THE FOLLOWING CONTRIBUTED TO THE PRODUCTION OF THIS MAP BOOK

The City and County of Honolulu (Department of Design and Construction, Facilities Division; Department of Facility Maintenance, Division of Road Maintenance; Department of Planning and Permitting), Hawaii Department of Land and Natural Resources (Division of Aquatic Resources, Office of Conservation and Coastal Lands), Hawaii Office of Planning, Hawaii Department of Transportation, Hawaii Department of Health, U.S. Army Corps of Engineers (Honolulu District), University of Hawaii Sea Grant Program, Troy Heitmann.
Figure 1 Oahu stream mouth locations included in this map book are indexed geographically beginning with Ala Wai and proceeding clockwise around the island. Yellow highlighted streams are managed.
# Table of Contents

Acknowledgements .......................................................................................................... i
Location Map .................................................................................................................... ii
Introduction and Coastal Characteristics ........................................................................... 1
Stakeholder Meeting Notes ................................................................................................. 11

## Managed Stream Mouths

<table>
<thead>
<tr>
<th>Stream Mouth</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ala Wai</td>
<td>12</td>
</tr>
<tr>
<td>Kaha</td>
<td>13</td>
</tr>
<tr>
<td>Nanakuli</td>
<td>14</td>
</tr>
<tr>
<td>Mailiili</td>
<td>16</td>
</tr>
<tr>
<td>Kaupuni</td>
<td>17</td>
</tr>
<tr>
<td>Eku</td>
<td>19</td>
</tr>
<tr>
<td>Makaha</td>
<td>20</td>
</tr>
<tr>
<td>Waikomo</td>
<td>21</td>
</tr>
<tr>
<td>Kaiahi</td>
<td>22</td>
</tr>
<tr>
<td>Makua</td>
<td>23</td>
</tr>
<tr>
<td>Kawaihapai</td>
<td>24</td>
</tr>
<tr>
<td>Pahole</td>
<td>25</td>
</tr>
<tr>
<td>Makaleha Ditch</td>
<td>26</td>
</tr>
<tr>
<td>Makaleha</td>
<td>27</td>
</tr>
<tr>
<td>Aweoweo</td>
<td>28</td>
</tr>
<tr>
<td>Kiki</td>
<td>29</td>
</tr>
<tr>
<td>Paukauila</td>
<td>30</td>
</tr>
<tr>
<td>Anahulu</td>
<td>31</td>
</tr>
<tr>
<td>Lokoena</td>
<td>32</td>
</tr>
<tr>
<td>Laniakua</td>
<td>33</td>
</tr>
<tr>
<td>Kawaiola</td>
<td>34</td>
</tr>
<tr>
<td>Kaalaena</td>
<td>35</td>
</tr>
<tr>
<td>Waimea</td>
<td>36</td>
</tr>
<tr>
<td>Kalunawaikaala</td>
<td>37</td>
</tr>
<tr>
<td>Pakulena</td>
<td>38</td>
</tr>
<tr>
<td>Paumalu</td>
<td>39</td>
</tr>
<tr>
<td>Kaunala</td>
<td>40</td>
</tr>
<tr>
<td>Waialae</td>
<td>41</td>
</tr>
<tr>
<td>Kahawaiwai</td>
<td>42</td>
</tr>
<tr>
<td>Wailele</td>
<td>44</td>
</tr>
</tbody>
</table>

## Aakakii

<table>
<thead>
<tr>
<th>Stream Mouth</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aakakii</td>
<td>46</td>
</tr>
<tr>
<td>Kokololio</td>
<td>47</td>
</tr>
<tr>
<td>Waimanana</td>
<td>53</td>
</tr>
<tr>
<td>Kaluanui</td>
<td>54</td>
</tr>
<tr>
<td>Kapano</td>
<td>55</td>
</tr>
<tr>
<td>Punaluu</td>
<td>56</td>
</tr>
<tr>
<td>Punaluu Ditch</td>
<td>57</td>
</tr>
<tr>
<td>Puupie</td>
<td>58</td>
</tr>
<tr>
<td>Kahana</td>
<td>59</td>
</tr>
<tr>
<td>Kelae O lo</td>
<td>60</td>
</tr>
<tr>
<td>Waimanalo</td>
<td>62</td>
</tr>
<tr>
<td>Inoaoe</td>
<td>63</td>
</tr>
<tr>
<td>Kaiono</td>
<td>64</td>
</tr>
<tr>
<td>Kuliuouou</td>
<td>65</td>
</tr>
<tr>
<td>Pia</td>
<td>66</td>
</tr>
<tr>
<td>Wailupe</td>
<td>67</td>
</tr>
<tr>
<td>Waialae Iki</td>
<td>68</td>
</tr>
</tbody>
</table>

## List of Figures:

- Figure 1 Location map of stream mouths around Oahu ................................................ ii
- Figure 2 The four coastal segments of Oahu ................................................................. 1
- Figure 3 Oahu rainfall ................................................................................................... 2
- Figure 4 Kaelapulu stream mouth, Kailua Beach Park ................................................... 3
- Figure 5 Aukai Beach Park, Hauula ............................................................................... 3
- Figure 6 Dominant swell regimes in Hawaii ................................................................. 3
- Figure 7 South shore SWAN model results location map .............................................. 4
- Figure 8 South shore SWAN model results ................................................................. 4
- Figure 9 Southwest shore SWAN model results location map ..................................... 5
- Figure 10 Southwest shore SWAN model results ......................................................... 5
- Figure 11 West shore SWAN model results location map ............................................. 6
- Figure 12 West shore SWAN model results ................................................................. 6
- Figure 13 North shore SWAN model results location map .......................................... 7
- Figure 14 North shore SWAN model results ............................................................... 7
- Figure 15 Northeast shore SWAN model results location map .................................... 8
- Figure 16 Northeast shore SWAN model results ......................................................... 8
- Figure 17 East shore SWAN model results location map ............................................ 9
- Figure 18 East shore SWAN model results ................................................................. 9
Introduction and Coastal Characteristics

**INTRODUCTION** This map book was produced to assist in the development of appropriate sediment management practices at 59 stream mouths that empty into the ocean on Oahu. Streams are presented in clockwise order around the island beginning with the Ala Wai Canal. These have been identified largely through two sources: the Hawaii Geographic Information System (GIS) Office located in the Hawaii Department of Business and Economic Development (DBEDT); and the *Atlas of Hawaiian Watersheds & Their Aquatic Resources* provided by the Division of Aquatic Resources (DAR) located in the Hawaii Department of Land and Natural Resources (DLNR). Most of these streams are intermittent and do not require regular sediment management. However, at least 11 streams do require regular maintenance.

This map book devotes one page to each stream mouth including a description of the littoral setting, an orthophoto map is included showing location as well as ground level photographs. Superimposed on the orthophoto map are symbols indicating wind and wave approach that may impact sediment transport.

**STREAM NAMES** The majority of stream names around the island of Oahu were collected from the state inventory of streams geographic information system layer for the island of Oahu. There are several instances where these names are different from signage at the stream location and the common name used by the local community. In these instances care was taken to include alternative names and their source.

**CLIMATE** Managing stream mouths requires an awareness of coastal littoral sediment transport as well as discharge and sediment delivery from the adjacent watershed; Hence, island climatology is important. Island-wide, the climate is sub-tropical oceanic. Honolulu has a mean monthly temperature of 21.7°C (71.1°F) in January, rising to 25.6°C (78.2°F) in July, and an average annual rainfall of 802 mm (31.6 in). However, due to wind and rain shadowing and orographic effects there is significant climate diversity across the island. Specific localized rainfall, wind, and wave conditions govern sediment behavior, accumulation, and composition at the shoreline.

**STREAM MOUTH SETTING** The island of Oahu has four primary coastal segments: north shore, windward, south shore, and leeward (Figure 2).

**RAIN** Oahu Island lies in the zone of northeasterly tradewinds, which bring rainfall to the windward mountain slopes while the leeward coasts are in rain shadow (Figure 3). Oahu’s preeminent example of this orographic rain is the difference in rainfall between the windward shoreline (1524-2032 mm/yr; 60-80 in/yr) and the more arid west shore (508-762 mm/yr; 20 to 30 in/yr).

Streams drain watersheds that experience variable rainfall along their length. Streams draining windward slopes are fed by watersheds with rainfall ranging from 2032 to 6604 mm/yr (80 to 260 in/yr). West shore watersheds are semi-arid, with annual rainfall of 762 to 1524 mm (30 to 60 in) throughout their watersheds. South shore watersheds drain lands receiving 762 to 5080 mm/yr (30 to 200 in/yr) and north shore watersheds receive 1016 to 5080 mm/yr (40 to 200 in/yr).

**FLOODS** Flashfloods pose significant management challenges at stream mouths (Fletcher et al. 2002). Capable of experiencing over 254 mm (10 in) of rainfall in an hour, Oahu watersheds on all sides of the island may evolve from dry stream beds to raging flood waters in less than one hour. Under these conditions, stream mouths that are clogged with sediment pose a potential flood problem for stream bank communities located on low coastal lands. During high tide or periods of high waves when the sea level is high, stream mouths may not drain effectively. As a result flood waters flow over the bank and accumulate on the coastal plain. These may cause damage to low lying communities such as Laie, Hauula, and portions of Kailua, Waimanalo, and others.

**SEA LEVEL** Tide range on Oahu is small. Honolulu has a mean spring tide range of 0.6-0.8 m (2.0-2.6 ft). The Honolulu tide gauge records a long-term mean sea level rise of approximately 1.5 mm/yr (0.6 in/decade). However, submerged wave cut notches and raised coral reef can be found at various elevations and locations around Oahu indicating past oscillations of land and sea level (Fletcher et al., 2008). On most shores, a high sea level about 3000 years ago deposited sand on which we have since built roads and communities.

Because of global warming, sea level rise has accelerated globally (Church and White, 2006). In a study of Hawaii tide gauges, Firing and Merrifield (2004) found that superimposed on the long...
term rate of rise are punctuated short term periods of accelerated rise that are increasing in frequency and magnitude. As sea level continues to rise, the ability of stream mouths to effectively drain into the ocean is reduced. With marine inundation, stream mouths will deepen and widen into estuaries rimmed by tidal wetlands. This trend will be marked by increasingly frequent and damaging flooding events especially where runoff and high tide coincide. With a rise of 0.75 - 1.9 m projected by the end of the 21st century (Vermeer and Rahmstorf, 2009), many Oahu stream mouths will broaden into significant estuarine ecosystems with new management challenges. Flooding will increase in frequency and magnitude and the effects of high tide and high wave periods will be felt by an increasingly large portion of the community and ecosystem.

**SAND**

Many streams on Oahu are intermittent, only flowing during times of direct rainfall; hence the stream mouth is often clogged with coastal sand (Figure 4) as that is the only sediment in active transport most times of the year. A critical issue for stream mouth management is the disposal of beach quality sands that are periodically removed as part of maintenance. Year after year beaches are deprived of sand that is hauled away from coastal stream mouths. This may contribute to chronic coastal erosion. Proper disposal of beach quality sands on the adjoining shoreline should be a matter of establishing best management practices wherein both beaches and the stream mouth are co-managed with equal consideration under the same plan.

Beaches include creamy white calcareous (CaCO₃) sand, derived from the tests of micro-organisms, weathered coral, calcareous marine algae, lithic fragments (typically of Pleistocene skeletal limestone), mollusk and echinoderm fragments (Harney et al. 2000), and black and green sand derived from volcanic material. Ferromagnesian olivine and other basaltic minerals are relatively unstable in the tropical climate of Hawaii, and are reduced by weathering. Calcareous beaches are dominant on Oahu where significant coral reef communities have been able to develop.

Most of the Oahu shoreline is fronted by fringing reefs (Figure 5). These are home to organisms that produce much of the coastal sand that tends to fill stream mouths. Other sources of sand include erosion of the adjacent coastal plain which releases sand deposited there by wind and past higher sea levels, and landward transport of sand through channel incised into fringing reefs. Most Oahu beaches are dominated by longshore transport so that managing sand requires knowledge of sediment movement along the adjacent shore.

Two organisms serve as principal architects of Hawaiian reefs: scleractinian (stony or hard) corals, and coralline and calcareous algae. There are over fifty species of coral found in the Hawaiian Islands but only a few are common. The more abundant Hawaiian genera include rice corals (Montipora species), lobe and finger corals (Porites species), cauliflower or moosehorn corals (Pocillopora species), and false brain corals (Pavona species). These may be bioroed and/or abraded and battered by high waves to yield coral sand.

Coraline algae and calcareous algae are members of a marine plant group on the reef that deposits calcium carbonate in its tissue. When the algae die, it leaves a fossil skeleton that is hard and whitish. A few species of calcareous algae, such as the Halimeda, are especially abundant in Hawaii and important reef components. Hard plant debris builds up as piles of sediment in reef environments and is an important source of beach sand, making up over half the grains on many Hawaiian beaches. The coralline algae look like coral and grow in a binding and encrusting form on the reef, competing for space with corals. Most coralline algae are red, but there are some exceptions. A visit to any intertidal rocky coast in Hawaii will reveal the encrusting coralline community coloring the rocks a brilliant hue in between the rise and fall of the waves. However, their sand products are whitish.

The coastal plains of most Hawaiian Islands hold major calcareous eolian (wind), littoral (intertidal), and marine sand deposits formed during and following high sea levels about 3,000 years ago (Fletcher and Jones 1996; Grossman and Fletcher 1998) and persistent recent deposition under seasonal winds. Sand is also stored on the reef flat in shore-normal reef channels and shallow Pleistocene karst depressions (Fletcher et al. 2008). Longshore transport dominates sediment movement on the coast in distinct littoral cells.

**CLASTS**

Stream mouths are also the site of basalt clast deposition. Clasts are gravel and boulders typically brought from the watershed during flashfloods. Clasts are usually composed of basalt and derived from the volcanic outcrops that line the streambed and banks in steeper sections of the watershed. Clasts and basaltic sand, as well as red mud produced by chemical weathering of basalt, mix with carbonate sand and gravel on the shoreline to form small delta deposits in some stream mouths. These control the sedimentology and the morphology of the shoreline in the
Waves In addition to northeasterly waves generated by the tradewinds there are ocean swells from the north in the winter and the south in the summer months. The central Pacific location of Oahu exposes it to wind and ocean swells from all directions. Portions of coastline may have rain, wind, and wave shadows, and are either protected from, or vulnerable to, wind and wave impact. The four dominant regimes responsible for large waves in Hawaii are: north Pacific swell, tradewind swell, south swell, and Kona storms. The regions of influence of these regimes, outlined by Moberly & Chamberlain (1964), are shown in Figure 6; a wave rose depicting annual swell heights and directions has been added to their original graphic (Vitousek and Fletcher, 2008).

Inter-annual and decadal cycles including El Niño Southern Oscillation (ENSO) occurring approximately every three to four years, and Pacific Decadal Oscillation (PDO) occurring around 20–30 years, influence the variability of the wave climate. These large-scale oceanic and atmospheric phenomena are thought to control the magnitude and frequency of extreme swell events. For example, times of strong ENSO may result in larger and more frequent swell. Understanding the magnitude and frequency of extreme wave events is important as they may control processes such as sediment transport, beach morphology, and sea level position that modulates stream mouth flooding.

In the winter, Hawaii receives large ocean swell from extra-tropical storms that track predominantly eastward from origins in the northwest Pacific. These storms produce waves that travel for thousands of kilometers until reaching the shores of Hawaii. North swell have annually recurring maximum deep-water significant wave heights of 7.7 m (25.2 ft) with peak periods of 14-18 s. However, the size and number of swell events each year is highly variable – varying by a factor of 2. The annual maximum wave height ranges from about 6.8 m (22.3 ft; in 1994, 1997, 2001) to 12.3 m (40.3 ft; 1988).

Occurring about 75% of the year, the tradewinds arrive from the east and northeast with an average speed of 25 km/hr (15 miles/hr) and direction 73°. In winter months, the north Pacific high generating these winds flattens and moves closer to the islands decreasing tradewind persistence. Although the number of windy days in summer months increases, the mean tradewind speed in summer and winter months remains similar. The trades generate choppy seas with average wave heights of 2 m (6.6 ft; $\sigma = 0.5$ m; 1.6 ft) and peak periods of 9 s ($\sigma = 2.5$ s) from the northeast. Although these represent nominal conditions, tradewind swell can exceed 5 m (16.4 ft) in height and have periods of 15–20 s. Southern swell arriving in Hawaii is typically generated farther away than north Pacific swell. These are usually produced by storms south of the equator near Australia, New Zealand and as far as the Southern Ocean and propagate to Hawaii with little attenuation outside the storm-generated region. South swells occur in summer months (southern hemisphere winter) and reach Hawaii with an annual significant wave height of 2.5–3 m (8.2-9.8 ft) and peak periods of 14–22 s, which are slightly longer than north Pacific swell.

Kona storms are low-pressure areas (cyclones) of subtropical origin that usually develop northwest of Hawaii in winter and move slowly eastward, accompanied by southerly winds from whose direction the storm derives its name, and by the clouds and rain that have made these storms synonymous with bad weather in Hawaii. Strong Kona storms generate wave heights of 3–4 m (9.8-13.1 ft) and periods of 8–11 s, along with wind and rain, and can cause extensive damage to south and west facing shores. While minor Kona storms occur practically every year in Hawaii, major Kona storms producing strong winds, large wave heights and resulting shoreline change tend to occur every 5–10 years during the 20–30 year negative PDO cycle. Consequently, positive (warm) PDO, and El Niño phases tend to suppress Kona storm activity.
It is notable that the worst flash flooding has happened in association with Kona activity that either settles in over the islands for a prolonged stay, or a passing storm of such intensity that it overwhelms the discharge capacity of a watershed within hours and produces damaging flooding usually at the stream mouth where it enters the ocean.

**Coastal Erosion**

There is widespread but variable coastal erosion in Hawaii in response to human interference with sand availability, waves and currents, and the inferred influence of sea level rise. For instance, researchers at the University of Hawaii measured the historical rate of shoreline change on every beach on the island of Kauai. Their data reveal that 72 percent of the beaches on Kauai are eroding and the average rate of erosion is 0.3 m/yr (1 ft/yr). On 22 percent of the eroding beaches, the rate of erosion is accelerating.

In pristine coastal areas calcareous sand stored on the low-lying coastal plain is released to the beach as sea level rises, allowing a wide sandy shore to be maintained even as the shoreline recedes. However, the threat to coastal property has led to extensive armoring of the coastline. Artificial hardening to protect coastal land may occur at the expense of the beach, preventing waves from accessing the sandy reservoirs impounded behind the seawalls and revetments. Thus, efforts to mitigate coastal erosion have created a serious sand deficiency on armored

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**Figure 7** Locations for SWAN model results showing wave direction on the south shore. Wave conditions acquired from the National Data Buoy Center (NOAA-NDBC).

**Figure 8** Modeled swell directions south shore: 8a - north swell (top); 8b - south swell (middle); 8c - tradewind swell (bottom)
beaches leading to widespread beach loss, particularly on Oahu where nearly one-quarter of the length of beaches at World War II had been lost by the late 1990’s (Fletcher et al., 1997). The need to address this issue is acknowledged by the state and local communities. A broadly scoped management plan would keep a balance between the natural coastal morphology and human resource demands. Appropriate management of stream mouth sediment is one very important step in improving beach management.

**Longshore Wave Approach**

The SWAN model simulates wave approach across deep and shallow bathymetry. SWAN results have been used to depict swell directions for coastal segments along the Oahu coast. Figures 7 - 18 shows results for Oahu. These provide background information to assist in decision-making for stream mouth management. Arrow diagrams can be interpreted in light of additional information of a more specific nature to assess longshore sand movement.

**Hardened Structures**

At many locations around Oahu, stream mouth locations and nearby shorelines are stabilized using groins, channels, and seawalls. Where shore-normal structures exist at sediment rich locations, these may impede the longshore transportation of sand and lead to sand accumulation on the up-drift side and erosion on the down-drift side of the structure. If sand builds up in stream mouths because of this tendency, it may lead to obstruction of stream flow and flooding on the adjacent coastal plain. Sand trapping such as this will require maintenance to clear the sediment. In the case of shore-parallel structures such as sea walls and revetments, sediment is impounded landward of the structure. This may result in a net sediment deficiency in the littoral cell and overall migration of sand out of the active sandy beach system. In summary, sandy coastlines can be viewed as a “sand-sharing system” wherein it is appropriate for management practices to be evaluated in light of their potential to negatively impact adjacent environments.

**Managing Oahu’s Stream Mouth Sediment**

There is a large burden on federal, state and local government to effectively balance the myriad interests involved in accessing, moving and placing stream mouth sediment. Intense development along the Oahu coastline immediately surrounding stream mouths brings scrutiny to any sediment management activities. A general lack of beach quality sand coupled with water quality concerns have resulted in ad hoc
management rather than integrated planning that balances all issues. At the time of this publication, the City and County of Honolulu (C&C) Department of Facilities and Maintenance (DFM) provides maintenance responsibility to stream mouths around Oahu to protect the public and public infrastructure from flood hazards. They hold a general permit for sand moving that requires notification of the State Department of Health and Army Corps of Engineers before maintenance work. Notification takes the form of a schedule of works to be performed at specified locations, on specified dates.

Mandated sediment management responsibility lays with the Department of Land and Natural Resources (DLNR). However, required permitting on a case-by-case basis, limits their ability to provide regular coordinated management. In the interest of public safety and the protection of private property, the DFM routinely clears 12 stream mouths of upland debris and sediment on a scheduled monthly basis. Of these 12, 11 are described in this book (the 12th, Ewa canal contains no beach sediment and is not included in this study). Additional stream mouths are cleared as needed or requested by concerned communities and other C & C or state agencies with responsibilities near stream mouths (i.e. State Department of Transportation). The works are carried out by DFM district depots that use available equipment. The type of equipment used largely dictates the type of sediment clearing and flexibility of placement.

(Continued on p. 8)
Figure 13 Locations for SWAN model results showing wave direction on the north shore.

Figure 14 Modeled swell directions north shore: 14a - north swell (below left); 14b - south swell (top right); 14c - tradewind swell (bottom right)
Managed Stream Mouths

Eleven stream mouths are recognized as actively managed by the C&C, DFM.

- Ulehawa p. 15
- Laie Loa p. 43
- Koloa p. 45
- Waipilo p. 48
- Maakua p. 49
- Hauula p. 50
- Waipuhi p. 51
- Meheiwi p. 52
- Kaelepulu p. 61
- Waialae Nui p. 69
- Kahala p. 70

Scheduled clearing removes sediment from the mouth to allow stream water access to the ocean. Work is scheduled and completed on Monday, Tuesday or Wednesday to allow settling of suspended sediment related to the work prior to weekend public use. Removed sediment is required to be placed above the high water line (hwl) adjacent to the stream mouth at the discretion of the clearing crew. Clearing is contingent on the weather and available equipment. Generally sand is placed on the adjacent beach, and silty sand is disposed at Waimanalo Gulch landfill.

(Continued on p. 10)
Figure 17 Locations for SWAN model results showing wave direction on the east shore.

Figure 18 Modeled swell directions east shore: 18a - north swell (right); 18b - south swell (top right); 18c - tradewind swell (bottom right)
RECOMMENDED MANAGEMENT This map book provides baseline data and information on stream mouths around the island of Oahu. Some of these locations possess significant sand resources. The effective management of this sand is likely to benefit the adjacent beach and dune environment, perhaps even neighboring roads and buildings that are vulnerable to coastal erosion. Approximately 30 stream mouths receive routine or requested maintenance throughout the year. In some cases, stream mouths will clear naturally when sufficient rainfall in the watershed supplies the stream with the discharge necessary to mobilize and transport sediment out of the mouth. This is the preferred method of stream clearing and ideally every stream would clear itself by this means on a regular basis, returning sand to the adjacent littoral system. However, when the surface relief of the deposited sediment at the mouth is higher in elevation than surrounding stream banks, flooding becomes a concern and management of the stream mouth sediment is needed. Additionally, during flooding, a blocked stream mouth may lead to avulsion, a channel jumping process by which a stream finds a new path to the sea. Current management practices demonstrate a need for a coordinated interagency effort to routinely monitor and move sediment at stream mouth locations that pose a significant danger to public health and safety and infrastructure. A solution which reintroduces beach sand into the source littoral cell at locations of identified need (such as erosion hotspots) may introduce additional stakeholders, both public and private, into the management process who might otherwise regard stream maintenance solely as the government’s province.

Any public/private endeavor to effectively manage stream mouth sediments requires permits from appropriate agencies. At the time of publication, discussions between the US Army Corps of Engineers, State of Hawaii DLNR, and City and County of Honolulu indicate a willingness to establish a framework of needs and priorities that include establishment of a best management practices (BMP) guide for work to ensure effective results. The role of government in this setting would advise contractors and agencies through the permit process, supplying expertise and knowledge to effectively address the myriad public health, environmental, and legal concerns accompanying BMP development. Interagency teams, working with local communities and stakeholders, could identify public infrastructure designs and practices that might aid in mitigating the volume of sediments in stream mouths. Final permit authority will require Hawaii State Department of Health approval.

STAKEHOLDER MEETING NOTES The following notes are from a meeting of stakeholders involved in the Oahu Regional Sediment Management Study, Oahu Stream Management Study. The meeting was held on 15 December, 2009 at the State of Hawaii, Department of Land and Natural Resources. In attendance were: Tom Smith, Peter Galloway, Justin Goo, Sam Lemmo, Dolan Eversole, Terry Hildebrand, Clifford Lau, Thomas Takeuchi, Charles Fletcher, Matt Dyer and Matthew Barbee.

The meeting was held to discuss draft versions of this map book, stream mouth management around the island of Oahu, relevant policy and procedures to effectively manage the sediment moved during stream mouth clearing, and possible solutions within the framework of existing policy to appropriately make use of cleared sediment resources.

1) Sunset Beach
   a) Stream plugged from recent swell. Need to identify an area to backpass the material to.
   b) Staff inquired as to whether they can put it at along the bike path in the area that was recently impacted by high surf run-up.
   c) Subsequent DLNR/C&C Parks meetings discussed backpassing 500 cy of sand from stream mouth to eroded bank.

2) Stream Names: There are multiple names for some of the streams on Oahu. The names come from various sources. Need to determine which name to use for each stream. Beaches of Oahu reference book and state GIS system used for stream naming.

3) Wave Modeling: UH used the SWAN wave transformation numerical model to determine general sediment transport directions for the Stream Mouth Map Book

4) C&C of Honolulu Currently Managed Stream Mouths
   a) C&C Stream Clearing Maps: UH requested copies of C&C maps that provide current management practices at the streams that are actively maintained. C&C to determine whether or not they can provide the maps for public release. These streams are cleared monthly.
   b) Big Rain/Runoff Events: C&C has pre-event stream mouth clearing protocol.
   c) Stream Clearing: Current C&C practice is to side cast materials onto stream slopes.
      • Request was made to add current clearing practice to map book for each stream.
   d) Water Placement: DOH has issues with placing stream sediment in the water (fines/contaminants).
   e) General Notes:
      • Stream mouths are plugged by natural processes.
      • Natural processes are rarely enough to clear out sediment plugs. In many cases there is not enough discharge to naturally flush the system.
      • May want to try creating small opening in a stream mouth plug and allow the initial flow to open up the stream and discharge material into the nearshore.
   f) Stream maintenance currently conducted on a site specific basis but done on a scheduled rotation.

5) Regulatory Issues
   a) Notice of stream clearing sent out by the C&C. Notices currently sent to USACE (Honolulu District- POC is George Young; Chief, Regulatory Branch).
   b) Current problem with the placement of cleared sand on the beach due to 401 constraints with placement of material into state waters. This has led to a practice of placing cleared sediment on stream banks rather than the beach system and may result in a sediment sink for the system.
   c) Need to pursue a state-wide Programmatic Authority for stream clearing. Also need to develop a state-wide stream mouth clearing program. This would be preferable to doing permits on a stream-by-stream basis. Think in terms of Regional General Permit (RGP).
   d) Section 10 & Section 404 Permits: Section 404 dependent upon extent of tidal influence within each stream. Federal Authority dependent upon extent of tidal waters upstream. Section 404 not necessary above high tide line provided that there is no return flow.
   e) General Permits are for 5 Years. Can be extended while active.
   f) Right of Way Entry: May need blanket Right of Entry for access through state lands.
   g) BMP’s: Need to adhere to the latest BMP’s. Specific Federal requirements based on extent of tidal waters.
   h) Stream Discharge is DOH’s jurisdiction.

6) Pilot Stream Mouth Sediment Projects
   a) Kaaawa
      • Current Federal Project
• Southern transport clogging stream
• Good candidate for backpassing material to the updrift shoreline.
• City currently has Sea Engineering assessing all beach parks on Oahu.
b) Kailua Beach Park Kaelepulu, and Kaaawa are highest priority areas for the C&C of Honolulu Design and Construction Office.

REFERENCES


Coastal Processes:

Ala Wai Canal is an artificial waterway that was completed in 1929 in order to divert water from Manoa, Palolo, and Makiki streams in order to drain the Waikiki area. The canal empties into the ocean in the Ala Wai boat harbor at the western end of Waikiki on Oahu’s south shore. The mouth of the Ala Wai is well protected from winds and waves but does experience tides and tidal currents. Flow rates for the Ala Wai are generally very low and are not sufficient to flush the canal; hence fine sediment and debris tends to accumulate over time.
Coastal Processes

Kahe Stream mouth is located on the west shore of Oahu just north of Koolina Beach and south of Nanakuli. Kahe Beach is approximately 60 ft wide and is bounded by a rock jetty to the south and a rocky headland to the north. The overall length of the beach is about 0.5 mi. Tradewinds blow offshore at this location and wave energy is seasonally variable; from the south in the summer and from the north in the winter.
Nanakuli Stream mouth is located on the west shore of Oahu in Nanakuli at the south end of Nanakuli Beach Park. The stream mouth is approximately 140 ft wide and is typically blocked by beach sand. The beach at Nanakuli is primarily fine calcareous sand. This small bay is bounded to the north and south by carbonate rock headlands. Tradewinds blow offshore at this location. Nanakuli beach is exposed to swells from the north (winter) and summer (south). The beach is steep and slopes into deep water offshore where a sand-filled channel cuts through the fringing reef. This beach is characterized by heavy shore-break.

Coastal Processes

Nanakuli Stream (perennial, NDAR_CODE 35001001)
Lat. 21.375
Long. -158.141 (stream mouth)
Coastal Processes:
Ulehawa Stream is located on the west shore of Oahu to the north of Nanakuli. The beach consists of fine to medium carbonate sand overlying carbonate rock. Ulehawa Stream has been hardened and is approximately 90 ft wide. It is typically blocked by beach sand. The absence of a fringing reef exposes the shoreline to variable wave conditions from the north (winter) and south (summer). The shifting wave climate alternately buries and exposes the rock platform with beach sand.

Ulehawa Stream (perennial, NDAR_CODE 35002001)
Lat.  21.611
Long.  -157.909 (stream mouth)

Photo 1. November 29, 2009 looking toward the ocean from the bridge.

Photo 2. November 29, 2009 looking south from the north side of stream.
Coastal Processes

Maipalaoa Stream is a channelized system that flows into the ocean at Maili on the west coast of Oahu. The stream is about 90 ft wide at the bridge. North and south of the channel are carbonate rock headlands with perched beaches sitting above the tidal zone. There is significant reef structure seaward of the stream mouth which provides some protection from the onshore energy of seasonally variable north (winter) and south (summer) swells.
Coastal Processes

Mailiili Stream is located on the west shore of Oahu in Maili. The channelized stream is approximately 150 ft wide at the mouth. Both the north and the south banks have been hardened. Directly to the north is a carbonate rock headland. Directly to the south is the wide carbonate sand beach at Maili Beach park. Tradewinds blow offshore at this location. This shoreline is exposed to seasonally variable swell arriving from the north (winter) and south (summer).
Coastal Processes:

Kaupuni Stream mouth is located on the west shore of Oahu directly south of Waianae Boat Harbor in the northern corner of Pokai Bay. The stream mouth, approximately 100 ft wide, is hardened (channelized) on both banks. Tradewinds blow offshore and swell energy approaches from directly offshore.

**Kaupuni Stream** (non-perennial, NDAR_CODE 35005001)

Lat. 21.448
Long. -158.193 (stream mouth)

Photo 1. November 29, 2009 looking south across the stream mouth.

Photo 2. November 29, 2009 looking at the beach and seawall directly north of the stream mouth.

Coastal Processes:

Kaupuni Stream mouth is located on the west shore of Oahu directly south of Waianae Boat Harbor in the northern corner of Pokai Bay. The stream mouth, approximately 100 ft wide, is hardened (channelized) on both banks. Tradewinds blow offshore and swell energy approaches from directly offshore.
Coastal Processes:
Eku Stream is located on the west side of Oahu, south of Makaha and is typically blocked by beach sand. The beach at Eku is approximately 0.5 mi long and consists of fine to medium carbonate sand overlying a rock platform. Wave and current energy at this location is seasonally variable from the north (winter) and south (summer).

Eku Stream (non-perennial, NDAR_CODE 35009001)
Lat. 21.459
Long. -158.205 (stream mouth)

Photo 1. November 29, 2009 looking seaward down the stream bed from the side of the road.

Photo 2. November 29, 2009 looking seaward and north across the beach and exposed carbonate platform.
Coastal Processes

Makaha Stream mouth is located in Makaha on the west shore of Oahu where two streams discharge to the ocean within a short distance. Both stream mouths are typically blocked by sand. The beach is primarily fine carbonate sand. Tradewinds trend offshore at this location. Makaha Beach is exposed to seasonally variable waves, refracting into the bay from the north in the winter and the south in the summer.

Makaha Stream (intermittent (south), perennial (north)), NDAR_CODE 35007001)
Lat. 21.477
Long. -158.220 (north stream mouth)

Photo 1. November 29, 2009 looking west across Makaha Beach.

Photo 2. November 29, 2009 looking downstream.
Waikomo Stream is located on the west shore of Oahu. The beach is primarily fine carbonate sand which typically blocks the stream mouth. Tradewinds blow offshore at this location. This stretch of coastline is exposed to seasonally variable swell events from the north and south. As a result, longshore sediment transport is variable depending on the seasons and blocking from local headlands. Directly to the south carbonate rock outcrops at the water line.

Waikomo Stream (Non-Perennial), NDAR_CODE 35010001) This stream is labeled Waikomo Stream on the bridge but labeled Keaau Stream in the Hawaii Statewide GIS data.
Lat. 21.496
Long. -158.229 (stream mouth)

Coastal Processes:
Waikomo Stream is located on the west shore of Oahu. The beach is primarily fine carbonate sand which typically blocks the stream mouth. Tradewinds blow offshore at this location. This stretch of coastline is exposed to seasonally variable swell events from the north and south. As a result, longshore sediment transport is variable depending on the seasons and blocking from local headlands. Directly to the south carbonate rock outcrops at the water line.
Coastal Processes:

Kaiahi Stream mouth is located on Oahu’s leeward coastline at the south end of Makua Beach and is typically blocked by beach sand. Makua Beach ranges in width from 50 to 200 ft and sand is fine to medium grained. Tradewinds blow offshore here and the site is exposed to seasonally variable swell energy from the south and north. The beach is bounded by rocky headlands to the north and south.
Coastal Processes

Makua Stream mouth is located on the west shore of Oahu. The stream mouth is approximately 60 ft wide and typically blocked by beach sand. The beach is primarily fine carbonate sand that changes morphology in response to seasonally variable wave conditions. Tradewinds blow offshore. North waves in the winter and south waves in the summer drive sand movement along the shoreline.

**Makua Stream** (intermittent, NDAR_CODE 35008001)

Lat. 21.530
Long. -158.229(stream mouth)

Photo 1. November 29, 2009 looking south across the stream mouth and beach.

Photo 2. November 29, 2009 looking west down the stream and across beach.
Coastal Processes:
Kawaihapai Stream mouth is located on the Mokuleia shoreline on the north coast of Oahu. Kawaihapai is narrow (<50 ft in width), and typically blocked by beach sand. The beach is primarily composed of carbonate sand and beachrock outcrops characterize the foreshore and shallow surf zone of the beach. Trade winds approach from the east and seasonal swell from the north and northwest. A shallow fringing reef dissipates much of the wave energy before it arrives at the beach.

Kawaihapai Stream (perennial, NDAR_CODE 36001001)
Lat. 21.577
Long. -158.261 (stream mouth)
Coastal Processes

Pahole Stream mouth is located on the Mokuleia side of the north shore on Oahu. The stream cuts across a fine carbonate sand beach and is typically blocked by beach sand. This area of coastline is exposed to tradewind waves and large swell in the winter. There is a shallow fringing reef directly offshore so that much of the wave energy is dissipated. Sediment transport is typically at high tide and driven by tradewind waves.

Pahole Stream (perennial, NDAR_CODE 36002001)
Lat. 21.580
Long. -158.177 (stream mouth)

Photo 1. December 13, 2009 looking seaward from the stream bank.

Photo 2. December 13, 2009 looking from beach to the stream mouth.
Makaleha Ditch is located on the Mokuleia side of the north shore of Oahu. It is typically blocked by beach sand. The stream is approximately 100 ft in width. The beach is primarily fine carbonate sand with carbonate rock outcropping at the base of the foreshore. The north shore of Oahu is exposed to large swell energy in the winter from the northeast to the west. The majority of large swell events occur between the months of October and March. Tradewinds approach this coastline from the east, producing longshore sediment transport.

**Makaleha Ditch** (ditch, NDAR_CODE N/A)
Lat. 21.580
Long. -158.170 (ditch mouth)

**Coastal Processes:**
Makaleha Ditch is located on the Mokuleia side of the north shore of Oahu. It is typically blocked by beach sand. The stream is approximately 100 ft in width. The beach is primarily fine carbonate sand with carbonate rock outcropping at the base of the foreshore. The north shore of Oahu is exposed to large swell energy in the winter from the northeast to the west. The majority of large swell events occur between the months of October and March. Tradewinds approach this coastline from the east, producing longshore sediment transport.
Coastal Processes

Makaleha Stream is located on the Mokuleia side of the north shore of Oahu. The stream is less than 50 ft in width and it typically blocked by beach sand. The beach is primarily fine carbonate sand with carbonate rock outcropping at the base of the foreshore. The north shore of Oahu is exposed to large swell energy in the winter from the northeast to the west. The majority of large swell events occur between the months of October and March. Tradewinds approach this coastline from the east, producing longshore sediment transport.

Makaleha Stream (perennial, NDAR_CODE 36004001)
Lat. 21.579
Long. -158.167 (stream mouth)

Photo 1. December 14, 2009 looking west down the beach and across the stream mouth.

Photo 2. December 14, 2009 looking down the stream mouth from mid-beach.
Coastal Processes:
Aweoweo Stream mouth is located on east Mokuleia Beach just west of Kaiaka Bay on the north shore of Oahu. The beach in this area is composed of medium carbonate sand and ranges in width from approximately 40 to 70 ft. The reef at this location is wide so the majority of long period wave energy is dissipated. However, tradewinds and currents moving across the reef surface deliver substantial energy to the beach and determine sediment transport. Tradewinds arrive from the east, hence transport at the stream mouth is predominantly from east to west.

Aweoweo Stream (non-perennial, NDAR_CODE 36019001)
Lat. 21.582
Long. -158.130 (stream mouth)
Kiikii Stream

Kaiaka Bay

Photo 1. December 13, 2009 looking east and seaward.

Photo 2. December 13, 2009 looking landward at stream mouth.

Kiikii Stream (Perennial, NDAR_CODE 36007001 Paukauila, 36006001 Kiikii)
Lat. 21.577
Long. -158.261 (stream mouth)

Coastal Processes:
Kaiaka Bay is a small bay on the north shore of Oahu. Kiikii stream and Paukauila Stream converge here and form one stream mouth. There is no beach to the west. The beach to the east is a mix of carbonate sand and terrigenous sediment.
Coastal Processes:
Paukauila Stream enters Kaiaka Bay at Haleiwa on the north shore of Oahu. The stream is open throughout the year and largely protected from ocean waves. Sedimentation in the area is dominated by terrigenous mud and little carbonate sand is found. The stream mouth is estuarine and tidal.
Coastal Processes:
Anahulu River mouth is located in Waialua Bay in Haleiwa Harbor on the north shore of Oahu. The stream is approximately 60 ft wide where it enters the ocean. The west bank is hardened and acts as the eastern boundary of the harbor. The east bank is also hardened but does not extend offshore. The sand in this area is calcareous ranging from carbonate silt to coarse gravel sized clasts. There is a sand bar at the mouth of Anahulu River that changes position and shape reflecting waves and current conditions.
Loko Ea Stream is located on the north side of Haleiwa on the north shore of Oahu. The stream mouth is inside Haleiwa Harbor and as a result is sheltered from most wave energy. The waters are estuarine and tidal.

**Loko Ea Stream** (Perennial, NDAR_CODE 36009001)
- Lat. 21.577
- Long. -158.261 (stream mouth)

**Coastal Processes:**
Loko Ea Stream is located on the north side of Haleiwa on the north shore of Oahu. The stream mouth is inside Haleiwa Harbor and as a result is sheltered from most wave energy. The waters are estuarine and tidal.

**Photo 1.** December 14, 2009 looking behind the bridge at the stream mouth.
**Photo 2.** December 14, 2009 looking at the stream mouth from the east side of the bridge.
Coastal Processes:
Laniakea Stream mouth is located on the north shore of Oahu on Laniakea Beach. This stream is typically blocked by sand. Immediately to the north, fossil reef outcrops at the beach toe and continues to the north end of the beach. South of the stream mouth is a long and sandy beach. The position of the beach toe in this area can vary depending on swell intensity and direction. During north swell in the winter months, the longshore current generally runs from the north. Tradewinds approach from the east; hence, longshore transport tends to be to the west.

Laniakea Stream (perennial, NDAR_CODE 36020001)
Lat. 21.577
Long. -158.261 (stream mouth)

Photo 1. December 5, 2009 looking across the stream on the landward side of the bridge.

Photo 2. December 5, 2009 looking landward at the bridge from Laniakea Beach.
Coastal Processes:

Kawailoa Stream mouth is located on the north shore of Oahu on Kawailoa Beach. It is typically blocked by beach sand. Approximately 600 ft to south there a basalt rock headland marks the end of the littoral cell. The stream mouth is approximately 30 to 50 ft in width. This region is exposed to large seasonal swell energy from the north and west. Trade winds approach from along the shoreline from the east. The beach is primarily fine to medium grained carbonate sand.

Kawailoa Stream
(non_perennial, NDAR_CODE 36021001)
Lat. 21.623
Long. -158.081 (stream mouth)
Kaalaea Stream is located at the north end of Kawailoa Beach on the north shore of Oahu. The beach at this location tends to be sand-depleted and is a mixture of coarse carbonate sand and basalt boulders. The stream is narrow (~10 ft). This location is exposed to strong, but seasonal swell from the north and west in winter, and lies in the lee of tradewinds that blow throughout the year.

**Kaalaea Stream (non-perennial, NDAR_CODE 36022001)**
Lat. 21.628
Long. -158.074 (stream mouth)

**Coastal Processes:**
Kaalaea Stream mouth is located at the north end of Kawailoa Beach on the north shore of Oahu. The beach at this location tends to be sand-depleted and is a mixture of coarse carbonate sand and basalt boulders. The stream is narrow (~10 ft). This location is exposed to strong, but seasonal swell from the north and west in winter, and lies in the lee of tradewinds that blow throughout the year.
Coastal Processes

Waimea Stream mouth is located in Waimea Bay on the north shore of Oahu. This beach is a pocket beach and bound in the north and south by basaltic headlands. The stream mouth is typically blocked by beach sand. The beach is primarily fine to medium grained calcareous sand. Tradewinds blow offshore at this location. The beach has a steep cross-section with deep offshore waters; hence wave energy can be extremely variable but is strong in the winter. This stream mouth is exposed to winter swell from the west through northeast.

**Waimea Stream** (NDAR_CODE 36010001)

Lat. 21.641
Long. -158.063 (stream mouth)

Photo 1. December 14 2009 from Waimea Beach up toward the stream mouth.

Photo 2. December 14, 2009 looking toward Waimea Bay with stream in back ground.
Coastal Processes:

Kalunawaikaala Stream mouth is located on Ke Iki beach on the northern shoreline of Oahu. The stream mouth is approximately 30 to 50 ft across and is typically blocked by beach sand. Ke Iki Beach is primarily composed of fine to coarse carbonate sand and ranges in width from 100 to 200 ft. The beach terminates to the south into a large carbonate headland. The north shore of Oahu is exposed to high winter swell energy from the northeast through the west, and yearlong energy from the northeast tradewinds.
Coastal Processes

Pakulena Stream is located on the north shore of Oahu. It is typically blocked by beach sand. This area is exposed to large swell energy in the winter and tradewind waves throughout much of the year. The beach is primarily fine to medium carbonate sand and is transported largely from east to west along the shoreline.

Photo 1. November 29, 2009 looking seaward from the road, down the stream bed.

Photo 2. November 29, 2009 looking northeast and across the stream bed.

Pakulena Stream (intermittent, NDAR_CODE 31002001)
Lat. 21.661
Long. -158.058 (stream mouth)
Paumalu Gulch is located at the southwest end of Sunset Beach on the north shore of Oahu. The north shore of Oahu is exposed to large swell energy in the winter season and tradewinds throughout the year. The beach is primarily fine to medium grained carbonate sand and the stream is typically blocked by beach sand.

**Paumalu Gulch** (intermittent, NDAR_CODE 31003001)

- **Lat.** 21.673
- **Long.** -158.042 (stream mouth)

**Coastal Processes**

Paumalu Gulch is located at the southwest end of Sunset Beach on the north shore of Oahu. The north shore of Oahu is exposed to large swell energy in the winter season and tradewinds throughout the year. The beach is primarily fine to medium grained carbonate sand and the stream is typically blocked by beach sand.
Kaunala Stream mouth is located on the north shore of Oahu. The beach at this location ranges between 50 and 150 ft wide and is typically blocked by calcareous beach sand. Tradewinds at this location blow alongshore from east to west. Energy from large northerly swell impinges on the beach and shapes morphologic changes.

Kaunala Stream (non-perennial, NDAR_CODE 31023001)
Lat.  21.681
Long. -158.034 (stream mouth)

Coastal Processes
Kaunala Stream mouth is located on the north shore of Oahu. The beach at this location ranges between 50 and 150 ft wide and is typically blocked by calcareous beach sand. Tradewinds at this location blow alongshore from east to west. Energy from large northerly swell impinges on the beach and shapes morphologic changes.
Waialae Stream mouth is located on the North shore of Oahu just SE of Kawela Bay. This area of coast is exposed to side onshore trade winds and trade wind generated swell. This area is also exposed to larger swell or of the directions ranging from NE through W.

Waialae Stream (Non-Perennial, NDAR_CODE, 31025002)
Lat. 21.691
Long. -158.022 (stream mouth)

Coastal Processes
Waialae Stream mouth is located on the North shore of Oahu just SE of Kawela Bay. This area of coast is exposed to side onshore trade winds and trade wind generated swell. This area is also exposed to larger swell or of the directions ranging from NE through W.
Kahawainui Stream mouth is located in Laie on the northeast shore of Oahu. The stream is channelized landward of the bridge and its mouth is typically blocked by beach sand. Seaward of the bridge the stream remains wide but it is in a natural state. Tradewinds blow onshore on this location. Large waves are generally blocked due to the presence of Goat Island and a fringing reef.

Kahawainui Stream

Kahawainui (NDAR_CODE 31007001)
Lat. 21.633
Long. -157.921 (stream mouth)

Coastal Processes:
Kahawainui Stream mouth is located in Laie on the northeast shore of Oahu. The stream is channelized landward of the bridge and its mouth is typically blocked by beach sand. Seaward of the bridge the stream remains wide but it is in a natural state. Tradewinds blow onshore on this location. Large waves are generally blocked due to the presence of Goat Island and a fringing reef.

Photo 1. November 30, 2009 looking northeast from the bridge.
Photo 2. November 30, 2009 looking down stream from the bridge toward the ocean.
Coastal Processes:

Laie Loa Stream mouth is located in Laie on the northeast shore of Oahu just north of Laie Point. The stream mouth is typically blocked by beach sand. Tradewinds blow onshore on this location. Large waves are generally blocked due to the presence of Goat Island, Laie Point and a fringing reef.

Laie Loa Stream (NDAR_CODE 31007001) This stream is labeled Laie Loa on the bridge but named Kaha-wainui in the Hawaii Statewide GIS database.

Lat. 21.633
Long. -157.921 (stream mouth)

Photo 1. November 30, 2009 looking landward at the bridge from the beach.

Photo 2. November 30, 2009 looking seaward, down stream from the bridge.
Coastal Processes

Wailele Stream mouth is located on the northeast shore of Oahu in Laie at the north end of Laie Beach Park. At this location two streams come together where they empty into the ocean. This stream mouth is typically plugged by sand. The beach is primarily fine to medium carbonate sand. This beach is bound by a carbonate rock headland to the south and a hardened stretch of shoreline to the north. Tradewinds blow onshore in this location the majority of the year. There is a narrow entrance to this bay through fringing reef so most northeast swell energy is dissipated before reaching the shoreline.

Wailele Stream (Perennial NDAR_CODE 31009001 Koloa, Perennial NDAR_CODE 31008001 Wailele)
Lat. 21.633
Long. -157.921 (stream mouth)
Koloa Stream mouth is located on the northeast shore of Oahu in Laie at the north end of Laie Beach Park. At this location two streams come together where they empty into the ocean. This stream mouth is typically plugged by sand. The beach is primarily fine to medium carbonate sand. This beach is bound by a carbonate rock headland to the south and a hardened stretch of shoreline to the north. Tradewinds blow onshore in this location the majority of the year. There is a narrow entrance to this bay through fringing reef so most northeast swell energy is dissipated before reaching the shoreline.

**Koloa Stream** (Perennial NDAR_CODE 31009001 Koloa, Perennial, NDAR_CODE 31008001 Wailele)

Hawaii Statewide GIS labels the south most stream here Koloa, Department of Facility Maintenance Division of Road Maintenance refers to this stream as Laie Wai.

Lat. 21.633  
Long. -157.921 (stream mouth)

**Coastal Processes:**
Koloa Stream mouth is located on the northeast shore of Oahu in Laie at the north end of Laie Beach Park. At this location two streams come together where they empty into the ocean. This stream mouth is typically plugged by sand. The beach is primarily fine to medium carbonate sand. This beach is bound by a carbonate rock headland to the south and a hardened stretch of shoreline to the north. Tradewinds blow onshore in this location the majority of the year. There is a narrow entrance to this bay through fringing reef so most northeast swell energy is dissipated before reaching the shoreline.
Coastal Processes:
Aakakii Stream mouth is located at the northern end of Kokololio Beach Park on Oahu’s northeast coastline. The beach in this area is primarily fine calcareous sand and generally ranges between 50 and 200 ft in width. This area is bounded by rocky Pali Kilo Ia to the north. Tradewinds blow onshore and slightly to the south at this location hence longshore transport is predominantly north to south.

Aakakii Stream (non-perennial, NDAR_CODE 31031001)
Lat. 21.627
Long. -157.921 (stream mouth)

Photo 1. November 30, 2009 looking south along Kokololio Beach.

Photo 2. November 30, 2009 looking north along Kokololio Beach.
Coastal Processes:

Aakakii Stream mouth is located at the northern end of Kokolololio Beach Park on Oahu's northeast coastline. The stream mouth is approximately 25 ft across. The beach in this area is primarily fin calcareous sand and general ranges between 50 and 200 ft in width. This area is bounded by Pali Kilo Ia in the north and shallow reef off the point at the south end of Kokolololio Beach park. Trade winds blow onshore at this location. Trade wind generated swell at this location is onshore however some of the energy is blocked from offshore reefs and the angle of the channel.
Coastal Processes:

Kokololio Stream mouth is located at Kokoloio Beach on the east shore of Oahu. The beach at this location is composed of carbonate sand and ranges in width from 15 to 50 ft. Fringing reef to the north and south dissipate much wave energy, but large events do impact the shoreline each winter season. The stream mouth is typically blocked with beach sand.
Coastal Processes:

Waipilopilo stream mouth is located in Hauula on Oahu's northeast coastline. Waipilopilo stream empties onto a fine carbonate sand beach that extends to Kaipapau stream approximately 200m to the north and to Kapalaoa Beach park in the south. To the north this beach becomes increasingly more narrow as the shoreline transitions from a dominant carbonate sand beach to a hard shoreline composed of cobble, silt and carbonate rock and sea wall. To the south the beach remains characterized by fine carbonate sand.

Waipilopilo Stream (Perennial, NDAR_CODE 310010004)
Lat.  21.615
Long.  -157.913 (stream mouth)

Photo 1. November 30, 2009 looking South from south bank.

Photo 2. November 30, 2009 looking North from south bank.
Coastal Processes:
Located at Kapalaoa Beach Park in Hauula, Maakua Stream mouth empties into the ocean on a primarily carbonate sand beach. Typically the stream mouth is partially or wholly blocked by beach sand. The stream is located at the southern boundary of a shallow fringing reef system and the northern boundary of a small sandy bay. The reef provides some protection to Maakua Stream mouth from seasonal north to north east swell and tradewind energy. The shoreline directly to the north is characterized by a narrow sand and cobble beach with a significant erosional scarp at the high waterline indicating an area of chronic erosion.
Coastal Processes

Waipuhi Stream mouth is located in Hauula on the east shore of Oahu. It is a channelized stream approximately 30 ft wide at the bridge, and typically blocked by beach sand. Hauula stream mouth empties into the ocean on a primarily fine carbonate sand beach. The stream is located at the head of a sand channel that cuts through the fringing reef. Tradewind waves approach from offshore and refracted north swell is seasonally prevalent. Discharge from the adjacent watershed governs the hydrology of the channel.

Hauula Stream (NDAR_CODE NA) This stream is not labeled on the Hawaii Statewide GIS database but is called Hauula Stream by the Department of facilities and Maintenance.
Lat. 21.607
Long. -157.907 (stream mouth)

Photo 1. November 30, 2009 looking south from the north side of the stream mouth
Photo 2. November 30, 2009 looking seaward from the bridge.
Waipuhi Stream

Waipuhi Stream mouth is located in Hauula on the east shore of Oahu. It is a channelized stream approximately 30 ft wide at the bridge, and typically blocked by beach sand. Waipuhi stream mouth empties into the ocean on a primarily fine carbonate sand beach. The stream is located at the head of a sand channel that cuts through the fringing reef. Tradewind waves approach from offshore and refracted north swell is seasonally prevalent. Discharge from the adjacent watershed governs the hydrology of the channel.

Waipuhi Stream (non-perennial, NDAR_CODE 31032001) This stream is labelled Hauula on the Hawaii Statewide GIS database but is called Wipuhi by the Department of facilities and Maintenance.

Lat. 21.607
Long. -157.907 (stream mouth)

Coastal Processes

Photo 1. November 30, 2009 looking seaward toward the stream mouth from the side of the road.

Photo 2. November 30, 2009 looking landward from stream mouth.
Coastal Processes

Meheiwi Stream mouth is located in Hauula on the east shore of Oahu. The stream empties into the ocean on a primarily fine carbonate sand beach and it is typically blocked by sand. Offshore of the stream mouth is a shallow fringing reef and a deep, sand-filled channel that cuts into the reef. Refracted north swell in the winter, and tradewind-generated waves throughout the year, govern sediment transport along the shoreline.

Meheiwi Stream (non-perennial, NDAR_CODE 31033001) This stream is labelled Meheiwi on the bridge but named Makao on the Hawaii Statewide GIS database
Lat. 21.607
Long. -157.906 (stream mouth)

Photo 1. November 30, 2009 looking south from the southern side of the stream mouth.

Photo 2. November 30, 2009 looking north across the stream mouth.
Waimanana Stream

Coastal Processes

Waimanana Stream is located in Hauula on the east shore of Oahu. The stream mouth, approximately 50 to 100 ft wide, is typically blocked by a small accumulation of beach sand. The immediate coastal segment is severely depleted with respect to sand and is characterized by seawalls and revetments protecting homes and the coastal highway. Adjacent to the stream mouth is a CRM and rubble mound jetty located to the north.
Coastal Processes:
Kaluanui Stream mouth is located on the east shore of Oahu in Hauula. The beach in this location is primarily fine to medium carbonate sand with small amounts of terrigenous sediment and gravel sized carbonate debris. The stream mouth is typically blocked by beach sand. Conditions are typical of the windward shoreline of Oahu with consistent onshore winds and generate small short period swell across the reef flat. The stream mouth is approximately 50 to 100 ft wide and the flow fluctuates depending on rainfall in the adjacent watershed.
Kapano Stream is located on the east shore of Oahu north of Kahana Bay. The stream is approximately 30 to 75 ft across and is typically blocked by beach sand. Tradewinds regularly blow onshore and from the north at this location. Tradewind swell and refracted seasonal north swell tend to be effectively dissipated by the shallow fringing reef, however at high tide additional energy does impinge onto the beach and transport sand. Small and short period waves are generated by the tradewinds across the fringing reef surface.

Kapano Stream (non-perennial, NDAR_CODE 31037001)
Lat. 21.583
Long. -157.887 (stream mouth)

Coastal Processes
Kapano Stream is located on the east shore of Oahu north of Kahana Bay. The stream is approximately 30 to 75 ft across and is typically blocked by beach sand. Tradewinds regularly blow onshore and from the north at this location. Tradewind swell and refracted seasonal north swell tend to be effectively dissipated by the shallow fringing reef, however at high tide additional energy does impinge onto the beach and transport sand. Small and short period waves are generated by the tradewinds across the fringing reef surface.
Punaluu Stream is located on the east shore of Oahu. The northern bank extends across the stream mouth as a sandy spit. This will close the channel on occasion depending on discharge from the adjacent watershed. Tradewinds and seasonal refracted north swell approach from directly offshore. The presence of the spit indicates that sediment transport is along-shore from the north.

**Coastal Processes**

Punaluu Stream mouth is located on the east shore of Oahu. The northern bank extends across the stream mouth as a sandy spit. This will close the channel on occasion depending on discharge from the adjacent watershed. Tradewinds and seasonal refracted north swell approach from directly offshore. The presence of the spit indicates that sediment transport is along-shore from the north.
Punaluu Ditch is located on the east shore of Oahu. The channel is narrow and flow is intermittent depending on discharge from the adjacent watershed. Typically the channel is blocked by beach sand. Tradewinds and seasonal refracted north swell approach from directly offshore.

Punaluu Stream (non-perennial, NDAR_CODE 31016047)
Lat. 21.577
Long. -157.881 (stream mouth)

Coastal Processes
Punaluu Ditch is located on the east shore of Oahu. The channel is narrow and flow is intermittent depending on discharge from the adjacent watershed. Typically the channel is blocked by beach sand. Tradewinds and seasonal refracted north swell approach from directly offshore.
Puupiei Stream is located in Kahana Bay on the East, windward shoreline of Oahu. The beach in Kahana Bay is primarily medium to fine grained carbonate sand. The beach ranges in width from 35ft to 120ft. Trade winds blow directly onshore at this location and trade wind swell is directly onshore. Offshore in Kahana Bay the bottom is sandy, shallow and gently sloping, dissipating onshore energy as it approaches the beach.

Puupiei Stream (non-perennial, NDAR_CODE 31018004 west mouth)
Lat. 21.557
Long. -157.876 (stream mouth)

Coastal Processes
Puupiei Stream is located in Kahana Bay on the East, windward shoreline of Oahu. The beach in Kahana Bay is primarily medium to fine grained carbonate sand. The beach ranges in width from 35ft to 120ft. Trade winds blow directly onshore at this location and trade wind swell is directly onshore. Offshore in Kahana Bay the bottom is sandy, shallow and gently sloping, dissipating onshore energy as it approaches the beach.
Coastal Processes

Kahana Stream is located in Kahana Bay on the east, windward shoreline of Oahu. Kahana Stream divides into two outflows at the shoreline which empty into the bay at central and eastern portions of the shoreline. The central outflow is typically blocked by beach sand, whereas the outflow to the east is often open. The beach in Kahana Bay is primarily medium to fine-grained carbonate sand and ranges in width from 35 to 120 ft. Tradewinds tend to blow onshore or from the northeast at this location. Tradewind and north swell refract into the bay so that they approach from directly offshore. The bottom is sandy, shallow and gently sloping, and tends to dissipate wave energy as it approaches the beach. The bay accretes sand from fringing reefs to the north thus contributing to stream mouth blockage.

Kahana Stream (non-perennial, NDAR_CODE 31018004 west mouth)
Lat. 21.556
Long. -157.875 (west stream mouth)

Photo 1. November 30, 2009 photo of the western mouth looking seaward and north out of Kahana Bay.

Photo 2. November 30, 2009 looking Landward under the bridge of the western most outflow of Kahana Stream.
Coastal Processes:

Kalae O'io Stream mouth is located on the east shore of Oahu in Kaaawa at Kalae O'io Beach Park and is typically blocked by beach sand. The beach at this location is primarily medium-grained carbonate sand with small amounts of terrigenous sediment. Consistent onshore tradewinds and small short period waves are the dominant influence on the coastline. Longshore transport is weakly to the north. Kaaawa Stream mouth is approximately 80 ft wide and the flow fluctuates depending on rainfall in the immediate watershed of Kaaawa Valley.

Kaaawa Stream (perennial, NDAR_CODE 31019001) This Stream is labelled as Kalae O'io on the bridge and as Kaaawa on the Hawaii Statewide GIS database.

Lat. 21.545
Long. -157.845 (south stream mouth)

Photo 1. November 30, 2009 looking seaward and south from the north side of the stream mouth.

Photo 2. November 30, 2009 looking landward and south back under the bridge.
Coastal Processes:

Kaelepulu Stream mouth is located at the southern end of Kailua Beach on Oahu's windward coast. It is typically blocked by beach sand. This location is characterized by east to northeast tradewinds that blow onshore the majority of the year. Kailua Bay has a broad but relatively deep carbonate reef system characterized by a major sand channel, sand fields, and encrusting coral and carbonate and calcareous algae. This reef system and blocking by Mokapu Peninsula immediately to the north are responsible for dissipating portions of seasonal north swell energy. However, the bay is open to tradewind energy. The stream mouth is also protected by Popoio Island located ~¼ mi offshore. Breaking wave height is typically <2 ft on the shoreline here. Near the stream mouth, Kailua Beach is composed primarily of fine carbonate sand that has undergone severe erosion in recent years. Dominant alongshore transport at the stream mouth is to the north.

Kaelepulu Stream:

(perennial, NDAR_CODE32014001)
Lat. 21.397
Long. -157.726 (stream mouth)

Photo 1. October 19, 2009 looking down stream from the bridge to the stream mouth.

Photo 2. October 19, 2009 sand from stream mouth clearing.
Coastal Processes

Waimanalo Stream is located in Waimanalo Bay on the south East shore of Oahu. This beach is composed of fine calcareous sand with no exposed rock except for the engineered jetties on the north and south sides of the stream mouth. This area of coast experiences onshore trade winds and trade wind generated swell. This area is exposed to large NE through E swell events but onshore energy is greatly reduced due to an extensive offshore reef crest.

Waimanalo Stream (non-perennial, NDAR_CODE 32015001)
Lat.  21.365
Long. -157.710 (stream mouth)
Inoaole Stream

Coastal Processes:
Inoaole Stream mouth is located in the middle of Waimanalo Beach on the eastern shoreline of Oahu. It is typically blocked by beach sand. Waimanalo Beach is composed primarily of fine calcareous sand. The beach ranges in width from 50 to 150 ft. Waimanalo Beach is curved; hence tradewinds blow both alongshore and directly onshore depending on location. At Kahe wai predominate tradewind energy approaches from offshore. Waimanalo Bay ranges in depth from 10 to 25 ft across a wide fringing reef. Thus the energy from large swell events is effectively dissipated and breaking wave heights at the shoreline are rarely more than 3-4 ft.

Inoaole Stream (non-perennial, NDAR_CODE 31018004)
Lat. 21.351
Long. -157.706 (stream mouth)

Photo 1. October 24, 2009 aerial image looking at Kahewai stream and Waimanalo Beach.

Photo 2. October 24, 2009 looking down Waimanalo Beach toward Kahewai Stream mouth.
Coastal Processes:

Kaiono Stream mouth is located at the southern end of Waimanalo Beach on the eastern shoreline of Oahu and is typically blocked by beach sand. The beach is composed primarily of fine calcareous sand and ranges in width from 50 to 200 ft. Waimanalo Beach is curved; hence tradewinds blow both alongshore and directly onshore depending on location. At Kaiono predominate tradewind energy approaches from offshore. Waimanalo Bay ranges in depth from 10 to 25 ft across a wide fringing reef. Thus the energy from large swell events is effectively dissipated and breaking wave heights at the shoreline are rarely more than 3-4 ft.
Coastal Processes:
Located in Hawaii Kai at Kuliouou Beach park, Kuliouou stream empties into Maunalua Bay through a channelized segment of the watershed. This area is typically calm as it is sheltered by the Koko Head headland. Tradewinds blow from east to west along the shoreline, though the stream mouth lies largely beyond their reach. A wide and shallow fringing reef creates calm conditions at the stream mouth and sediments are characterized by some carbonate sand mixed with fine terrigenous much from the watershed.

Kuliouou Stream (perennial, NDAR_CODE 33003001)
Lat. 21.284
Long. -157.722 (stream mouth)

Photo 1. October 24, 2009 looking landward toward Kalanianiole Hwy.

Photo 2. October 24, 2009 looking Southwest towards Hawaii Kai back reef.
Coastal Processes:
Pia Stream mouth is located between Wailupe Peninsula and Hawaii Kai boat ramp on the southern shoreline of Oahu. The beach is narrow, typically less than 30 ft wide and is often absent at high tide. The beach is primarily carbonate sand with varying amounts of terrigenous sediment. This area of coast is heavily armored with seawalls. A broad fringing reef blocks the majority of swell energy and waters are typically shallow, <4 ft. The stream is channelized and typically blocked with a mixture of sand and mud.

Pia Stream (perennial, NDAR_CODE 33004001
Lat. 21.280
Long. -157.738 (stream mouth)

Coastal Processes:
Pia Stream mouth is located between Wailupe Peninsula and Hawaii Kai boat ramp on the southern shoreline of Oahu. The beach is narrow, typically less than 30 ft wide and is often absent at high tide. The beach is primarily carbonate sand with varying amounts of terrigenous sediment. This area of coast is heavily armored with seawalls. A broad fringing reef blocks the majority of swell energy and waters are typically shallow, <4 ft. The stream is channelized and typically blocked with a mixture of sand and mud.
Coastal Processes:

Wailupe Stream mouth is located on the eastern side of Wailupe peninsula on the southern shoreline of Oahu. The beach in this area is narrow, typically less than 30 ft wide and often absent on high tide. The beach is primarily carbonate sand but also has a varying amount of terrigenous sediment mixed in. This area of coastline also has a large proportionate amount of sea walls. The back reef in Wailupe is extensive, located approximately 900 ft offshore. Backwaters are typically less than 1m in depth. Typical conditions for this area are consistent trade winds and trade wind swell as well as southerly ground swell. The presence of the reef crest protects the shoreline from the majority of the onshore energy. Wailupe stream mouth has hardened banks and is less than 60 ft wide.
Coastal Processes

Waialae Iki Stream mouth is located in Kahala between Black Point and Wailupe Peninsula. This area of coastline is exposed to side onshore trade winds and swell ranging in direction from SE to SW. There is a shallow back reef (<6ft deep) and an extensive and shallow fringing reef that provide the shoreline with protection against onshore energy.
Coastal Processes:
Waialae Nui Stream mouth is located in Kahala between Black Point and Wailupe Peninsula. This area of coastline is exposed to tradewinds from the east and refracted south swell that is largest in summer months. A shallow fringing reef (<6 ft deep) provides the shoreline with protection against onshore energy although at high tide currents may develop.

Waialae Nui Stream (perennial, NDAR_CODE 33060011) This stream is named Waialae Nui in the Hawaii Statewide GIS database but called Kapakahi Stream by the Department of Facilities and Maintenance
Lat.  21.269
Long.  -157.777 (stream mouth)
Coastal Processes

Kahala Stream mouth is located several hundred feet west of Waialae Beach Park in Kahala on Oahu's southern shoreline. Kahala Stream empties onto a shallow reef flat in water typically <4 ft deep. Southern swell and tradewind swell are common at this location, but due to the fringing reef much of the energy is dissipated offshore at low tide. However, along-shore currents can be strong during southern swell at high tide. Tradewinds in this area typically blow onshore or from the northeast.

Kahala Stream (non-perennial, NDAR_CODE 33017001) This stream is named Kahala in the Hawaii Statwide GIS database but called Waialae stream by the Department of Facilities and Maintenance
Lat.  21.267
Long. -157.779 (stream mouth)


CD. (See also: http://geopubs.wr.usgs.gov/open-file/of01-308)

American Society of Civil Engineers, p. 67-81.


13. Hampton et al., 2003) provides original research on sand fields using sub bottom geophysical data and vibracore analysis to confirm the character of the sand fields. An analysis of reef-top sand field resources at Waikiki, performed for the Hawaii State Geology Group. The data are provided in map form in this report. This data informed the decision-making with regard to the Kuhio Beach renourishment project (Eversole, 2004). Similar seismic data and cores from fields around the entire island of Oahu.

14. Support for preparing this report was provided by the U.S. Army Corps of Engineers. Additional work has been performed under commercial contracts.

Several recommendations emerge from this review:

- More research is needed on the U.S. Army Corps of Engineers' ability to locate and characterize reef-top sand resources.
- Further research is needed on the U.S. Army Corps of Engineers' ability to assess the potential for nourishing Greys Beach, Waikiki with approximately 15,000 yd^3 of sand.
- The "Reef Runway" sand field fronting the Honolulu airport has been identified as a potential source of sand for nourishing Waikiki. However, further assessment is needed to confirm the potential for nourishing Greys Beach, Waikiki with approximately 15,000 yd^3 of sand.
- Offshore sand assessment for fields on the leeward coast (pending the analysis in Hampton et al), and Maunalua Bay are justified as these locations are proximal to Waikiki.
- Sand needs on Maui are significant. Further assessment is justified at West Maui and the north shore.
- Sand fields deemed viable as a beach resource using preliminary tactics (i.e., diver deposit. Surface samples, jet probing) will need vibracore analysis to confirm the character of the sand deposits.
- A large field of thick coarse carbonate sand fronting the fringing reef there (in depths of 15 to 80 ft) would be justified.
- Additional research is needed on the U.S. Army Corps of Engineers' ability to assess the potential for nourishing Greys Beach, Waikiki with approximately 15,000 yd^3 of sand.
Figure 6: Jet probing of sand bodies in Waikiki reveals sand thickness from which sand body volumes may be calculated.
Figure 5: Diamond Head reeftop sand resources. Results indicate approximately 87,000 m² of non-ephemeral sand within the Diamond Head sand body area calculation extent (right shaded area).

Legend:
- Ephemeral sand - historic
- Ephemeral sand - modern
- Non-ephemeral sand bodies

Diamond Head sand body area calculation extent:
- 25 m
- 20 m
- 15 m
- 5 m
- 10 m
- 30 m

157°47'30"W 157°48'W 157°48'30"W 157°49'W 157°49'30"W 157°50'W

21°16'N

Legend:
- Non-ephemeral sand bodies
- Ephemeral sand - modern
- Ephemeral sand - historic
Figure 4 Waikiki reeftop sand resources. Results indicate approximately 460,000 m³ of non-ephemeral sand within the Waikiki sand body area calculation extent (light shaded area).
Figure 3: Iroquois Pt. reeftop sand resources. Results indicate approximately 100,000 m$^2$ of non-ephemeral sand within the Iroquois Pt. sand body area calculation extent (light shaded area).
The jet probe is built from a small diameter pipe connected to a high-pressure water pump via fire hose. High-pressure water is pumped out of the pipe to displace sediment as the diver pushes it into sandy substrate. A volume of sediment is washed out of the hole by water pressure (called "outwash") affording observations of buried sediment texture, composition, and color. The probe stops penetrating when it contacts a boundary with bedrock or an impenetrable layer of consolidated sediment. Depth of penetration provides a measure of unconsolidated sediment thickness. The probe length is 3.0 m; if sand body thickness exceeds 3.0 m, a value of 3.1 m is recorded. Among reef-top sand bodies, few fields exceed the 3.0 m length of the probe. These sand bodies could be considerably thicker; hence all thickness interpolation labeled as 3.0 m and should be considered a minimum estimate. At each sample location three thickness measurements were taken within a 20 m radius of the anchored boat and the average is used.

**Sand Body Research**

The State of Hawaii and the island of Oahu (in particular), have a long history of offshore sand research. The primary references describing this work are Dollar (1979), who summarizes the early work, and Barry (1995) and Sea Engineering (1993) who update the summary to 1995. Sea Engineering offshore sand fields.

2000's for volume calculation methods.

The nearshore area is characterized by a single sand body between 5 and 10 m water depth. The Iroquois Pt. Harbor Channel and Ewa Beach contains approximately 100,000 m$^2$ of stable sand. The nearshore area of the west of Pearl Harbor Channel (see Figure 2) contains approximately 490,000 m$^2$ suspended sediment in the shallow water.

Modern coverage in these areas indicates significant modern sand bodies offshore of Ewa Beach Park to the west of Pearl Harbor Channel (see Figure 2). However, no apparent bottom is visible in historic imagery due to large amounts of suspended sediment.

Sand body analysis of the south shore of Oahu between Ewa Beach and Black Point indicates approximately 680,000 m$^2$ of non-ephemeral sand. The extent of mosaic coverage offshore of Ewa Beach that are considered consistent with reef and hard bottom interspersed with sand pockets and fields in 0 - 15 m water depth. Sandy area that is unchanging between historical and modern coverage. Historic and modern coverage is used to quantify and compare the size and spatial extent of modern and historical sand body data; these provide sand body surface area. The extent of mosaic coverage offshore of Ewa Beach to the west of Pearl Harbor Channel (see Figure 2) contains approximately 490,000 m$^2$ of non-ephemeral sand. The remaining section of the study area between Black Point and Diamond Head (Figure 5) contains approximately 87,000 m$^2$ of non-ephemeral sand. The Iroquois Pt. Harbor Channel and Ewa Beach contains approximately 100,000 m$^2$ of stable sand. The nearshore area of the west of Pearl Harbor Channel (see Figure 2) contains approximately 490,000 m$^2$ suspended sediment in the shallow water.