CHANGES IN RIVERINE HYDROLOGY ON ST. THOMAS, U.S. VIRGIN ISLANDS: A PILOT STUDY

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LIST OF ACRONYMS

APC	Area of Particular Concern
CDC	Conservation Data Center
cfs	cubic feet per second
DPNR	Department of Planning and Natural Resources
EPA	Environmental Protection Agency
GIS	Geographic Information System
GPD	gallons per day
GPS	Global Positioning System
USGS	United States Geological Survey
USVI	United States Virgin Islands
UVI	University of the Virgin Islands

ABSTRACT

Streams were traditionally the major source of freshwater in the U.S. Virgin Islands. In addition, the streams, and the watercourses through which they flowed, provided diverse habitats for wildlife, and thereby food and recreational opportunities for residents of the U.S. Virgin Islands.

Since the 1690s, development pressures have impacted negatively on these streams and watercourses, by changing the land-use patterns in the associated watersheds, and in more recent years, altering the watercourses themselves. These changes affected the consistency and volume of stream flow, resulting in the need to develop other sources of potable water, notably wells and community catchments.

The existence of these alternate sources of water has reduced the level of attention paid to streams and the protection of watercourses. However, the traditional uses of streams and watercourses still continue, and for some farmers on St. Thomas, watercourses still form the major source of water for agriculture.

This pilot study was designed to ascertain whether there is any direct link between land-use patterns, increased surface runoff, and reduced stream flows. The study was also intended to identify community uses of watercourses, as well as recommend future research opportunities associated with freshwater systems.

The timeframe during which the study was conducted proved to be too short to undertake the detailed research necessary to verify the afore-mentioned assumptions. However, it was determined that stream flows have changed since the 1960s. In addition to changing flow patterns, the streams are increasingly being contaminated as a result of inappropriate land management practices.

Consultations with members of the community also confirmed that the community still uses watercourses as a source of water and recreation.

The report concludes by recommending six areas of potential study associated with freshwater resources and watercourses in the U.S. Virgin Islands. There research topics are:

- Development of a policy framework and plan for management of watercourses;
- Assessment of the feasibility for development of community water supply systems for agricultural purposes;
- Development of a hydro-geological model for land-use planning;
- Conducting a characterization of the watersheds contributing to the recharge of the Kingshill Area Aquifer;
- Conducting a statistical review of stream discharge data from streams in the U.S. Virgin Islands; and
- Biodiversity assessment of freshwater fauna in the U.S. Virgin Islands.

CHANGES IN RIVERINE HYDROLOGY ON ST. THOMAS, U.S. VIRGIN ISLANDS

1. INTRODUCTION

St. Thomas, with a size of approximately 31 sq. miles (81 km^2), is the second largest island in the group of islands forming the United States Virgin Islands (Figure 1). The island is 13 miles long by 4 miles wide, and is aligned on an east to west axis. The topography of the island is fairly hilly, consisting of a main ridge running east to west along the center of the island, smaller branching ridges, and a small percentage of flat land. The island is volcanic in nature, with a shallow cover of mixed clay soils. The highest point is Crown Mountain, which reaches an elevation of 1,556 ft. (475 m).

The Unified Watershed Assessment Report (Department of Planning and Natural Resources, 1998) states that, on St. Thomas, "*more than 70% of the land surface has a slope that exceeds 35 degrees*". Additionally, the 2004 Wetlands Inventory Report (Devine et al, 2004) indicates that, due to the steep slopes, "*Greater amounts of rainfall and runoff quickly gather and flow into the marine environment*". Though the latter report is focused on the impact of land-based pollutants on the marine environment, both the pollution loadings and the changed flow regimes have major impacts on the consistency of flow in the streams, as well as the stream ecology.

Though much is not currently known about the ecology of the streams, the habitat value of the vegetation in the watercourses (guts) is believed to be high. The high comparative value results primarily from the low habitat diversity in many of the watersheds on St. Thomas, a situation derived from the level of past and current disturbance in the watersheds. Watercourses (guts) form some of the most diverse habitats on the island, and are therefore highly valuable from an ecological perspective (Devine et al, 2004, and Thomas and Devine, 2005).

In addition to the variety of terrestrial habitats provided by guts, they also provide the primary freshwater habitats in the United States Virgin Islands (USVI). This is due to the fact that there are few natural freshwater ponds in the USVI, and streams flow only intermittently. The larger guts contain numerous small pools, which support a variety of freshwater fauna (e.g. fish and shrimp).

Historically, both the terrestrial and aquatic gut habitats provided food for human consumption (birds, shrimp, and fish) and spaces for recreational activities. Just as important, streams provided much of the potable water for St. Thomas during the period 1690 to the late 1950s (Olasee Davis, personal communication[1]). The changing development pattern on St. Thomas resulted in changes in the runoff regime, necessitating the establishment of wells and other community water supply systems (catchments) to provide water for the general population.

[1] This information was compiled for a newspaper article, which was eventually printed in The Daily News, Wednesday, May 2, 2007 (page 22).

Today, guts remain threatened landscapes, with direct and indirect impacts resulting from construction activities and other poor land management practices.

Figure 1: Map of the U.S. Virgin Islands

2. PROBLEM DESCRIPTION

The main sources of potable water in the United States Virgin Islands (USVI) were traditionally streams, springs, and rainfall. Though the streams have largely been reduced to only intermittent flow, they are still important for water supply and recreation. The 2004 State of the Environment Report for the USVI states that groundwater currently accounts for 30% of the water supply in the USVI, with approximately 706 public and private wells producing approximately 2,927,000 GPD (Division of Environmental Protection, 2004). The report also states that as much as 100% of potable water is provided by groundwater sources immediately following major disasters.

The Unified Watershed Assessment Report (Department of Planning and Natural Resources, 1998) notes that "*Nonpoint source pollution, as runoff, impairs more water bodies than any other source of pollution in the Virgin Islands*", and that "*Sediment - from dirt roads, farmlands, construction sites, urban encroachments, and other disturbed soils - is the primary nonpoint source pollutant threatening the islands' water resources*". The report further noted that, of the "… *numerous problems associated with nonpoint source pollution, the two primary problems affecting the Virgin Islands are sedimentation and bacterial contamination*".

The problem of sedimentation arises partially from the nature of the topsoil. The topsoil on St. Thomas is typically thin clay loam over rock, resulting in (a) low water storage capacity; (b) rapid runoff from even modest rainfall events; and (c) high levels of sedimentation in guts and the nearshore marine areas after rainfall events. The soil profile also makes it unsuitable for sub-surface disposal of sewage effluent, hence the problem with bacterial contamination. Thousands of septic systems are associated with residential development on St. Thomas, and the primary effluent disposal method from conventional septic systems is sub-surface disposal.

Programs to address threats to groundwater sources in the USVI have focused primarily on prevention of contamination. In addition, the past incidences of over-pumping of some wells have resulted in temporary closure of wells in a particular basin. In response, the USVI Department of Planning and Natural Resources (DPNR) developed a permitting system for the establishment and withdrawal of groundwater. Even with a permitting program in place, the resource is being depleted. For example, the Unified Watershed Assessment Report (1998) states that the groundwater table elevation in the Smith Bay area has declined from approximately 30-40 feet below ground level in 1990 to more than 100 feet below ground level at the time the report was compiled. The report also noted the low storage capacity of the geologic formations of the USVI, as well as the fact that "…*the denuding/paving of a significant portion of St. Thomas has had an effect on the increased velocity and volume of stormwater runoff*".

More recent studies conducted by researchers from the Cooperative Extension Services, University of the Virgin Islands (UVI), found that streams/guts are still used for recreational activities.

The importance of guts in the USVI is underscored by the protection offered in law (V.I. Code (Title 12, Chapter 13, Sections 121-125)), which prohibits the cutting of vegetation close to natural watercourses. Additional legislative attention is given to watercourses and streams in the following sections of the Virgin Islands Code:

- Title 7, Chapter 3 – Soil Conservation;
- Title 12, Chapter 1 - Wildlife;
- Title 12, Chapter 3 – Vegetation Adjacent to Watercourses;
- Title 12, Chapter 5 – Water Resources Conservation;
- Title 12, Chapter 7 – Water Pollution Control;
- Title 12, Chapter 9A – Commercial Fishing; and
- Title 12, Chapter 13 – Environmental Protection.

However, there is no program that translates the law into actual protection strategies or that offers protection of guts through the development control process. Additionally, physical planners and other environmental professionals have expressed concern that the continued residential development in the watersheds does not include adequate measures to reduce surface runoff.

The central premise of this study is that development patterns have increased surface runoff, thereby reducing groundwater recharge, and that this reduced recharge has resulted in reduced flows in streams. That furthermore, this reduced stream flow has affected not only the recreational uses of streams, but also influenced stream ecology.

3. METHODOLOGY

This study is designed essentially as a pilot study to test the above premise, and to use the results to recommend possible directions and scope for future detailed studies concerning stream hydrology and ecology in the U.S. Virgin Islands. The study included the following elements:

(a) Identification of changes in development coverage in selected watersheds;
(b) Identification of past and current uses of streams/guts;
(c) Determination of the distribution/range of selected species of fauna in selected streams/guts; and
(d) Determination of changes in discharge patterns of selected streams.

Six (6) watersheds were initially selected for study, representing north versus south and east versus west geographic spread across St. Thomas. Additional factors used in the selection of the watercourses/guts included; (a) their locations within the three watershed categories (unimpaired, moderately disturbed, and highly developed) identified by the Conservation Data Center in their 2004 wetlands inventory study; (b) whether the streams they contained have direct connections to the sea; and (c) the ease of access to the guts. This preliminary selection was made using the spatial database of guts maintained by the Conservation Data Center, University of the Virgin Islands. The six guts initially selected are located in the following watersheds:

- Botany Bay Watershed;
- Dorothea Bay Watershed;
- Frenchman's Bay Watershed;
- Perseverance Bay Watershed;
- Smith Bay Watershed; and
- St. Thomas Harbor Watershed.

Due to difficulty of access to one (1) gut (land ownership and terrain), and the absence of water in a second, only four (4) guts were eventually selected for observation and sampling for aquatic fauna.

Changes in the status of the selected watersheds were determined using the land use information from 1989 and 1999 contained in the geographic information system (GIS) maintained by the Conservation Data Center (CDC).

Information on the social uses of streams and guts was gathered from residents of St. Thomas, using a questionnaire (Appendix 1). The questionnaire was used primarily in an interview format, but was also distributed via email to persons who stated a preference for completing the questionnaire on their own.

The distribution of faunal species in the guts was determined by sampling the pools in the guts. The indicator species selected were shrimp and a goby. The shrimp was selected because they spend part of their life cycle in the sea and part in fresh water. It was assumed that since shrimp must migrate up the streams, any change in hydrology would likely affect the distribution of these species (assuming they were present in the streams in the past).

Additionally, previous work conducted by the Cooperative Extension Services, University of the Virgin Islands, indicated that both types of animal were present in streams in the U.S. Virgin Islands.

Sampling tools included dip nets and strainers (the dip nets became easily clogged in pools with detritus). The location of all pools sampled was mapped using global positioning system (GPS) technology (Appendix 2). Identification of species was conducted via internet searches of relevant literature and photo databases, such as those of the U.S. Fish and Wildlife Service and the University of Puerto Rico.

Changes in runoff regime from the watersheds were to be determined through an assessment of the discharge rates of two streams (Bonne Resolution and Turpentine Run) monitored by the U.S. Geological Survey.

The main limitation to this pilot study was the short time period available for field observations. The project should have commenced in July 2006, to ensure that both rain and dry seasons were covered. However, due to the unavailability of the researcher, the project did not start until January 2007, and was completed in April 2007.

4. FINDINGS

The four (4) guts that formed the focus of this pilot study were (Figures 2-5):

- Dorothea Bay Watershed – Bonne Resolution Gut;
- Smith Bay Watershed – gut leading to pond;
- Frenchman's Bay Watershed – gut between Green Cay Resort and Frenchman's Bay Resort; and
- St. Thomas Harbor Watershed – Contant Gut.

4.1 General Description of Guts

Bonne Resolution Gut

The main channel of the Bonne Resolution Gut starts high up in the watershed, close to the main ridge that runs along the east-west axis of St. Thomas, and drains to the northern coastline of the island. The drainage area for the gut is approximately 0.4 square miles (http://nwis.waterdata.usgs.gov/vi/nwis). The area of the watershed that drains to the gut is moderately disturbed by human activity, primarily agriculture and residential development. The vegetation in the upper reaches of the drainage basin is Gallery Forest, and the cover is mostly intact (Photo 1). The vegetation along the edges of the gut varies in density, structure, and diversity as the gut descends to the shoreline (Photos 2-4).

Photo 1: Sub-Watershed contributing to the Bonne Resolution Gut

The upper portion of the gut is characterized by a shallow channel, gentle-sloping sides, and a mixture of vines and shrubs growing within the channel (Photo 2). Pools of standing water are absent from this portion of the gut. The bottom of the channel is mainly rock, but a thin layer of soil is present.

Photo 2: Upper Portion of the Bonne Resolution Gut

From approximately 200 meters above (south of) the bridge to an area just south of the Dorothea Condominiums (on the coast), the gut gets increasingly steep, and is filled with large boulders (Photo 3). Trees (within the gut) are few in number along this stretch, but standing pools of water are numerous. The larger pools of water also support water reeds (Photo 4), indicating that some of the pools may be permanent. The largest pool of water in this gut was located at the mouth of the gut, where a sand bar formed a natural barrier (Photo 5). Some of the natural and man-made features along this strip of the gut were mapped using GPS (Figure 2 and Appendix 2).

In addition to the aquatic fauna that formed the focus of this pilot study, the gut supports other species of animals. These include numerous species of birds (particularly the White-crown Dove), iguanas, and goats.

Photo 3: Mid-channel of the Bonne Resolution Gut

Photo 4: Pool and Water Reeds

Photo 5: Sand Berm at Mouth of Gut

Dorothea Watershed

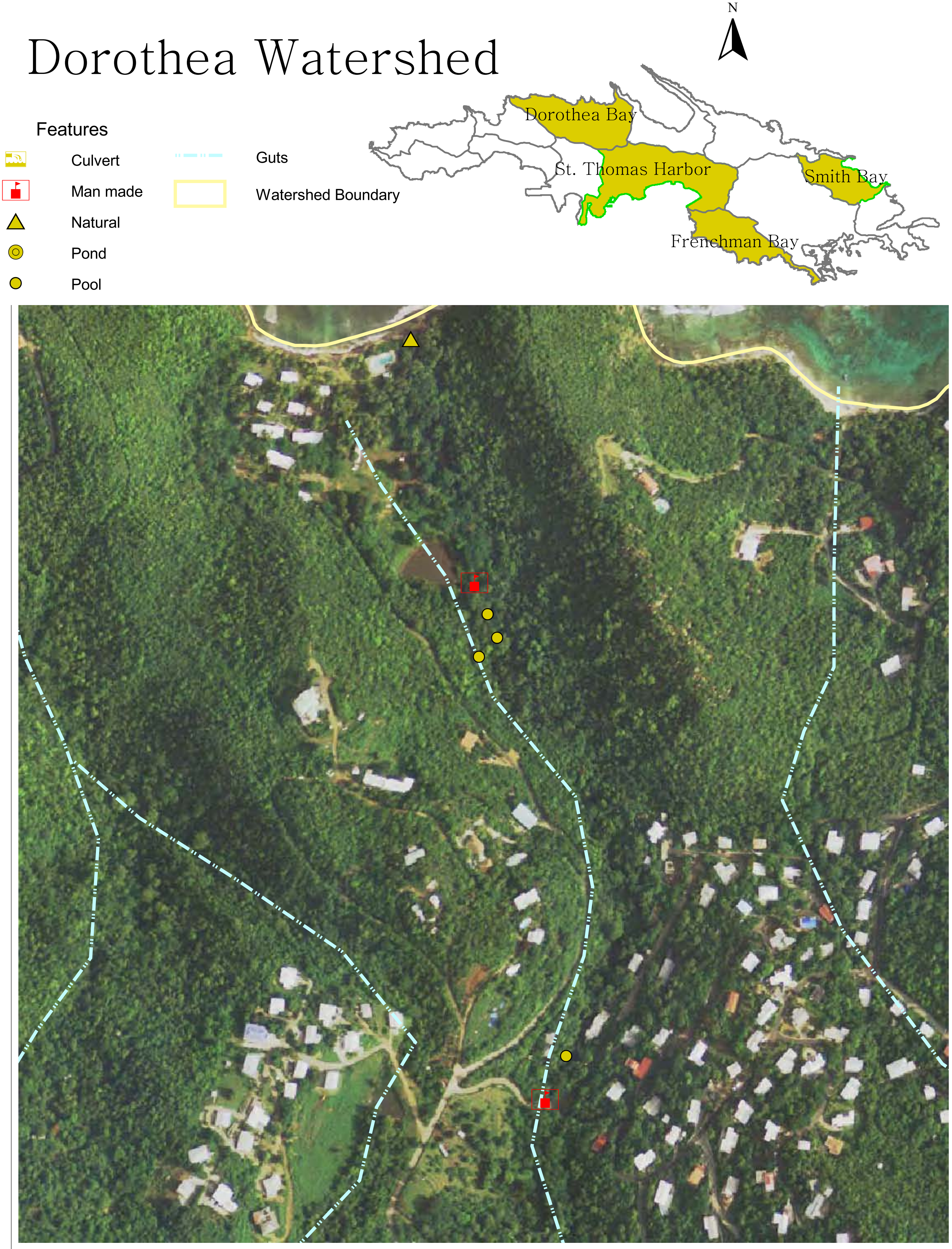


Figure 2: Data Points on the Lower Portion of the Bonne Resolution Gut

Smith Bay Gut

The area upslope of the main road (Route 38) is covered by mixed vegetation, primarily Tantan (*Leucaena leucocephala*). The area is gently sloping, and the channel is really a shallow drainage channel for surface runoff, not a true gut that supports a stream. In fact, the culvert across the main road does not appear to have required any special engineering work on either side of the main road (Photos 6 & 7).

The distance between the main road and the seashore is approximately 150 metres, and is mostly at sea level. The vegetation along the main road is composed of a narrow fringe of mixed vegetation (mostly *Acacia* sp. and Guinep), but the stand is dominated by White Mangrove (*Laguncularia racemosa*) and Seaside Mahoe (*Thespesia* sp.) (Photo 8). The raised sand berm along the coastline also supports mixed vegetation, dominated by *Acacia* sp. (Photo 9).

The moist nature of the sand, the presence of a dense network of crab holes, and the existence of breathing roots of the mangroves indicate that the site is inundated for long periods. There is a permanent pool at the end of the drainage channel (Photo 10 and Figure 3).

Photo 6: Western (Upslope) Side of Culvert along Smith Bay Main Road

Photo 7: Eastern (Downslope) Side of Culvert along Smith Bay Main Road

Photo 8: Vegetation between Road and Seashore

Photo 9: Vegetation on Sand Berm

Photo 10: Smith Bay Pond

Smith Bay Watershed

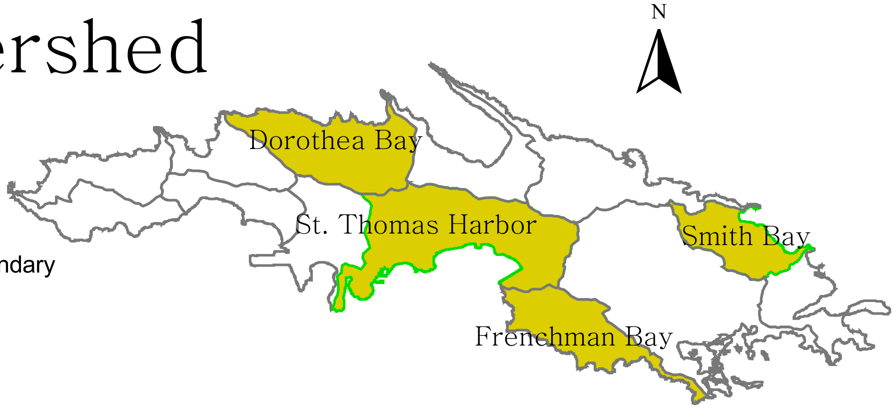


Figure 3: Data Points in the Smith Bay Gut

Frenchman's Bay Gut

The sub-watershed that drains to the Frenchman's Bay Gut is fairly small, and though the upper slopes are fairly steep, the discharge volume of the surface runoff is apparently insufficient to create a deep channel. In fact, the drainage channel up-slope (north) of the main road (Route 30) is almost undefined (Photo 11). Below the main road, the drainage channel is narrow and shallow (Photo 12). Approximately midway between the main road and the beach, the gut crosses the private (dirt) road on the Frenchman's Bay Development property. Below this private road, the gut smoothes out and essentially disappears as a flat area behind the beach (Photos 13 and 14)

Photo 11: Frenchmans' Bay Gut, above Main Road

Photo 12: Frenchmans' Bay Gut

Photo 13: Frenchmans' Bay Gut - crossing property road close to beach

Photo 14: Frenchmans' Bay Gut – flat area behind beach

No running water was observed in the Frenchman's Bay Gut, though a small number of very small pools were observed during two visits to the site. These pools, contained in rock, appeared to be simply leftover from surface runoff resulting from a rainfall event (Photos 15 and 16).

The locations of the main pool, as well as the man-made features, were mapped using GPS technology (Figure 4 and Appendix 2). However, none of the pools contained any of the faunal indicator species for this study. In fact, only tadpoles and dragonfly larvae were found in the pools.

The vegetation in the sub-watershed is essentially dry forest mixed with scrub. As such, both the surrounding forest and the gut support a large number of bird species (particularly doves), lizards, and iguanas.

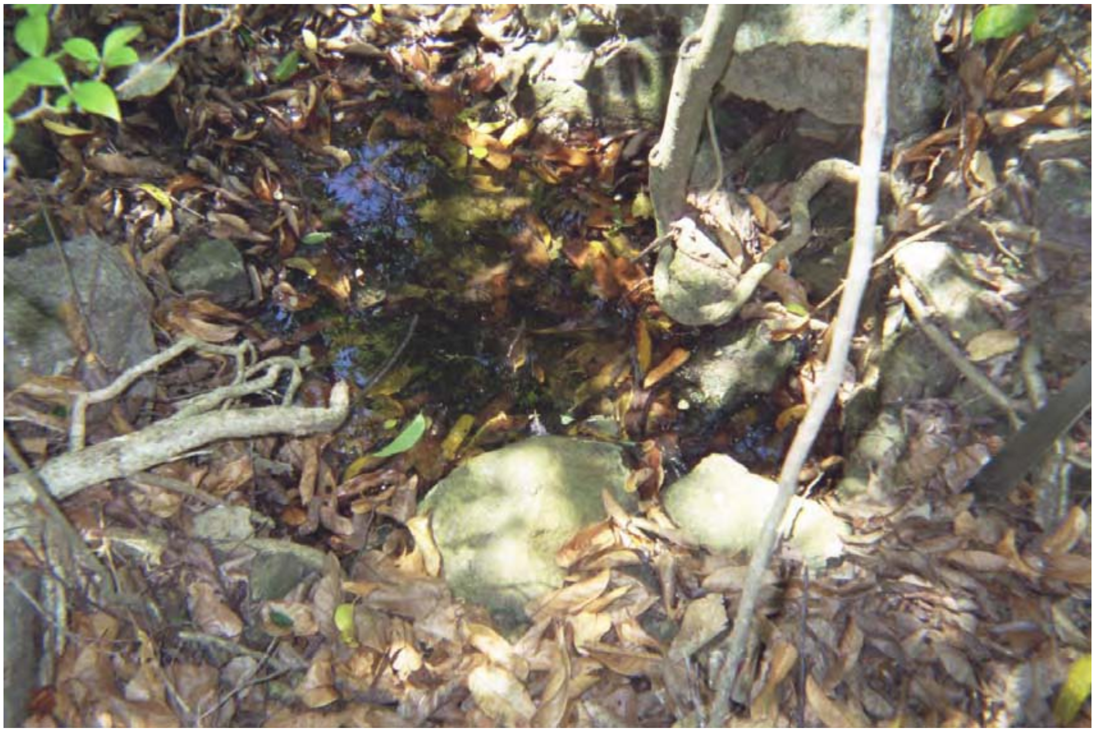


Photo 15: Pool in Frenchmans' Bay Gut

Photo 16: Largest Pool in Frenchmans' Bay Gut

Frenchman's Bay Watershed

Features

- Culvert
- Man made
- Natural
- Pond
- Pool
- Guts
- Watershed Boundary

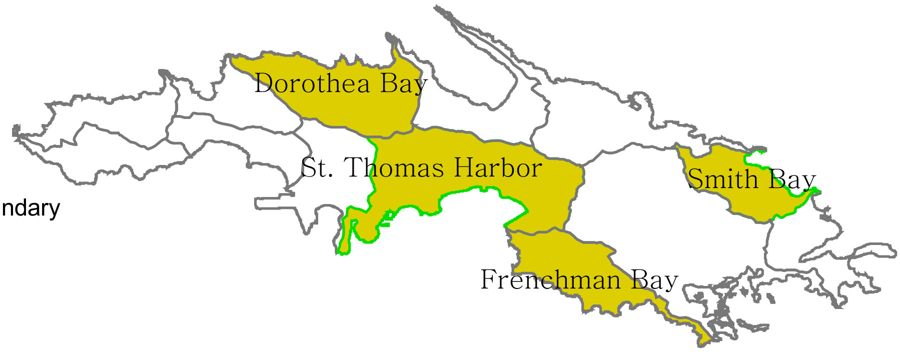


Figure 4: Data Points in the Frenchman's Bay Gut

Contant Gut

The Contant Gut starts in upper Contant/Scotsfree and enters the sea under the container port at Crown Bay. The sub-watershed drained by this gut has been significantly disturbed for residential development in the upper and middle portions (Photo 17), and by commercial development in the lower portions (Figure 5). As a result, this gut has been modified along its lower portion (from the Bridge Bar to the sea) to serve as a storm drain and to accommodate the development in that area.

The vegetation along the upper and middle portions of this gut is Gallery Forest. The gut retains a fairly good forest structure in the upper and middle portions (Photo 17), with the most mature stand (size and height of trees) occurring in the middle portion below the small "waterfall" (Photo 18). Coincidentally, this is also the portion of the gut that is deepest and in which the slope is steepest.

Pools of water of varying sizes (Photos 19 and 20) are found in the middle portion of the gut (immediately above and below the waterfall). There is a consistent, if very small, trickle of water over the falls that maintain the permanent pools below.

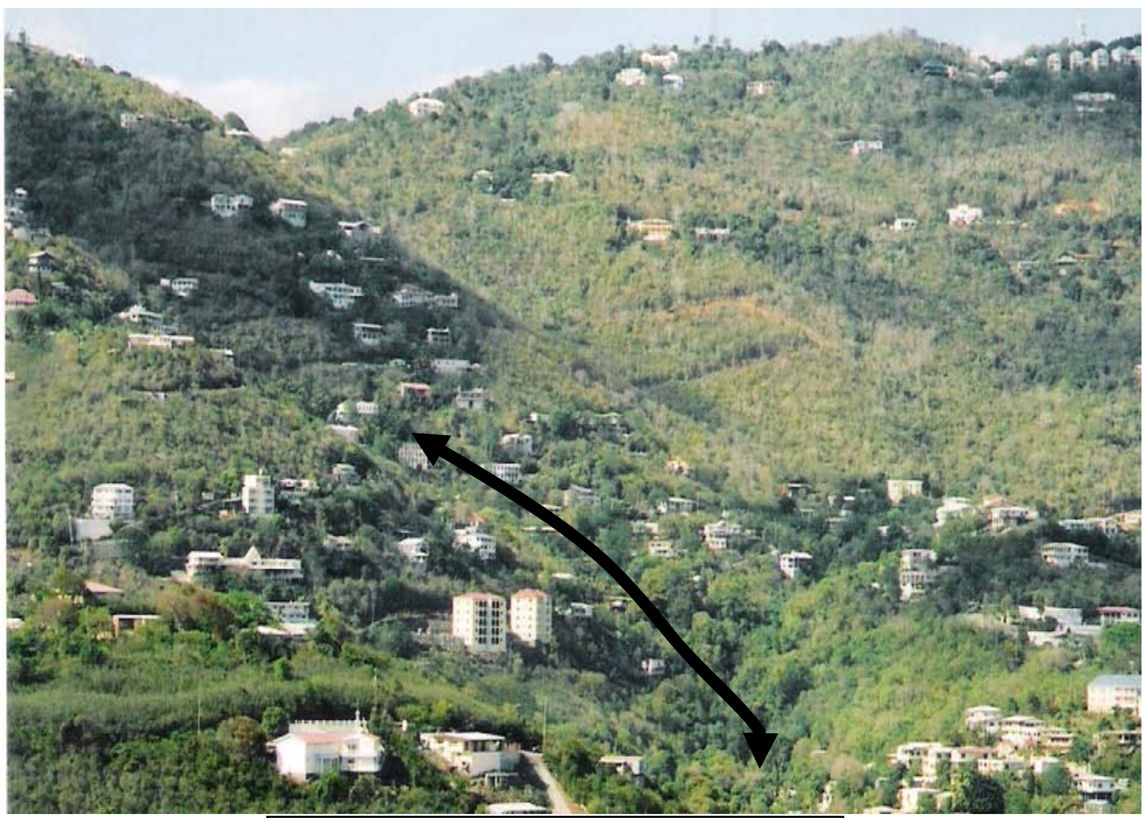
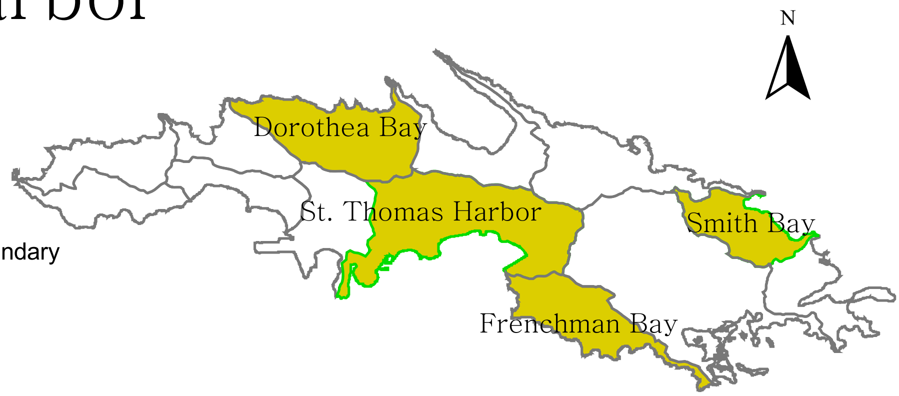


Photo 17: Upper Portion of Contant Gut

St. Thomas Harbor Watershed



Features

Culvert

Man made

Natural

Pond

Pool

Guts

Watershed Boundary

Figure 5: Data Points in the Contant Gut

Photo 18: Waterfall in Middle Portion of Contant Gut

Photo 19: Pool above Waterfall - Contant Gut

Photo 20: Pool immediately below Waterfall - Contant Gut

In spite of the steepness of the surrounding slopes, the gut itself is fairly shallow, and the only significant change in elevation takes place at the waterfall. The base of the gut is composed of soil in the upper portion, changing slowly to bedrock through the middle portion, and finally to a concrete storm drain at the lower portion.

The forested portions of the gut provide habitats for a variety of animals, primarily birds. The presence of White-crown Dove in this gut was noted almost exclusively in the forested area around the waterfall.

4.2 Distribution of Aquatic Fauna

As mentioned in Section 3, the indicator species selected were a shrimp and a goby. The major species identified were:

- Guppy – *Poecilia reticulate* (Photo 21);
- Mountain Mullet – *Agnostomus monticota* (Photo 22);
- Mozambique Tilapia – *Oreochromis mossambicus*;
- Shrimp[2] – *Atya* sp.;
- Crayfish[3] – *Macrobrachium* spp. (Photos 23 & 24); and
- Goby[4] – *Scydium* sp.

None of the species listed above was observed in the Smith Bay or Frenchman's Bay Guts. This is not surprising, given the fact that both guts are essentially drainage channels. Attempts to sample the Smith Bay Pond were unsuccessful, due primarily to the use of inappropriate sampling gear for the size of the water body. As such, the identification of the faunal species in the pond was not ascertained.

Of the above-listed species, only the guppy was found in the Contant Gut. The fish occurred in fairly large numbers in two pools immediately above the "waterfall", as well as in the pools immediately below the "waterfall".

In the Bonne Resolution Gut, the guppies were observed in pools occurring from the gauging station of the U.S. Geological Survey (USGS) to the pools immediately above (south of) the concrete revetment constructed across the gut south of the Dorothea Condominiums (see Figure 1 and Appendix 2 for data points). It was the species most commonly observed, most abundant, and most widely distributed (occurring in almost every pool found between the two points given above). The shrimp was also widely distributed in this gut. In contrast, the crayfish was observed in only five (5) pools in the lower portion of the gut (above the concrete revetment). Information provided by a resident of the Dorothea Condominiums indicate that large crayfish have been caught in the gut, primarily from the large pool at the end of the gut and the impoundment behind the USGS gauging station. The same person stated that fish of a size to be eaten have been caught in these latter two pools. That information was not verified during this study. However, Mountain Mullet (Photo 22) was observed in several pools, and though occurring in small numbers, the sizes observed suggest that they could reach a large enough size to be harvested as a food fish. Rarer still was the goby, found in only three (3) pools. The single *Tilapia* was seen in a large pool adjacent to a house immediately below the USGS gauging station.

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[2] The identification of the shrimp species is uncertain. The exact match could not be found in the databases searched. Previous work done by the Cooperative Extension Service (UVI) suggests that the shrimp may be an *Atya* species.

[3] The species of crayfish is either *M. heterochirris* or *M. carcinus*, based on the specimens observed in the field.

[4] The species of the goby is uncertain. The selection of the species is based on the white and yellowish stripes running along the body of the fish. However, since no specimen was actually captured, the identification could not be verified.

Photo 21: Guppy

Photo 22: Mountain Mullet

Photo 23: Crayfish

Photo 24: Carcass of Crayfish

The following factors should be taken into account in any consideration of the faunal species:

(i) The sampling equipment was not the most appropriate for sampling in rock pools with numerous crevices.

(ii) Sampling activities were restricted to the time of day when sunlight reached the floor of the gut, usually between 10:00 a.m. and 3:00 p.m. Outside of those hours the shadows cast by the canopy produced poor light conditions. The same effect is produced on overcast days. Additionally, some species, such as the crayfish, are also nocturnal feeders, and the middle of the day may not be the best sampling time.

(iii) A number of animals, primarily birds, capture fish in the pools, which may partially explain why fish and crayfish may be present in a particular pool on one field visit and missing the next.

(iv) Rainfall events may have also flushed pools between field visits.

Other species of fauna found in the three guts with standing pools were dragonfly larvae and tadpoles. On a visit to the Contant Gut on April 10, 2007, a Red-footed Tortoise (*Geochelone carbonaria*) was observed in a pool close to the foot of the waterfall (Photo 25).

Photo 25: Tortoise in Contant Gut

Information provided by the respondents to the questionnaire survey indicates that a range of animals were hunted/caught in guts on St. Thomas in the 1940s to 1970s (Section 4.3). These animals included fish, shrimp/crayfish, birds, and deer.

The available information indicates that guts provide a valuable habitat for a variety of species, both terrestrial and aquatic. However, those species are no longer as abundant as 50 years ago, and this reduction can be directly linked to shorter periods of continuous stream flow, development impact on the guts themselves, and pollution inputs to the guts.

4.3 Social Uses of Streams and Guts

A number of human uses of guts were observed during this study. Additionally, brief discussions with a small number of persons during the visits to the Bonne Resolution, Frenchman's Bay, and Contant Guts provided information on other uses. Current uses include:

(i) Recreation – catching shrimp, hiking, and provision of access to the beach (latter activity observed at Smith Bay).

(ii) Water Supply – for animals and crops.

(iii) Waste Disposal – solid waste, effluent, and construction waste (such as the concrete mix deposited into the Frenchman's Bay Gut). The construction of a small wooden building in the gut in upper Contant (Photo 26) suggests that guts may be used for sewage disposal by residents in isolated cases. Additionally, a number of sewerages operated by the V.I. Waste Management Authority use guts as discharge points when a treatment facility has to be bypassed to facilitate emergency repairs to a line or pump station.

(iv) Spiritual Renewal – This explanation was provided by a resident when questioned about the "rock art" observed in the Bonne Resolution Gut (Photo 27).

The three respondents to the survey also identified past and current uses of guts and streams. Guts and streams on St. Thomas identified as supporting community uses in the past include Upper Hospital Ground, Lower Carret Bay, Contant (John Dunkuh), deJongh Gut, Mahogany Estate, Boschulte Gut, Neltjiberg Gut, and Magens Bay Gut.

Photo 26: Building in Contant Gut

Photo 27: 'Rock Art' in Bonne Resolution Gut

As indicated by the survey, past uses of guts and streams, covering the period 1942-1978, included:

(a) Recreation:
  - (i) Fishing (fish and shrimp); and
  - (ii) Swimming.

(b) Hunting for food – deer, birds (partridge, mountain pigeon, ground dove), fish, shrimp/crayfish.

(c) Collection of potable water.

(d) Collection of water for other uses – washing, watering animals (livestock and chickens), and water for crops.

Two of the respondents noted that, in addition to themselves and their families, the use of guts and streams had been widespread throughout the community. Though they no longer use guts for the above-mentioned purposes, they know persons who occasionally do. The third respondent still uses guts and streams, though the type of use has changed over time. Current uses by the community include:

(a) Recreation[5] – mainly hiking and access to selected beaches.

(b) Potable water (very limited current use).

(c) Bathing and washing (limited use).

(d) Research – post-graduate studies and for supporting undergraduate teaching in biology.

Responding to the question of whether or not the watercourses/guts had more water in the past, the respondents to the survey noted the following:

- The springs contained “much more” water in the past, and some, such as the spring in the deJongh Gut, were perennial streams. The spring in the deJongh Gut ran all year until the early 1960, and became a seasonal stream thereafter.
- In the past, the seasonal streams flowed for longer periods after significant rainfall events.
- There is evidence that there is some sub-surface flow in guts.

Perceived changes in quality of the water in streams over time include:

- Large amounts of debris and solid waste are transported in the streams after rainfall events.
- There is more sediment in the water.

Additional information and perspectives offered by the respondents are:

- Construction activity resulted in the paving of some stream beds (e.g. watercourse adjacent to the Jane E. Tuitt Elementary School), and the closing of some watercourses (e.g. Upper Hospital Ground).
- Studies on St. Croix indicate that bats also feed on the fish in the streams.
- In the 1960s, houses were built close to guts due to proximity to water.
- Persons on hikes through guts sometimes collect endangered species of plants, which concerns the environmentalists that are aware of the practice.

[5] A newspaper article concerning a hike and water-related issues in the USVI is shown as Appendix 3.

- Medicinal plants are still collected from some guts, and those sites should be protected by law.
- Current laws protecting watercourses/guts are not adequately enforced.
- The guts could be used to support an ecotourism initiative.
- Some local persons have knowledge of an extensive trail network for hiking. However, they are not inclined to share that information due to fears that increased traffic will destroy the sites. Such persons have also indicated that they do not want too many persons to use the beaches at the end of some guts.
- There have been a number of “writings” about guts over the years, some from the time of the Danish rule and others more recently by naturalists.

All respondents, and a number of the persons met during the field observations, considered it important to bring issues related to guts more to the attention of the general public.

One use of watercourses that deserve special attention is the collection of water for agriculture. On St. Croix, this is usually done by construction of ponds by individual farms to collect surface runoff. In the Bordeaux area (western end) of St. Thomas, three ponds have been constructed at the bottom of three different watercourses to store surface runoff for watering crops (Photo 28). Given the mountainous terrain on St. Thomas, this method of storing freshwater for agriculture should be considered for wider use. A system of collection from different points in a watercourse could also be devised to augment the end-of-pipeline approach currently being used.

Photo 28: Water Storage Pond in Bordeaux

Inadequate water supply as an impediment to agricultural production in the USVI has been the topic of newspaper articles and studies. A number of those reports (e.g. Smith, 1989 and Natural Resources Conservation Service, 1999) have noted the potential for harnessing rainfall runoff to address small farmer water demand. Further technical studies should be undertaken to assess the feasibility of some of the options identified in previous reports.

4.4 Impact of Land-use Changes on Stream Flow

This study included an assumption that changes in land use in the watersheds have influenced the volume and rate of storm-water runoff, as well as the consistency of stream flow over time (Section 2). The approach used to check this assumption was to compare the 1989 and 1999 land-use maps for the four watersheds[6]. Though changes in the density of residential units could be clearly seen, the scale and degree of change was insufficient to determine the percentage change in the different landuse categories, as well as to determine changes in the percentage cover of impervious surfaces over the same time period.

Dorothea Bay Watershed – The density of residential development increased over the period, with expansion of both low and medium density residential uses. Some of that change took place in the sub-watershed draining to the Bonne Resolution Gut, including a significant increase in residential development in the upper reaches of the drainage area of the gut. A second notable change in land use in the sub-watershed is the increase in agriculture on the western slopes in the middle portion of the area.

Smith Bay Watershed – There was significant increase in density of residential uses, with some expansion of use class as well. Much of that expansion took place in the middle and western portions of the watershed. In the sub-watershed contributing to the gut in this study, the only change in land use is from agriculture to medium-density residential use. The acreage affected by this change remained approximately the same (at least on the southern side of the main road).

Frenchman's Bay Watershed – This watershed also experienced a significant increase in density of residential use. Other land-use changes include an increase in public facilities and establishment of an industrial/manufacturing area. For the sub-watershed that is of interest to this study, there was a slight increase in the acreage of low-density residential development.

St. Thomas Harbor Watershed – though this watershed was very disturbed by 1989, there were still land-use changes apparent between 1989 and 1999. Much of this change is an increase in density of residential use in the upper (north-western) portion of the watershed, part of which contributes to the Contant Gut.

Though land use can be used to show changes in watershed development patterns, more detailed information would be required to support modeling of run-off regimes for St.

[6] The land-use maps, projected on the 2004 aerial photograph for the areas, are contained in Appendix 4.

Thomas. Other important factors to be considered include: (i) increase in housing units, (ii) number of septic systems, and (iii) percentage change in impervious surfaces.

A project was initiated in 1984 to use guts in St. John to calibrate a rainfall-runoff model for small tropical drainage basins (watersheds) (Colón-Dieppa and Smith, 1984). The results of the project were not found during this study, but an expansion of that model to include land-use parameters may produce a useful model for land-use planning in the USVI.

4.5 Riverine Hydrology

The central premise of this study is that development patterns have increased surface runoff, thereby reducing groundwater recharge, that this reduced recharge has resulted in reduced flows in streams, and that the reduced stream flow has affected not only the recreational uses of streams, but also influenced stream ecology (Section 2).

In order to verify the above premise, the following parameters were reviewed:

- Land-use changes in the selected watersheds;
- Surface discharge data for Bonne Resolution Gut and Turpentine Run;
- Groundwater levels in the selected watersheds;
- Social uses of streams; and
- Distribution of stream aquatic fauna.

The available information on land-use changes is inadequate to establish any direct link between changes in stream runoff regime and development patterns in the watersheds (Section 4.4). The review period (1989-1999) is too short, land-use change is not a precise measure of development activity within land-use categories, and the stream discharge data for the entire period of the record (1962 to 2007) were not available.

The social uses of streams and their habitats have not changed significantly, though it appears that the level of use for different forms of recreation has changed. While potable water has replaced some of the domestic demand, agricultural demand may be increasing. Similarly, the harvesting of aquatic fauna seems to have decreased, though whether the decrease is due to reduced demand or reduced availability is unknown. Certainly, based on the anecdotal information, the volume and distribution of fish and shrimp in streams on St. Thomas have decreased.

It was assumed at the start of the study that discharge data from the Bonne Resolution Gut and Turpentine Run would be adequate to detect any trend in changes in discharge volumes over time. There would then be an attempt to correlate the discharge data with rainfall data for the same periods, and to determine whether there was any correlation between the two variables, and whether any detectable change was significant. The database of the U.S. Geological Survey (USGS) for Puerto Rico and the U.S. Virgin Islands contains surface discharge for the periods December 1962 to February 1967, March 1979 to April 1981, and May 1982 to 2007 (http://nwis.waterdata.usgs.gov/vi/nwis). Unfortunately, all attempts to access the database failed. The data that was ultimately used were contained in five (5) annual reports for Puerto Rico and the USVI for the water years 1988 to 2002.

The data is insufficient to show any trends, and in fact the highest and lowest daily flows, the highest and lowest mean flows, and the maximum peak flows all took place prior to 1986. However, the data shows a marked difference between runoff after rainfall events and normal discharge rates. Flows after rainfall events peak and return to almost normal flows within 2-3 days. For example, the reports show discharge rates for the Bonne Resolution Gut in December 2001 increasing from 0.02 cfs on December 14 to 11 cfs on December 15, then decreasing to 6.3 cfs on December 16, and further to 0.3 cfs on December 17. That rate of change suggests that there is limited infiltration taking place in the watershed. However, the available data does not suggest whether this has always been the case, or whether, as the anecdotal information suggests, the changes in the flow regimes took place in the 1960s.

No data was found during this study to support any examination of the relationship between run-off rates and groundwater levels. However, the Unified Watershed Assessment Report (1998) states that the groundwater table elevation in the Smith Bay area declined by approximately 60-70 feet during the period 1990-1998 (Department of Planning and Natural Resources, 1998), and attributes that change to increased denudation in the watershed and the resultant increased runoff.

5. CONCLUSIONS AND RECOMMENDATIONS

While this pilot study did not have sufficient scope to conduct the level of research necessary to examine the links between land-use and stream flows as suggested above, it seems clear that historically there have been changes in the flow regimes of streams in the USVI. Increased development pressure in the watersheds is expected, resulting in an increase in factors such as percentage of impervious surface, increased number of septic systems, and modification of drainage systems. Those changes in the watersheds should continue to alter stream flows in the watercourses, with the potential to negatively impact on water availability (surface and ground water), flooding, continued degradation of coastal water quality, and loss of biodiversity.

Based on the results of this pilot study, the recommended areas of research associated with water resources in the U.S. Virgin Islands, which are not currently being conducted by other institutions, are:

(a) **Development of a policy framework and plan for management of watercourses in the U.S. Virgin Islands**.

In the USVI, guts are protected by law. The V.I. Code (Title 12, Sections 121-125) prohibits the cutting of vegetation close to natural watercourses. However, there is no program that translates the law into actual protection strategies or that offers protection of guts through the development control process. For example, the wildlife strategy for the USVI, prepared by the DPNR-Division of Fish and Wildlife, does not include guts in the classification of wetlands, and does not offer any direction for protection of this ecosystem.

Recent studies have reconfirmed the significant ecological value of guts, and a management plan adopted by the relevant regulatory agencies would provide a framework for conservation of this valuable resource.

(b) **Assessment of the feasibility for development of community water supply systems for agricultural development in selected farming communities on St. Croix and St. Thomas**.

Farmers in the USVI have complained consistently that inadequate water resources is one of the constraints to agricultural production in the Territory. One method of addressing the scarcity of water for aquaculture is the development of a hydroponic system by the University of the Virgin Islands (UVI). However, the startup cost of such systems is still beyond the reach of most farmers, and not all crops can be grown using that technology.

The old community water supply systems based on harvesting rainwater were taken out of use several decades ago. However, in many cases, the catchments and storage tanks remain, and while the water from this particular source cannot be used for drinking purposes, it may be useful for agricultural purposes.

The project would assess the feasibility of development of a community water supply system, composed of rainwater catchments, stream collection, and micro-dams, to provide water to farmers in particular areas of St. Croix and St. Thomas.

(c) **Development of a hydro-geological model for land use planning in the U.S. Virgin Islands**.

Land use planning is usually based on some defined spatial boundary, either biophysical (such as watersheds or bioregions) or political (such as counties or states). Within the USVI, there is no defined spatial basis for land use planning, with an arbitrary two-tiered system used for development control.

Superimposed on this land use planning process is a natural resources management regime that has developed programs aimed primarily at reducing the negative impacts of the land use planning and development control processes.

The programs to reduce non-point sources of pollution focus on activities taking place in the watersheds. Similarly, the Areas of Particular Concern (APCs) are defined primarily along watershed boundaries. The topography of these small islands create surface runoff regimes that result in damage to primary infrastructure, periodically prevent the proper functioning of some infrastructure (mainly sewerage), and occasionally cause serious disruption to community life and economic activity through flooding of schools, homes, and businesses.

It has been suggested that it is appropriate to base land use planning and development control on a hydro-geogical model rather than on the current 2-tier system that is based on an arbitrary line drawn on a map.

(d) **Conduct a characterization of the watersheds contributing to the recharge of the Kingshill Area Aquifer**.

The Government of the U.S. Virgin Islands, Department of Planning and Natural Resources, Division of Environmental Protection, has petitioned the U.S. Environmental Protection Agency (EPA) to designate the Kingshill Area Aquifer on St. Croix a Sole Source Aquifer. The EPA in August 2006 issued a Public Notice concerning this petition, requesting public comments prior to making a final decision on the designation.

The Unified Watershed Assessment Report (DPNR, 1998) notes that "*Nonpoint source pollution, as runoff, impairs more water bodies than any other source of pollution in the Virgin Islands*", and that "*Sediment - from dirt roads, farmlands,* *construction sites, urban encroachments, and other disturbed soils - is the primary nonpoint source pollutant threatening the islands' water resources*".

Designation of the aquifer as a Sole Source Aquifer affects Federal assistance grants, as the grants cannot be used to fund projects that may contaminate the aquifer through a recharge zone. Given the concern with the non-point sources of pollution in the USVI, a program will have to be developed to reduce the sources of, and activities generating, contaminants in that area. However, the Kingshill Area Aquifer covers 25 square miles. It is therefore necessary, even without the Sole Source Aquifer designation, that a watershed management program for the recharge areas be implemented in an effort to protect the aquifer.

This project would produce critical background data necessary for management planning for the watersheds contributing to the recharge of the Kingshill Area Aquifer. The project could also be used to test an approach for integration of programs from several agencies into one management framework.

(e) **Compile and conduct a statistical review of stream discharge data from streams in the U.S. Virgin Islands**.

With increased demand for water for the agriculture sector in the USVI, and with more attention being paid to watercourses as potential sources of that water, it is appropriate that an assessment be conducted of the long-term trends in stream flows. In addition to having the data available to support research, it is important to determine whether the flow patterns can support sustained harvesting for agricultural and other uses.

(f) **Conduct biodiversity assessment of freshwater fauna in the U.S. Virgin Islands**.

Based on anecdotal information, the changes in stream flow patterns have impacted negatively on freshwater fauna previously harvested in the USVI. Some species, such as the shrimp, is said to spend part of its life cycle in the sea. Given the modification of the coastal zone in St. Thomas, there is no apparent consistent connection of streams to the sea that would allow migration of such species upstream. Yet such species persist. The rationale given by persons interviewed during this study, that there are underground pools in which shrimp survive periods of low stream flow, could not be verified. Similarly, stories of fish swimming upstream during peak runoff events could not be verified.

The critical question is not whether such species exist in the USVI, since it is obvious they do. The more interesting question is whether or not any sub-speciation has taken place. A biodiversity assessment of the streams of the USVI would provide answers to both questions.

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Appendix 1:
Questionnaire for Social Use Survey of Guts

University of the Virgin Islands
WATER RESOURCES RESEARCH INSTITUTE

Project Title: Changes in Riverine Hydrology on St. Thomas, U.S. Virgin Islands

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Good ……… My name is Lloyd Gardner. I am a researcher at the Water Resources Research Institute, University of the Virgin Islands. I am conducting a study to test the assumption that development patterns have increased surface runoff, thereby reducing groundwater recharge, which in turn has resulted in reduced water flows in streams/guts. This interview is being conducted to gather information on the:

- Location and names of streams and guts;
- Perceptions of past and current levels and periodicity of flows;
- Past and current uses of streams/guts; and
- Animal species captured or observed.

The completed questionnaire should be returned to me at the Water Resources Research Institute, UVI. I can also be reached by phone at: 340-513-3562.

Date of Interview:

Name of Respondent: Age: Sex:

1. What streams/guts did you or other members of your family visit? [Mark & Name on map]

2. In what ways did you use the streams? [swimming, fishing, etc.]

3. Was your use of the stream/gut on a general basis or on special occasions? If visited on special occasions, name the occasions.

4. Is there a particular time of year that you used the streams/guts for the purposes mentioned above? If so, what times did you carry out which activities?

5. During which years did you use the stream/guts in the ways stated above?

6. What types of animals were caught or seen in the pools in the guts? [Obtain information on quantity and location for each type of animal]

7. Did other persons in your community also use the streams on St. Thomas? If so, was the use widespread or by a small number of persons?

8. Do you still visit the streams/guts? If yes, which ones? For what purpose?

9. Do you know of other persons that still use the streams/guts? If yes, which ones? For what purpose?

10. Did streams/guts have more water in them in past years? If so, how much more? If less, how much less?

11. In the past, after rainfall events did the streams flow for longer or shorter periods than current day? [days, weeks, months]

12. What changes, if any, have you noticed in the quality of the water in the streams?

13. Is there any other difference between the streams/guts now and when you used them in the past? If so list the differences?

14. Any general thoughts/memories/comments you wish to share with me.

Thank you.

Appendix 2:
GPS Data Points in Guts

Project: Riverine Hydrology Pilot Study
Date: April 3, 2007

Map Location: St. Thomas Harbor Watershed – Contant Gut				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Latitude**	**Longitude**
001	DMV-north side of road	Inlet to culvert	18° 20.217'	64° 57.062'
002	DMV-south side of road	Outlet from culvert	18° 20.212'	64° 57.062'
003	Bellows south, Route 30	Inlet to culvert	18° 20.237'	64° 57.082'
004	Bellows-north side	Outlet from culvert	18° 20.313'	64° 57.050'
005	Bellows-north side	Inlet to drain from road	18° 20.315'	64° 57.049'
006	Sototown-Bridge Shop	Middle of bridge	18° 20.511'	64° 57.193'
007	Sototown-north side of bridge in gut	Sample pool	18° 20.513'	64° 57.193'
008*	Waterfall	Pool at foot of waterfall-west side	18° 20.682'	64° 57.100'
009	Waterfall	Pool at foot of waterfall	18° 20.696'	64° 57.100'
010	Waterfall	Pool at foot of waterfall	18° 20.697'	64° 57.096'
011	Scotsfree-Route 332(b)	Cross-drain in road	18° 20.796'	64° 57.118'
012	Scotsfree-upper Contant	Building in gut	18° 20.776'	64° 57.099'

013	Upper Contant in gut	Pool-just below first house	18° 20.744'	64° 57.106'
014	Scotsfree – Route 332	Inlet to culvert	18° 20.835'	64° 57.147'
015	Scotsfree – Route 332	Middle of road-second culvert	18° 20.834'	64° 57.122'
031	Waterfall	3rd pool downstream from falls	18° 20.687'	64° 57.100'
032	Waterfall	Top of cliff	18° 20.711'	64° 57.096'
033	Waterfall	2nd pool from edge of cliff/largest pool above waterfall	18° 20.711'	64° 57.090'

- * Point ID 008 may be discarded, as the GPS unit lost satellite contact when the point was being marked.
- Waypoints 031, 032, and 033 were taken on Tuesday April 10, 2007.
- DMV = Department of Motor Vehicles

Project: WRRI Riverine Hydrology Pilot Study
Date: April 3, 2007

Map Location: Dorothea Bay Watershed – Bonne Resolution Gut				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Latitude**	**Longitude**
016	South of Dorothea Condominiums	Concrete revetment across gut	18° 22.048'	64° 57.612'
017	Upstream of concrete revetment	First large pool with fish	18° 22.031'	64° 57.605'
018	Further upstream of concrete revetment	2nd pool-with fish and shrimp	18° 22.018'	64° 57.599'
019	Further upstream of concrete revetment	Large pool above mango tree in gut	18° 22.008'	64° 57.610'
020	Mouth of gut at beach	Sand berm across gut	18° 22.178'	64° 57.647'
021	Bridge-west of USGS station	Middle of bridge	18° 21.772'	64° 57.575'
022	Revetment at USGS gauging station	Pool behind impoundment	18° 21.795'	64° 57.563'

Project: Riverine Hydrology Pilot Study
Date: April 10, 2007

Map Location: Smith Bay Watershed – Gut leading to Pond				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Latitude**	**Longitude**
023	Route 38 – east of Saffire Bay Hotel and Red Hook	Outlet from culvert under road	18° 20.295'	64° 51.555'
024*	Smith Bay pond	Northern edge of pond	18° 20.365'	64° 51.469'
025	Smith Bay pond	Northern edge of pond	18° 20.367'	64° 51.468'
026	Smith Bay pond	Sand berm on southern edge of pond	18° 20.371'	64° 51.457'
027	Smith Bay pond	Coconut tree on sand berm on south-eastern side of pond	18° 20.393'	64° 51.462'

- * Waypoint 024 may be discarded, as the GPS unit lost satellite connection during the process of marking the point.

Project: Riverine Hydrology Pilot Study
Date: April 10, 2007

Map Location: Frenchman's Bay Watershed – Gut between Green Cay Plantation development and Frenchman's Bay development				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Latitude**	**Longitude**
028	Main gate to Green Cay Plantation	Outlet from culvert/inlet for road runoff	18° 19.336'	64° 54.253'
029	Gut	Only large pool	18° 19.163'	64° 54.314'
030	Frenchman's Bay sub-division road cross gut	Inlet to box culvert	18° 19.110'	64° 54.335'

GPS Field Data Sheet-Faunal Sampling

Project: Riverine Hydrology Pilot Study
Date: 2007

Map Location: St. Thomas Harbor Watershed – Contant Gut				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Pool Size$^{\Phi}$**	**Fauna**
007	Sototown-north side of bridge in gut	Sample pool	N/A	Guppy
008*	Waterfall	Pool at foot of waterfall-west side	17' long x 11' wide x 18" deep at deepest point	Guppy
009	Waterfall	Pool at foot of waterfall	17' long x 11' wide x 18" deep at deepest point	Guppy
010	Waterfall	Pool at foot of waterfall	17' long x 11' wide x 18" deep at deepest point	Guppy
013	Upper Contant - within gut	Pool-just below first house	N/A	Tadpoles
031	Waterfall	3rd pool downstream from falls	7' long x 3' wide x 10.5" deep	Guppy, turtle
032	Waterfall	Top of cliff	8' long x 7' wide x 10" deep	Guppy
033	Waterfall	2nd pool from edge of cliff/largest pool above waterfall	18" deep x 6' wide x 10' long	Guppy

- * Point ID 008 may be discarded, as the GPS unit lost satellite contact when the point was being marked.
- N/A = not available
- Φ = pool size differs from one visit to the next, depending on rainfall

GPS Field Data Sheet-Faunal Sampling

Project: WRRI Riverine Hydrology Pilot Study
Date: 2007

Map Location: Dorothea Bay Watershed – Bonne Resolution Gut				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Pool Size$^{\Phi}$**	**Fauna**
017	Upstream of concrete revetment	First large pool with fish	9 inches deep	Mountain mullet, shrimp, guppy
018	Further upstream of concrete revetment	2nd pool-with fish and shrimp	30" long x 18" wide x 6" deep	Goby, guppy, crayfish, shrimp
019	Further upstream of concrete revetment	Large pool above mango tree in gut	15' long x 10' at widest point, 4' at narrowest point x 12" deep, at deepest point	Guppy, shrimp
022	Revetment at USGS gauging station	Pool behind impoundment	N/A	Guppy
Φ = pool size differs from one visit to the next, depending on rainfall				

GPS Field Data Sheet-Faunal Sampling

Project: Riverine Hydrology Pilot Study
Date: 2007

Map Location: Smith's Bay Watershed – Gut leading to Pond				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Pool Size**	**Fauna**
024*	Smith Bay pond	Northern edge of pond	N/A	Fish fry (species not identified)
025	Smith Bay pond	Northern edge of pond	N/A	Fish fry (species not identified)

- * Waypoint 024 may be discarded, as the GPS unit lost satellite connection during the process of marking the point.
- N/A = not available

GPS Field Data Sheet-Faunal Sampling

Project: Riverine Hydrology Pilot Study
Date: 2007

Map Location: Frenchman's Bay Watershed – Gut between Green Cay Plantation development and Frenchman's Bay development				
GPS Point ID	**Attribute 1**	**Attribute 2**	**Attribute 3**	**Attribute 4**
	Location	**Feature**	**Pool Size**	**Fauna**
029	Gut	Only large pool	40" long x 36" wide	Tadpoles

Appendix 3:
Newspaper Article on Water Catchment Systems

The Daily News
Wednesday, May 2, 2007
Page 22

V.I. Water Catchment System

Some weeks ago I conducted a hike in deJongh Gut. On this expedition we discussed many things, but one was the hillside water catchments on the western and eastern side of the gut.

When St. Thomas was settled under the leadership of Gov. Jorgen Iversen in 1672, the island had permanent streams. However, the streams water was not sufficient for the growing population of colonists who settled the island. The late Michael Paiewonsky in his historical notes on Kongens Quarter and the early history of St. Thomas said rivers once ran year round on St. Thomas. He stated:

"In the 1690s, the rivers we now know as guts – one runs through 'Goat Street'; one separates Kongens Quarter from Dronningens Quarter and Kronprindsens Quarter at Guttet Gade – were just beginning to dry up because of the attempts to farm the hills above town without terracing".

As planters began to cultivate the hillsides of St. Thomas, so much top soil was lost that most farming moved to St. John in 1716 and then to St. Croix after 1733.

Paiewonsky further mentioned that even in the late 1950s that the Fireburn Gut ran year round with water. It was common in those days to see women carrying buckets of water in their hands or on their heads from the streams early in the morning to their homes. The early development of houses was built near streams of fresh water.

Like the first colonists settlement on St. Thomas, the surface water began to disappear and wells were dug to supply drinking water as well as for other domestic use.

The island also experienced prolonged droughts at times when the guts might dry up and disappear. The colonial historical background of water supply for St. Thomas started as far back in the 17th century. Wells were developed after streams were not reliable.

The inhabitants resorted to wells, locally called "pytter" during the Danish period. For the most part, the wells were located near the house. Other wells were located along bay sides. However, some well water was brackish possibly because of sea water intrusion contaminated wells. Therefore, these wells were not used for human consumption. Nevertheless, some enslaved Africans had no choice but to drink the brackish water. They first boiled the water with white cinnamon and disposed the cloudy residue from the water before drinking.

Cisterns were other means of storing water when there was an over extended period of no rain. Great houses, manager's dwelling and other structural buildings on the plantation had cisterns.

The roofs of houses were designed in such a way with gutters directing rain water into cisterns near or under the buildings. During this period, cisterns were commonly constructed of mortar and stone in a rectangular shape with dome roofs and walls in some cases up to 2 feet thick. Water from the cisterns would be transferred into large Dutch clay pots about two or three the size of barrels and placed inside rooms of houses. The Dutch clay pots kept the water cool.

In those days like today, mosquitoes were a problem. Cisterns, barrels and pots were covered to keep mosquitoes from breeding in the water. During the Danish period, deJongh Gut was a flowing stream. At times when the island was very dry, the gut supplied water to the inhabitants. Today, the spring in deJongh is still flowing.

Also, water was brought in from Water Island on large casks by boats to St. Thomas during very dry spells.

Water Island had many fresh water springs for which the island was named. According to Johan Lorentz Carstens, a Creole planter on St. Thomas in the 1730s, a bucketful of water from Water Island was sold for 12 Danish shillings. From the colonial period to early U.S. rule of the Virgin Islands, the United States government built hillside catchments.

In 1926, the first hillside catchments in the Virgin Islands were built by the U.S. military. These catchments provided water for the U.S. military personnel station on St. Thomas. The local Department of Public Work as well as some private citizens expanded the network of catchments throughout the islands. There were 22 catchments on St. Thomas, four on St. John and five on St. Croix.

As the islands progress, water is being supplied through public distribution systems from desalination and underground aquifers. With a population of more than 100,000 inhabitants and an annual rainfall averaging 45 inches, water will be a crucial commodity to expand the islands economy. The protection of watershed areas like the deJongh Gut region is even more critical. You see, politicians are not thinking ahead like those in colonial times that made ways to solve their water problems.

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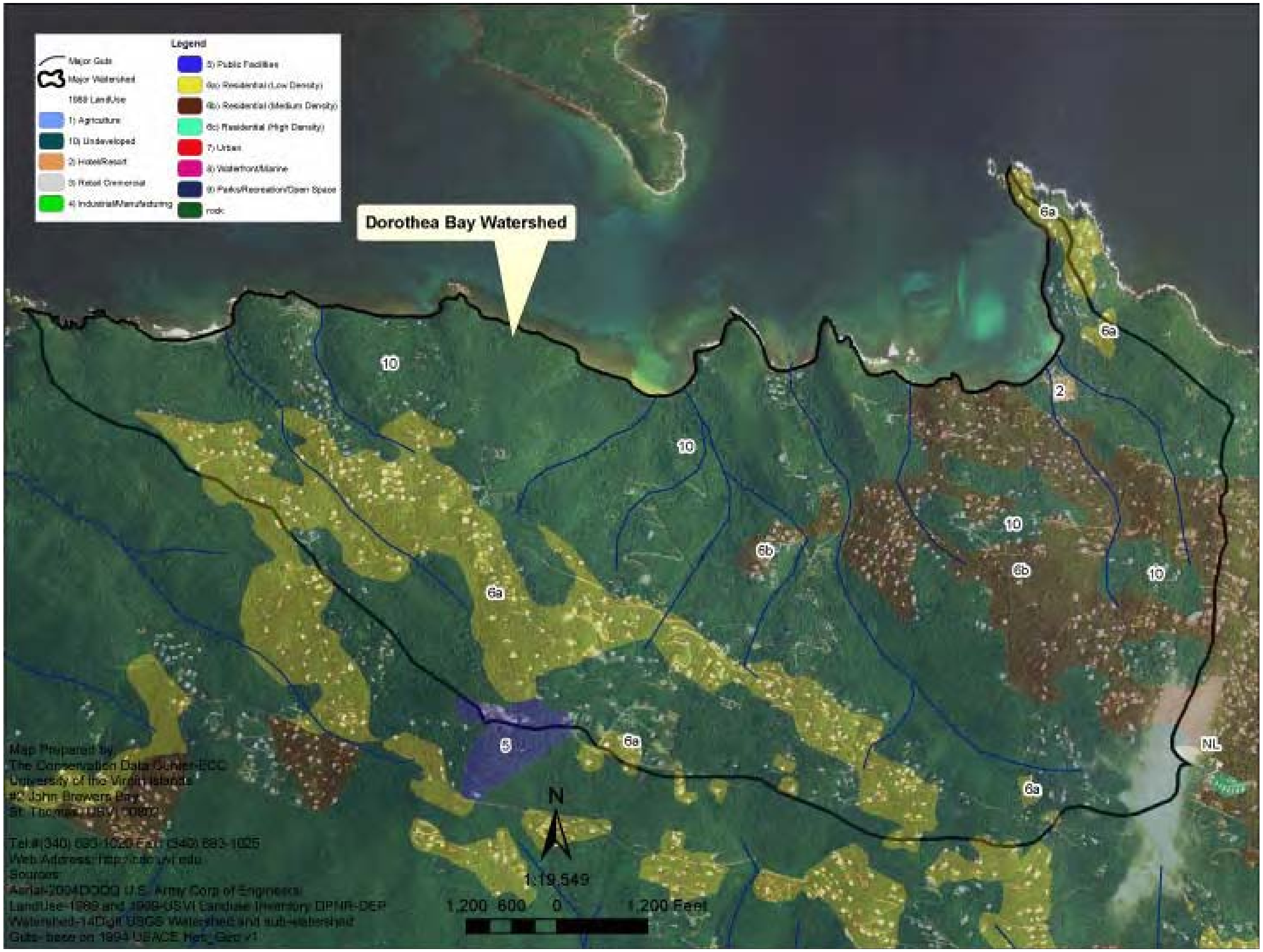
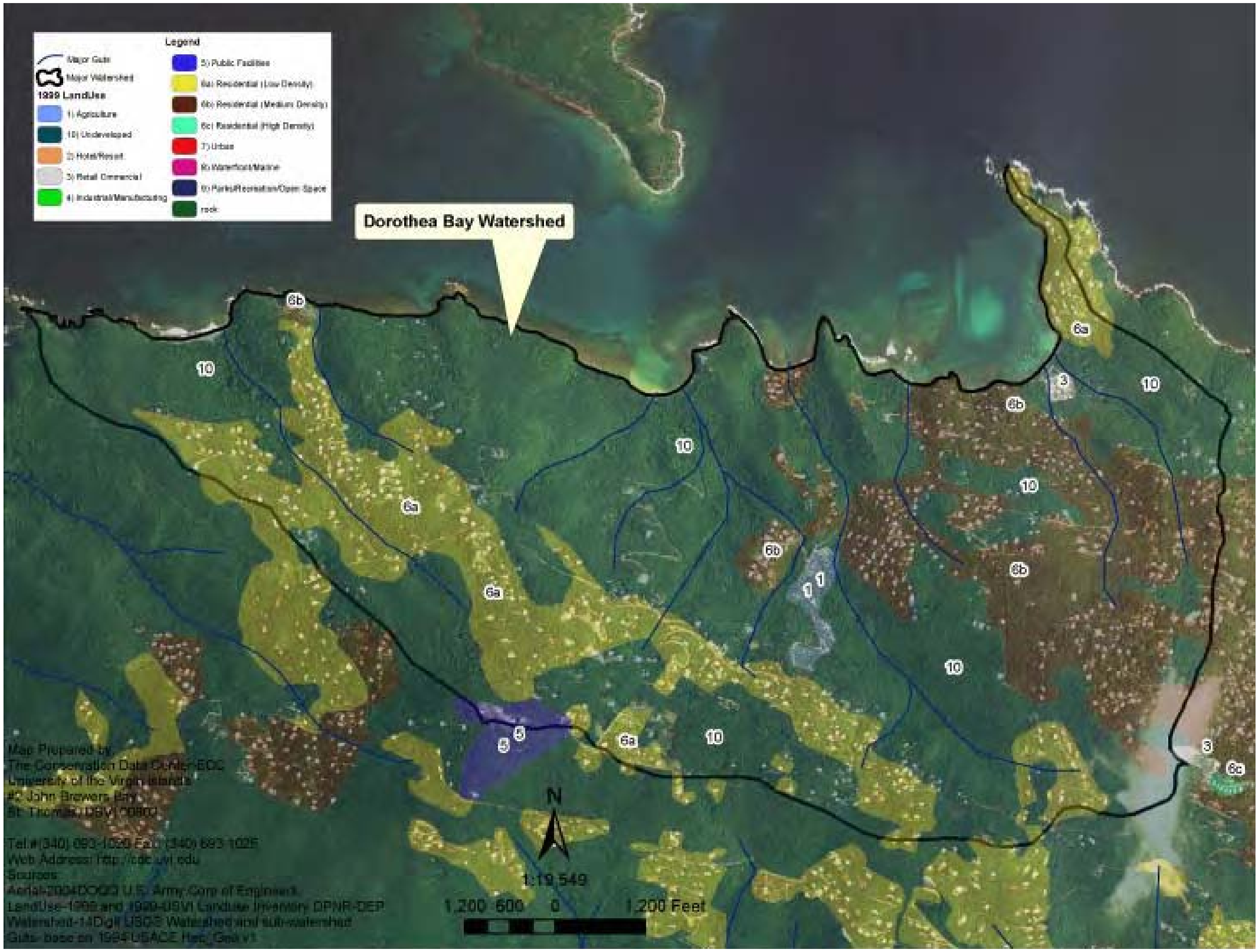
Appendix 4:
1989 and 1999 Land-Use Maps

The land-use maps are projected on the 2004 aerial photograph. As such, interpretation of these maps should be based on the land-use categories, not on the physical features (such as buildings) seen on the photographs.

Dorothea Bay Watershed: Land Use 1989



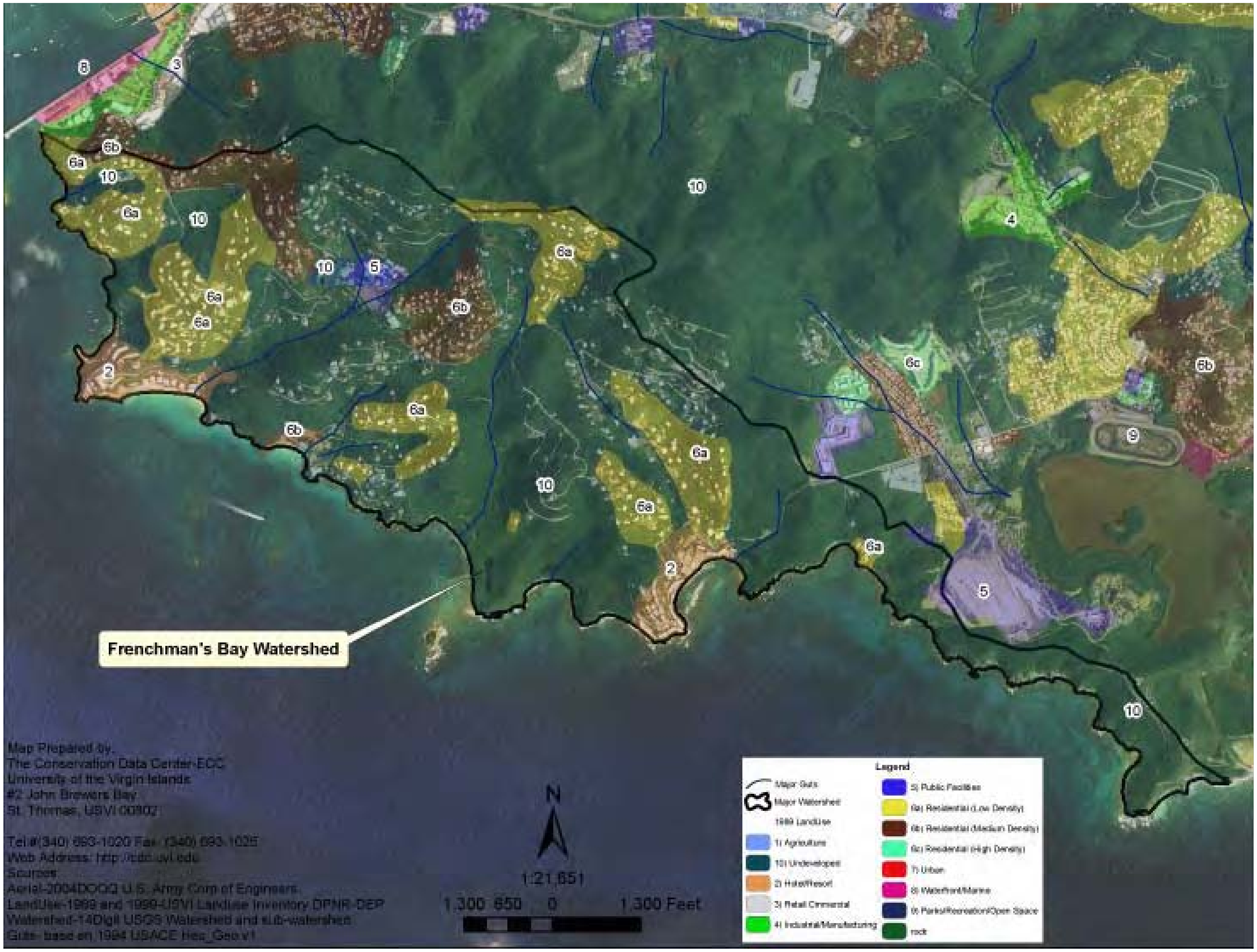
Dorothea Bay Watershed: Land Use 1999



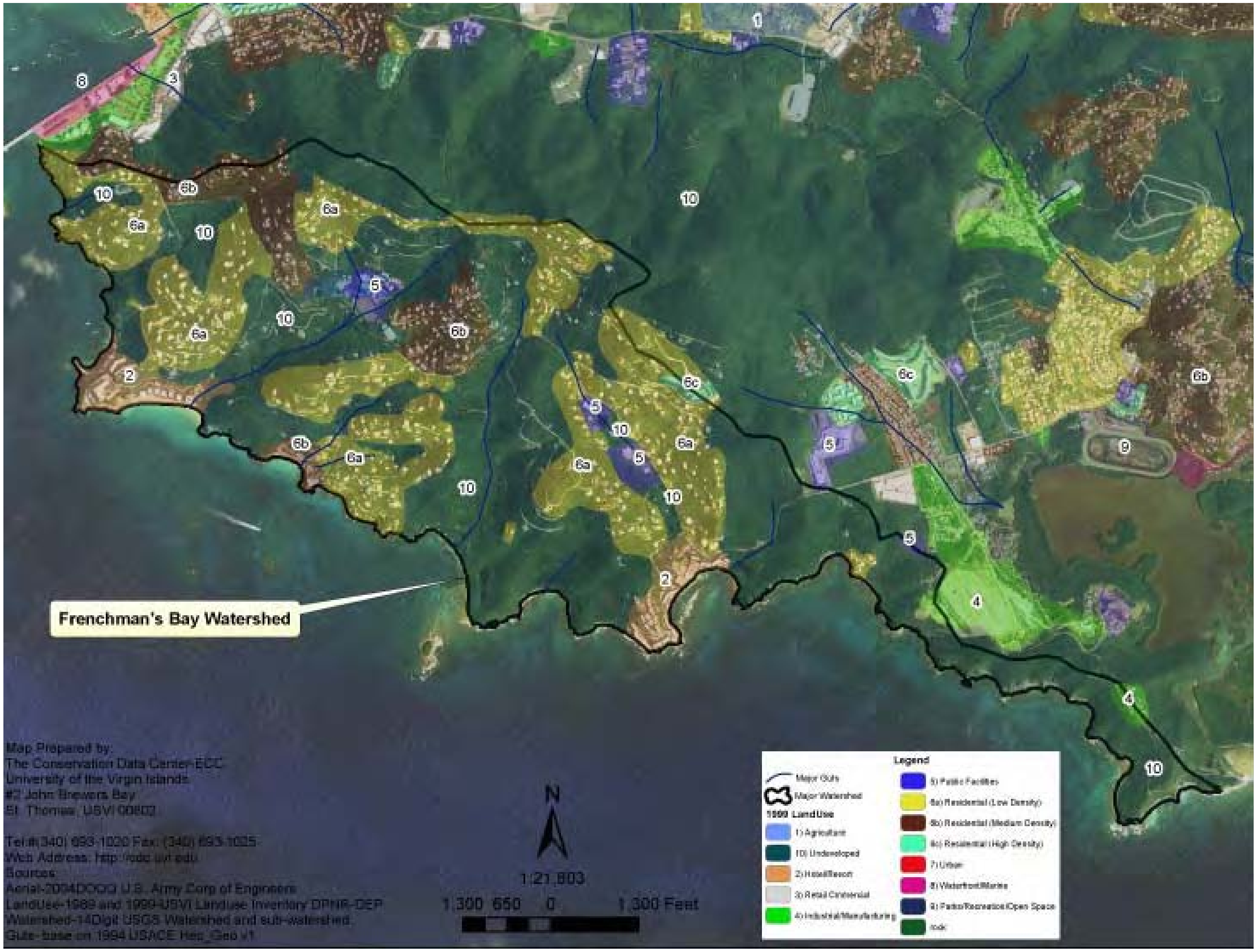
Smith Bay Watershed: Land Use 1989

Smith Bay Watershed: Land Use 1999

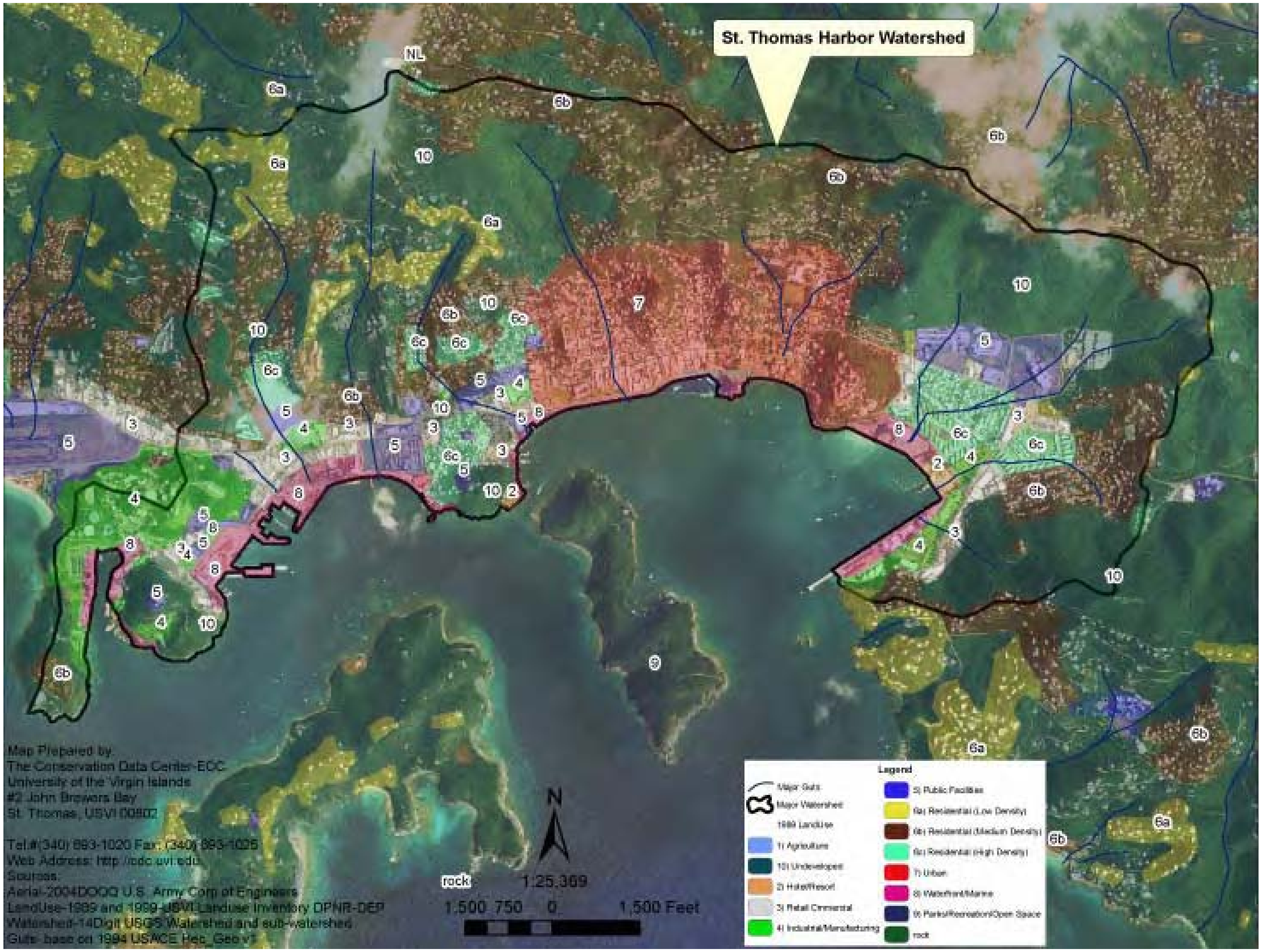
Frenchman's Bay Watershed: Land Use 1989



Frenchman's Bay Watershed: Land Use 1999



St. Thomas Harbor Watershed: Land Use 1989



St. Thomas Harbor Watershed: Land Use 1999