season, Kona winds generate waves from the southwest with characteristics similar to those of trade waves. Kona conditions occur most frequently from November through April. Infrequently, a Kona storm associated with a large low-pressure system generates large storm waves from the southwest.

3. ***North Pacific Swell*** – The North Pacific swell, for which the large surf on the north and northwest coasts of Hawaii has become famous, is due to the waves generated from North Pacific extra-tropical cyclones. These large waves have heights in excess of 20 feet and periods ranging from 10 to 15 seconds. The North Pacific cyclones travel eastward and generate waves that approach the northwestern exposed shores of the islands. These waves are most likely to occur from October through April.

4. ***Southern Hemisphere Swell*** – Southern hemisphere swell that can reach the Hawaiian Islands is generated in the South Pacific Ocean. Large, extra-tropical storms generate waves and swell that travel 5,000 miles with breaking wave heights ranging up to 10 to 15 feet annually. The wave heights in deep water are 3 to 6 feet, with 14 to 18 second periods. These waves are generally characterized by rather long wave lengths, distinct wave groups, and are independent of the local wind system.

5. ***Local Storms and Hurricanes*** – Local storms and hurricanes are infrequent. Tropical storms generated off the coast of Mexico move westward through the equatorial region and occasionally deflect northward toward the Hawaiian Islands. Hurricane Iniki in September 1992, Hurricane Iwa in November 1982, Hurricane Dot in August 1959, and Hurricane Nina in December 1957 are the major hurricanes that have caused damage to the Hawaiian shoreline in the past 40 years.

2. Wave Exposure at Maui's North Coast

The Wailuku-Kahului Wastewater Reclamation Facility and Wailuku Wastewater Pump Station are located on Maui's North Central Coast, adjacent to Kahului Harbor. The North Central Coast is exposed to Northeast trade waves and North Pacific swell. The Northeast trade waves approach the Kahului area from the Northeast and the North Pacific swell approach from the North to Northwest.

C. Wind

The predominant winds in the vicinity of the Hawaiian Islands are the northeast trade winds, which are present approximately 70% to 75% of the year. The other 25% to 30% of the year produces Kona Winds predominantly from the south to southwest. Trade winds generally range from 10 to 25 mph, although can reach 40 to 50 mph during extreme events (Fletcher et al. 2002). On Maui, the trade winds are strongly influenced by topographic conditions. For example, at Maalaea and Kihei the wind speeds may be higher than the north shore due to the trade winds accelerating across the island's isthmus. At the Kahului site, the Northeast trade wind direction is unaffected by the island topography, and is clearly from the unobstructed prevailing northeast direction.

Winter is characterized by a weakening of the northeast trade winds (Moberly and Chamberlain 1964) and the appearance of southwesterly winds, known as Kona winds. The Kona winds are characterized by light and variable winds that persist for a few days to a few weeks at a time. Although Kona storms are capable of generating wind speeds exceeding 30 knots, the frequency of occurrence is low.

D. Precipitation

The average monthly precipitation at Kahului is presented in the table below. The average annual total is estimated to be approximately 19 inches per year (Western Regional Climate Center website at <<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?hikahu>>).

Table 2. Average Monthly Rainfall at Kahului

Average Rainfall at Kahului, Maui from 4/1/1954 to 3/31/2004 (in inches)												
Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
3.73	2.59	2.55	1.44	0.67	0.24	0.48	0.48	0.36	1.05	2.37	3.13	19.08

E. Typical Hawaiian Beach Characteristics

The following provides a general description of Hawaiian beaches including their formation and composition. Most of the information was derived from the study *Hawaiian Beach Systems* by Moberly and Chamberlain (1964), unless otherwise noted.

Each of the Hawaiian Islands was formed by volcanoes that built up basaltic lava in intermittent layers from the seafloor. The general succession of island formation has been from northwest down the island chain to the southeast, with Maui being one of the more recent geologic formations. Maui was formed by the two adjacent volcanoes of Haleakala and West Maui, with an isthmus connecting the two. Kahului is located on the north side of Maui.

Coral reefs are found along much of the Hawaiian Island shorelines. These wave-resistant structures are formed by shallow water organisms in warm water environments. The most common type of reefs found in Hawaiian waters is fringing reefs. Fringing reefs along the sheltered leeward coasts in Hawaii are some of the wider and flatter reefs in the islands. Commonly, they have detrital (originating from the land after weathering and erosion) grains mixed with the predominantly calcareous sands covering them and their adjacent beaches. These reefs were the ones most utilized by the ancient Hawaiians for their fish ponds.

Hawaiian beaches mainly consist of medium grain-size sand, although their sediments actually range from gravel to sandy mud. Many beaches have coarse sand; most Maui beaches have fine sand. Hawaiian beach sand is composed of two general types of grains mixed together in proportions that vary from one locality to another. Light-colored calcareous grains of biochemical origin, the fragments of skeletal parts of certain marine invertebrate animals and algae, contrast with dark-colored silicate grains of detrital origin.

III. SITE DESCRIPTION

A site visit was conducted on July 16, 2004, to the WWRF and the WWPS. Appendix A contains photographs from the site visit. This section describes each site and existing conditions, uses, and features.

A. Kahului-Wailuku WWRF

The Kahului-Wailuku WWRF is located on the north shore of the island of Maui, and approximately one mile east of the Kahului Harbor. Figure 1 is an aerial photograph of the site. The area immediately west of the WWRF is considered to be a heavy industrial area and includes oil tank farms, auto storage yards, warehouses, and a power plant (Brown and Caldwell 1990). The port facilities at Kahului Harbor are located approximately ½ mile to the west of the WWRF. The Kahului Airport is located approximately one mile east of the

WWRF and Kanaha Beach Park is located approximately ¾ mile to the east of the WWRF.

The WWRF site is bounded on the north by approximately 1350 linear feet of shoreline in Kahului Bay. There is a 520-foot existing rock revetment along this shoreline that was constructed between 1977 and 1978 fronting the WWRF retention pond (Makai Ocean Engineering and Sea Engineering 1991). Observations during the site visit on July 16, 2004, indicated that the east flank of the revetment is being outflanked from recent erosion trends in the area (see Figure 2 and Figure 3).

The shoreline along this reach has experienced severe erosion as can be seen by the remnants of an old WWII pill box offshore of the beach (Figure 4). Also, there are a series of old groins east of the plant that were constructed during WWII to retard the erosion process (USEPA 1974).

The 13,000-foot long beach that extends east from Kahului Harbor is also known as Sprecklesville Beach. This reach is broken into a series of pocket beaches separated by manmade groins and natural beachrock and lava points (Moberly 1963 and USACE 1971). The beach sand is poorly sorted calcareous sand, ranging in size from medium-sized grains to cobbles. The beaches along this reach are backed by large sand dunes. The Sprecklesville Beach area is primarily used by locals and visitors for world-class kite surfing and windsurfing, as well as fishing and regular beach recreation.

There is a large fringe reef just offshore that extends for several miles along this reach. The reef is characterized by a wide crest (one-half to one mile in width) that extends from a shallow nearshore toe to depths ranging from 10 to 30 feet (Cox 1954). Closer to the Kahului Harbor, the reef is narrow or absent (Cox 1954).

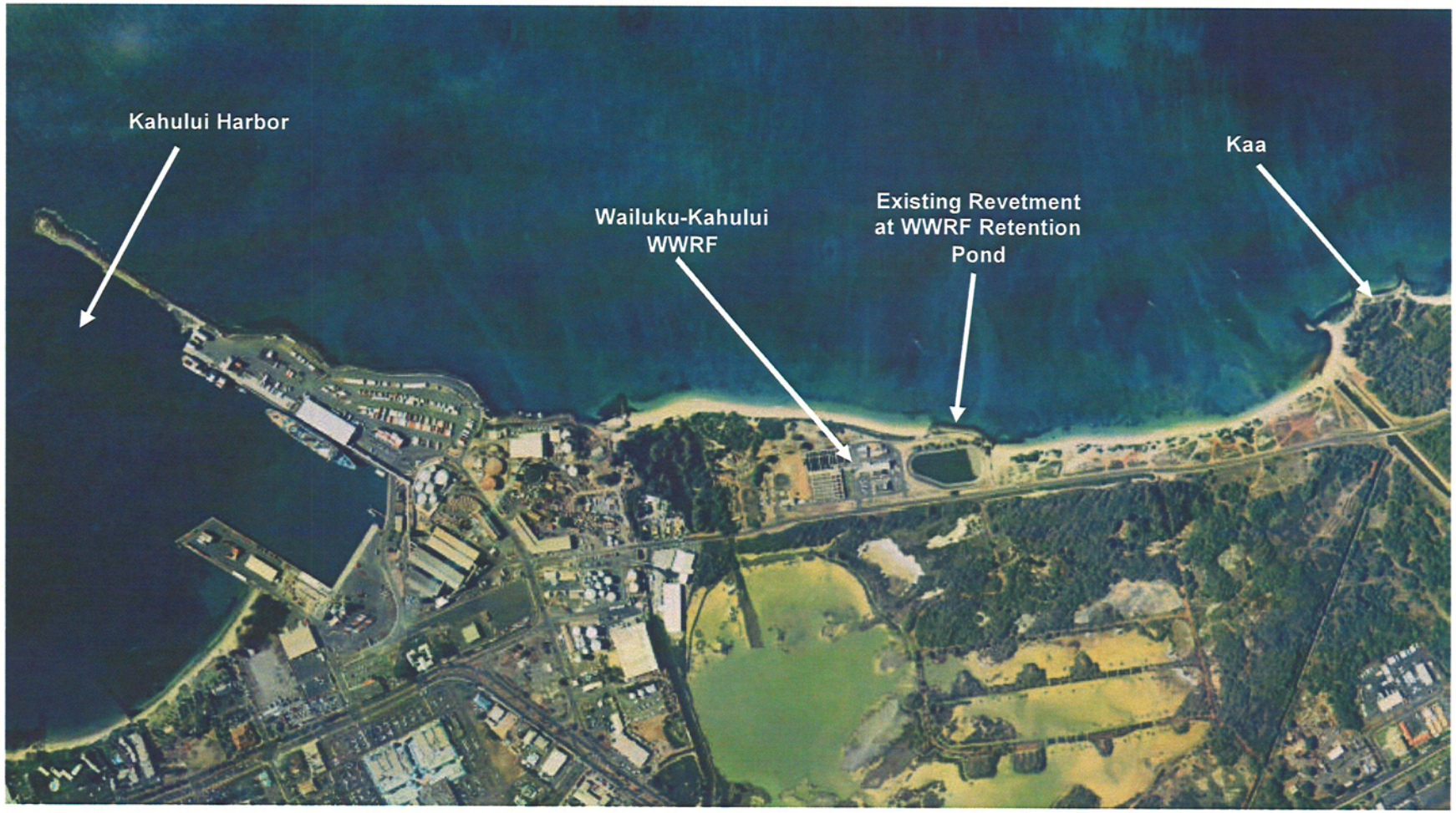


Figure 1. Aerial photograph of the coast from Kahului Harbor to Kaa
[obtained from <<http://www. soest.hawaii.edu/coasts/Islandimagery.html>>]

Figure 2. East flank of the revetment fronting the Wailuku-Kahului WWRF.

Figure 3. Looking West towards the Wailuku-Kahului WWRF revetment.

Figure 4. Looking East from the revetment at the Wailuku-Kahului WWRF. (Notice the old "pill box" offshore.)

B. Wailuku Wastewater Pump Station

The shoreline along the coast west of the Kahului Harbor is characterized as a narrow beach of poorly sorted sand and gravel (USACE 1971). Figure 5 is an aerial photograph of the Wailuku WWPS site. The Waihee Reef extends from Waihee Point to Kahului Harbor. The width of this reef near the harbor is about 500 feet wide.

The Wailuku Wastewater Pump Station is located west of the Kahului Harbor. Observations during the site visit on July 16, 2004, indicated a rocky shoreline, which consisted of natural cobbles and boulders, and also concrete rubble and armor stone. The rocky slope did not appear to be unstable or erodible. However, there is upland erosion on the site appearing to be from high water levels and storm waves reaching higher elevations on the beach slope, causing the upland soil to erode, leaving a high vertical escarpment. This escarpment can be seen in Figure 6 and Figure 7. Verbal communication with County staff (Dave Taylor, July 16, 2004) indicated that a large storm in 1993 caused over 10 feet of horizontal upper bank loss in one day. In early February 1993, 25 to 30-foot waves were recorded on the North Shore of Maui (Fletcher et al. 2002)

Also, the shoreline along this reach does not appear to be generally used by the public for beach access and/or recreation. North of the site, it appears the residential area is highly armored with vertical seawalls (Figure 7).

Figure 5. Aerial photograph of the coast at the Wailuku Wastewater Pump Station. [obtained from <<http://www. soest.hawaii.edu/coasts/Isla ndimagery.html>>]

Figure 6. Large escarpment fronting the WWPS property (fence).

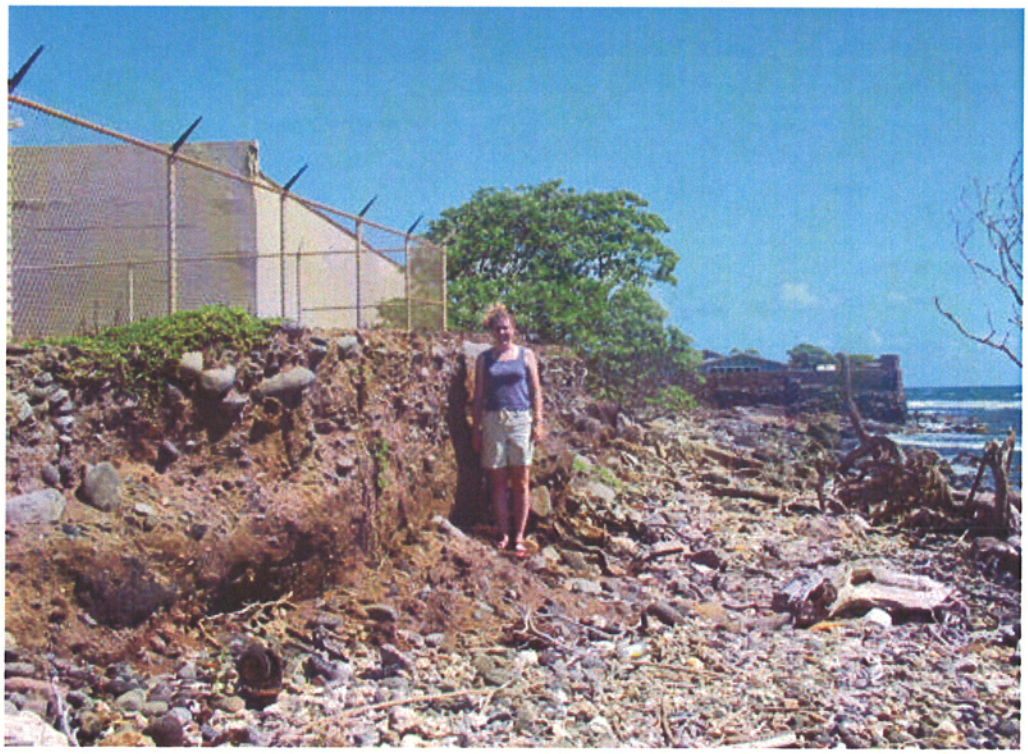


Figure 7. Escarpment and shoreline looking northwest from WWPS.
(notice large seawall fronting property to the north.)

IV. WAILUKU-KAHULUI WWRF SHORELINE CHANGES

A. Long-Term Changes

This section discusses long-term shoreline changes over the last 50 to 100 years. The shoreline reach that is discussed is a 13,000-foot long reach extending from Kahului Harbor. It is broken into a series of pocket beaches by manmade groins and natural lava and beachrock points.

Shoreline erosion in the vicinity of the Kahului WWRF has been documented for over 100 years. Doak Cox (1954) stated the shoreline between Kahului and Paia had been eroding for at least 50 years, since soon after the turn of the last century. Cox stated the only portion of the shoreline that was not eroding was the area east of the Kahului East breakwater where the beach had been accreting over a length of 2,400 feet. This accretion resulted from the construction of the Kahului Harbor breakwaters and the longshore transport of sediment flow from east to west. Cox's 1954 report does indicate this area adjacent to the east breakwater was recently receding.

Other reports which outline early erosional trends along the project area include a report by Moberly (1963), which states that "lines of beachrock awash at the waterline as much as 800 feet offshore show the historical record of erosion is merely the latest stage in a process operating over the last few hundred years." In the report, Moberly indicates sand mining was being conducted along the western end of the 5-mile long section of beach that extends east from the Kahului Harbor. He states this causes changes in the beach configuration because of the mining and stockpiling operations. Another report by the US Army Corp of Engineers and the State of Hawaii (1964) describes the beach as having "moderate to minor erosion in recent years."

These studies are also complimented by the County of Maui Shoreline Erosion Maps. These maps were compiled using aerial photography and historic T-sheets to determine long-term historic trends in shoreline position. The earliest shoreline position on the County Maps is the 1899 shoreline, followed by 1912, 1929, 1960, 1975, 1987, 1988, 1997, and 2002. The long-term shoreline erosion rate for the section of coast from Hobron Point to Kaa is indicated in Figure 8. The red bars indicate the Annual Erosion Hazard Rate (AEHR) in feet per year (ft/yr). At the western end of the map, the AEHR ranges from -0.5 ft/yr to almost -3.0 ft/yr. From the western edge of the WWRF property line, the AEHR increases gradually from near 0.0 ft/yr to slightly over -4.0 ft/yr at the eastern terminus of the map. Directly fronting the WWRF, the historic long-term AEHR is shown to be between -1.0 and -2.5 ft/yr. It is noted however, that once a section of coast is armored, the long-term shoreline erosion rate only consists of the pre-armored time frame. This may represent a skewed view of the erosion rate fronting the WWRF revetment, because the structure itself halts further shoreline retreat and therefore decreases the erosion rate over time.

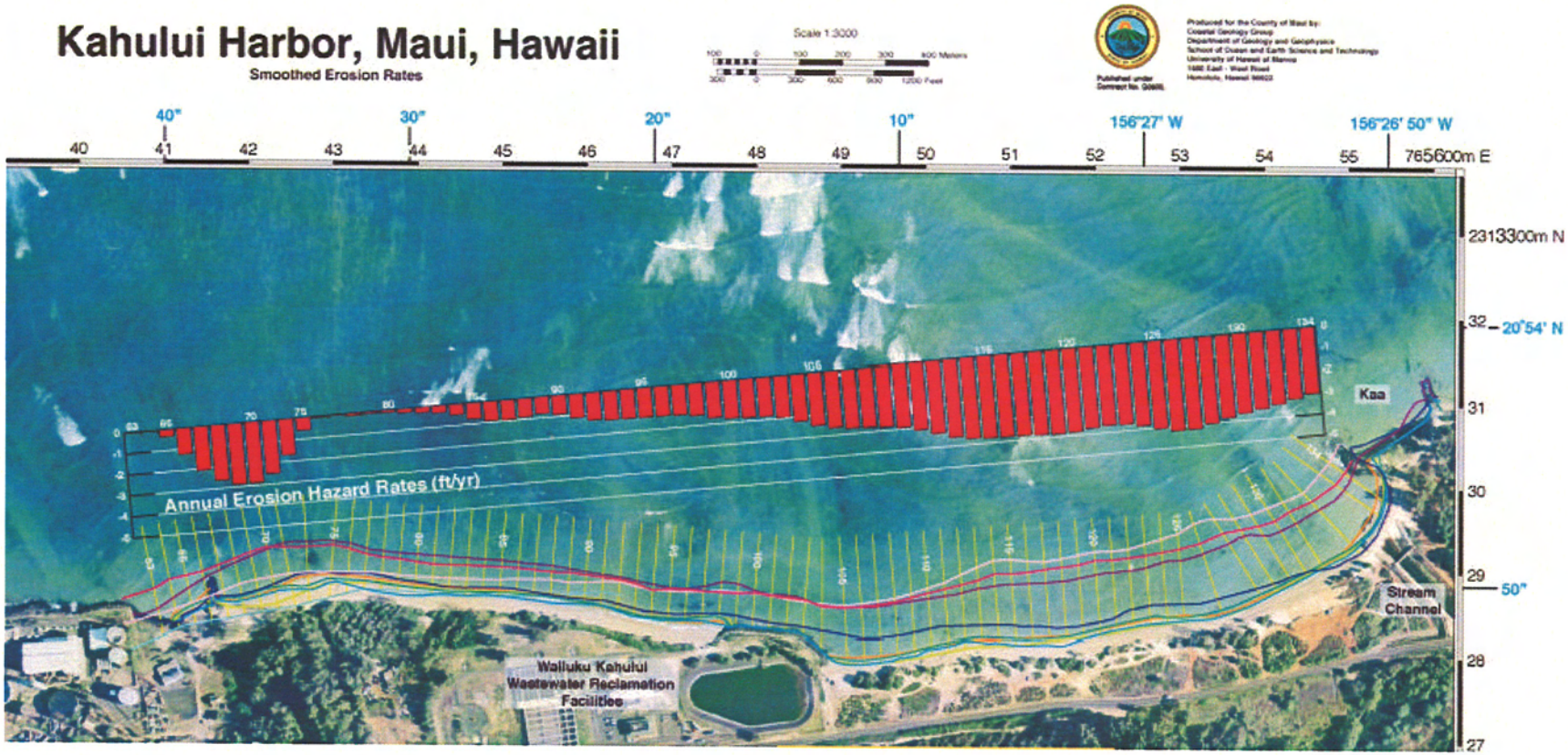


Figure 8. County of Maui Shoreline Erosion Map at the Wailuku-Kahului Wastewater Reclamation Facility.

B. Shorter-Term and Current Shoreline Changes

This section includes analysis of the historic data and summarizes the changes in shorter (decadal) intervals. This will provide a better understanding of how the shoreline erosion has changed over time. The data used in the County of Maui Shoreline Erosion Maps was obtained to determine short-term erosion rates. Shorter-term erosion rates will provide information as to whether the erosion is increasing, decreasing, or constant through time and may aide in assessing potential causes for erosion based on historical events. Also, the data presented in Sea Engineering (1991) report will be compared to the County of Maui shoreline data.

Figure 9 through Figure 11 illustrate shorter-term erosion trends between the various surveys available for this coast. The shoreline position at each transect was subtracted from the previous shoreline position and then divided by the number of years between shoreline surveys. This produces a shoreline change rate in feet per year (ft/yr). Each Figure shows the shoreline change rate along each of the transects indicated on the County Shoreline Erosion Maps. For reference, station 70 of the County Shoreline Erosion Map is located west of the WWRF property, and Station 134 is located at Kaa, east of the Stream Channel.

1. 1912-1929 and 1929-1960

Figure 9 shows that from 1912 to 1929 (dashed red line), there is a trend of shoreline advance west of the WWRF and slight erosion occurring east of the facility. The accretion west of the site is typical for a westward longshore transport where the littoral sediments move from the east to the west and are trapped at the East Jetty at Kahului Harbor (East Jetty construction began in 1906). The rate of accretion decreases to approximately 0.0 ft/yr along the shoreline just fronting where the revetment and retention pond is now located. From the location of the revetment to approximately 400 feet east, the shoreline has a slight erosional trend on the order of -0.5 ft/yr. From approximately 400 feet east of the pond and revetment to the end of the reach, this rate of shoreline change increases to approximately –4.0 ft/yr.

The next time step shown in Figure 9 represents the shoreline change rate from 1929 to 1960 (blue solid line). This graph shows the beach west of the WWRF is advancing at a much lower rate than the previous time interval (approximately 1.0 ft/yr). East of the facility, the rate of shoreline recession is slightly less than the 1912-1929 time interval (approximately 1.0 to 2.0 ft/yr). The shoreline immediately fronting the location of the WWRF revetment is similar between the two time intervals (e.g., 0.0 ft/yr).

The reason for change in the rate of shoreline advance is not known, but it could be speculated that the impoundment area could have reached its maximum capacity, and thus no further shoreline advance

would occur. Another possible scenario is that the sand mining operations were started in the early part of the century (Guild 1999), which may have contributed to the erosional trend to the east. In fact, Moberly (1964) states sand mining was being conducted along the eastern end of reach. This would cause less sediment available to the longshore transport, and may contribute to the lower shoreline advance rate west of the WWRF.

Makai Ocean Engineering and Sea Engineering (1991) analyzed shoreline positions from 1950 and 1964 and determined that the shoreline change rate ranged from -2.9 ft/yr west of the WWRF, to almost -5 ft/yr near Kaa. These data are also shown on the Figure (blue triangles). These erosion rates are slightly higher than the 1929-1960 data. This increase in erosion may be because of the increased rate of sand mining during the latter part of this time interval.

2. 1960-1975 and 1975-1987

Figure 10 shows the shoreline change rate trends from 1960 to 1975 (red dashed line) and from 1975 to 1987 (solid blue line) from the County of Maui Shoreline Erosion Map data. Over the entire reach, the rate of shoreline erosion from 1960 to 1975 increased substantially, from about -8.0 ft/yr to the west of the WWRF, to over -16.0 ft/yr at the eastern bounds of the reach. This correlates to a 120-foot shoreline recession west of the WWRF to over 240 feet of recession adjacent to Kaa over the 15-year time interval. Data from Makai Ocean Engineering and Sea Engineering comparing 1964 and 1975 shoreline data are also plotted on the Figure (red diamonds). These data show close correlation between the time series with the County's data.

This dramatic increase in the erosion rate over these 15 years is most probably due to the sand mining efforts conducted during this time. Potential causes for shoreline erosion are presented in Section VI of this report.

The period from 1975 to 1987 (blue solid line) shows the rate of shoreline erosion is lessening over this time, but it is still significant. For this 12-year interval, the shoreline west of the WWRF has a change rate of approximately -2.0 to -4.0 ft/yr (25 to 50 feet of shoreline retreat). Immediately east of the WWRF revetment, the shoreline change dips to approximately -9.0 ft/yr (approximately 100 feet of shoreline retreat over 12 years). Along the remainder of the east reach, the shoreline change rate decreases from this -9.0 ft/yr to a slightly advancing beach (+2.0 ft/yr) at Kaa. The Makai Ocean Engineering and Sea Engineering data comparing the 1975 and 1988 shorelines are also plotted below (blue triangles). These data are very consistent with the County's data and show the same trends.

The decrease in the rate of shoreline recession could largely be due to the cessation of the sand mining efforts along this coast in the 1970s. Large-scale sand mining was prohibited in 1986 (University of Hawaii Sea Grant Extension Service and County of Maui Planning Department 1997).

3. 1987-1997 and 1997-2002

Figure 11 shows the shoreline change rate trends from 1987 to 1997 (red dashed line) and from 1997 to 2002 (solid blue line) from the County of Maui Shoreline Erosion Map data. For both data sets, the rate of shoreline erosion is substantially less than the previous time series, and in some locations the shoreline is accreting.

From 1987 to 1997, the shoreline west of the WWRF revetment has a change rate of approximately +2.0 ft/yr. This equates to a shoreline advance of approximately 20 feet. At the revetment, the shoreline change rate is 0.0 ft/yr. This is because the revetment is a fixed structure and does not change in time. East of the revetment, the shoreline shows a slightly erosional trend, on the order of 0.0 to -2.0 ft/yr.

The next time series compares the 1997 shoreline to the 2002 shoreline. This is shown on the Figure (blue solid line) and appears to have an opposite trend as the earlier time series. From 1997 to 2002, the shoreline west of the revetment has been eroding at a rate of -4.0 to -6.0 ft/yr (approximately 30 feet of recession). East of the revetment, the shoreline change rate is approximately +6.0 ft/yr and decreases to 0.0 ft/yr towards the eastern end of the reach. This change in trends from 1987-1997 to 1997-2002 suggests that the revetment at the WWRF is acting like a groin and causing accretion on the updrift side (east) and erosion on the downdrift side (west).

Both of these data sets represent more current trends in the shoreline. It appears that the beach is more stable now than it was in the 1960 to 1987 time intervals in that the rate of erosion is much less (maximum of -6 ft/yr compared to over -14 ft/yr) and is showing signs of accretion along some sections that has not been noted in the previous time intervals.

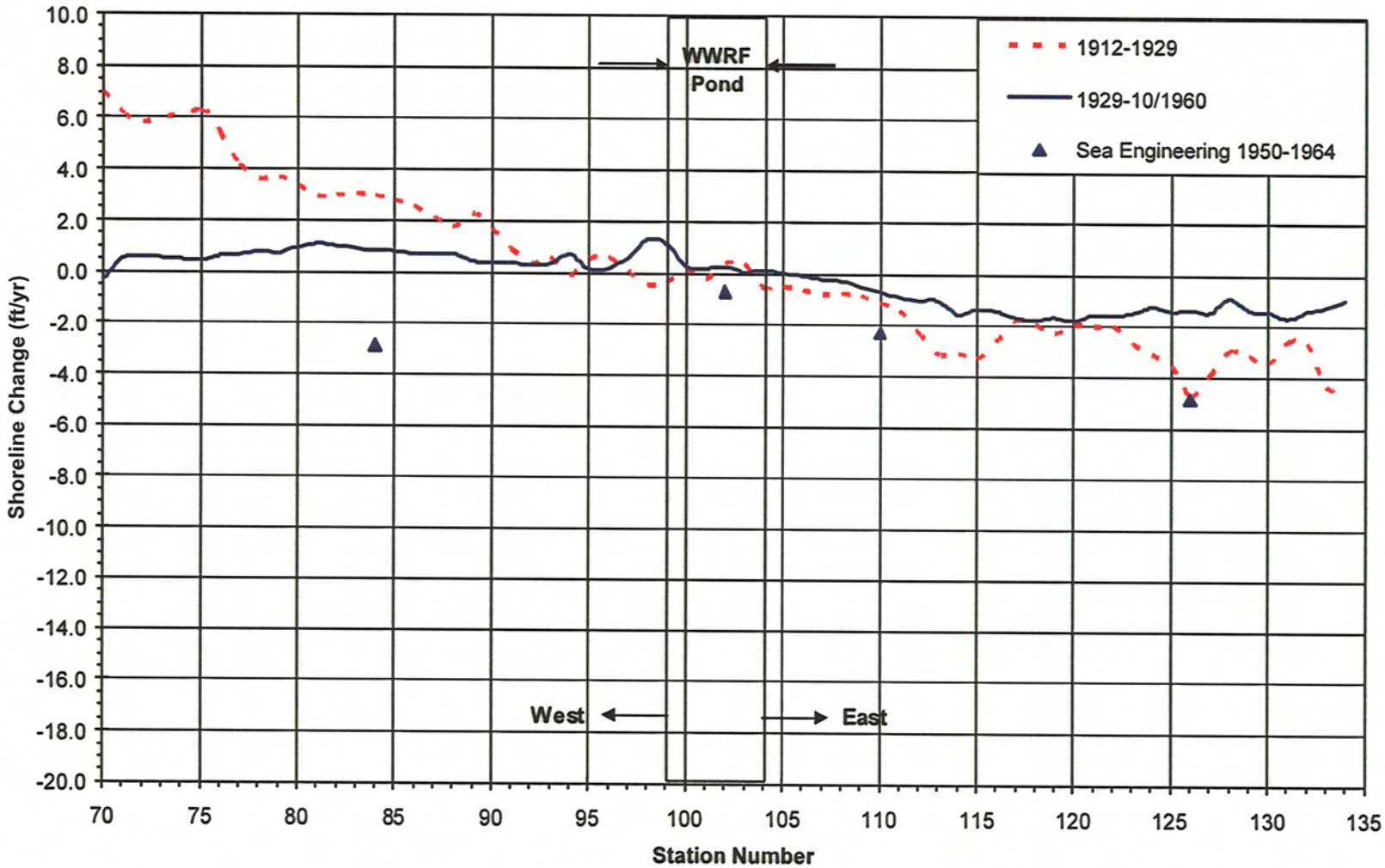


Figure 9. Shoreline Change Rate from 1912-1929 and 1929-1960 at the WWRF.
[from UH and County of Maui Shoreline Erosion Map data and Makai Ocean Engineering & Sea Engineering (1991)]

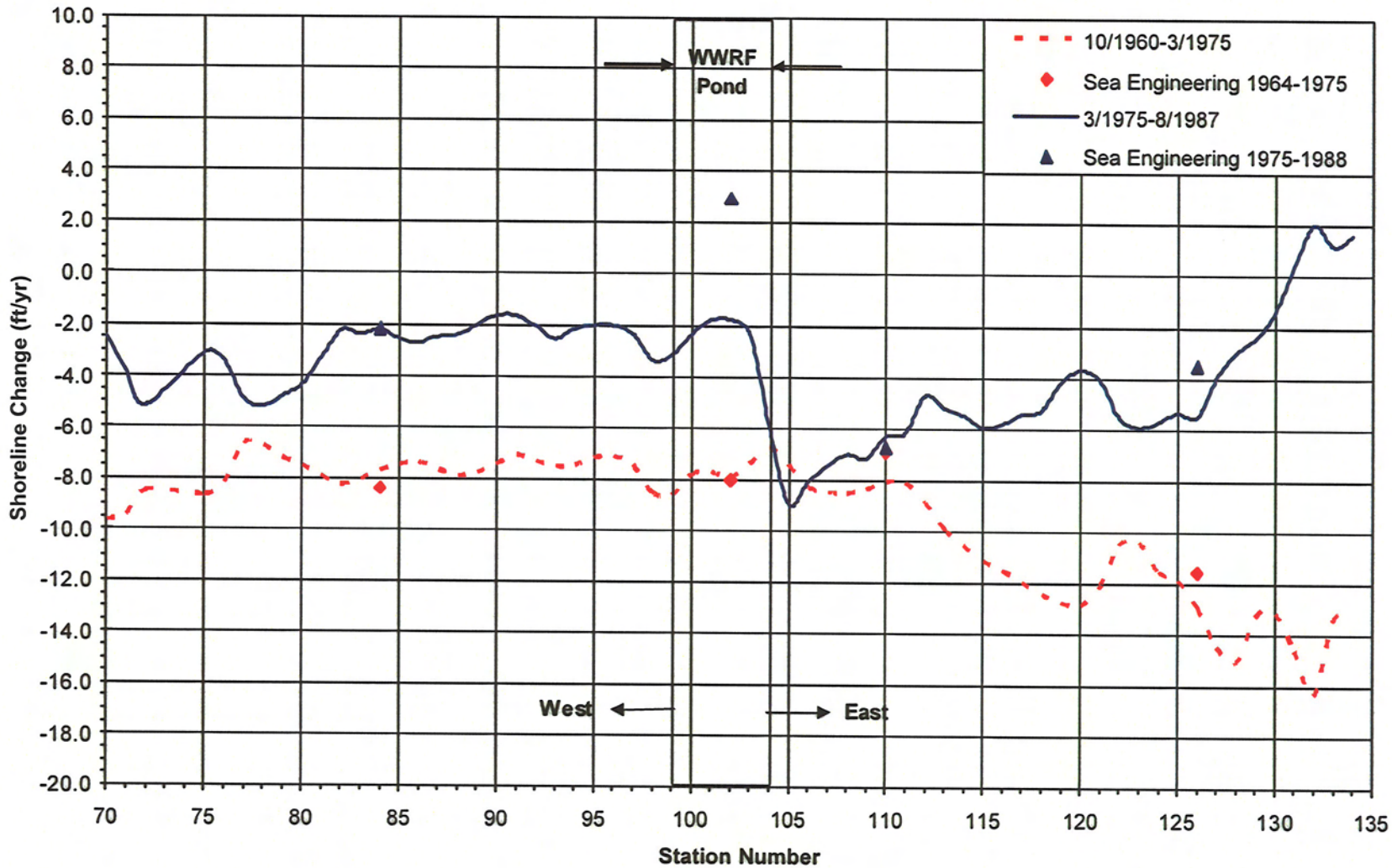


Figure 10. Shoreline Change Rate from 1960-1975 and 1975-1987 at the WWRF.
[from UH and County of Maui Shoreline Erosion Map data and Makai Ocean Engineering & Sea Engineering (1991)]

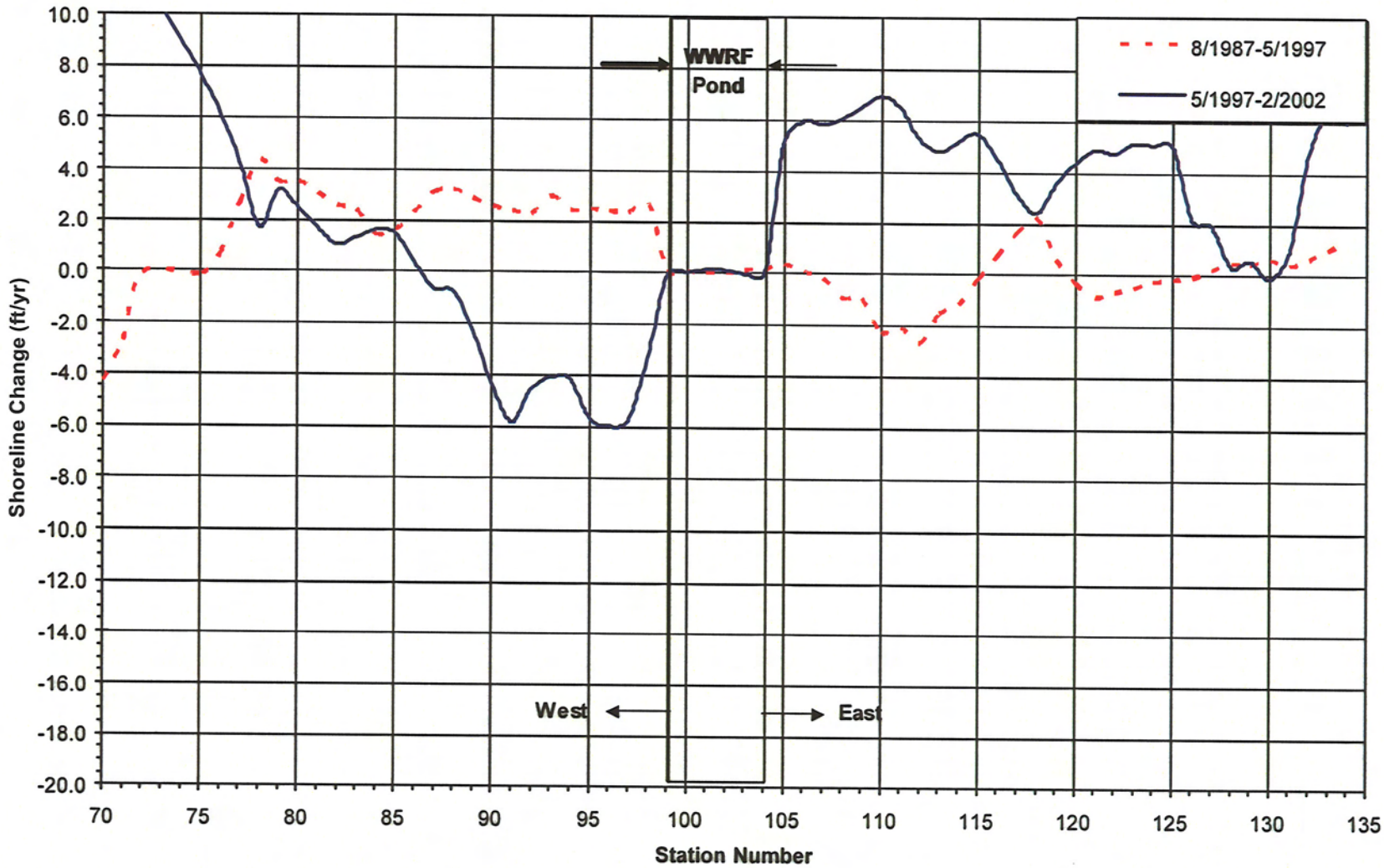


Figure 11. Shoreline Change Rate from 1987-1997 and 1997-2002 at the WWRF.
[from UH and County of Maui Shoreline Erosion Map data]

4. Recent Profile and Shoreline Survey Data

USGS profile data: Profile data from 1995 to 1999 were obtained from the USGS website (<<http://geopubs. wr.usgs.gov/open-file/of01-308/HTML1/Mnorth.html>>). A copy of the map indicating the locations of the profile stations is shown in Figure 12. For this study, the profile data at VKHL were reviewed to determine any current short-term trends in shoreline position near the WWRF. It is important to compare data from the same seasons (winter to winter) to obtain an accurate picture of the shoreline trends without the seasonal fluctuations.

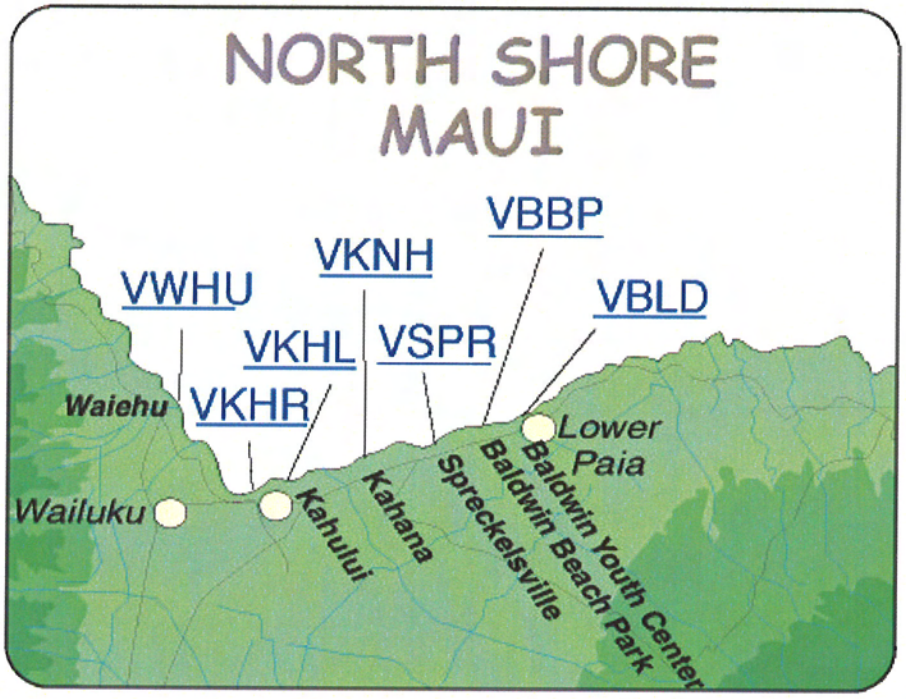


Figure 12. Location of the USGS profile transects on Maui's North Shore.

At VKHL, the winter profile data (Figure 13) show that from January 1995 (purple) to February 1996 (blue), the 0-meter depth contour receded approximately 12 meters. The shoreline position remained constant at this position through January 1998 (yellow). The January 1999 (black) data indicate that the shoreline had recovered (advanced) approximately 10 feet.

The summer profiles show a similar trend (Figure 14). The shoreline recedes approximately 10 feet between September 1995 (yellow) and August 1996 (red). By June 1997 (blue), the shoreline receded an additional 7 to 8 feet. The following two years, the shoreline advances, such that by July 1999 (black) the shoreline position is almost at the same

position as the 1995 shoreline. These data indicate that the shoreline erosion trends along this reach are similar to those discussed in the previous section; the shoreline is fairly stable with trends of recession and accretion. Just comparing the 1995 and 1999 profile data at this location, it is seen there is a slight erosional trend, at least for this short time interval.

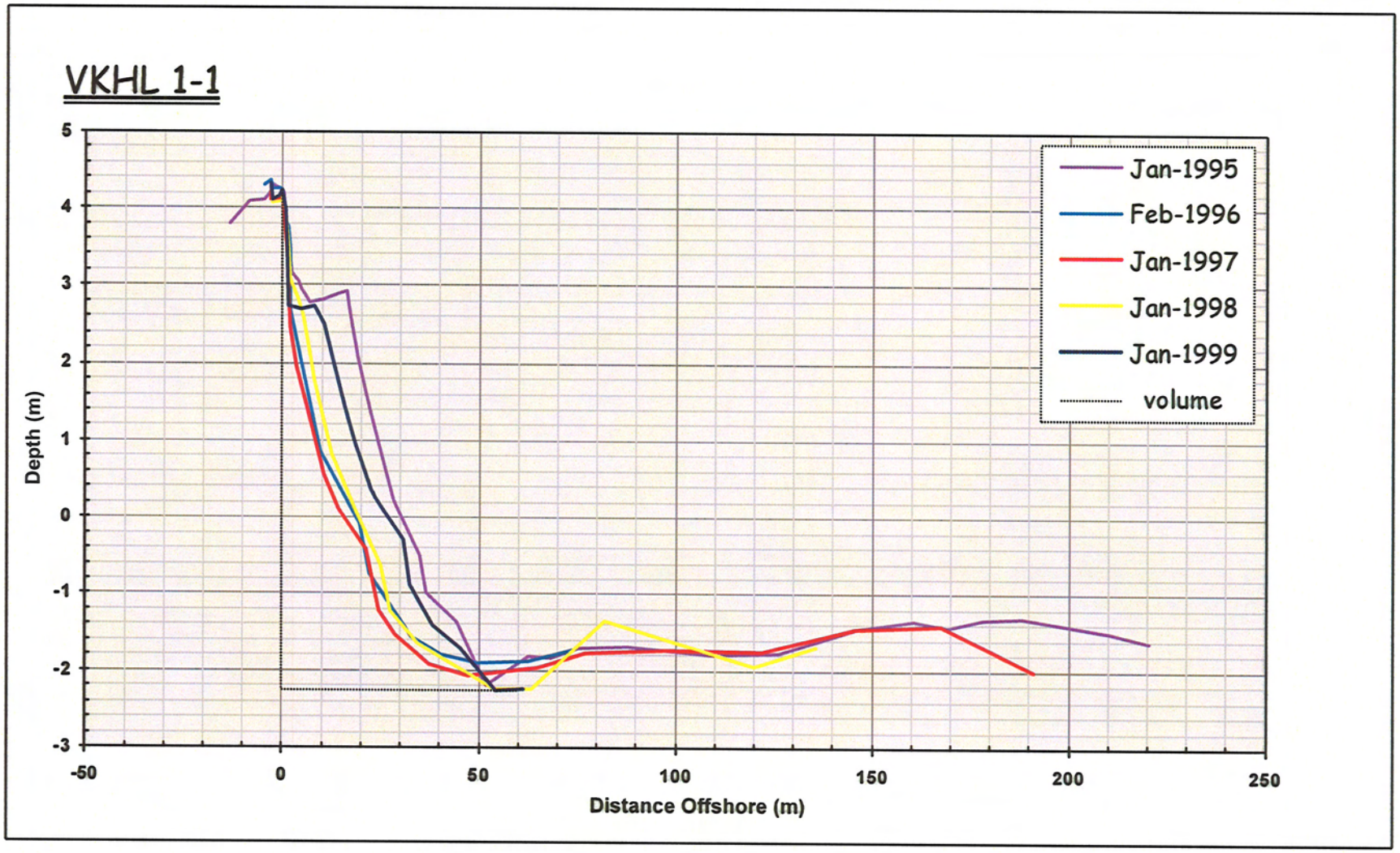


Figure 13. Winter profile data at VKHL from 1995 to 1999.

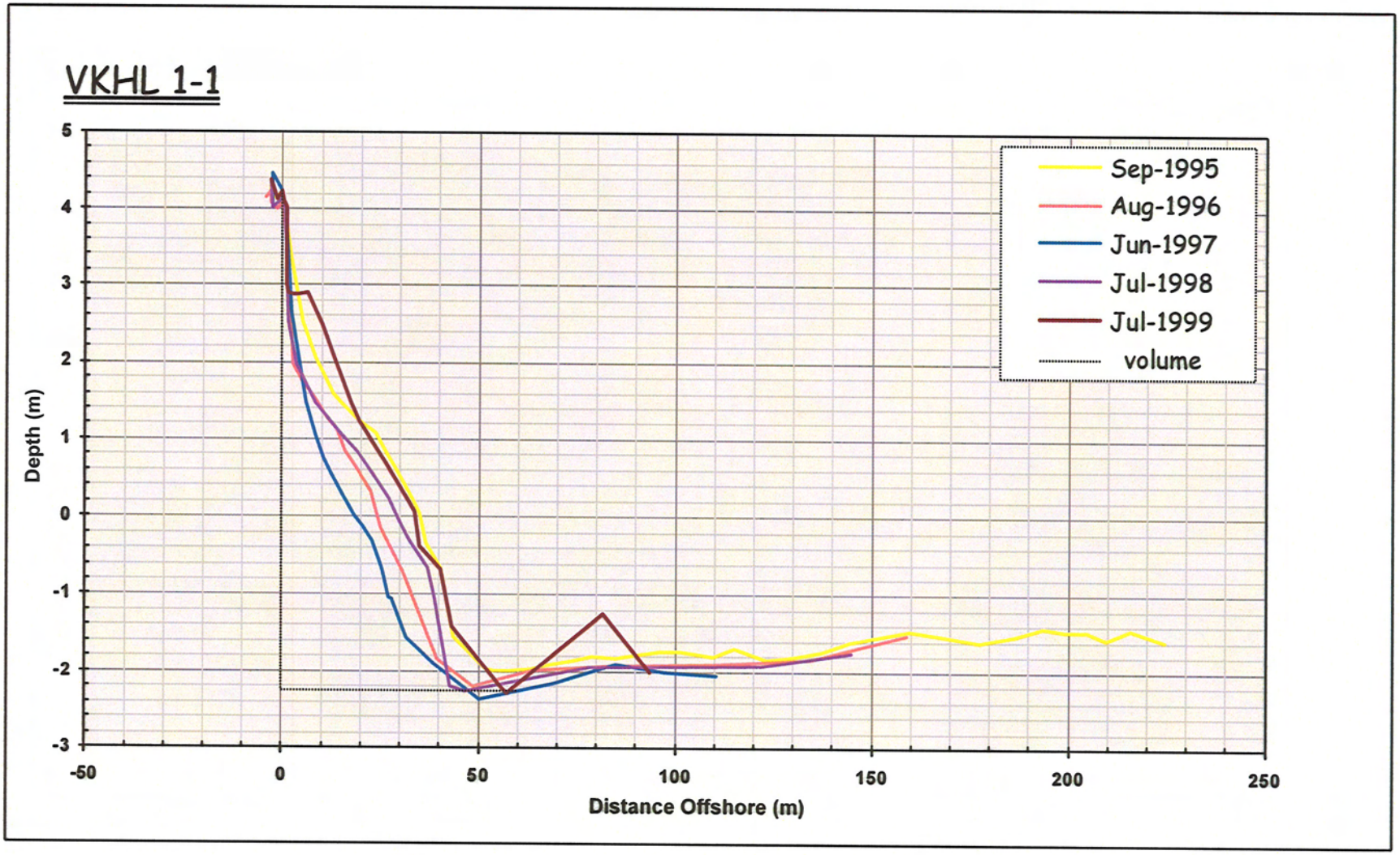


Figure 14. Summer profile data at VKHL from 1995 to 1999.

V. WAILUKU WWPS SHORELINE CHANGES

A. Long-Term Changes

This section discusses long-term shoreline changes over the last 50 to 100 years at the WWPS. The section of coast from one-half mile northwest of Waihee, south to Kahului Harbor is generally characterized as a depositional coast (Moberly 1963) due to the Waihee Reef and Iao Stream. The delta of the Iao Stream is located at Nehe Point, about one-half mile north of the WWPS. The Waihee Reef extends along the coast, with its width narrowing towards the Kahului Harbor. The south section of this reach, including the location of the WWPS, is characterized as a "low, eroding sandy coast" (Moberly 1963).

The County of Maui Shoreline Erosion Maps were obtained for the Waiehu reach, which includes the location of the WWPS (see Figure 15). The earliest shoreline position on the County Maps is the 1899 shoreline, followed by 1912, 1929, 1960, 1975, 1987, 1988, 1997, and 2002. The long-term shoreline erosion rate for the section of coast from Nehe Point to the Kahului Harbor west jetty is indicated on the below figure. The red bars indicate the Annual Erosion Hazard Rate (AEHR) in feet per year (ft/yr). Along the entire reach, the AEHR ranges from 0.0 ft/yr to -1.0 ft/yr. Directly fronting the WWPS, the historic long-term AEHR is approximately -0.3 ft/yr.

B. Historic and Current Decadal Shoreline Changes

Similarly to Section IV.B, this section will look at the historic data and summarize the changes in shorter (decadal) intervals. This will provide a better understanding of how the shoreline erosion has changed over time. The data used in the County of Maui Shoreline Erosion Maps was obtained to determine short-term erosion rates. Shorter-term erosion rates will provide information as to whether the erosion is increasing, decreasing, or constant through time and may aide in assessing potential causes for erosion based on historical events.

Figure 16 through Figure 18 illustrate shorter-term erosion trends between the various surveys available for this coast. The shoreline position at each transect was subtracted from the previous shoreline position and then divided by the number of years between shoreline surveys. This produces a shoreline change rate in feet per year (ft/yr). Each Figure shows the shoreline change rate along each of transect indicated on the County Shoreline Erosion Maps. For reference, station 135 of the County Shoreline Erosion Map is located south of Nehe Point and Station 197 is located adjacent to the west jetty at Kahului Harbor.

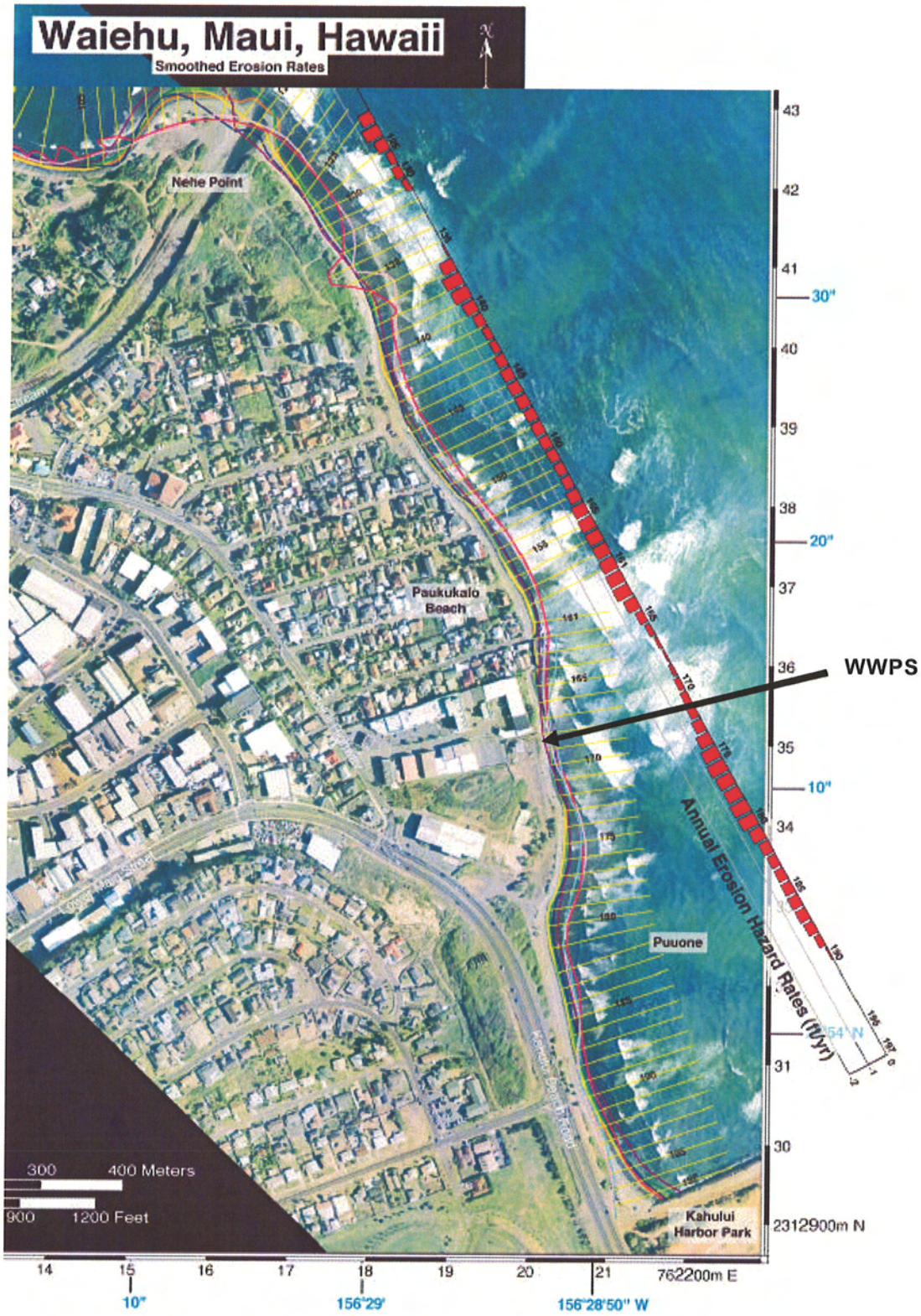


Figure 15. County of Maui Shoreline Erosion Map at the Wailuku Wastewater Pump Station.

1. 1912-1929 and 1929-1960

Figure 16 shows that from 1912 to 1929 (dashed red line), there is a trend of shoreline advance along most of the shoreline reach. The rate of change varies from 0.0 ft/yr to +2.0 ft/yr. Directly fronting the WWPS, the rate of change is approximately +1.0 ft/yr.

The next time step shown on Figure 16 represents the shoreline change rate from 1929 to 1960 (blue solid line). During this time interval, the shoreline trend reverses to slightly erosional over the entire reach. The Figure indicates that there is a -1.0 to -2.0 ft/yr erosion rate.

2. 1960-1975 and 1975-1988

Figure 17 illustrates the data from 1960 to 1975 and from 1975 to 1988. From 1960 to 1975, the shoreline along this reach remained slightly erosional, with trends ranging from 0.0 ft/yr to -2.0 ft/yr. Directly fronting the WWPS, the shoreline exhibits a positive shoreline change of over +2.0 ft/yr.

The following time interval from 1975 to 1988, the shoreline exhibits a slightly more erosional trend, ranging from 0.0 ft/yr to -2.0 ft/yr. The shoreline fronting the WWPS has a slight erosion rate of -1.0 ft/yr over these 12 years.

3. 1988-1997 and 1997-2002

Figure 18 presents the shoreline change rates between 1988 and 1997 and between 1997 and 2002. From 1988 to 1997, there was a slight erosional trend along most of the reach on the order of 0.0 ft/yr up to -2.0 ft/yr. Immediately fronting the WWPS, the shoreline was stable, with slight accretion (0.0 to +1.0 ft/yr).

From 1997 to 2002, the shoreline had a reversed to a slight accretional trend along the reach. Along most of the reach, the shoreline changed from 0.0 ft/yr to +2.0 ft/yr. At the WWPS, the shoreline appears to have an erosion-accretion wave with change rates from -2.0 ft/yr to +2.0 ft/yr. South of the site, towards the harbor, the shoreline position advanced from +2.0 to +4.0 ft/yr, which equates to a shoreline advance of 10 to 20 feet.

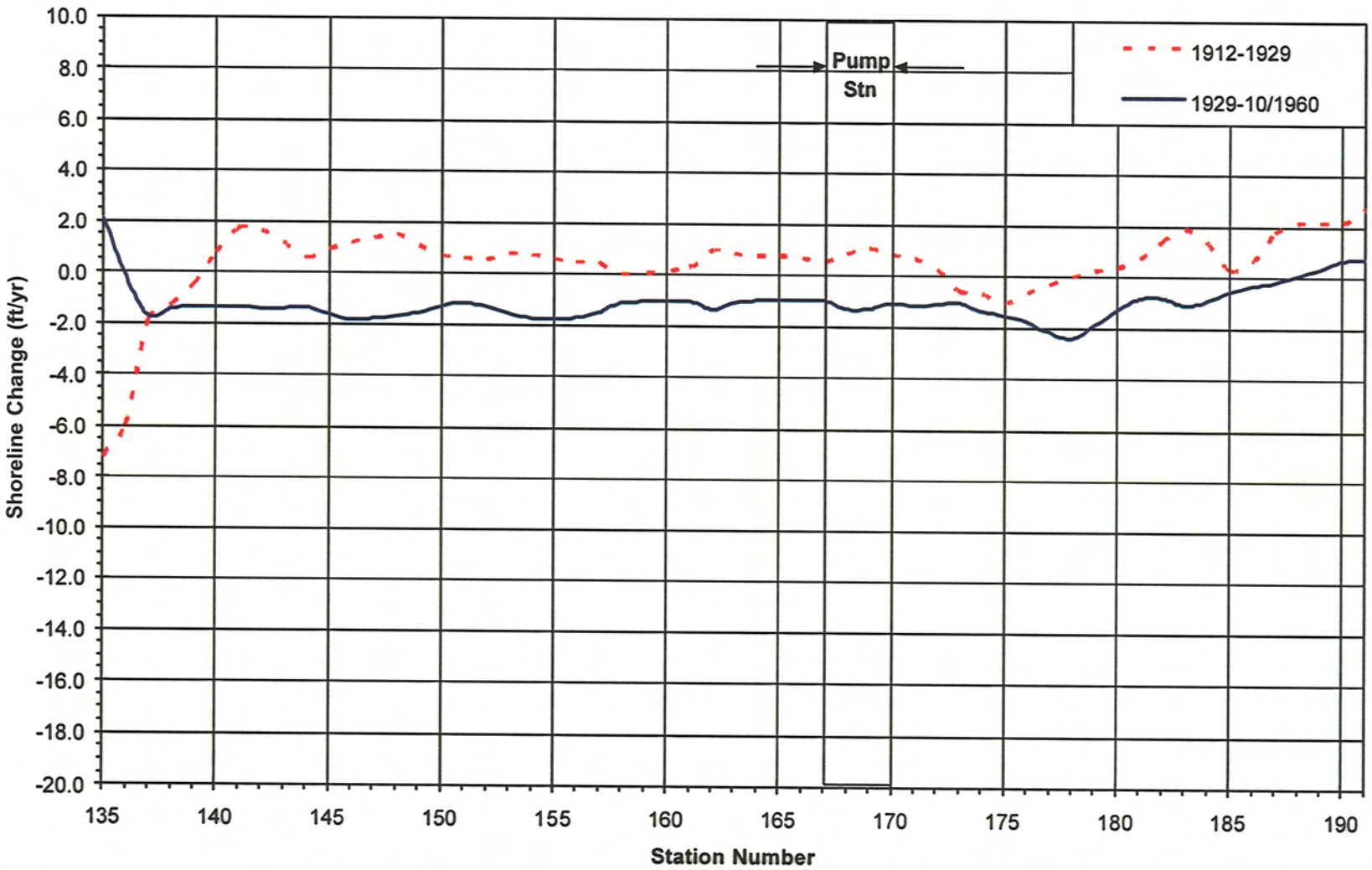


Figure 16. Shoreline Change Rate from 1912-1929 and 1929-1960 at the WWPS.

[from UH and County of Maui Shoreline Erosion Map data]

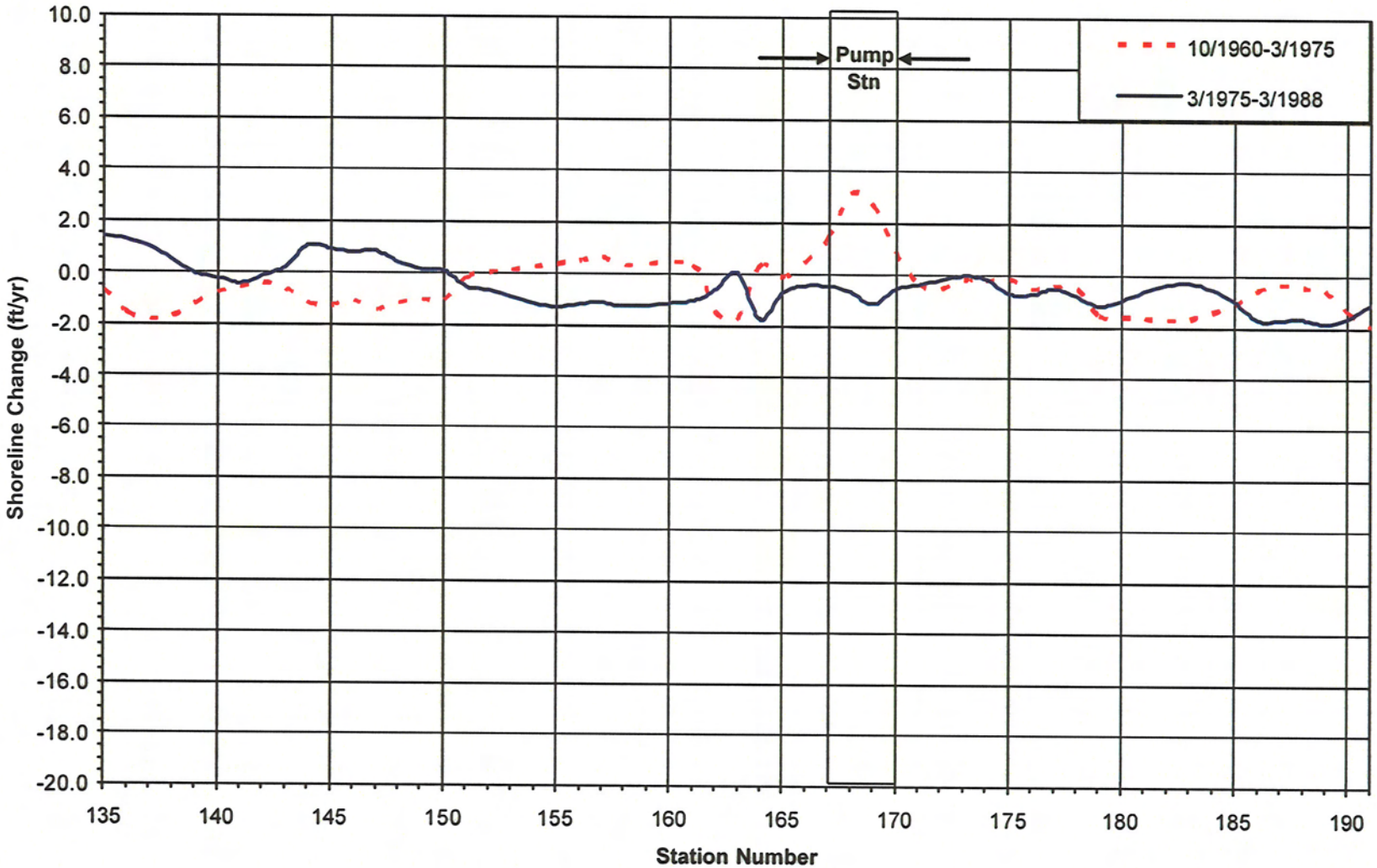


Figure 17. Shoreline Change Rate from 1960-1975 and 1975-1988 at the WWPS.
[from UH and County of Maui Shoreline Erosion Map data]

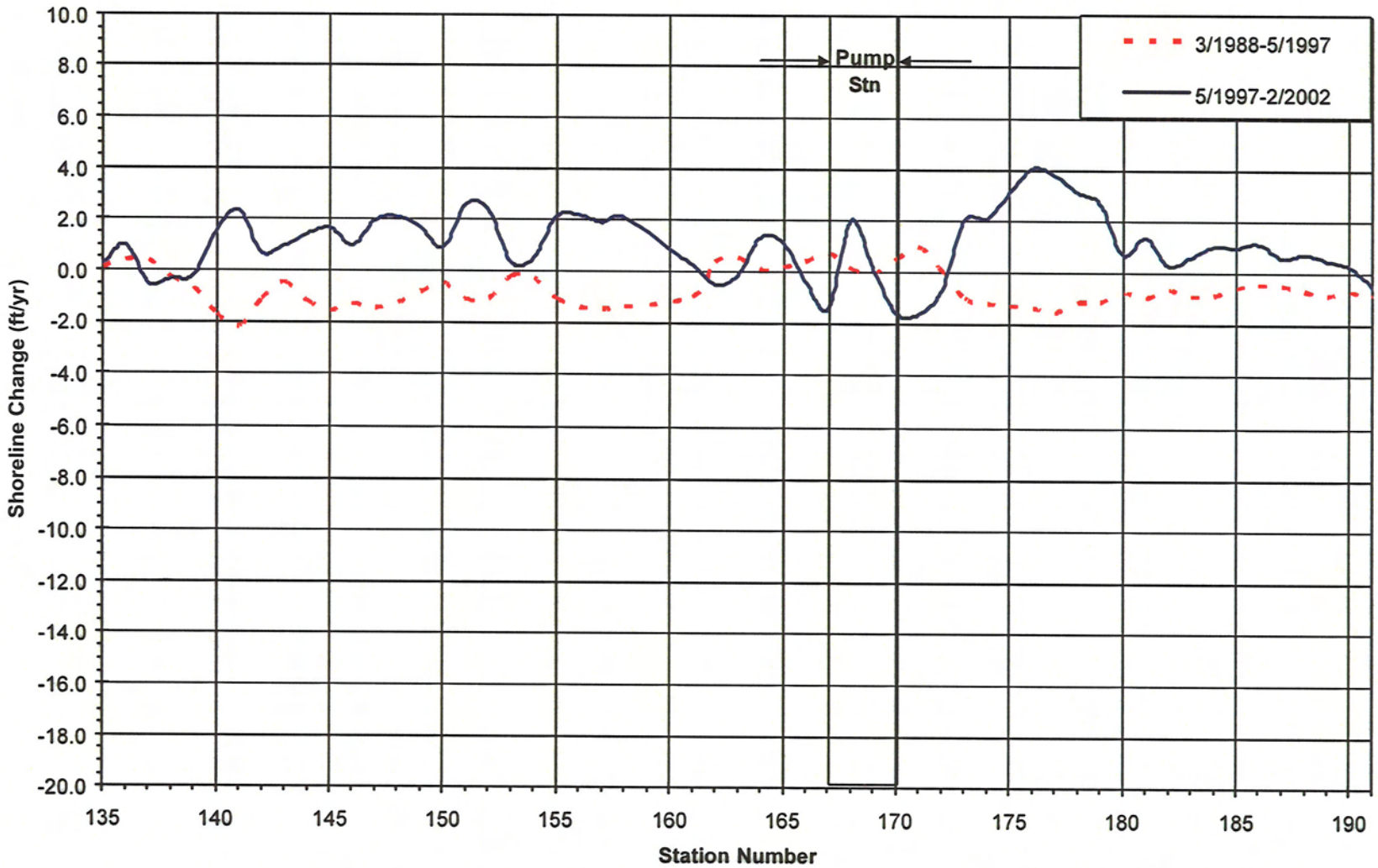


Figure 18. Shoreline Change Rate from 1988-1997 and 1997-2002 at the WWPS.

[from UH and County of Maui Shoreline Erosion Map data]

VI. POTENTIAL CAUSES OF EROSION

There are both natural and man-made influences that can contribute to shoreline erosion. The naturally occurring influences may include sea level rise, storm impacts, tsunamis, and reef changes. Man-made influences include, but may not be limited to harbor construction, shore protection structures, sand mining, damage to dune system, and reef destruction. This section presents some of the potential causes for erosion at the project area.

A. Natural Influences

1. Sea Level Rise

Relative sea level changes on the Hawaiian Islands are caused by rising sea levels, caused by global warming, and land subduction, caused by the plate movements of the islands. Globally, the mean sea level has risen by 10 to 30 cm (4 to 12 inches) over the last century. Sea level is projected to rise twice this amount (2 feet) over the 21st Century (Fletcher, et al. 2002).

In the Hawaiian Islands, the long-term trend of sea level rise caused by land subduction decreases from the island of Hawaii to the northwest (D. Jeon 1995). Therefore, the island of Maui subsides faster than Oahu and Kauai, since it is located closer to Hawaii. Tide gauge data from Kahului, Maui shows a relative sea level rise of 2.46±0.23 cm per decade (0.97±0.09 inches per decade). Approximately 1.3 cm per decade of this amount is caused by global sea level change.

Several studies indicate that future sea level rise may increase considerably (Fletcher 1992 and Fletcher *et al.* 2002). The median sea level increase on Maui is predicted to be 9.1 inches over the next 50 years and over 19 inches over the next century. With the average slopes in Hawaii varying from 1:15 to 1:6, this equates to a shoreline recession of 6 to 15 inches for every inch of sea level rise (Oceanit Laboratories, Inc. 1997).

At the Kahului Beach area, the USGS profile data indicate the shoreline slope is approximately 10 feet horizontal to one foot vertical (Brown & Caldwell 2002). With this slope a one-inch change in sea level relates to a 9.7-inch change in the relative shoreline position per decade (approximately 0.081 feet per year, or 0.97 inches per year). Overtime, the erosive effects of storms could be enhanced because of the rising sea levels.

2. Storms (Wave-induced flooding)

Elevated water levels (storm surge and wave setup) during storm events provide an elevated platform for the large storm waves to react with the shoreline. The waves can then reach higher on the beach profile and

cause upper beach and dune erosion. This is evident at the WWPS site, where storm waves were elevated and reached the upper reaches of the back beach, causing sever erosion and escarpments.

3. Reefs

It has been speculated (Sea Engineering 1991 and Guild 1999) that the reefs located offshore of the Sprecklesville Beach area may not be as productive as they have been in the past. If the reef is less productive, then there would be a decrease in the coralline sand washed onshore from the reef system. The most important function of the reefs is the protection they offer against erosion (Levin 1970).

Stream flooding can cause significant flows from Maui's rivers. The discharge can cause high levels of turbidity in coastal waters. The increased turbidity, if prolonged, may have an adverse impact on the local reefs.

B. Man-Induced Influences

1. Kahului Harbor

Limited study has apparently been done assessing the effects of Kahului Harbor and its jetties on the adjacent shoreline. The long-term effects of the structures and dredging practices are not known at this time.

2. Sand Mining

In 1954, it was estimated (Cox) that approximately 12,000 cy/yr of sand had been mined from the beach area to the east of the WWRF. The sand mining continued into 1970s. The effects of this practice is evidenced in Figure 10, which shows the rate of shoreline erosion was -8 to over -16 ft/yr along the beach reach fronting the WWRF.

Also, Levin (1970) states the dredging during the sand mining efforts change the bathymetry of the nearshore area, creating "new deep water areas" and may also cause turbidity which can affect the adjacent reef systems. As stated in the previous section, reefs are needed to provide protection against erosion. Since the cessation of the sand mining, the erosion rate in this area has substantially lessened. Current shoreline change rates are around -6.0 to +6.0 ft/yr.

3. WWII Training Exercises

WWII training exercises destroyed portions of Maui's reefs during the early to mid-1940s. This is evidenced on South Maui, at south Kalama Park in 1943-1945. The Navy underwater demolition team blew up reef as practice for beach landings for the war in the Pacific. Also, there is evidence that other reefs in south Maui were destroyed by the Navy in

1945 at the request of the County of Maui in an attempt to improve the quality of the swimming beach (Halama Beach Homeowners Association 1999).

Evidence supporting these types of activities on Maui's north shore have not been found, but it has been speculated that some of the WWII training exercises did take place along Sprecklesville Beach area.

4. Dune Destruction

Dunes are important components to the coastal processes. Dunes serve to trap wind-blown sand, store excess beach sand, and serve as natural erosion protection. Increased public access over the natural dune system can destroy the natural stabilizing dune vegetation. Also, flood control channels that cross the natural dune system can contribute to the dune destruction. Both of these cases cause direct sand loss, as well as allowing wind-blown sand to migrate inland of the shoreline and out of the littoral system. A region-wide dune restoration project could have a significant impact on reduction of shoreline erosion. This type of program is recommended by the Beach Management Plan for Maui (1997).

VII. NO-PROJECT ALTERNATIVE

A. WWRF

The most recent shoreline surveys indicate the shoreline west of the WWRF revetment is eroding at a rate of up to six feet per year. The average shoreline change rate along the WWRF property is approximately -2.4 feet per year. The County of Maui shoreline Erosion maps indicate the long-term Annual Erosion Hazard Rate (AEHR) is -2.2 feet per year along the coast from Hobron Point to Kaa.

For the no-project alternative, it is assumed that current shoreline change trends will continue in the future and no further shoreline protection will be constructed at the site. A 2001 shoreline survey and site map of the WWRF (Brown and Caldwell 2002) were analyzed to determine when the first structures at the WWRF site could be threatened. This site map is illustrated in Figure 19. The equation below was developed to calculate the years until a structure is threatened.

$$Y = \frac{D - W}{SL + LTE}$$

Where D is the distance between the structure and the back of the beach (approximately the +10-ft contour), W is the winter recession, SL is the shoreline recession due to sea level rise, and LTE is the current longer term erosion rate.

Maximum and Average values were used for the winter recession and the current erosion rate to calculate a range of years until the structures are threatened.

For this analysis, it is assumed the revetment will remain and be maintained in place and will provide protection to the holding pond and other upland structures behind the revetment. It is assumed the revetment has ceased further erosion to the area immediately behind it.

Table 3 below outline the approximate number of years until WWRF structures could be threatened using both, the maximum current erosion rate (-6.0 feet per year) and the average current erosion rate (-2.4 feet per year) (See Section IV for further details on these rates) . The seasonal recession was determined from analyzing the USGS profile data from 1995 to 1999. For this time period, the minimum recession is 0 ft (no change between summer and winter) and the maximum is 53.5 ft between summer and winter. It is noted that these data are very limited and no extreme storms or large hurricanes occurred during the 1995 to 1999 time period (Gibbs, Richmond, and Fletcher 2000). Section VI.A discusses the effects of sea level rise and states that a change of approximately 0.081 feet of horizontal recession occurs every year at the project area as a result of relative sea level rise.

Subtracting the winter recession (W) from the distance of the structure to the back of the beach (D), and then dividing by the combined erosion rate (SL + LTE), gives the time before the structure is considered threatened.

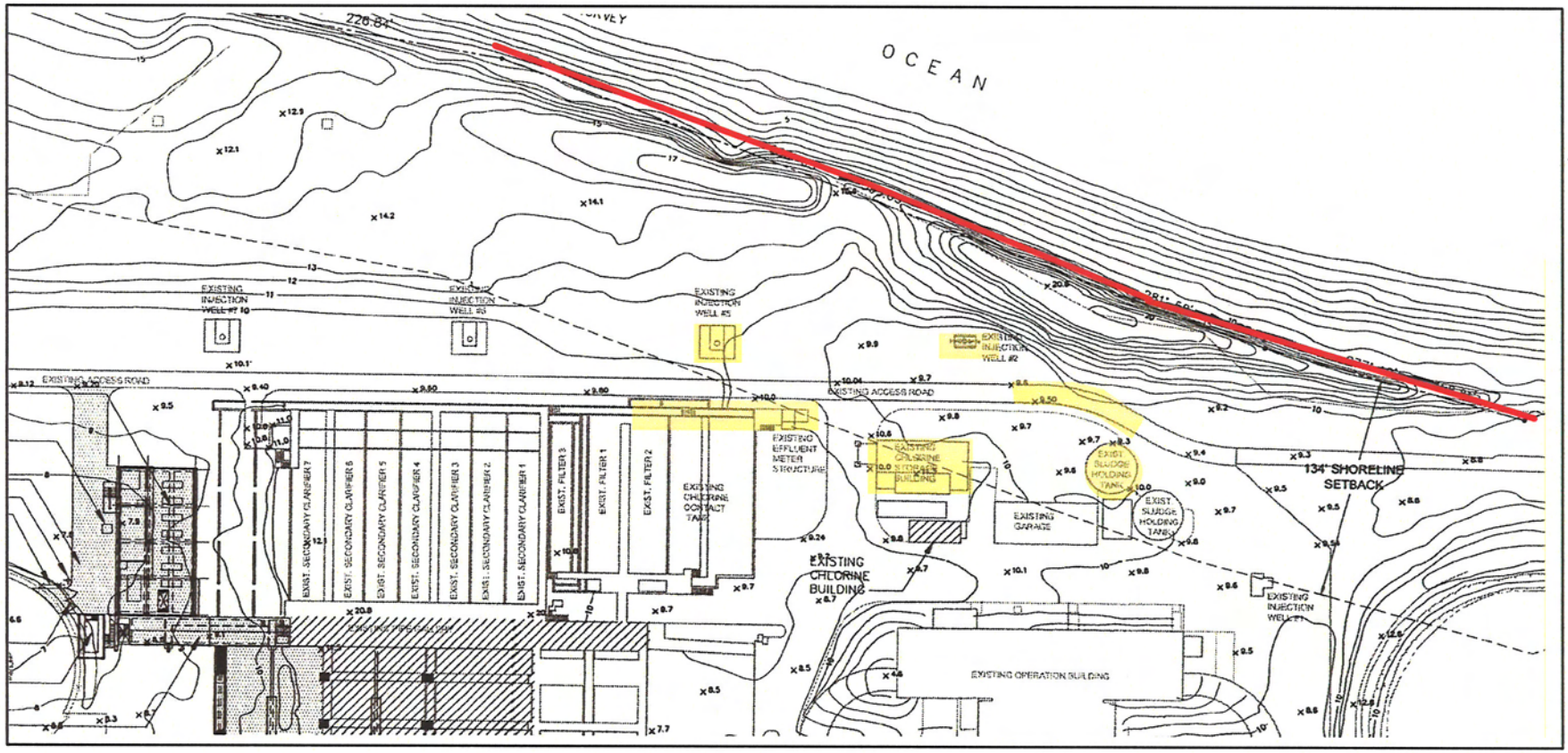


Figure 1. Wailuku-Kahului Wastewater Reclamation Facility
[from Brown and Caldwell 2002]

Table 3. Calculation of Years until WWRF Structures are Threatened.

		MINIMUM/AVERAGE CONDITIONS				MAXIMUM CONDITIONS			
Structure	**Distance between top of berm and structure (ft)**	**Minimum Winter Recession (ft)**	**Average Recent Erosion Rate (ft/yr)**	**Sea Level Rise Recession Rate (ft/yr)**	**Approx. Yrs until Threatened**	**Maximum Winter Recession (ft)**	**Maximum Recent Erosion Rate (ft/yr)**	**Sea Level Rise Recession Rate (ft/yr)**	**Approx. Yrs until Threatened**
Existing Access Road	65	0.0	2.4	0.0807	26	53.5	6.0	0.0807	2
Sludge Holding Tank	90				36				6
Chlorine Storage Bldg	120				48				11
Effluent Meter Structure	140				56				14
Existing Injection Well #2	72				29				3
Existing Injection Well #5	110				44				9

Table 3. Calculation of Years until WWRF Structures are Threatened. (Continued)

		MIN-MAX CONDITIONS				MAX-AVG CONDITIONS			
Structure	**Distance between top of berm and structure (ft)**	**Minimum Winter Recession (ft)**	**Maximum Recent Erosion Rate (ft/yr)**	**Sea Level Rise Recession Rate (ft/yr)**	**Approx. Yrs until Threatened**	**Maximum Winter Recession (ft)**	**Average Recent Erosion Rate (ft/yr)**	**Sea Level Rise Recession Rate (ft/yr)**	**Approx. Yrs until Threatened**
Existing Access Road	65	0.0	6.0	0.0807	11	53.5	2.4	0.0807	5
Sludge Holding Tank	90				15				15
Chlorine Storage Bldg	120				20				27
Effluent Meter Structure	140				23				35
Existing Injection Well #2	72				12				7
Existing Injection Well #5	110				18				23

The previous tables illustrate that in as few as 3 years, the existing injection well #2 could be threatened using the maximum current erosion rate and maximum winter recession rate that was observed from 1995 to 1999. The access road could be threatened in as few as 2 years and the existing sludge holding tanks in as few as 6 years. The chlorine storage building is located approximately 120 feet from the fence line, which relates to a minimum of 11 years before the structure is threatened using the maximum erosion rate and seasonal change. Table 4 below outlines the structures evaluated on the WWRF site and the minimum, maximum, and average time until each structure is considered threatened. These values are also supported by the recent exposure of an effluent line east of the revetment resulting from the erosional trends and winter storm response at the beach.

Table 4. Summary of WWRF Structures that may be Threatened.

Structure	Approx. Minimum Time (yrs)	Approx. Maximum Time (yrs)	Approx. Average Time (yrs)
Existing Access Road	2	26	11
Sludge Holding Tank	6	36	18
Chlorine Storage Bldg	11	48	26
Effluent Meter Structure	14	56	32
Existing Injection Well #2	3	29	13
Existing Injection Well #5	9	44	24

It is possible that most of these structures identified above could be relocated elsewhere on the WWRF property. However, the northeast corner of the Chlorine contact tank and effluent meter structure is located approximately 140 feet from the existing fence line. The size of this structure and its position in the wastewater treatment cycle would prohibit it from being relocated elsewhere on the property. With this distance, the chlorine contact tank and effluent meter could be threatened in as little as 14 years.

Also, observations during the site visit on July 16, 2004, indicated signs of flanking around the ends of the revetment. If this flanking continues, the revetment could become unstable and the shoreline in its immediate shadow may take on erosion hot-spots. It is imperative that the revetment be maintained for the life of the WWRF to provide protection to the upland structures.

B. WWPS

The shoreline at the WWPS is naturally protected by rubble beach from further short-term erosion. However, the upland property and structures are not protected from erosion caused by storms (elevated water levels and subsequent wave attack). Therefore, the upland property will continue to fail and erode during large storms unless protection is offered. Estimating the amount of time before structures at the WWPS are threatened is difficult to assess since the majority of erosion at this site is caused by large storms and waves, which occur at irregular intervals.

VIII. POTENTIAL PROJECT ALTERNATIVES AT THE WWRF

This section reviews potential alternatives for protection of the WWRF property. The alternatives that are presented include beach nourishment, groins with beach nourishment, revetment, revetment with beach nourishment, and coral rubble revetment.

A. Alternative 1 - Beach Nourishment

Beach nourishment is a proven method to stabilize a shoreline against erosion and protect threatened upland areas. However, there is very limited beach nourishment experience in Hawaii, especially using offshore sand sources. This limited experience makes it difficult to predict performance as well as assess construction and maintenance costs of a larger-scale beach nourishment project. Historically, most small-scale beach nourishment projects on Maui have used sand from inland sources. These inland sediments are typically finer grained than the natural beach sand, and may not be the most compatible sediments available for large-scale projects, such as the WWRF beach site.

Recent smaller-scale beach nourishment projects have occurred on Maui at Sugar Cove, located approximately 4 miles east of Kahului Harbor. These projects include trucking sand from the inland quarries and placing the material in a small (600-ft long) pocket beach. The initial nourishment costs were approximately $100,000 and approximately $20,000 per year for ongoing maintenance. From 1995 to 2000, Sugar Cove has placed approximately 18,000 cy of sand on their beach. The larger projects during this time included approximately 5,800 cy in 1996 and approximately 6,300 cy in 1998. Research indicates the Sugar Cove project has purchased and placed the sand for about $12/cubic yard from the local inland source. All of the project costs have been covered by the Sugar Cove residents and approvals for the projects have been readily obtained (<http://www.hawaii.gov/dbedt/czm/ce111997.htm>).

Another recent beach nourishment project is a pilot project at Waikiki, scheduled to begin in late February/early March 2005. This project is a small-scale pilot project that involves pumping 10,000 cy of sand from an offshore sand source to Kuhio Beach. Total project costs are approximately $450,000, which includes $320,000 for the direct cost of pumping the sand ($32 per cubic yard) (Eversole, e-mail communication, 2005).

The U.S. Army Corps of Engineers (USACE), Honolulu District, is conducting an erosion study in the Kihei area. The study will look at the restoration of approximately seven miles of shoreline. The study reach is on Maui's southeast coast and extends from Kihei park in the north to Keawekapu point in the south (USACE 2003). Potential sand sources should be identified in the study.

It is well established that beach nourishment projects constructed with larger volumes and coarser materials tend to remain on the upper portion of the beach for longer time periods. Smaller and finer-grained projects tend to disperse

more rapidly and remain on the upper beach for a shorter time period. Therefore, it is important to use the best-suitable sand source for any beach nourishment project.

The two alternatives presented in this section propose to acquire sandy material from either upland and/or offshore sand sources and placed along the shore fronting the WWRF.

1. Alternative 1A – 4,000-ft Long Beach Nourishment

The project reach for this alternative extends from Kaa to the WWRF western property boundary; a distance of approximately 4,000 feet. The purpose of nourishing the entire reach is to allow for the upcoast (east) beach area to act as a feeder beach to the downcoast (west) beach area. Since the net sediment transport is from east to west, the material placed near Kaa would migrate west over time, offsetting some of the maintenance required for the downdrift area fronting the WWRF.

This alternative requires approximately 215,000 cy of initial fill placement to create an 80-foot wide berm to provide a sand buffer between the property and the ongoing erosion. The nourished beach would continue to erode as it would under natural conditions and periodic maintenance nourishments would be required for the life of the project. The USGS profile data indicate that the maximum seasonal variation along the shore at the WWRF is approximately 50 feet. Therefore, the project would require renourishment when the nourished beach width has receded approximately 30 feet, preserving the 50-foot seasonal change. It is estimated that approximately 85,000 cy would be required for this renourishment every 10 years to maintain the project design width. However, the frequency may be longer than this estimate if the updrift beach acts effectively as a feeder beach providing more material to the beach fronting the WWRF. Figure 20 provides a cross-section illustration of the beach fill at the site and Figure 21 provides a plan view of the project reach.

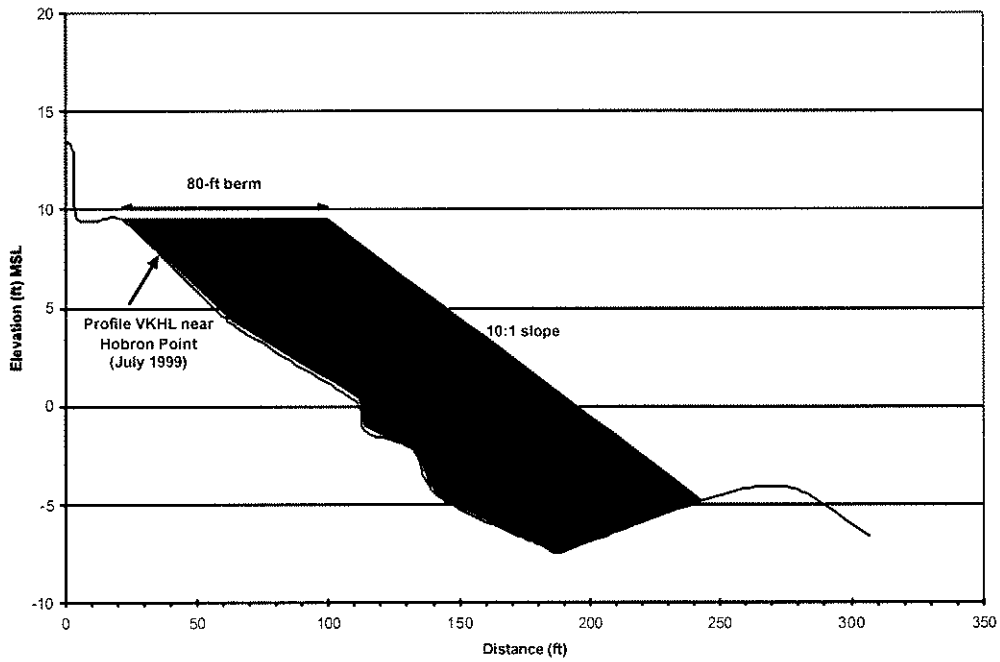


Figure 20. Alt. 1A and 1B - Cross-section of beach nourishment at the WWRF site.

Figure 21. Plan view of the beach nourishment alternatives at the WWRF site.

2. Alternative 1B – 2,650-ft Long Beach Nourishment

This alternative is similar to Alternative 1A, above; however, the beach fill length is reduced to approximately 2,650 feet. The nourishment extends along the WWRF property to about 1,000 feet east of the existing revetment. Similar to above, the nourishment area would continue to erode as it would under natural conditions. However, smaller beach nourishment projects typically have less success with retaining beach area over the long term. Therefore, careful consideration should be exercised in analyzing a reduced beach nourishment length.

Since the project reach is shortened, the upcoast (east) fill area will not provide as much feeder material to the downcoast (west) beach area fronting the WWRF. Therefore, the frequency of renourishment may need to be increased. This alternative requires approximately 145,000 cy of initial beach fill to create an 80-foot beach berm. Approximately 55,000 cy would be required every 8 years to renourishment and maintain the project design width. Figure 20 provides a cross-section illustration of the beach fill at the site and Figure 21 provides a plan view of the project reach for both beach nourishment alternatives.

3. Sand Sources

Moberly and Chamberlain (1964) conducted sand samples analyses on various Hawaiian beaches. The sands from the Kahului to Sprecklesville area were almost entirely carbonate. Mechanical analyses were made of sand samples taken from the berm and approximate sea level. At the beach adjacent to the east breakwater at Kahului Harbor, the grain size was found to be 0.2-0.5 mm at the berm and 0.3-1.0 mm at sea level. The median diameter of Maui's Windward beaches had a median diameter of 0.18 mm. They concluded that finer-grained sediments were found on the windward coasts of all of the islands analyzed; however, the authors found that Maui's beach sands were typically finer than sands found on the other Hawaiian Islands.

There are several known inland sources of sand for construction of a beach nourishment project. Maui dune sand is relatively fine sand that is found in the upland areas and is used for dune and minor beach fills. Typically, fine-grained sediments are not ideal for high-energy beaches, such as the Kahului Beach area. Bodge (1999) stated the Honokowai Beach Park site, the upland dune material exhibited a 45% overfill requirement. There is an inland dune quarry that has been used for source material located in Happy Valley, approximately 10 miles from Sugar Cove (Guild 1999). The inland sand mines on Maui have historically charged between $10 and $18 per cubic yard. However, on other islands, the cost has ranged from $25 to $60 per cubic yard (Honolulu Advertiser, September 9, 2004).

For this analysis, a cost of $25 per cubic yard was assumed for the sand material, but whether inland, offshore, or a combination of sources is not defined. It is noted, however, that the costs for inland sources may increase substantially due to the large volume required to construct Alternatives 1A or 1B. These large volumes will likely make the use of inland source material cost-prohibitive. Ultimately, offshore borrow areas may be less costly for a beach nourishment project requiring large volumes.

Using offshore borrow areas involves dredging the sandy material and pumping it to the shore. The Waikiki demonstration project will be the first major pumping operation of its kind in the Islands, and could be a prime example for slowing beach erosion across the state (Honolulu Advertiser, September 9, 2004). Maui's Beach Management Plan (University of Hawaii Sea Grant Extension Service and County of Maui Planning Department 1997) recommends that a pilot project for beach nourishment is "very much needed." This plan also states that in order to ensure a successful pilot beach nourishment project, a site-specific, coastal engineering study would be needed.

B. Alternative 2 - Beach Nourishment Augmented with Sand Retention Structures (T-Groins)

This alternative includes constructing seven sand retention structures (groins) along the 2,640-foot project reach and filling the area with sandy material. The groins replicate natural sand barriers, such as headlands and smaller rock outcroppings, blocking the longshore transport and "trap" the sand in the pockets between the structures. Therefore, the initial fill volume and renourishment volume and frequency are decreased compared to conventional beach nourishment.

Approximately 40,000 tons of quarried rock is required to construct the groin system and approximately 130,000 cy of sand is required for the initial beach fill. Renourishment is proposed every 10 years with approximately 40,000 cy of sand to maintain the design profile within the project area. This alternative provides added longevity to the beach fill and provides better public access than a revetment alone. Figure 22 and Figure 23 illustrate the groins and beach fill.

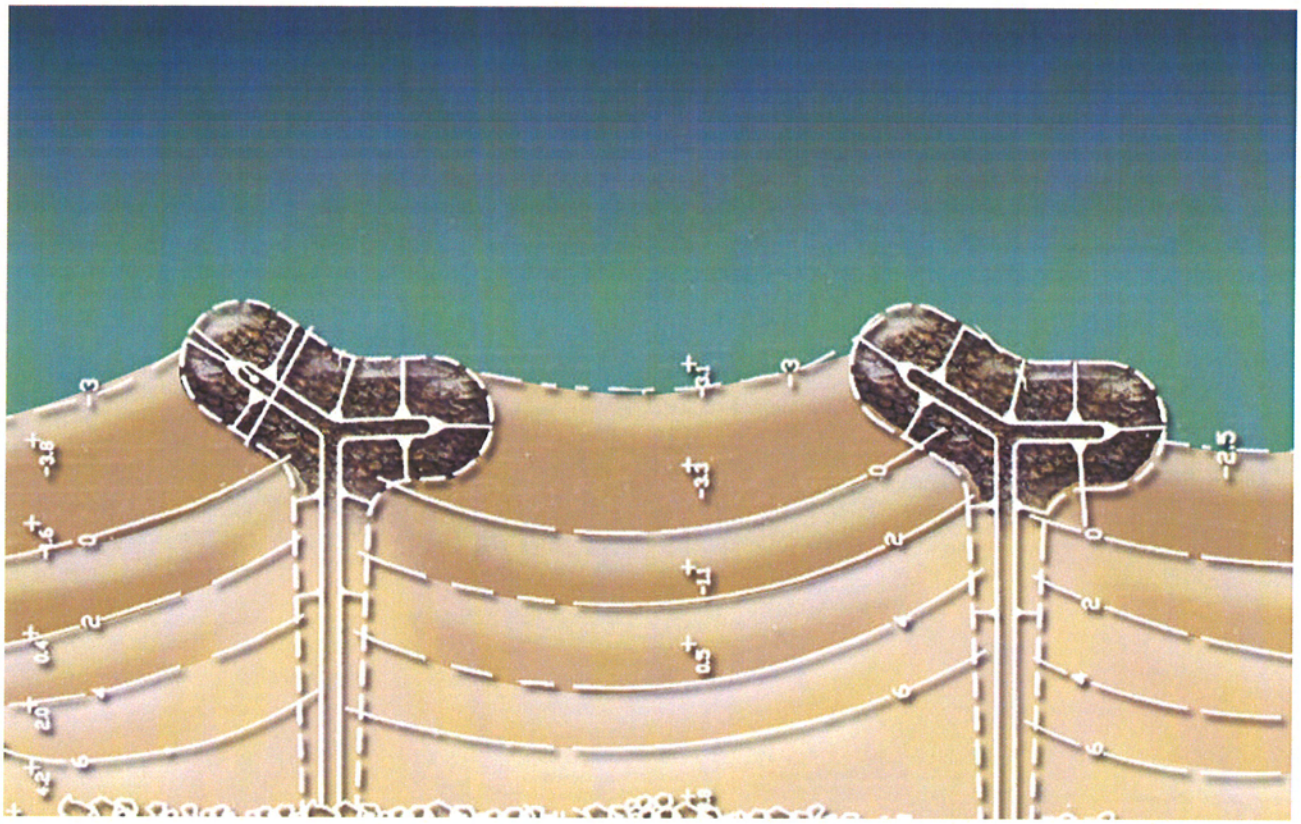


Figure 22. Details of the T-Groin Structure

1. Sources of Armor and Nourishment Material

Both inland quarries and inland boulder fields are typically used for acquiring armor stone for beach protection structures. The inland boulders are typically located in the sugar cane fields and are found from the preparation of the soil for planting and/or harvesting.

The beach nourishment material may be acquired from inland and/or offshore sand sources, as described in Section VIII A.3. For this study, we estimate a cost of $75 per ton for the large armor stone, $65 per ton for the under layer rock, and $25 per cubic yard for the nourishment material.

Figure 23. Plan view of site with T-Groins and Beach Nourishment.

C. Alternative 3 - Armor Rock Revetment

Hard structures, such as revetments and seawalls, can provide shoreline protection as a last line of defense from coastal erosion resulting from storm wave attack, storm- and tsunami-induced erosion, and long-term shoreline retreat. Without the structures, the beach would continue to erode and threaten the upland area. Typically, hard structures are not as acceptable to the public or regulatory agencies as soft structures, such as beach nourishment. At the WWRF site, the existing revetment could be extended along the property to provide upland protection from severe erosion and storm events. The east flank of the existing revetment may need to be extended or revised to minimize further flanking.

1. Alternative 3A – Revetment Extension

The USACE constructed the original 450-foot revetment in 1979 for a total cost of approximately $300,000 with federal and non-federal funds. For this alternative, the revetment would be extended to the west along the WWRF property length, a distance of approximately 1,200 feet, and would require approximately 14,000 tons of armor and under layer rock. The revetment would be constructed along the back portion of the beach, close to the existing fence line, and would be a similar design to the existing revetment. The existing beach material that was removed to construct the revetment would be replaced over the structure, but no further sand would be added to the system. Figure 24 and Figure 25 illustrate the plan view and cross-section of the revetment alternative.

2. Alternative 3B – Buried Revetment

This alternative includes adding beach nourishment with the revetment to provide a recreational beach area and to minimize impacts to littoral transport and adjacent beaches. The revetment would remain buried and would retain a last line of defense for protection of the WWRF in the event of severe erosion caused by storms or tsunami. A decreased beach width is proposed, since it is not necessary to provide protection from the seasonal fluctuations as the revetment will protect the property in the absence of any sand. Normal seasonal accretion in front of the revetment will be encouraged such that the revetment remains covered the bulk of the time. With proper planning of the revetment location and periodic beach nourishment maintenance, the seasonal erosion and accretion will occur naturally in front of the revetment.

This alternative includes approximately 75,000 cy of initial beach fill, creating a 50-foot beach berm. The beach nourishment extends along the entire length of the proposed and existing revetment and to the east for an additional 500 feet. The total project length is approximately 2,150 feet. Approximately 30,000 cy of renourishment is required every eight years to maintain the project design width. The profile would be similar to Figure 25, but would be buried by the nourishment material. Sources for the armor and nourishment material are discussed in Sections VIII A.3 and VIII B.1, above.

Figure 24. Plan view of Revetment Alternative

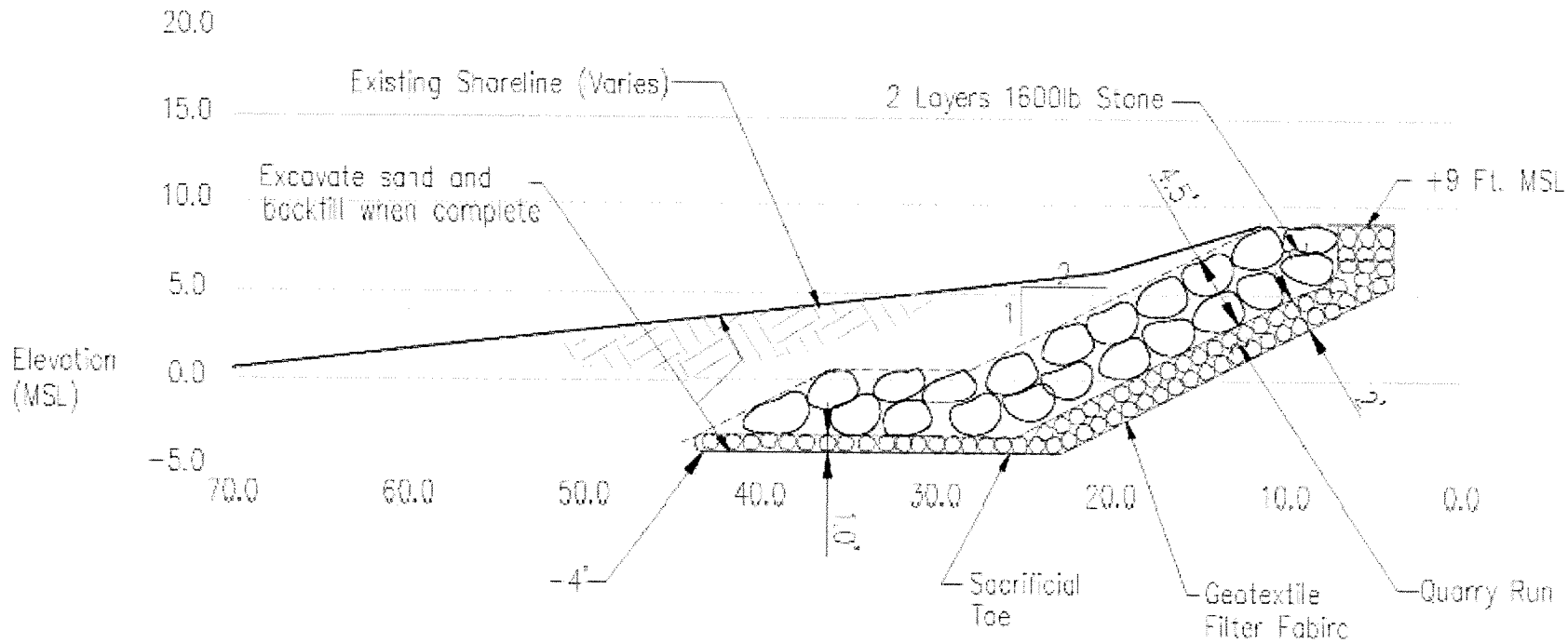


Figure 25. Typical Revetment Cross-Section

D. Other Alternatives

1. Coral Rubble Fill

Use of cobble as beach nourishment is not typical along most areas of the U.S. The practice has achieved wider acceptance in Europe. There have been some small-scale projects constructed in Southern California along reaches where the beach is naturally composed of cobble. A photograph of a cobble beach nourishment project in Southern California is provided in Figure 26. Applying a similar project to the WWRF property would include using coral rubble as the fill material. This would potentially provide a more stable beach than using sand, since the coral rubble is heavier and less subject to longshore transport. Overtime, the coral would break apart by the wave action and create a sandy surface.

The County had historically used coral rubble as road base material until this practice was discouraged since the rubble is littoral material and should remain in the littoral zone. Sources for such a coral rubble fill are not extensively known, although accumulations of this material can be observed along many of Maui's shorelines.

Due to the severity of the erosion at the WWRF and the high importance of the recreational beach use and reclamation facility to Maui residents, this type of project may not be practical and conventional methods are probably preferred.

2. Vertical Seawall and Hybrid Structure

Because the site is already protected by an armor stone revetment and because of the relatively limited public use of the beach fronting the property, a vertical seawall is not considered further. It is our experience this type of structure is significantly more expensive and is more beneficial in areas where the public benefits of retaining beach space far outweighs the costs of construction and maintenance.

Figure 26. Picture of a cobble nourishment project, City of Ventura in Southern California.

E. Potential Environmental Impacts

Potential impacts from construction of any of the alternatives may include temporary and permanent impacts. Temporary impacts include traffic congestion from trucking sand or armor to the beach; air quality impacts from the trucking, construction equipment, and dredge equipment; and turbidity impacts during placement of sand.

Permanent impacts from construction of a shore protection project include increased sedimentation at Kahului Harbor, impacts to adjacent shorelines, biological impacts (reefs), and impacts to public access. Precautions would be taken to prevent eroded soils, construction debris, and other contaminants from entering the coastal waters. Increased sedimentation at Kahului Harbor may occur from the placement of large quantities of beach fill along the reach east of the harbor. This may require more frequent maintenance dredging to maintain the design depth in the harbor.

Surrounding beaches may benefit from the placement of sand as the sand disperses and longshore transport carries the sand up- and downcoast. However, careful design and modeling may be necessary prior to implementation of any beach fill alternative to ensure the fill material does not migrate significantly offshore, burying the reefs along the project coast.

Impacts to adjacent beaches from the construction of a revetment or shore-parallel structures, such as seawalls, are the subject of much controversy. Most science indicates such structures do not negatively impact adjacent shorelines, unless they prevent erosion of an upland source of sand for a beach downdrift or are so situated that they act as a groin. Revetments and seawalls are usually constructed on eroding beaches to protect the upland property. They are also constructed in some cases on stable beaches, providing as needed protection against short-term storm-induced erosion. The former is the case for this project. Maui's north coast is actively eroding and will continue to erode under natural conditions.

Beach nourishment provides better public access than hard structures, such as the groin system and revetment. However, the groin system does provide more sand retention, requiring less volume of initial sand and less frequent renourishment. The revetment will provide a last-line of defense to the facility if a major storm or tsunami occurs. Beach nourishment alone will probably not provide the same protection to the facility.

Monitoring will be required for any alternative constructed at the site and may include beach profiling, grain size analysis, project performance, and any observable adverse water quality impacts.

F. Regulatory Requirements

The State of Hawaii and County of Maui are the local regulatory agencies for permitting shore protection structures. The main regulations pertaining to shore protection include the Hawaii Revised Statutes Chapter 205-A, Coastal Zone Management, and the Shoreline Rules for the Maui Planning Commission.

In general, the State and County will not approve any shore protection (except sand placement) unless a structure is imminently threatened. An imminent threat means the structure is within the shoreline setback area. At the WWRF facility, the shoreline setback line is approximately 134 feet from the chain link fence on the northern boundary of the property. Some of the WWRF structures are located within this setback area.

If a structure is within the shoreline setback area and is not under an emergency situation, then the County proceeds in its regular process of building a new structure in the Special Management Area (SMA). The first item the County considers is if the structures can be relocated. In the case of the WWRF, some structures may be relocated, but most of the large process areas cannot be relocated because of limited area at the site. Since many of the structures at the WWRF cannot be relocated, County regulators may require a long-term commitment to beach replenishment program be implemented and also provide safe lateral public access along the shoreline. This can either be a walkway on or near the revetment or beach area for the public.

In general, the State will not allow hard structures to be placed within its jurisdiction, so most applications for hard structures will be permitted under the County SMA, and will need to be placed entirely within the boundaries of the property owner (landward of the shoreline). In order to acquire a variance from the County to construct a hard structure, an Environmental Assessment, public notice, and a public hearing will need to be conducted. A variance can be approved for improvements proposed by public agencies or public utilities regulated under Hawaii Revised Statutes (HRS) Chapter 269. The Wailuku-Kahului Wastewater Reclamation Facility is a County-owned pubic utility regulated under this statute

G. Cost Estimates

Costs for each of the alternatives were estimated based on both, Present Value and Annualized costs for both the construction and maintenance cycle. Each alternative has a 50-year design life. A more detailed cost estimate for each alternative is provided in Appendix B.

Present Value Costs calculate the initial construction and future maintenance costs based on current value dollars. The maintenance costs were inflated for each maintenance cycle to address inflation, future labor rates, future construction costs, etc. It is assumed that this inflation is a simple interest of 2.3% based on the Engineering News Record Construction Cost Index since 1977. For each maintenance cycle, the maintenance costs were then translated to present-value dollars assuming a 7.13% rate of return

Table 5 outlines the Present Value total cost for construction and future maintenance for each alternative for the WWRF. Alternative 1A, 4,000-foot long beach nourishment, has the highest cost at approximately $10 million, because of the large volume of sand needed to construct the project. The decreased length beach nourishment alternative (1B) is less expensive ($7.4 million), however, does require more frequent renourishment to maintain the design beach width. The nourishment with groin system is the third most expensive alternative ($9.8 million), mainly due to the large amount of armor stone that would be required to construct the groins. Both of the revetment alternatives are the least expensive ($1.6 million and $4.4 million). However, it is noted the buried revetment does provide additional recreational and aesthetic benefits over the revetment alone.

Table 5. Approximate Present-Value Cost Estimates for the WWRF Alternatives

Alternative		*Total Cost*
1A	Beach Nourishment (4,000 ft project length)	$10,200,000
1B	Beach Nourishment (2,650 ft project length)	$7,400,000
2	Beach Nourishment with Groin System (2,640 ft project length)	$9,800,000
3A	Revetment (1,200 ft project length)	$1,600,000
3B	Revetment with Beach Nourishment (1,200 ft revetment, 2,150 ft nourishment)	$5,400,000

Annualized Costs calculate the annual cost of each alternative over the life cycle of the project (50-years). Annualized Construction Costs indicate the annual value of the initial construction costs over a 50-year life cycle. Whereas, the Annualized Maintenance Costs indicate the annual cost needed to conduct the future maintenance over the 50-year life cycle. The rate of return used in the Annualized Costs is 7.13%. The table below outlines the construction, maintenance, and total annualized cost for each alternative.

As shown in Table 6, Alternative 1A has the highest annualized total cost of approximately $724,000 per year for 50-years. Alternatives 1B and 2 have the next highest annualized total costs ($553,000 and $609,000 per year, respectively). The revetment and buried revetment have the two lowest annualized costs ($87,400 and $118,000 per year, respectively). However, it is again noted that the buried revetment does provide additional benefits over the revetment alone.

Table 6. Approximate Annualized Cost Estimates for the WWRF Alternatives

Alternative		*Annualized Construction Cost **	*Annualized Maintenance Cost **	*Total Annualized Cost **
1A	Beach Nourishment (4,000 ft project length)	$400,000	$324,000	$724,000
1B	Beach Nourishment (2,650 ft project length)	$271,000	$282,000	$553,000
2	Beach Nourishment with Groin System (2,640 ft project length)	$459,000	$150,000	$609,000
3A	Revetment (1,200 ft project length)	$82,000	$5,400	$87,400
3B	Revetment with Beach Nourishment (1,200 ft revetment, 2,150 ft nourishment)	$82,000	$36,000	$118,000

**Costs represent dollars per year ($/yr) for a 50-year life cycle.*

IX. POTENTIAL PROJECT ALTERNATIVES AT THE WWPS

The WWPS site is a small lot located to the west of Kahului Harbor with a beach front width of approximately 150 feet. This section describes alternatives that could be constructed at the WWPS site to minimize future scour and erosion from severe storms. Each of these alternatives only provides protection for the 150-foot property width. However, further scour erosion would occur up- and down-coast of the property unless they are also protected. If only the WWPS property is protected, then careful design of the flanking areas needs to be considered to minimize impacts from erosion occurring around the ends of the protective structure. Since this site is not generally accessed by the public, hard structures may be more amenable by the public and regulatory agencies.

A. Alternative 1 - New Revetment

This alternative includes removing the rubble fronting the site and replacing it with a new engineered revetment. Initial estimates assume the same cross-section as the revetment fronting the WWRF, as shown in Figure 25. The site would be graded and a layer of filter fabric placed under the proposed revetment. Approximately 1,800 tons of armor and under layer rock are required for construction of the 150-foot long revetment. The filter fabric and engineered design provide adequate protection from future storm surge and requires minimal maintenance over the project life.

B. Alternative 2 - Repair Rubble Revetment

It does not appear the existing rubble at the site was placed in any engineered configuration, but rather just randomly dumped. This alternative includes repairing and replacing the existing rubble at the site to provide better protection from severe storms. Placement of filter fabric is not proposed for this alternative, but the general cross-section would be similar to the revetment shown in Figure 25. Some grading is proposed and it is estimated a portion of the existing rubble may be reused at the site, but at least half of the volume needed would be brought in from outside sources. It is estimated that approximately 1,700 tons of rubble would be required in addition to the material available at the site. Future storms may cause the rubble to move and resettle and would require more frequent maintenance after storm events.

C. Other Alternatives

1. Seawall

A seawall is another alternative that could be constructed for shore protection. Typically, seawalls are constructed to minimize encroachment onto the beach system and minimize impacts to recreational beach users. However, since this site is fronted by a rubble mound, public access is currently restricted. Also, the cost for seawall construction compared to a revetment is much greater and at this site the benefits are minimal. Therefore, a seawall at the WWPS site is not considered further.

2. Beach Nourishment

A beach nourishment project could also be constructed at the WWPS. However, this shoreline currently consists of a cobble, rock, and rubble foreshore and a large volume of sand could be required along the entire reach and not just fronting the WWPS property. The entire reach from the Kahului west jetty to the adjacent armoring structure to the north would need to be filled to provide adequate protection. If a sandy beach were constructed just on the shore immediately fronting the WWPS, the fill material would disperse up- and downcoast, and offshore and the WWPS would be threatened again. It is also noted the major threat at this site appears to be from sever storm events and not recent erosion trends.

D. Cost Estimates

Costs for each alternative at the WWPS were estimated based on both, Present Value and Annualized costs for both the construction and maintenance cycle. Each alternative has a 50-year design life. A more detailed cost estimate for each alternative is provided in Appendix B.

Present Value Costs calculate the initial construction and future maintenance costs based on current value dollars as discussed in Section VIII.G. Table 7 outlines the total cost for construction and future maintenance for each

alternative for the WWPS. Alternative 1 is the newly engineered revetment and has a slightly higher cost than Alternative 2, repair of existing rubble revetment ($260,000 vs. $205,000, respectively). Although the initial construction cost for Alternative 1 is higher, the maintenance cost for Alternative 2 is much higher than Alternative 1. It is noted the new engineered revetment provides better protection from severe storm surges. A more detailed cost estimate for each alternative is provided in Appendix B.

Table 7. Approximate Present-Value Cost estimates for the WWPS Alternatives

Alternative	*Total Cost*
1 Revetment (150 ft project length)	$260,000
2 Repair Rubble Revetment (150 ft project length)	$205,000

Annualized Costs calculate the annual cost of each alternative over the life cycle of the project (50-years) as discussed in Section VIII.G. Table 8 shows that Alternative 1 has a slightly higher annualized cost than Alternative 2 ($14,400 and $11,800 per year for 50 years, respectively). As stated above, the new engineered revetment (Alternative 1) does provide better storm protection compared to the rubble repair (Alternative 2).

Table 8. Approximate Annualized Cost Estimates for the WWRF Alternatives

Alternative		*Annualized Construction Cost **	*Annualized Maintenance Cost **	*Total Annualized Cost **
1	Revetment (150 ft project length)	$13,400	$1,000	$14,400
2	Repair Rubble Revetment (150 ft project length)	$9,300	$2,500	$11,800

**Costs represent dollars per year ($/yr) for a 50-year life cycle.*

X. RANKING CRITERIA

This section discusses the various ranking criteria used to evaluate each of the alternatives described in Sections VIII and IX. The evaluation criteria include:

- Construction Cost – Initial costs for construction of the alternative
- Maintenance Cost – Life-cycle costs for maintenance of the alternative
- Public Access and Usage – Affects to public beach access and recreational use
- Design Life – Offers best protection over design life
- Regulatory Compliance – Best meets regulatory regulations
- Aesthetics – Effects to the aesthetics of the existing area
- Impacts to Kahului Harbor – Increased frequency of dredging at Kahului Harbor or other adverse impacts
- Environmental Impacts to Biology – Impacts to biological resources in the area
- Environmental Impacts to Adjacent Shoreline – Impacts to adjacent shoreline areas

These alternatives were evaluated to determine a weighted value for each. Some criteria are more important than others in evaluating the alternatives and should be weighted more than other less-important criteria. Table 9 shows the criteria and the weighted value assigned to each.

Environmental impacts to both biology and adjacent shorelines received the highest rank. This is because it is extremely difficult and costly to mitigate for biological impacts if any were caused by the shore protection alternative. Impacts to Kahului Harbor are slightly less important than the environmental impacts, because the main cause of any impact is sedimentation at the harbor, which would increase the maintenance dredging cycle, but not cause any long-term negative impact. Design life is slightly more important than construction and maintenance cost to ensure that the quality of the alternative in providing protection is cost effective.

Regulatory compliance received a lower score than the previous criteria, not because it is not important to comply with the regulations, but because these sites are part of a public utility and variances are generally more permissible than at private locations and many existing structures at the sites are already located within the shoreline setback line. Public access and usage and aesthetics received the lowest score mainly because these sites are not a heavily used site by the public. The beaches to the east of the WWRF are used by the locals and wind surfing or kite surfing community.

Table 9. Weighted Value of Evaluation Criteria

Criteria	Weighted Value
Construction Cost	21
Maintenance Cost	21
Public Access and Usage	16
Design Life	24
Regulatory Compliance	19
Aesthetics	17
Impacts to Kahului Harbor	28
Environmental Impacts - Biology	35
Environmental Impacts - Adj shorelines	35

Each alternative was evaluated based on the criteria listed above. A value of 1 through 5 was assigned to each criteria evaluation for each alternative. A 5 represents the best value for the criteria and a 1 is the poorest value. Then a weighted score is calculated by multiplying the value assigned to the criteria and the weighted value of each criteria. For each alternative, the total scores are summed to determine a ranking of alternatives. The alternative with the highest score is the preferred alternative based on the evaluating criteria.

The following tables show the weight value of each criteria in *italics* under each criteria heading. For each alternative, the value assigned to each criteria is shown in the gray box, and the score calculated for each criteria is in bold.

The total score column of the tables indicates the preferred alternative at the WWRF and WWPS are the Buried Revetment and New Engineered Revetment, respectively.

Table 10. WWRF Alternative Evaluation

	Construction Cost		Maintenance Cost		Public Access & Usage		Design Life		Regulatory Compliance		Aesthetics		Impacts to Kahului Harbor		Environmental Impacts to Biology		Environmental Impacts to Adjacent Shorelines		TOTAL SCORE	RANK
Criteria Weighted Value	*21*		*21*		*16*		*24*		*19*		*17*		*28*		*35*		*35*			
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score		
ALT 1A- 4000-FT BEACH FILL	2	**42**	1	**21**	5	**80**	2	**48**	5	**95**	5	**85**	2	**56**	2	**70**	5	**175**	**672**	3
ALT 1B- 2500-FT BEACH FILL	3	**63**	2	**42**	4	**64**	1	**24**	5	**95**	4	**68**	2	**56**	2	**70**	4	**140**	**622**	5
ALT 2- BEACH FILL W/ GROINS	1	**21**	3	**63**	3	**48**	3	**72**	3	**57**	3	**51**	4	**112**	3	**105**	3	**105**	**634**	4
ALT 3A- REVETMENT	5	**105**	5	**105**	1	**16**	5	**120**	1	**19**	2	**34**	5	**140**	4	**140**	2	**70**	**749**	2
ALT 3B- BURIED REVETMENT	4	**84**	3	**63**	4	**64**	4	**96**	4	**76**	4	**68**	3	**84**	3	**105**	4	**140**	**780**	1

Table 11. WWPS Alternative Evaluation

	Construction Cost		Maintenance Cost		Public Access & Usage		Design Life		Regulatory Compliance		Aesthetics		Impacts to Kahului Harbor		Environmental Impacts to Biology		Environmental Impacts to Adjacent Shorelines		TOTAL SCORE	RANK
Criteria Weighted Value	*21*		*21*		*16*		*24*		*19*		*17*		*28*		*35*		*35*			
	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score	Value	Score		
ALT 1- NEW REVETMENT	3	**63**	4	**84**	2	**32**	4	**96**	2	**38**	3	**51**	3	**84**	3	**105**	3	**105**	**658**	1
ALT 2- RUBBLE REPAIR	4	**84**	2	**42**	2	**32**	2	**48**	2	**38**	2	**34**	3	**84**	3	**105**	3	**105**	**572**	2

XI. SUMMARY AND CONCLUSIONS

A. Wailuku-Kahului WWRF

Evaluation of the available shoreline data indicates the rate of recession was highest from 1960 to 1975 and from 1975 to 1987. The rate of shoreline recession has since decreased and shoreline advance has occurred in some areas along the study reach. However, immediately west of the revetment at the WWRF, the rate of shoreline recession from 1997 to 2002 indicates a strong (up to 6 feet per year) rate of shoreline recession.

Using this maximum shoreline recession rate, it is estimated that some structures at the facility may be threatened in as little as two to three years. However, some of these early-threatened structures can be relocated to other areas on the WWRF property. The first major structure that would be threatened is the Effluent Meter at the end of the Chlorine Contact Tank. This structure may be threatened in as little as 14 years. For average recession conditions, this structure may be threatened in approximately 26 years. It is noted, this erosion rate is an average of recent conditions, and significant storms can accelerate and localize the erosion in the area.

Methods to provide protection to the WWRF site include beach nourishment and construction of revetment. Preliminary alternatives described in this study include beach nourishment with compatible sand material, beach nourishment with retention structures, continuing the revetment along the property, and a combination of a revetment extension and beach nourishment.

Evaluation of the alternatives indicates the preferred alternative is the buried revetment. This alternative provides a last line of defense against severe storms and tsunamis and also provides a recreational beach area which is more amenable to the general public and regulatory agencies. A long-term commitment must be made to ensure future funding for maintenance of the beach fill.

B. Wailuku WWPS

Analysis of the available shoreline data indicates that this area has exhibited slight recession. The most recent trends from 1997 to 2002 indicate that the shoreline has been fairly stable. This is most probably due to the fact that properties have been armored or the beach face area is rocky, halting further shoreline recession.

The WWPS shoreline is naturally protected by a rubble beach from further short-term erosion. Any further damage to the upland areas will be caused by severe storms (elevated water levels and subsequent wave attack) and tsunami. The upland property will continue to fail and erode during large storms unless it is protected.

This site appears to be fairly easy and acceptable to construct a revetment within the existing rubble footprint, because of the large amounts of rubble and

boulders already existing along the reach and limited public use. Evaluation of the alternatives indicates that the preferred alternative is a new engineered revetment. This alternative provides a last line of defense against severe storms and tsunamis without degrading the rubble beach further.

C. Recommended Future Studies

Future recommended studies include a sediment budget analysis of the Kahului region and investigation study of potential offshore sand sources.

1. Sediment Budget Analysis

A more-detailed study is required to better understand the physical processes of the shoreline, as well as determine the efficacy of the alternatives presented in this report. A sediment budget analysis should be considered as the next step for Maui's north coast to better identify and quantify specific causes of the erosion problem. A sediment budget analysis is a continuity exercise to quantify fluxes of sediment into and out of a specific control volume. The budget is developed to (1) estimate the incoming and outgoing volumes of sediment to the extent possible with the existing information; (2) sum all losses and gains; (3) compare the results with measured changes in volume within the control volume; and (4) use judgment and perhaps additional data to adjust the fluxes until they best balance. The goal for a sediment budget analysis at the Kahului beach areas is to estimate the amount of sand available in the system, identify and quantify the major fluxes of sediment that can affect the shoreline, estimate changes in them before and after various natural and man-induced impacts occurred, and identify those changes that are considered reversible due to shore protection.

Specific elements of the sediment budget analysis should include:

- An assessment of the amount of sand within the littoral system based on field observations including jet probing
- Wind transport analysis using improved predictive models that can be calibrated with field measurements
- Estimate past, present and potential future rates of sand production from the fringing reef system
- More information on the shoreline evolution after construction of Kahului Harbor
- Sand transport through the reef system and around Kahului Harbor
- Sand transport/sedimentation within Kahului Harbor

2. Investigation of Offshore Sand Sources

A study investigating the potential of offshore sand sources should be conducted. The use of inland sand sources is viable for small-scale projects; however, it may be economically unfeasible for large-scale nourishment projects.

This study has been recommended by other interested parties in the Hawaiian Islands. University of Hawaii Sea Grant Extension Service and County of Maui Planning Department prepared a Beach Management Plan for Maui (1997). The plan recommends potential offshore borrow sites be identified, mapped, and sampled. The plan also recommends funding for the offshore sand resource studies could be shared by Maui County, DLNR, the University of Hawaii, and the U.S. Army Corps of Engineers.

Further, this Beach Management Plan recommends conducting a pilot project for beach nourishment on Maui to illustrate the engineering requirements, permitting requirements, problems and concerns.

XII. REFERENCES

1. Bodge, K.R. and S.P. Sullivan. 1999. Hawaii Pilot Beach Restoration Project: Coastal Engineering Investigation Prepared for Sate of Hawaii, Department of Land and Natural Resources, February 1999.

2. Brown and Caldwell Consultants. 1990. Environmental Assessment and Negative Declaration for the Wailuku-Kahului Wastewater Reclamation Facilities Additions and Modifications, Maui, Hawaii. Report prepared for the County of Maui, Department of Public Works Wastewater Reclamation Facility, November 16, 1990.

3. ———. 2002. Sheet 11, Drawing Number G9, from the Phase IIA Modifications of the Wailuku-Kahului Wastewater Reclamation Facility. Prepared for the County of Maui, Department of Public Works and Waste Management, Revision dated 1/02.

4. Clark, J.R.K. 1980. *The Beaches of Maui County.* The University of Hawaii Press, Honolulu.

5. Coastal Frontiers. 2002. SANDAG Regional Beach Monitoring Program – Spring 2002 State of the Coast Report. Report prepared for SANDAG, September 2002.

6. Cox, D.C. 1954. The Spreckelsville Beach Problem. Experiment Station of the Hawaiian Sugar Planters Association, Honolulu, Hawaii, August 1954.

7. Coyne, M.A., C.H. Fletcher, and B.M. Richmond. 1999. Mapping Coastal Erosion Hazard Areas in Hawaii: Observations and Errors. *Journal of Coastal Research*, Royal Palm Beach, Florida, Spring 1999, SI 28, pp. 171-184.

8. Coyne, M.A., R. Mulane, C.H. Fletcher, and B.M. Richmond. 1996. Losing Oahu: Erosion on the Hawaiian Coast. *Geotimes*, December 1996, pp. 23-26.

9. Eversole, D. 2005. E-mail Communication dated January 19, 2005, Subject: Waikiki Beach.

10. Fletcher, C.H. 1992. Sea-level trends and physical consequences: applications to the U.S. Shore. *Earth-Science Reviews*, 33, 73-109.

11. Fletcher, C.H., E.E. Grossman, B.M. Richmond, and A.E. Gibbs. 2002. Atlas of Natural Hazards in the Hawaiian Coastal Zone, Maui Section. Prepared in cooperation with University of Hawaii, State of Hawaii Office of Planning, and National Ocean and Atmospheric Administration, U.S.G.S Geologic Investigations Series I-2761, U.S. Government Printing Office.

12. Fletcher, C.H. and S.J. Lemmo. 1999. Hawaii's Emergent Coastal Erosion Management Program. *Shore & Beach*, vol. 67, No. 4, October 1999, pp. 15-20.

13. Fletcher, C.H., R.A. Mullane, and B.M. Richmond. 1997. Beach Loss Along Armored Shorelines on Oahu, Hawaiian Islands. *Journal of Coastal Research*, Fort Lauderdale, Florida, Winter 1997, 13:1, pp. 209-215.

14. Gibbs, A.E, B.M. Richmond, and C.H. Fletcher. 2000. Beach Profile Variation on Hawaiian Carbonate Beaches. *Carbonate Beaches 2000, First International Symposium on Carbonate Sand Beaches*, American Society of Civil Engineers, December 5-8, 2000, Key Largo, Florida.

15. Guild, B.Q. 1999. Beach Restoration at Sugar Cove, Maui, Hawaii. *Shore & Beach*, vol. 67, No. 2&3, April & July 1999, pp. 4-18.

16. Hwang, D.J. and C.H. Fletcher. 1992. Beach Management Plan with Beach Management Districts. Hawaii Office of State Planning, Coastal Zone Management Program, Honolulu, pp. 146.

17. Jeon, D. 1995. Sea Level Change and Coastal Erosion in the Pacific Islands. Ph.D. Dissertation, University of Hawaii, May 1995

18. Johnson, J.M. 1973. Letter from University of Hawaii Environmental Center, Beach retreat at proposed site of Wailuku-Kahului wastewater treatment plant, dated March 2, 1973.

19. Laevastu, T., D.E. Avery, and D.C. Cox. 1964. Coastal Currents and Sewage Disposal in the Hawaiian Islands. Final Report prepared as part of the Coastal Currents Project supported by contract with the Department of Planning and Economic Development, State of Hawaii, June 1964, Report No. HIG-64-1.

20. Levin, J. 1970. A Literature Review of the Effects of Sand Removal on a Coral Reef Community. Prepared under the National Science Foundation, Sea Grant Program, Grant No. GH-93, December 1970.

21. Makai Ocean Engineering, Inc. and Sea Engineering Inc. 1991. Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. Prepared for the State of Hawaii, Office of State Planning, Coastal Zone Management Program, June 1991.

22. Moberly, R. and T. Chamberlain. 1964. Hawaiian Beach Systems. Final Report prepared for Harbors Division, Department of Transportation, State of Hawaii, May 1964, Report No. HIG-64-2.

23. Moberly, R., et al. 1963. Coastal Geology of Hawaii. Report prepared as part of the Shoreline Plan of the State of Hawaii, November 1963, HIG Report No. 41.

24. Moffatt & Nichol Engineers. 2000. Kihei Flood Control Systems Analysis and Shoreline Impact Study. Report prepared for the County of Maui, Department of Public Works and Waste Management, August 2000.

25. Nakashima, H.S. 1976. Shore Protection for Kahului Harbor, Maui, Hawaii. *Shore & Beach*, vol. 44, No 3, October 1976, pp. 9-16.

26. National Research Council. 1995. Beach Nourishment and Protection. National Academy Press, Washington, D.C.

27. Noda, E.K. 1991. Final Report – Tsunami Flood Impact Analysis, County of Maui Wastewater Facilities, Wailuku-Kahului, Maui, Hawaii. Report prepared for Austin, Tsutsumi & Associates, September 1991.

28. Oceanit Laboratories, Inc. 1997. Coastal Protection and Beach Restoration Feasibility Study for Maui County. Prepared for the County of Maui, Planning Department, November 1997.

29. University of Hawaii, School of Ocean and Earth Science and Technology. 1998. Coastal Erosion Management Plan (COEMAP) of the State of Hawaii. Technical Supplement Part C. Technical Report 98-04.

30. University of Hawaii Sea Grant Extension Service. 1999. Coastal Erosion and Beach Loss on Maui. *Coastlines*, Issue 9.6, December 1999, pp. 2-3.

31. University of Hawaii Sea Grant Extension Service and County of Maui Planning Department. 1997. Beach Management Plan for Maui. Report dated December 1997.

32. U.S. Army Corps of Engineers. 1971. Hawaii Regional Inventory of the National Shoreline Study. U.S. Army Engineer Division, Pacific Ocean Corps of Engineers, Honolulu, Hawaii, August 1971.

33. ———. 1987. Ports of Hawaii. Prepared by the Water Resources Support Center, Fort Belvoir, Virginia, Port Series No. 50.

34. ———. 1989. Review of the Coasts of the Hawaiian Islands, Navigation Facilities. Interim Report, U.S. Army Engineer Division, Pacific Ocean Corps of Engineers, Honolulu, Hawaii, March 1989.

35. ———. 2003. Kihei Area Erosion, Maui, Hawaii. Information Paper, U.S. Army Corps of Engineers, Honolulu District, Hawaii, 4 November 2003.

36. U.S. Army Engineer District, Honolulu and State of Hawaii. 1964. Hawaiian Island Beaches. Cooperative Beach Study, December 15, 1964.

37. U.S. Environmental Protection Agency. 1974. Final Environmental Statement, Wailuku-Kahului Wastewater Treatment and Disposal System, County of Maui, Hawaii. Prepared by the USEPA, Region IX, San Francisco, California, June 1974.

38. Wiegel, R.L. 2002. Seawalls, Seacliffs, Bedrock: What Beach Effects? Part 1. *Shore and Beach*, Vol. 70, No. 1, January 2002, pp. 17-27.

39. ———. 2002. Seawalls, Seacliffs, Bedrock: What Beach Effects? Part 2. *Shore and Beach*, Vol. 70, No. 2, April 2002, pp. 13-22.

40. ———. 2002. Seawalls, Seacliffs, Bedrock: What Beach Effects? Part 3. *Shore and Beach*, Vol. 70, No. 3, July 2002, pp. 2-14.

APPENDIX A

SITE PHOTOGRAPHS OF THE SHORELINE FRONTING THE WAILUKU-KAHULUI WASTEWATER RECLAMATION FACILITY AND THE WAILUKU WASTEWATER PUMP STATION

JULY 16, 2004

Photo 1. East flank of the revetment fronting the Wailuku-Kahului WWRF.

Photo 2. Looking East from the revetment at the W-K WWRF.
(Notice the old "pill box" offshore.)

Photo 3. Looking West towards the W-K WWRF revetment.

Photo 4. Looking West from the crest of the revetment towards Kahului Harbor.

Photo 5. Looking East from the Revetment. (Notice the old "pill box" offshore.)

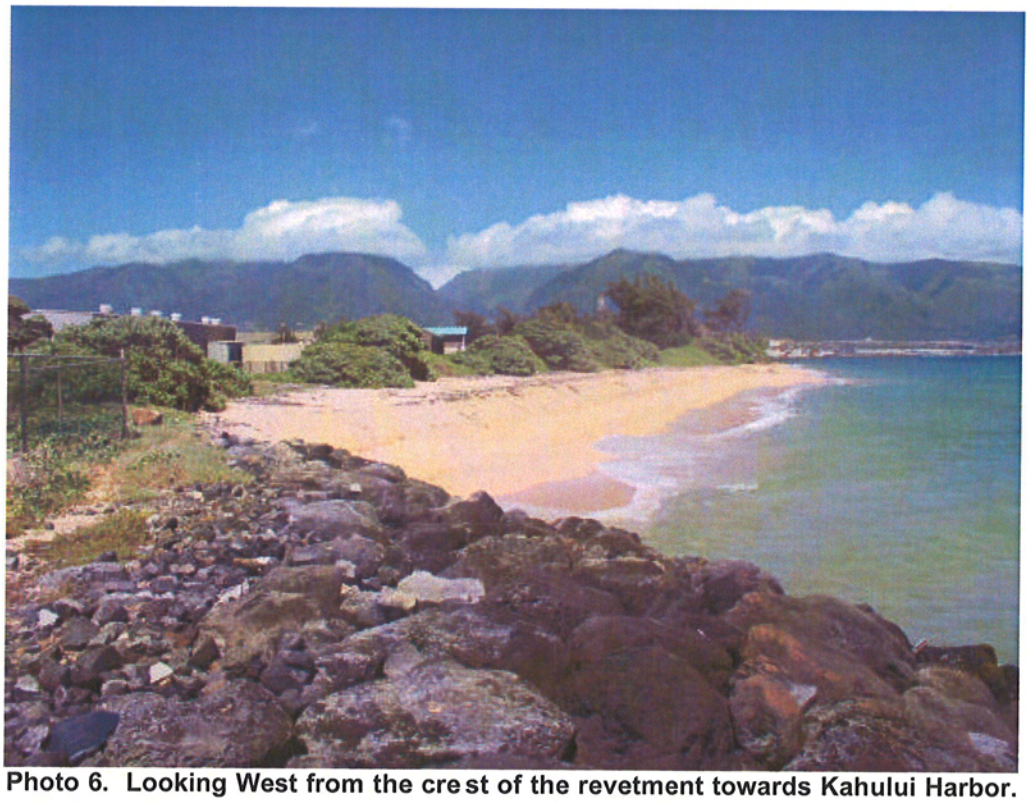


Photo 6. Looking West from the crest of the revetment towards Kahului Harbor.

Photo 7. Looking West from the revetment towards Kahului Harbor.

Photo 8. Looking East towards the revetment.

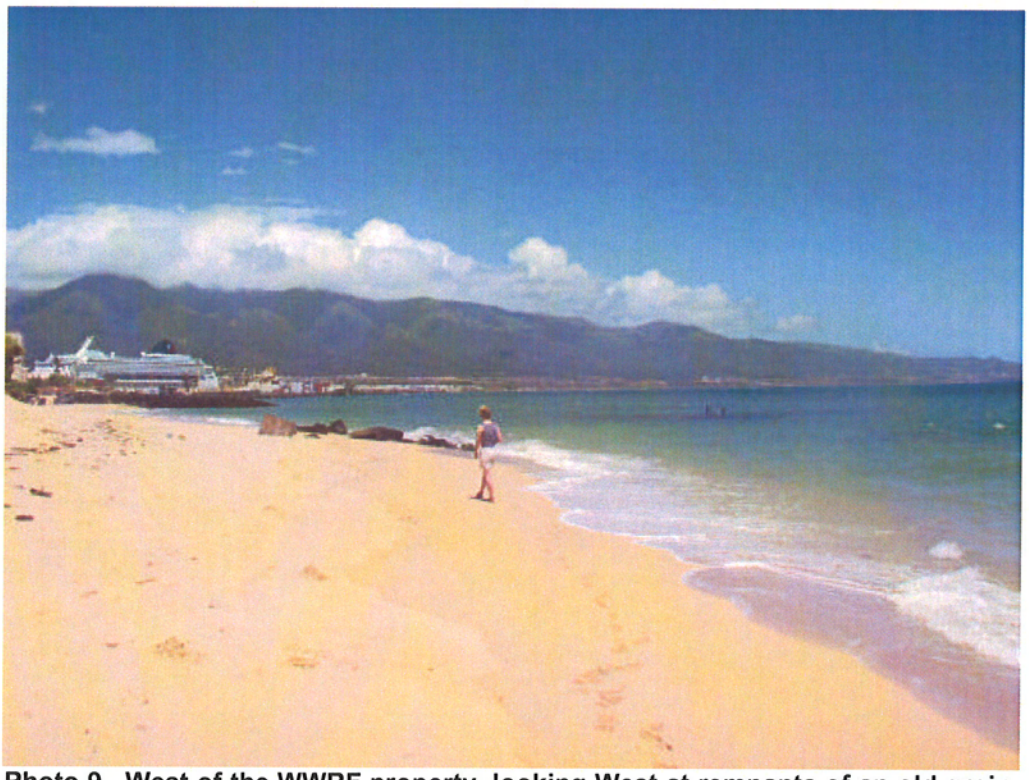


Photo 9. West of the WWRF property, looking West at remnants of an old groin. Kahului Harbor is seen in the background.

Photo 10. Remnants of an old groin (same location as above).

Photo 11. Shoreline looking northwest towards the WWPS.

Photo 12. Shoreline looking southeast towards Kahului Harbor.

Photo 13. Large escarpment fronting the WWPS property (fence).

Photo 14. Looking Southeast along WWPS property line towards Kahului Harbor.

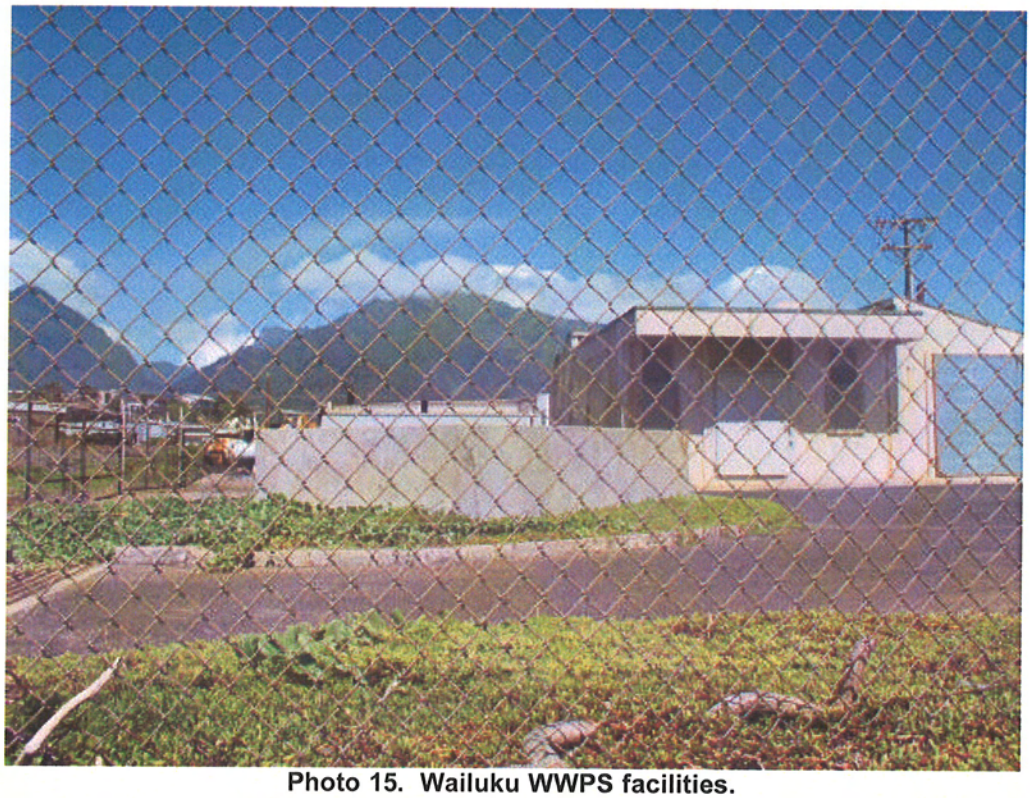


Photo 15. Wailuku WWPS facilities.

Photo 16. Shoreline fronting the WWPS, looking southeast.

Photo 17. Exposed drainage pipe at the WWPS.

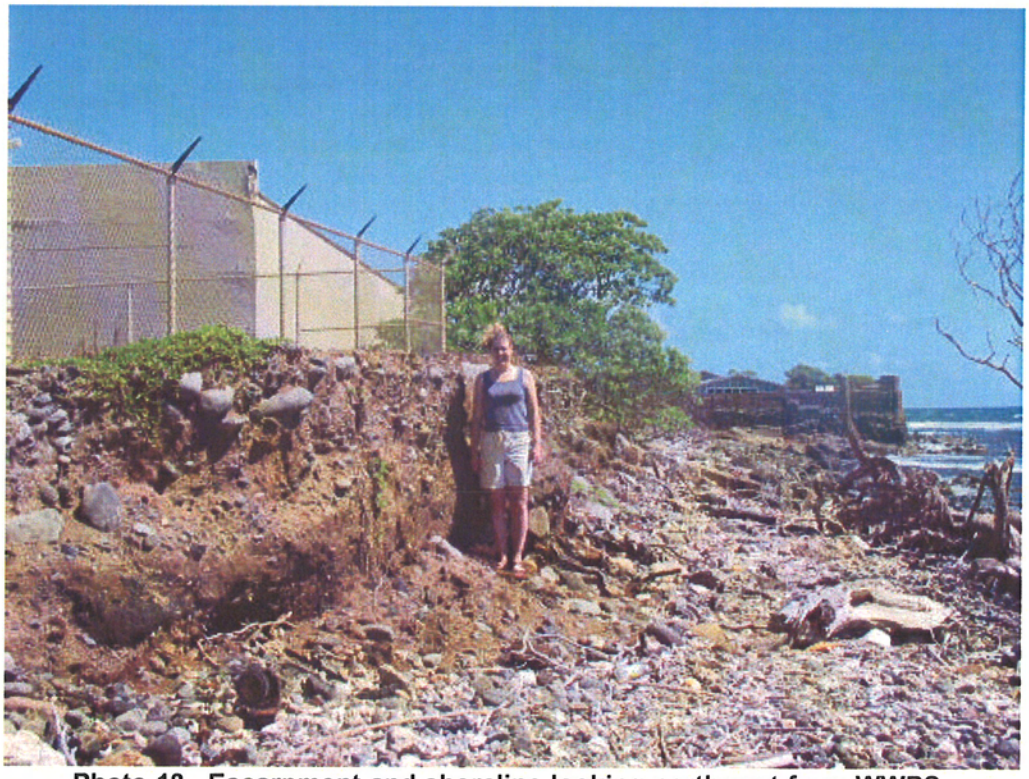


Photo 18. Escarpment and shoreline looking northwest from WWPS.
(notice large seawall fronting property to the north.)

APPENDIX B – COST ESTIMATE DETAILS

WWRF ALTERNATIVES

Alternative 1A - Beach Nourishment (4,000 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
Fill material	215,000	CY	$25	$5,375,000
			Initial Construction Subtotal	$5,425,000
Present Construction Rate Maintenance Costs	86,000	CY	$25	$2,150,000
- 40% of original volume every 10 years				
Project Year			Future Inflated Cost	Present Worth
10			$2,644,500	$1,328,105
20			$3,139,000	$791,716
30			$3,633,500	$460,248
40			$4,128,000	$262,600
			Subtotal	$8,267,670
			Supervision and Administration (6%)	$325,500
			Engineering & Design (10%)	$542,500
			Contingency (20%)	$1,085,000
			TOTAL	**$10,220,670**

Alternative 1B - Beach Nourishment (2,650 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
Fill material	145,000	CY	$25	$3,625,000
			Initial Construction Subtotal	$3,675,000
Present Construction Rate Maintenance Costs	55,000	CY	$25	$1,375,000
- 40% of original volume every 10 years				
Project Year			Future Inflated Cost	Present Worth
8			$1,628,000	$938,352
16			$1,881,000	$624,901
24			$2,134,000	$408,628
32			$2,387,000	$263,449
40			$2,640,000	$167,942
			Subtotal	$6,078,272
			Supervision and Administration (6%)	$220,500
			Engineering & Design (10%)	$367,500
			Contingency (20%)	$735,000
			TOTAL	**$7,401,272**

Alternative 2 - Beach Nourishment with Groin System (2,640 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$100,000	$100,000
Armor Rock	25,050	TN	$75	$1,878,750
Underlayer Rock	14,620	TN	$65	$950,300
Fill Material	132,000	CY	$25	$3,300,000
			Initial Construction Subtotal	$6,229,050
Present Construction Rate Maintenance Costs	40,000	CY	$25	$1,000,000
- 30% of original volume every 10 years				
Project Year			Future Inflated Cost	Present Worth
10			$1,230,000	$617,723
20			$1,460,000	$368,240
30			$1,690,000	$214,069
40			$1,920,000	$122,140
			Subtotal	$7,551,222
			Supervision and Administration (6%)	$373,743
			Engineering & Design (10%)	$622,905
			Contingency (20%)	$1,245,810
			TOTAL	**$9,793,680**

Alternative 3A - Revetment (1,200 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
2000-lb Armor Rock	9,000	TN	$75	$675,000
Quarry Rock	5,000	TN	$65	$325,000
Filter Fabric	12,000	SY	$5	$60,000
			Initial Construction Subtotal	$1,110,000
Present Construction Rate Maintenance Costs	1	LS	$55,500	$55,500
- 5% of original cost every 10 years				
Project Year			Future Inflated Cost	Present Worth
10			$68,265	$34,284
20			$81,030	$20,437
30			$93,795	$11,881
40			$106,560	$6,779
			Subtotal	$1,183,381
			Supervision and Administration (6%)	$66,600
			Engineering & Design (10%)	$111,000
			Contingency (20%)	$222,000
			TOTAL	**$1,582,981**

Alternative 3B - Revetment with Beach Nourishment (1,200 ft revetment, 2,150 ft nourishment)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
2000-lb Armor Rock	9,000	TN	$75	$675,000
Quarry Rock	5,000	TN	$65	$325,000
Filter Fabric	12,000	SY	$5	$60,000
Fill Material	75,000	CY	$25	$1,875,000
			Initial Construction Subtotal	$2,985,000
Present Construction Rate Maintenance Costs				
Fill Material	30,000	CY	$25	$750,000
- 40% of original volume every 8 years				
Revetment	1	LS	$55,500	$55,500
- 5% of original cost every 20 years				
Project Year			Future Inflated Cost	Present Worth
8			$888,000	$511,828
16			$1,026,000	$340,855
20			$81,030	$20,437
24			$1,164,000	$222,888
32			$1,302,000	$143,700
40			$1,546,560	$98,384
			Subtotal	$4,323,091
			Supervision and Administration (6%)	$179,100
			Engineering & Design (10%)	$298,500
			Contingency (20%)	$597,000
			TOTAL	**$5,397,691**

WWPS ALTERNATIVES

Alternative 1 - Revetment (150 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
2000-lb Armor Rock	1,125	TN	$75	$84,375
Quarry Rock	625	TN	$65	$40,625
Filter Fabric	1,500	SY	$5	$7,500
			Initial Construction Subtotal	$182,500
Present Construction Rate Maintenance Costs	1	LS	$10,000	$10,000
- 5% of original cost every 10 years				
Project Year			Future Inflated Cost	Present Worth
10			$12,300	$6,177
20			$14,600	$3,682
30			$16,900	$2,141
40			$19,200	$1,221
			Subtotal	$195,722
			Supervision and Administration (6%)	$10,950
			Engineering & Design (10%)	$18,250
			Contingency (20%)	$36,500
			TOTAL	**$261,422**

Notes:

1) Armor rock was calculated based on the tons per linear foot for WWRF alternative and applying this to the 150-ft project length at the WWRF

2) Maintenance frequency and amount is est engineers estimate

Alternative 2 - Repair Rubble Revetment (150 ft project length)

			Unit Cost	Cost
Item Description	**Quantity**	**Unit**		
Mob/Demob	1	LS	$50,000	$50,000
Rubble	1,700	TN	$45	$76,500
			Initial Construction Subtotal	$126,500
Present Construction Rate Maintenance Costs	1	LS	$25,300	$25,300
- 15% of original cost every 10 years				
Project Year			Future Inflated Cost	Present Worth
10			$31,119	$15,628
20			$36,938	$9,316
30			$42,757	$5,416
40			$48,576	$3,090
			Subtotal	$159,951
			Supervision and Administration (6%)	$7,590
			Engineering & Design (10%)	$12,650
			Contingency (20%)	$25,300
			TOTAL	**$205,491**

Notes:

1) Assume the same amount of rubble (tons) is needed to repair the rubble revetment as was required for the design of the new revetment

2) Assume a cost of $45/ton for rubble. Some existing rubble can be reused and other rubble may have to be imported. The cost is an estimate based on engineering judgment

3) Maintenance assumes that more maintenance will be required of the rubble structure since it is not engineered. Storms will shift the rubble more frequently and require more frequent maintenance to ensure upland protection

APPENDIX C.

Wailuku-Kahului WWRF Preliminary Engineering Report, Shoreline Erosion Control

County of Maui

Wastewater Reclamation Division
Department of Environmental Management

Wailuku Kahului WWRF
Preliminary Engineering Report, Shoreline Erosion Control

November 2008

Prepared by:

moffatt & nichol

Wailuku Kahului WWRF
Preliminary Engineering Report for
Shoreline Erosion Control

Prepared for:
County of Maui
Wastewater Reclamation Division, Department of Environmental Management

Prepared by:
Moffatt & Nichol

In Association with:
SSFM International, Inc.

November 2008

M&N File: 6395

TABLE OF CONTENTS

1. EXECUTIVE SUMMARY 2
1.1 Problem Summary 2
1.2 Alternative Solutions 3
2. INTRODUCTION 7
2.1 Background 7
2.2 Scope 7
3. SITE DESCRIPTION 9
4. COASTAL PROCESSES AND CONDITIONS 11
4.1 Water Levels 11
4.2 Wind 12
4.3 Waves 12
4.4 Precipitation 13
4.5 Typical Hawaiian Beach Characteristics 14
5. WAILUKU-KAHULUI WWRF SHORELINE CHANGES 15
5.1 Introduction 15
5.2 Historical Changes and Anthropogenic Influences on the Shoreline 15
5.3 County of Maui Shoreline Erosion Maps 17
5.4 Recent Observations 23
5.5 USGS Profile Data 28
5.6 Certified Shorelines 32
5.7 Discussion 34
6. SEDIMENT BUDGET ANALYSIS 36
6.1 Overview 36
6.2 Beach Dimensions 36
6.3 Current Erosion Volume Rates 37
6.4 Sediment Inputs and Losses 37
6.5 Longshore Sediment Transport 38
7. PROJECT ALTERNATIVES 40
7.1 No Project Alternative 40
7.2 Alternative 1 - Beach Replenishment 43
7.3 Alternative 3 – Armor Rock Revetment 47
7.4 Alternatives Not Carried Further 53
8. SAND SOURCES 54
8.1 Native Sand Characteristics 54
8.2 Upland Sand Sources 54
8.3 Imported Sand 55
8.4 In-Water Sand Sources 55
9. ENVIRONMENTAL AND REGULATORY CONSIDERATIONS 60
9.1 Potential Environmental Impacts and Benefits 60
9.2 Regulatory Requirements 60
10. COST ESTIMATES 63

11. ALTERNATIVES 65

12. SUMMARY AND CONCLUSIONS 66
- 12.1 Erosion Rates and Infrastructure Risk 69
- 12.2 Sediment Budget 70
- 12.3 Alternatives Analysis 70
- 12.4 Initial Environmental Review 71

13. REFERENCES 72

APPENDIX A. ESTIMATE OF FUTURE BEACH BEHAVIOR

APPENDIX B. COST ESTIMATE SUMMARY

APPENDIX C. SAND SEARCH RESULTS

LIST OF FIGURES

Figure 1. Aerial photograph of the coast from Kahului Harbor to Kaa 10
Figure 2. Tsunami Hazard Map 13
Figure 3. County of Maui Shoreline Erosion Map at the Wailuku-Kahului Wastewater Reclamation Facility. 18
Figure 4. Long-Term Fluctuations in Beach Plan Area at the WWRF Beach, 1889-2007.. 19
Figure 5. Monthly Variation in Plan Area at the WWRF Beach, 1987-2007. 20
Figure 6. Trends in Plan Area at the WWRF Beach, 1987-2007, With and Without Removal of Seasonal Fluctuations 21
Figure 7. Shoreline Change Rate from 1987-1997 and 1997-2007 at the WWRF and Kite Beach. [From UH and County of Maui Shoreline Erosion Map data] 22
Figure 8. Accretion and Erosion at the Coast between Kahului Harbor and Kaa, July 2004 – November 2007 24
Figure 9. Looking East from the Revetment: July 2004 (Note Concrete "Pill Box") 25
Figure 10. Looking East from the Revetment: November 2007 (Note Accretion of Sand)... 25
Figure 11. Looking East from the Revetment: March 2008. (Little Change) 25
Figure 12. Looking West from the Revetment: July 2004 (Note High Back Beach) 26
Figure 13. Looking West from the Revetment: November 2007 (No Large Berm) 26
Figure 14. Looking West from the Revetment: March 2008 (Partial Recovery) 26
Figure 15. Outfall West of Revetment - 2004 (Note Rocks and Distance Offshore) 27
Figure 16. Outfall West of Revetment – 2007 (Rocks Buried and Beach Accretion) 27
Figure 17. Winter Profiles at VKHL from 1995 to 1999. 29
Figure 18. Summer Profiles at VKHL from 1995 to 1999 29
Figure 19. Seasonal Changes in Profiles at VHKL, 1995-1996 and 1996-1997 30
Figure 20. Seasonal Changes in Profiles at VHKL, 1997-1998 and 1998-1999 30
Figure 21. Initial and Final Profiles at VKHL predicted by an SBEACH Model Run for an Extreme Wave Event 32
Figure 22. Certified shorelines at the WWRF, 1997 and 2007 33
Figure 23. Threatened Infrastructure at Wailuku-Kahului Wastewater Reclamation Facility41
Figure 24. Alt. 1A and 1B - Cross-section of beach replenishment at the WWRF site. 44
Figure 25. Plan view of the beach replenishment alternatives at the WWRF site. 46
Figure 26. Plan view of Revetment Alternative 3A 50
Figure 27. Typical Revetment Cross-Section 51

Figure 28. Plan view of Revetment Alternative 3B (With Beach Replenishment) 52
Figure 29. Nearshore Geomorphology near WWRF 56
Figure 30. Sand Thicknesses and Grab Sample Locations (Sea Engineering 2008) 57
Figure 31. Grab Sample 8 Sand 58

LIST OF TABLES

Table 1. Kahului Harbor Tidal Datums 11
Table 2 Average Monthly Rainfall at Kahului (4/1/1954 to 12/31/2005, inches) 13
Table 3. Recession from "Certified Shoreline" Data 32
Table 4. Long-Term Sediment Transport Rates at the Kahului WWRF [Estimates by Everts Coastal: see Appendix A] 38
Table 5. Calculation of Years until WWRF Structures are Threatened, Based on October 2007 Certified Shoreline 42
Table 6. Summary of WWRF Structures that may be threatened 43
Table 7. Approximate Costs for the WWRF Alternatives 64
Table 8. WWRF Alternative Evaluation Criteria 66

Wailuku Kahului WWRF
Preliminary Engineering Report - Shoreline Erosion Control

1. EXECUTIVE SUMMARY

The County of Maui owns and operates the Wailuku-Kahului Wastewater Reclamation Facility (WWRF) on the North Shore of Maui adjacent to the Kahului Harbor. The facility is reaching its design capacity and the County has decided to expand the plant in its present location. As a part of the decision process, Moffatt & Nichol (M&N) was retained to quantify shoreline erosion trends, assess potential causes for erosion, and develop preliminary shoreline protection alternatives for site. (M&N, "Central Maui Wastewater Reclamation Facility, Shoreline Evaluation Report" 2005.) This Preliminary Engineering Report is an update and continuation of the 2005 study and is intended to provide additional detail for the alternatives analysis and allow the County Council to select an option and begin the design and regulatory process.

1.1 Problem Summary

- The major cause of the long-term erosion of the north shore beaches is historic the removal of sand from the beaches for lime production by the sugar company and additional sand mining by others for cement manufacturing and aggregate. This permanent removal of sand from the littoral system has resulted in a deficit in the sediment budget and erosion over the length of the study area from Baldwin Beach to Kahului Harbor.
- The rate of shoreline erosion at the WWRF has slowed since the cessation of sand mining; however, it is still a significant consideration for the long-term safety of the facility.
- Based several different shoreline analysis techniques and data sets, we recommend that a typical seasonal variation of 20 to 30 feet and a maximum seasonal variation of 50 to 60 feet be used for planning. Similarly, we recommend using typical long-term erosion rate of 2.4 feet per year and a maximum long-term erosion rate of 6 feet per year for use in planning, engineering design and estimating the time until facilities are impacted.
- The shoreline at the WWRF facility has demonstrated long-term erosion that threatens several minor structures from a single large seasonal recession event within a year or less. The first major structures to be impacted by this shoreline recession may be threatened in as little as 13 years. If the estimates of acceleration in sea level rise are realized, then the time until the structures are threatened would be reduced. Given the small data set, unpredictability of future storms, unknowns concerning the acceleration of sea level rise, and the typical time required to design, permit, and construct a shoreline protection project (3 to 5 years), **it is recommended that a shoreline protection alternative be selected and implemented as soon as possible.**
- The results of a sediment budget analysis indicate that that the net rate of sediment transport at the shoreline adjacent to the Kahului Wastewater Reclamation Facility is currently between 1,300 and 4,000 cubic yards per year.

- Recent observations and photographs suggest that the shoreline has receded to the point that the existing WWRF revetment may be acting as a groin and may be limiting the transport of sand from Kite Beach towards the Kahului Harbor. This could result in increased erosion to the west of the revetment.

1.2 Alternative Solutions

- There were there basic shoreline stabilization alternatives considered:
    1. Beach Nourishment (two length variations),
    2. Revetment
    3. Buried Revetment.
- It should be assumed that there will be no upland sand sources available to provide suitable sand for a beach nourishment solution for erosion control due to quantity and quality requirements. However, a sand search seaward of the Kahului Harbor breakwater indicated a very large potential source of beach-quality sand that could be dredged for the project.
- A review of the permitting process indicates that the project may be subject to special legislation at the county level due to over-lapping jurisdictions and criteria at the certified shoreline.
- Two erosion control alternatives from the initial study were removed from further consideration. "T-Groins", and any other shore-perpendicular structures were removed due to the low longshore sand transport rates, and "Geotextile Tubes for Revetment" were removed due to durability and stability concerns.
- Four of the original concepts from the initial study were retained for comparative evaluation. Two different beach nourishment scenarios and two revetment scenarios. For planning of beach nourishment project, the estimates of renourishment volumes are 2,000-3,000 cubic yards per year at 8 year intervals. These higher rates provide a larger margin of safety and result in a more practical and economical renourishment plan that minimizes contractor mobilizations and takes advantage of economies of scale.
- A summary of the evaluation is tabulated as follows.

	Alternative 1A 3,800-ft Beach Replenishment	**Alternative 1B 2,400-ft Beach Replenishment**	**Alternative 3A 1,200-ft Revetment**	**Alternative 3B Revetment with Replenishment**
Economic Criteria				
Facility Protection Effectiveness	Basic shoreline erosion protection with sand reserve if properly maintained.	Basic shoreline erosion protection if properly maintained.	The revetment may provide some measure of tsunami protection to the upland facility in addition to protecting the facility from shoreline erosion.	The revetment may provide some measure of tsunami protection to the upland facility in addition to protecting the facility from shoreline erosion.
Initial Construction Cost*	$4 M to $6 M	$3 M to $4.5 M	$3.5 M to $4 M	$5 M to $6 M
Maintenance Cost (NPV)*	$4 M to $7 M	$3 M to $6 M	$0.5 M	$3 M to $6 M
Environmental Criteria				
Regulatory Compliance	Compliant	Compliant	Compliant. May be an unpopular solution (due to aesthetics and access) which may delay permitting. More likely to require mitigation.	Compliant
Effects to Adjacent Shoreline	Significantly increases the width of the beach east of the Kahului WWRF – by an average 40 feet Over time, will increase the width of the beach west of the Kahului WWRF to a lesser extent	Over time, will increase the width of the beach east of the Kahului WWRF through diffusion, and west of the WWRF through diffusion and net longshore transport This increase will be less than for Alternative 1A, and will likely be concentrated in the area close to the WWRF property	If the revetment acts as a groin, this alternative may limit the transfer of sand from the kite beach area to the beach west of the WWRF. Without adding additional sand, the revetment has the potential for causing passive erosion of the adjacent beaches and limiting lateral access.	Similar to Alternative 1B unless the seaward beach erodes, then the effects would be similar to Alternative 3B.

	Alternative 1A 3,800-ft Beach Replenishment	**Alternative 1B 2,400-ft Beach Replenishment**	**Alternative 3A 1,200-ft Revetment**	**Alternative 3B Revetment with Replenishment**
Biology	Short-term turbidity impacts may occur during construction. Additional sediment fate modeling is needed to ensure the reef will not be negatively impacted by sand transported offshore in the short- or long-term Provided appropriate work windows are maintained, the effects on species dependent on the beach are expected to be positive for this alternative	As Alternative 1A, except that both potential positive and negative effects are likely to be less.	Minor effects compared to existing conditions.	Similar to Alternative 1B
Environmental Criteria – Human				
Aesthetics	Positive effect if beach sand is selected with acceptable coloration	Similar to Alternative 1A, except that the effect is observed over a shorter stretch of beach.	The longer revetment may be considered unsightly	Similar to Alternative 1B
Public Access and Usage	Positive effect: approximately 6 acres of additional beach area directly adjacent to heavily-used beaches with good public access	Smaller but still positive effect: approximately 4 acres of additional beach area, approximately one-quarter mile from the most heavily-used beaches	Potential for passive erosion of shoreline and limitations to public access at the site a lateral access to adjacent beaches.	Similar to Alternative 1B if the beach fronting the revetment is maintained.

	Alternative 1A 3,800-ft Beach Replenishment	**Alternative 1B 2,400-ft Beach Replenishment**	**Alternative 3A 1,200-ft Revetment**	**Alternative 3B Revetment with Replenishment**
Effects to Kahului Harbor	Little or no effects anticipated. The proposed replenished beach is well within the historical range of beach widths, and dramatic changes in required maintenance dredging at Kahului Harbor have not been observed over time	Little or no effects anticipated	Little or no effect	Little or no effects anticipated

* Note: Costs are very dependent on the availability of suitable sand for replenishment, and may vary outside this range

2. INTRODUCTION

2.1 Background

The County of Maui owns and operates the Wailuku-Kahului Wastewater Reclamation Facility (WWRF) and has recently completed a study (Austin, Tsutsumi & Associates, "Central Maui Wastewater Reclamation Facility Study," 2005) that addresses the future wastewater treatment for the next 20 to 30 years. The WWRF is nearing its design capacity and is located on an actively eroding shoreline, so the report presented alternatives including relocating the facility, increasing the capacity of the current facility, or directing some of the future flows to another facility or facilities. Based on the report findings, the County concluded the WWRF should remain in its present location and erosion control measures should be implemented to provide long-term protection for the facility.

As a part of the initial study, Moffatt & Nichol (M&N) was retained to quantify the shoreline erosion trends, assess potential causes for erosion, and develop preliminary shoreline protection alternatives for the Kahului WWRF site. (M&N, "Central Maui Wastewater Reclamation Facility, Shoreline Evaluation Report," 2005.) This report is a continuation of the 2005 study and is intended to provide additional detail for the alternatives analysis and allow the County Council to select an option and begin the design and regulatory process.

2.2 Scope

The specific scope for this phase of the project included:

- Site Visits – Attend kick-off meeting, site investigation, meetings with regulatory agencies in Honolulu.
- Data Review – Review updated data, drawings, surveys, and reports. Identify additional data requirements.
- Develop General Evaluation Criteria – Update the criteria from the Shoreline Evaluation Report with input from the County. At present, these criteria are presented in a qualitative form for discussion. If the County wishes, they will be quantified for use in a pairwise ranking analysis as defined in the scope.
- Sediment Budget Analysis – Conduct a preliminary sediment budget analysis to evaluate the past and present littoral transport of the system, identify short- and long-term variations in the transport rates, and evaluate seasonal changes in transport to help determine potential beach replenishment and maintenance volumes.
- Investigate Sand Sources – Investigate existing studies and data, and meet with local sand suppliers to gather information on material quality, available quantities, and cost.
- Develop Mitigation Alternatives – Identify mitigation alternatives for the observed shoreline erosion, including beach replenishment, beach replenishment with retention structures, geotextile solutions, and shore protective devices such as revetment or seawalls. The evaluation of these alternatives will result in the identification of one preferred approach, however, it is anticipated that all of the measures will be carried to the permitting phase to satisfy the regulatory agencies' alternatives analysis requirements.

- Investigate Permit Requirements – Coordinate with the local planner on the team to identify permits required for project implementation and meet with the Corps of Engineers, County of Maui Planning Department, and the DLNR to help determine an acceptable alternative.
- Develop Construction and Maintenance Costs – Develop opinions of probable construction and maintenance costs for each mitigation alternative. Costs are presented both as present value and annualized costs to assist in overall comparison of life-cycle costs.
- Prepare Matrix Analysis of Alternatives – Preparation of a matrix showing each of the alternatives, summarizing advantages, disadvantages, cost information and permit issues, as well as rankings under the various evaluation criteria to assist in formulating a basis for selection of a recommended alternative.

3. SITE DESCRIPTION

The Kahului-Wailuku WWRF is located on the north shore of the island of Maui, approximately one mile east of the Kahului Harbor. Figure 1 is an aerial photograph of the site. The area immediately west of the WWRF is considered a heavy industrial area and includes oil tank farms, auto storage yards, warehouses, and a power plant (Brown and Caldwell 1990). The port facilities at Kahului Harbor are located approximately ½ mile to the west of the WWRF. The Kahului Airport is located approximately one mile east of the WWRF and Kanaha Beach Park is located approximately ¾ mile to the east of the WWRF.

The 13,000-foot long beach extending east from Kahului Harbor is also known as Spreckelsville Beach (and Kite Beach). This reach is broken into a series of pocket beaches separated by manmade groins and by natural beachrock and lava points (Moberly 1963 and USACE 1971). The beach sand is poorly sorted calcareous sand, ranging in size from medium-sized grains to cobbles. The beaches along this reach are backed by large sand dunes. The Spreckelsville Beach area is heavily used by locals and visitors for world-class kite surfing and windsurfing, as well as fishing and regular beach recreation.

The WWRF site is bounded on the north by approximately 1,350 linear feet of shoreline in Kahului Bay. A 520-foot existing rock revetment along this shoreline constructed between 1977 and 1978 fronts the WWRF retention pond (Makai Ocean Engineering and Sea Engineering 1991). For much or all of the time since its construction, there has been essentially no beach in front of the revetment.

A large fringe reef located just offshore extends for several miles along this reach. The reef is characterized by a wide crest (one-half to one mile in width) extending from a shallow nearshore toe to depths ranging from 10 to 30 feet (Cox 1954). Closer to the Kahului Harbor, the reef is narrow or absent (Cox 1954).

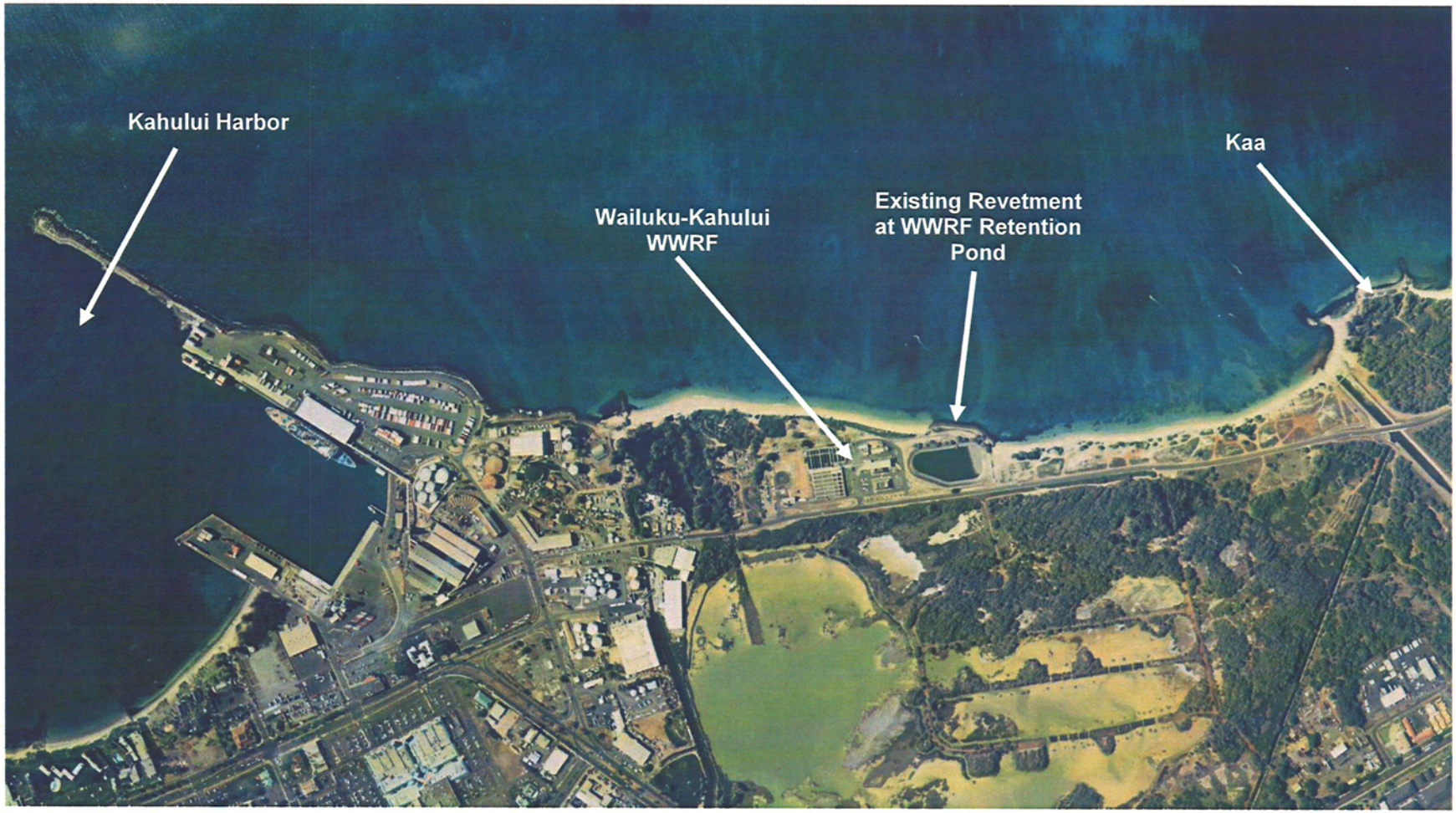


Figure 1. Aerial photograph of the coast from Kahului Harbor to Kaa

4. COASTAL PROCESSES AND CONDITIONS

This section presents a summary of the water levels, wave conditions, and climate conditions (wind and precipitation) for the site as determined in the Shoreline Evaluation Report (M&N 2005) and as background to the Sediment Budget Analysis (see Appendix A).

4.1 Water Levels

Tides in the Hawaiian Islands are semi-diurnal, with two high waters and two low waters each tidal day. The tidal range varies from tide to tide, thus the tides are considered to have a diurnal inequality. The mean tide range is approximately two feet, and the maximum annual tide range is approximately four feet. Tide data for Kahului Harbor are presented in Table 1 [1].

Table 1. Kahului Harbor Tidal Datums

Highest Observed Water Level (1/9/74)	3.70 feet
Mean Higher High Water (MHHW)	2.35 feet
Mean High Water (MHW)	1.97 feet
Mean Sea Level (MSL)	1.17 feet
Mean Tide Level (MTL)	1.16 feet
Hawaiian Geodetic Vertical Datum (HGVD)	0.90 feet
Mean Low Water (MLW)	0.35 feet
Mean Lower Low Water (MLLW)	0.00 feet
Lowest Observed Water Level (6/20/55)	-1.40 feet

In addition to normal short-term periodic fluctuations of the sea surface, there is also a progressive change in sea level. Relative sea level changes on the Hawaiian Islands are caused by rising sea levels, which may be accelerated by global warming, and land subduction, which are caused by the plate movements of the islands.

Globally, the mean sea level has risen by 10 to 30 cm (4 to 12 inches) over the last century. In the Hawaiian Islands, land subduction increases the rate of relative sea level rise. The rate of land subduction decreases from the island of Hawaii to the northwest (D. Jeon 1995). Therefore, the island of Maui subsides faster than Oahu and Kauai, since it is located closer to Hawaii. Tide gauge data from Kahului, Maui presented by NOAA[2] show a relative sea level rise of 2.09±0.43 mm per year (8.2±1.7 inches per century).

Several studies indicate future sea level rise may increase considerably (Fletcher 1992 and Fletcher *et al.* 2002). The median sea level increase on Maui is predicted to be 9.1 inches over the next 50 years and over 19 inches over the next century. More recent (date) work by Fletcher (http://www.soest.hawaii.edu/coasts/sealevel/) indicates that a value of 40 inches by 2100 is "highly likely." The risk of seal level rise to Maui's critical infrastructure is highlighted in Norcross-Nu'u, Charles Fletcher, et al. 2008, *Bringing Sea-Level Rise Into Long-Range Planning Considerations on Maui, Hawaii*, where the WWRF facility is explicitly identified. In addition, the paper cites the potential for rates that range as high as 1.6m (63 inches) per century. The large variations in these potential predictions warrants serious consideration for shore protection systems at critical infrastructure locations with a design life of 50 – 100 years.

[1] Obtained from <<http://co-ops.nos.noaa.gov/benchmarks/1615680.html>>
[2] Obtained from << http://tidesandcurrents.noaa.gov/sltrends/sltrends_station.shtml?stnid=1615680>>

4.2 Wind

The predominant winds in the vicinity of the Hawaiian Islands are the northeast trade winds, which are present approximately 70 to 75 percent of the time – primarily between April and November. The other 25 to 30 percent of the year produces Kona winds predominantly from the south to southwest.

Trade winds generally range from 10 to 25 mph, although they can reach 40 to 50 mph during extreme events (Fletcher et al. 2002). On Maui, the trade winds are strongly influenced by topographic conditions. For example, at Maalaea and Kihei the wind speeds can be higher than at the north shore due to the trade winds accelerating across the island's isthmus. At the Kahului site, however, the northeast trade wind direction is unaffected by the island topography, and is from the unobstructed prevailing northeast direction.

Winter is characterized by a weakening of the northeast trade winds (Moberly and Chamberlain 1964) and the appearance of the southwesterly Kona winds. The Kona winds are characterized by light and variable winds that persist for a few days to a few weeks at a time. Although Kona storms are capable of generating wind speeds exceeding 30 knots, the frequency of occurrence is low.

4.3 Waves

Ocean waves are the critical driving force in the movement of beach sand along a shoreline. This section provides a brief summary of the wave climate that affects the WWRF site on the north shore of central Maui.

Northeast Trade Waves – These waves are generated by the northeast trade winds that prevail approximately 75 percent of the year. Northeast trade waves are characterized in deep water by wave heights which are typically 4 to 12 feet but up to 20 feet, and periods ranging from 5 to 12 seconds. They occur most frequently and are the largest during the months from April through November. Information from north Maui residents and a lifeguard indicate the season with the most sand loss on the beach occurs during the period of the northeast trade waves and the sand losses increase towards the end of the season.

North Pacific Swell – The North Pacific swell, for which the large surf on the north and northwest coasts of Hawaii has become famous, is due to the waves generated from North Pacific extra-tropical cyclones. These large waves have heights in excess of 20 feet and periods ranging from 10 to 15 seconds. The North Pacific cyclones travel eastward and generate waves that approach the northwestern exposed shores of the islands. These waves are most likely to occur from October through April.

Local Storms and Hurricanes – Local storms and hurricanes are infrequent. Tropical storms generated off the coast of Mexico move westward through the equatorial region and occasionally deflect northward toward the Hawaiian Islands. Hurricane Iniki in September 1992, Hurricane Iwa in November 1982, Hurricane Dot in August 1959, and Hurricane Nina in December 1957 are the major hurricanes that have caused damage to the Hawaiian shoreline in the past 40 years.

Tsunami – Tsunamis are "the mostly deadly natural affecting Hawai'i" (Curtis 2008), although they are relatively infrequent. The WWRF is located well within the Tsunami Hazard Zone established by University of Hawai'i under direction of State Civil Defense. (Figure 2) The 1946 Tsunami destroyed the waterfront at Hilo, Hawaii and caused widespread flooding as far as 1.6 km (1 mile) inland. (Keating, 2008) Walker (1994) found that since 1937 there have been

11 tsunamis with a wave runup of 1 meter (3.3 feet) or more, with certain areas of Oahu experiencing runups of 7.2 meters (24 feet.). Modifications to the WWRF for tsunami protection area subject of a larger study presently being performed by the County.

Figure 2. Tsunami Hazard Map

4.4 Precipitation

The average monthly precipitation at Kahului is presented in the table below. The average annual total is estimated to be approximately 19 inches per year (Western Regional Climate Center website at <<http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?hikahu>>).

Table 2 Average Monthly Rainfall at Kahului (4/1/1954 to 12/31/2005, inches)

Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	TOTAL
3.70	2.55	2.64	1.44	0.69	0.23	0.48	0.48	0.35	1.03	2.31	3.04	18.93

4.5 Typical Hawaiian Beach Characteristics

The following provides a general description of Hawaiian beaches including their formation and composition. Most of the information is derived from the study *Hawaiian Beach Systems* by Moberly and Chamberlain (1964).

Each of the Hawaiian Islands was formed by volcanoes that built up basaltic lava in intermittent layers from the seafloor. The general succession of island formation has been from northwest down the island chain to the southeast, with Maui being one of the more recent geologic formations. Maui was formed by the two adjacent volcanoes of Haleakala and West Maui, with an isthmus connecting the two. Kahului is located on the north side of Maui.

Coral reefs are found along much of the Hawaiian Island shorelines. These wave-resistant structures are formed by shallow-water organisms in warm-water environments. The most common type of reefs found in Hawaiian waters is fringing reefs. Fringing reefs along the sheltered leeward coasts in Hawaii are some of the wider and flatter reefs in the islands. Commonly, they have detrital (originating from the land after weathering and erosion) grains mixed with the predominantly calcareous sands covering them and their adjacent beaches. These reefs were the ones most utilized by the ancient Hawaiians for their fish ponds.

Hawaiian beaches mainly consist of medium grain-size sand, although their sediments actually range from gravel to sandy mud. Many beaches have coarse sand; most Maui beaches have fine sand. Hawaiian beach sand is composed of two general types of grains mixed together in proportions that vary from one locality to another. Light-colored calcareous grains of biochemical origin, the fragments of skeletal parts of certain marine invertebrate animals and algae, contrast with dark-colored silicate grains of detrital origin.

5. WAILUKU-KAHULUI WWRF SHORELINE CHANGES

5.1 Introduction

This section discusses long-term shoreline changes over periods during the last 100 years. The shoreline reach considered here is approximately 5-miles long and extends east from Kahului Harbor to Paia Bay. It is broken into a series of pocket beaches by manmade groins and natural lava and beachrock points. Most of the attention is applied to the 4,400-feet stretch of beach from the Kahului Harbor breakwater to Kaa Point, and in particularly the 2,100 feet of beach west of the WWRF revetment and fronting the WWRF. This section refers to the shoreline west of the WWRF revetment as the WWRF beach, and the shoreline east of the WWRF revetment as Kite Beach.

Natural and anthropogenic processes affecting this shoreline are unusually varied and complex. Seasonal fluctuations are overlaid on long-term changes in the beach caused by long-term changes in sediment supply and littoral transport.

The primary sediment source is from biological production, with foraminifers and other small marine organisms transported in from the reef edge. Sand is transported by winds and waves, and additional sand enters the littoral system as the beaches retreat and the underlying substrate erodes. Anthropogenic processes affecting the system have included construction of Kahului Harbor and its east breakwater, sand mining and later beach replenishment east of the WWRF, damage to the coastal dune system, construction of revetments and groins along the shoreline, and (possibly) a decrease in reef productivity resulting from ocean warming and/or increased turbidity in nearshore waters. Some of these influences are described in more detail in Sections 5.2.2 to 5.2.5.

This section reviews the different sources of data used to describe and understand past shoreline behavior, and so to predict its future behavior. The main data sources are: early, generally qualitative literature (lime kiln removal of sand, etc.); erosion maps from the County of Maui (based upon aerial photography over the past century); site visits performed by Moffatt & Nichol in 2004 and 2007; and beach profiles measured by the USGS between 1995 and 1999.

5.2 Historical Changes and Anthropogenic Influences on the Shoreline

5.2.1 Early Observations

Shoreline erosion in the vicinity of the Kahului WWRF has been documented for over 100 years. Doak Cox (1954) stated the shoreline between Kahului and Paia had been eroding for at least 50 years, since soon after the turn of the last century. Cox stated the only portion of the shoreline that was not eroding was the area east of the Kahului Harbor breakwater, where the beach had been accreting over a length of 2,400 feet. This accretion resulted from the construction of the Kahului Harbor breakwaters and the longshore transport of sediment flow from east to west. Cox's 1954 report does indicate this area adjacent to the east breakwater had recently started to recede.

Other reports which outline early erosional trends along the project area include a report by Moberly (1963), which states "lines of beachrock awash at the waterline as much as 800 feet offshore show the historical record of erosion is merely the latest stage in a process operating over the last few hundred years." In the report, Moberly indicates sand mining was being

conducted along the eastern end of the 5-mile long section of beach that extends east from the Kahului Harbor. He identified changes in the beach configuration caused by the mining and stockpiling operations. Another report by the US Army Corps of Engineers and the State of Hawaii (1964) describes the beach as having "moderate to minor erosion in recent years."

5.2.2 Kahului Harbor Breakwater

The east breakwater of Kahului Harbor was originally constructed in 1900, and the first breakwater improvements constructed by the Corps of Engineers were completed in 1913 (USACE 1988). While the long-term effects of the breakwater structure and dredging practices are not known in detail, it is clear that the breakwater (and adjacent groin to the east) caused significant accretion to the adjacent WWRF beach in the early years of the twentieth century.

5.2.3 Sand Mining

Sand mining for lime production by the sugar company and later mining by others for cement manufacturing and aggregate has had a profound effect on the beaches between Kahului Harbor and the mining site at the lime kilns near Baldwin Beach, nearly 5 miles east of the Kahului Harbor breakwater. Mining apparently began around 1900 and ended sometime between 1960 and 1975. Large-scale sand mining was prohibited in 1986 (University of Hawaii Sea Grant Extension Service and County of Maui Planning Department 1997).

In 1954, it was estimated (Cox) that approximately 12,000 cubic yards per year (cy/yr) of sand had been mined from the beach area to the east of the WWRF. Also, Levin (1970) states the dredging during sand mining efforts offshore of the lime kilns changed the bathymetry of the nearshore area, creating "new deep water areas"; it may also have caused turbidity which can affect the adjacent reef systems. Since the cessation of the sand mining, the erosion rate in the area has substantially lessened.

5.2.4 Beach Replenishment

Sugar Cove is located approximately 3 to 3.5 miles east of the Kahului WWRF. Sand has been added to the beach at Sugar Cove by the Sugar Cove Apartment Owners Association resulting in significant increases in the local beach width. 17,000 cubic yards of sand were placed at Sugar Cove between 1996 and 2002, according to data supplied by Ms. Barbara Guild of the Association. More details of the beach replenishment are given in Appendix A.

5.2.5 Reefs

Biological production is responsible for all the new sediment entering the littoral system east of Kahului Harbor according to Moberly (1963). The chief constituent is foraminifers. These small marine organisms are transported in from the reef edge. Living mollusks and echinoids are found there too, but they, as well as living coral, are rare or absent on the reef flat. Algae are the only common inhabitants there. From high to low in scale of supply, the sources of beach sediment are: foraminifer skeletons, mollusks, red algae, echinoids, corals, and green algae.

It has been speculated (Sea Engineering 1991 and Guild 1999) that the reefs located offshore of the Spreckelsville Beach area may not be as productive as they have been in the past. If the reef is less productive, then there would be a decrease in the coralline sand washed onshore from the reef system. This may be a result of ocean warming. In addition, stream flooding can cause significant flows from Maui's rivers. The discharge can cause high levels of turbidity in coastal waters. The increased turbidity, if prolonged, may have an adverse impact on the local reefs.

WWII training exercises destroyed portions of Maui's reefs during the early to mid-1940s. This is evidenced on South Maui, at south Kalama Park in 1943-1945. The Navy underwater demolition team blew up reefs as practice for beach landings for the war in the Pacific. Also, there is evidence that other reefs in south Maui were destroyed by the Navy in 1945 at the request of the County of Maui in an attempt to improve the quality of the swimming beach (Halama Beach Homeowners Association 1999). Evidence supporting these types of activities on Maui's north shore has not been found, but it has been speculated that some of the WWII training exercises did take place along the Spreckelsville Beach area.

5.3 County of Maui Shoreline Erosion Maps

5.3.1 General Description

The County of Maui Shoreline Erosion Maps were compiled using aerial photography and historic T-sheets to determine long-term historic trends in shoreline position. The earliest shoreline position on the County Maps is the 1899 shoreline (which does not include the WWRF revetment); this is followed by 1912, 1929, 1960, 1975, 1987, 1988, 1997, and 2002. More recent (2007) aerial photography, used here to update the erosion estimates, was obtained from the University of Hawaii.

Using the digitized shorelines, the County calculates the Annual Erosion Hazard Rate (AEHR) in feet per year (ft/yr). The shorelines and associated AEHR (red bars) for the section of coast from Hobron Point to Kaa are shown in Figure 3. At the western end of the map, the AEHR ranges from -0.5 ft/yr to almost -3.0 ft/yr. From the western edge of the WWRF property line, the AEHR increases gradually from near 0.0 ft/yr to slightly over -4.0 ft/yr at the eastern terminus of the map. Directly fronting the WWRF, the historic long-term AEHR is shown to be between -1.0 and -2.5 ft/yr. Once a section of coast is armored, the long-term shoreline erosion rate only consists of the pre-armored time frame. The current erosion rate at the WWRF revetment is likely less than shown here, because the structure has halted further shoreline retreat.

5.3.2 Further Analysis

More detailed analysis of the information contained in the aerial photography has been performed by M&N and is described in this section. The analysis includes seasonal, short-term (a few decades), and long-term (up to a century) effects.

The basic analysis performed by M&N included the digitization of the shoreline from the June 2007 aerial photography, measurement of beach widths and beach plan areas from those photographs, and measurement of changes in those beach widths and beach plan areas between the earlier dates (listed above) and June 2007. The following discussion, and the sediment budget in Appendix A, is based on these measurements.

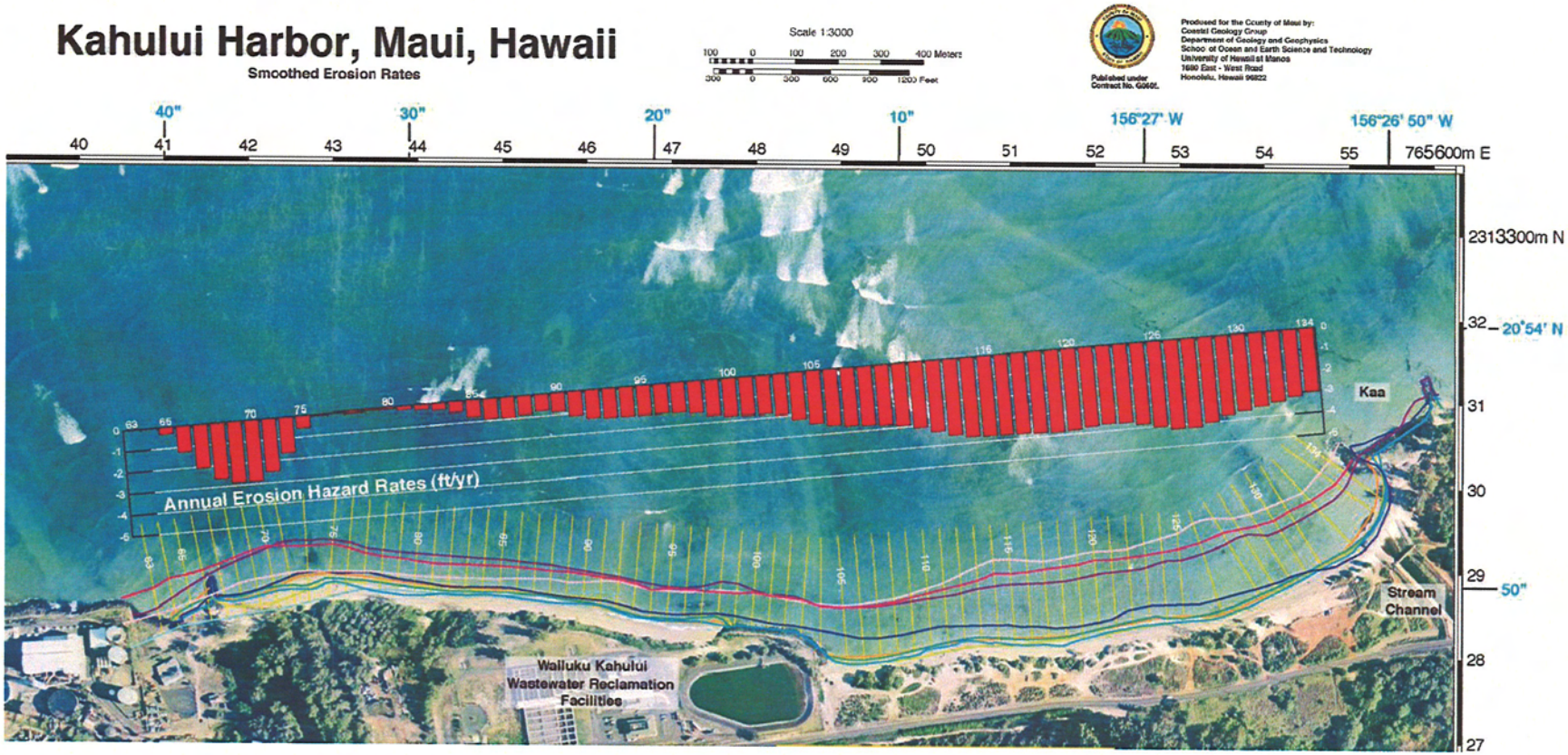


Figure 3. County of Maui Shoreline Erosion Map at the Wailuku-Kahului Wastewater Reclamation Facility.

5.3.3 Long-Term Changes

Figure 4 illustrates the long-term fluctuations in the plan area of the WWRF beach (west of the revetment fronting the WWRF pond) and Kite Beach (east of the revetment) relative to the 2007 beach area. The behavior of the two beaches was very different in the early part of the century. It appears that the WWRF beach accreted rapidly in response to the construction of the Kahului Harbor breakwater in the early 1900s, but the effects of the breakwater did not extend to Kite Beach. Dramatic erosion at both beaches between 1960 and 1987 has been followed by a relatively stable period from 1987 to 2007.

As will be described in Section 6, the decrease in erosion rate is believed to be associated with the cessation of large-scale sand mining east (upcoast) of this stretch of shoreline, and with the general decrease in the rate of sediment transport that comes with shoreline retreat.

A more detailed spatial analysis of the long-term shoreline accretion and erosion trends, from 1912 to present, and a comparison with data presented by Sea Engineering (1991), are given in M&N's "Central Maui Wastewater Reclamation Facility, Shoreline Evaluation Report" (2005). Shorter-term (seasonal and decadal) fluctuations are discussed in more detail below.

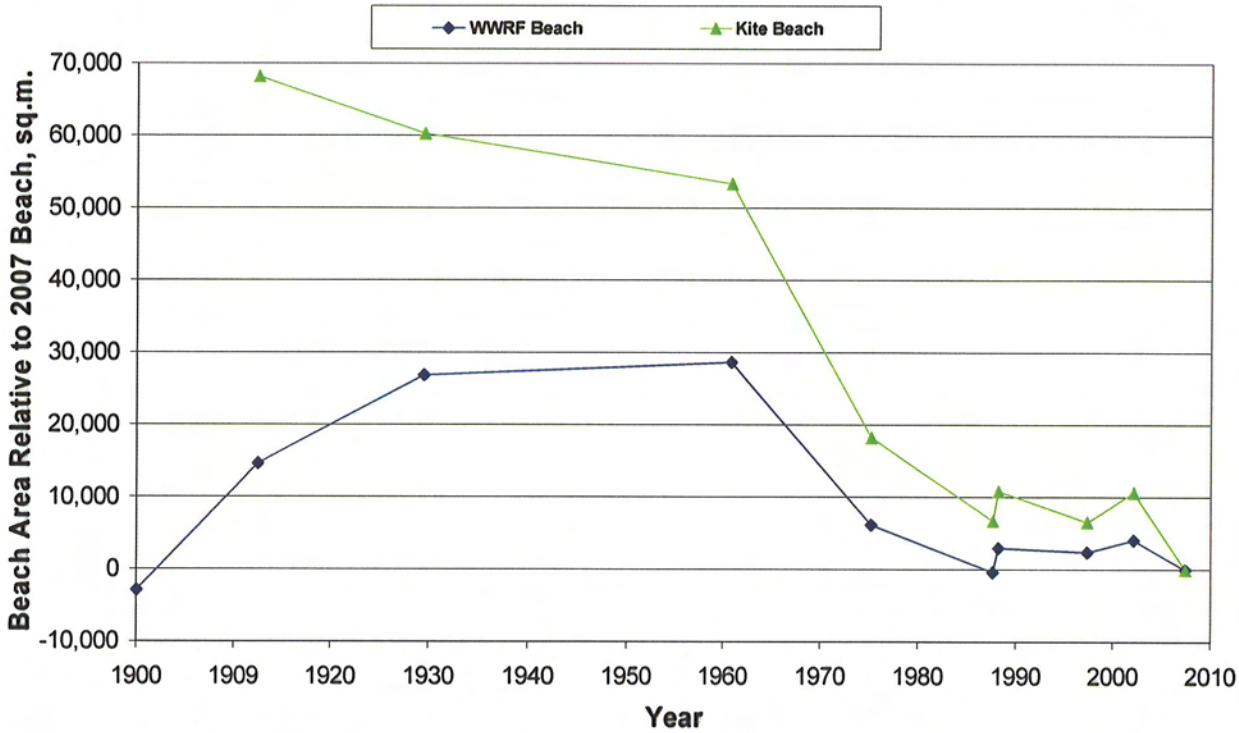


Figure 4. Long-Term Fluctuations in Beach Plan Area at the WWRF Beach, 1889-2007.

5.3.4 Seasonal Fluctuations

As shown in Figure 4, the WWRF beach has been relatively stable since 1987. An estimate of average seasonal fluctuations in the beach can be obtained by plotting the beach plan area over this period against the month of observation. The results, shown in Figure 5, strongly suggest the beach area decreases during the summer months. This figure gives the plan area relative to the widest, February 2007, data set.

The seasonal change in plan area measured in this way is approximately 50,000 square feet of beach for the 2,160 shoreline feet of the WWRF beach. The change in beach area corresponds to a seasonal beach width fluctuation of 23 feet. The results for Kite Beach are more variable but are generally consistent with this value.

This is a typical change in beach area, and does not account for inter-annual variability or for additional losses that may occur at the end of the northeast trade season – between August and October. As such, it appears to provide a lower limit on the seasonal fluctuations that should be incorporated in the design of a beach replenishment or other infrastructure protection program.

To highlight the importance of the seasonal fluctuations, Figure 6 shows the plan area of the WWRF beach, with and without correction for these average seasonal fluctuations, for the period 1987 to 2007. The majority of the fluctuations appear to be seasonal rather than inter-annual.

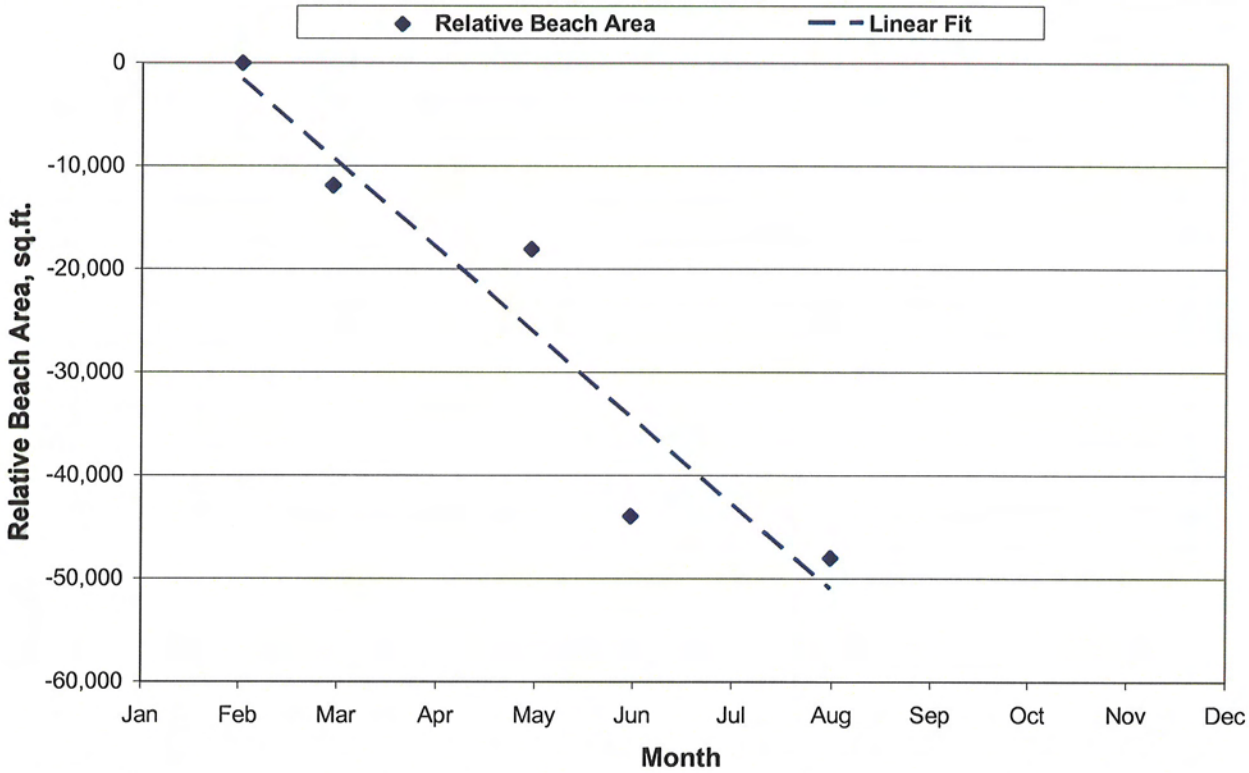


Figure 5. Monthly Variation in Plan Area at the WWRF Beach, 1987-2007.

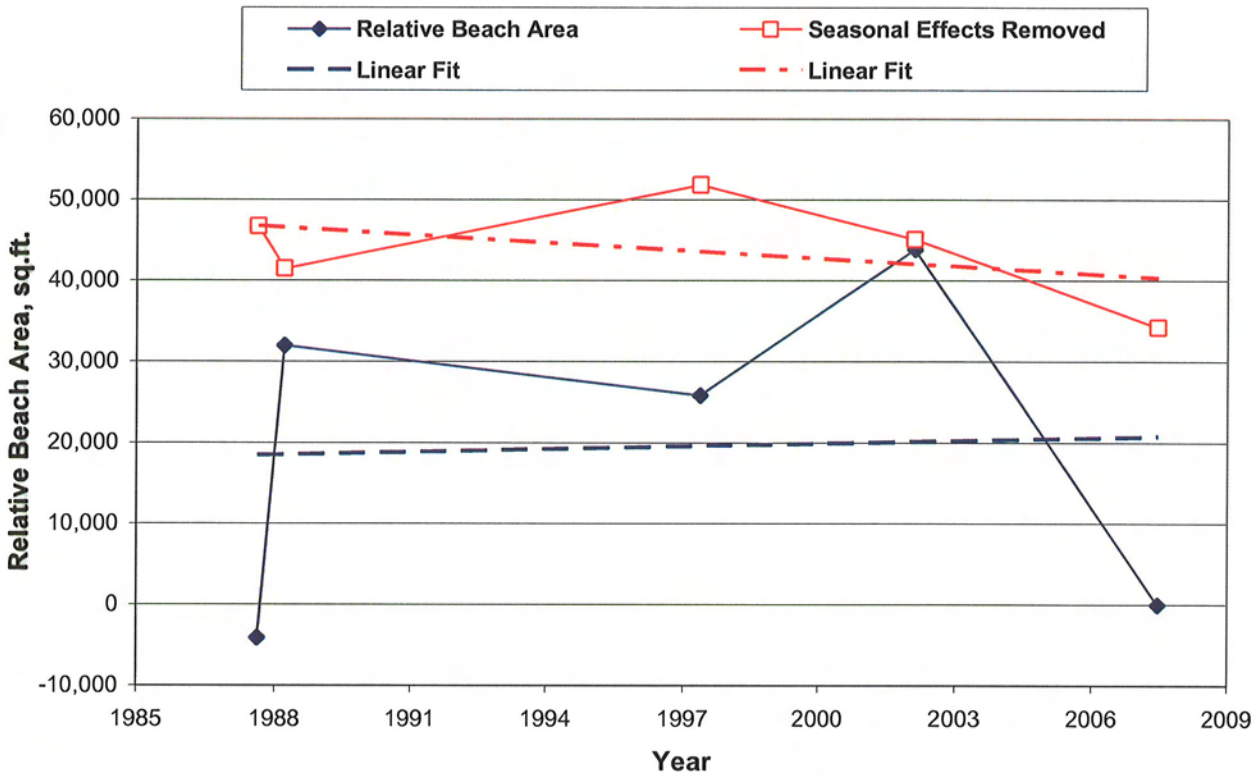


Figure 6. Trends in Plan Area, WWRF Beach, 1987-2007, With and Without Seasonal Fluctuations

5.3.5 Alongshore Patterns of Shoreline Change

The shorter-term (decadal) patterns of shoreline change west and east of the WWRF pond and revetment can be investigated by plotting the change in beach area or shoreline position between measurements. This section focuses on the recent decades 1987 to 2007. Earlier shoreline accretion and erosion trends, from 1912 to present, and a comparison with data presented by Sea Engineering (1991), are given in M&N's "Central Maui Wastewater Reclamation Facility, Shoreline Evaluation Report" (2005).

Figure 7 illustrates the erosion (negative) and accretion (positive) rates between recent surveys at ten-year intervals for the WWRF beach and Kite Beach. The shoreline change rate is shown for each transect on the County Shoreline Erosion Maps. The transect spacing is approximately 20 meters (66 feet): Station 70 is located west of the WWRF property, and Station 134 is located at Kaa, east of the Stream Channel.

The intervals shown are from 1987 to 1997 (dashed pink line) and from 1997 to 2007 (solid blue line). The shoreline position at each transect was subtracted from the previous shoreline position and then divided by the number of years between shoreline surveys. This produces a shoreline change rate in feet per year (ft/yr).

From 1987 to 1997 (dashed pink line), the WWRF beach west of the WWRF revetment accreted at a rate of approximately +2.0 ft/yr over most of its length. This equates to a shoreline advance of approximately 20 feet. At the revetment, the shoreline change rate is 0.0 ft/yr. As shown in Figure 1 and Figure 3, there is essentially no beach in front of this revetment, which is acting as a fixed point. At Kite Beach east of the revetment, the shoreline showed a slightly erosional trend, on the order of 0.0 to -2.0 ft/yr, between 1987 and 1997.

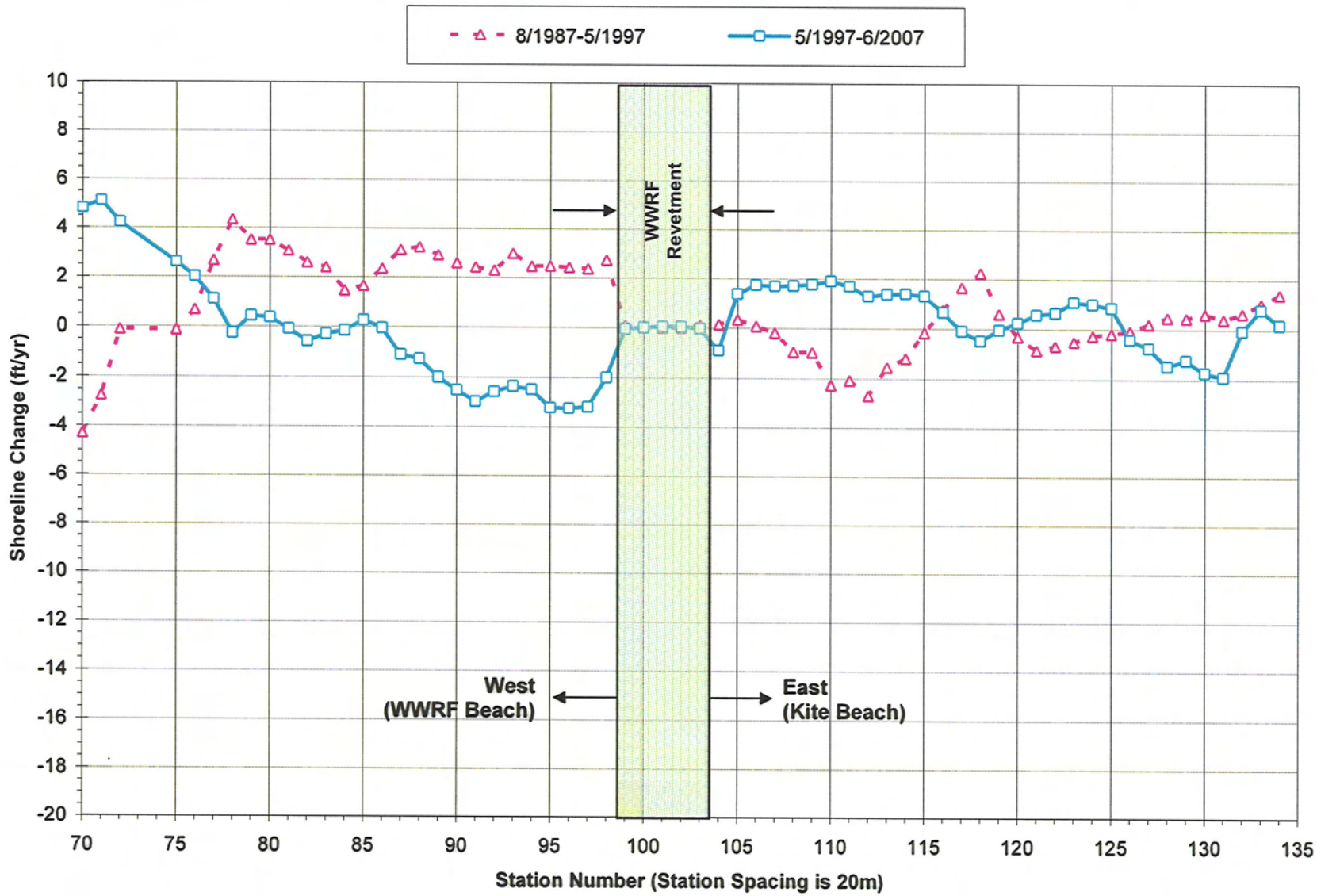


Figure 7. Shoreline Change Rate from 1987-1997 and 1997-2007 at the WWRF and Kite Beach. [From UH and County of Maui Shoreline Erosion Map data]

These trends are essentially reversed between 1997 and 2007 (blue solid line). The WWRF beach west of the revetment has been eroding at a rate of up to -3.0 ft/yr (approximately 30 feet of recession). East of the revetment, the shoreline change rate is approximately +2.0 ft/yr, decreasing to 0.0 ft/yr towards the eastern end of the reach. These recent trends suggest the WWRF revetment is now extending far enough into the surf zone to have some of the characteristics of a groin and the revetment has the tendency to cause accretion on the upcoast side (east) and erosion on the downcoast side (west).

5.4 Recent Observations

M&N visited the site in July 2004, November 2007, and March 2008; Figure 9 through Figure 16 illustrate the condition of the shoreline in the vicinity of the WWRF revetment on these dates.

In 2004, there were signs that the eastern end of the revetment was in danger of being flanked. Between July 2004 and November 2007, this area of the beach accreted (compare Figure 9 and Figure 10). This is consistent with the conclusion that the WWRF revetment may be acting as a partially blocking groin, with the direction of sediment transport from east to west. The beach behavior immediately west of the revetment was also consistent with this conclusion: this area of beach eroded between July 2004 and November 2007 (compare Figure 11 and Figure 12). Still further west, the beach accreted in this period (compare Figure 15 and Figure 16).

The period between November 2007 and March 2008 was outside the season of the northeast trade winds. The strength of sediment transport in from east to west is expected to be much less during this period; the transport could even reverse in response to southwesterly Kona winds and associated wave activity. Relatively little change was observed east of the revetment during this period (compare Figure 10 and Figure 11), while the beach west of the revetment actually accreted (compare Figure 13 and Figure 14).

These observations do not constitute a formal field investigation: the dates and available time for the site visits were determined by the scheduling of meetings associated with project milestones, rather than by the seasons, tide levels, etc. As such, detailed and firm conclusions cannot be drawn from these observations alone. However, the observations are entirely consistent with the general conclusions gained from M&N's analysis from shoreline surveys: the WWRF revetment is acting as a partially blocking groin, and the sediment transport between the beaches east and west of the revetment is limited by the revetment.

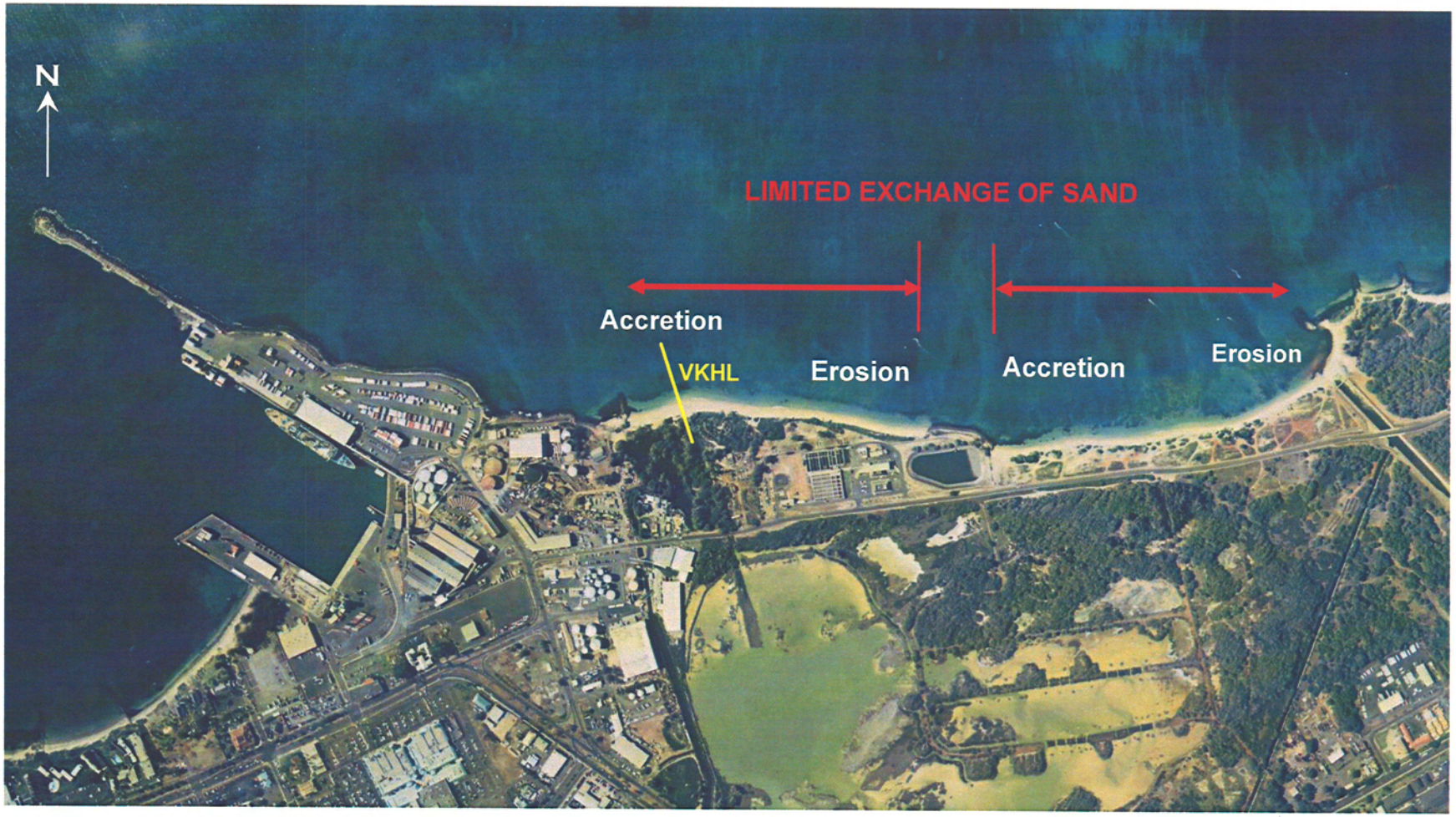


Figure 8. Accretion and Erosion at the Coast between Kahului Harbor and Kaa, July 2004 – November 2007

Figure 9. Looking East from the Revetment: July 2004 (Note Concrete "Pill Box")

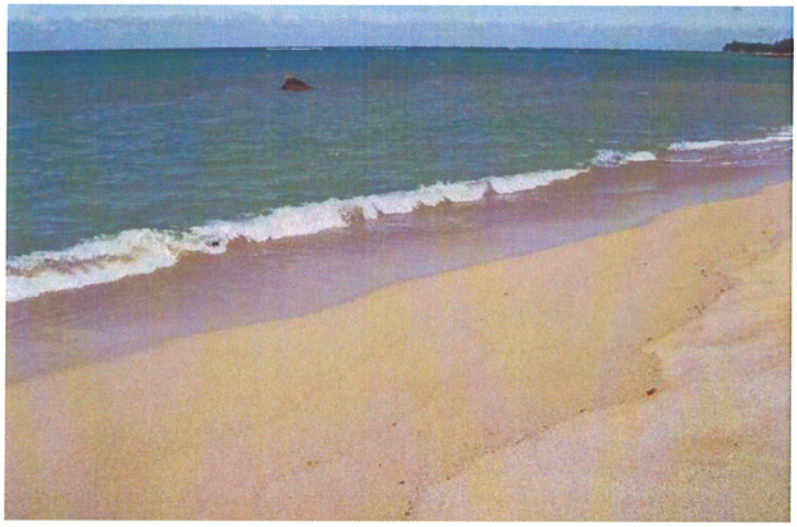


Figure 10. Looking East from the Revetment: November 2007 (Note Accretion of Sand)

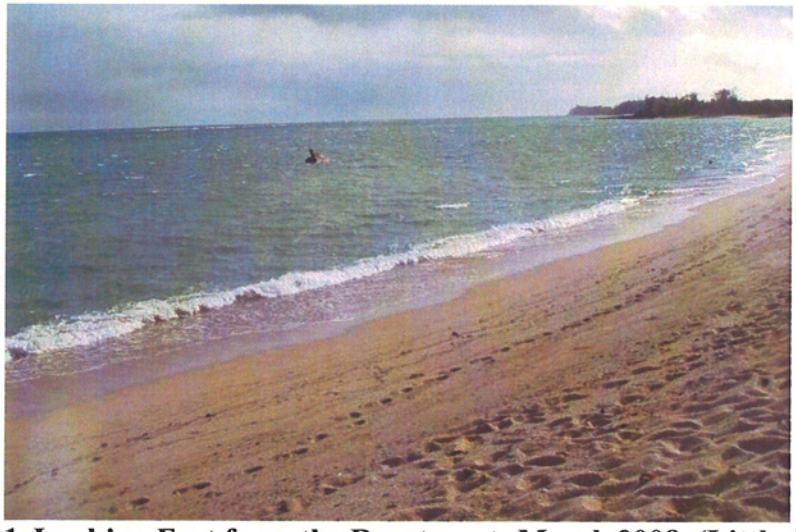


Figure 11. Looking East from the Revetment: March 2008. (Little Change)

Figure 12. Looking West from the Revetment: July 2004 (Note High Back Beach)

Figure 13. Looking West from the Revetment: November 2007 (No Large Berm)

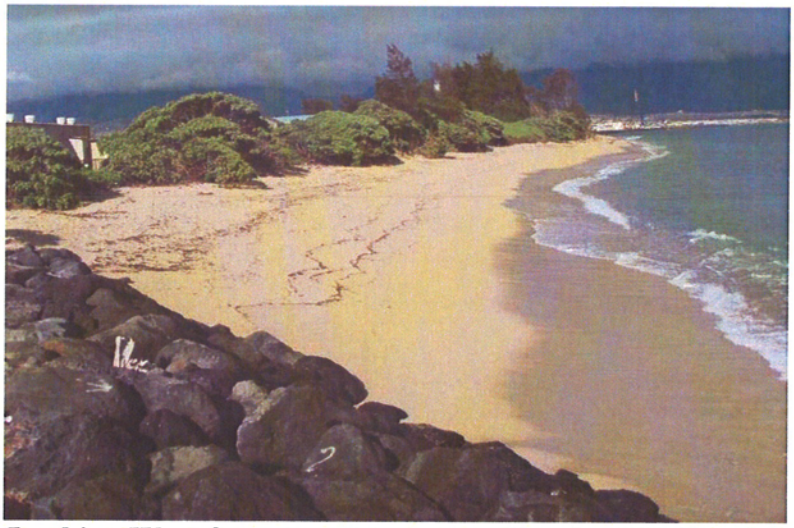


Figure 14. Looking West from the Revetment: March 2008 (Partial Recovery)

Figure 15. Outfall West of Revetment - 2004 (Note Rocks and Distance Offshore)

Figure 16. Outfall West of Revetment – 2007 (Rocks Buried and Beach Accretion)

5.5 USGS Profile Data

Profile data measured by the USGS from 1995 to 1999 measured by were obtained from the USGS website (<http://geopubs.wr.usgs.gov/open-file/of01-308/HTML1/Mnorth.html>). The nearest profile location to the project site is called VKHL and it is located near the western property line of the WWRF, close to Station 72 in the County Erosion Maps. The data from these profiles were reviewed to evaluate short-term – annual and seasonal – changes in trends in shoreline position west of the WWRF.

5.5.1 Annual Changes

For the annual shoreline change rates, it is important to compare data from the same seasons to obtain an accurate picture of the shoreline trends without the seasonal fluctuations.

At VKHL, the winter profile data (Figure 17) show that from January 1995 (black line with crosses) to February 1996 (dark blue/squares), the MLLW contour receded approximately 42 feet. The shoreline position remained similar at the January 1997 measurement, but recovered somewhat by 1998 (light blue/triangles). The January 1999 (gray/ circles) data indicate the shoreline had advanced again and had almost reached the original January 1995 position.

The summer profiles show a similar trend (Figure 18). The shoreline receded approximately 30 feet between September 1995 (dark red/squares) and August 1996 (light red/diamonds). By June 1997 (yellow/triangle), the shoreline receded an additional 12 feet. The shoreline advanced over the following two years, such that by July 1999 (mauve/crosses) the shoreline position was almost at the same position as the 1995 shoreline.

These data indicate the shoreline at this location has varied in recent years around a mean rather than displaying a consistent erosional or accretional trend. The maximum variation from year to year is 40 to 45 feet.

5.5.2 Seasonal Changes

The shoreline also moves between summer and winter profiles every year. The direction of movement is the opposite of that suggested by the analysis of plan view changes (Section 5.3.4) and general observations regarding the generally erosional effects of waves generated by northeast trade winds (Section 4.3). As is shown below, the winter profiles, measured before the northeast trade season (January/February), are consistently landward of the summer profiles, measured in the middle and end of the season (June through September) – the opposite trend to Figure 5. The likely reasons for this are discussed below, after the data have been presented.

Figure 19 and Figure 20 present the seasonal changes for each year of the shoreline profile data. The winter profiles are consistently landward of the previous summer profiles. From Figure 19, the largest recession is on the order of 42 feet, observed between September 1995 and February 1996. The 1997-1998 and 1998-1999 profiles show little or no erosion (a maximum of 6 feet) between the summer and subsequent winter locations.

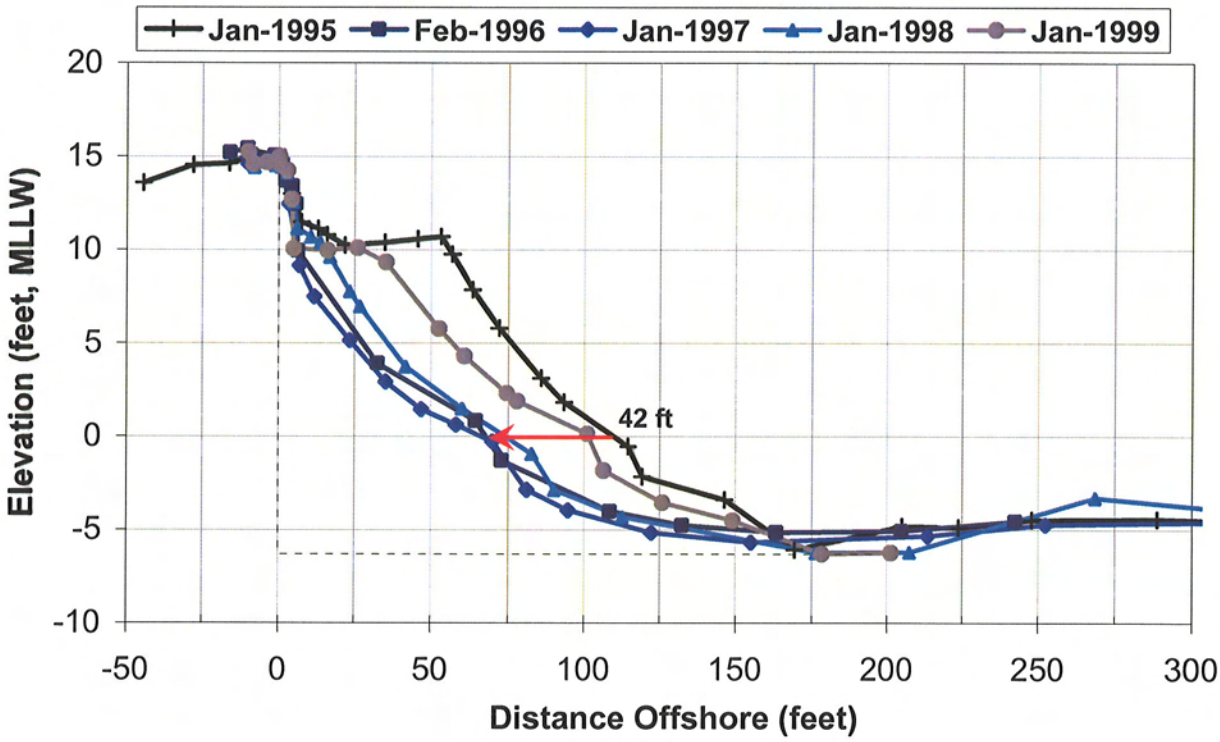


Figure 17. Winter Profiles at VKHL from 1995 to 1999.

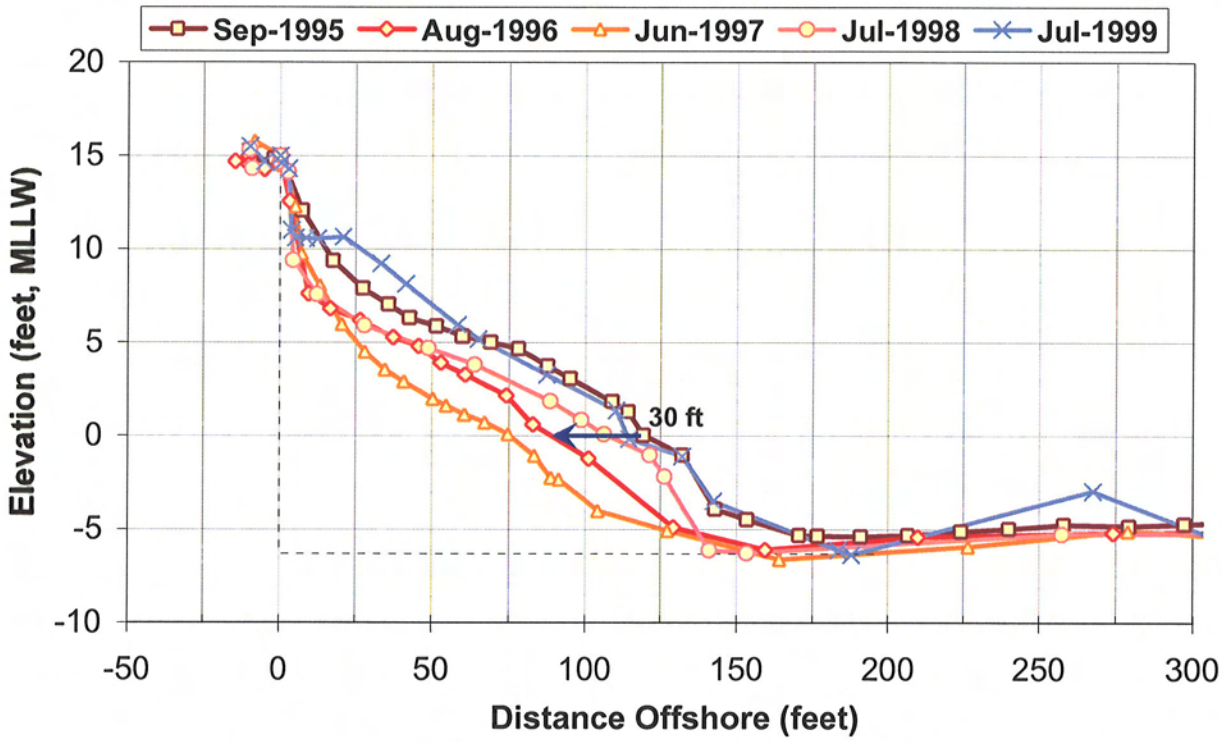


Figure 18. Summer Profiles at VKHL from 1995 to 1999.

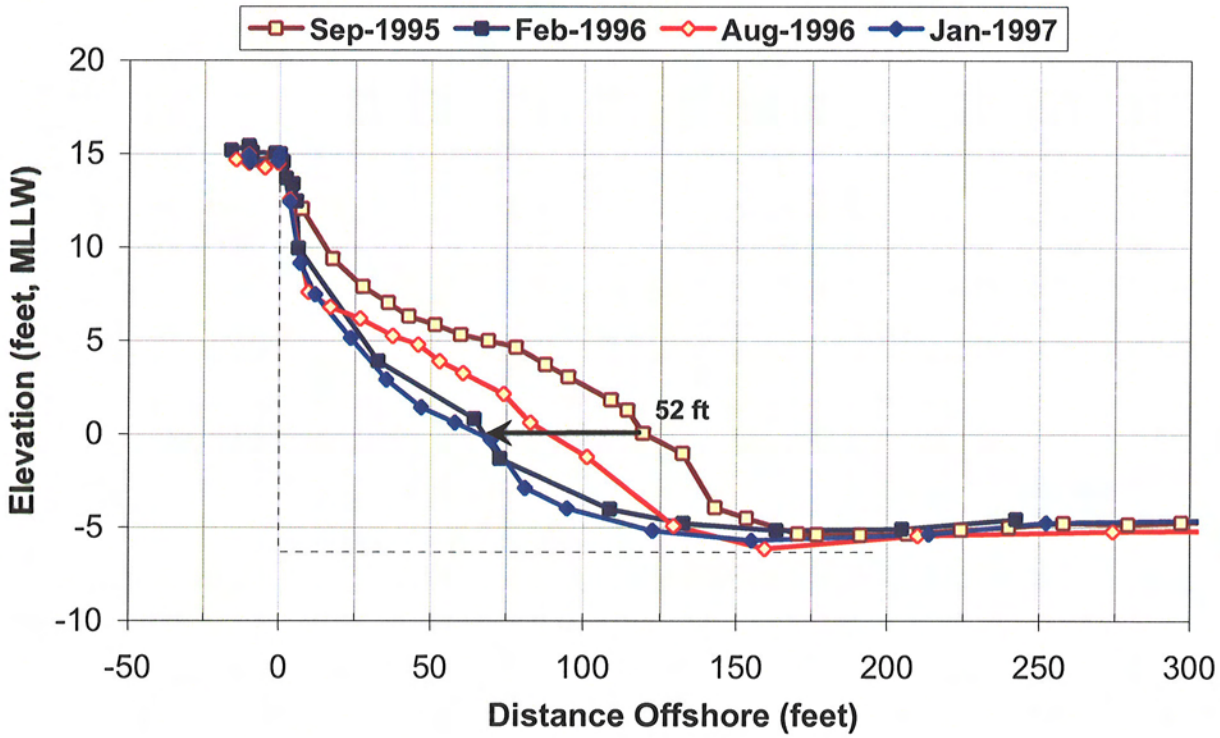


Figure 19. Seasonal Changes in Profiles at VHKL, 1995-1996 and 1996-1997

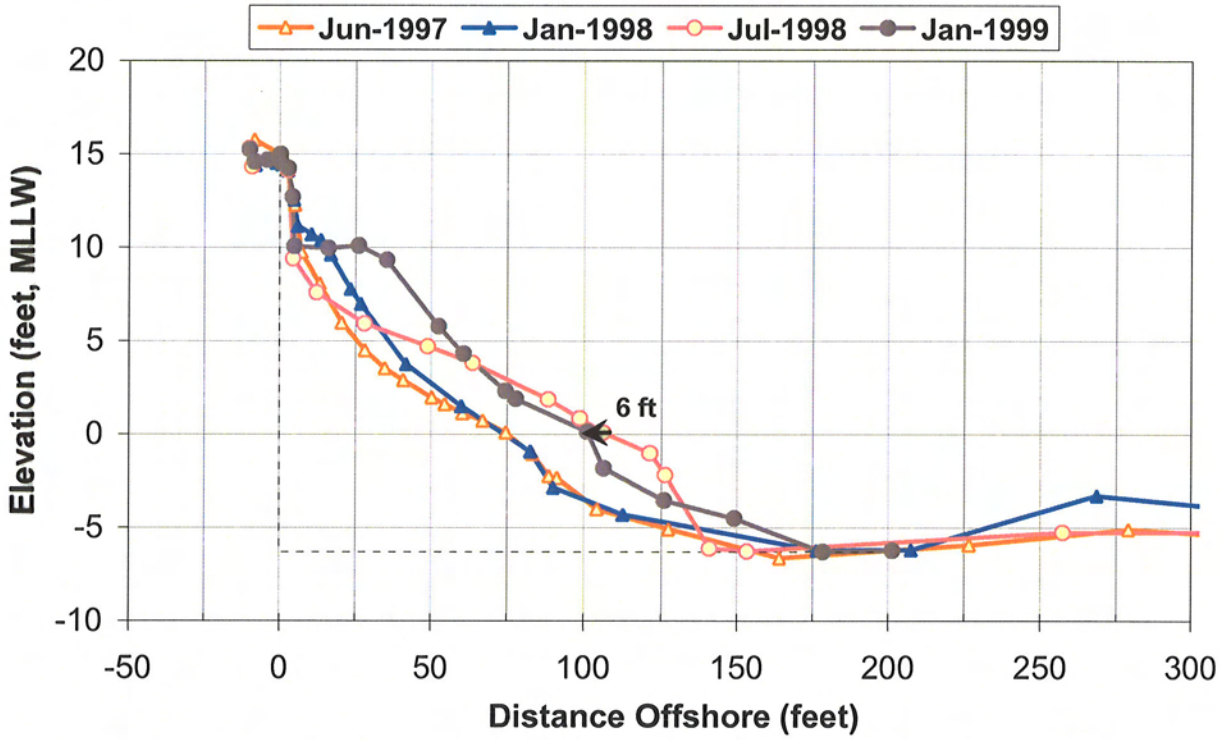


Figure 20. Seasonal Changes in Profiles at VHKL, 1997-1998 and 1998-1999

The reason for this contrary behavior of the shoreline at VHKL – with the shoreline accreting rather than receding during the northeast trade season – is that the profile is located close to the western limit of the WWRF beach (see Figure 8). During the northeast trade season, the WWRF beach and Kite Beach both generally experience erosion. However, since the waves generated by the northeast trade winds are directed towards the southwest, there is also a tendency for the sediment within the two, largely isolated, beaches to move towards the west. The movement of sediment towards VHKL near the western limit of the WWRF beach apparently outweighs the general narrowing of the WWRF beach during this season.

Figure 7 shows recent decadal changes in the beach at VHKL, at approximately Station 72, are directed contrary to the decadal changes in the WWRF beach as a whole. Repeating the analysis of Figure 5 for the western, middle, and eastern thirds of the WWRF beach, show the expected seasonal changes (narrowing during the northeast trade season) are by far the most consistent in the middle of this littoral subcell. The typical seasonal variation in this middle portion of the beach is about 30 feet.

5.5.3 SBEACH Analysis

The USGS measurements at VKHL did not include a significant storm season. M&N developed an SBEACH model of the site to investigate whether a dramatically greater level of erosion would be expected from a major storm event. The results presented here do not rise to the level of a detailed modeling study: the model is uncalibrated, and only a single event is considered. However, the results give a general indication of the degree of erosion that may be caused from a major storm.

The initial (pre-storm) shoreline was based on the January 1999 VHKL profile, extended offshore based on the nautical chart and extended inshore based on the available topographic information (Figure 23). Storm conditions included two-feet of storm surge superimposed on a relatively high tide, for a peak water surface elevation of 4.8 feet MLLW; and waves with a deepwater significant wave height of 25 feet and an 18-second period approaching the shoreline for 12 hours total. The 25-foot, 18-second wave is the design offshore wave used for the Kahului Harbor breakwater and is considered an extreme event.

Figure 21 shows the initial (pre-storm) and final shoreline resulting from this event. The final shoreline is shown two days after the event (the offshore bar is still migrating offshore at this time: however, the dry beach is no longer evolving).

About 60 feet of upland erosion is shown to be caused by the storm. This is similar to the maximum erosion distance observed during a single, not particularly stormy, winter season at VKHL. The wide offshore reef provides a significant level of protection to the shoreline. Thus, the risk to the WWRF caused by erosion from major storm events does not appear to be dramatically greater than the risk during a more normal season.

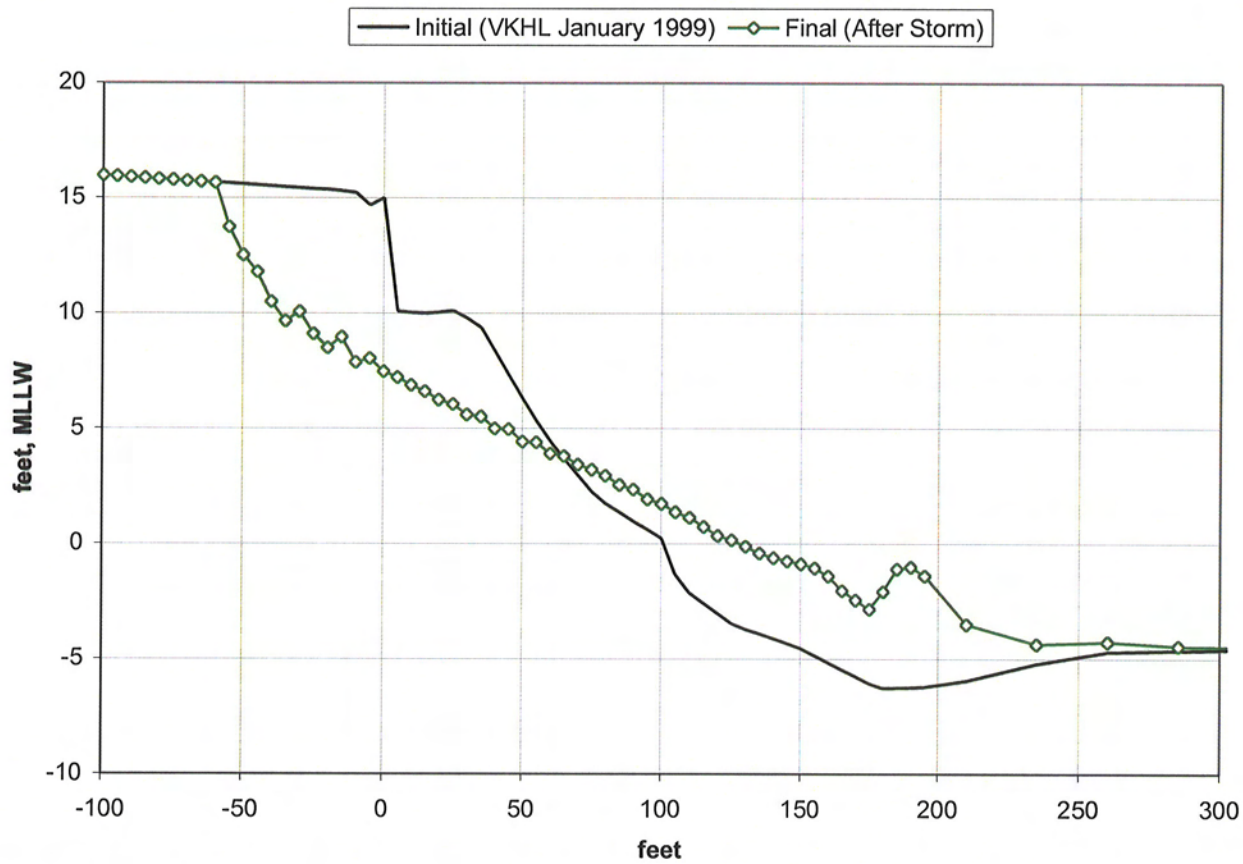


Figure 21. Initial and Final Profiles at VKHL predicted by an SBEACH Model Run for an Extreme Wave Event

5.6 Certified Shorelines

Several surveys have been performed to establish the "Certified Shoreline" position for the WRRF facility.

Figure 22 presents a comparison of the November 1977 and October 2007 "Certified Shorelines" at the WWRF facility and Table 3 presents a summary of the recession at the site.

Table 3. Recession from "Certified Shoreline" Data

Shoreline Recession 1997-2007	Total Recession (Feet)	Recession Rate (Feet/Year)
Maximum	38	1.3
Average	14	0.5
Minimum	4	0.1

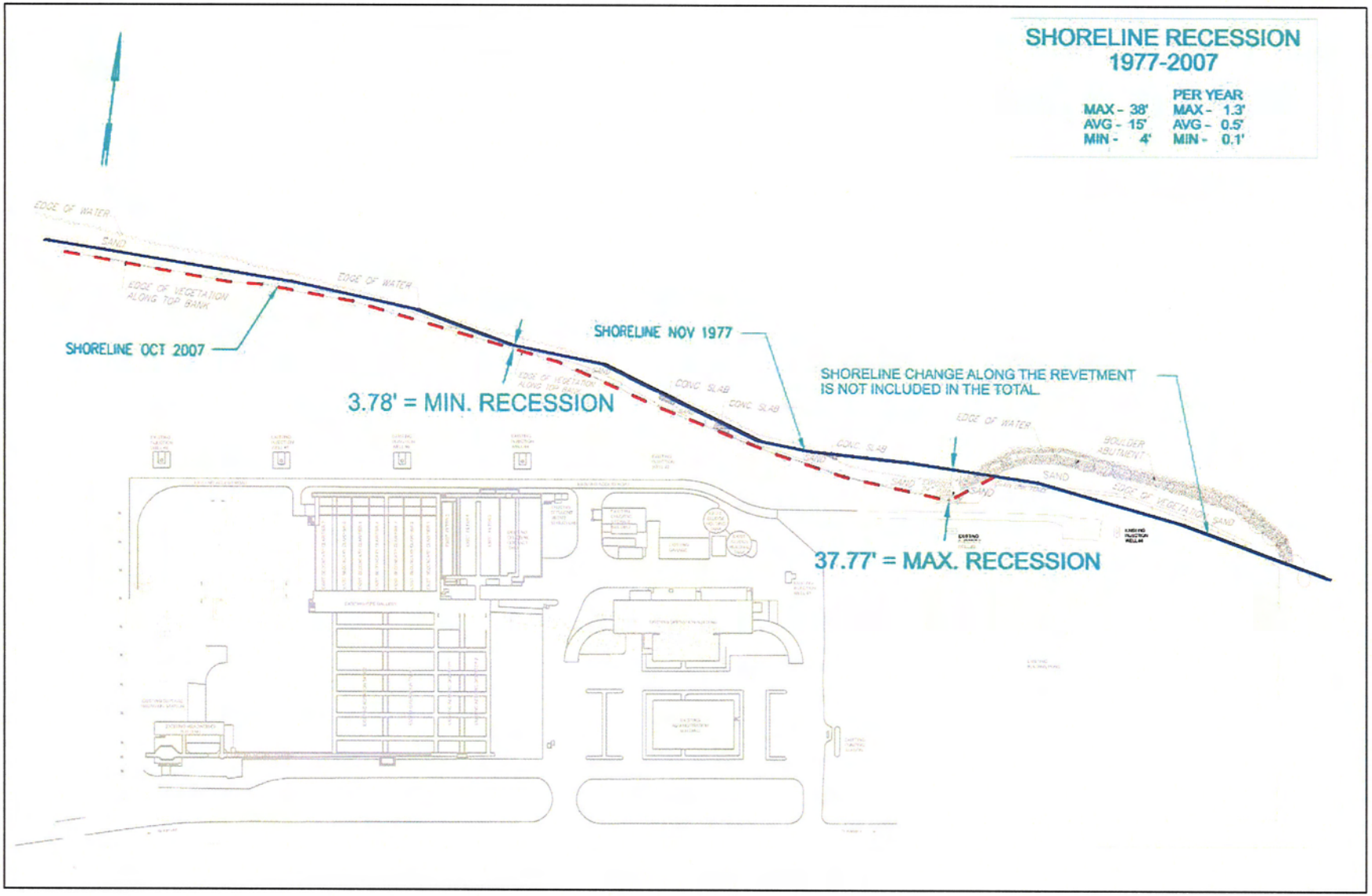


Figure 22. Certified shorelines at the WWRF, 1997 and 2007

5.7 Discussion

The aim of this review of historical shoreline behavior is to address the following questions:

1. What is the maximum likely seasonal and interannual shoreline retreat at the site?
2. What is the average or typical long-term shoreline retreat rate?

The first of these questions sheds light on the current vulnerability of the WWRF infrastructure to worst-case erosional events, and allows the buffer width appropriate to a beach replenishment protection scheme to be determined. The second question is relevant to the vulnerability of the WWRF infrastructure to the more likely (typical case) future shoreline recession, and provides input to the planning of future beach renourishment frequencies and quantities.

Fluctuations observed in the data set described here include the following:

- Analysis of variations in the beach plan area at the WWRF beach (Section 5.3.4) gives a typical seasonal fluctuation of 23 feet between February and August. Restricting the analysis to the middle portion of the WWRF beach increases the typical seasonal variation to about 30 feet.
- The largest annual recession observed at the USGS profile VHKL was 42 feet; see Section 5.5. This included a seasonal recession of 52 feet followed by recovery. While the seasonal behavior at this location differed from that observed for the beach at a whole, the general range of seasonal fluctuations is similar.
- Based on these observations, we recommend a typical seasonal variation of 20 to 30 feet and a maximum seasonal variation of 50 to 60 feet be used for planning. Given the typical pattern of seasonal shoreline erosion followed by recovery, it is not necessary to consider the worst-case interannual shoreline retreat in addition to the maximum seasonal shoreline retreat – the interannual shoreline retreat is typically smaller than the seasonal retreat as the beach recovers after an erosional season. For comparison, the setbacks required by the County of Maui include a buffer of 25 feet to allow for acute erosion events (County of Maui 2008).
- Long-term shoreline retreat at the WWRF site has slowed in recent years. Given that the general timescales associated with beach replenishment is a few years, the decade 1997-2007 is used to assess current retreat rates. Observations of the shoreline retreat in this period, discussed in Section 5.3.5, are as follows.
- The average retreat rate over the decade for the portion of the WWRF beach exhibiting significant decadal erosion is 2.4 feet per year. Stations 87 to 98 in Figure 7 were used in this average: these stations eroded 10 feet or more over the decade. The area used in the average is a little over one-third of the total length of the WWRF beach.
- The maximum retreat rate observed at the WWRF over the decade 1997-2007 beach is 3.2 feet per year: this was observed at Stations 95 and 96. However, much of the retreat occurred between 1997 and 2002. Within this period, Station 96 retreated at an annual rate of 6 feet per year.

- Based on these observations, we recommend a typical long-term erosion rate of 2.4 feet per year and a maximum long-term erosion rate of 6 feet per year for use in planning. The value of 2.4 feet is slightly larger than the County's Average Erosion Hazard Rate (AEHR) at the WWRF (Figure 3), but slightly smaller than the AEHR immediately east of the revetment, in the areas at risk of outflanking.

6. SEDIMENT BUDGET ANALYSIS

6.1 Overview

Everts Coastal[3] (2007 – Appendix A) prepared a detailed analysis of the sediment inputs, losses, and historical and likely future volume changes along much of the north Maui coast, with a focus on the shoreline fronting the Kahului WWRF. The two main outputs of the analysis are an estimate of the longshore sediment transport rate at the WWRF beach, and an estimate of the likely future beach changes and associated volumes.

The longshore sediment transport rate depends on the wave conditions, sediment characteristics, and – critically – on the nature of the shoreline. A shoreline with abundant sand tends to have wide, straight beaches that are not broken up by natural headlands, groins, or other blocking features. The wave energy that reaches such a shoreline is able to transport sediment very effectively. Consequently, the longshore sediment transport rate tends to increase with increasing beach widths. It is important to estimate the sediment budget, including the longshore sediment transport rate, at the WWRF beach in order to address the following technical questions:

Is the longshore sediment transport rate sufficiently large that sand retention structures such as groins will be needed in order for a beach replenishment project to perform acceptably? With no sand retention structures, if the transport rate at the nourished beach is large compared to the planned renourishment rate then the sand that is placed at the site will immediately be swept downcoast (west) or offshore at the Kahului Harbor breakwater.

Does the sediment budget analysis suggest that the future behavior of the beach will be similar to the recent past behavior, or are further changes to be expected and planned for?

6.2 Beach Dimensions

One of the most comprehensive data sets for modern beach dimensions have been compiled by the Sugar Cove Association of Apartment Owners as a result of their efforts to nourish and maintain their beach. Sugar Cove is located approximately 3 to 3.5 miles east of the Kahului WWRF. Sand has been added to the beach at Sugar Cove by the Association since 1996, as described in Section 5.2.4.

- An extensive set of beach profiles at Sugar Cove was made available, allowing the response of the beach to the recent replenishment efforts to be analyzed in some detail. Based on these profiles, the following are considered to be typical estimates the for the north Maui coast:
- Elevation of the backbeach line (the upper limit of the active beach) relative to the local sea level datum is +12 feet;
- Elevation of the shorebase (approximate depth of closure, beyond which no seasonal or short-term changes in the sea bed are observed) relative to the local sea level datum is -8 to -10 feet;

3 Note: Dr Craig Everts is a former Moffatt & Nichol employee who formed Everts Coastal as a specialist coastal geomorphology firm. M&N retained Everts Coastal for their particular expertise on shoreline evolution and their familiarity with the Hawaiian Islands.

- Horizontal distance from the shoreline (at local sea level datum) to the shorebase is 250 to 400 feet.

Thus, the vertical extent of the active littoral zone is taken to be 20 to 22 feet. The backbeach at the WWRF is slightly lower than elsewhere, and it is assumed that the vertical extent of the active littoral cell in that region is at the lower end of the range (20 feet).

6.3 Current Erosion Volume Rates

As described in Section 5.3.3 and Figure 6, the WWRF beach is relatively stable at present. The average change in beach plan area from 1987 to 2007 was used to estimate the shoreline change rate at between -6 inches per year and +2 inches per year. Using this average shoreline change rate, a shoreline length of 2,160 feet (which excludes the beach immediately in front of the WWRF revetment), and a moderate acceleration in the rate of sea level rise, an average beach replenishment quantity of between 650 cubic yards per year and 1,300 cubic yards per year (500 to 1,000 cubic meters per year) was estimated.

These estimates are scientific in nature and are not conservative in an engineering sense. This analysis is based the average shoreline change rate on a relatively stable historical period, 1987 to 2007. In addition, the volume estimates are based on the average shoreline rate over the entire beach – including portions that are not currently erosional. As described further in Section 7.2, a more conservative engineering approach that includes a safety factor and takes advantage of cost savings due to economies of scale may be more appropriate for project planning purposes.

6.4 Sediment Inputs and Losses

In order to estimate the longshore sediment transport rate at the Kahului WWRF, the sediment budget analysis first estimates the sediment inputs to, and losses from, each identified cell between the rocky headland immediately east of Sugar Cove and the Kahului Harbor breakwater. The following inputs are considered:

Biological flux of calcareous sediments - As noted in Section 5.2.4, the rate of production of beach sediments from reefs in the area may have dropped over the past century. The reefs may have suffered a loss of productivity as ocean waters have become warmer and as human influences may have affected it. The reef input was estimated to be 3,700 cubic yards per year for each mile of shoreline until 1975, dropping to 2,100 cubic yards per year per mile thereafter (1,750 dropping to 2,100 cubic meters per year per kilometer).

- Substrate sediment flux – that is, the input of sediment that is scoured from the previously inactive shoreline and contributed to the active beach. A major unknown associated with the substrate sediment flux is the fraction of substrate that is of sand size; this was estimated to be between 50 percent at the Kahului WWRF, dropping to 10 percent in the vicinity of Sugar Cove.
- Beach replenishment – 17,000 cubic yards (13,000 cubic meters) of sand were placed at Sugar Cove between 1996 and 2002.

The following losses of sediment are considered:

- Aeolian flux – that is, losses due to wind transport, generally to the coastal dune system.

- Overwash flux – in this case, loss of sand upland of the back beach line resulting from tsunamis.
- Grain abrasion – which may be an important loss of sand in calcareous beaches, reef type sediment can lose mass up to 2,000 times as rapidly as quartz sediments of similar size and roundness.

The loss rates due to aeolian and overwash flux vary along the north Maui coast, depending on the relative wind and tsunami wave exposure.

Sand mining in the area is not explicitly included in the sediment budget, as the majority of the extraction lies outside (east of) the area analyzed. Rather, the (significant) effects of sand mining are observed through the lack of sediment input from the beaches east of Sugar Cove. The rocky headland that forms the eastern boundary to Sugar Cove can currently be considered a blocking structure, such that no sediment enters the littoral system from the east.

6.5 Longshore Sediment Transport

The sediment budget analysis calculates the annual average input of sediment to, and loss of sediment from, each of 13 littoral cells along the north Maui coast, between the Kahului Harbor breakwater and Sugar Cove. The two cells at the far western end are the WWRF beach and Kite Beach, immediately west and east of the revetment at the Kahului WWRF. The residual sediment – that is, the difference between the identified sediment inputs and losses – is assumed to arrive at these two cells, and eventually to be lost offshore at the Kahului Harbor breakwater.

A summary of the calculated long-term sediment transport rates at the WWRF beach is given in Table 4. The transport rates are calculated for two periods: before and after the beach retreat associated with sand mining. For comparison, two cases are considered: one in which the earlier (pre-retreat) interval is taken to end in 1975, and a second in which that interval is taken to end in 1960.

Table 4. Long-Term Sediment Transport Rates at the Kahului WWRF

Interval	Transport rate cubic yards per year (cubic meters per year)	
Case 1		
1912-1975	7,100	(5,400)
1975-2002	5,400	(4,100)
Case 2		
1912-1960	8,500	(6,500)
1960-2002	6,000	(4,600)

It is noted that since the shoreline did not stabilize until about 1987, the transport rate has probably decreased compared to the long-term average shown here. The conclusion drawn is that ***the net rate of sediment transport at the shoreline adjacent to the Kahului Wastewater Reclamation Facility is currently between 1,300 and 4,000 cubic yards per year (1,000 to 3,000 cubic meters per year).*** This rate is likely to continue in the future.

Two conclusions can be drawn from this estimate. First, the sediment transport rate is relatively small in comparison to the quantities of sediment that are estimated to be required for beach replenishment and (more important) for periodic renourishment at the site; see Section 7.2 for a discussion of the beach replenishment alternatives. Shore-normal beach retention structures such as groins are typically used to stabilize beach replenishment in situations with high rates of littoral transport. Consequently, the benefits of a shore-normal retention structure at this site would be low.

The earlier shoreline evaluation report by Moffatt & Nichol (2005) proposed the use of T-Groins in one of the project alternatives, although even at the time this alternative was not considered preferred. Based on this relatively low estimate of longshore sediment transport, this earlier conclusion is confirmed. The rock that would be needed for the T-Groins would be more effectively used in a revetment, as the major threat for the facility appears to be storms and the potential for cross-shore loss of sand. Therefore, the alternative including T-Groins (or other shore-normal retention structures) is not taken further.

The second use of the longshore transport rate is as a guide to potential future changes to the degree of erosion and/or accretion at the Kahului WWRF. This is of particular importance for project alternatives based around beach replenishment, with or without a backing seawall or revetment. In the worst case, longshore sediment transport to the shoreline at the Kahului WWRF could potentially drop to zero (it appears very unlikely that the direction of net sediment transport would reverse to be east-directed). In this case, the quantity of beach renourishment would increase by up to 4,000 cubic yards per year (3,000 cubic meters per year). This increase would be in addition to the increase associated with other potential factors that directly affect the shoreline at the WWRF (e.g., accelerated local sea level rise).

7. PROJECT ALTERNATIVES

The project alternatives described in the Shoreline Evaluation Report have been reviewed, updated, and (in some cases) eliminated from further consideration based on newly available sand source information (see Section 8) and the sediment budget. This section describes the remaining alternatives, together with the No Project alternative. It should be understood that the No Project alternative is not a practical solution given the decision to keep the WWRF in its present location and the erosion rates at the site; it is presented as a baseline for comparison and planning purposes only.

7.1 No Project Alternative

For the no-project alternative, it is assumed that current shoreline change trends will continue in the future and no further shoreline protection will be constructed at the site. The 2007 certified shoreline and a site map of the WWRF (Brown and Caldwell 2002) were analyzed to determine when the first structures at the WWRF site could be threatened. This site map is illustrated in Figure 23. For this analysis it is assumed the revetment will remain and be maintained in place and will provide protection to the holding pond and other upland structures behind the revetment: these structures are not considered threatened.

The equation below was used to calculate the years until a structure is threatened:

$$Y = \frac{D - SR}{LTE}$$

where D is the distance between the structure and the back of the beach (approximately the +10-ft contour), SR is the seasonal recession, and LTE is the current longer-term erosion rate. Maximum and minimum values were used for the seasonal recession and the current longer-term erosion rate to calculate a range of years until the structures are threatened. As summarized in Section 5.7, the maximum and typical values of the seasonal recession are 50 to 60 feet and 20 to 30 feet respectively: the minimum seasonal recession is taken as zero. The maximum and typical longer-term erosion rates are 6.0 feet per year and 2.4 feet per year, respectively. These erosion rates implicitly include the effects of present-day sea level rise. Since the time until the structures are threatened is relatively short compared to the decades over which sea level rise is likely to accelerate, the effects of sea level rise are not explicitly included in the present estimate. If the rate of sea level rise accelerates, these times would be significantly reduced.

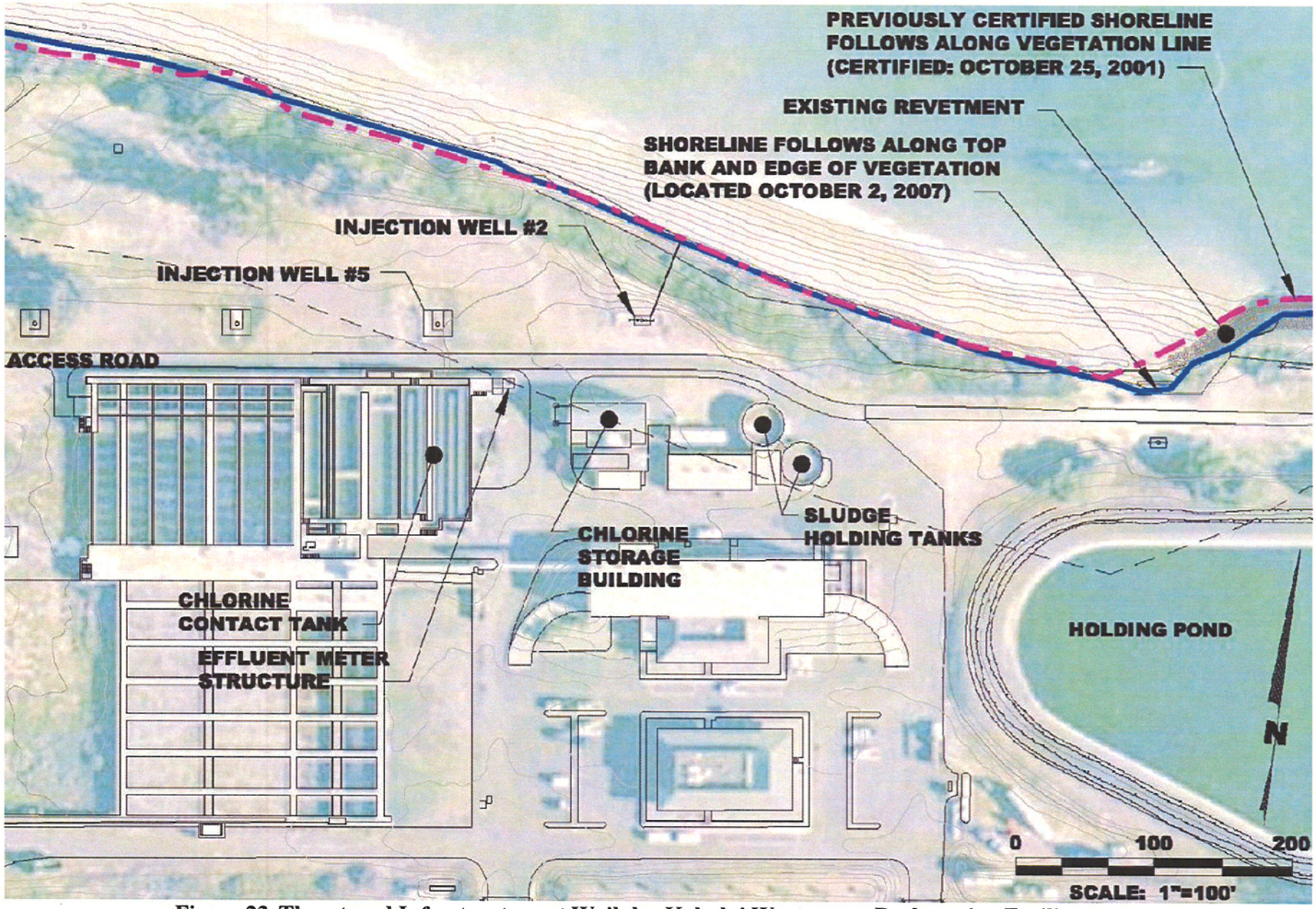


Figure 23. Threatened Infrastructure at Wailuku-Kahului Wastewater Reclamation Facility

Table 5. Calculation of Years until WWRF Structures are Threatened, Based on October 2007 Certified Shoreline

Structure	Distance from Top of Berm to Structure (ft)	Minimum Winter Recession (ft)	Average Recent Erosion Rate (ft/yr)	Approx. Yrs until Threatened
Minimum Seasonal Recession / Typical Long-Term Erosion				
Existing Access Road	63	0.0	2.4	26
Sludge Holding Tank	85			35
Chlorine Storage Bldg	118			49
Effluent Meter Structure	141			58
Existing Injection Well #2	59			24
Existing Injection Well #5	113			47
Minimum Seasonal Recession / Maximum Long-Term Erosion				
Existing Access Road	63	0.0	6.0	10
Sludge Holding Tank	85			14
Chlorine Storage Bldg	118			19
Effluent Meter Structure	141			23
Existing Injection Well #2	59			9
Existing Injection Well #5	113			18
Maximum Seasonal Recession / Typical Long-Term Erosion				
Existing Access Road	63	60.0	2.4	**1**
Sludge Holding Tank	85			10
Chlorine Storage Bldg	118			24
Effluent Meter Structure	141			33
Existing Injection Well #2	59			**< 1**
Existing Injection Well #5	113			22
Maximum Seasonal Recession / Maximum Long-Term Erosion				
Existing Access Road	63	60.0	6.0	**< 1**
Sludge Holding Tank	85			4
Chlorine Storage Bldg	118			9
Effluent Meter Structure	141			13
Existing Injection Well #2	59			**< 1**
Existing Injection Well #5	113			8

The data used to develop the maximum seasonal recession are very limited. In particular, no extreme storms or large hurricanes occurred during the period 1995 to 1999 when the USGS was measuring nearshore profiles (Gibbs, Richmond, and Fletcher 2000; see Section 5.5).

The previous table illustrates that the existing injection well #2 is already at threat of damage based on the worst-case seasonal recession. The access road could be threatened in only one year and the existing sludge holding tanks in as few as 4 years. The Chlorine storage building is located approximately 120 feet from the fence line, which relates to a minimum of 11 years before the structure is threatened using the maximum erosion rate and seasonal change. Table 6 summarizes the minimum, maximum, and average time until each structure is considered threatened. These values are supported by the recent exposure of an effluent line east of the revetment resulting from the erosional trends and winter storm response at the beach.

Table 6. Summary of WWRF Structures that may be threatened.

Structure	Approx. Minimum Time (yrs)	Approx. Maximum Time (yrs)	Approx. Average Time* (yrs)
Existing Access Road	< 1	26	5
Sludge Holding Tank	4	35	12
Chlorine Storage Bldg	9	49	21
Effluent Meter Structure	13	58	28
Existing Injection Well #2	< 1	24	4
Existing Injection Well #5	8	47	20

* Median value

It is possible that most of these structures identified above could be relocated elsewhere on the WWRF property. However, the northeast corner of the Chlorine contact tank and effluent meter structure is located approximately 120 feet from the existing fence line. The size of this structure and its position in the wastewater treatment cycle would prohibit it from being relocated elsewhere on the property. With this distance, the chlorine contact tank and effluent meter could be threatened in as little as 14 years.

Given the variability in these projections, the unpredictability of future storms, and the typical time required to design, permit, and construct a shoreline protection project (3 – 5 years), it is recommended a shoreline protection alternative be selected and implemented as soon as possible.

7.2 Alternative 1 - Beach Replenishment

Beach replenishment is a proven method to stabilize a shoreline against erosion, protect threatened upland areas, and advance a shoreline seaward. Recent smaller-scale beach replenishment projects have occurred on Maui at Sugar Cove, located approximately 4 miles east of Kahului Harbor. These projects included trucking sand from the inland quarries and placing the material in a small (600-ft long) pocket beach. The initial replenishment costs were approximately $100,000 and approximately $20,000 per year for ongoing maintenance. From 1995 to 2000, Sugar Cove has placed approximately 18,000 cubic yards of sand on their beach. The larger projects during this time included approximately 5,800 cubic yards in 1996 and approximately 6,300 cubic yards in 1998.

Beach replenishment projects constructed with larger volumes and coarser materials tend to remain longer on the upper portion of the beach for longer periods. Smaller and finer-grained projects tend to disperse more rapidly and remain on the upper beach for a shorter length of time. Therefore, it is important to use the best-suitable sand source for any beach replenishment project.

The alternatives presented in this section would build out the beach berm at an elevation of +10 feet MLLW by a distance of 40 feet. Assuming the existing beach width fluctuates seasonally between zero and 30 feet in width, this would give a nourished beach width expected to fluctuate seasonally between 40 and 70 feet in width. The 70 feet of width at the start of the erosional season would protect the upland area against (worst-case) long-term erosion rates of up to 6 feet per year for 3 years or more, followed by a (nearly worst case) seasonal retreat of 50 feet in a single season. The more likely long-term erosion rate, used in the estimate of renourishment frequencies and quantities, is 2.4 feet per year.

The beach face would be constructed at a slope of 1V:10H, as illustrated in Figure 24. This profile is selected to match the existing beach slope (measured at the USGS site VKHL). The natural profile meets the nourished profile at a depth of approximately -6 feet MLLW. The replenishment sand is proposed to be dredged from offshore sand sources (see Section 0).

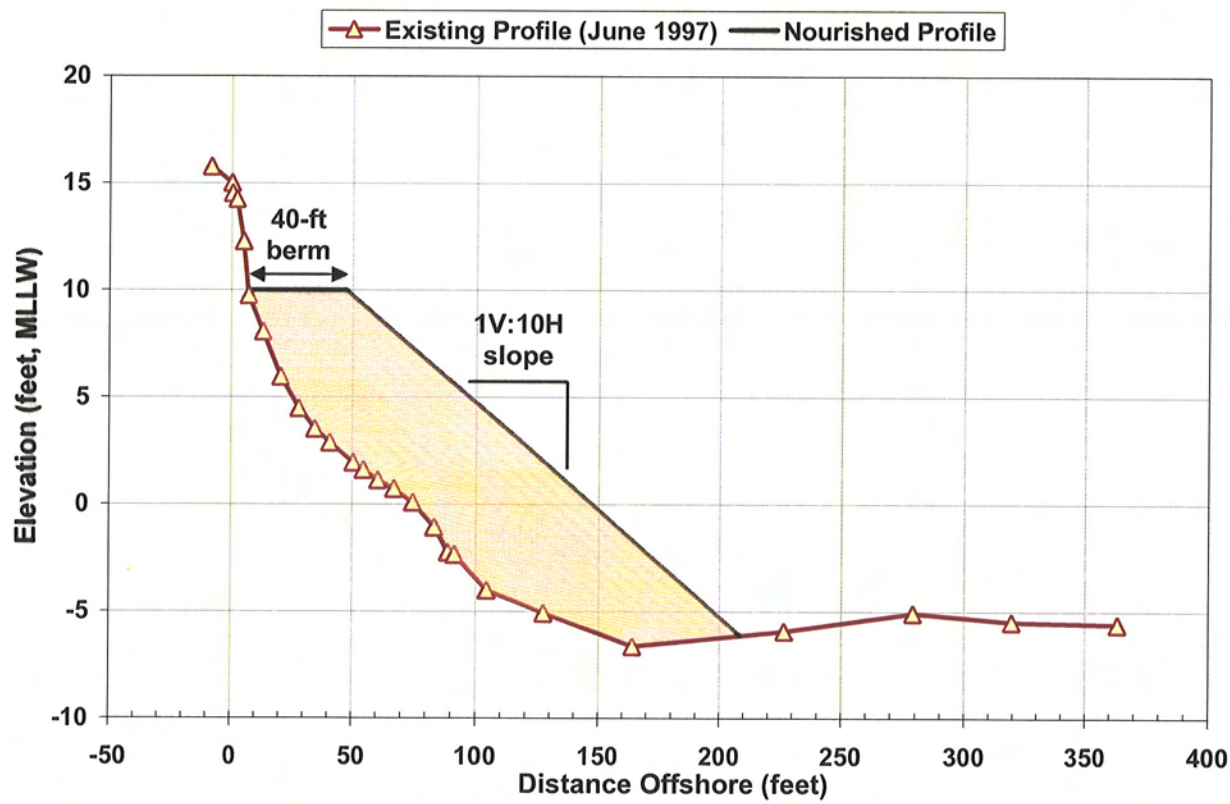


Figure 24. Alt. 1A and 1B - Cross-section of beach replenishment at the WWRF site.

The renourishment volumes presented for the beach replenishment alternatives are much greater than the basic sediment budget estimates presented in Section 6.3. The main reason for this is that these estimates are conservative in an engineering sense, while the sediment budget estimates are more scientific in nature and do not include a "safety factor". The engineering

analysis estimates use the erosion rate over the relatively recent, and erosional, period 1997 to 2007, and focus on the most erosional 700 feet of the WWRF beach. In contrast, the Sediment Budget Analysis (Section 6.3) uses the longer and relatively less erosional period 1987 to 2007, and uses the average retreat rate over the entire beach – including portions that are not currently erosional. The project planning must account for the possibility that shoreline stretches which are not currently erosional, particularly areas retained by the short groin east of the Kahului Harbor breakwater, may become erosional once the replenishment project has made the beach wider and straighter.

7.2.1 Alternative 1A – 3,800-ft Long Beach Replenishment

The project reach for this alternative extends from approximately the WWRF western property boundary to approximately 100 feet east of the stream channel adjacent to Kaa, a distance of approximately 3,800 feet. The purpose of nourishing the entire reach is to develop a relatively natural beach plan form (the plan is similar to the beach observed in October 1960, and illustrated in the County erosion maps). The net sediment transport is from east to west, so that over the long term the material placed near Kaa would migrate west and could decrease the amount of maintenance replenishment required for the downdrift area fronting the WWRF. In the shorter term (a few years), the initial placement of a natural beach plan would decrease loss of sand from the area fronting the WWRF to adjacent areas through diffusion. Figure 25 provides a plan view of this replenishment alternative.

Alternative 1A requires approximately 105,000 cubic yards of initial sand placement to create an additional 40-foot wide berm along the full 3,800-feet length of the project (this would create a beach fluctuating seasonally between 40 and 70 feet in width). The nourished beach would continue to erode as it would under natural conditions and periodic maintenance nourishments would be required for the life of the project. Based on the average erosion rate of 2.4 feet per year, the beach would retreat by 20 feet in approximately 8 years. Once the beach width has retreated by 20 feet, it is possible for the entire beach to be lost in a single season, based on the worst-case seasonal fluctuations developed in Section 5.7: the beach should therefore be renourished at this stage. Taking into account that approximately 1,600 feet of the beach have been erosional over the past decade (Figure 7), it is estimated that approximately 21,000 cubic yards of sand would be required every 8 years to maintain the project design width – about 2,600 cubic yards per year.

7.2.2 Alternative 1B – 2,400-ft Long Beach Replenishment

This alternative is similar to Alternative 1A, above, except that the project length is reduced to approximately 2,400 feet. The replenishment extends along the WWRF property to about 500 feet east of the existing revetment; Figure 25 (dotted lines) illustrates the initial plan view of this beach replenishment alternative. The initial sand quantity is approximately 65,000 cubic yards.

Similar to Alternative 1A, the replenished area would continue to erode as it would under natural conditions. Approximately 1,200 feet of this stretch of the beach have been erosional over the past decade (Figure 7). Assuming a slightly greater renourishment density to account for the fact that smaller beach replenishment projects typically have less success with retaining beach area over the long term, it is estimated that approximately 16,000 cubic yards of sand would be required every 8 years to maintain the project design width – about 2,000 cubic yards per year.

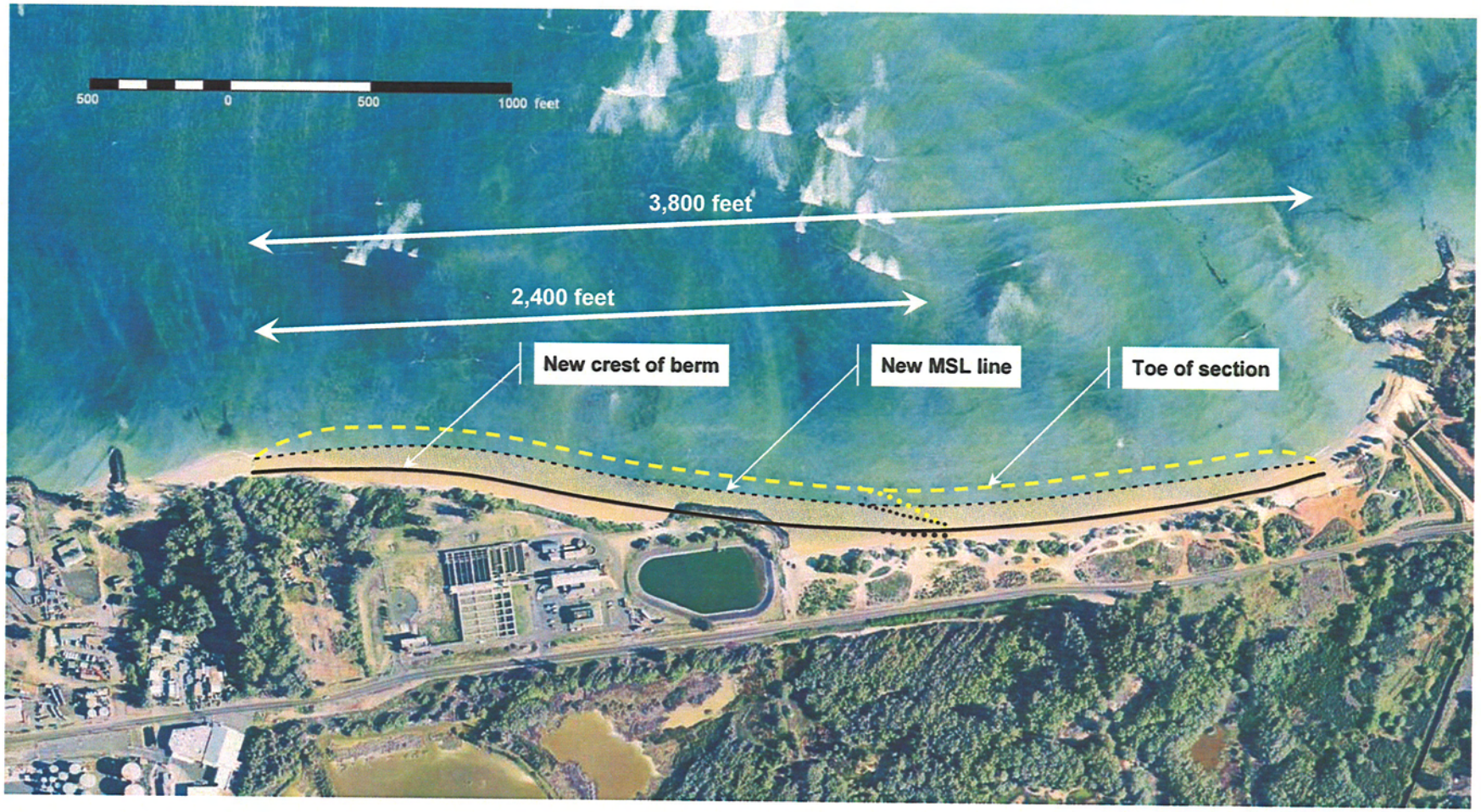


Figure 25. Plan view of the beach replenishment alternatives at the WWRF site.

7.2.3 Additional Beach Replenishment Alternatives

If beach replenishment is selected as the preferred alternative, additional sub-alternatives could be considered as the engineering design progresses. These additional sub-alternatives would be considered as part of the design optimization – they are not considered further in this document, and would only be constructed if they were more cost-effective and at least as environmentally benign as Alternatives 1A and 1B considered here. Examples are as follows.

Carry out the initial beach replenishment according to Alternative 1A, but place renourishment preferentially along the shoreline fronting the WWRF site. This could provide a wider beach for infrastructure protection, at a similar cost to Alternative 1A and while providing a similar beach area for recreational purposes.

Replenish only the relatively short reach of beach fronting the WWRF site and west of the revetment. Construct a low groin in the vicinity of the WWRF revetment to decrease the rate of diffusion of sand to the east. This low groin could be constructed of sand-filled geotubes or other readily removable construction material if it is desired to test this alternative before finally committing to a groin.

Additionally, beach replenishment at another site could be considered as mitigation for any potential environmental effects associated with Alternative 3A, the revetment extension. This would be considered and suitable sites identified as part of the environmental and regulatory process.

7.3 Alternative 3 – Armor Rock Revetment

Hard structures, such as revetments and seawalls, can provide a last line of defense against coastal erosion – limiting the distance to which erosion can proceed and preventing the erosion from threatening the upland area. Observations from the Boxing Day Tsunami on 2004 indicate that structures located behind seawalls as small as 1 m (3.3 ft) high were more protected than adjacent structures of similar construction without seawalls. (Dalrymple, et al 2005)

Hard structures do not protect the seaward beach, which can continue to erode until it is narrow or nonexistent. On shorelines that experience a net long term erosion or are subject to relative sea level rise, the shorelines adjacent to hard structures can migrate landward, resulting in "passive erosion", which can limit lateral access to the adjacent beaches. (Griggs 2005)

The USACE constructed the original 450-foot revetment in 1979 for a total cost of approximately $300,000 with federal and non-federal funds. The revetment protects the seaward edge of the holding pond. The revetment designs presented in this section extend the revetment to provide protection to the remainder of the facility and are based on the following assumptions regarding waves and water levels.

The design tide level is taken to be the maximum observed water level at Kahului Harbor, 3.5 feet above MLLW.

Based on NOAA Nautical Chart number 19342, Kahului Harbor and Approaches, the bottom elevation for a significant distance (several hundred yards) offshore of the WWRF beach, on the reef flat, is taken to be in the range 3 to 6 feet (½ to 1 fathom), with a value of 4.5 feet or ¾ fathom used for the design.

Offshore waves are taken to have a significant wave height of 25 feet and a period of 18 seconds, which is the design condition used for the Kahului Harbor breakwater (USACE 1988).

The offshore waves are depth-limited when they reach the WWRF beach. Based on the design tide level and assumed sea bed elevation, the water depth is 8 feet and a typical depth-limited wave height would be 6 feet. To account for loss of energy over the reef flat, additional water depths associated with wave setup are not included in the calculation.

To summarize, the design waves at the WWRF shoreline are taken to be 6 feet significant wave height with a period of 18 seconds. Based on these wave conditions and the Hudson equation, the rock size is calculated at approximately 2 tons – that is, a rock diameter of about 3 feet. This is only slightly larger than the rock size at the existing WWRF revetment.

7.3.1 Alternative 3A – Revetment Extension

For this alternative, the revetment would be extended to the west along the WWRF property length, a distance of approximately 1,200 feet. The east flank of the existing revetment may also need to be revised or extended landward to minimize the potential for flanking by the beach as erosion proceeds. The revetment would be constructed along the back portion of the beach, close to the existing fence line, and would be a similar design to the existing revetment. Figure 26 and Figure 27 illustrate the plan view and cross-section of this revetment alternative.

Alternative 3A would require approximately 13,000 tons of 2-ton armor stone and 6,000 tons of bedding stone. The existing beach material that was removed to construct the revetment would be replaced over the structure, but no further sand would be added to the system. Thus, Alternative 3A would not encroach on the existing beach, but it would not protect the beach or provide additional beach area.

Alternative 3A would not protect the upland area from runup and overwash associated with a major storm or tsunami event. Flooding and minor damage to the upland area can be expected in the event of a significant storm.

7.3.2 Alternative 3B – Buried Revetment

This alternative includes adding beach replenishment to the revetment solution to provide a recreational beach area and to minimize impacts to littoral transport and adjacent beaches. The revetment would be identical to that in Alternative 3A, except in that it would be buried. The revetment would remain buried for the most part, and would act as a last line of defense for the WWRF in the event of severe erosion caused by storms or tsunami. The revetment and beach replenishment plan is shown in Figure 28; the revetment section is the same as in Alternative 3A, see Figure 27.

The proposed beach is narrower than that proposed in Alternative 1B, Beach Replenishment. The beach is narrower – a 20-foot increase in beach crest – because it need not be wide enough to provide protection from seasonal fluctuations. The revetment will protect the property in the event of a large seasonal fluctuation that temporarily removes sand from the shoreline fronting the WWRF property. It is anticipated, however, that normal seasonal accretion would occur and that the revetment would remain covered the bulk of the time. With proper planning of the revetment location and periodic beach replenishment maintenance, the seasonal erosion and accretion will occur naturally in front of the revetment.

In addition to the rock quantities listed in Alternative 3A, this alternative includes approximately 30,000 cubic yards of initial beach fill for the 20-foot increase in beach width. The renourishment quantity would be similar to that in Alternative 1B: approximately 16,000 cubic yards of replenishment sand would be required every 8 years to maintain the project design width.

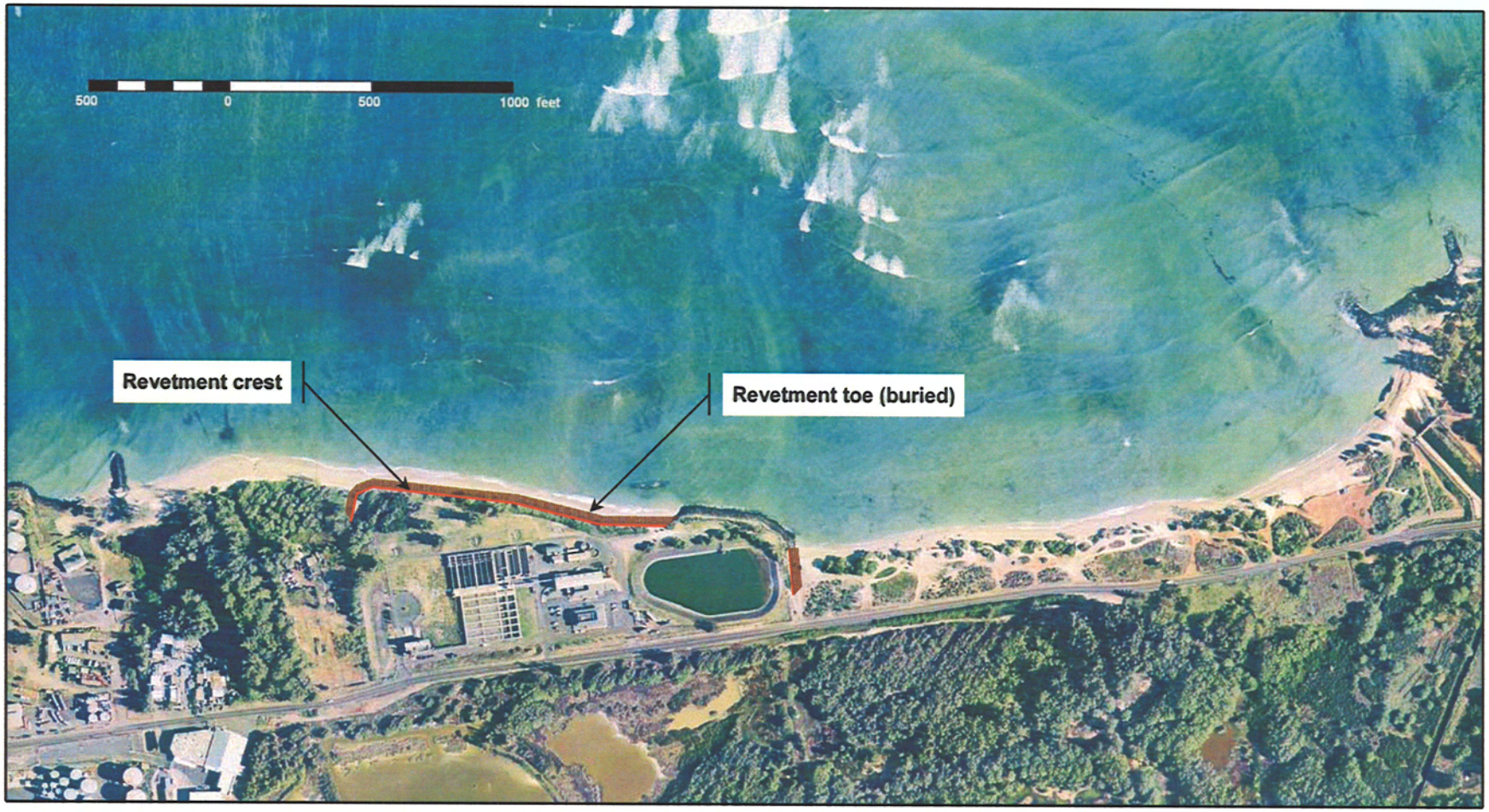


Figure 26. Plan view of Revetment Alternative 3A

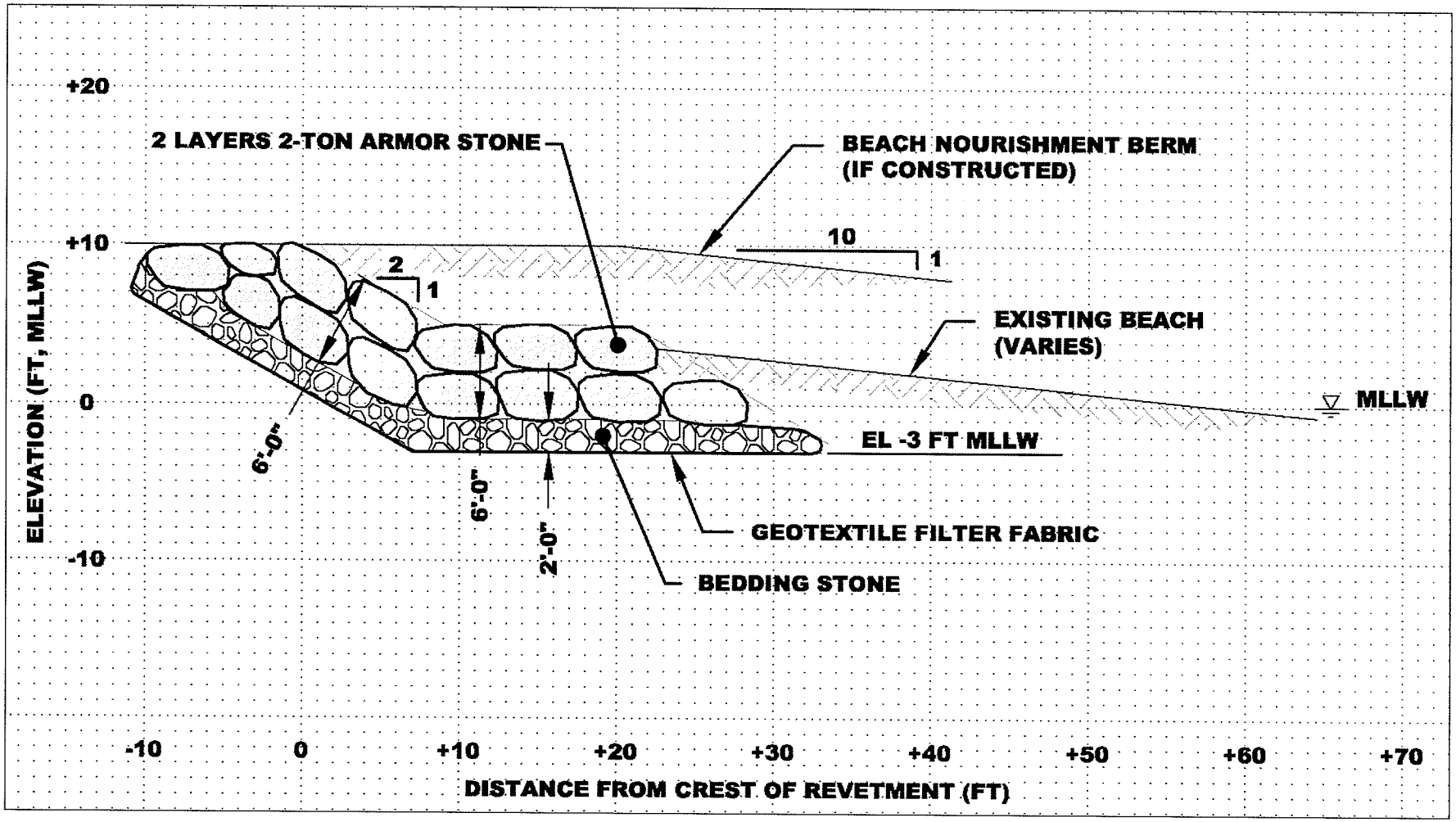


Figure 27. Typical Revetment Cross-Section

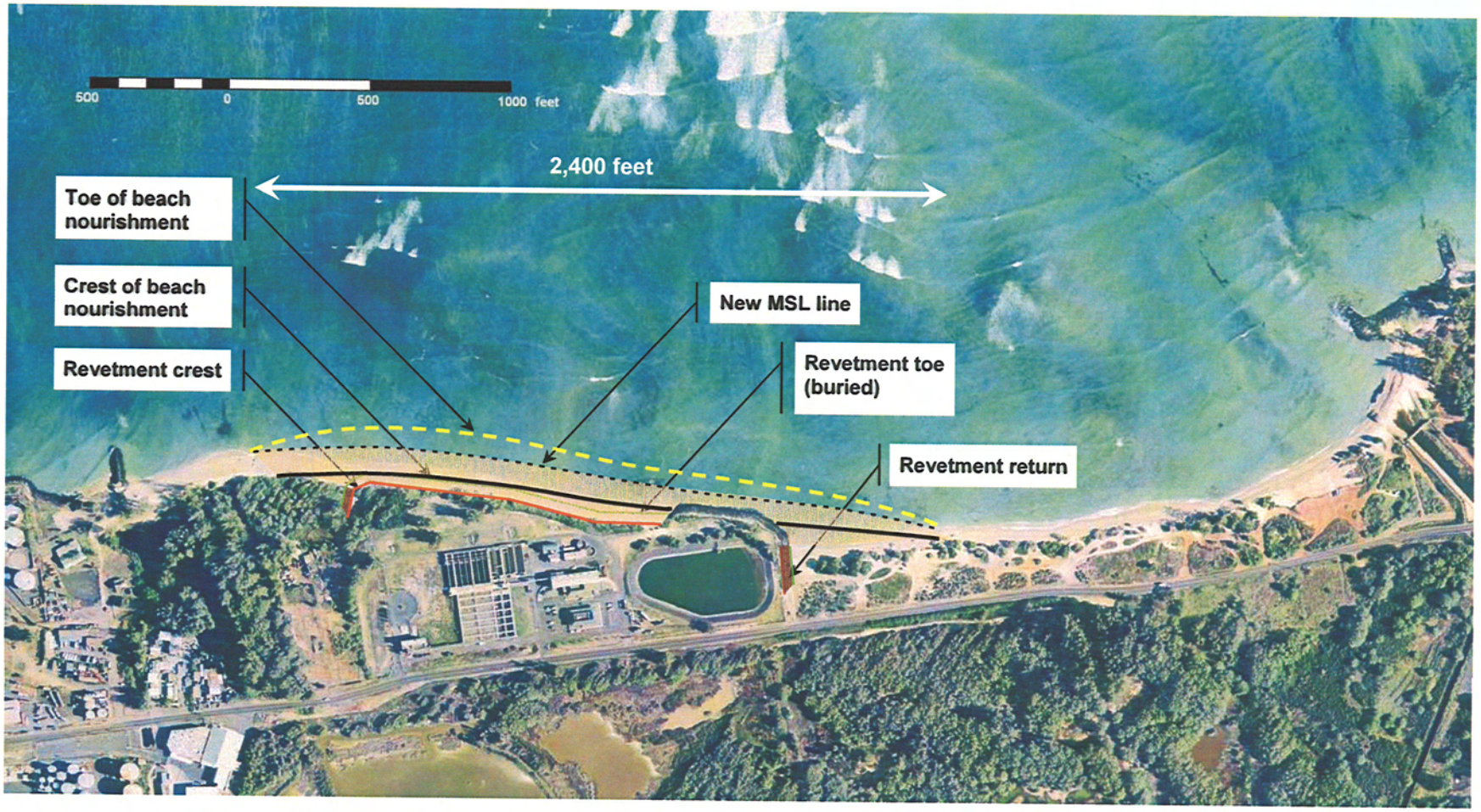


Figure 28. Plan view of Revetment Alternative 3B (With Beach Replenishment)

7.4 Alternatives Not Carried Further

Two alternatives previously suggested for the WWRF shore protection are eliminated from further consideration: beach replenishment with multiple T-groins, and the use of sand-filled geotubes as a revetment alternative.

As mentioned in Section 7.2.3, one possible beach replenishment alternative would include a single groin in the vicinity of the existing WWRF revetment, to retain beach sand along the shoreline fronting the WWRF and to avoid its moving east (updrift) through diffusion effects. This sub-alternative would involve a single, much less intrusive, groin than the full groin field previously suggested. The groin could potentially be constructed of a single sand-filled geotube as a pilot or test project: if successful, it would likely need to be replaced with a rock groin in the long-term. Because of the limited extent of the groin in this sub-alternative, it is not explored in detail in this report.

7.4.1 Beach Replenishment with T-Groins

This alternative was proposed as Alternative 2 in the initial Shoreline Evaluation Report (M&N 2005). At the time, the relative magnitude of the longshore sediment transport rate and the volume erosion rate were unknown. In cases where the longshore sediment transport is large compared to the volume erosion rate, beach replenishment without sand retention structures such as a groin field is unlikely to be cost-effective – the placed sand will immediately be swept downcoast.

This does not appear to be the case at the Maui WWRF. The most likely average rate of longshore sediment transport to the WWRF beach is estimated at approximately 2,600 cubic yards annually (Section 6.5), which is similar to the quantity of sand that will be placed annually. Thus, the rate of longshore transport does not dominate the system and a dense groin field is not required. The main threat to the WWRF appears to be cross-shore loss of sand during seasonal fluctuations, rather than alongshore loss of sand to the Kahului Harbor breakwater and offshore. This alternative is not taken further.

7.4.2 Geotubes as Revetment Alternatives

Geotubes are simply large geotextile bags that are hydraulically pumped full of sand and used as elements of a revetment or groin system, typically in place of stone. Given the high cost and limited availability of sand on Maui, using rock is a more effective solution. In addition, the durability and long-term stability of geotubes in an open-ocean application is questionable, therefore this alternative was eliminated as a revetment alternative.

8. SAND SOURCES

Almost all of the recommendations for erosion control include beach replenishment. One of the critical unknowns is the availability of sand and the estimated costs for placement. This section reviews the findings from M&N's 2005 *Shoreline Evaluation Report* and presents updated information from the quarries and a preliminary search for potential offshore sand deposits.

8.1 Native Sand Characteristics

One of the critical parameters for the success of beach replenishment projects is the ability to match the native (existing) and source sands. Although this phase of the work did not include a sampling program, the following information provides a baseline for developing the native sand parameters to guide the search for suitable beach-compatible sand.

Moberly and Chamberlain (1964) analyzed sand samples on various Hawaiian beaches. The sands from the Kahului to Spreckelsville area were almost entirely carbonate. Mechanical analyses were made of sand samples taken from the berm and at approximately mean sea level. At the beach adjacent to the east breakwater at Kahului Harbor, the grain size was found to be 0.2-0.5 mm at the berm and 0.3-1.0 mm at sea level. The median diameter of Maui's windward beaches was 0.18 mm. Moberly and Chamberlain concluded that finer-grained sediments were found on the windward coasts of all of the islands analyzed; however, they found that Maui's beach sands were typically finer than sands found on the other Hawaiian Islands.

8.2 Upland Sand Sources

Maui dune sand is relatively fine sand that is found in the upland areas; this sand has been used for dune and minor beach fills. One upland dune quarry that has been used for source material is located in Happy Valley, approximately 10 miles from Sugar Cove (Guild 1999). However, these relatively fine-grained sediments are not ideal for high-energy beaches such as the Kahului area. For example, Bodge (1999) stated the Honokowai Beach Park site, the upland dune material exhibited a 45% overfill requirement. (Overfill is the additional sand that must be placed on the beach due to the source sand being finer than the native sand. The higher this ratio, the more material must be placed, and the higher the project costs.)

The inland sand mines on Maui have historically charged between $10 and $18 per cubic yard. On other islands, the cost has ranged from $25 to $60 per cubic yard (Honolulu Advertiser, September 9, 2004).

In 2006, SSFM completed the *Maui Inland Sand Resource Quantification Study* (SSFM International 2006) to help the County of Maui mange its limited sand resources. The most significant finding from this report was that the upland sand resources for both concrete and larger-scale beach replenishment will be exhausted within 5 to 6 years. Some estimates predict the available beach quality sand will run out in as little as 2 years (Honolulu Advisor 2007). While there may still be some smaller sites available for small-scale beach replenishment projects this likely will be at a higher cost that the existing "production" site.

Due to the probable sand quantity and quality requirements for the WWRF project, it should be assumed that there will be no upland sand sources available to provide suitable beach sand for the Kahului WWRF erosion control project.

8.3 Imported Sand

Sand is regularly imported from Canada for use in concrete production, and sand from China and Australia has been used for beach replenishment on Waikiki in the past (Tim Folks, Hawaiian Cement, telephone communication, 2007).

Three Canadian sources of sand for concrete production are at Sechelt, BC, which is about 60 miles north of Vancouver; Earle Creek, about 20 miles further north; and Orcas Sand and Gravel on Vancouver Island. The sand from Canada is generally silicate rather than the carbonate sand typical of Hawaiian beach sand: for example, the sand from Orca Sand and Gravel is granite with a little basalt, and is salt and pepper or dark gray in color. The cost to import sand to Oahu is slightly more than the cost of Hawaiian sand, although the costs increase further if the sand is to be moved to another island.

8.4 In-Water Sand Sources

There is very limited beach replenishment experience in Hawaii, especially using offshore sand sources. This makes it difficult to predict performance as well as to assess construction and maintenance costs of a larger-scale beach replenishment project.

Historically, most small-scale beach replenishment projects on Maui have used sand from upland sources. As described in the Section 8.2, sand from these sources is not likely to be available in sufficient quantities and of a suitable quality for use at the Kahului WWRF. Imported sand sources are unlikely to be economically viable. Consequently, a primary recommendation of the M&N's 2005 "Shoreline Evaluation Report" was to conduct a study to investigate the potential of offshore sand sources. This study has also been recommended by other interested parties in the Hawaiian Islands. For example, the University of Hawaii Sea Grant Extension Service and County of Maui Planning Department prepared a *Beach Management Plan for Maui (1997).* The plan recommended potential offshore borrow sites be identified, mapped, and sampled. NOAA (2007) recently completed a characterization of the geomorphology and biology of the nearshore regions around Maui. Figure 29 presents the area near the WWRF and indicates that there are two potential borrow locations within one mile of the site. The larger of the two is well over 200 acres, and may be more than adequate to provide all of the present and future replenishment needs at the site. The biological coverage maps indicate that these sites have very limited coral cover, so they may be good candidates as borrow areas from a biological impact aspect.

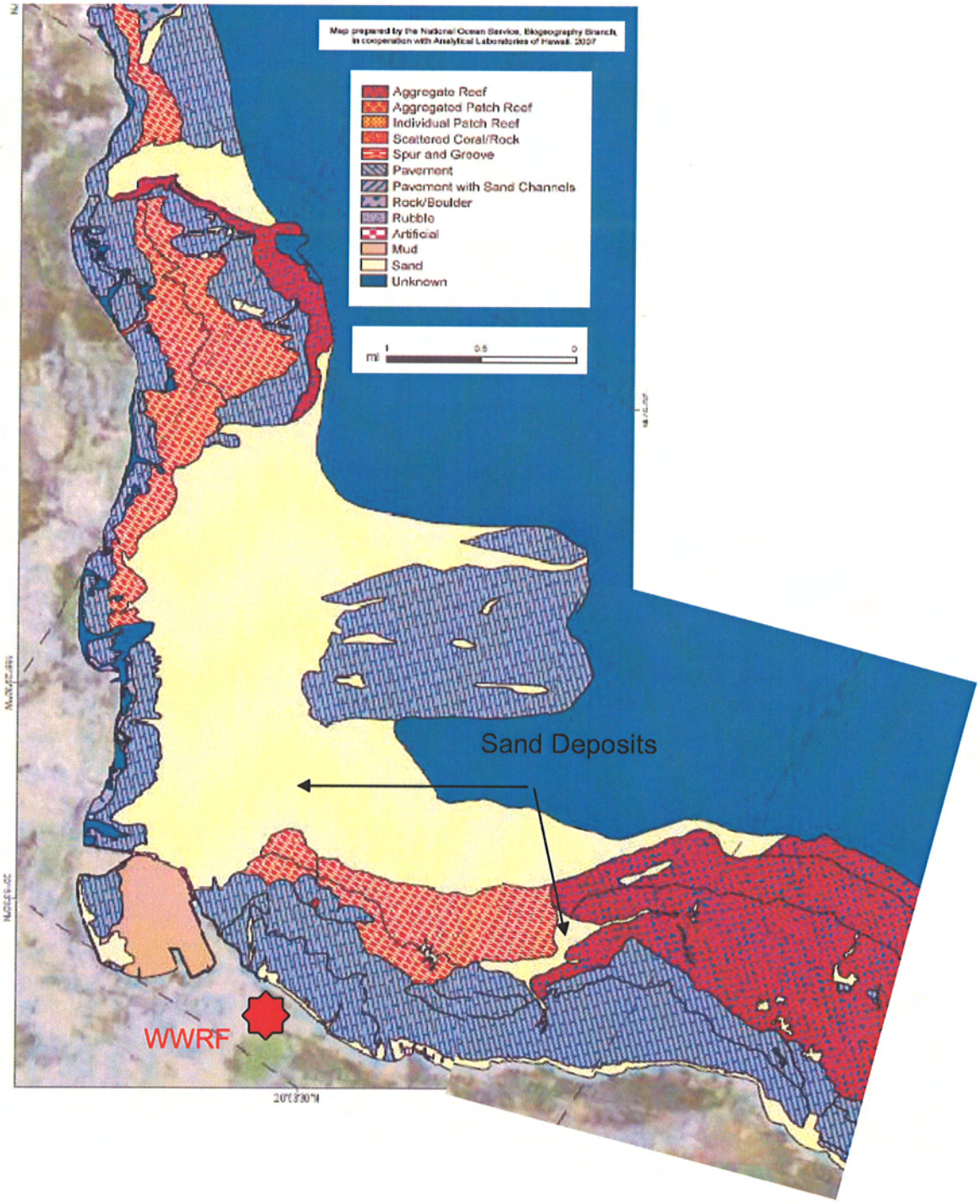


Figure 29. Nearshore Geomorphology near WWRF

To investigate this potential source for sand, M&N subcontracted Sea Engineering, Inc. to perform a sub-bottom geophysical survey with grab samples offshore of the Kahului Harbor. The survey was performed in May 2008, covering an area of approximately 5.5 square miles and collecting 8 grab samples over the course of two days. The results confirmed that there is a large deposit of sand, 10-20 feet deep over much of the sampled area. Figure 30 presents the sampling area, the depths of the sand deposits, and the locations of the grab samples.

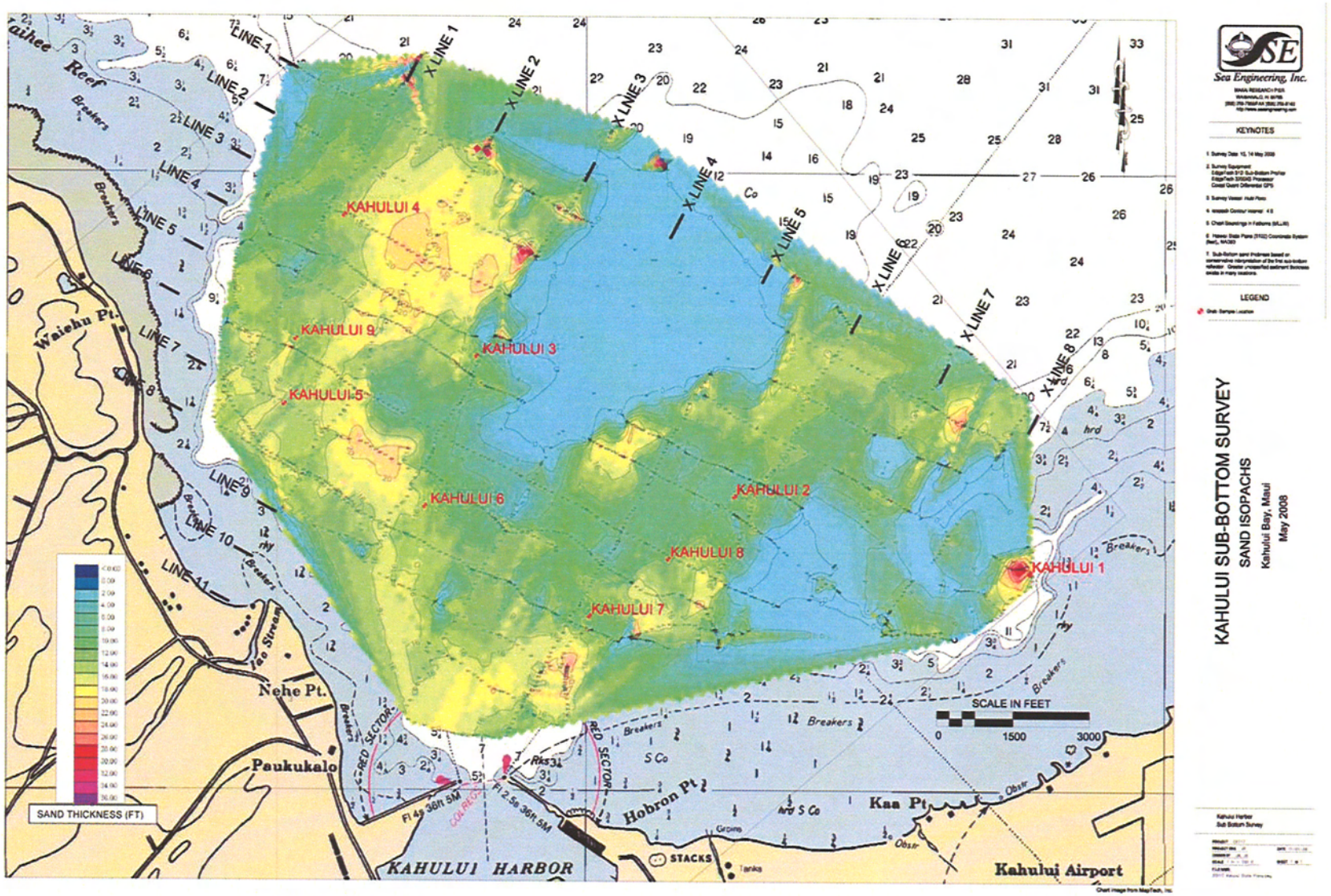


Figure 30. Sand Thicknesses and Grab Sample Locations (Sea Engineering 2008)

Of the nine samples collected, 2 two (Samples 5 and 8) had booth good color and grain size for use as beach-quality sand. Figure 41 presents a photo of the sample from location 8 (D50 ~ 0.50mm), and the entire Sea Engineering Report is presented as Appendix C.

Figure 31. Grab Sample 8 Sand

Unit costs for beach replenishment using dredged material can vary widely depending on the characteristics and proximity of the borrow site. In the 2005 "Shoreline Evaluation Report", M&N used a cost basis of $25 per cubic yard, based on mainland dredging projects. Discussions with local contractors indicate that the costs at the potential borrow site offshore of Kahului may be more than $70 per cubic yard due to the dredging depths, wave exposure, and potential environmental restrictions that could reduce production rates. A recent small-scale pilot project at Waikiki, constructed in late February/early March 2005, involved pumping 10,000 CY of sand from an offshore sand source to Kuhio Beach. The total project costs were approximately $450,000, including $320,000 for the direct cost of pumping the sand and $75,000 for mobilization. Based on the sand placement costs alone, this gives a unit cost (in 2005) of $39.50 per cubic yard (Eversole, e-mail communication, 2005).

A recent 100,000 cubic yard confidential analysis for a project in Maui was quoted with a total unit cost of $40-$50 per cubic yard, constructed as follows:

Mobilization and Demobilization: $1.1 million. Equipment included the following:

- 1 – crane barge w off shore mooring equipment mobilized from Oahu
- 1 – 2,000 hp tugboat for crane barge utilized because of 24 hr/day operations
- 1 – 500 hp workboat
- 1 – 10" submersible pump. Toyo DP150 or equal
- 1 – 100 KW generator
- 1 – D8 Dozer
- 1 – Cat 322 excavator
- 1 – Cat 980 loader
- 6 – light plants for beach work

Production rate 1,600 cubic yards per day
Work 7 days per week
15% downtime due to weather
The offshore sand source was approximately 0.5 km to 1 km offshore of the beach.

The present cost analysis is based on these values for mobilization/demobilization and production rate. An additional outcome of this analysis is that, given the relatively high costs of mobilization for dredging, it is recommended that additional sand be dredged and stockpiled for future beach renourishment and/or emergency use.

9. ENVIRONMENTAL AND REGULATORY CONSIDERATIONS

9.1 Potential Environmental Impacts and Benefits

Potential impacts from construction of any of the alternatives may include temporary and permanent impacts. Temporary impacts include traffic congestion from trucking sand or armor to the beach; air quality impacts from the trucking, construction equipment, and dredge equipment; and turbidity impacts during placement of sand.

Permanent impacts from construction of a shore protection project include the potential for impacts to adjacent shorelines, reef health, and public access. Precautions should be taken to prevent eroded soils, construction debris, and other contaminants from entering the coastal waters. There is also a small chance of increased sedimentation at Kahului Harbor if large quantities of beach fill are placed along the reach east of the harbor. This may require more frequent maintenance dredging to maintain the design depth in the harbor; however, the present lack of beach quality sand at the mouth of the harbor indicates that beach sand is not being transported there.

Surrounding beaches may benefit from the placement of sand as the sand disperses and longshore transport carries the sand up- and downcoast. However, careful design and modeling may be necessary prior to implementation of any beach fill alternative to ensure the fill material does not migrate significantly offshore, burying the reefs along the project coast.

Impacts to adjacent beaches from the construction of a revetment or shore-parallel structures, such as seawalls, are the subject of much controversy. Most science indicates such structures do not negatively impact adjacent shorelines unless they prevent erosion of an upland source of sand for a beach downdrift or are situated to act as a groin. On shorelines that experience a net long term erosion or are subject to relative sea level rise, the shorelines adjacent to hard structures can migrate landward, resulting in "passive erosion", which can limit lateral access to the adjacent beaches. (Griggs 2005) Revetments and seawalls are usually constructed on eroding beaches to protect the upland property. They are also constructed in some cases on stable beaches, providing as needed protection against short-term, storm-induced erosion. The former is the case for this project.

Maui's north coast is actively eroding and will continue to erode under natural conditions. If a revetment alternative is selected, it may be beneficial to propose beach replenishment at a different location – for example, at a beach that is more heavily used for public access and recreation – in mitigation for potential impacts. This may provide more valuable benefits than on-site beach replenishment as assumed in the buried revetment alternative.

Monitoring will be required for any alternative constructed at the site and may include beach profiling, grain size analysis, project performance, and observable water quality impacts.

9.2 Regulatory Requirements

The State of Hawaii and County of Maui are the local regulatory agencies for permitting shore protection structures. The main local regulations pertaining to shore protection include the *Hawaii Revised Statutes Chapter 205-A,* Coastal Zone Management, and the *Shoreline Rules* for the Maui Planning Commission. Other agencies involved with the permitting of a shore-protection project will be the State of Hawaii Conservation and Coastal Lands Department, the

Hawaii Health Department Clean Water Branch, and the US Army Corps of Engineers (USACE).

The first step will be for an Environmental Impact Statement (EIS) to be prepared for the project. This document will describe the proposed project; any impacts associated with the project, and proposed mitigation. It is highly recommended that a pre-consultation with the regulatory agencies be conducted during the preparation of the Draft EIS to better understand agency positions and resolve any issues prior to the Draft EIS being released for public comment.

The Draft EIS is circulated for public review and comments and will go to a public hearing. After all comments have been received and addressed, the EIS can be finalized. The Final EIS also will have a public hearing process for approval.

After the EIS is approved and certified, pre-application meeting with the local, state, and federal agencies can commence. The County will process their application first, followed by the State Conservation Use Permit application, and finally the USACE Section 404/Section 10 and the Water Quality 401 Certification.

The County of Maui permits include a Shoreline Setback Variance and a Special Management Area (SMA) permit. All proposed activities and/or structures within the SMAs will undergo an assessment to determine what special conditions or controls on development, if any, are required before the activity or structure is permitted. Most coastal projects fall within the jurisdiction of the County's Coastal Zone Management program. The Maui County Planning Department also works closely with the State of Hawaii Coastal and Conservation Lands Office in helping find the best long-term solutions to coastal erosion problems. These two agencies also consult with the University of Hawaii's Sea Grant Program for their technical assistance on the proposed coastal activity.

If a structure is within the shoreline setback area and is not under an emergency situation, then the County proceeds in its regular process of building a new structure in the Special Management Area (SMA). The WWRF alternatives will all fall under the Major SMA permit, which includes projects that cost more than $125,000 or may have coastal or other environmental impacts. Major SMA permits are required to go through a public hearing process and approval is by the Maui Planning Commission. The first item the County considers is if the structures can be relocated. In the case of the WWRF, some structures may be relocated, but most of the large process areas cannot be relocated because of limited area at the site. Since many of the structures at the WWRF cannot be relocated, County regulators may require a long-term commitment to beach replenishment program be implemented and also provide safe lateral public access along the shoreline. This can either be a walkway on or near the revetment or beach area for the public.

The State generally does not allow hard structures to be placed within its jurisdiction, so most applications for hard structures need to be placed entirely within the boundaries of the property owner (landward of the shoreline), if possible, and as such are permitted under the County SMA,. In order to acquire a variance from the County to construct a hard structure, an Environmental Impact Statement, Environmental Assessment, public notice, and a public hearing will need to be conducted as described above. A variance can be approved for improvements proposed by public agencies or public utilities regulated under *Hawaii Revised Statutes (HRS) Chapter 269*. The Kahului-Wailuku Wastewater Reclamation Facility is a County-owned pubic utility regulated under this statute. To facilitate permitting, the County could create a special zoning designation for the project.

The USACE permits fall under the *Rivers & Harbors Act 1899 § 10 and/or the Clean Water Act § 404*. Section 10 of the Rivers and Harbors Act of 1899 requires approval by the USACE prior to any work in navigable waters of the United States, or which affects the course, location, condition or capacity of such waters. For the WWRF project, any dredging offshore would require a Section 10 permit. Section 404 of the Clean Water Act requires approval by the USACE prior to discharging dredged or fill material into the waters of the United States. This would include beach fill material as well as riprap for revetment construction. The USACE may also initiate a Section 7 consultation with the United States Fish and Wildlife Service (USFWS) if any aspect of the project may impact any endangered or threatened species or adversely impact any critical habitat of these species. The USACE will likely process any project at the WWRF as an individual permit, which undergoes through a public notice period. Processing of Individual permits can take up to 180 days for complex and highly controversial projects.

The State of Hawaii Department of Health, Clean Water Branch is the agency charged with issuing 401 Water Quality Certifications under the *Clean Water Act - § 401*. Section 401 of the Clean Water Act requires that any project requiring a Section 404 Federal Permit shall also require approval to ensure that the discharge will comply with the applicable provisions of the Clean Water Act.

In Hawaii, there is a special permit process for small-scale beach replenishment projects. Projects that propose placement of less than 10,000 CY of carbonate sand in waters and land of the State of Hawaii can be permitted through the State of Hawaii Department of Land and Natural Resources under a streamlined permit application process. This small-scale beach replenishment permit consolidates the permits required under Local County, State, and federal agencies. These permits include the statewide DLNR, Conservation District Use Permit (CDUP), the US Army Corps of Engineers (USACE), State Programmatic General Permit (SPGP), the State of Hawaii Department of Health Section 401 Water Quality Certification and the Hawaii Coastal Zone Management Federal Consistency Review. Although this permit would probably not apply to the base project, it may be applicable for future renourishment and/or emergency sand placement.

10. COST ESTIMATES

Costs for each of the alternatives were estimated based on a 50-year design life and include estimates for engineering and construction support. Due to the unknowns regarding the permitting requirements and level of community resistance to various schemes, the costs for permitting have not been included. (For budgeting purposes, the permitting costs are anticipated to be on the order of $300,000 - $400,000.) A more detailed cost estimate for each alternative is provided in Appendix B.

Present Value Costs calculate the initial construction and future maintenance costs based on current-value dollars. The maintenance costs were inflated for each maintenance cycle to address inflation, future labor rates, future construction costs, etc. The inflation rate is taken at 3.5%, based on the Engineering News Record Construction Cost Index between 1990 and 2005. Recent construction inflation has been higher than this: the Construction Cost Index increased by 9% in 2004, and increases were even higher for heavy construction such as the shore protection considered here. However, given the beach replenishment alternatives require renourishment over a period of 50 years; the relatively long-term construction inflation rate is more relevant than the recent dramatic increases.

The inflated costs for maintenance were reduced to a Present Value cost using the present (2008) interest rate for USACE projects, 4.875%.

Annualized Costs calculate the annual cost of each alternative over the life cycle of the project (50-years). This section provides Annualized Maintenance Costs, indicating the annual cost needed to conduct the future maintenance over the 50-year life cycle. The rate of return used in the Annualized Costs is 4.875%.

Table 7 outlines the Net Present Value (NPV) total cost for construction and future maintenance for each alternative for the WWRF. The annualized maintenance cost is also shown. Note the annualized maintenance cost is shown for convenience – it is not in addition to the NPV maintenance cost.

Table 7. Approximate Costs for the WWRF Alternatives

Item	Initial Construction	NPV of Maintenance	NPV of Total Cost	Annualized Maintenance*
Alternative 1A: 3,800-foot Beach Replenishment				
Dredged Sand	$6,000,000	$7,100,000	$13,100,000	$380,000
Purchased Sand	$4,300,000	$3,700,000	$8,100,000	$200,000
Alternative 1B: 2,400-foot Beach Replenishment				
Dredged Sand	$4,400,000	$5,900,000	$10,400,000	$320,000
Purchased Sand	$2,800,000	$2,700,000	$5,500,000	$150,000
Alternative 3A: 1,200-foot Revetment Extension				
Initial Construction	$3,700,000	$500,000	$4,200,000	$50,000
Alternative 3B: Revetment with 2,400-foot Beach Replenishment				
Dredged Sand	$5,800,000	$5,900,000	$11,700,000	$320,000
Purchased Sand	$5,000,000	$2,700,000	$7,700,000	$170,000

* The annualized maintenance cost is *not* in addition to the NPV maintenance cost: this column is provided for convenience

Two alternative costs are provided for the alternatives that include beach nourishment: these account for the fact that mobilization costs are likely to be significantly higher if the replenishment sand must be dredged specifically for this project. More generally, the costs for the beach replenishment alternatives depend critically on the availability of suitable beach sand. While general nearshore geomorphology (see Figure 29 and 30) suggests the presence of suitable sand sources, the costs and viability of dredging this material have not been confirmed. The results of a targeted sand search and dredging feasibility analysis could dramatically change the costs given here.

The initial construction costs for the different alternatives are relatively similar – potentially varying between $2.8 million and $5.8 million. As a result of the need for ongoing renourishment, the alternatives with a beach replenishment component have larger total costs. However, these alternatives also provide recreational and habitat benefits in addition to the benefits association with protection of the WWRF.

11. ALTERNATIVES EVALUATION

A number of evaluation criteria are available to determine the most appropriate shoreline erosion solution for the Kahului WWRF. No single solution is best in all possible circumstances. This truism results not only from physical differences – for example, the availability of sufficient beach sand – but also from the different weight applied to the evaluation criteria by different organizations or individuals.

- Three main categories of evaluation criteria can be identified:
- Economic: initial construction cost, life-cycle costs, design life.
- Environmental / Biological: effects on biological resources in the area including sea turtles and the reef.
- Environmental / Human: effects on direct human interests in the area, including aesthetics, the potential for impacts to Kahului Harbor such as increase dredging frequency, effects on recreation.

One criterion that ties in all three areas is the potential for effects on adjacent shoreline areas. These can be economic (e.g., erosion or accretion caused by the project could change the potential for storm damage at an adjacent property); biological (e.g., changes to turtle nesting areas); or recreational (changes in the available beach area). Because of the importance of this criterion, it is called out separately in the present analysis.

Regulatory compliance is a critical criterion: if an alternative is not consistent with current regulations then it must be rejected. However, it is unlikely to distinguish between acceptable alternatives – this is a pass/fail criterion.

Table 8. WWRF Alternative Evaluation Criteria

	Alternative 1A 3,800-ft Beach Replenishment	Alternative 1B 2,400-ft Beach Replenishment	Alternative 3A 1,200-ft Revetment	Alternative 3B Revetment with Replenishment
Economic Criteria				
Facility Protection Effectiveness	Basic shoreline erosion protection with sand reserve if properly maintained.	Basic shoreline erosion protection if properly maintained.	The revetment may provide some measure of tsunami protection to the upland facility in addition to protecting the facility from shoreline erosion.	The revetment may provide some measure of tsunami protection to the upland facility in addition to protecting the facility from shoreline erosion.
Initial Construction Cost*	$4 M to $6 M	$3 M to $4.5 M	$3.5 M to $4 M	$5 M to $6 M
Maintenance Cost (NPV)*	$4 M to $7 M	$3 M to $6 M	$0.5 M	$3 M to $6 M
Environmental Criteria				
Regulatory Compliance	Compliant	Compliant	Compliant. May be an unpopular solution (due to aesthetics and access) which may delay permitting. More likely to require mitigation.	Compliant
Effects to Adjacent Shoreline	Significantly increases the width of the beach east of the Kahului WWRF – by an average 40 feet Over time, will increase the width of the beach west of the Kahului WWRF to a lesser extent	Over time, will increase the width of the beach east of the Kahului WWRF through diffusion, and west of the WWRF through diffusion and net longshore transport This increase will be less than for Alternative 1A, and will likely be concentrated in the area close to the WWRF property	If the revetment acts as a groin, this alternative may limit the transfer of sand from the kite beach area to the beach west of the WWRF. Without adding additional sand, the revetment has the potential for causing passive erosion of the adjacent beaches and limiting lateral access.	Similar to Alternative 1B unless the seaward beach erodes, then the effects would be similar to Alternative 3B.

	Alternative 1A 3,800-ft Beach Replenishment	**Alternative 1B 2,400-ft Beach Replenishment**	**Alternative 3A 1,200-ft Revetment**	**Alternative 3B Revetment with Replenishment**
Biology	Short-term turbidity impacts may occur during construction. Additional sediment fate modeling is needed to ensure the reef will not be negatively impacted by sand transported offshore in the short- or long-term Provided appropriate work windows are maintained, the effects on species dependent on the beach are expected to be positive for this alternative	As Alternative 1A, except that both potential positive and negative effects are likely to be less.	Minor effects compared to existing conditions.	Similar to Alternative 1B
Environmental Criteria – Human				
Aesthetics	Positive effect if beach sand is selected with acceptable coloration	Similar to Alternative 1A, except that the effect is observed over a shorter stretch of beach.	The longer revetment may be considered unsightly	Similar to Alternative 1B
Public Access and Usage	Positive effect: approximately 6 acres of additional beach area directly adjacent to heavily-used beaches with good public access	Smaller but still positive effect: approximately 4 acres of additional beach area, approximately one-quarter mile from the most heavily-used beaches	Potential for passive erosion of shoreline and limitations to public access at the site a lateral access to adjacent beaches.	Similar to Alternative 1B if the beach fronting the revetment is maintained.

	Alternative 1A 3,800-ft Beach Replenishment	**Alternative 1B 2,400-ft Beach Replenishment**	**Alternative 3A 1,200-ft Revetment**	**Alternative 3B Revetment with Replenishment**
Effects to Kahului Harbor	Little or no effects anticipated. The proposed replenished beach is well within the historical range of beach widths, and dramatic changes in required maintenance dredging at Kahului Harbor have not been observed over time	Little or no effects anticipated	Little or no effect	Little or no effects anticipated

* Note: Costs are very dependent on the availability of suitable sand for replenishment, and may vary outside this range

12. SUMMARY AND CONCLUSIONS

12.1 Erosion Rates and Infrastructure Risk

The analysis of recession rates at the Kahului WWRF has been updated to include the most recent (2007) aerial photography. The analysis shows the rate of recession was generally less during the period 2002 to 2007 than it was during the previous 5 years. This may result from normal interannual fluctuations, or it may represent a real slowing of shoreline erosion resulting from the decrease in longshore sediment transport with a narrowing beach.

The lower rate of recession has not been in place for long enough to rely on it for predictions of future behavior. Some structures, notably the access road and Injection Well No. 2, are within about 60 feet of the shoreline and will be at threat from a single large seasonal recession event within a year or less. The first major structure to be threatened by shoreline recession is the Effluent Meter adjacent to the Chlorine Contact Tank. This structure may be threatened in as little as 13 years, with an average anticipated period of 28 years until the structure is threatened. (For comparison, M&N estimated the minimum time for this structure to be threatened at 14 years in 2005).

In summary, the revised estimate of erosion rates and infrastructure risk has not significantly affected M&N's earlier (2005) conclusions, however, given the variability in these projections, the unpredictability of future storms, and the typical time required to design, permit, and construct a shoreline protection project (3 – 5 years), it is recommended a shoreline protection alternative be selected and implemented as soon as possible.

Key Points

- The largest contribution to the long-term erosion of the north shore beaches is the removal of sand from the beaches for lime production by the Sugar Company and additional sand mining by others for cement manufacturing and aggregate. This permanent removal of sand from the littoral system has resulted in a deficit in the sediment budget and erosion over the length of the study area from Baldwin Beach to Kahului Harbor.
- The rate of shoreline erosion at the WWRF has slowed since the cessation of sand mining; however, it is still a significant consideration for the log-term safety of the facility.
- Based several different shoreline analysis techniques and data sets, we recommend using that a typical seasonal variation of 20 to 30 feet and a maximum seasonal variation of 50 to 60 feet be used for planning. Similarly, we recommend using typical long-term erosion rate of 2.4 feet per year and a maximum long-term erosion rate of 6 feet per year for use in planning, engineering design and estimating the time until facilities are impacted.
- The shoreline at the WWRF facility has demonstrated long-term erosion that threatens several minor structures from a single large seasonal recession event within a year or less. The first major structures to be impacted by this shoreline recession may be threatened in as little as 13 years. If the estimates of acceleration in sea level rise are realized, then the time until the structures are threatened would be reduced. Given the small data set, unpredictability of future storms, unknowns concerning the acceleration of sea level rise,

and the typical time required to design, permit, and construct a shoreline protection project (3 – 5 years), **it is recommended a shoreline protection alternative be selected and implemented as soon as possible.** .

12.2 Sediment Budget

A major recommendation of M&N's 2005 *Shoreline Evaluation Report* was that a sediment budget analysis of the Kahului region should be performed. This report summarizes the results of this analysis, which is included in its entirety in Appendix A.

The major conclusion from the sediment budget analysis is the rate of longshore littoral transport is relatively small compared to the anticipated renourishment quantities required by the different beach replenishment alternatives. This means one of the previously proposed alternatives – beach replenishment retained by multiple T-groins – has been eliminated from consideration.

Secondary conclusions from the sediment budget include an independent estimate of the seasonal recession rate, which is consistent with the values developed by M&N; and estimates of the likely quantities of sand needed for future beach replenishment, which are generally smaller than the values developed by M&N. It is reasonable that the estimates of sand are different, in that the values provided here are conservative in an engineering sense and account for the importance of not underestimating future budgetary needs – while the values provided by the sediment budget analysis have the nature of a scientific "most likely" estimate. The engineering estimates provide a larger margin of safety and result in a more practical and economical renourishment plan that minimizes contractor mobilizations and takes advantage of economies of scale.

Key Points

- The results of a sediment budget study indicate that that the net rate of sediment transport at the shoreline adjacent to the Kahului Wastewater Reclamation Facility is currently between 1,300 and 4,000 cubic yards per year.

12.3 Alternatives Analysis

The previous *Shoreline Evaluation Report* considered three main alternatives: beach replenishment alone, beach replenishment with multiple T-groins, and a revetment. As mentioned above, the beach replenishment with multiple T-groins has been eliminated as an alternative. The two remaining alternatives, with two sub-alternatives for each, are analyzed further in this report:

- Alternative 1A: 3,800-foot long, 40-foot wide beach replenishment project;
- Alternative 1B: 2,400-foot long, 40-foot wide beach replenishment project;
- Alternative 3A: 1,200-foot long revetment extension;
- Alternative 3B: 1,200-foot long revetment extension, buried under a 2,400-foot long, 20-foot wide beach replenishment project.

Costs to construct and maintain these alternatives have been updated based on more recent construction information and updated designs. Results of the recent geophysical investigations (Barry 2008) offshore of Kahului identified large areas of potential beach-quality sand that has the potential to be dredged for the project. The costs could vary dramatically depending on the suitability of this material, the quantities required, and on any environmental conditions that may apply.

Key Points

- It should be assumed that there will be no upland sand sources available to provide suitable sand for a beach nourishment solution for erosion control due to quantity and quality requirements. However, a sand search seaward of the Kahului Harbor breakwater indicated a very large potential source of beach-quality sand that could be dredged for the project.
- A review of the permitting process indicates that the project may be subject to special legislation at the county level due to over-lapping jurisdictions and criteria at the certified shoreline.
- Two erosion control alternatives from the initial study were removed from further consideration. "T-Groins", and any other shore-perpendicular structures were removed due to the low longshore sand transport rates, and "Geotextile Tubes for Revetment" were removed due to durability and cost concerns.
- Four of the original concepts from the initial study were retained for comparative evaluation. Two different beach nourishment scenarios and two revetment scenarios. For planning of beach nourishment project, the estimates of renourishment volumes are 2,000-3,000 cubic yards per year at 8 year intervals. These higher rates provide a larger margin of safety and result in a more practical and economical renourishment plan that minimizes contractor mobilizations and takes advantage of economies of scale.

12.4 Initial Environmental Review

Initial discussions with regulatory agencies should be performed at an early stage to verify their concerns, mitigation needs, etc. Permits will be required on the Local, State, and Federal levels. It is anticipated that an EIS will be required for the project and that there will considerable community interest and involvement in the process.

13. REFERENCES

Barry, J. 2008. E-mail Communication dated May 15, 2008, Subject: Kahului Survey.

Bodge, K.R. and S.P. Sullivan. 1999. Hawaii Pilot Beach Restoration Project: Coastal Engineering Investigation. Prepared for Sate of Hawaii, Department of Land and Natural Resources, February 1999.

Brown and Caldwell Consultants. 1990. Environmental Assessment and Negative Declaration for the Wailuku-Kahului Wastewater Reclamation Facilities Additions and Modifications, Maui, Hawaii. Report prepared for the County of Maui, Department of Public Works Wastewater Reclamation Facility, November 16, 1990.

———. 2002. Sheet 11, Drawing Number G9, from the Phase IIA Modifications of the Wailuku-Kahului Wastewater Reclamation Facility. Prepared for the County of Maui, Department of Public Works and Waste Management, Revision dated 1/02.

County of Maui. 2008. Shoreline Setback Areas. Viewed online at <http://www.mauicounty.gov/departments/Planning/czmp/ssa.htm> on April 28, 2008.

Cox, D.C. 1954. The Spreckelsville Beach Problem. Experiment Station of the Hawaiian Sugar Planters Association, Honolulu, Hawaii, August 1954.

Curtis, G.D. 2008.Tsunami Mitigation in Hawai'i. *Solutions to Coastal Disasters 2008 Tsunamis*, American Society of Civil Engineers, April 2008.

Dalrymple, R.A. and Kriebel, D.L. 2005. *Lessons Learned from the Tsunami in Thailand*, National Academy of Engineering Website Open Document, 2005.

Eversole, D. 2005. E-mail Communication dated January 19, 2005, Subject: Waikiki Beach.

Everts, C. 2007, Estimate of Future Beach Behavior at the Kahului Wastewater Reclamation Facility, North Maui, Report prepared for Moffatt and Nichol Engineers by Everts Coastal. 2007

Fletcher, C.H. 1992. Sea-level trends and physical consequences: applications to the U.S. Shore. *Earth-Science Reviews*, 33, 73-109.

Fletcher, C.H., E.E. Grossman, B.M. Richmond, and A.E. Gibbs. 2002. Atlas of Natural Hazards in the Hawaiian Coastal Zone, Maui Section. Prepared in cooperation with University of Hawaii, State of Hawaii Office of Planning, and National Ocean and Atmospheric Administration, U.S.G.S Geologic Investigations Series I-2761, U.S. Government Printing Office.

Gibbs, A.E, B.M. Richmond, and C.H. Fletcher. 2000. Beach Profile Variation on Hawaiian Carbonate Beaches. *Carbonate Beaches 2000, First International Symposium on Carbonate Sand Beaches*, American Society of Civil Engineers, December 5-8, 2000, Key Largo, Florida.

Griggs, G.B. 2005. The Impacts of Coastal Armoring. *Shore & Beach* Vol. 73, No 1, Winter 2005.

Guild, B.Q. 1999. Beach Restoration at Sugar Cove, Maui, Hawaii. *Shore & Beach*, vol. 67, No. 2&3, April & July 1999, pp. 4-18.

Jeon, D. 1995. Sea Level Change and Coastal Erosion in the Pacific Islands. Ph.D. Dissertation, University of Hawaii, May 1995

Keting, Barbara, 2008. The 1946 Tsunami at Kahuku, NE Oahu, Hawaii, *Solutions to Coastal Disasters 2008 Tsunamis*, American Society of Civil Engineers, April 2008

Levin, J. 1970. A Literature Review of the Effects of Sand Removal on a Coral Reef Community. Prepared under the National Science Foundation, Sea Grant Program, Grant No. GH-93, December 1970.

Makai Ocean Engineering, Inc. and Sea Engineering Inc. 1991. Aerial Photograph Analysis of Coastal Erosion on the Islands of Kauai, Molokai, Lanai, Maui and Hawaii. Prepared for the State of Hawaii, Office of State Planning, Coastal Zone Management Program, June 1991.

Moberly, R. and T. Chamberlain. 1964. Hawaiian Beach Systems. Final Report prepared for Harbors Division, Department of Transportation, State of Hawaii, May 1964, Report No. HIG-64-2.

Moberly, R., et al. 1963. Coastal Geology of Hawaii. Report prepared as part of the Shoreline Plan of the State of Hawaii, November 1963, HIG Report No. 41.

Oceanit Laboratories, Inc. 1997. Coastal Protection and Beach Restoration Feasibility Study for Maui County. Prepared for the County of Maui, Planning Department, November 1997.

Norcross-Nu'u, et al. 2008. Bringing Sea-Level Rise Into Long Range Planning Considerations on Maui, Hawaii, *Solutions to Coastal Disasters 2008*, American Society of Civil Engineers, April 2008.

SSFM International, Inc. 2006. Maui Inland Sand Resource Quantification Study. Prepared for the County of Maui, Department of Public Works & Environmental Management, February, 2006.

University of Hawaii Sea Grant Extension Service and County of Maui Planning Department. 1997. Beach Management Plan for Maui. Report dated December 1997.

U.S. Army Corps of Engineers. 1971. Hawaii Regional Inventory of the National Shoreline Study. U.S. Army Engineer Division, Pacific Ocean Corps of Engineers, Honolulu, Hawaii, August 1971.

———. 1988. Case Histories of Corps Breakwater and Jetty Structures. Prepared by the Waterways Experiment Station, Vicksburg, Mississippi, Technical Report REMR-CO-3.

U.S. Army Engineer District, Honolulu and State of Hawaii. 1964. Hawaiian Island Beaches. Cooperative Beach Study, December 15, 1964.

Walker, D.A. 1994.*Tsunami Facts*. SOEST Technical Report 94-03, University of Hawaii, Honolulu, 1994.

Walker, D.A., 2004. *Maps of Runups for Large, Pacific-Wide 20th Century Tsunamis*, Tsunami Memorial Institute, Honolulu Hawaii, Oahu Map, 2004.

APPENDIX A –ESTIMATE OF FUTURE BEACH BEHAVIOR

ESTIMATE OF FUTURE BEACH BEHAVIOR AT THE KAHULUI WASTEWATER RECLAIMATION FACILITY, NORTH MAUI

Report prepared for Moffatt and Nichol Engineers
Report prepared by Everts Coastal
13 December 2007

Abstract

An estimated 1000 to 3000 cubic meters of sand per year is transported to the west along the beach in front of the Kalului Water Reclamation Facility. This net longshore sand transport rate is likely to continue into the future in the absence of any further upcoast human interventions and a continuation of the current sediment fluxes. A net addition of 0.002 meters/year to the present sea level rise rate (a distinct possibility) over the next 50 years could reduce this rate by 500 to 1000 cm/y. Our certainty in the estimates, on a scale of one (low) to 10 (high) is 5, an indication the analysis is a work in progress.

With conditions as they now exist, the shoreline movement rate at KWRF beach for the next 50 years will probably be somewhere in the range -0.15 to 0.05 m/y. This estimate is the rate at which the mean width of the beach will change since its back boundary will likely be fixed by a seawall. The volume change to shoreline change ratio is between 3000 and 6000 cubic meters per meter of shoreline retreat or advance.

To maintain the KWRF shoreline at its present mean position will require an estimated 400 to 900 cm/y of artificially-placed beachfill. If the sea level rise rate accelerates by 0.002 m/y, this estimate will increase by 80 to 200 cm/y and possibly slightly more due to a reduced input from upcoast. On a scale of 1 to 10, our certainty that the beachfill requirement will average between 500 and 1000 cm/y is a 6. Less beachfill will be required at the beginning of a 50-year project; more will be needed leading up to its conclusion.

TABLE OF CONTENTS

1.0 INTRODUCTION 1
2.0 BEACH PERFORMANCE DATA SET 2
3.0 HISTORIC BEACH BEHAVIOR 6
4.0 SEDIMENT BUDGET INPUT PARAMETERS 12
4.1 Control Volume Boundaries and Dimensions. 13
4.2 Mean Beach Widths and Retreat Rates. 18
4.3 Substrate Sediment Flux. 19
4.4 Net Longshore Sand Transport Fluxes. 20
4.5 Aeolian Sediment Flux. 25
4.6 Beachrock (Formation) Flux. 25
4.7 Sand Mining and Beach Restoration. 26
4.8 Offshore Sediment Source. 28
4.9 Seaward-Directed Flux Past the Shorebase. 28
4.10 In-Situ Gains and Losses. 29
4.11 Overwash Flux. 29
5.0 SEDIMENT BUDGETS AND NET LONGSHORE SAND TRANSPORT ALONG KWRF BEACH 30
5.1 Sediment Budget Results 32
5.2 Uncertainty 32
5.3 Net Longshore Sand Transport Estimate for KWRF Beach 33
6.0 ESTIMATE OF FUTURE PERFORMANCE OF KWRF BEACH 35
6.1 Net Future Beach Volume Change Estimate 35
6.2 Uncertainty 36
7.0 CONCLUSIONS 37
8.0 ACKNOWLEDGEMENTS 37
9.0 REFERENCES 38

LIST OF FIGURES

1.0 INTRODUCTION 1

2.0 BEACH PERFORMANCE DATA SET 2

Figure 1. Beach area as a function of survey month for KWRF beach and Kite beach (1987-2007) 4

Figure 2. KWRF beach area change with and without seasonal effects removed 5

3.0 HISTORIC BEACH BEHAVIOR 6

Figure 3. Beach area as a function of shoreline date adjusted for seasonal fluctuations, KWRF and Kite beaches. 6

Figure 4. Annual shoreline position change between 1912 and 2002. 7

Figure 5. Net shoreline change rates shown for the mid-points of time intervals between 1912 and 2007 averaged for the reach between KWRF beach and Blue Tile House beach, with the latest estimate limited to the reach from KWRF beach to the east end of Kanaha Park (data are not adjusted for reversible seasonal effects) 8

Figure 6. Beach plan area changes by coastal cell relative to a zero change for the entire 1912-1960 time period; large losses in cells 15-18 are due to sand mining, in cells 4 and 5 to the formation of hook-shaped bays by shore retreat just downcoast of large boulder groins, and the large gain in cell 1 to the formation of a fillet on the east side of the Kahului Harbor breakwater. 9

Figure 7. Beach plan area changes by coastal cell relative to a zero change for the entire 1960-1975 time period; the large loss on KWRF and Kite beaches (cells 1 and 2) is due to the formation of a hook-shaped bay to the west of a large groin at Kaa Point (between cells 2 and 3), the losses in cells 13-18 are in response to a continuation of beach sand mining, and the comparatively large gain in cell 4 probably reflects an extension of the groin between cells 3 and 4. 9

Figure 8. Beach plan area changes by coastal cell relative to a zero change for the entire 1975 and 1987 time period; large losses in cells 1 through 3 are due to a continuation of the evolution of hook-shaped bays in those cells. 10

Figure 9. Beach plan area changes by coastal cell relative to a zero change for the entire 1988-1997 time period; the large gain in cell 4 is apparently due to another extension of the groin between cells 3 and 4 and a continuation of the accretionary cycle of fillet formation. 10

Figure 10. Beach plan area changes by coastal cell relative to a zero change for the entire 1997-2002 time period; the large loss at cell 16 is due to the incipient formation of a hook-shaped bay immediately downcoast of the lime kiln revetment at cell 17. 11

4.0 SEDIMENT BUDGET INPUT PARAMETERS 12

4.1 Control Volume Boundaries and Dimensions. 13

Figure 11. Cumulative quantity of sand placed in Sugar Cove, cubic meters. 15

Figure 12. Beach areas above -1.6 ft (local sea level datum) at Sugar Cove during a period of artificial beach nourishment, in square feet as compiled by the apartment owners association; Profile (range) 3A is at the east end of the beach, 5A in the middle, and 7A at the west end. 16

Figure 13. Volume of sand artificially placed in Sugar Cove, cubic meters per placement episode. 17

Figure 14. Envelope of all profiles on Range 3A at Sugar Cove, Maui, 1996-2006; Range 3A is on the east side of the beach and near the middle of the cove. 18

4.2 Mean Beach Widths and Retreat Rates. 18

4.3 Substrate Sediment Flux. 19

4.4 Net Longshore Sand Transport Fluxes. 20

4.5 Aeolian Sediment Flux. 25

Figure 15. Estimated aeolian sediment transport flux for north Maui. 25

4.6 Beachrock (Formation) Flux. 25

4.7 Sand Mining and Beach Restoration. 26

Figure 16. Changes in coastal plan areas between 1975 and 2002 except in Cells 1 through 7 (cells with groins that have affected the coast since before 1960). 27

4.8 Offshore Sediment Source. 28

4.9 Seaward-Directed Flux Past the Shorebase. 28

4.10 In-Situ Gains and Losses. 29

4.11 Overwash Flux. 29

5.0 SEDIMENT BUDGETS AND NET LONGSHORE SAND TRANSPORT ALONG KWRF BEACH 30

Figure 17. Shoreline changes on north Maui for 1912-1975 and 1975-2002, adjusted for seasonal reversible fluctuations; cell numbers begin at the origin and go to 21 about 9000 meters from KWRF beach. 31

Figure 18. Shoreline changes on north Maui by time interval, 1912-1960 and 1960-2002, adjusted for seasonal reversible fluctuations; cell numbers begin at the origin and go to 21 at about 9000 meters from KWRF beach. 32

5.1 Sediment Budget Results 32

5.2 Uncertainty 32

5.3 Net Longshore Sand Transport Estimate for KWRF Beach 33

6.0 ESTIMATE OF FUTURE PERFORMANCE OF KWRF BEACH 35

Figure 19. Recent (1987-2002) shoreline behavior, KWRF beach. 35
6.1 Net Future Beach Volume Change Estimate 35
6.2 Uncertainty 36
7.0 CONCLUSIONS 37
8.0 ACKNOWLEDGEMENTS 37
9.0 REFERENCES 38

LIST OF TABLES

1.0 INTRODUCTION 1
2.0 BEACH PERFORMANCE DATA SET 2
Table 1. Cells with sandy beaches included in this analysis. 3
3.0 HISTORIC BEACH BEHAVIOR 6
4.0 SEDIMENT BUDGET INPUT PARAMETERS 12
Table 2. Dimensions of the littoral sediment lens. 17
Table 3. Beach changes upcoast of Kahului Harbor breakwater, 1899-1987. 21
Table 4. Groin location and effects, north Maui. 22
Table 5. Summary of net longshore sand transport estimates in and near KWRF beach. 24
Table 6. Beach behavior in the vicinity of the lime kilns during and immediately after the sand mining period 26
Table 7. Summary: sand mining and beachfill fluxes 28
5.0 SEDIMENT BUDGETS AND NET LONGSHORE SAND TRANSPORT ALONG KWRF BEACH 30
Table 8. Estimated net longshore sand transport rates at KWRF beach; based on sediment budget residuals 32
Table 9. Mean shoreline position change rates, west end of north Maui littoral system. 32
6.0 ESTIMATE OF FUTURE PERFORMANCE OF KWRF BEACH 35
7.0 CONCLUSIONS 37
8.0 ACKNOWLEDGEMENTS 37
9.0 REFERENCES 38

1.0 INTRODUCTION

This report was completed under a contractual agreement with Moffatt and Nichol, Engineers. Its primary objective is to estimate future beach behavior at the Kahului Wastewater Reclamation Facility, North Maui. As a part of a plan to protect the facility from wave attack, the goal is to quantify the requirement for artificial beachfill to retain the shoreline in a dynamically fixed position for the next 50 years, and to estimate the annual amount of sand that will be supplied from upcoast.

This report describes how the results were obtained using existing information and observations made during a three-day field trip. To increase confidence we used two methods to estimate the past behavior of the study beach in order to predict future performance.

An extrapolation of historic changes is a useful beginning. This approach suffers, though, because the causes of future beach behavior are not likely to be the same as those that affected it in the past.

An historic sediment budget analysis - a continuity of sediment volume approach - was used to sort out recurring and non-recurring effects. Non-recurring effects are sand mining in the last century, recent beach restoration at Sugar Cove, and the construction of groins, a revetment, and the Kahului Harbor breakwater. Isolating the non-recurring effects in a sediment budget provides a means to estimate the future contribution of sand to KWRF beach from the east and to estimate its performance.

2.0 BEACH PERFORMANCE DATA SET

University of Hawaii shoreline positions as defined on a set of 2002 aerial photograph underlays, and augmented with shorelines from a set of 2007 aerial photographs, were used by Moffatt and Nichol to calculate the plan area of coast change for the reach between Blue Tile House beach and Kalului Harbor. These data are the foundation upon which our results are predicated. Resources did not allow time to check the UH shoreline selections or the Moffatt and Nichol area change data. We took them at face value.

The study reach was segmented into the 21 cells listed in Table 1. Each cell contains a sandy beach. UH shorelines are defined for these cells from the following times: 1912, 1960, 1975, 1987, 1997 and 2002. All areas calculated by Moffatt and Nichol are referenced to the UH 2002 shoreline. The shoreline year and month are provided by UH for all shorelines from 1960 onward. Only year is available for the 1912 shoreline. UH shorelines are the "beach step", located at the base of the foreshore. Three other cells from Blue Tile House beach to Hookipa point at the east end of the sandy northeast Maui littoral system have fewer shorelines than the 21 cells to the west. These small easternmost cells are not included in the shoreline analysis. Sand collected from almost all 24 beaches indicated these three beaches are not supplying much material to beaches west of them. In addition, they are separated from the more westerly beaches by a dominant headland around which sand may not pass in quantity to the west. The main reason for excluding them, however, was to retain a consistent data set.

Seasonal fluctuations were removed from the data set with the use of five shorelines from KWRF beach in the period 1987-2007 as shown in Figure 1. This beach was relatively stable then (in comparison to others like adjacent Kite Beach, also included in the figure). Fluctuations correspond well with the seasonality of waves on the north coast of Maui. Moberly (1963), Moberly and Cox (1964, 1968 revision) and Gibbs, Richmond and Fletcher (2000) describe two main wave seasons: (1) April through October of strong NE trade winds with deep water heights of 4 to 12 feet and spectral periods of 5 to 8 seconds, and (2) December to March of north Pacific swell with deep water heights averaging 8 to 12 feet with a spectral period of 10 to 15 seconds. Information from north Maui residents and a lifeguard indicates the season of most sand loss above mean sea level (MSL) occurs during the period of NE trades and losses increase toward the end of the NE trade season.

Table 1. Cells with sandy beaches included in this analysis.

Cell	Location	Hawaii easting	Hawaii northing	Distance east and north of FWRC beach, meters	Beach length, meters	East boundary	West boundary
1	FWRF	764500	2312900	0	658	Revetment at FWRF	Structures at breakwater
2	Kite beach	765100	2312780	612	694	Pre-1960 groin at Kaa Point	Revetment at FWRF
3	Kanaha Beach Park (west)	766000	2313100	1513	670	Groin probably constructed in phases beginning around 1929	Five large groins constructed before 1960
4	Kanaha Beach Park (central)	766400	2313450	1978	444	Groin constructed before 1960	Groin probably constructed in phases beginning around 1929
5	Kanaha Beach Park (east)	766850	2313600	2452	385	Groin constructed before 1960	Groin constructed before 1960
6	East of Kanaha beach	767150	2313750	2783	179	Groin constructed before 1960	Groin constructed before 1960
7	?	767400	2314050	3120	475	Shoreline bulge; sandy beach not evident revetment or beachrock outcrop today	Groin constructed before 1960
8	Spreckelsville beach on UH map	767700	2314200	3454	271	Beachrock exposures	Shoreline bulge; sandy beach not evident
9	/Coral Beach on UH map	768000	2314350	3788	309	Papaula Point, large beachrock exposures	Beachrock exposures
10	Stables Beach on UH map	768300	2314200	4016	321	Natural boulder point incl.submerged section	Papaula Point, large beachrock exposures
11	Spreckelsville (west) on UH map	768750	2314200	4444	402	Large sandy point retained by offshore beachrock bench	Natural boulder point incl.submerged section
12	Spreckelsville (east) on UH map	769100	2314150	4767	360	Natural boulder point incl.submerged section	Large sandy point retained by offshore beachrock bench
13	Sugar Cove	769500	2314300	5192	260	Natural boulder point incl.submerged section	Natural boulder point incl.submerged section
14	Baby Beach	770200	2314700	5977	241	Large sandy point retained by offshore beachrock bench	Natural boulder point incl.submerged section
15	Baldwin Beach	770700	2314700	6456	939	Large sandy point retained by offshore beachrock bench	Large sandy point retained by offshore beachrock bench
16	Sm beach west of lime kiln revetment	771300	2314900	7088	135	Lime kiln revetment constructed before 1960	Large sandy point retained by offshore beachrock bench
17	Lime kiln revetment	771450	2315000	7260	180	Lime kiln revetment constructed before 1960	Lime kiln revetment constructed before 1960
18	Paia Bay (west end) from UH map	771700	2315000	7500	241	Natural boulder point incl.submerged section	Lime kiln revetment constructed before 1960
19	Paia Bay (east end) from UH map	772100	2315100	7912	619	Large protruding basalt point incl.submerged section	Natural boulder point incl.submerged section
20	Mantokuji Bay	772600	2315550	8522	221	Paia Bay (west end) from UH map	Large protruding basalt point incl.submerged section

21	Kuau Bay	773100	2315850	9092	267	Paia Bay (west end) from UH map	Paia Bay (west end) from UH map

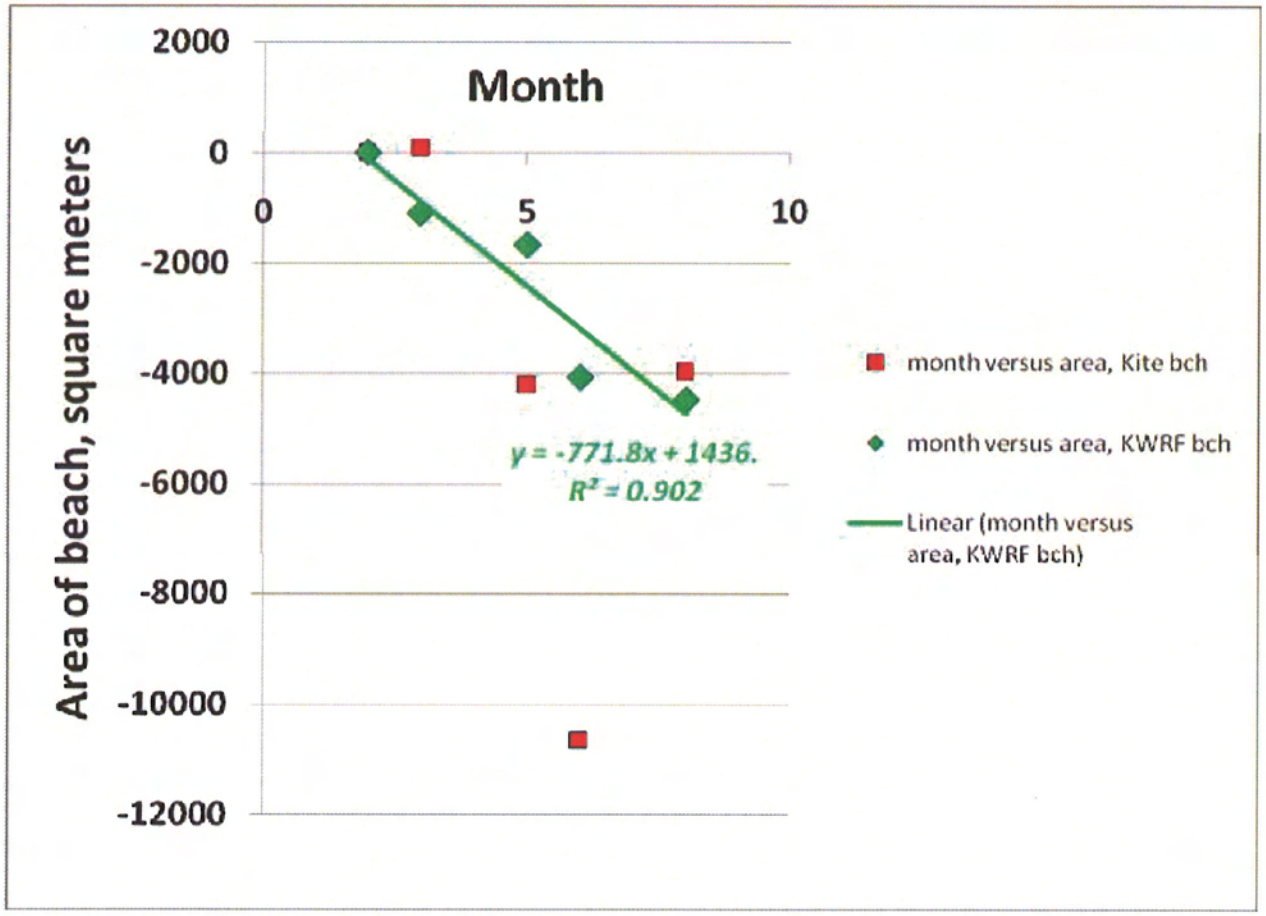


Figure 1. Beach area as a function of survey month for KWRF beach and Kite beach (1987-2007)

Gibbs, Richmond and Fletcher (2000) found the 5-yr maximum change in beach volume from summer to winter conditions to be 18 cubic meters per shoreline meter (cm/m) on KWRF beach, which translates to a similar change as that shown in Figure 1. They found no net volume change during their 5-yr monitoring period.

Figure 2 shows the consequences of removing seasonal reversible effects. For the period 1987 to June 2007, the removal of seasonal effects resulted in a least squares fit annual loss of 29 square meters of plan area landward of the shoreline. Without the removal of seasonal effects, the 20-yr trend of plan area increase was 12 sm/y. These values are well within the margin of error in selecting the shorelines and in estimating seasonal effects.

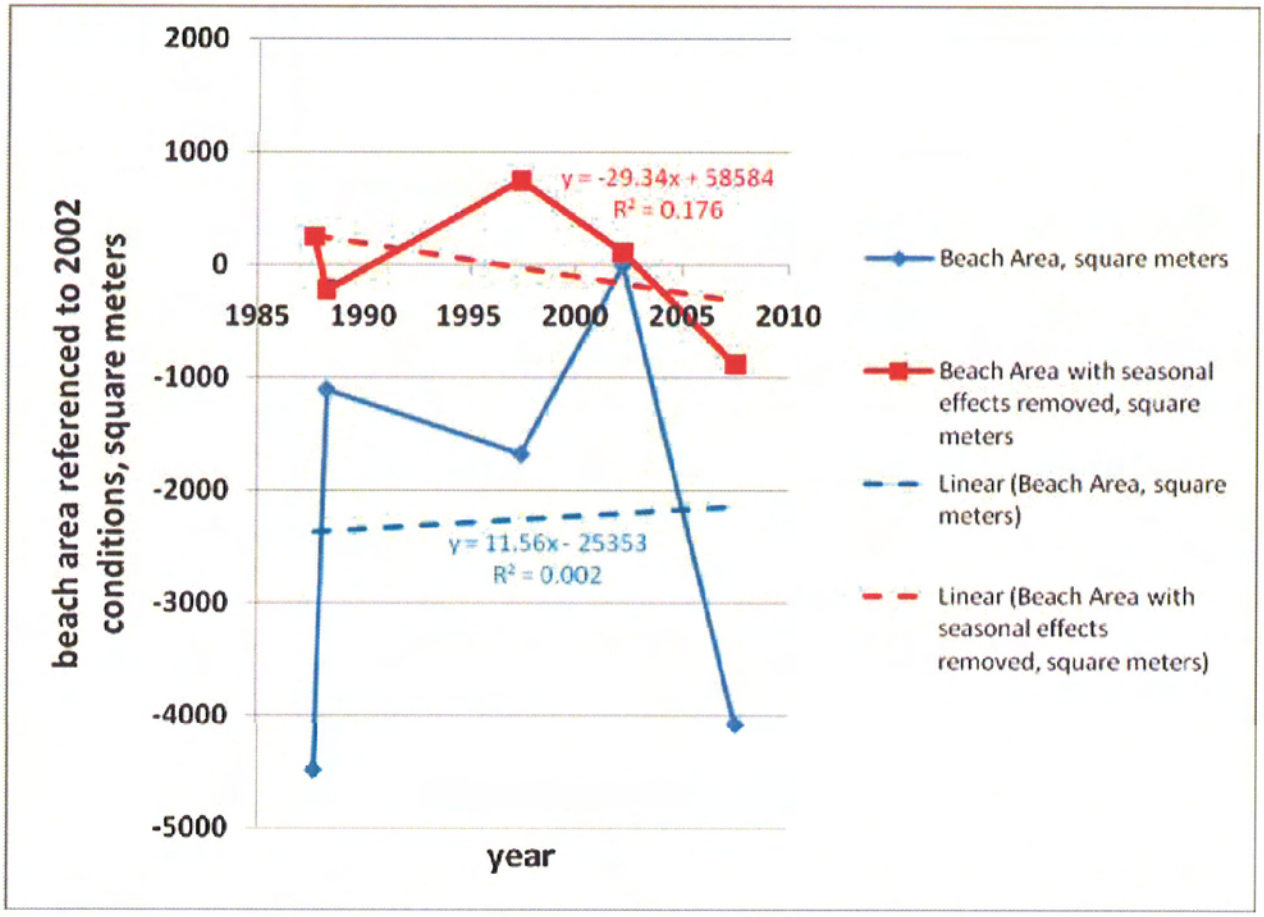


Figure 2. KWRF beach area change with and without seasonal effects removed.

3.0 HISTORIC BEACH BEHAVIOR

Both of the curves in Figure 2 indicate a near stable KWRF shoreline in the past 20 years. Figure 3, however, with the long-term behavior of KWRF and Kite beaches with seasonal adjustments filtered out using the formula in Figure 1, clearly shows the KWRF shoreline advanced between 1912 and 1960 and retreated a great deal between 1960 and 1988. The question is: What caused these changes and why did Kite beach behave differently? Did non-recurring factors have a substantial effect on the earlier large retreat of the shoreline? What is responsible for the more recent apparent stability? How will the answers affect our ability to forecast 50 years into the future and how do we identify and exclude non-recurring effects from our projections?

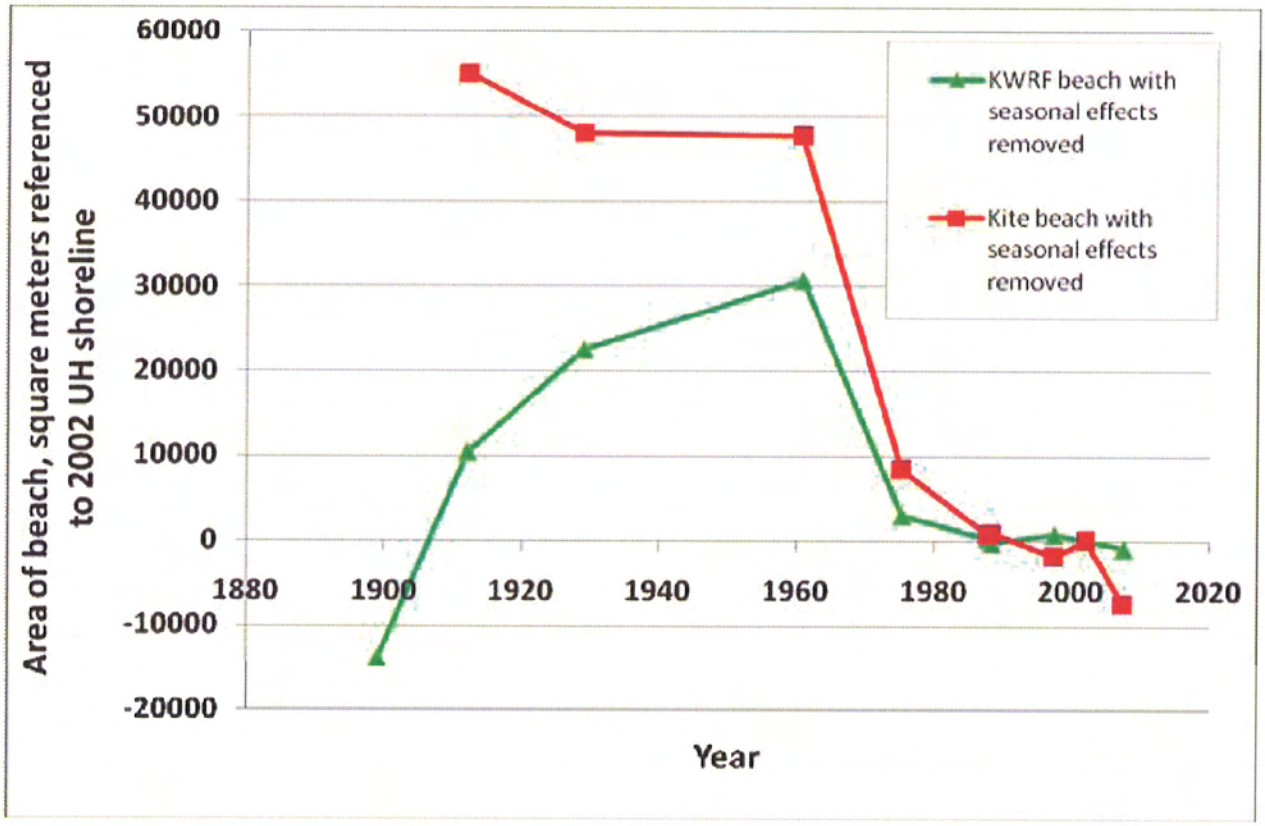


Figure 3. Beach area as a function of shoreline date adjusted for seasonal fluctuations, KWRF and Kite beaches.

An important objective of a sediment budget focused on predicting future beach behavior is that of separating natural conditions that are likely to be nearly the same in the future, such as the wave climate, from non-recurring effects. Most non-recurring effects are human interventions that will likely not be repeated or will be repeated, but to a different level, in the next 50 years. Sea level rise affects beaches and its rate of change is an example of a natural effect that will likely accelerate in the next 50 years. In order of construction, non-recurring projects that have

affected the beach from Kahului Harbor to Blue Tile House Beach are: (1) construction of the east breakwater at Kahului Harbor, (2) sand mining, (3) groins east of the KWRF beach, the groin at the west end of KWRF beach, (4) the revetment at the east end of KWRF beach, and (5) beach restoration at Sugar Cove. The latter effort may or may not continue over the life of the project and other beach nourishment projects may come on line.

The 19 cells east of KWRF and Kite beaches (Table 1) may have affected KWRF beach between 1912 and 2002. Figure 4 is an overview of changes that occurred in the position of the shoreline between KWRF beach and Blue Tile House beach in that time period. The cells can be located by counting from left to right. Figure 4 indicates a greater retreat of the shoreline in the east part of the reach than the west, but the correlation is poor. It also suggests a need to pin down the changes to more limited time intervals in order to sort out and quantify causes.

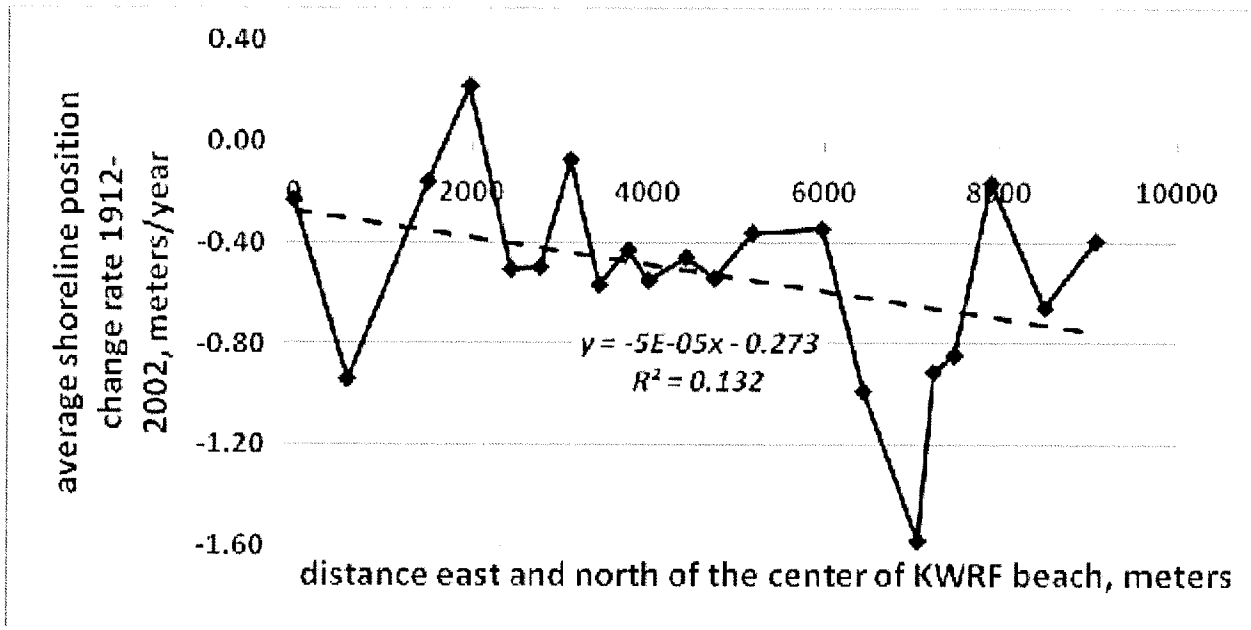


Figure 4. Annual shoreline position change between 1912 and 2002.

Figure 5 illustrates the average change in shoreline position by lumping the 21 beach cells by time interval from 1912 to 2002 as defined in the UH shoreline maps. Note shoreline retreat in the 1912-1960 period was at an annual rate at least 3 times as great as any other e period. It also suggests a more recent overall stability or even a slight advance on beaches. A 2002-2007 advance (not included) is indicative of shoreline behavior only along the westerly 4 km of this coast. But Figure 5 still does not pinpoint the locations of below and above average beach performance, either in time or location.

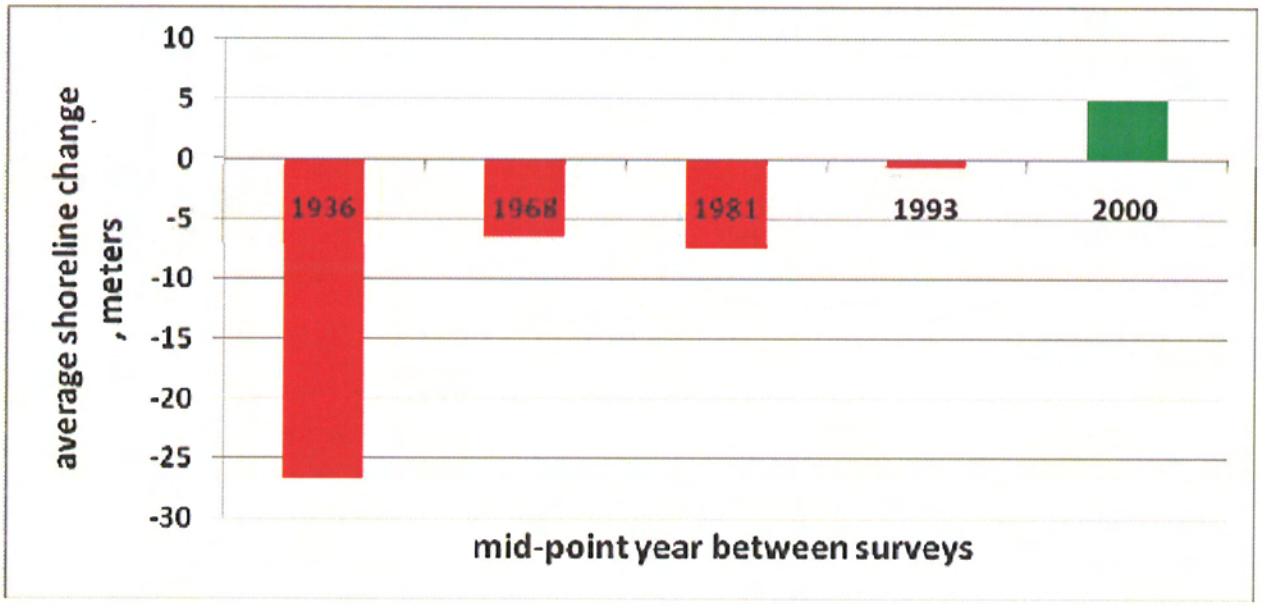


Figure 5. Net shoreline change rates shown for the mid-points of time intervals between 1912 and 2007 averaged for the reach between KWRF beach and Blue Tile House beach, with the latest estimate limited to the reach from KWRF beach to the east end of Kanaha Park (data are not adjusted for reversible seasonal effects).

Figures 6 through 10 illustrate alongshore variations in the change in beach plan area that occurred in time intervals between 1912 and 2002 between KWRF beach (Cell 1) and Blue Tile House beach (Cell 21). These changes are referenced to a zero change for the entire reach. , i.e., the sum of beach area change by time period is zero when the area changes for all 21 sandy beaches in this reach are totaled by length. Gains and losses balance. By highlighting alongshore differences in this way it is easier to isolate and quantify non-recurring effects for the respective time periods and to follow them from one time period to another. Based solely on these measured beach area changes, however, it was not possible to isolate the effects of the groin at the west end of KWRF beach, the revetment between KWRF and Kite beaches, and recent artificial beach restoration at Sugar Cove. In contrast, the effects of the Kahului Harbor breakwater, sand mining, and groins between Kaa Point and Papaula Point are quite evident. Comments included in the figure captions are expanded in later sections of this report.

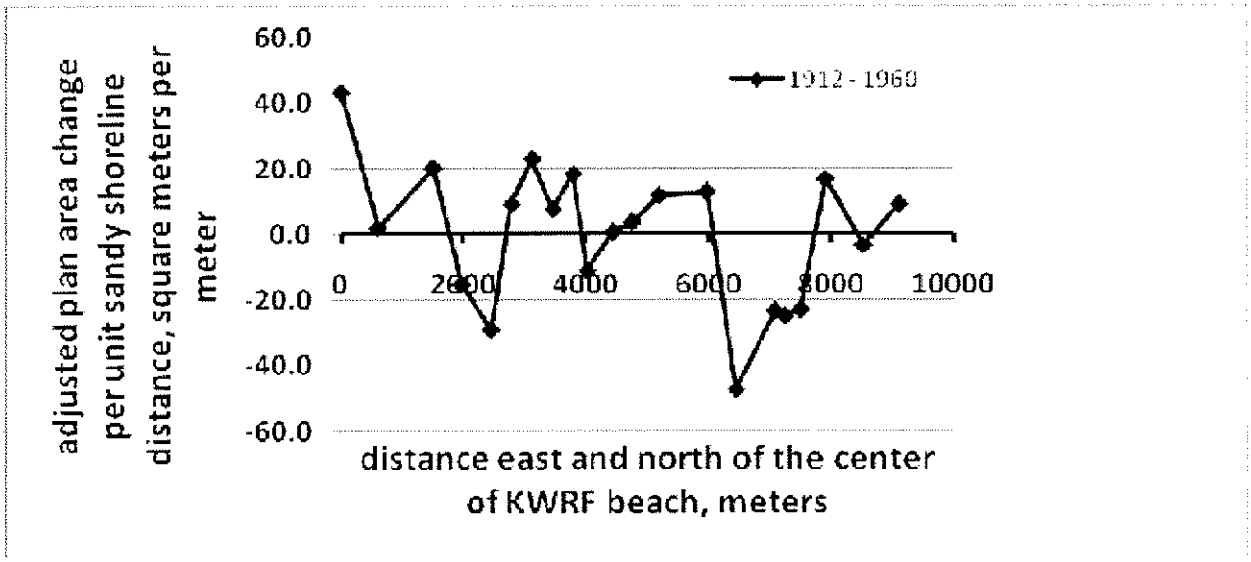


Figure 6. Beach plan area changes by coastal cell relative to a zero change for the entire 1912-1960 time period; large losses in cells 15-18 are due to sand mining, in cells 4 and 5 to the formation of hook-shaped bays by shore retreat just downcoast of large boulder groins, and the large gain in cell 1 to the formation of a fillet on the east side of the Kahului Harbor breakwater.

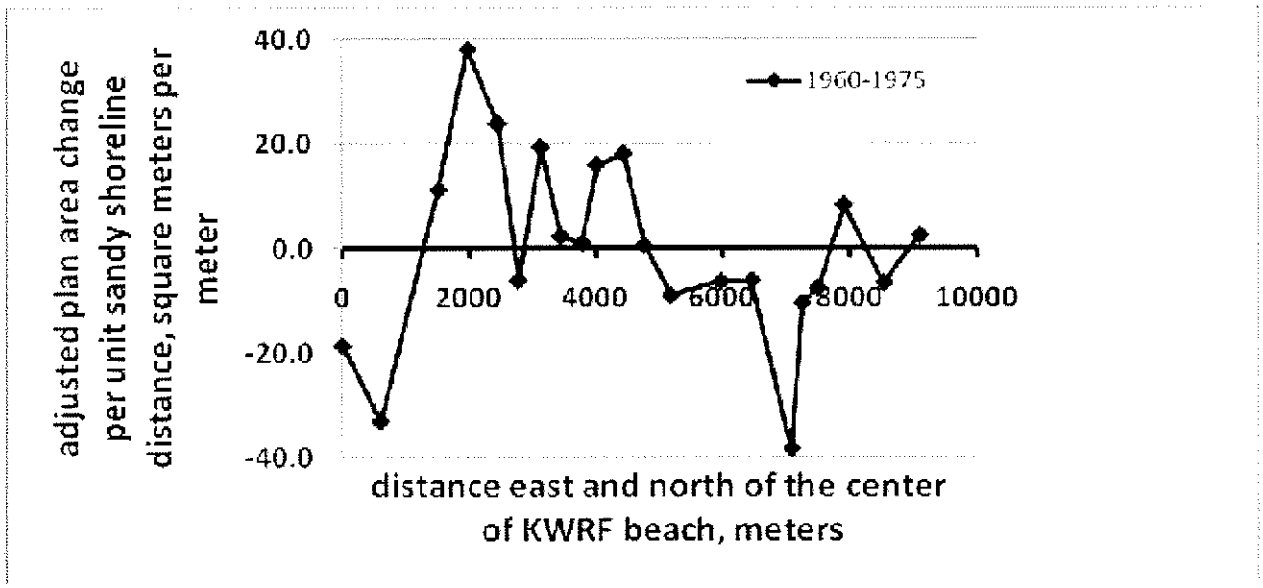


Figure 7. Beach plan area changes by coastal cell relative to a zero change for the entire 1960-1975 time period; the large loss on KWRF and Kite beaches (cells 1 and 2) is due to the formation of a hook-shaped bay to the west of a large groin at Kaa Point (between cells 2 and 3), the losses in cells 13-18 are in response to a continuation of beach sand mining, and the comparatively large gain in cell 4 probably reflects an extension of the groin between cells 3 and 4.

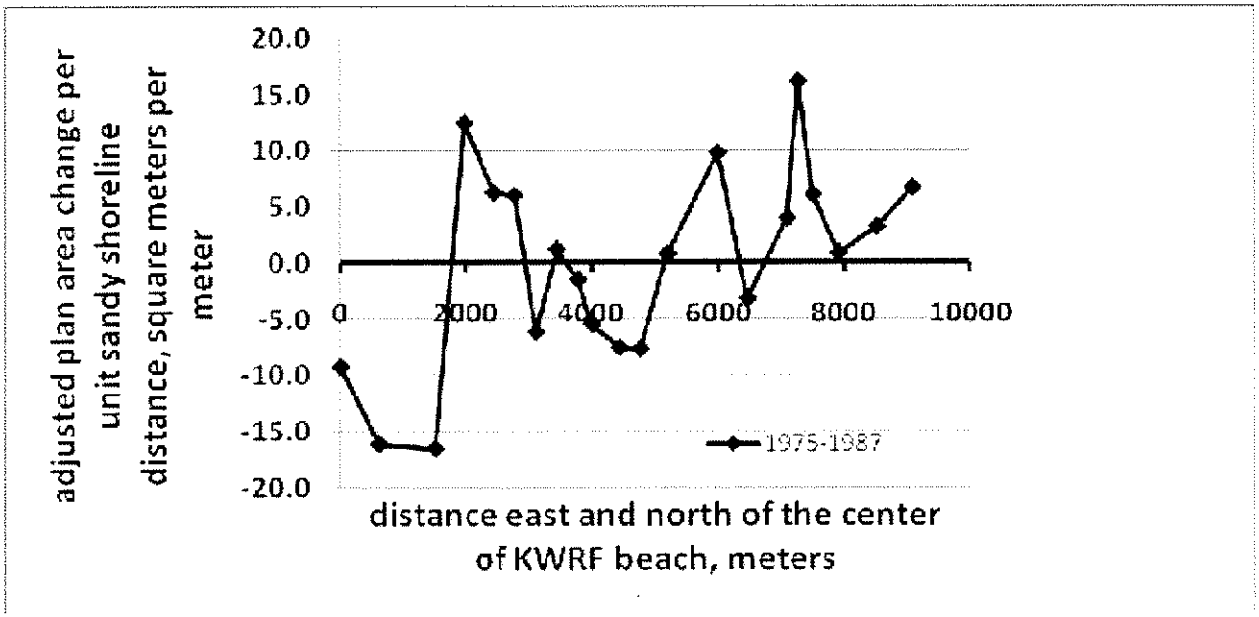


Figure 8. Beach plan area changes by coastal cell relative to a zero change for the entire 1975 and 1987 time period; large losses in cells 1 through 3 are due to a continuation of the evolution of hook-shaped bays in those cells.

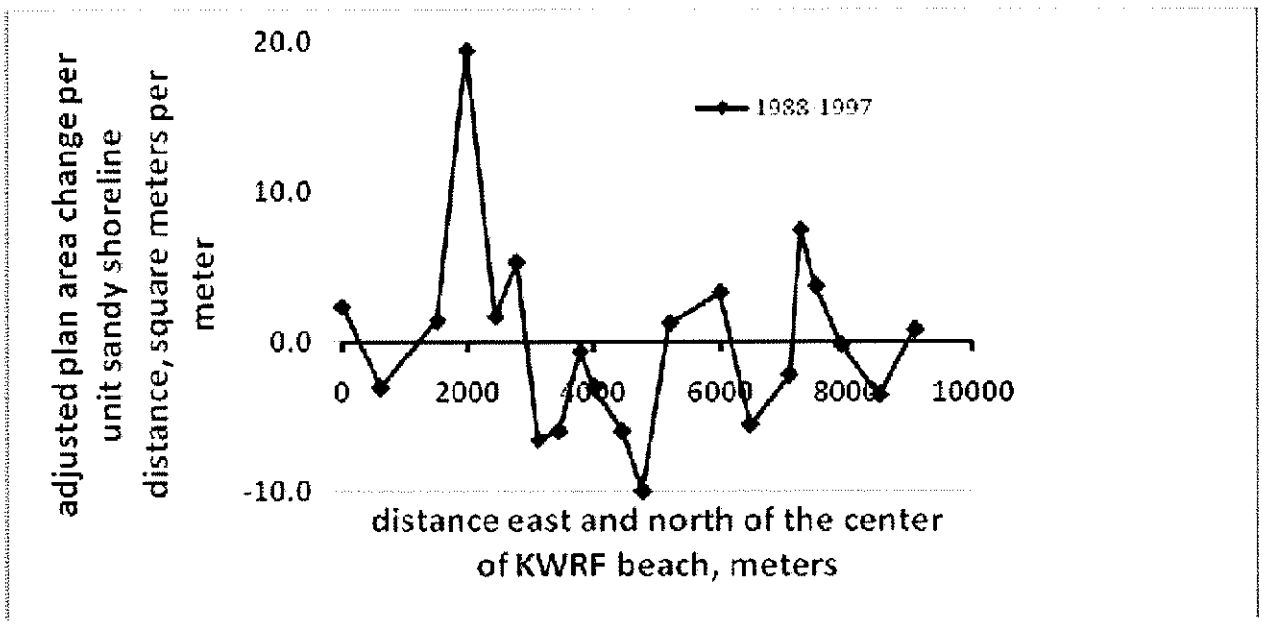


Figure 9. Beach plan area changes by coastal cell relative to a zero change for the entire 1988-1997 time period; the large gain in cell 4 is apparently due to another extension of the groin between cells 3 and 4 and a continuation of the accretionary cycle of fillet formation.

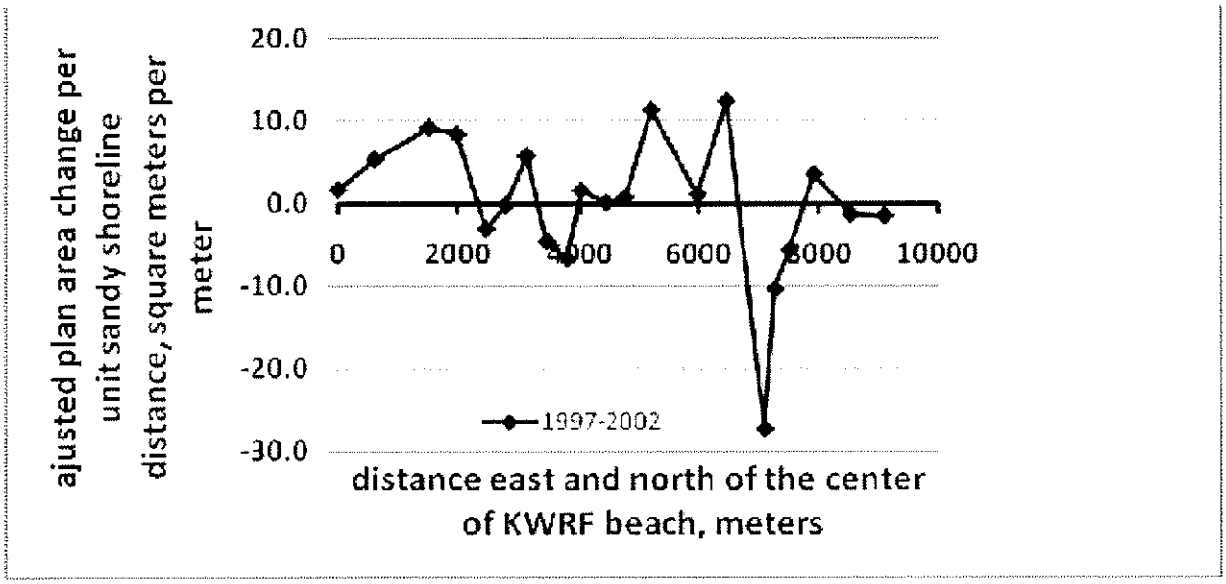


Figure 10. Beach plan area changes by coastal cell relative to a zero change for the entire 1997-2002 time period; the large loss at cell 16 is due to the incipient formation of a hook-shaped bay immediately downcoast of the lime kiln revetment at cell 17.

4.0 SEDIMENT BUDGET INPUT PARAMETERS

Reaching an understanding on what reasonably can and cannot be done to manage the coastal sand resource is greatly aided by an awareness of the condition of the beach and what might affect it in the future, especially if conditions change. Sediment budgets are a fundamental element of coastal sediment processes studies encompassing applications such as this. They serve as a useful framework to understand the sources, sinks, transport pathways and magnitudes for a selected region of coast within a defined period of time. By altering fluxes in a calibrated historic budget it is usually possible to answer "what if" planning and design questions. For instance, how will the mean width and rate of beach retreat be altered if the rate of sea level rise doubles? A third application is to alter the historic budget to forecast future beach behavior, but it involves timing future event forcings, a statistical task, so it is probably the least accurate application.

Sediment budgets are summations of sediment gains and losses within a designated coastal control volume over a given time interval. The continuity equality is

$$\sum_{i=1}^{n} q_i + \frac{\Delta V_t}{\Delta t} = residual \qquad (1)$$

in which $\sum q_i$ = the sum of all fluxes, both import (gain) and export (loss), including those occurring within the control volume, such as biological production, chemical precipitation, chemical solution, and mechanical abrasion, artificial beach enhancement, restoration, and nourishment, and sand mining from the beach; $\Delta V_t / \Delta t$ = average rate of sediment volume change in the control volume; and *residual* = amount by which the sediment budget is not in balance.

As a basis for "what if" and future predictions, a continuity of sediment volume analysis in completed in two parts. An historic littoral sediment budget is first adjusted until it is in balance. Then one or more fluxes in that calibrated budget are altered, for instance, the removal of the historic effects of sand mining, to predict future beach change. The calibration task follows a sequence: (1) define the alongshore and cross-shore bounds of the control volume, (2) identify the entire suite of relevant sediment fluxes across those boundaries as well as in-situ gains and losses within them, (3) determine a meaningful historic averaging time period for the fluxes, in our case 1912-1960 or -1975, and 1960- or 1975-2002 for the reach between Kahului Harbor and Blue Tile House beach, (4) estimate a mean value for each historic flux based on available information, (5) establish a hierarchy of perceived uncertainty in the mean flux values and control volume boundary parameters for the specified averaging period, and (6) sum all fluxes and balance the budget in steps with adjustments generally proportional to uncertainty in the preliminary fluxes and the mean control volume change using a trial and error approach. The last

step is akin to getting the residual in Equation 1 to zero or using the residual as a proxy for an unknown flux as we do for the net longshore sand transport rate along KWRF beach (which fortunately is at the downcoast end of the north Maui study reach). The volume change in that equation, and the substrate sediment flux, which are both based on UH shoreline positions, is considered the most reliable parameter.

A long view is inherent in this approach. Confidence in a measured or estimated historical average is usually proportional to the length of time over which it is made. The requirement for averaging over at least scale of decades is evident in all facets of a sediment budget analysis. While not steady, some fluxes like the net longshore sand transport rate into and out of the control volume, or aeolian transport out of it, usually vary less than a few hundred percent from year to year. But episodic flux-producing events may be many years apart, such as sediment contributions from hinterland erosion during infrequent extreme storms or tsunami-caused overwash. Sometimes decades pass between these events with no flux at all.

In the predictive budget the dependent variable is either the shoreline position change rate, mean beach width and width change rate, or beach retreat or advance rate, or several of those. It is simply a rerun of the historical budget, but with one or more changed fluxes. Since it is impossible, with certainty, to predict future forcings, the flux change is always a bit of a guess. Accordingly, the forecast is only as good as the prediction of future forcings so this is an important constraint since we are forecasting 50-years ahead at KWRF beach. We really don't know what nature is going to bring us so we go on past behavior and instinct.

4.1 Control Volume Boundaries and Dimensions.

We refer to the control volume, or mobile part of the coastal zone, as the *littoral sediment lens*. Five key assumptions concerning the LSL are: (1) mean beach width is proportional to its volume, (2) a net change in LSL volume occurs when there is an imbalance between the cumulative magnitudes of import and export sediment fluxes across its boundaries and/or a net change in the rate of sediment loss or gain within it, (3) reversible seasonal and most storm-related sediment movements occur within it and have no affect on its volume, (4) as the beach retreats or advances at the rate, $\Delta\bar{S}_b/\Delta t$, and/or moves vertically with a net change in sea surface elevation at the rate, $\Delta\bar{a}/\Delta t$, it moves in its entirety at the same horizontal and vertical rate and in the same direction, and (5) if it retreats it is into the substrate behind and below it and if it advances a new substrate is created with littoral sediment from it. Littoral sediment is any material small enough to be moved by waves and currents, but large enough that it contributes to the volume of the LSL.

Coastal features that are affected when the LSL moves are: (1) the *hinterland*, (2) the *substrate* beneath the LSL, and (3) the *ramp* or inner portion of the Continental Shelf seaward of the LSL. As the LSL moves landward it encroaches on the hinterland while leaving behind a new segment

of ramp at its seaward edge. If it advances seaward it covers a portion of ramp, and at its landward edge a wide beach leaves behind a new segment of hinterland up to the elevation of the berm. The *beach* is the landward portion of the LSL. It is vertically separated from the *shoreface* at a designated sea level datum. The landward limit of the beach is the *backbeach line*. The seaward bound of the shoreface is the *shorebase*. The *shoreline* separates the beach from the shoreface. The supporting substrate surface is composed of two segments, the typically steeply sloping *backbeach substrate surface* and the comparatively less steep *basal substrate surface* that come together at the *notch*. The notch is commonly located near mean sea level where the most wave energy per unit vertical distance is expended when the hinterland is scoured during severe erosional events. Unless there is a change in the characteristics of the sediment within the LSL or a change in the wave climate, we assume an unchanging dynamic equilibrium beachface (foreshore) and shoreface profile. A profile in shape dynamic equilibrium, the distance between the mean positions of the shoreline and the shorebase is a constant even as the beach advances or retreats. The only LSL surface parameter dependent upon the volume of the LSL is the mean width of the beach. Without evidence to the contrary, we also assume the movement of the combined backbeach and basal substrate surface occurs without a change in it its dynamic equilibrium shape. Thus, although the upper and lower profiles of the LSL vary on all scales of time and are almost never in complete equilibrium with the waves that shape them, over decade long intervals we assume they fluctuate about mean shapes.

The locations of the shorebase, backbeach line, and substrate surface are prescribed by (1) nature, (2) the constraints imposed by the sediment continuity approach, and (3) the time averaging period of the sediment budget. The shorebase is the seaward most location of *reversible* shore-normal sediment transport. Onshore- and offshore-directed shore-normal transport that affects the volume of the LSL passes across the shorebase. One way to define it is as the depth (or offshore distance) at which the shoreface profile is morphodynamically inactive. This "pinchout depth" or "depth of closure" are usually defined as the location where bottom fluctuations decrease to less than the resolution of profile measurements, and by implication the seaward limit of "significant cross-shore transport". Reversible offshore and onshore transport is primarily a seasonal phenomenon, nearly canceling annually. However, in any year more sediment may be moved farther from shore during storms than is returned to the beach during episodes of long-period swell. But over many years these fluctuations average out except for the residual amount that passes across it. We refer to that residual as the shorebase flux and in our sediment budgets we assume it is zero.

Two lines of evidence provide a rough indication of the shorebase location in the study areas: (1) a small scale bathymetric chart (C-Map, 1:5000, WGS1984), and (2) Sugar Cove survey data. The chart indicates a shallow reef flat with an irregular surface. Given the paucity of soundings it is only possible to identify the depth of the inner flat surface in the range 2 to 5 m below MSL.

The base of the envelope of repetitive surveys is a more definitive way to define the bounds of the LSL and the only place we know of to do that is at Sugar Cove. Sand has been artificially added there since 1996 as shown in Figure 11. This figure is based on data supplied by the Sugar Cove Apartment Owners Assn through Mrs. Barbara Guild.

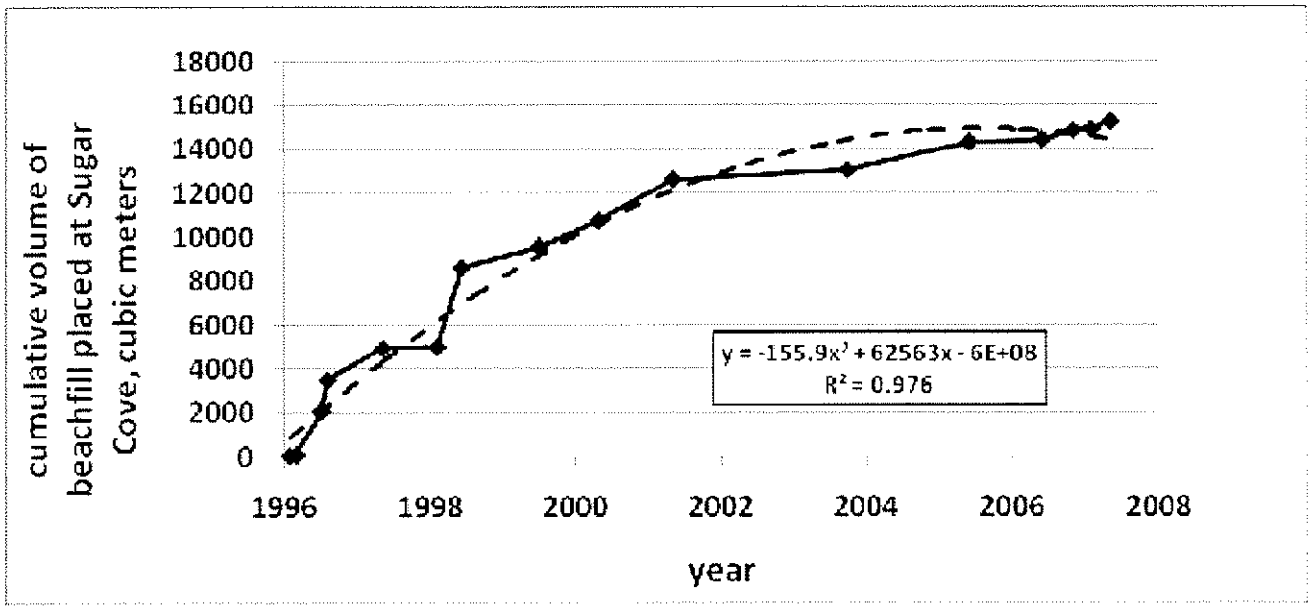


Figure 11. Cumulative quantity of sand placed in Sugar Cove, cubic meters.

We assume the beach was almost absent before any beachfill was placed. Then, as shown in Figure 12, which is based on surveys made by the apartment owners association, the beach gained sand until about 2000 and from then on it remained quite stable in cross-sectional area for the next 6-plus years. As shown in Figure 13, about 3500 cm/y were placed in the first four years of this ongoing project and only about 1000 cm/y in the last 7 years. The widest beach was in 2005.

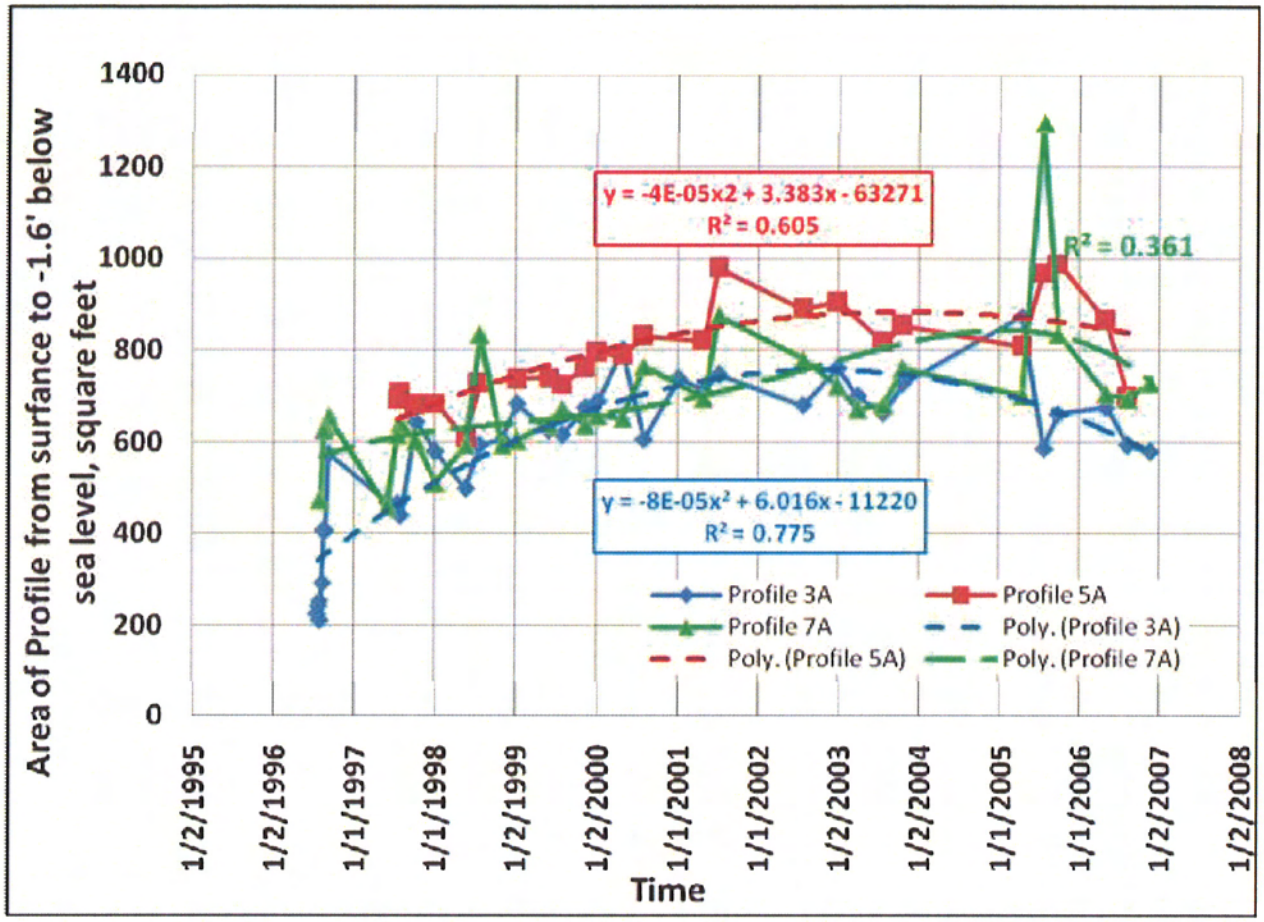


Figure 12. Beach areas above -1.6 ft (local sea level datum) at Sugar Cove during a period of artificial beach nourishment, in square feet as compiled by the apartment owners association; Profile (range) 3A is at the east end of the beach, 5A in the middle, and 7A at the west end.

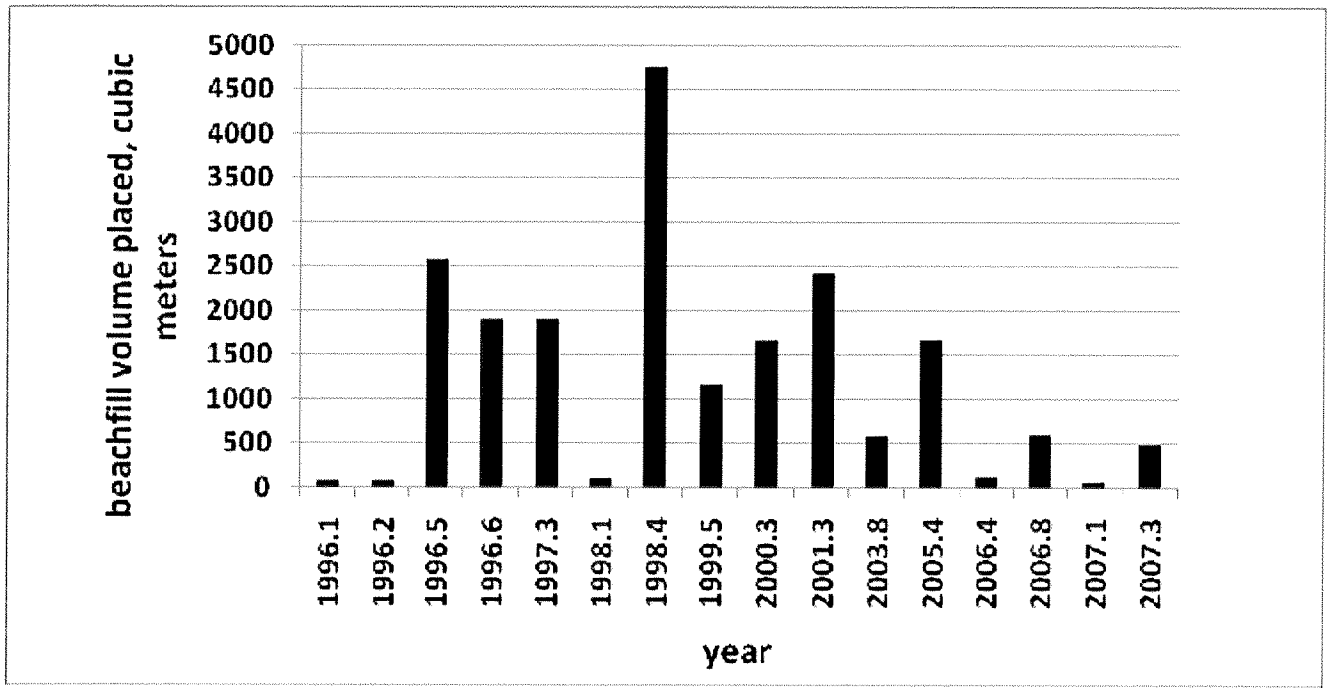


Figure 13. Volume of sand artificially placed in Sugar Cove, cubic meters per placement episode.

Figure 14 shows the beachfill did not extend out to the pinchout depth. However, it is still possible to estimate the relationship between mean beach width and the cross-sectional area of the littoral sediment lens by extrapolating the position of the shorebase seaward with consideration of the chart bathymetry. As shown in this figure, the mean width of the beach at local sea level elevation is 60-80 ft (about 20 m) and the height of the beach is about 12 ft (4 m) referenced to that datum (Sugar Cove measurements were archived in English units). A berm is rarely present in the restored beach. By extrapolation the depth to the shorebase is probably in the range -8 to -10 ft and its distance from the mean position of the shoreline seems to be between 250 and 400-ft. Given we have no better data available concerning the north Maui shorebase, and no reason to believe substantial changes occur between cells, we assume the LSL parameters listed in Table 2 are appropriate for all 21 cells.

Table 2. Dimensions of the littoral sediment lens.

Lens component	Estimated value	Range
Mean beach width, $\bar{w}$, meters	Approx 20 in 2002	18 to 24
Elevation of backbeach line above sea level, h_b, meters	4	3 to 4.5
Shoreface depth, z_s meters	3	2.5 to 5
Horizontal distance, shoreline to shorebase, y_s, meters	100	75 to 125

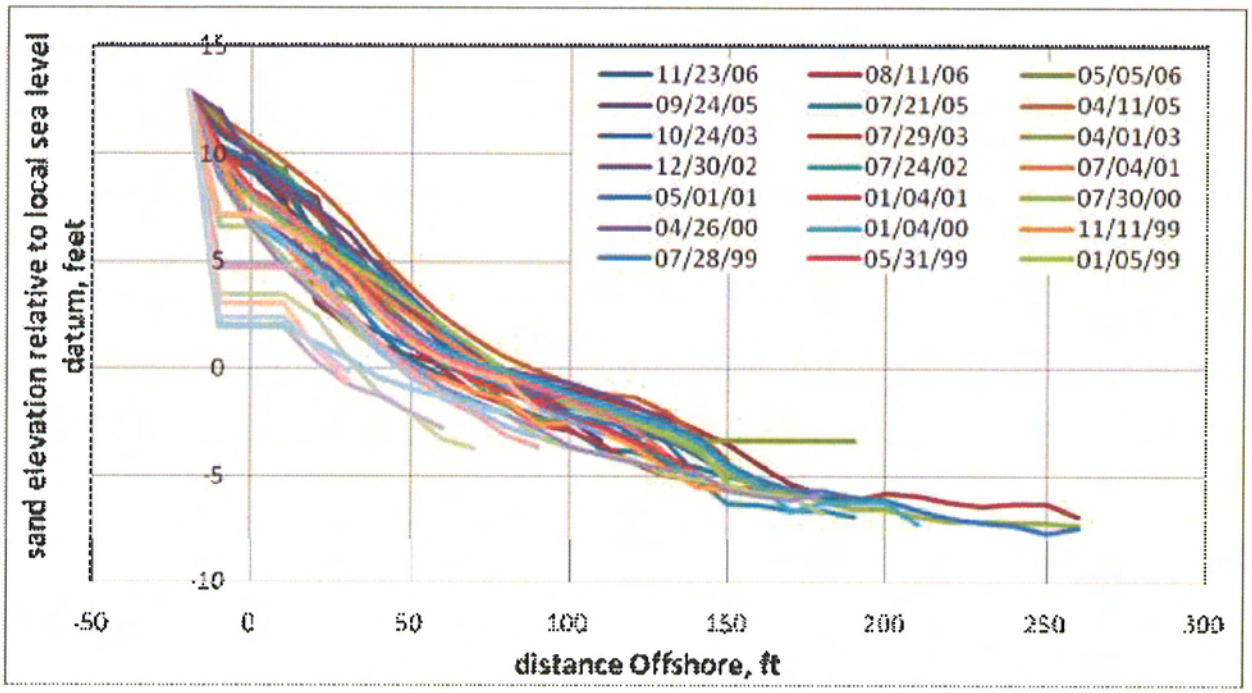


Figure 14. Envelope of all profiles on Range 3A at Sugar Cove, Maui, 1996-2006; Range 3A is on the east side of the beach and near the middle of the cove.

With the estimated LSL dimensions, the volume of the Sugar Cove littoral sediment lens appears to be 600 to 900 cubic feet per foot of sandy shoreline (55 to 85 cm/m). Thus, the ratio of mean beach width to LSL volume per unit sandy shoreline distance at Sugar Cove is about 1:10. The total volume of sand in the Sugar Cove littoral sediment lens is perhaps 6000 to 9000 cm.

Alongshore boundaries of the 21 cells between KWRF and Blue Tile House beaches are provided in Table 1. All are fixed between physiographic features like large rocky or boulder headlands, boulder groins, or sandy projections of the shoreline in the lee of natural offshore bathymetric highs.

4.2 Mean Beach Widths and Retreat Rates.

Mean beach width is an important parameter since it partially controls the rate of beach retreat. It also affects the sea level rise impact on the size of the LSL. According to UH map text and a 1950 aerial photo supplied by Moffatt and Nichol, while most beaches have retreated, mean beach widths have not changed much since 1950 and especially 1960, except perhaps at KWRF beach where they declined. This suggests a dynamic equilibrium LSL. It also suggests, with less certainty, there was no substantial permanent change in a major flux in the last almost 50 years. "Island of Maui" (1962 plus) states the mean width of Spreckelsville Beach in 1962 was 62 ft,

the beach from Papaula Pt to Maliko Bay was 75 ft wide and the beach at Lower Paia was 80 ft wide and arcuate in shape.

We have little idea of the mean widths of the 1912 beaches, but we (I think realistically) assume they were larger than today's since the shoreline was less convoluted. Consequently the net longshore sand transport rate was also larger then. Alongshore sand transport along the north Maui coast is energy constrained, not limited by availability. In turn, the alongshore component of wave energy at the breakpoint is controlled in part by the orientation of the shore. For the purposes of our sediment budget, we assume the 2002 mean beach width was near 20 m in most cells. Further we assume the mean width at any year in the period 1912 - 2002 can be defined as

$$\bar{w}(t) = \left[\frac{S(t)}{S_{max}}\right]20 \qquad (2)$$

in which S_{max} = maximum distance the mean position of the shoreline retreated in any cell by 2002, and S = position of the shoreline on any date it was identified. This approach assures no 1912 mean beach width is greater than 40 m, probably a reasonable assumption given no other information on beach widths 100 years ago. The relationship between a change in mean beach width (from Eq. 2), a change in shoreline position (known values), and the rate of beach (backbeach line) advance or retreat, $\Delta\overline{S_b}/\Delta t$ is

$$\frac{\Delta\overline{S_b}}{\Delta t} = \frac{\Delta\bar{S}}{\Delta t} - \frac{\Delta\bar{w}}{\Delta t}. \qquad (3)$$

A change in the LSL volume is reflected by a change in the mean width of the beach; a change in the mean width of the beach affects a change in the beach movement rate.

4.3 Substrate Sediment Flux.

The substrate sediment flux is important almost everywhere beaches are retreating and all of the beaches in the study area are in this category. At KWRF, the substrate flux is that quantity of littoral-type sediment that is scoured and contributed to the LSL as it retreats minus the amount that is added as the LSL moves upward in response to sea level rise. The amount of material released as the substrate and hinterland retreat is dependent upon the compatibility of the released material with material in the LSL. Eroded silt and mud will not long remain there.

A change in the cross-sectional area of the substrate surface as it retreats and ascends defines the substrate sediment flux, $\bar{q}_s$, when the portion of littoral-type sediment is considered, is

$$\bar{q}_s = -x\left[\left[\rho_h(h_h - h_b) + \rho_b h_b + \rho_s z_s\right]\frac{\Delta \bar{S}_b}{\Delta t} + \left(\bar{w} + y_s\right)\frac{\Delta \bar{a}}{\Delta t}\right] \qquad (4)$$

in which x = alongshore length of the control volume (LSL), ρ_h, ρ_b, ρ_s = portions of the material that will be compatible with sediment in the LSL as it is contributed, respectively, as the hinterland, backbeach substrate surface, and basal substrate surfaces are eroded, h_h, h_b, z_s = respectively, the vertical distances to the crest of the hinterland substrate surface above the elevation of the backbeach line, to the crest of the backbeach substrate surface, and to the shorebase referenced to sea level datum, y_s= horizontal dimension of the shoreface, assumed constant unless there is an alteration in the long-term wave climate. The rate of beach movement is positive for an advance and negative when it retreats.

For Maui, sea level rise has been estimated at 2.46 plus or minus 0.23 mm/yr by Jeon (?), and in another case (citation not given) at 2.67 mm/yr, both in recent years. In the study area the composition of the basal and backbeach substrate is mostly unknown. This is a major impediment in quantifying the substrate sediment flux. The portion of littoral-type material that is released could vary from 0 to 1.0, which translates to an order of magnitude variation in the flux as indicated in Equation 4. Beach retreat has been an important factor and as a consequence, the substrate sediment flux is the most substantial natural component of the sediment budget in the earlier periods. We have little knowledge of the portion of sediment in the backbeach substrate, but anecdotal evidence is that it is mostly volcanic, such as the red clay that outcrops in many places behind the beach, but that the portion of sand increases to the west of Cell 11. We have no knowledge of the portion of littoral-type material in the basal substrate although it may be hard coral rock or basalt boulders in a volcanic fines matrix as at Red Hill Point. As a consequence for sediment budget purposes we consider the composite portion of littoral-type material in the basal and backbeach line substrate to be 0.5 in Cells 1 and 2, 0.2 in Cells 3 through 11, and 0.1 further to the east. Materials above beach elevation were in most cases deposited by wind or possibly overwash. Its portion of sand is near 1.0.

4.4 Net Longshore Sand Transport Fluxes.

The second important unknown in our sediment budget analysis is the quantity of sediment that is transported to KWRF beach from the east. The first advantage we have is that KWRF beach seems to be at the downcoast end of the littoral system. A second advantage is that shoreline positions are available from near the time construction apparently began on the breakwater at Kahului Harbor (in 1910?) through the present. Figure 6 shows the addition to the beach plan area in the form of a fillet that evolved between 1912 and 1960. Today the breakwater continues to retain a part or all of KWRF beach. It also reflects waves and is apparently responsible for the bulge in the shoreline just east of the groin at the west end of KWRF beach. The plan area

changes, as obtained from the UH shoreline map at Kuhului Harbor are shown in Table 3 and our interpretation is as follows:

1. The 1899-1912 value is surprising if the breakwater was completed in 1910. An examination of the data suggests an accumulation rate of 10 to 45 thousand cubic meters per year just after construction. The lower value is predicated on the deposit not extending out to the present shorebase depth and the berm elevation being lower than it is today due to the rapid buildup. This rate would have been near the total amount of sand that reached KWRF beach in that time period, but the large magnitude is still is hard to reconcile with other results.

2. In the 1912-1929 interval the accumulation rate averaged between 3000 and 5000 cm/y. The net transport rate at Kaa Point may have been larger with some of it carried through the KWRF system thence offshore near the breakwater (or east of there). This value correlates well with Cox (1954) who concluded about 240,000 cy of sand accumulated at the east breakwater between 1910 and 1950 or an average 4600 cm/y.

3. The fillet accumulation rate between 1929 and 1960 was much lower, averaging only a few hundred cm/y. The hooked bay that evolved in KWRF and Kite beaches between 1912 and 1987 was only beginning between 1912 and 1929 due to a huge amount of sand that was passing Kaa Point as other hooked bays formed further east in the lee of other newly-constructed groins.

4. After 1960, the huge loss of sand from KWRF beach occurred as a hook-shaped bay formed west of Kaa Point (and including KWRF beach). The result of this loss of coastal area was sand either carried directly offshore (unlikely) or moved further west to the breakwater where it was then carried offshore. Depending on the portion of littoral-type material that was liberated, the net longshore sand transport rate to the west averaged between near zero and perhaps as much as 10,000 cm/y.

Table 3. Beach changes upcoast of Kahului Harbor breakwater, 1899-1987.

Time interval	Change in beach plan area, square meters	Estimated change in coastal sand volume, cubic meters	Remarks
1899-1912	+13,000	Gain: 20,000 to 90,000	Fillet formation at breakwater with modest beginning of hook-shaped bay formation west of Kaa Point
1912-1929	+12,000	Gain: 55,000 to 85,000	Fillet formation with continuing modest beginning of hook-shaped bay formation west of Kaa Point
1929-1960	1000	4500 to 6000	Very small addition to fillet
1960-1975	-27,800	Loss: <125,000 to 170,000	Change throughout KWRF beach due to rapid formation of a hook-shaped bay west of Kaa Point
1975-1987	-2700	Loss: <12,000	Change throughout KWRF beach due to

		to17,000	completion of formation of a hook-shaped bay west of Kaa Point

Groins constructed before 1960 have affected all beaches in Cells 1 through 7 (Table 1). The coast on their east or upcoast sides generally performed with less loss of property than elsewhere and in some cases they were outstandingly effective in this regard. However, beaches to the west or downcoast, generally lost more land than elsewhere and in three cases they lost dramatically more due to the formation, by erosion, of hook-shaped bays. As previously noted, our interest in the effects of these structures comes in the quantity of sand that was released to downcoast (west) beaches. KWRF and Kite beaches were both affected by the five groins constructed at Kaa Point (actually the one at the west end) in the period 1912-1987. After the revetment was constructed to protect the KWRF pond, only Kite beach was directly affected by the evolution of this bay. However, it appears that by 1987 it had formed to near its dynamic equilibrium shape. The loss centroid in Cells 2, 3, 5 and 6 tended to move from east to west with time, indicative of the east to west net longshore sand transport regime.

Table 4. Groin location and effects, north Maui.

Groin location between cells:	Downcoast effect	Time period of maximum change	Year of maximum landward excursion of hooked shoreline	Remarks
2 and 3	Large hook-shaped bay ***First very nice smooth hook in Cell 2***	1960-1975	1987 & 1997	Hook formed in Cells 1 and 2 between 1912 and 1975 with cell 2 being the only reach that was directly affected after 1987 (?) when construction of the KWRF revetment separated cells 1 and 2
3 and 4	Large hook-shaped bay ***Second very nice smooth hook in Cell 3*** between eastern groin and most eastern groin in the Kaa Point group of five	1912-1960	1987 & 1997	Hook formed east of the most easternmost of the 5 groins constructed east of Kaa Point
4 and 5	Very small hook-shaped bay formed	?	1960	The shoreline is approximately straight in Cell 4 and 2 groins within it are now only functioning minimally; cell was accretional between 1960 and 2002
5 and 6	Large hook-shaped bay ***Third very nice smooth hook in Cell 5***	1912-1960	1960	Well defined hooked shoreline
6 and 7	Medium-sized (compared to others) hook-shaped bay formed	1912-1960	1987 & 1997	Five or more small groins in the Cell 7 reach maintain a nearly straight shoreline

These downcoast effects are in contrast to the effects of a reduction in the net longshore sand transport rate downcoast of a beach sand mining site. Sand mining effectively lengthens the downcoast sediment blocking structure and the amount that passes it declines as mining progresses. The formation of a hook-shaped bay produces sand that is carried downcoast as the

bay evolves. This quantity is greater than the pre-hook-formation amount, but as the bay evolves the amount produced and carried downcoast declines until the littoral zone returns to a state of dynamic equilibrium. At that time net longshore sand transport through the bay, all other factors being equal, returns to its pre-hook rate.

An important question is therefore: Why did the net longshore sand transport rate apparently decline with time at Kaa Point? The answer lies in the impact of the substrate on the net longshore sand flux on a coast broken by headlands and other obstructions. Overall this rate is controlled by the: (1) transporting capacity of incident waves, (2) tidal history of the region and its consequent effect on the foreshore and surf zone transport conduit, (3) beach and shoreface profile, (4) characteristics of the sediments, (5) sediment supply, and importantly in the case of north Maui, (6) three-dimensional shape of the LSL-substrate surface. With respect to the last factor, mean beach width seems to be a reasonable proxy for how efficiently sediment is moved along a coast when there are impediments to its movement. Substrate impediments to alongshore transport reduce the amount moved for three reasons.

First, if the substrate surface is exposed so that wave energy is expended on it rather than on moving sand along the coast, the energy used in moving sediment will be inversely proportional to the (1) area of substrate that outcrops through the beach and shoreface LSL, (2) portion of time the outcrop is exposed, and (3) roughness of the surface and its effect on friction and turbulence losses. It will also be affected by the cross-shore location of the exposure with respect to the cross-shore gradient in the longshore component of wave energy flux. Added beach width increases the coverage of substrate outcrops. This factor – wide beaches that extended further out along the rocky points - is why there was a greater net transport in the early part of the last century than today after the impact of sand mining at and near Baldwin Beach worked its way to KWRF beach.

Second, a longshore transport impediment exists if beach contours and shoreface isobaths are non-parallel and/or not straight. With a larger sand supply, beaches in bays tend to widen and straighten creating an increase in the downcoast component of wave energy flux and a reduction in the upcoast component. The result is an increase in the net longshore sediment transport rate. This factor also affected the north Maui coast and is responsible for a lower net longshore sand transport rate today than existed in 1912.

Third, all manner of irregular structures, including rocky headlands, reefs, and groins, function to force sediment around, through and over them, thereby slowing its downcoast progress. When these structures are partially or wholly exposed or their effective lengths increased as a beach narrows or retreats, the amount of sediment that passes them is reduced, another factor at north Maui. A question then is: If the net longshore sand transport rate declined between 1912 and today why was there a greater amount of material available for movement in earlier times? The most obvious answer is that the reef was more productive then than it is today.

Of interest then is the relationship between the net longshore sand transport rate and the mean width of the beach on north Maui. To a minor extent it can be extracted from the previously discussed Sugar Cove data. About 1000 cm/y was the net amount of sand added and lost from Sugar Cove while the beach was maintained at a near-constant beach width of 20 m after 2000 as shown in Figures 12-14. The total amount that moved out of the cove was equal to this 1000 cm/y plus the amount that entered from offshore (or minus the amount lost offshore) and especially the quantity that entered from upcoast. If we assume the only substantial flux into the Sugar Cove LSL was the amount that entered from the east, both before and after beach replenishment began, then the ratio of the added net longshore sand transport as a function of beach width is 1000 cm/y for a 20 m advance in mean width or 40 to 60 cm/y of additional net longshore sand transport per meter of added mean beach width (at least in the 0 to 20-m range).

Table 5 is a summary list of net longshore sand transport rate estimates by location and time period. This is a guide; we treat the net longshore sand transport rate as an unknown in our historic sediment budget calculations.

Table 5. Summary of net longshore sand transport estimates in and near KWRF beach.

Time period	Location of estimate	Net longshore sand transport rate, cubic meters per year	Evidence	Remarks
1910-1912	West end of KWRF beach	10,000 – 45,000	UH shoreline position maps	Short time interval; and all that reached the bkwtr was trapped
1912-1929	West end of KWRF beach	3000 - 5000	UH shoreline position maps	Average for a time that formation of upcoast hooked bays increased the net rate; value is minimum
1910-1950	West end of KWRF beach	4600	Cox (1953)	Average for a time that formation of upcoast hooked bays increased the net rate; value is minimum
1929-1960	West end of KWRF beach	Few hundred	UH shoreline position maps	Fillet formation complete by 1929; most sand reaching the west end of KWRF beach is carried offshore
1960 – 1975	West end of KWRF beach	0 – 10,000 plus	UH shoreline position maps	Rate of evolution of hooked bay west of Kaa Point is at a maximum
1975-1987	West end of KWRF beach	0 – 1500 plus	UH shoreline position maps	Source is hooked bay forming west of Kaa Point
1997-2002	Sugar Cove	1000 plus	Sugar Cove Assn survey data	Increase in net longshore sand transport rate as mean beach width increased from near zero to 20 meters

4.5 Aeolian Sediment Flux.

Moberly (1963) hypothesizes aeolian transport at 2000 cyy per mile of coast, locally (about 1 cm/my). He reports the beach from Kahului Harbor to Hookpia Park was low and mostly backed by sand dunes on the low gradient slopes of Hiealakala around 1960. Lineations in vegetated dunes on the UH (aerial) shoreline maps show the predominant wind direction is from the NNE (30 to 35 degrees, true north). Today aeolian transport from the beach to the hinterland behind it seems to be most prevalent on NE-facing portions of the coastal cells and near their western ends. A detailed determination of the aeolian transport flux or even all of its locations has not been made. One location, however, where there is a clue to the transport rate is at Baby Beach just east of Red Hill Point (Cell 14). Perhaps 1000 cm/y has moved inland there in the past 75 years along a 100-m long portion of coast (10 cm/my). This, to our brief observation, is a maximum for north Maui. Accordingly, from field observation and what we can glean from 2002 and 2007 aerial photos, for sediment budget purposes we use this as basis and Moberly's approximation to apportion aeolian losses as shown in Figure 15.

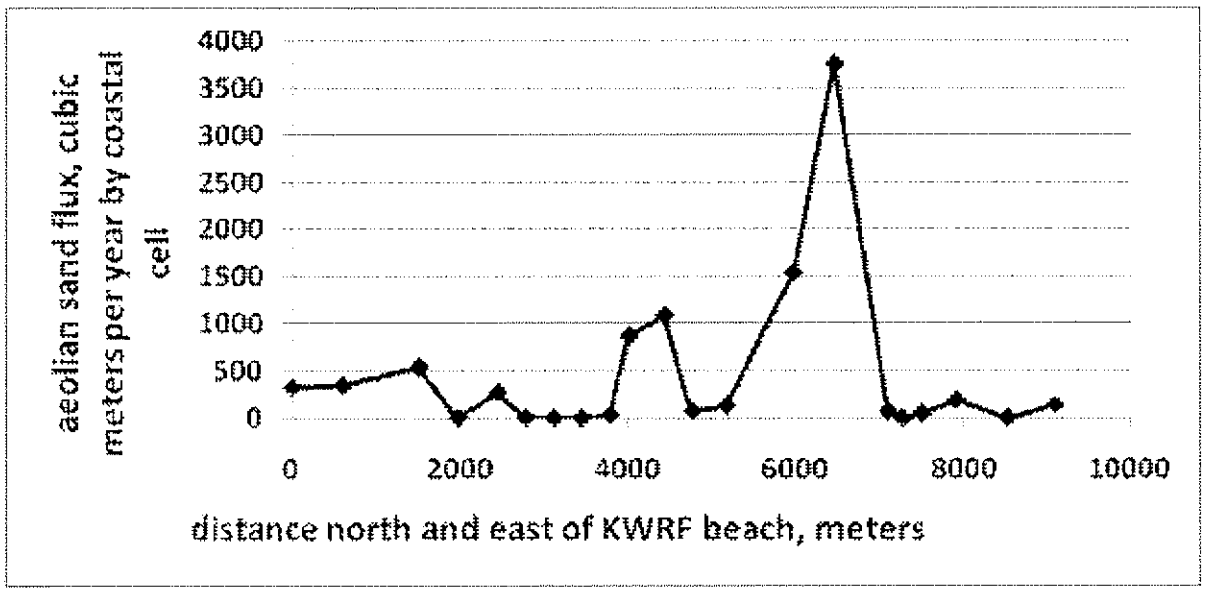


Figure 15. Estimated aeolian sediment transport flux for north Maui.

4.6 Beachrock (Formation) Flux.

Beachrock is present in many cells, often as offshore benches. Moberly (1963) reckons its formation is an important sink for beach sand in the study area. He hypothesizes it is created at a rate of 100 cyy per mile of beach (about 0.5 cm/my of beach). For our purposes, however, we conclude that when it forms it is buried in the beach, not exposed. Further, if it is forming today,

it is occupying a portion of the LSL volume and as a consequence, it does not seem realistic to subtract it from the budget so we assume the beachrock-formation flux is zero.

4.7 Sand Mining and Beach Restoration.

Sand mining for lime production by the sugar company and later mining by others for cement manufacture and aggregate has had a profound effect on the east end of the north Maui reach. Mining apparently began around 1900 and ended sometime after 1960 and before 1975. Shoreline retreat data indicate it was concentrated in Cells 15 through 18 along 1500-m of sandy beaches. The region offshore the revetment constructed to protect the sugar company lime kilns in Cell 17 was also mined as Figures 6 and 7 illustrate. Clearly most of the loss was at and to the west of the lime kilns and the most affected location was 940-m long Baldwin Beach. In the 1912-1960 period the average loss of coastal land area in Cells 15-18 was -1200 sm/y and in the 1960-1975 period it was only slightly less at -970 sm/y. These translate to volume losses of -5400 to -7200 cm/y in the earlier period, and -4300 to -5800 cm/y in the latter period, or total of a bit over 500,000 cm. These values outlined in Table 6 are of lost coastal material. They exceed the volume mined and consequently provide a check on an estimate of the quantity mined.

Table 6. Beach behavior in the vicinity of the lime kilns during and immediately after the sand mining period.

Cell number	Cell Length, meters	1912-1960 average shoreline retreat, meters (sq.m)	1960-1975 average shoreline retreat, meters (sq.m)	1975-1987 average shoreline retreat, meters
15	939	-47.4 (44500)	-6.1 (5700)	-3.2
16	135	-23.4 (3200)	-38.3 (5200)	+4.0
17	180 (lime kilns)	-24.9 (4500)	-10.3 (1900)	+16.2
18	241	-23.1 (5600)	-7.6 (1800)	+6.1

Cox (1954) estimated about 3500 cyy was removed for lime production in the 40 years prior to about 1953 and in the later part of that interval about 170 cy per week was removed for other purposes, mostly from Baldwin Beach. An extrapolation of these quantities to about 1900 when mining presumably began, and to about 1970 when mining apparently ended, yields a total of 200 to 400 thousand cm of sand removed from beaches in Cells 15-18. We see no evidence that sand - in quantity - was mined in other areas. Thus the ratio of sand volume mined to coastal volume lost is 0.4 to 0.8. This is the value of $\rho_b + \rho_s$ for those cells in Equation 4.

The lime kilns are no longer there. But the revetment constructed to protect them still exists and it is responsible for the 1997-2002 loss of shoreline position in Cell 16 (as shown in Figure 10) just to the east of the revetment. The revetment is responsible for the beginning formation of a hook-shaped bay. In this 135-m long cell in that 5-yr period the shoreline retreated about 27 m on average and the hooked shoreline will likely evolve and affect the east end of Baldwin Beach in the near future.

With the exception of this evolving hook-shaped bay the previously mined beaches in Cells 15-18 have been slowly recovering. Figure 16 compares these "sand mined" beaches with those east and west of them except those in Cells 1-7 that have been substantially affected by the construction of groins. Although there are times when beaches in and adjacent to the sand mining reach are eroded during the NE trades season, as occurred on Baldwin Beach (Cell 15) in 2005, this portion of coast performed in a superior manner in comparison to its downcoast neighbors that lost plan area in the 1975-2002 period. Net changes are: (1) an average loss of 115 sm/y outside the sand mining zone (Cells 9-14 and 19-21), and (2) a net gain of 215 sm/y within it (Cells 15-18). Without the hooked bay forming in Cell 16, the gain would be +334 sm/y in the former sand mining reach for the 1975-2002 period. This result is not unexpected. As previously noted, natural boundaries separating cells function to contain sand proportional to the distance between the shoreline and the projecting headland (or groin). When the shoreline retreats with respect to that fixed boundary, there is a reduction in the amount of sand carried past it, so over time and with distance downcoast beaches are adversely affected. Therefore, with the mined beaches now apparently recovering, that recovery is to some extent at the expense of downcoast beaches.

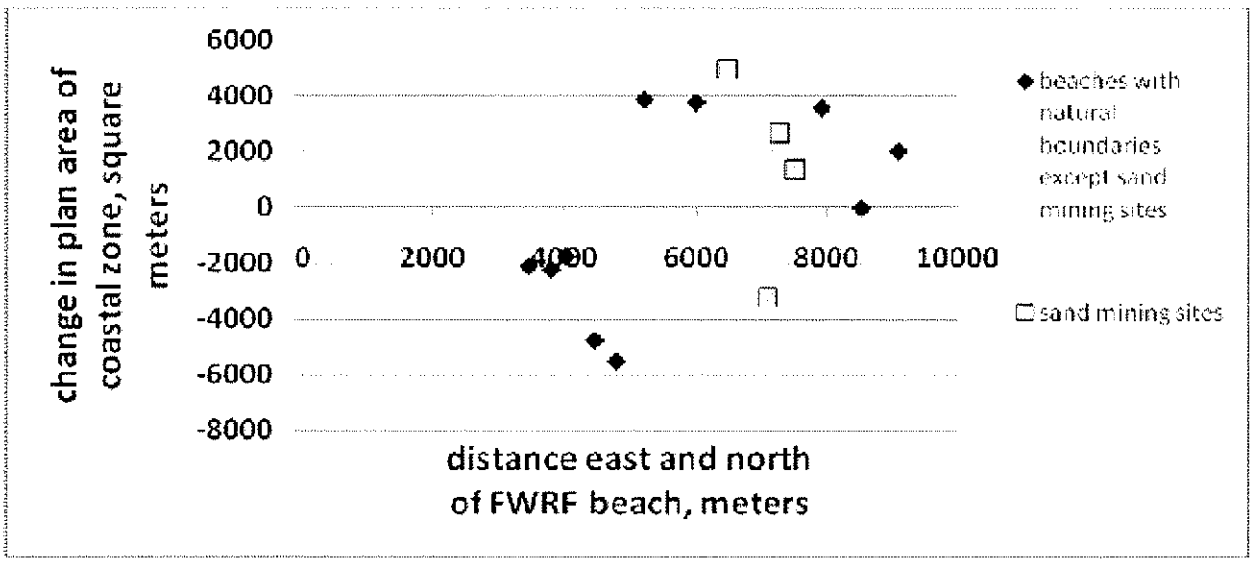


Figure 16. Changes in coastal plan areas between 1975 and 2002 except in Cells 1 through 7 (cells with groins that have affected the coast since before 1960).

Sugar Cove placed about 12,500 cm/y of sandy beachfill in the littoral zone there in the 1996-2002 period. This is the only beach building that has ever been done in the study area to our knowledge. Its effect cannot be detected away from Sugar Cove on the UH shoreline position maps. The 1997-2002 beach plan area for that cell (No.13), however, indicates a gain of 2250 sm or about 750 cm/y between 1997 and 2000 at which time the beach reached state of dynamic equilibrium with the nourishment flux. The 2250 sm translates to an advance of the shoreline of about 15 m or close to the advance shown in Figure 14.

Sand mining losses and beach restoration gains as treated in the sediment budget are summarized in Table 7.

Table 7. Summary: sand mining and beachfill fluxes.

Cell number	Cell Length, meters	1912-1960 average sand volume removed by mining, in cubic meters	1960-1975 average sand volume removed by mining , in cubic meters
15	939	315000	39900
16	135	22400	36400
17	180 (lime kilns)	31500	13300
18	241	39200	12600
13	260	Sugar Cove added beachfill: 1988-1997 = 5000 cm, 1997-2002 = 8000 cm	

4.8 Offshore Sediment Source.

Beach sediments from Kahului Harbor to Blue Tile House beach are calcareous. Biological production is responsible for all the new sediment entering this reach according to Moberly (1963). The chief constituent is foraminifers. These small marine organisms are transported in from the reef edge. Living mollusks and echinoids are found there too, but they as well as living coral are rare or absent on the reef flat. Algae are the only common inhabitants there. Also according to Moberly (1963), from high to low in scale of supply, the sources of beach sediment are: foraminifer skeletons, mollusks, red algae, echinoids, corals, and green algae He hypothesizes the average sand contribution per kilometer of reef to be 1 to nearly 2.5 thousand cm/y in Hawaii with biologic activity contributing 0.5 to 2 thousand cm/y per km of well developed reef (the rest is presumably broken coral debris). Moberly also states the mean grain size of Maui beach sand is 0.18 mm, of which 30-40% is oblate, 40% is bladed, and 10% or less is equant. Most of the Maui sand is semi-rounded.

We assume a reef flux of 1750 cm/y per km for the period 1912-1975 and 1000 cm/y per km for years thereafter. This reflects the possibility the reef has suffered a loss of productivity as ocean waters have become warmer and as human influences may have affected it.

4.9 Seaward-Directed Flux Past the Shorebase.

The shorebase between Kalului Harbor and Blue Tile House beach is not as deep as it would be if it were not supported on the reef flat. This situation favors onshore rather than offshore transport under "normal" wave conditions. Offshore directed transport probably only occurs during severe events. Examples might be tsunamis and severe winter swell from the NW. Trades may be responsible for offshore directed sand movement at deflection points, but with the

exception of the clear break in the reef with a sand filling between Cells 4 and 5, the location of these sites is not known to us (note: we have not had an opportunity to examine aerial photos that show the reef edge off KWRF beach taken when the water was clear). Moberly and Cox (1964) conclude in some places there is up to four times as much sand in reef channels (some more than 15-ft thick) as on the beach. They consider them to be temporary reservoirs for sand storage. At Kahului they state 59,000 cy is held, at Papaula 79,000 cy is held, and at Paia 97,000 cy is held in these channels. We did not attempt to verify these values.

For our sediment budget analysis we began with the assumption that the seaward-directed sand flux across the shorebase is negligible except at KWRF beach (the west end).

4.10 In-Situ Gains and Losses.

Grain abrasion may be an important factor in the loss of sand on the study beaches. This is to be expected since (1) the source is the reef edge and it is composed of skeletal carbonate clasts that are less dense than quartz or solid carbonate, (2) it is elongate, and (3 especially) it is not as durable as other beach components. Tests in wet tumblers indicate this sort of reef type sediment loses mass 100 to 1000 or even 2000 times as fast as quartz of the same size and roundness. Moberly (1963) notes abrasion declines with size and echinoids abrade the fastest. We assume abrasion destroys 300 cm/y per km of LSL sand.

4.11 Overwash Flux.

Tsunamis that affect the north shore of Maui are probably the only events that create conditions where overwash carries sand inland past the backbeach line. The extent of that transport is unknown, but it is possible to make a guess based on the water surface super-elevation and number of waves that moved inland during some past tsunamis. The most extreme tsunami during the 1912-2002 period occurred on 1 April 1946. It originated with an earth displacement in the east Aleutian Islands and caused a surge reported to be 8.5 m above MSL on north Maui. Several waves came ashore, houses near the beach were lost in some places, including Spreckelsville beach, and flooding was reported almost a kilometer inland. Severe tsunamis also affected the north shore and pushed beachfront homes off their foundations in 1952, 1957 and as a result of the Alaskan Earthquake of 1964. The surge in these events was apparently 5 or 6 m above MSL with the 1964 event being the least severe.

We assume each of the 21 cells (that are not backed by a high seacliff) was thus affected by all four tsunamis. Due to the different severity of the events, we assign them a different flux. We assume the 1946 event pushed 3cm of sand past the backbeach line per meter of sandy shoreline, the 1952 and 1957 events pushed 1cm/m ashore, and the 1964 event carried 0.5 cm/m landward off the beach. Thus, for the 1912-1960 period a total of 5cm/m (or 0.1 cm/my) were lost to the littoral system and 0.5 cm/m (or 0.03 cm/my) were lost inland between 1960 and 1975.

5.0 SEDIMENT BUDGETS AND NET LONGSHORE SAND TRANSPORT ALONG KWRF BEACH

Our sediment budget effort has a singular purpose. It is to estimate the present net longshore sand transport rate at the west end of KWRF beach and the range of uncertainty in that estimate. We employ two sets of historic budgets in our attempt to accomplish that. The first part of the first set is for the period 1912-1975. This is when the most change occurred in the position of the shoreline on north Maui. Sand mining and the emplacement of groins (structures that impounded sand on their east sides and caused the formation of hook-shaped bays on their west sides) had an enormous impact almost all of the beaches east of Kahului Harbor. The second part of this set is for the period 1975-2002, after sand mining and most groin construction ended. The first part is for a 63-year period and the second for a 27-year period. The second set of sediment budgets is for the periods 1912-1960 and 1960-2002, respectively 48 and 42 year long intervals. This budget was selected to include near equal decades-long averaging intervals. Both sets of budgets are for the reach between Kahului Harbor and Blue Tile House beach. Separate budgets for each of the five time periods (six shorelines) in the UH data set were of little use because year-to-year fluctuations in shoreline movement were much greater than the longer-term net change.

The sediment budget used for the north shore of Maui to estimate the net longshore sand transport rate at KWRF beach is

$$Q_{in}(\Delta T) = q_s(\Delta T) + q_a(\Delta T) + q_o(\Delta T) + q_{SM}(\Delta T) + q_{BP}(\Delta T) + q_{re}(\Delta T) + q_{ia}(\Delta T) + \Delta V_l(\Delta T) + residual(\Delta T) \quad (5)$$

in which Q_{in} = the longshore sand transport flux to KWRF beach from the east during the averaging period, ΔT, q_s = substrate sediment flux, mostly positive, but in some cases it is slightly negative when the sea level rise effect is greater than the beach retreat effect (this flux is only considered when the beach movement rate is negative), q_a = aeolian sediment flux, a negative quantity, q_o = overwash sediment flux during severe tsunamis, a negative quantity, q_{SM} = sand mining flux, a negative quantity, q_{BP} = beachfill placement flux, a positive quantity, q_{re} = reef edge source flux, a positive quantity, q_{ia} = insitu abrasion flux, a negative quantity, ΔV_l = flux to or from the littoral sediment lens as it expands or contracts, may be either positive or negative, and $residual$ = amount of sediment unaccounted for in the sediment budget, may be either positive or negative. The two sets of sediment budgets were run simultaneously (excel) using common parameters in the sediment fluxes.

Figure 17 shows the seasonally adjusted shoreline change rates for the unequal averaging periods when displayed as a function of location. These are the values used in our first set of sediment budgets. The average shoreline change rate for the 1912-1975 period is -0.41 meters per year; for the 1975-2002 period it is -0.02 m/y. The earlier value is a reflection of the era of sand mining (Cells 15-18) and the main period of groin construction (mostly Cells 1-7). The later value

reflects more "natural" conditions. The large shoreline advance in Cell 4 is apparently due to the expansion of a fillet after a groin was extended between Cells 3 and 4 in the period 1975-1997. The large shoreline retreat in Cell 16 is due to the rapid degradation of the previously-mentioned sandy salient in the lee of a beachrock bench between Cells 15 and 16.

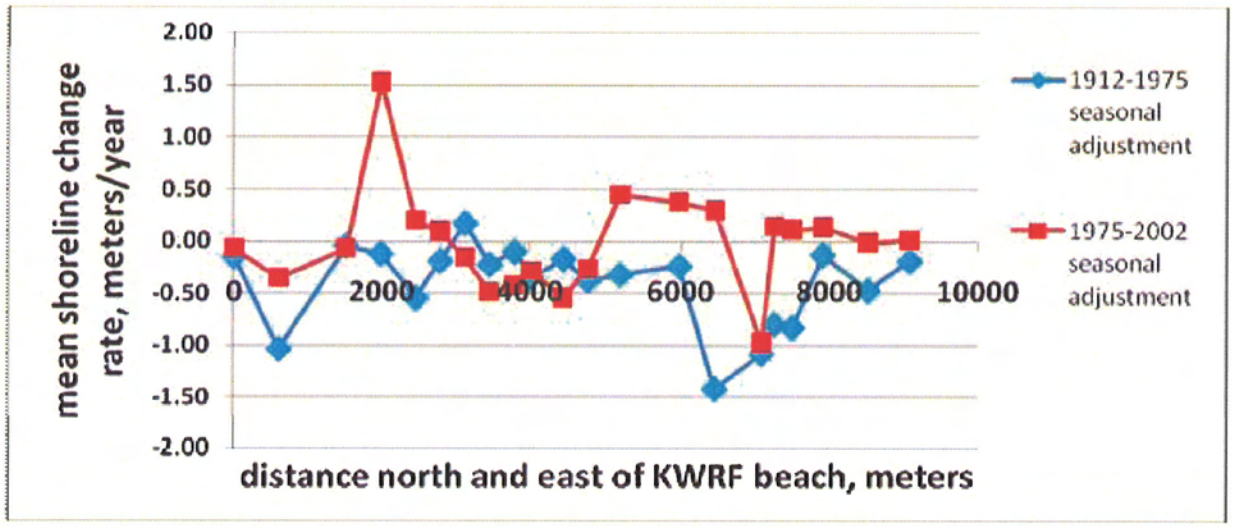


Figure 17. Shoreline changes on north Maui for 1912-1975 and 1975-2002, adjusted for seasonal reversible fluctuations; cell numbers begin at the origin and go to 21 about 9000 meters from KWRF beach.

The second set of budgets is for the near-equal averaging periods, 1912-1960 and 1960-2002. Shoreline changes are similar in pattern, but not magnitude in the two sets of data as shown in a comparison of Figures 17 and 18.

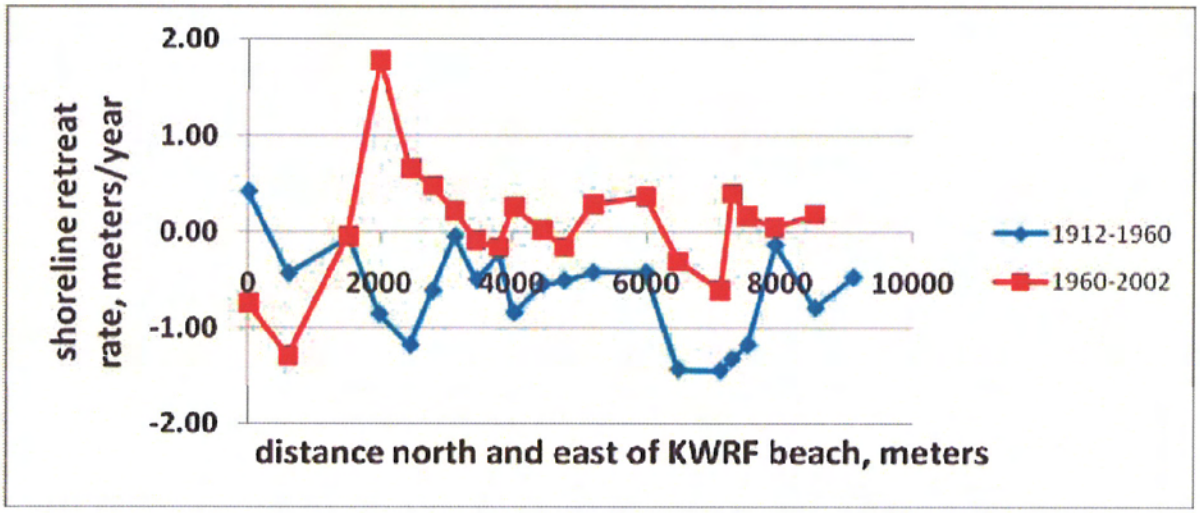


Figure 18. Shoreline changes on north Maui by time interval, 1912-1960 and 1960-2002, adjusted for seasonal reversible fluctuations; cell numbers begin at the origin and go to 21 at about 9000 meters from KWRF beach.

5.1 Sediment Budget Results

We present the results of the two sets of sediment budgets in Table 8 and employ Table 9 to assist in explaining them. Table 8 shows the budget-derived estimate of the net longshore sand transport is somewhat larger in the earliest time interval in both sets. In 1912 the shoreline was well seaward of its later positions and in an alongshore sense it was smoother and less indented at the upcoast headlands. Our analysis of the recent Sugar Cove data suggests the net longshore sand transport rate increased there by about 50cm/y for each meter of added mean beach width (or mean shoreline advance). Early more seaward beaches surely resulted in a larger net longshore sand discharge to KWRF beach. This finding is not surprising since, as shown in Table 9, the period to 1960 was one of the most overall shoreline retreat. From 1960 trough 1975 Kite beach contributed the most sand to KWRF beach as the former evolved as a hook-shaped bay. It wasn't until 1988 that that hooked bay equilibrated in planform and the revetment separating Kite and KWRF beaches became an effective boundary between them. Most likely the average 4000 plus cm/y contributions from upcoast after 1975 (set 1) and 1960 (set 2) declined, especially after 1975.

Table 8. Estimated net longshore sand transport rates at KWRF beach; based on sediment budget residuals.

sediment budget set	**ONE**		**TWO**	
time interval	**1912-1975**	**1975-2002**	**1912-1960**	**1960-2002**
rate, in cm/y	5400	4100	6500	4600

Table 9. Mean shoreline position change rates, west end of north Maui littoral system.

Time interval	**1912-1960**	**1960-1975**	**1975-1987**	**1988-1997**	**1997-2002**
Kite beach	**-19**	**-51**	**-17**	**-6**	**9**
KWRF beach	**21**	**-35**	**-10**	**-1**	**3**
Average of remaining upcoast cells	**-30**	**-3**	**-7**	**-6**	**5**

5.2 Uncertainty

Sediment budgets rarely get more complicated. The north Maui littoral system is complex in comparison to most others because of the irregular planform of the shore, the many natural and

artificial beach retention structures (headlands, shore-parallel beachrock reefs, and groins), and the effect of the irregular bathymetry of the reef edge and reef flat on incident waves. Sediment fluxes are poorly known and some are uncommon. Reef-edge source and abrasion of complex carbonate grains are examples. Estimates of these and some of the other fluxes are at best order of magnitude guesses.

Other aspects of this littoral system remain unanswered as well. For example: Why did the three small beaches to the east of Blue Tile House beach lose more coastal land or beach between 1912 and 1975 than in more recent times, even when they were probably not subject to sand mining and are upcoast of the sand mining region? It was either a period of great loss everywhere, the no-sand-mining assumption is wrong, or the USC&GS shoreline is incorrectly located. Cell 19 had little change in this period, but Cell 20 had a lot: Why? Cells 22-24 show quite a bit of change 1912-1975, but little after that. Could sand have been mined there and in Cell 20, but not Cell 19? Alternatively, Cells 22-24 are seacliff backed and they might have suffered more than elsewhere during the 1946 tsunami by offshore losses, since there was no release of the long-period wave by overwash.

Thus, due to the lack of good input to define some of the fluxes, and questions such as these, the sediment budget results are somewhat questionable. It would be possible to tighten up the most important ones and possibly answer those questions. One task would involve a detailed beach-retention-structures and hook-shaped bay analysis. Another would require a field investigation. The alternative is to go with the results of this investigation with periodic and scheduled nourishment to maintain the mean width of the KWRF beach in front of a newly-constructed seawall. An important caveat is that an alteration in the project might be required in future. With a good monitoring program and further investigation this might be the more cost effective approach without a major technical downside.

5.3 Net Longshore Sand Transport Estimate for KWRF Beach

The net longshore sand transport rate at KWRF beach is of interest mainly (1) in whether it would be cost effective or technically feasible to capture all of part of it (as a sand source) before it is lost offshore, and (2) how KWRF beach might be stabilized with a beach retention structure whose function is partly controlled by Q_{in} . Magnitudes and trends shown in Tables 3, 5 and 8, indicate the net longshore sand transport rate at KWRF beach was high in the early 1900's due to the more seaward position of the shoreline. It remained high after groins were constructed along the western portion of the study reach as hook-shaped bays evolved with substantial erosion downcoast of the structures. It stayed high through 1987 as the last hooked bay evolved downcoast of Kaa Point. After 1987 beach retreat rates declined everywhere and they remain low or some shorelines even exhibit an advance to the present. **This indicates the net rate at present, and the rate likely to continue into the future, will be between 1000 and 3000 cm/y, perhaps averaging 2000 cm/y.** The assumption is that human interventions will be no more

invasive (in a good way) than the 1000 cm/y that is artificially placed on Sugar Cove beach or in any adverse ways. That said, any other upcoast artificial beachfills are not likely to increase the amount reaching KWRF beach by much since they will not advance the beaches at Kanaha Beach Park by much. **A net addition of 0.002 m/y to the present sea level rise rate in the next 50-years could reduce the net longshore sand transport rate by 500 to 1000 cm/y at KWRF beach.**

Uncertainty in each of the sediment-budget-related estimates of the net longshore sand transport rate at KWRF beach is substantial (Table 8). However, given the redundancy in the two budget-related estimates and the correlation with other estimates, and a fairly good idea of what caused changes; confidence is improved in the range of the estimate. The estimate, however, should be considered a work in progress. **Our subjective take on the accuracy of the future net longshore sand transport rate estimate, on a scale of one (low) to10 (high), is 5.**

6.0 ESTIMATE OF FUTURE PERFORMANCE OF KWRF BEACH

Figure 19 shows the most recent shoreline behavior at KWRF beach with data adjusted for seasonal effects. The slight recession depicted, -0.044 m/y, shows poor correlation, and indeed if the seasonal adjustment is eliminated (see Figure 2, which illustrates the unadjusted coastal plan area as a function of time) there would be a slight net advance between 1987 and 2007. The shoreline at Kite beach also receeded between 2002 and 2007 (Fig. 3), but beaches at Kanaha Beach Park advanced and in total the western portion of the study area advanced in this latest period.

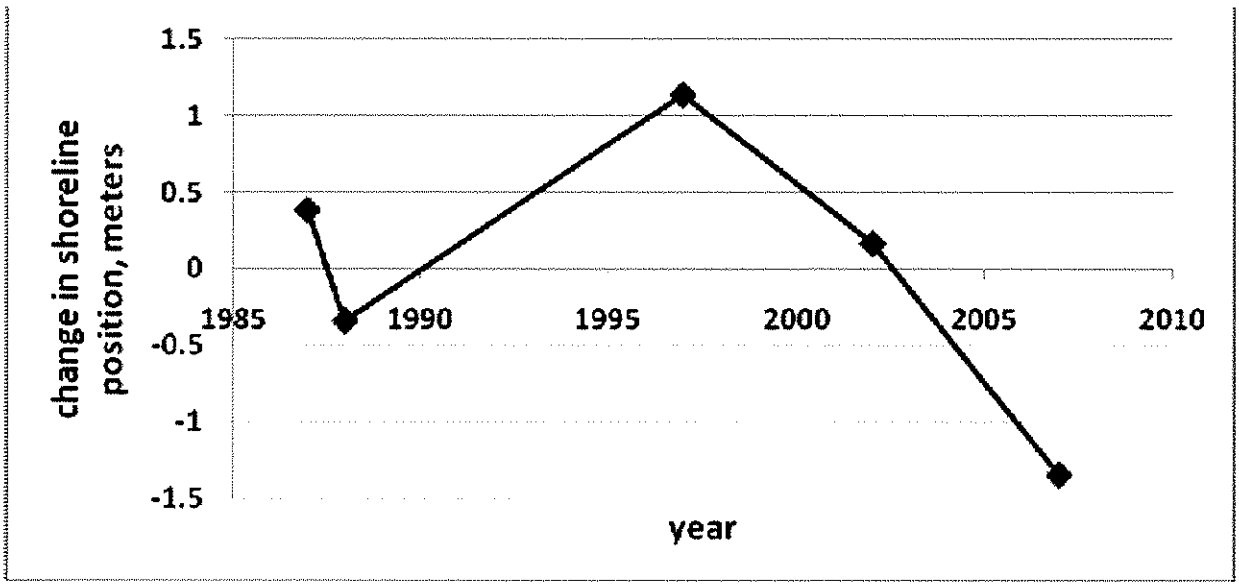


Figure 19. Recent (1987-2002) shoreline behavior, KWRF beach.

6.1 Net Future Beach Volume Change Estimate

Of most interest is the beachfill requirement to artificially nourish FWRF beach in the future if a seawall is constructed at its landward edge. The two most definitive aspects of beach behavior are changes in its size, i.e., mean beach width, $\Delta\bar{w}$ and changes in its position, i.e., of the backbeach line, $\Delta\bar{S}_b$. Figure 19 is an historical glimpse of the behavior of its shoreline, i.e., changes in its position, $\Delta\bar{S}$. The seawall, if successful, will arrest any movement of its backbeach line and hold it in a fixed position so

$$\Delta\bar{S}(\Delta T) = \Delta\bar{w}(\Delta T), \qquad (6)$$

since any change in the position of the shoreline will be reflected as a change in beach width and LSL volume. At KWRF beach, the shoreline change to volume change ratio is between 3000 and

6000 cubic meters of sand per 1 meter of shoreline retreat or advance. A realistic value is probably 4000 cm/m. Thus, given the results in Figure 19 and the near stability of the position of the shorelines in the western part of the study area in the past 40 or so years (Figs. 17 and 18), we conclude the shoreline change rate at KWRF beach without a change in the position of the beach (no retreat) will probably be somewhere in the range -0.15 m/y to +0.05 m/y. Without a change in the recent past sea level rise rate, this translates to a beachfill requirement to maintain it at its present mean position of 400 to 900 cm/y. If the sea level rise rate accelerates by 0.002 m/y, the requirement will increase by 80 to 200 cm/y, averaged over the next 50 years, with an increasing need over time. ***Conservatively, in the next 50 years, the average annual beachfill need will likely be between 500 and 1000 cm.***

6.2 Uncertainty

Sediment input to KWRF beach will likely remain near its present upcoast supply rate of 1000 to 3000 cm/y from Kite beach if the sea level rise rate remains constant. If it increases that amount may decline by 500 to 1000 cm/y. This coupled with the uncertainty in the shoreline change forecast and uncertainty in the shoreline change to volume change ratio, implies the requirement for beachfill to maintain the 2007 mean beach width could be as much as 1000 cm/y. Interestingly, this is the amount of beachfill the Sugar Cove folks have placed, on average, since 2000 to maintain a mean width of 20-m, but for a beach that is only 40% as long. ***On a scale of 1 to 10, our subjective take is an uncertainty of 6 that the beachfill requirement will average between 500 and 1000 cm/y.*** Less than the average will be required at the beginning and more will be required leading up to 2057.

7.0 CONCLUSIONS

Future net longshore sand transport at KWRF beach is of interest mainly (1) in determining whether it would be cost effective to capture all of part of it (as a sand source) before it is lost, presumably offshore, and (2) how KWRF beach might be stabilized with a beach retention structure whose function is partly controlled by the characteristics of the longshore sand transport regime. The net longshore sand transport rate at present, and one that is likely to continue into the future in the absence of upcoast human interventions and changed natural sediment fluxes, will be between 1000 and 3000 cm/y, perhaps averaging 2000 cm/y. A net addition of 0.002 m/y to the present sea level rise rate over the next 50-years could reduce the net longshore sand transport rate by 500 to 1000 cm/y. Our subjective take on the accuracy of these estimates, on a scale of one (low) to 10 (high), is 5.

Of most interest if a seawall is constructed at the landward edge of KWRF beach is the beachfill requirement to maintain the 2007 mean width for the next 50 years. We conclude the shoreline change rate at KWRF beach without a change in its position (due to it being fixed by the seawall), and with conditions as they now exist, will probably be somewhere in the range -0.15 m/y to +0.05 m/y. Without a change in the recent past sea level rise rate, this translates to a beachfill requirement to maintain it at its present mean position of 400 to 900 cm/y. If the sea level rise rate accelerates by 0.002 m/y, the requirement will increase by 80 to 200 cm/y, averaged over the next 50 years. On a scale of 1 to 10, we believe the certainty that the beachfill requirement will average between 500 and 1000 cm/y is 6 on a scale of 1 to 10. Less than this range will be required at the beginning and more required leading up to the end of a 50-year project.

8.0 ACKNOWLEDGEMENTS

Barbara Guild graciously provided beach replenishment data for Sugar Cove. Patti Cadiz led a number of trips to sites along the north Maui coast and explained its history. Rob Sloop and Russ Boudreau accompanied the author on a three-day visit to the study area and Anne-Lise Lindquist provided much needed background information.

9.0 REFERENCES

Cox, D.C., 1954, "The Spreckelsville Beach Problem", report prepared for the Hawaiian Sugar Planters Association, 10p plus plates.

Gibbs, A.E., Richmond, B.M., and C.H. Fletcher, 2000, "Beach Profile Variations on Hawaiian Carbonate Beaches", Proceedings Carbonate Beaches 2000, p99-110.

Guild, B.Q., 1999, "Beach Restoration at Sugar Cove, Maui, Hawaii", Shore and Beach, v.67, n.2&3, p4-18.

Moberly, R. Jr, and T. Chamberlain, 1968, "Hawaiian Beach Systems", report prepared for Harbors Division, Dept of Transportation, State of Hawaii, 86p.

Moberly, R. Jr., Cox, D.C., Chamberlain, T., McCoy, F.W. Jr., and J.F. Campbell, 1964, "Coastal Geology of Hawaii", report prepared as part of the Shoreline Plan of the State of Hawaii, 182p.

APPENDIX B – COST ESTIMATE DETAILS

ALTERNATIVE 1A: 3,800 FEET BEACH REPLENISHMENT

DREDGED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Dredge Mob/Demob	1	LS	$1,500,000	$1,500,000
Dredged Sand	105,000	CY	$30	$3,150,000
Initial Construction Subtotal (Rounded)				**$4,650,000**
Maintenance (2008 Dollars)				
Dredge Mob/Demob	1	LS	$500,000	$500,000
Dredged Sand	21,000	CY	$40	$840,000
Maintenance Subtotal (Rounded)				**$1,300,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$1,711,852	$1,169,743
Year 16			$2,254,182	$1,052,537
Year 24			$2,968,327	$947,075
Year 32			$3,908,720	$852,180
Year 40			$5,147,038	$766,793
Year 48			$6,777,666	$689,962
Maintenance Subtotal (Rounded)				**$5,500,000**
Construction Subtotal				**$10,150,000**
Eng., Const. Support (12%)				$1,218,000
Contingency (15%)				$1,705,200
TOTAL PROJECT COST				**$13,100,000**

PURCHASED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Mob/Demob	1	LS	$200,000	$200,000
Purchased Sand	105,000	CY	$30	$3,150,000
Initial Construction Subtotal (Rounded)				**$3,350,000**
Maintenance (2008 Dollars)				
Mob/Demob	1	LS	$50,000	$50,000
Purchased Sand	21,000	CY	$30	$630,000
Maintenance Subtotal (Rounded)				**$700,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$921,766	$629,861
Year 16			$1,213,790	$566,751
Year 24			$1,598,330	$509,963
Year 32			$2,104,695	$458,866
Year 40			$2,771,482	$412,889
Year 48			$3,649,512	$371,518
Maintenance Subtotal (Rounded)				**$2,900,000**
Construction Subtotal				**$6,250,000**
Eng., Const. Support (12%)				$750,000
Contingency (15%)				$1,050,000
TOTAL PROJECT COST				**$8,100,000**

ALTERNATIVE 1B: 2,400 FEET BEACH REPLENISHMENT

DREDGED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Dredge Mob/Demob	1	LS	$1,500,000	$1,500,000
Dredged Sand	65,000	CY	$30	$1,950,000
Initial Construction Subtotal (Rounded)				**$3,450,000**
Maintenance (2008 Dollars)				
Dredge Mob/Demob	1	LS	$500,000	$500,000
Dredged Sand	16,000	CY	$40	$640,000
Maintenance Subtotal (Rounded)				**$1,100,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$1,448,490	$989,782
Year 16			$1,907,385	$890,608
Year 24			$2,511,661	$801,371
Year 32			$3,307,378	$721,075
Year 40			$4,355,186	$648,825
Year 48			$5,734,948	$583,814
Maintenance Subtotal (Rounded)				**$4,600,000**
Construction Subtotal				**$8,050,000**
Eng., Const. Support (12%)				$966,000
Contingency (15%)				$1,352,400
TOTAL PROJECT COST				**$10,400,000**

PURCHASED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Mob/Demob	1	LS	$200,000	$200,000
Purchased Sand	65,000	CY	$30	$1,950,000
Initial Construction Subtotal (Rounded)				**$2,150,000**
Maintenance (2008 Dollars)				
Mob/Demob	1	LS	$50,000	$50,000
Purchased Sand	16,000	CY	$30	$480,000
Maintenance Subtotal (Rounded)				**$500,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$658,405	$449,901
Year 16			$866,993	$404,822
Year 24			$1,141,664	$364,260
Year 32			$1,503,354	$327,762
Year 40			$1,979,630	$294,921
Year 48			$2,606,794	$265,370
Maintenance Subtotal (Rounded)				**$2,100,000**
Construction Subtotal				**$4,250,000**
Eng., Const. Support (12%)				$510,000
Contingency (15%)				$714,000
TOTAL PROJECT COST				**$5,500,000**

ALTERNATIVE 3A: 1,200 FEET REVETMENT

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Mob/Demob	1	LS	$500,000	$500,000
2 ton Armor Stone	13,200	TON	$70	$924,000
Bedding Stone	6,000	TON	$30	$180,000
Geotextile	80,000	SF	$7	$560,000
Excavation & Backfill	16,000	CY	$40	$640,000
Initial Construction Subtotal (Rounded)				**$2,800,000**
Maintenance (2008 Dollars)				
5% of Initial Construction Cost every 10 years				$140,000
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 10			$197,484	$122,691
Year 20			$278,570	$107,522
Year 30			$392,951	$94,228
Year 40			$554,296	$82,578
Maintenance Subtotal (Rounded)				**$400,000**
Construction Subtotal				**$3,200,000**
Eng., Const. Support (15%)				$480,000
Contingency (15%)				$552,000
TOTAL PROJECT COST				**$4,200,000**

ALTERNATIVE 3B: 1,200 FEET REVETMENT WITH BEACH REPLENISHMENT

DREDGED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Revetment (As 3A)	1	LS	$2,800,000	$2,800,000
Dredge Mob/Demob	1	LS	$500,000	$500,000
Dredged Sand	30,000	CY	$40	$1,200,000
Initial Construction Subtotal (Rounded)				**$4,500,000**
Maintenance (2008 Dollars)				
Dredge Mob/Demob	1	LS	$500,000	$500,000
Dredged Sand	16,000	CY	$40	$640,000
Maintenance Subtotal (Rounded)				**$1,100,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$1,448,490	$989,782
Year 16			$1,907,385	$890,608
Year 24			$2,511,661	$801,371
Year 32			$3,307,378	$721,075
Year 40			$4,355,186	$648,825
Year 48			$5,734,948	$583,814
Maintenance Subtotal (Rounded)				**$4,600,000**
Construction Subtotal				**$9,100,000**
Eng., Const. Support (12%)				$1,092,000
Contingency (15%)				$1,528,800
TOTAL PROJECT COST				**$11,700,000**

PURCHASED SAND

Item	Quantity	Unit	Unit Cost	Total Cost
Initial Construction (2008 Dollars)				
Revetment (As 3A)	1	LS	$2,800,000	$2,800,000
Mob/Demob	1	LS	$200,000	$200,000
Purchased Sand	30,000	CY	$30	$900,000
Initial Construction Subtotal (Rounded)				**$3,900,000**
Maintenance (2008 Dollars)				
Mob/Demob	1	LS	$50,000	$50,000
Purchased Sand	16,000	CY	$30	$480,000
Maintenance Subtotal (Rounded)				**$500,000**
Maintenance (Future Dollars and Net Present Value)				
Maintenance Cycle			**Inflated Cost**	**Present Value**
Year 8			$658,405	$449,901
Year 16			$866,993	$404,822
Year 24			$1,141,664	$364,260
Year 32			$1,503,354	$327,762
Year 40			$1,979,630	$294,921
Year 48			$2,606,794	$265,370
Maintenance Subtotal (Rounded)				**$2,100,000**
Construction Subtotal				**$6,000,000**
Eng., Const. Support (12%)				$720,000
Contingency (15%)				$1,008,000
TOTAL PROJECT COST				**$7,700,000**

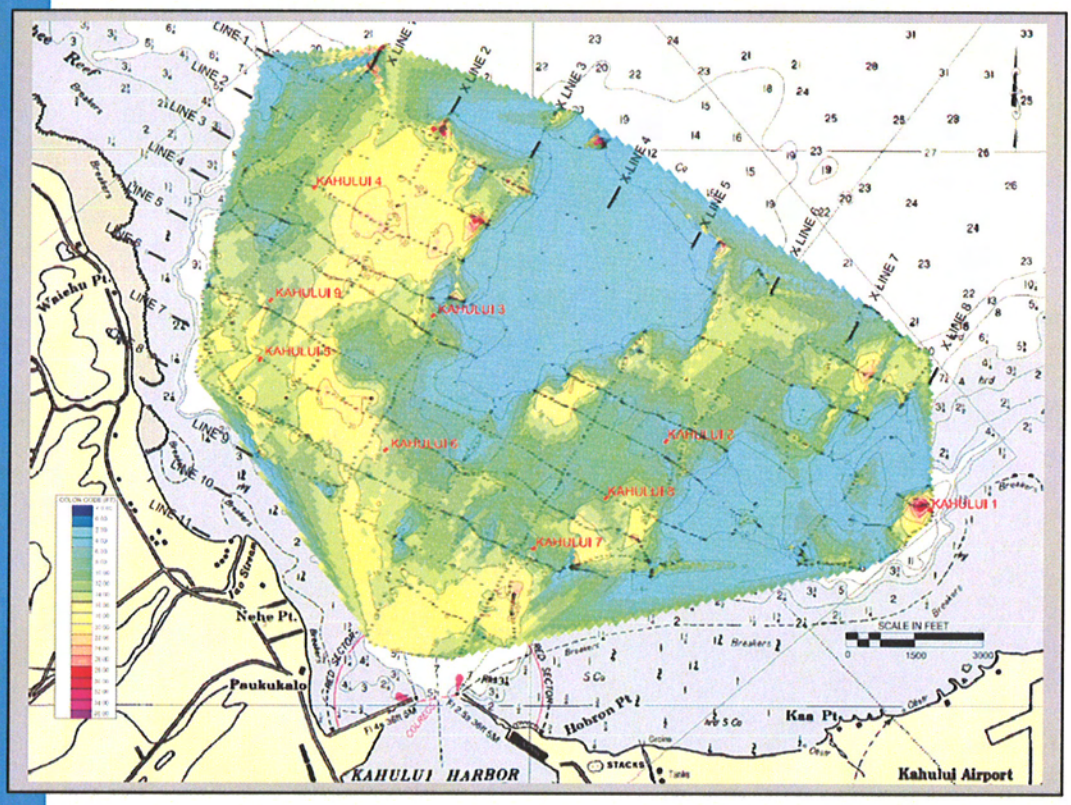
COST SUMMARY
INCLUDES ALL MARKUPS AND CONTINGENCY

Item	Initial Construction	NPV of Maintenance	NPV of Total Cost	Annualized Maintenance
Alternative 1A: 3,800-foot Beach Replenishment				
Dredged Sand	$6,000,000	$7,100,000	$13,100,000	$380,000
Purchased Sand	$4,300,000	$3,700,000	$8,100,000	$200,000
Alternative 1B: 2,400-foot Beach Replenishment				
Dredged Sand	$4,400,000	$5,900,000	$10,400,000	$320,000
Purchased Sand	$2,800,000	$2,700,000	$5,500,000	$150,000
Alternative 3A: 1,200-foot Revetment Extension				
Initial Construction	$3,700,000	$500,000	$4,200,000	$30,000
Alternative 3B: Revetment with 2,400-foot Beach Replenishment				
Dredged Sand	$5,800,000	$5,900,000	$11,700,000	$320,000
Purchased Sand	$5,000,000	$2,700,000	$7,700,000	$150,000

APPENDIX C – SAND SEARCH RESULTS

KAHULUI BAY SUB-BOTTOM SURVEY

November 2008



Prepared for:
Moffatt & Nichol
3789 Kilroy Airport Way, Suite 600
Long Beach, CA 98060

Prepared by:
Sea Engineering, Inc.
Makai Research Pier
Waimanalo, Hawaii 96795

SEI Job No.25117

TABLE OF CONTENTS

1. INTRODUCTION 1

2. METHODOLOGY 2

2.1 SUB-BOTTOM PROFILING METHODS 2
2.2 SUB-BOTTOM DATA PROCESSING AND INTERPRETATION 2
2.3 BOTTOM SEDIMENT SAMPLES 4

3. RESULTS 5

3.1 SUB-BOTTOM SURVEY RESULTS 5
3.2 SAND SAMPLE RESULTS 5

4. DISCUSSION 7

APPENDIX 1. SAMPLE PHOTOGRAPHS AND DESCRIPTIONS 8

LIST OF FIGURES

FIGURE 1-1 SURVEY LOCATION AND PLAN 1
FIGURE 2-1 TYPICAL SUB-BOTTOM IMAGERY IN KAHULUI BAY 3
FIGURE 2-2 SUB-BOTTOM IMAGERY SHOWING EMERGENCE OF REEF SUBSTRATE 3
FIGURE 2-3 GRAPH OF SAMPLE GRAIN SIZE DISTRIBUTION 4
FIGURE 3-1 KAHULUI BAY SAND THICKNESS AND SAMPLE LOCATIONS 6

LIST OF TABLES

TABLE 2-1 SAMPLE GRAIN SIZE DISTRIBUTION 4

1. INTRODUCTION

In May, 2008, Sea Engineering, Inc. (SEI) was retained by Moffatt & Nichol to conduct a sub-bottom survey using geophysical methods of Kahului Bay on the north shore of the island of Maui. The survey was designed to investigate the nature of sand deposits in the bay. Previous benthic surficial mapping by NOAA (National Oceanographic and Atmospheric Administration) had indicated the broad presence of sand deposits within the bay, however there were no data available to determine the thickness of the sand deposits.

The survey covered an area of approximately 5.5 square miles. Primary survey lines were run at 1,000-ft intervals, and survey cross-lines were run at 2,000-ft intervals. The project location and survey line plan is shown in Figure 1-1.

The geophysical work was conducted over the course of two days, May 13 and 14, 2008. In addition, a series of nine surficial sediment samples were collected using a Ponar grab sampler.

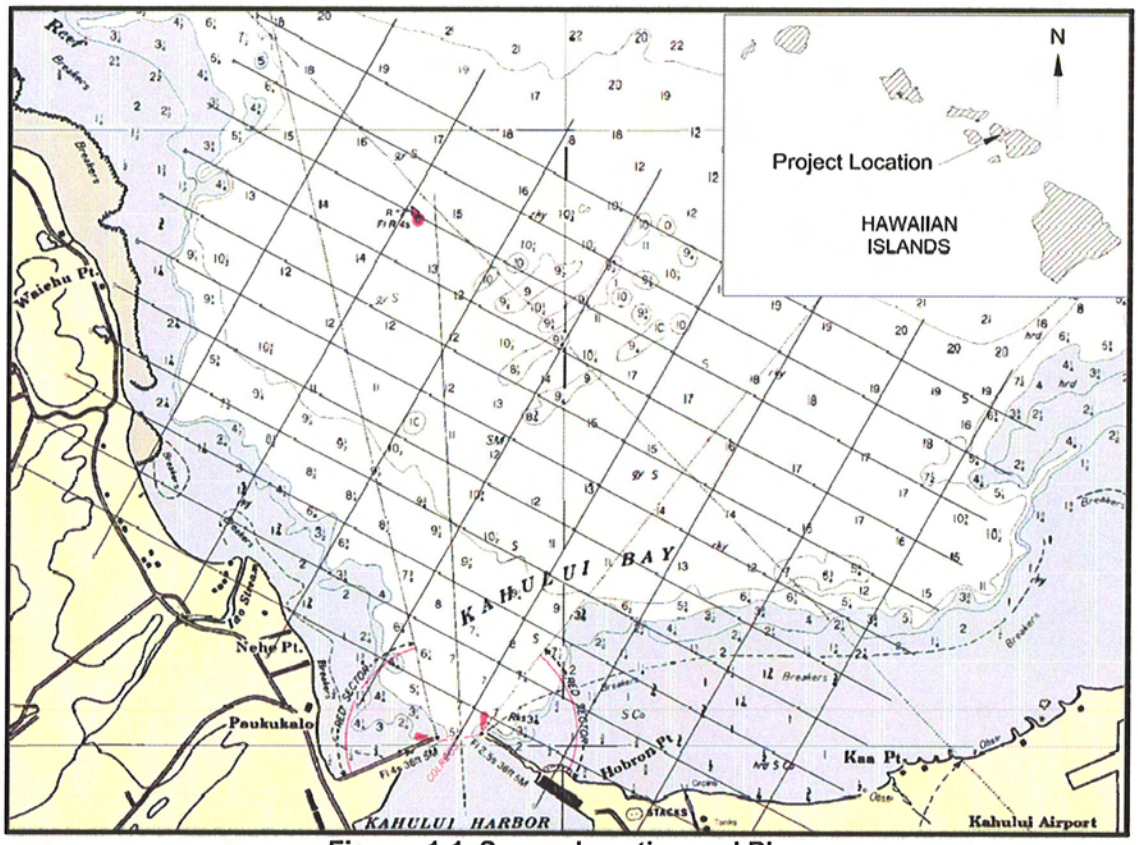


Figure 1-1 Survey Location and Plan

2. METHODOLOGY

2.1 Sub-Bottom Profiling Methods

Geophysical sub-bottom profiling systems are essentially echo-sounders that use lower acoustic frequencies to penetrate into the substrate. Where common echo-sounders may use an acoustic frequency in the vicinity of 200 kHz, sub-bottom system frequencies are typically between 500 Hz and 20 kHz. The term sub-bottom refers to a generally hard layer of sediment or rock that underlies recent soft sediment deposition. The lower the acoustic frequency, the deeper into the bottom the system can penetrate

For this survey, an EdgeTech 0512i "chirp" sub-bottom profiler was used with an EdgeTech 3200XS processing system. The chirp processors use signal processing to shape the acoustic wavelets used to image the substrate. They provide significantly greater image resolution than traditional impulsive systems such as boomers and sparkers. Different wavelets are available with the system for use in different terrains. After on-site system deployment, trial survey lines were conducted using various pulse configurations. The optimal pulse for the substrate in Kahului Bay was found to be a 20 ms pulse with a frequency range of 500 Hz to 7kHz. This is a relatively low frequency range, but necessary for penetration into the coralline limestone sands and gravels found in Hawaii. The EdgeTech 0512i system is in fact a specialty system for use in coarse sand environments.

2.2 Sub-Bottom Data Processing and Interpretation

The sub-bottom data were reviewed with EdgeTech software and sub-bottom horizons were digitized for processing. Sand thickness data were contoured using Digital Terrain Model (DTM) software, and final charts created using AutoCAD.

The offshore substrate around the Hawaiian Islands is complex, and can consist of different combinations of carbonate sand, coral gravels and cobbles, lithified or indurated sediment horizons, hard coralline limestone and some areas with volcanic rock features and terrigenous sediment. The sub-bottom horizons are therefore often difficult to interpret. As a generalized model, Kahului Bay appears to have a hard reef layer that is overlain by sediment layers 20 to 60 feet in thickness, and sometimes greater. The reef emerges from the bottom and outcrops in bathymetric high areas scattered throughout the survey area. However, the thick sediment overlying the reef has numerous acoustic reflectors that are indicative of hard layers. A conservative approach was taken for this study, and sand thickness was mapped to the first indication of a hard layer. Sand thickness in mapped areas is typically 10 to 20 feet. Sand deposits less than about 6 feet in thickness were difficult to map.

Figure 2-1 is a typical sub-bottom image showing the basal reef layer (acoustic basement – the limit of acoustic imaging) and overlying sediments, including about 15 to 20 ft of sand. The basal layer is approximately 40 to 60 feet below the seafloor. The intermediate sediments are likely to be an assortment of indurated sand, gravel, cobble and possibly even thin layers of

coralline reef limestone. Figure 2-2 is a section showing the emergence of reef limestone into a bathymetric high.

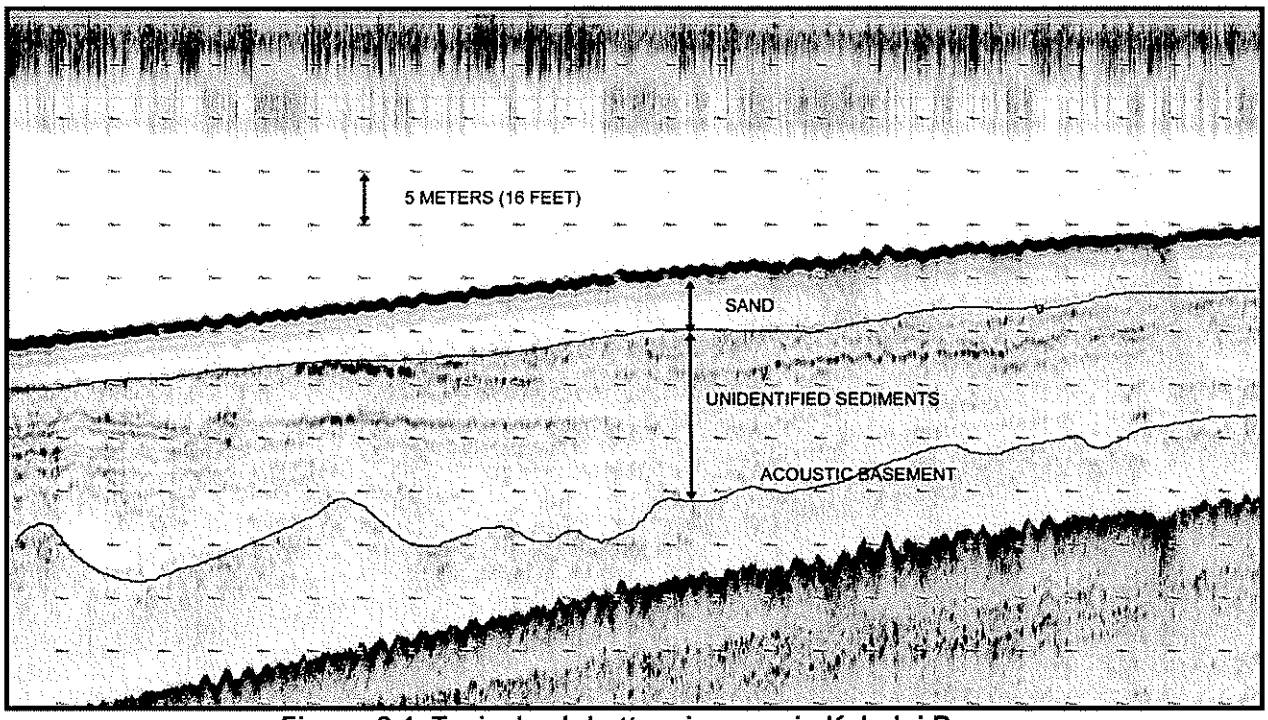


Figure 2-1 Typical sub-bottom imagery in Kahului Bay

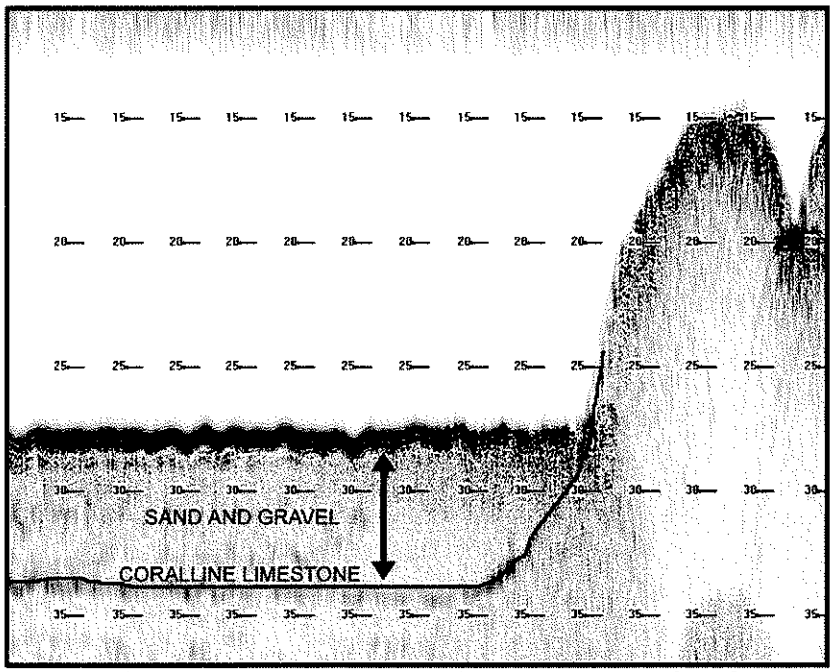


Figure 2-2 Sub-bottom imagery showing emergence of reef substrate

2.3 Bottom Sediment Samples

A total of nine bottom surface samples were retrieved using a Ponar sampler. Eight of the samples were analyzed for grain size by AECOS, Inc (note: sample Kahului 1 was not analyzed as it consisted of coral gravel and cobbles). Sediment descriptions and photographs are included as an appendix; size distribution results are shown in Table 2-1 and Figure 2-3.

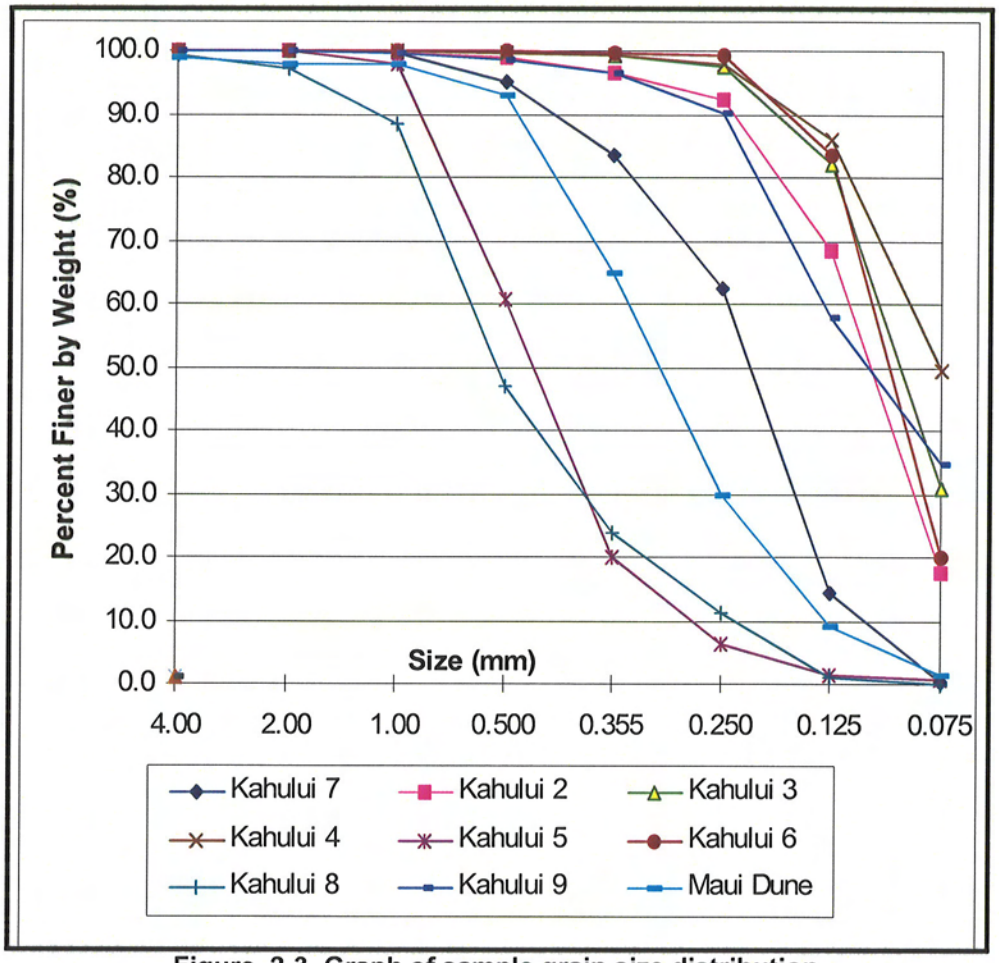


Figure 2-3 Graph of sample grain size distribution

Table 2-1 Sample grain size distribution

Percent Finer by Weight (%)								
size (mm)	**4.00**	**2.00**	**1.00**	**0.500**	**0.355**	**0.250**	**0.125**	**0.075**
Kahului 2	100.0	100.0	99.8	99.1	96.7	92.2	68.4	17.5
Kahului 3	100.0	100.0	100.0	100.0	99.2	97.4	82.1	30.8
Kahului 4	100.0	100.0	100.0	99.8	99.4	98.0	86.1	49.4
Kahului 5	100.0	99.8	97.8	60.6	19.8	6.4	1.6	0.8
Kahului 6	100.0	100.0	100.0	100.0	99.8	99.1	83.4	19.9
Kahului 7	100.0	100.0	99.8	95.0	83.7	62.4	14.3	0.4
Kahului 8	99.4	97.4	88.3	47.2	23.9	11.1	1.0	0.0
Kahului 9	100.0	100.0	99.6	98.4	96.5	90.2	58.1	34.7

3. RESULTS

3.1 Sub-bottom survey results

The presence of sand deposits 10 to 20 feet in thickness over much of Kahului Bay was confirmed by the sub-bottom survey. Figure 3-1 shows the results of the survey, with thickness contours highlighted in color. The bottom morphology of the bay is dominated by a broad central area with bathymetrically high reef areas (see Figure 2-2). With the exception of these emergent reef areas, it appears that most of the bay has at least 6 feet of sand substrate. As a conservative approach was taken during the interpretation process, it is possible that some areas have thicker sand deposits. As a general observation, the western portion of the bay appears to have somewhat thicker sand deposits. Differentiation between sand and gravel is difficult in sub-bottom images, and gravel areas were not mapped for that reason. However, what appear to be gravel deposits were more prevalent in the eastern portion of the bay.

The surface sand layers are commonly underlain by unknown sediment deposits that are stratified by acoustically reflective horizons. These sediments are likely to be inter-bedded layers of sand, gravel, indurated sand – in fact, any kind of coralline limestone reef derived deposits. It is also possible that viable sand deposits could be found underneath some of the hard reflectors that have been mapped as the base of the surficial deposits.

3.2 Sand sample results

Sand sample locations and photographs are contained in Appendix 1. Locations are also shown on the survey drawing, Figure 3-1 labeled as Kahului 1 through Kahului 9. Grain size distributions are shown in Figure 2-3 and Table 2-1. For comparison, Figure 2-3 also shows the distribution for Maui Dune Sand. The dune sand has been one of the major sources of sand for small-scale beach nourishment projects and sand bag protection projects on Maui. It is fine sand and barely meets grain size criteria for most beach projects, and is not really suitable for beach nourishment in energetic wave conditions.

Offshore sand deposits in Hawaii typically have two major limitations with respect to use for beach nourishment:

- Deposits are typically too fine-grained and,
- Deposits are often stained gray in color and therefore aesthetically un-pleasing.

Of the nine samples collected, two (Samples 5 and 8) had both good color and grain size characteristics. Sample 8 was coarse sand with a buff color that is attractive for beach sand. Sample 5 is exceptional in both color and grain size characteristics. It has a "salt and pepper" appearance due to a high percentage of terrigenous basalt fragments so it may not be suitable for all applications. Most of the samples (Samples 2, 3, 4, 6, 9) were both too fine and poorly colored. Sample 7 was too fine, although nicely colored, and Sample 1 consisted of large coral pieces.

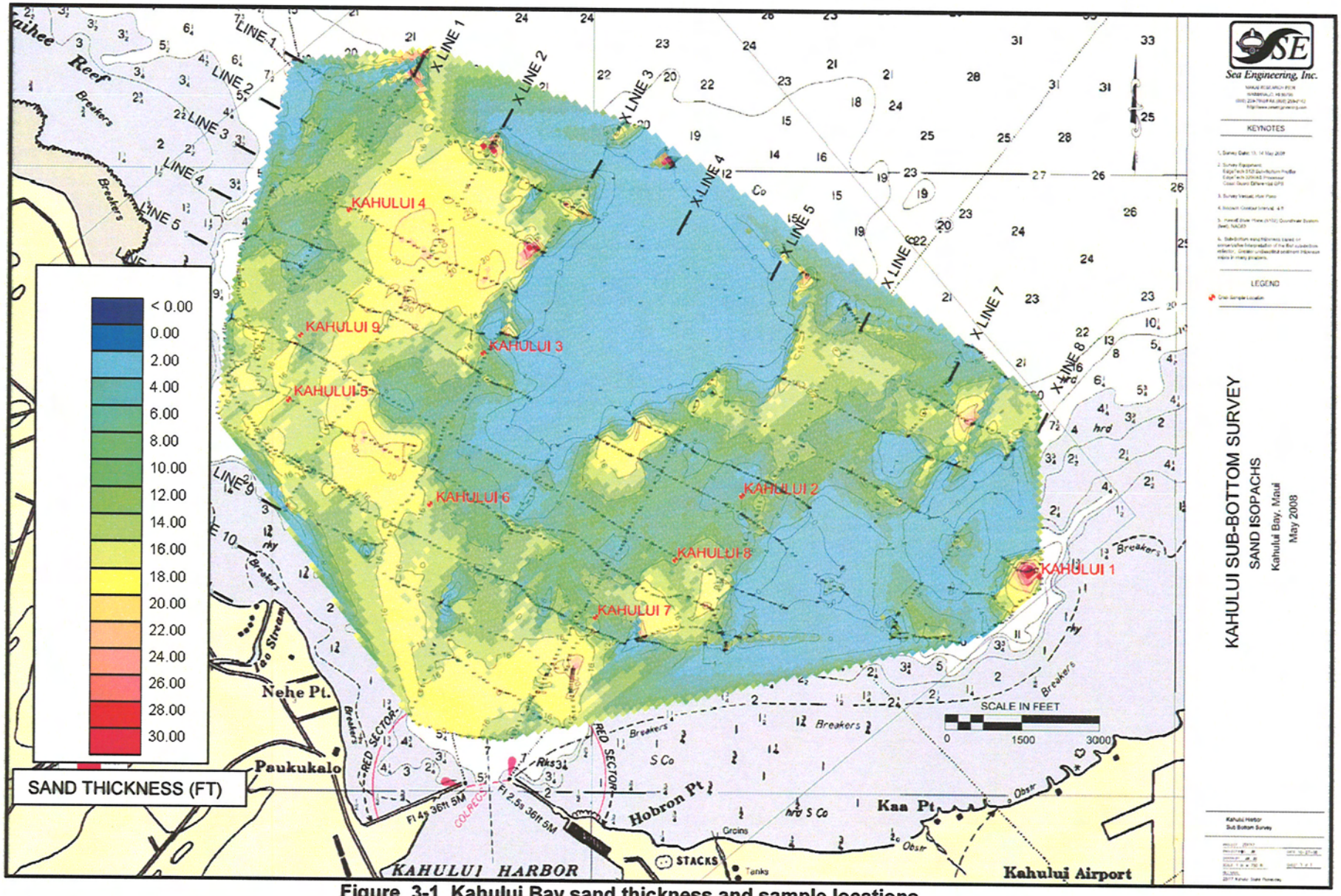


Figure 3-1 Kahului Bay sand thickness and sample locations

4. DISCUSSION

The survey results show the presence of widespread sand deposits in Kahului Bay. Most of the sand in the bay is probably too fine and poor in color for beach projects. However, two out of nine bottom samples indicated sand that would be suitable for beach nourishment, and in fact have excellent color and grain size characteristics. The extent of the suitable sand is not known and will require follow up investigations in order to characterize the areal extent of the deposits, and grain size and color characteristics below the surface.

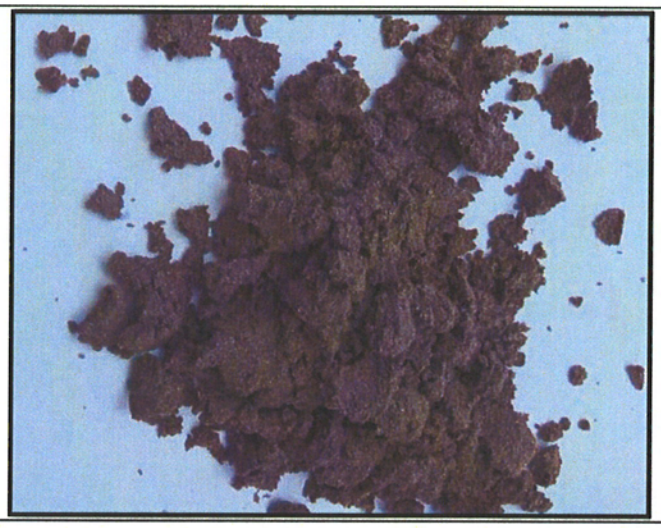
Follow on work may include survey work in the form of side scan sonar and drop camera surveys for acoustic and visual imaging of the bottom surface, a more intensive bottom sampling effort, and vibracore sampling to collect deposits below the bottom surface. SEI recently completed a comprehensive study of this type off West Maui for the Kaanapali Operators Association.

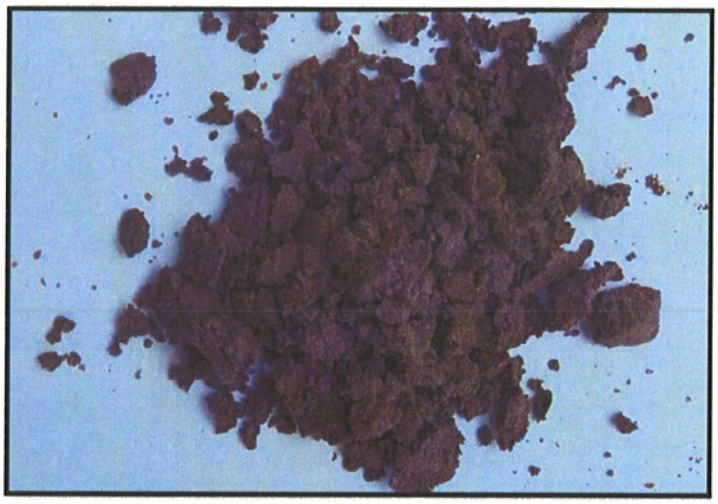
Kahului Bay is on the exposed windward side of the island, and conditions are generally poor for ocean work. Much of the fieldwork mentioned above will require calm weather windows, such as light and variable or Kona wind conditions, in order to produce good quality field data.

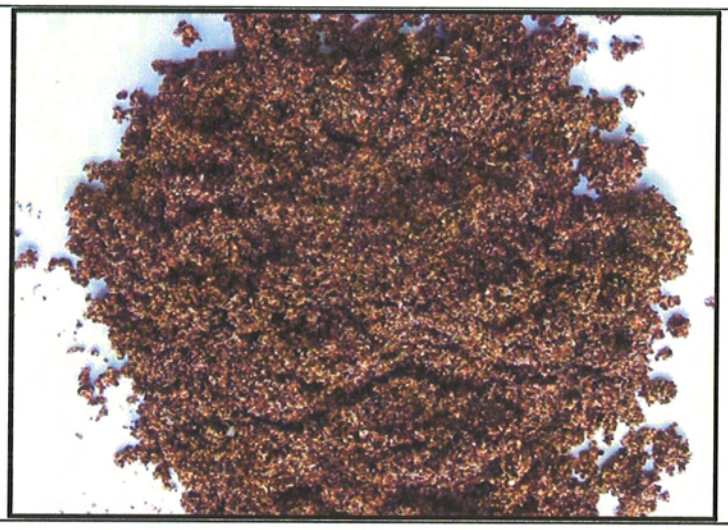
APPENDIX 1. SAMPLE PHOTOGRAPHS AND DESCRIPTIONS

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 1		
Position **(NAD83 State Plane, ft)**		**Description**
1,717,194 E / 210,174 N		Coral gravel and cobble, 0.5 to 3 inch fragments

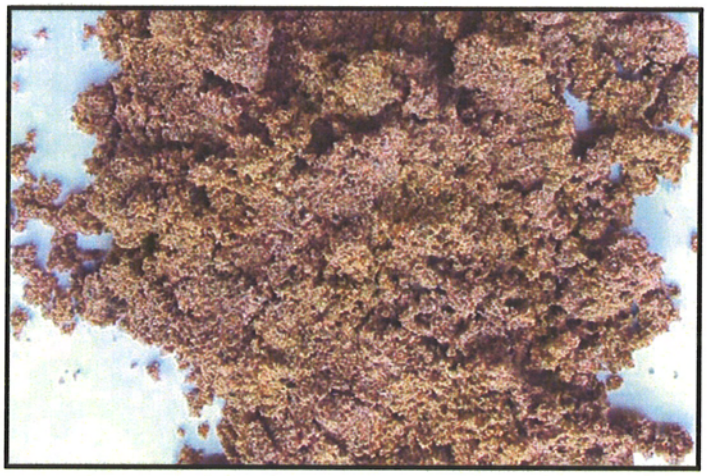
Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 2		
Position **(NAD83 State Plane, ft)**		**Description**
1,7115,79 E / 211,654 N		Well sorted light gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 3		
Position **(NAD83 State Plane, ft)**		**Description**
1,706,510 E / 214,379 N		Well sorted gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 4		
Position **(NAD83 State Plane, ft)**		**Description**
1,703,902 E / 217,150 N		Well sorted gray fine sand

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 5		
Position **(NAD83 State Plane, ft)**		**Description**
1,702,734 E / 213,427 N		Well sorted coarse sand, "salt and pepper" mix of coralline components and approx. 30% basalt components.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 6		
Position **(NAD83 State Plane, ft)**		**Description**
1,705,498 E / 211,443 N		Well sorted light gray fine sand.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 7		
Position **(NAD83 State Plane, ft)**		**Description**
1,708,736 E / 209,290 N		Moderately sorted fine-grained buff colored coralline sand.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 8		
Position **(NAD83 State Plane, ft)**		**Description**
1,710,287 E / 210,415 N		Moderately sorted coarse-grained buff colored coralline sand.

Ponar Surface Sample **Vessel: Huki Pono**		**Kahului Bay, Maui** **Date: 14 May, 2008**
Sample: Kahului 9		
Position **(NAD83 State Plane, ft)**		**Description**
1,702,960 E / 214,707 N		Well sorted gray fine sand.

APPENDIX D.

Maui County Council Resolution No. 06-12, "Accepting the Central Maui Wastewater Reclamation Facility Study and Concurring Recommendations and Long Term Plan"

Resolution

No. 06-12

ACCEPTING THE CENTRAL MAUI WASTEWATER
RECLAMATION FACILITY STUDY AND
CONCURRING RECOMMENDATIONS AND LONG TERM PLAN

WHEREAS, the County of Maui must decide how it will meet its wastewater treatment and disposal needs for the Central Maui Region for the next 20 to 30 years; and

WHEREAS, in order to decide the future needs of the Central Maui Region the County of Maui must also decide the future of the Wailuku/Kahului Wastewater Reclamation Facility ("WWRF"); and

WHEREAS, the three primary concerns regarding the future of the Wailuku/Kahului WWRF are the: (1) Remaining capacity; (2) Shoreline erosion; and (3) Potential impact of a tsunami; and

WHEREAS, in order to address these concerns the County of Maui completed a study of the Wailuku/Kahului WWRF to identify and develop a comprehensive list of conceptual treatment and disposal alternatives to meet the future wastewater infrastructure requirements for the Central Maui Region ("Study"); and

WHEREAS, the major sections of the Study included: (1) Community Participation; (2) Existing Central Maui Wastewater Infrastructure and Alternative Wastewater Capacity Demand Alternatives; (3) Regulatory Assessment; (4) Financial Planning; (5) Shoreline Evaluation; and (6) Existing Central Maui Wastewater Reclamation Facility Structural Evaluation; and

WHEREAS, to ensure meaningful and broad-based community participation a project Core Working Group ("CWG"), comprised of a diverse group of community members who collectively reflected a broad cross section of community values, was convened; and

WHEREAS, based on the Study and after meeting with the CWG for 13 months the Department of Public Works and Environmental Management ("DPWEM") recommends the following: (1) Leave the existing Wailuku/Kahului WWRF at the current site and expand in the future; (2) Strengthen the existing Wailuku/Kahului WWRF to withstand a 100 year (20 foot high) tsunami event; (3) Mitigate shoreline erosion through the construction of shoreline erosion structures or beach nourishment; and (4) Implement the long term plan of action to service the Central Maui Service Area; now, therefore,

Resolution No. 06-12

BE IT RESOLVED by the Council of the County of Maui:

1. That it hereby accepts the Study; and

2. That it concurs with the DPWEM recommendations to: (1) Leave the existing Wailuku/Kahului WWRF at the current site and expand in the future; (2) Strengthen the existing Wailuku/Kahului WWRF to withstand a 100 year (20 foot high) tsunami event; (3) Mitigate shoreline erosion through the construction of shoreline erosion structures or beach nourishment; and (4) Implement the long term plan of action to service the Central Maui Service Area; and

3. That certified copies of this resolution be transmitted to the Mayor of the County of Maui and the Director of Public Works and Environmental Management.

APPROVED AS TO FORM
AND LEGALITY:

TRACY FUJITA VILLAROSA
First Deputy Corporation Counsel
County of Maui

S:\ALL\TFV\Resolutions\centralwwrfstudy.wpd

COUNCIL OF THE COUNTY OF MAUI

WAILUKU, HAWAII 96793

CERTIFICATION OF ADOPTION

It is HEREBY CERTIFIED that RESOLUTION NO. 06-12 was adopted by the Council of the County of Maui, State of Hawaii, on the 17th day of February, 2006, by the following vote:

MEMBERS	G. Riki HOKAMA Chair	Robert CARROLL Vice-Chair	Michelle ANDERSON	Jo Anne JOHNSON	Dain P. KANE	Dennis A. MATEO	Michael J. MOLINA	Joseph PONTANILLA	Charmaine TAVARES
ROLL CALL	No	Aye	No	Aye	No	Aye	Aye	Aye	Aye

COUNTY CLERK

APPENDIX E.

April 1, 2010 Letter from Department of Land and Natural Resources

LINDA LINGLE
GOVERNOR OF HAWAII

LAURA H. THIELEN
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

RUSSELL Y. TSUJI
FIRST DEPUTY

KEN C. KAWAHARA
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES
OFFICE OF CONSERVATION AND COASTAL LANDS
POST OFFICE BOX 621
HONOLULU, HAWAII 96809

REF:OCCL:AB

Correspondence MA-10-189

APR - 1 2010

Cheryl Okuma, Director
County of Maui
Department of Environmental Management
2200 Main Street, Suite 100
Wailuku, Hawai'i 96793

SUBJECT: Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension, Located at Kahului, Maui, TMK: (2) 3-8-001:188

Dear Ms. Okuma:

The Department of Land and Natural Resources (DLNR) Office of Conservation and Coastal Lands (OCCL) has reviewed your letter regarding the Wailuku-Kahului Wastewater Reclamation Facility (WWRF) Shoreline Protection Extension, Located at Kahului, Maui, TMK: (2) 3-8-001:188.

According to the information provided, Executive Order No. 3006 grants the County of Maui management and control of the subject property for the purpose of operating the WWRF. An existing rock revetment was built in the 1970s to protect portions of the WWRF from shoreline erosion. The Maui Department of Environmental Management proposes to extend the shoreline revetment structure from approximately 5,350 feet to approximately 20,520 feet along the seaward boundary of the WWRF.

In your letter, you request clarification that the proposed shoreline rock revetment structure extension is ancillary to the WWRF, and within the scope of Executive Order No. 3006. You also request our concurrence that the Department of Environmental Management is the Accepting/Approving Authority pursuant to Chapter 343, Hawai'i Revised Statutes (HRS) and Chapter 200 of Title 11, Department of Health Hawai'i Administrative Rules (HAR).

ANALYSIS:

According to OCCL records, the subject property is located within the State Land Use Conservation District, Limited subzone. There is an existing Conservation District Use Permit (CDUP) for the subject WWRF, CDUP MA-349, which was approved by the Board of Land and Natural Resources on July 28, 1972. Subsequently, CDUP MA-3047 was approved on January

11, 2002 for modifications to the WWRF. The OCCL notes that no CDUP was obtained for the subject shoreline revetment structure.

The extension of the shoreline revetment structure is an identified land use in the Conservation District pursuant to HAR §13-5-23 *Identified Land Uses in the Limited Subzone* L-5 SEAWALLS AND SHORELINE PROTECTION (D-1) *Seawalls, shoreline protection devices, and shoreline structures.* **This proposed action requires the filing of a Conservation District Use Application (CDUA) for a Board permit.**

Because the proposed extension of the shoreline revetment structure may cause a significant impact in a particularly sensitive environment, the OCCL determines that **this proposed action would not be exempt from HRS Chapter 343 and HAR §11-200-8.**

The OCCL concurs that the revetment structure and proposed extension would be within the scope of Executive Order No. 3006, and the Department of Environmental Management may be the Accepting/Approving Authority pursuant to HRS Chapter 343 and HAR Chapter 200 of Title 11, Environmental Impact Statement.

Should you have any questions regarding this correspondence, please contact Audrey Barker of our office at (808) 587-0316 or audrey.t.barker@hawaii.gov.

Sincerely,

Samuel J. Lemmo, Administrator
Office of Conservation and Coastal Lands

C: Chairperson
MDLO/DOFAW
Maui Planning Department

APPENDIX F.

April 7, 2010 Letter from Office of Environmental Quality Control

LINDA LINGLE
GOVERNOR OF HAWAI'I

KATHERINE PUANA KEALOHA
DIRECTOR

STATE OF HAWAI'I
OFFICE OF ENVIRONMENTAL QUALITY CONTROL
235 S BERETANIA ST. SUITE 702
HONOLULU, HAWAI'I 96813
Tel. (808) 586-4185
Fax. (808) 586-4186
Email: oeqc@doh.hawaii.gov

April 7, 2010

Cheryl K. Okuma, Esq.
Department of Environmental Management
County of Maui
2200 Main Street, Suite 100
Wailuku, Maui, Hawaii 96793

Subject: Wailuku-Kahului Wastewater Reclamation Facility Shoreline Protection Extension

Thank you for your letter dated March 10, 2010, requesting the Office of Environmental Quality Control's (OEQC) opinion on whether the Department of Environmental Management can be the Accepting Authority for a proposed Environmental Impact Statement Preparation Notice for the subject proposed action. According to your letter, the property is under control of the County of Maui per Executive Order No. 3006.

According to Section 11-200-4(a)(2), Hawaii Administrative Rules, whenever an agency proposes an action, the final authority to accept a statement shall rest with the mayor, or an authorized representative, of the respective county. An Executive Order is sufficient to determine that the county has control over the land and is therefore the accepting authority.

The OEQC respectfully defers to the Department of Land and Natural Resources questions regarding the shoreline rock revetment extension that may be ancillary to the subject project since structures in the conservation district are under their jurisdiction.

If you have any questions, please call Rebecca Alakai at 586-4185.

Sincerely,

Rebecca Alakai
for Katherine Puana Kealoha, Esq.
Director

APPENDIX G.

April 21, 2010 Letter from the Office of Mayor

CHARMAINE TAVARES
MAYOR

200 South High Street
Wailuku, Hawaii 96793-2155
Telephone (808) 270-7855
Fax (808) 270-7870
e-mail: mayors.office@mauicounty.gov

OFFICE OF THE MAYOR
County of Maui

April 21, 2010

Ms. Cheryl K. Okuma, Esq., Director
Department of Environmental Management
2200 Main St. Suite 100
Wailuku, Hawaii 96793

Dear Ms. Okuma,

SUBJECT: DESIGNATION OF EIS ACCEPTING AUTHORITY FOR THE WAILUKU-KAHULUI WWRF SHORELINE EROSION CONTROL PROJECT ("ROCK REVETMENT EXTENSION") IN KAHULUI, HAWAII. COUNTY JOB WW08-08,

I have reviewed the April 1, 2010 letter from the State Department of Land and Natural Resources, Ocean Conservation and Coastal Lands (DLNR/OCCL) which confirms the proposed shoreline rock revetment extension is included under Executive Order No. 3006 and that the Department of Environmental Management (DEM) may be the accepting authority for the project's Environmental Impact Statement (EIS). Further, the State Office of Environmental Quality Control (OEQC), in a letter dated April 7, 2010, agreed that through Executive Order, the County of Maui had control of the land and is therefore the accepting authority.

Pursuant to Title 200, §11-200-4, Hawaii Administrative Rules, Environmental Impact Statement Rules, the mayor or an authorized representative possesses the final authority to accept the EIS. On April 15, 2010, the DEM and the Planning Department held a coordination meeting to discuss which agency should be the authorized representative for the County of Maui for this EIS. It was agreed that as the agency controlling the land, the DEM would be the mayor's authorized representative.

I hereby designate the Department of Environmental Management as the authorized representative for processing and accepting the EIS for the subject project.

Sincerely,

Charmaine Tavares
Mayor, County of Maui.

Attachments: Letter from DLNR/OCCL, Letter from OEQC
Copy: Jeff Hunt, Director of Planning
Juan Rivera, DEM/WWRD
Mich Hirano, Munekiyo & Hiraga, Inc.

APPENDIX H.

Letter Report on an Archaeological Field Inspection of Portions of the Central Maui Wastewater Reclamation Facility

XAMANEK RESEARCHES, LLC
P.O. BOX 880131
PUKALANI, MAUI, HI 96788
Phone/Fax: 572-8900
Phone/Fax: 572-6118
E-mail: xamanekresearchesllc@hawaii.rr.com

State Historic Preservation Division Maui Office
Department of Land and Natural Resources Annex
Wailuku, Maui
Fax: 243-5838

Attn.: Ms. Jenny Pickett, SHPD Maui Office **30 November 2007**

Subject: Letter report on an archaeological field inspection of portions of the Central Maui Wastewater Reclamation Facility, Wailuku *ahupua'a*, Wailuku District, Maui (TMK (2) 3-8-1: 188). Note: this study has been undertaken for the Tsunami Improvements project at the County of Maui Waste Water Treatment Plant at Kanaha, Maui.

Per our previous conversation, I am providing you with a letter report on a field inspection that I conducted on a portion of the County of Maui Waste Water Treatment Plant at Kanaha, Maui (Figures 1 and 2). The County is currently reviewing improvements that will be needed to "harden" the wastewater treatment facility, and protect it from tsunami inundation. My inspection of a portion of the 18.755 acre parcel was carried out on 29 November of this year.

The project area lies on the windward side of the isthmus of Maui on the coastline. The project area is located in Jaucus and beach sand deposit. This area is known to contain both isolated and clusters of Native Hawaiian burials and/or habitation sites. Much of the project area has been altered by the construction of this wastewater treatment facility, existing infrastructure, and roads. Observed vegetation on the project area consisted of alien weeds and grasses, *koa haole* (Leucaena leucocephela) shrubs, along with *kiawe* (Prosopis pallida) trees. *Naupaka kahakai* (Scaevola sericca) was noted along the makai portion of the parcel. It is estimated that this part of Maui receives between 20 and 30 inches of annual rainfall.

Results of the Field Inspection

I walked over non-built portions of the County parcel; noting portions of the facility that may be "hardened" to resist possible tsunami inundation (see Figure 3 and project photographs). During the course of my walk-over, I noted an area of shoreline erosion (Photograph). Inspection of a wave cut bank revealed what is interpreted as previously disturbed sand. No cultural materials were noted in the cut bank, which is near the *makai* boundary of the parcel. Sand dune deposits were noted in all non built

areas. In addition, sand deposits were noted along Amala Place, which provides access to the County facility and Kanaha Park.

It is noteworthy that a portion of Kanaha Pond (Site 50-50-05-1783) is located to the south of the facility, across Amala Place. The pond qualifies for significance under all four National Register Criteria as well as HRHP Criterion "e" for its traditional cultural value. However, the pond will not be impacted by this County project.

Summary and Recommendation

There were no significant material culture remains noted during my inspection. However, based on the presence of sand deposits and the proximity of the shoreline, precautionary monitoring is recommended during the construction of tsunami protection measures. We will prepare and submit a monitoring plan for the Tsunami Improvements project at the County of Maui Waste Water Treatment Plant at Kanaha, in the near future.

Please feel free to contact me @ 572-8900 should you have any questions or need additional information regarding this field inspection for the Tsunami Improvements project at the County of Maui Waste Water Treatment Plant at Kanaha.

Sincerely,

Erik M. Fredericksen

Erik M. Fredericksen

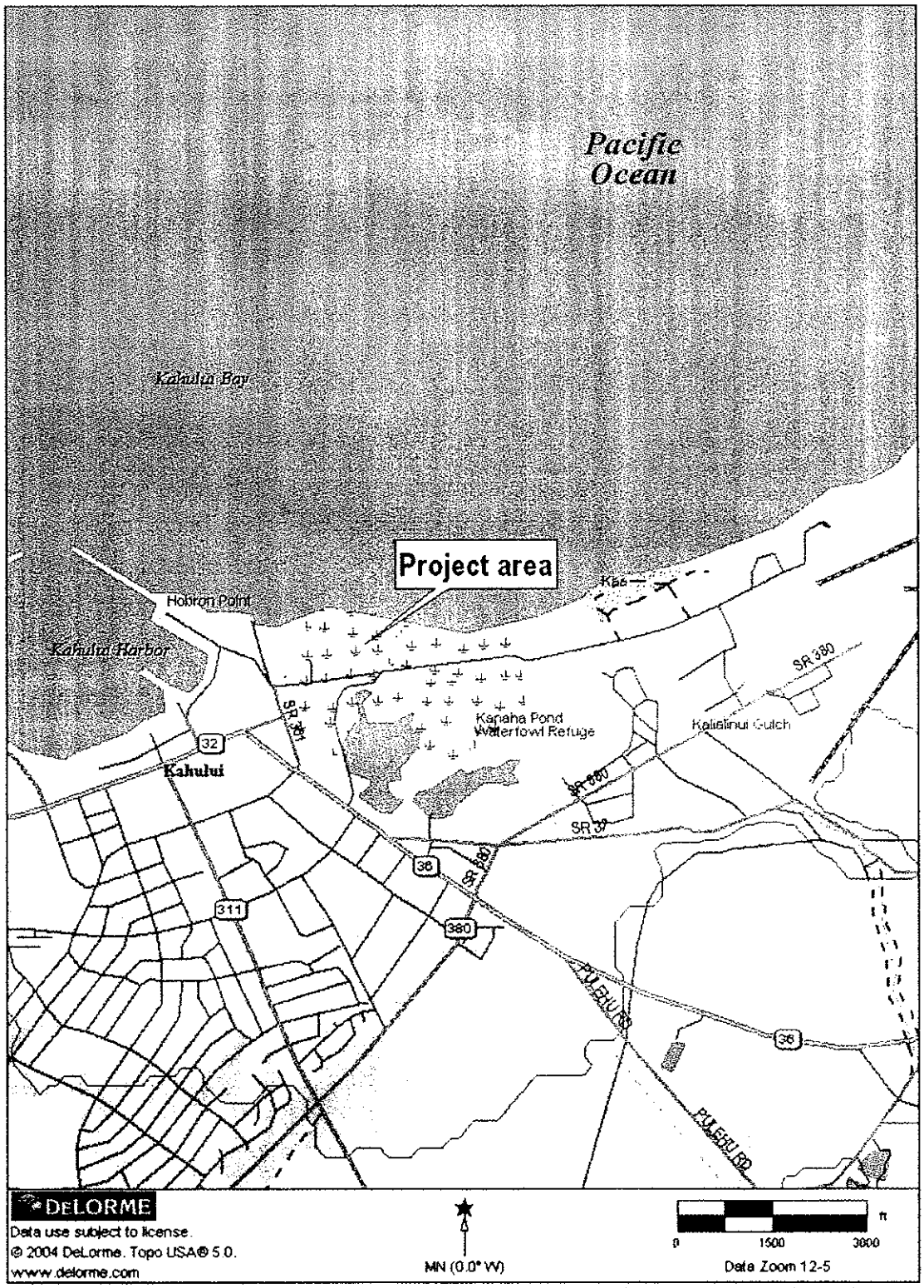


Figure 1: Topographic map with location of the project area, County of Maui Waste Water Treatment Plant at Kanaha, Maui.

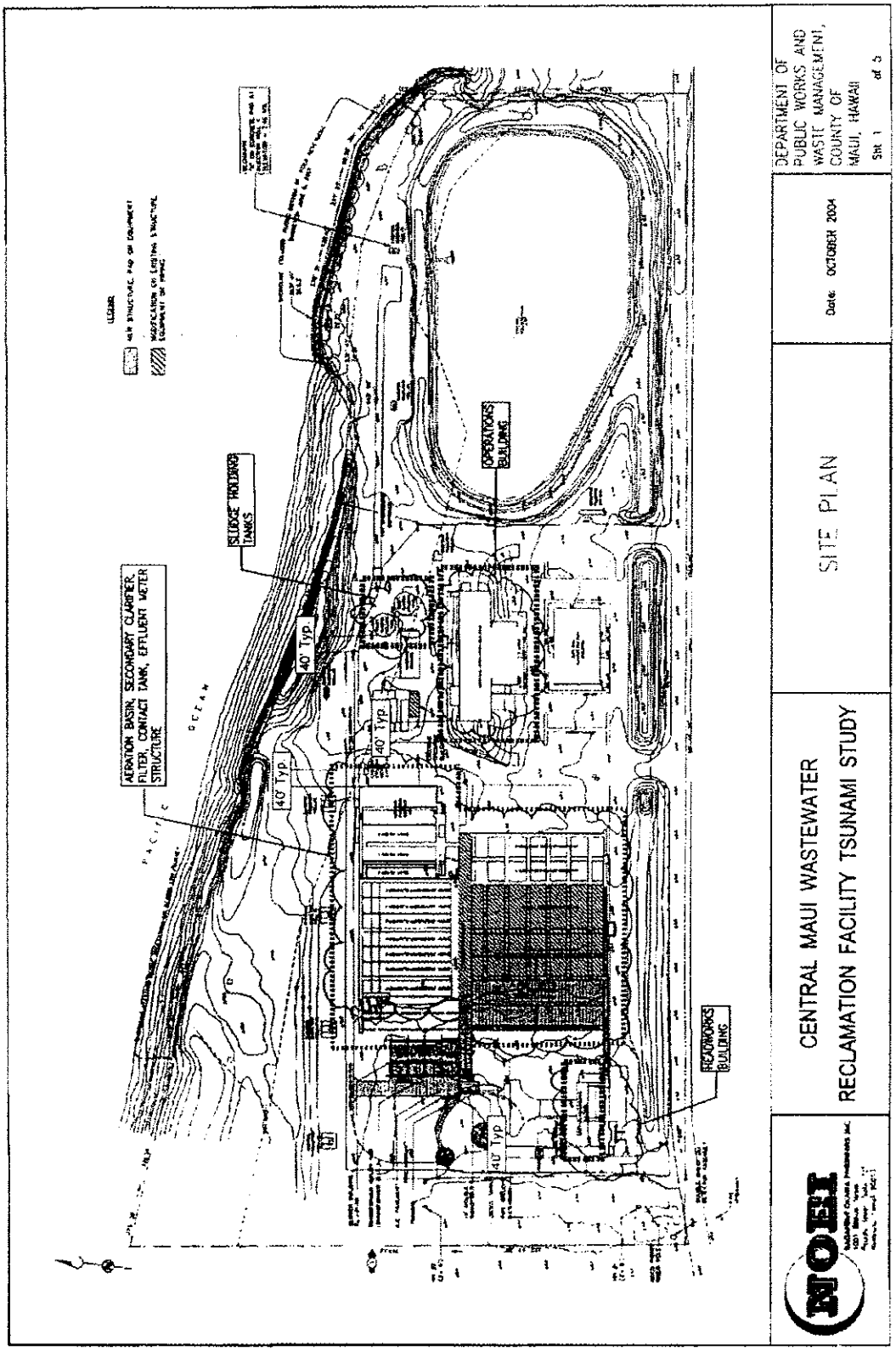
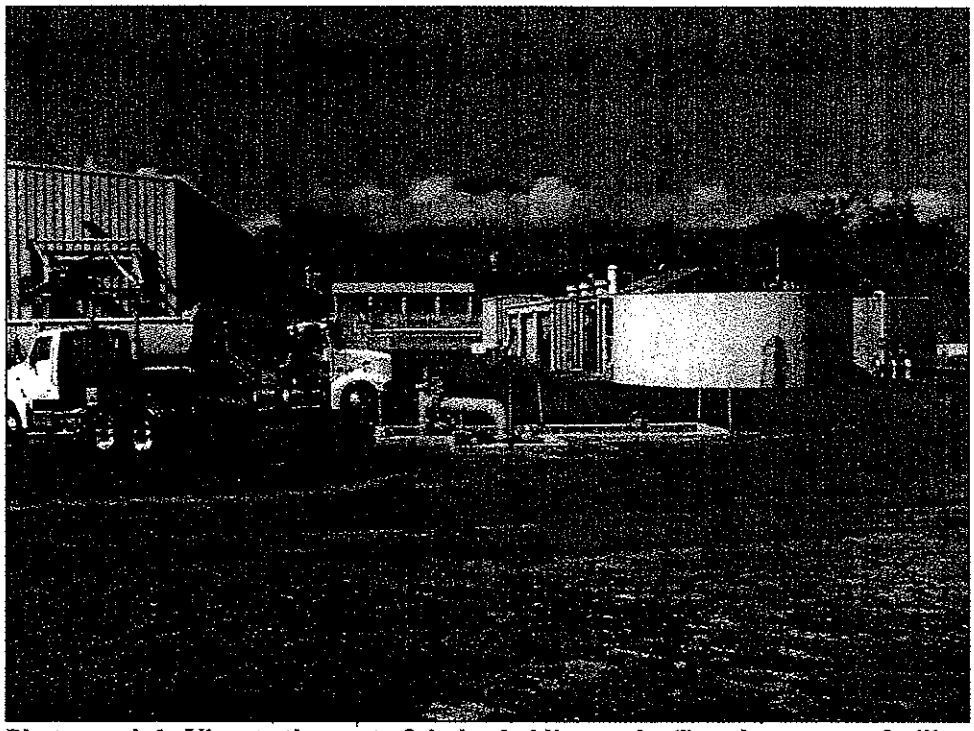


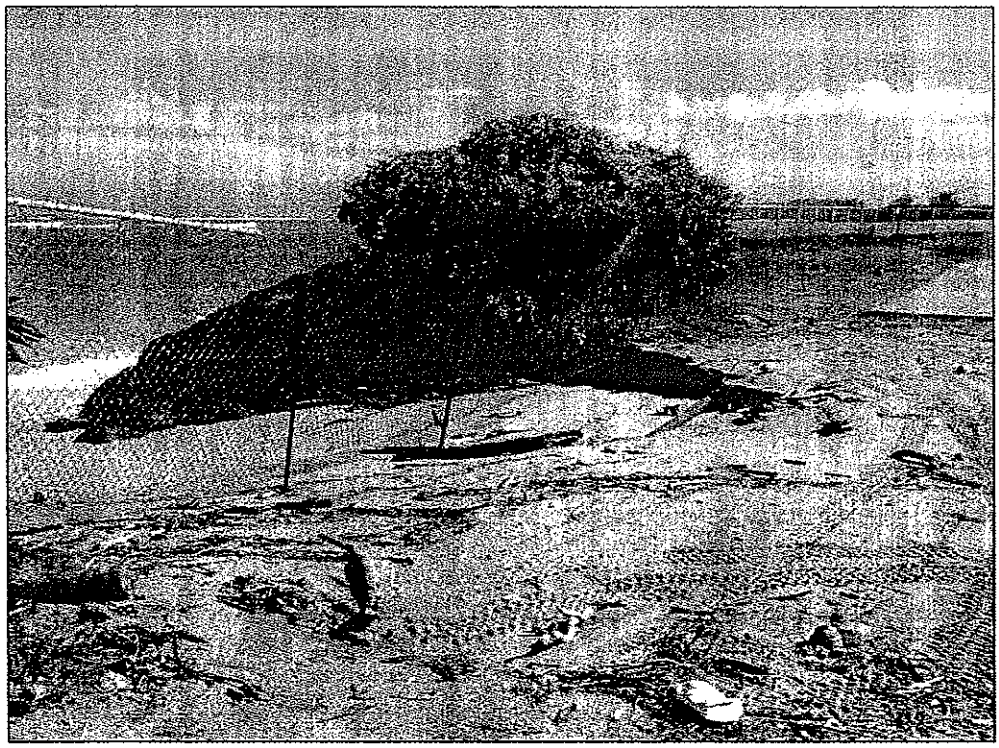
Figure 2: Plan view of the wastewater treatment facility; red areas to be "hardened".

Project Photographs

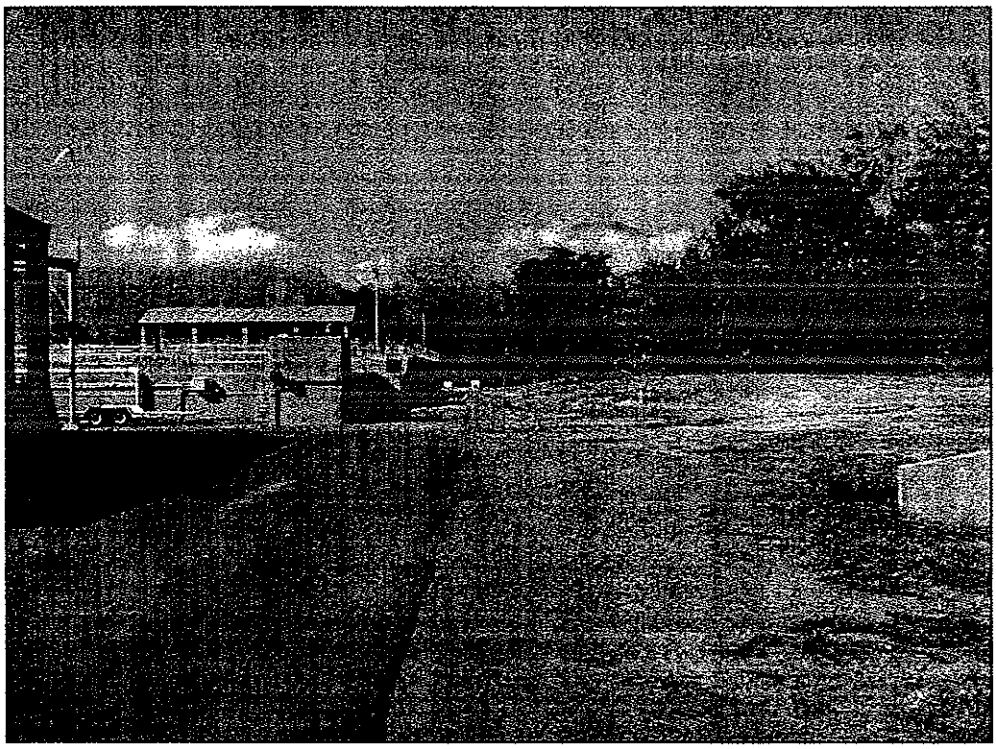


Photograph 1: View to the west of sludge holding tanks (l) and treatment facility.

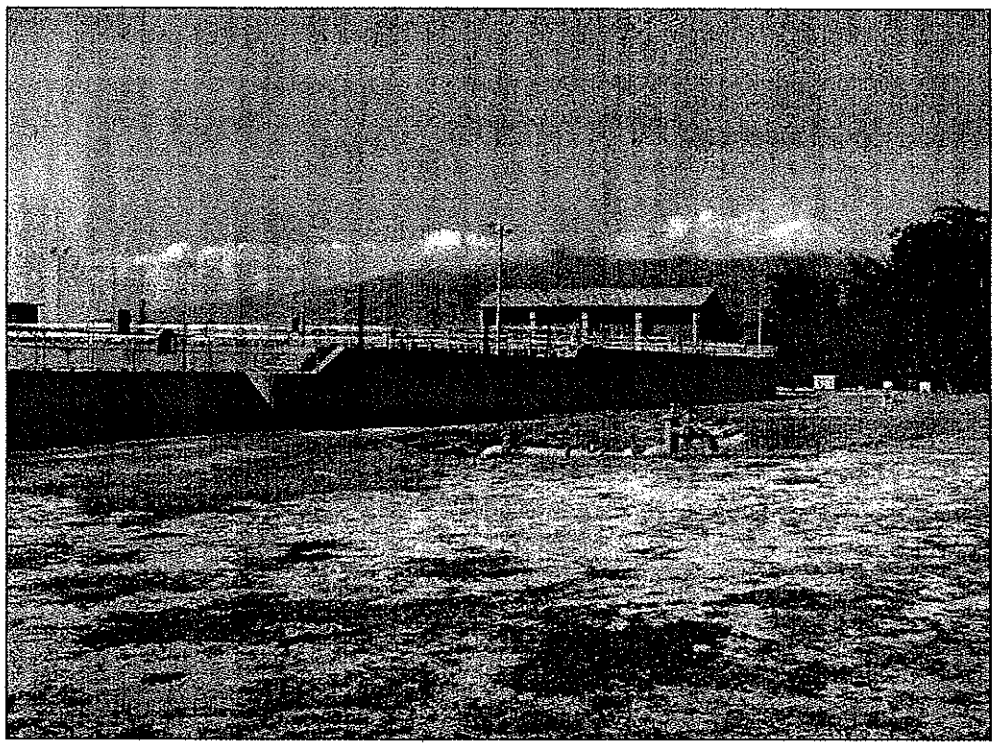
Photograph 2: View to the west of sludge holding tanks.



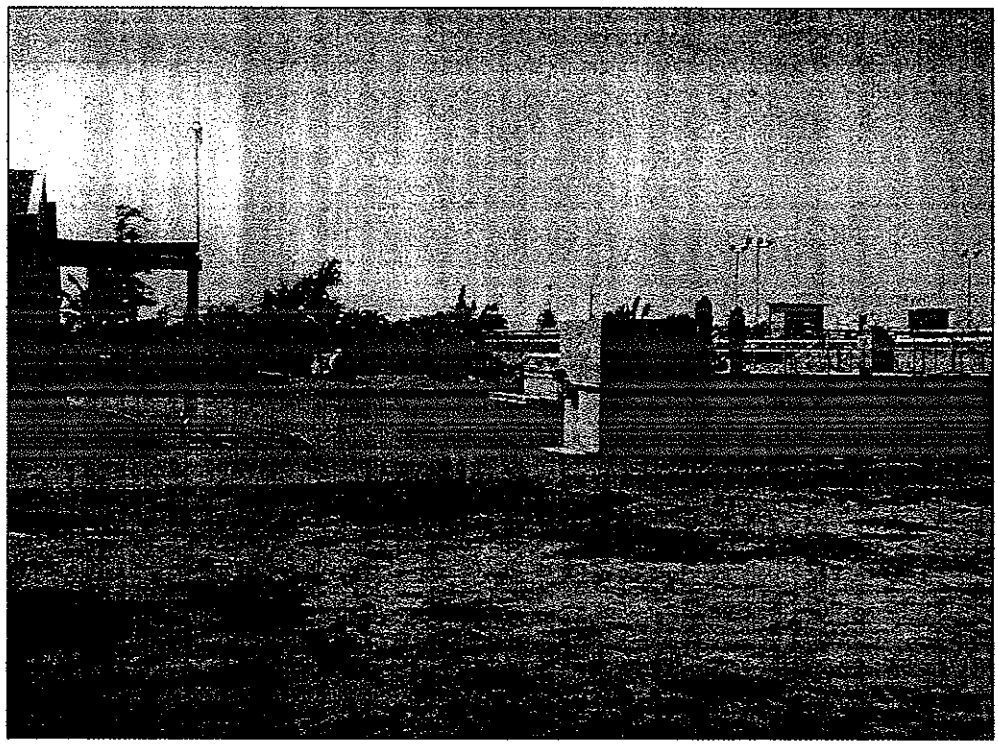
Photograph 3: View to the ENE of wave cut bank that was inspected.



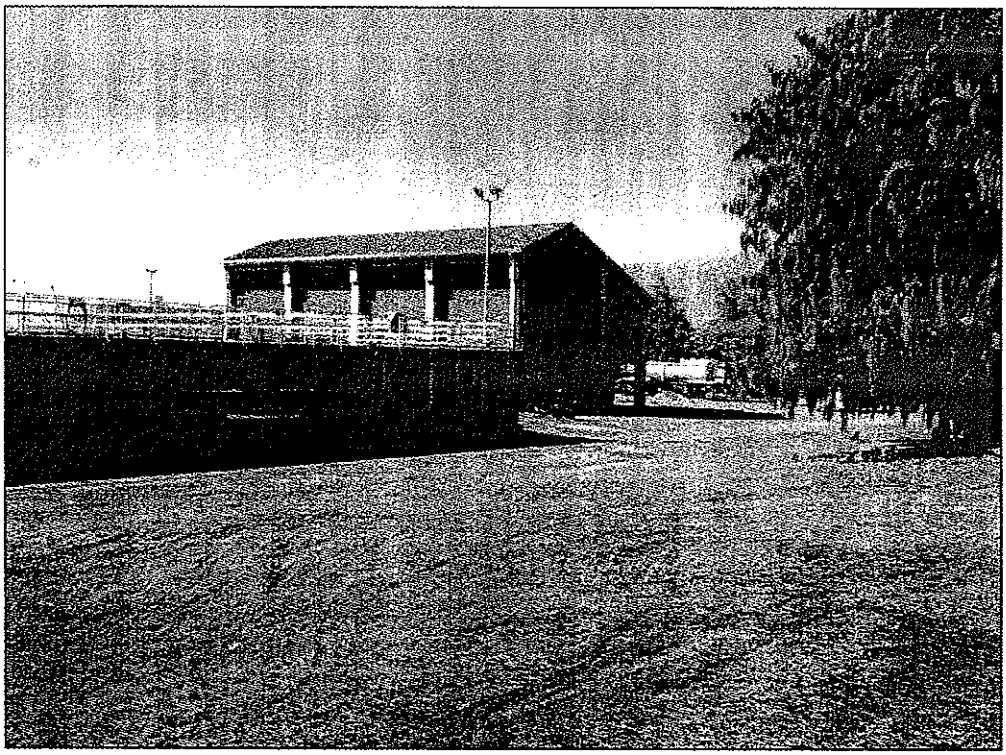
Photograph 4: View to the west towards aeration basin area.



Photograph 5: View to the west towards aeration basin area, pump in foreground.

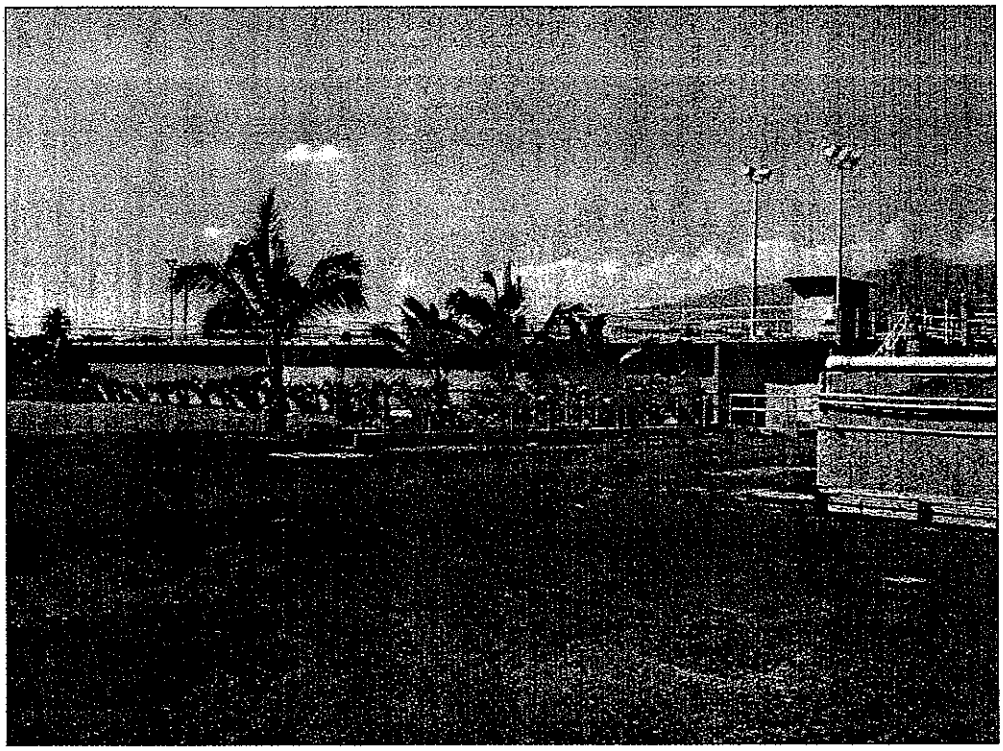


Photograph 6: View to the south of the area between the aeration basin area and the treatment facility.

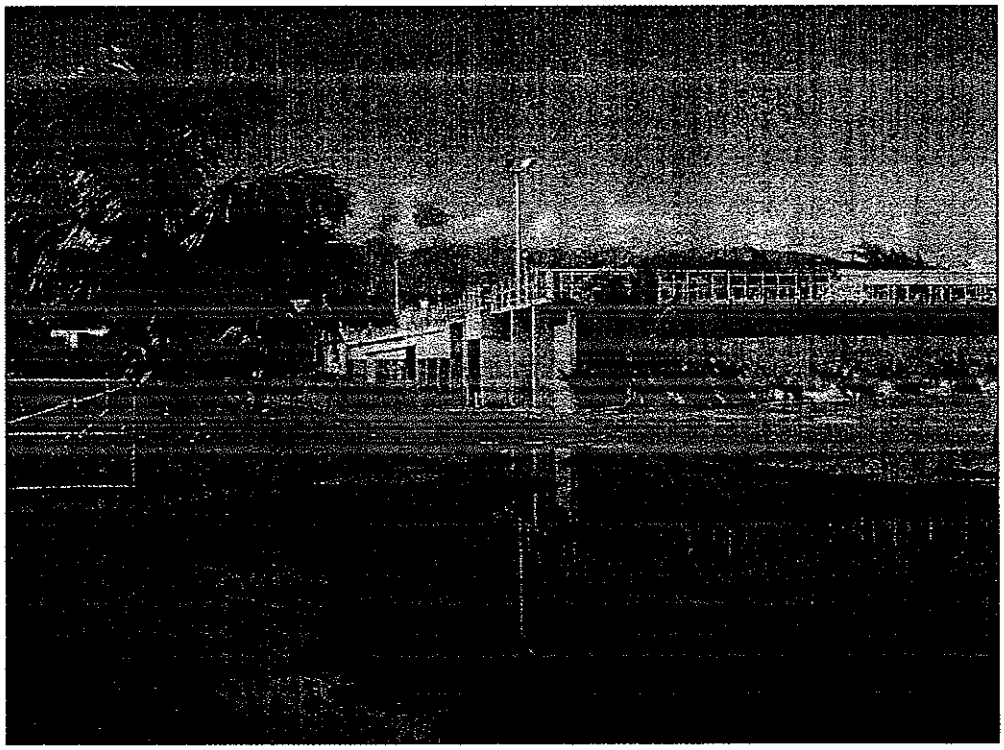


Photograph 7: View to the west towards western side of the aeration basin area.

Photograph 8: View to the south along the western side of the aeration basin area.



Photograph 9: View to the southwest along the eastern side of the aeration basin area.



Photograph 10: View to the WNW of the roadside portion of the aeration basin area.

APPENDIX H-1.

A General Archaeological Monitoring Plan for Scheduled Tsunami Improvements Project at the County of Maui Wastewater Treatment Plant at Kanaha, Wailuku Ahupua`a, Wailuku District, Maui Island

A GENERAL ARCHAEOLOGICAL MONITORING PLAN FOR THE SCHEDULED TSUNAMI IMPROVEMENTS PROJECT AT THE COUNTY OF MAUI WASTE WATER TREATMENT PLANT AT KANAHA, WAILUKU *AHUPUA`A*, WAILUKU DISTRICT, MAUI ISLAND (TMK: (2) 3-8-01: 188)

Prepared on behalf of:

County of Maui
Department of Environmental Management

Prepared by:

Xamanek Researches, LLC
Pukalani, Maui
Erik Fredericksen

4 December 2007

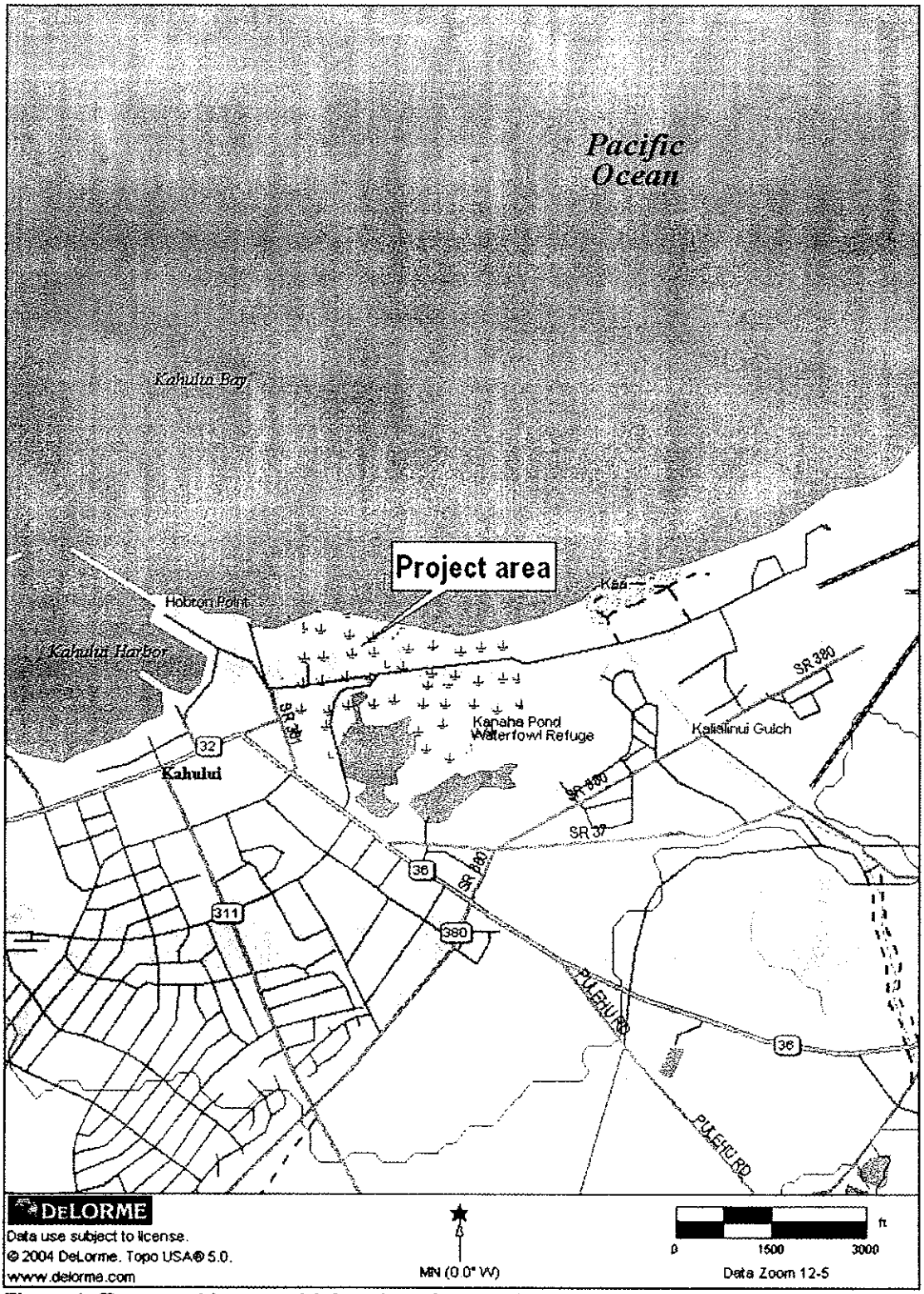


Figure 1: Topographic map with location of the project area, County of Maui Waste Water Treatment Plant at Kanaha, Maui.

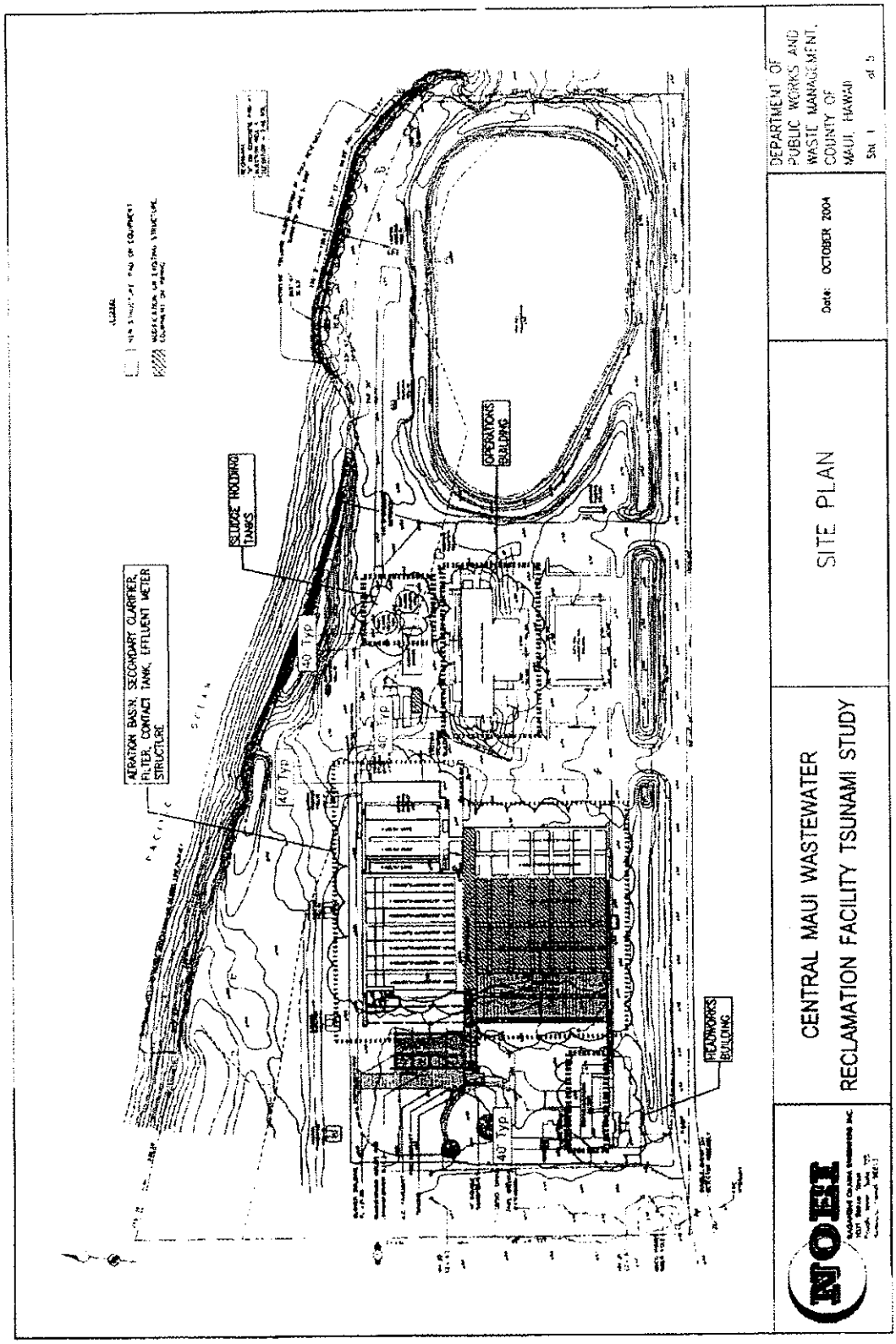


Figure 2: Plan view of the wastewater treatment facility; red areas to be "hardened".

INTRODUCTION

Mr. Michael Munekiyo of Munekiyo & Hiraga, Inc., contacted Xamanek Researches, LLC on behalf the County of Maui Department of Environmental Management in April 2007 about a proposed tsunami improvements project at the County of Maui Waste Water Treatment facility in Kanaha, Maui (Figures 1 and 2). This project would consist of earthmoving activities associated with the construction of various tsunami "hardening" measures at the treatment plant.

Given the coastal location of the project area, the State Historic Preservation Division (SHPD) was contacted. Per discussions with Dr. Melissa Kirkendall[1] of the SHPD Maui office, it was determined that a field inspection of the area would first be undertaken. In the event that significant cultural resources were noted during this field inspection, a reassessment of necessary work would then be made. We were given the notice to proceed with the field inspection in the fall of 2007.

Erik Fredericksen conducted the field inspection of the proposed impact areas at the waste water treatment facility on 29 November 2007 (see Figure 2). The non-built portions of the County parcel, near portions of the facility that may be "hardened" to resist possible tsunami inundation were inspected at this time. During the course of the walk-over, an area of shoreline erosion was noted. Inspection of a wave cut bank revealed what is interpreted as previously disturbed sand. No cultural materials were noted in the cut bank, which is near the *makai* boundary of the parcel. Sand dune deposits were noted in all non-built areas. In addition, sand deposits were noted along Amala Place, which provides access to the County facility and as well as Kanaha Park.

It is noteworthy that a portion of Kanaha Pond (Site 50-50-05-1783) is located to the south of the facility, across Amala Place. The pond qualifies for significance under all four National Register Criteria as well as HRHP Criterion "e" for its traditional cultural value. The pond will not be impacted by actions of this County project.

Based on the results of the field inspection, it was determined that precautionary archaeological monitoring would need to be carried out during earthmoving activities at the facility. This action was recommended because of the presence of sand deposits on the parcel.

[1] Dr. Kirkendall resigned from the SHPD at the end of June 2007.

The following archaeological monitoring plan has been prepared on behalf of the County of Maui Department of Environmental Management. This monitoring plan covers the proposed tsunami improvements project and any future on-site improvements at the facility (TMK (2) 3-8-1: 188).

BACKGROUND INFORMATION

The project area is located in Kanaha near Kahului Harbor on the windward side of the isthmus of the island of Maui. Marine sand and dune sand deposits are present in this region, which is part of the large Pu`uone dune system. The first phase of the Central Maui Waste Water Treatment facility was developed over 30 years ago. The project area is located in Jaucus and beach sand deposit. This general area is known to contain both isolated and clusters of Native Hawaiian burials and/or habitation site remnants. Much of the project area has been altered by the construction of this wastewater treatment facility, existing infrastructure, and roads. Observed vegetation on the project area consisted of alien weeds and grasses, *koa haole* (Leucaena leucocephela) shrubs, along with *kiawe* (Prosopis pallida) trees. *Naupaka kahakai* (Scaevola sericea) was noted along the *makai* portion of the parcel. It is estimated that this part of Maui receives between 20 and 30 inches of annual precipitation. The County parcel ranges from a low of c. 3 ft AMSL to a high of about 8 ft AMSL.

Previous archaeological work

Previously identified cultural resources in the vicinity of the waste water treatment facility include Sites 50-50-05-1777, 1798, 1799, 2849, 4197, and 1783. The bulk of these sites have been identified during work associated with the Kahului Airport. These previously identified sites are briefly summarized below.

Site 50-50-05-1777 consists of a subsurface cultural deposit that contains associated features, midden deposits, as well as numbers of artifacts. This habitation deposit was encountered during monitoring that was carried out for the installation of a sewer line in the 1980s. Radiocarbon analysis dated this site to c. AD 1380-1700. A 1996 SHPD review letter for an airport project indicates that inventory level work was needed on this site, in order to more fully evaluate Site 1777. In addition, the review letter also states that data recovery work would also be necessary. There does not appear to have been any inventory level work or data recovery work that has been carried out on this site since the 1996 SHPD letter.

Site 50-50-05-1798 is composed of an unknown number of human burials, a reburial area[2], and a subsurface terrace wall with associated pond field deposits. There is a Programmatic Agreement, signed in 1997, that covers this area, which lies to the north of the runway. To date, it remains unclear what work has been carried out in this area. We will be working on bringing preservation commitments into place. The 1996 SHPD review letter notes that it remains unknown whether Site 1798 extends beneath runways 5/23 and/or 5/20. The letter also indicates that data recovery work is recommended for the pond field and wall feature that are contained within Site 1798. In addition, SHPD also recommended that additional testing be conducted in order to better assess the extent of burials and human remains in this portion of the airport property. This testing has not, to the author's knowledge, been carried out at the writing of this memorandum. Finally, it was noted that some of the fill that the military used in this portion of the airport may have contained human skeletal remains. Should this indeed be the case, a precautionary treatment plan will need to be incorporated into a general monitoring plan for the overall airport project.

Site 50-50-05-1799 is located to the north of Site 1798 and consists of a c. 4 m long rock alignment and a possible coral pavement of unknown function. The 1996 SHPD comment letter notes that this site has not been adequately assessed. In addition, the review letter also indicates that further work is needed at this site.

Site 50-50-05-2849 is made up of an extensive subsurface cultural deposit that was identified during archaeological testing in c. 1990-1991. This site qualifies for significance under Criterion "d" because of its information content. The SHPD has recommended that data recovery work be undertaken on this cultural deposit.

Site 50-50-05-4197 consists of related features of the former WWII Naval Air Station (NASKA). An SHPD review letter indicates that additional work is needed for this complex. The letter goes on to note that an inventory survey of the area is needed before additional evaluations/recommendations can be made.

Site 50-50-05-1783 [Kanaha Pond]: as previously noted, a portion of Kanaha Pond is located to the south of the waste water treatment facility. This site qualifies for significance under all four National Register Criteria as well as HRHP Criterion "e" for its traditional cultural value.

---

[2] Mr. Charles Kauluwehi Maxwell Sr., current Chair, Maui/Lana'i Islands Burial Council (MLIBC), assisted in the reburial of human remains that were disturbed by airport construction activities over 20 years ago.

ARCHAEOLOGICAL MONITORING PLAN

Scope of monitoring

The scope of this monitoring plan includes having an archaeological monitor present during all subsurface earthmoving activities scheduled for the proposed tsunami improvements project at the County of Maui Waste Water Treatment facility in Kanaha, Maui. Actual on-site time and specific actions to be followed in the event of inadvertent discoveries will be discussed and agreed upon by the general contractor and the archaeological consultant at a pre-construction meeting held for this purpose. Additional meetings may be called, if either the monitoring archaeologist or contractor believes that other relevant information should be disseminated. As previously mentioned, this plan covers this current project as well as any future on-site improvements for the waste water treatment facility (TMK (2) 3-8-1: 188).

Monitoring methodology

Given the coastal location of the water treatment facility, there is a possibility that significant material culture remains may be inadvertently disturbed during earthmoving activities in this portion of coastal Maui. Possible cultural materials could include subsurface habitation deposits, human burials and/or human skeletal remains.

Close cooperation between the monitoring archaeologist and construction personnel is important to a successful monitoring program. The monitoring program will follow the 12 conditions listed below:

1) The contractor shall be responsible for ensuring that the archaeological consultant is aware of all pertinent construction schedules and that the monitor is present for <u>all</u> subsurface excavation activities on this coastal parcel.

2) Both the archaeological consultant and the contractor are responsible for ensuring that on-site work is halted in an area of significant findings and to protect any such find from any further damage (i.e., construction fencing, protective covering, etc.). The State Historic Preservation Division will recommend appropriate mitigation actions. The SHPD Burial Sites Program, the SHPD Maui office, and the Maui/Lana'i Islands Burial Council (MLIBC) will be consulted in the event that human remains are found (Change work order).

3) In the event of the discovery of human remains, work shall cease in the immediate find area. The monitoring archaeologist will be responsible for notifying the SHPD Maui office and the Historic Preservation Division Burial Sites Program (HPDBSP), which, in consultation with the Maui/Lana'i Islands Burial Council, will determine the appropriate mitigation measures. This notification will include accurate information regarding the context and composition of the find (Change work order).

4) The archaeological consultant will work in compliance with Hawai'i Revised Statutes Chapter 6E (procedures Relating to Inadvertent Discoveries).

5) The monitoring archaeologist will have the authority to closedown construction activities in areas where potentially significant discoveries have been made until they have been properly evaluated. Normally, construction activities may continue in unaffected portions of the project area (Change work order).

6) Field procedures to be followed for documentation of discovered cultural features or human skeletal remains: a) standard field methods including recordation of profiles showing stratigraphy, cultural layers, etc.; b) mapping and photographing of finds other than human remains; c) and excavation of cultural materials and/or exposed features.

7) The SHPD Maui archaeologist shall be notified and consulted with regarding treatment of identified features such as cultural layers, artifact or midden concentrations, structural remains, etc., considered to be of significance under S13-279-2 (definitions).

8) The contractor should take into account the necessity for machine excavation at a speed slow enough to allow for reasonable visual inspection of the work. The monitoring archaeologist must make a "best effort" to search for significant material culture remains (i.e. artifacts, features, midden, skeletal remains, etc.). Machine excavation speed will need to be slowed in an area where significant material culture remains have been identified (Change work order).

9) Significant archaeological discoveries, if they occur, shall be protected and identified by construction "caution" tape, fencing, or other reasonable means, until the SHPD Maui office and the archaeological consultant decide appropriate mitigation actions. All recovered material culture remains—with the possible exception of charcoal samples for radiometric analysis—will remain on Maui. Standard laboratory methods shall be utilized by the archaeological consultant in the event that cultural materials are recovered during monitoring and/or mitigation work. Cultural materials will be curated by the archaeological consultant (change work order)

10) One monitor in most instances will carry out the necessary fieldwork. Tasks will include observation of grubbing and earth-moving activities. However, the SHPD and the MLIBC require that one archaeological monitor be assigned to each piece of major earth-moving equipment in sand dune areas or other culturally sensitive locations (Change work order if more than one piece of machinery is to be utilized).

11) In the event of night work, the general contractor shall supply adequate lighting for the onsite monitor.

12) Chapter 6E-11 (a) specifies the following "It shall be unlawful for any person or corporate, to take, appropriate, excavate, injure, destroy, or alter any historic property or aviation artifact located on the private lands of any owner thereof without the owner's written permission being first obtained. It shall be unlawful for any person, natural or corporate, to take, appropriate, excavate, injure, destroy, or alter any historic property located upon lands owned or controlled by the State or any of its political subdivisions, except as permitted by the department."

Field methods utilized shall include photographic recordation (where appropriate), artifact excavation (recovery and recordation), profile documentation of cultural layers and stratigraphy, excavation and recordation of exposed features, and mapping of all pertinent features on an appropriate site map. A daily log (field notes) of activities and findings will also be kept. Gathered information shall be utilized in the preparation of the monitoring report to be submitted to the SHPD.

In the event human skeletal remains are inadvertently disturbed, the SHPD Maui office, the Burial Sites Program, and the Maui/Lana`i Islands Burial Council shall be notified, and appropriate mitigation actions determined (photographs of human skeletal remains will not be taken).

A supervisory archaeologist may periodically visit the monitoring site as often as is necessitated by the nature of the construction activities and archaeological findings. If significant discoveries are made, appropriate mitigation measures will be discussed with the SHPD Maui office.

The archaeological consultant shall curate all cultural materials recovered from this monitoring project on Maui, with the possible exception of human remains.[3] When analysis is completed, recovered material culture remains will be turned over to the appropriate parties. Long-term curation arrangements of such materials will be approved by the SHPD.

A draft monitoring report detailing the results of the monitoring program will be prepared. This draft report shall be submitted to the State Historic Preservation Division

[3] In the event that the SHPD Maui office has insufficient space for recovered human remains, then the consultant shall curate the human remains on Maui.

within 180 days of the completion of fieldwork, for comment and approval. Approved changes and corrections will result in the final monitoring report for this construction project for the Waste water treatment facility at Kanaha, Maui. Any future on-site improvements for this County of Maui facility located on TMK: (2) 3-8-1: 188 will be covered by this monitoring plan, but will require separate monitoring reports.

APPENDIX H-2.

State Historic Preservation Division Approval Letter of Monitoring Plan

LINDA LINGLE
GOVERNOR OF HAWAII

LAURA H. THIELEN
CHAIRPERSON
BOARD OF LAND AND NATURAL RESOURCES
COMMISSION ON WATER RESOURCE MANAGEMENT

RUSSELL Y. TSUJI
FIRST DEPUTY

KEN C. KAWAHARA
DEPUTY DIRECTOR - WATER

AQUATIC RESOURCES
BOATING AND OCEAN RECREATION
BUREAU OF CONVEYANCES
COMMISSION ON WATER RESOURCE MANAGEMENT
CONSERVATION AND COASTAL LANDS
CONSERVATION AND RESOURCES ENFORCEMENT
ENGINEERING
FORESTRY AND WILDLIFE
HISTORIC PRESERVATION
KAHOOLAWE ISLAND RESERVE COMMISSION
LAND
STATE PARKS

STATE OF HAWAII
DEPARTMENT OF LAND AND NATURAL RESOURCES

STATE HISTORIC PRESEERVATION DIVISION
601 KAMOKILA BOULEVARD, ROOM 555
KAPOLEI, HAWAII 96707

January 31, 2008

Mr. Erik Fredericksen
Xamanek Researches, LLC
P.O. Box 880131
Pukalani, Hawai'i 96788

LOG NO: 2007.4180
DOC NO: 0801JP06
Archaeology

Dear Mr. Fredericksen:

SUBJECT: Chapter 6E-8 Historic Preservation Review
Archaeological Monitoring Plan for the Scheduled Tsunami Improvements Project at the County of Maui Waste Water Treatment Plant at Kanaha
Wailuku Ahupua'a, Wailuku District, Maui Island
TMK: (2) POR of 3-8-001:188

Thank you for the opportunity to review the archaeological monitoring plan, which was received by our staff in December 2007 (Fredericksen 2007, *An Archaeological Monitoring Plan for the Scheduled Tsunami Improvements Project at the County of Maui Waste Water Treatment Plant at Kanaha, Wailuku Ahupua'a, Wailuku District, Maui Island [TMK: (2) 3-8-001:188]*)...Xamanek Researches, LLC, ms.

Archaeological field inspection occurred on the subject parcel and archaeological monitoring was the accepted mitigation. Statewide Inventory of Historic Places (SIHP) 50-50-05-1777, -1783, -1798, -1799, -2849, and -4197 have been documented in the vicinity of the current project area. The sites consist of World War II Naval Air Station remnants, significant subsurface cultural deposits, a rock alignment with coral, and several human burials. A portion of Kanaha Pond is located south of the facility, across Amala Place. Additional archaeological inventory survey and data recovery work has been recommended for the majority of the sites. None of the previously documented sites will be impacted by the proposed construction activities. Archaeological monitoring is necessary during all construction activities because of the possibility of the discovery of subsurface cultural deposits during the course of the project (including human burials).

This plan conforms to Hawaii Administrative Rules Chapter 13-279 which governs the standards for archaeological monitoring. The subject plan includes the following provisions: an archaeologist will be on site on a full-time basis and will have the authority to halt excavation in the event that cultural materials are identified. Consultation with the Maui State Historic Preservation Division (SHPD) will occur in this event, to determine an acceptable course of action. If human burials are identified, work will cease, the SHPD Burial Sites Program, Maui SHPD, O'ahu SHPD and the Maui/Lana'i Islands Burial Council will be notified, and compliance with procedures outlined in HRS 6.E-43 will be followed. Coordination meetings with the construction crew will be held prior to project initiation.

The plan further indicates that an acceptable report will be submitted to this office within 180 days of project completion. We understand that any future on-site improvements planned for this County of Maui facility on TMK (2) 3-8-001:188 will be covered by this monitoring plan but will require the submittal of phased monitoring reports.

The plan is acceptable. Please notify our Maui and O'ahu offices, via facsimile, at the onset and completion of the project and monitoring program. We believe it is unlikely that any historic properties will be affected with the implementation of this accepted monitoring plan. If you have any questions, please contact the Maui SHPD at (808) 243-4641.

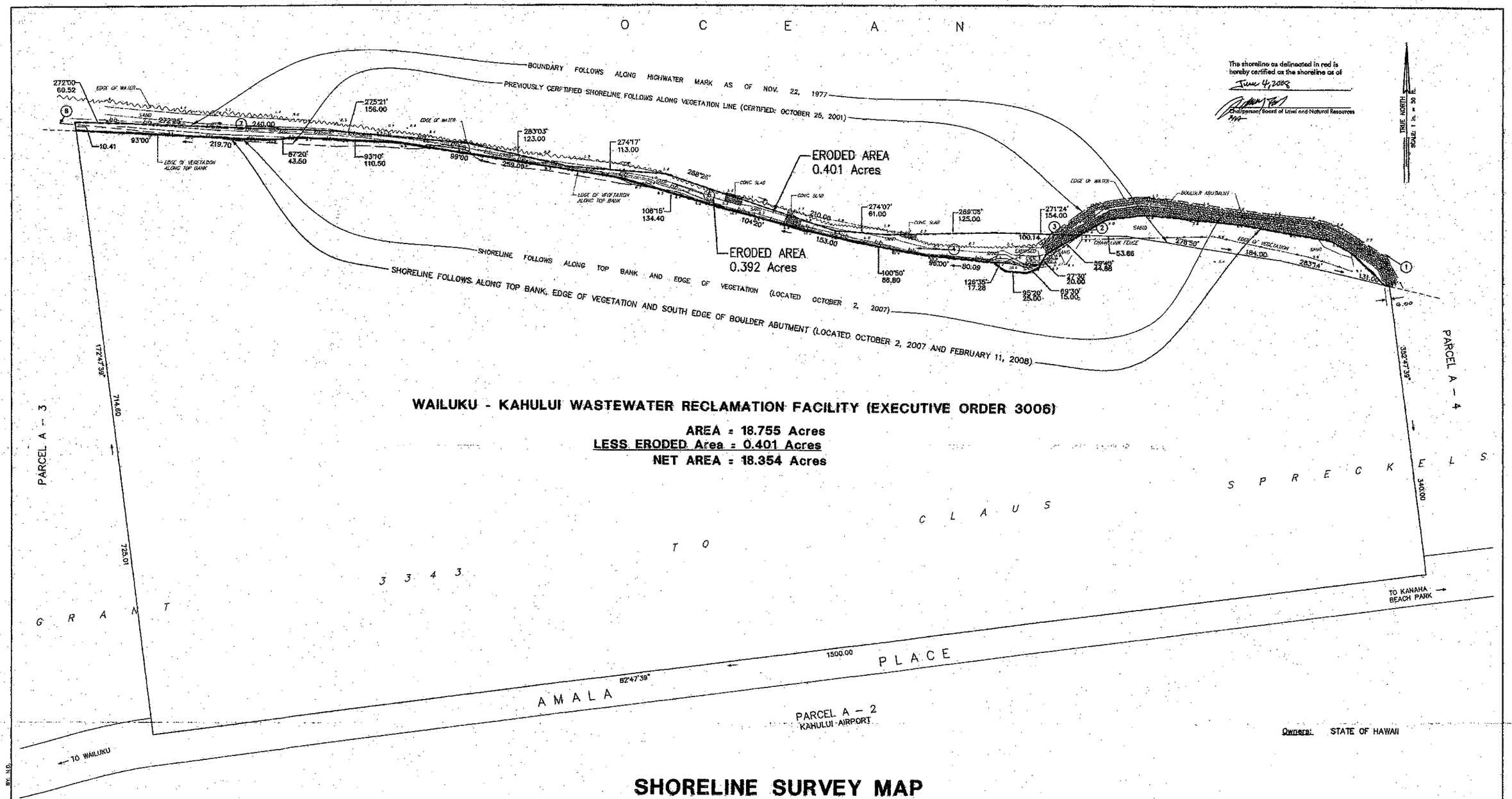
Aloha,

Nancy McMahon, Archaeologist and Acting Archaeology Branch Chief
State Historic Preservation Division

c: Director, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793
Maui Cultural Resources Commission, Dept. of Planning, 250 S. High Street, Wailuku, HI 96793
* DPWEM County of Maui

APPENDIX I.

Certified Shoreline Survey



WAILUKU - KAHULUI WASTEWATER RECLAMATION FACILITY (EXECUTIVE ORDER 3006)

AREA = 18.755 Acres
LESS ERODED Area = 0.401 Acres
NET AREA = 18.354 Acres

Owners: STATE OF HAWAII

SHORELINE SURVEY MAP
OF
KAHULUI WASTEWATER RECLAMATION FACILITY LOT

BEING A PORTION OF GRANT 3343 TO CLAUS SPRECKELS

AT KAHULUI, WAILUKU, MAUI, HAWAII

LEGEND:

- TOP BANK
- BOTTOM BANK
- SPOT ELEVATION
- LOCATION AND DIRECTION OF PHOTOGRAPHS TAKEN ON OCTOBER 3, 2007 AT 12:00 PM

50 25 0 50 100
GRAPHIC SCALE IN FEET

THIS WORK WAS PREPARED BY ME OR UNDER MY SUPERVISION

KIRK T. TANAKA
LICENSED PROFESSIONAL LAND SURVEYOR No. 7223-LS
HAWAII, U.S.A.

02/20/08
DATE

KIRK T. TANAKA
Licensed Professional Land Surveyor
Certificate No. 7223
License Expires: APRIL 30, 2008

Revised: FEBRUARY 15, 2008
OCTOBER 8, 2007
JOB NO. 07-052

Tax Map Key (2) 3-8-01 : 188

871 KOLU STREET, SUITE 201
WAILUKU, MAUI, HAWAII 96793

R. T. TANAKA ENGINEERS, INC.
LAND SURVEYORS - CIVIL & STRUCTURAL ENGINEERS

JN: 2007/07-052A
FILE: 2A-SHORELINE.dwg
19-FEB-2008
BY: N.D.