Virgin Islands Water Resources Research Institute Annual Technical Report FY 2007

Introduction

The United States Virgin Islands, USVI, is a Territory of the United States located in the Caribbean Sea consisting of four principal islands, Water Island, St. Croix, St. John and St. Thomas. Safe and sufficient water supplies have always been a major concern in these small volcanic islands where rain water harvesting, ground water and desalinated water currently are the principal water sources. In addition to the challenges of obtaining potable water in sufficient quantity and quality, disposal of wastewater is a major concern in the USVI's fragile environment where the tourism based economy is dependent on the pristine shorelines and nearshore areas.

The University of the Virgin Islands (UVI) is a principally undergraduate land−grant and Historically Black College or University (HBCU) with a student population of about 2,500 students. UVI has campuses on St. Croix and St. Thomas and has an environmental research station on St. John. It is the only institution of higher learning in the USVI. UVI strives to be particularly responsive to needs of the economically, socially, ethnically and culturally diverse community through its academic, research and outreach programs.

The Water Resources Research Institute (VI−WRRI) has been at UVI since 1973. It is part of UVI's Research and Public Service sub−component and receives guidance from a community based Advisory Council. Projects selected for funding through the VI−WRRI reflect water resources priority areas identified by this Advisory Council. Principal investigators on VI−WRRI projects are UVI personnel, members of the Virgin Islands community and collaborators from universities elsewhere in the nation. This annual report summaries the results of activities undertaken by the WRRI during the 2007−2008 program year.

Research Program Introduction

The VI−WRRI research program in 2007−2008 consisted of six projects. Two of these were projects being continued from previous years. One of these involved the determination of a methodology for using impervious surface analysis to monitor and manage water quality and habitat health of a watershed. The other project examined the relationship between the diversity of freshwater fish and invertebrates and water quality in a watershed.

The remaining four were new projects. Two of these projects considered ways of efficiently using water for agricultural purposes in the water−short U.S. Virgin Islands. The other two projects provided information that will be useful in management of the islands' guts. One project investigated the transport of sediments from the hillsides to coastal embayments and the second project considered aspects of the use of guts as urban recreational spaces.

Impervious Surface Analysis of Terrestrial Watersheds of the U.S. Virgin Islands with Application to the East End Marine Park, St. Croix

Basic Information

Title:	Impervious Surface Analysis of Terrestrial Watersheds of the U.S. Virgin Islands with Application to the East End Marine Park, St. Croix
Project Number:	2006VI67B
Start Date:	3/1/2006
End Date:	8/31/2007
Funding Source:	104B
Congressional District:	N/A
Research Category:	Water Quality
Focus Category:	Non Point Pollution, Water Quality, Methods
Descriptors:	
Principal Investigators:	Colin Finney, Henry H. Smith

Publication

1. None as yet.

PROBLEM AND RESEARCH OBJECTIVES

In the U.S. Virgin Islands, housing, roads, and commercial and industrial development are increasingly replacing natural terrestrial environments such as grasslands and forests. Increased sediment loading and nutrient enrichment from development activities in upland watersheds often result in degradation of inshore marine communities, particularly coral reefs and sea grass beds, which require clear water and high light levels to persist. Rogers (1990) has suggested that the primary cause of coral reef degradation in coastal areas of the U.S. Virgin Islands is development activities, especially land disturbances and dredging.

The natural landscape typically is made up of pervious surfaces - areas vegetated with trees, shrubs, and grasses - which under normal conditions allow precipitation to infiltrate the soil. One of the principal effects of development and urbanization is the conversion of pervious surfaces into impervious surfaces - man-made surfaces that inhibit the infiltration of water into the soil. This is complicated in the US Virgin Islands by the diversion of rainwater from roofs into private cisterns which limit run-off.

Research over the past two decades has indicated that increased quantities of impervious surfaces are closely associated with environmental degradation, specifically that the quantity of impervious surfaces in a watershed is inversely correlated with the health of that watershed and the health of water bodies, such as coastal environments, that receive discharges from that watershed (Center for Watershed Protection, 2003). On St. John, for instance, MacDonald *et al*. (1997) demonstrated that unpaved roads may contribute the majority of sediment to marine ecosystems.

The goal of the proposed study is to provide a methodology using impervious surface analysis for effectively monitoring and managing water quality and habitat health of a watershed. To attain this goal, it will be necessary to accurately map terrestrial impervious surfaces at a watershed scale.

METHODOLOGY

A detailed description of the methodology used to carry out this project will be presented in the final report. Broadly, the methodology for this study consists of the following:

Establish land-use categories that are consistent with both the U.S. Virgin Islands landscape and currently used land-use categories;

Establish current and baseline data of impervious surface coverage in the Coral Bay watershed, St. John;

Analyze change that occurred to impervious cover in this watershed between 1994 and 2004;

Design a brochure that describes actions to minimize impacts from impervious surfaces.

PRINCIPAL ACCOMPLISHMENTS AND PRELIMINARY RESULTS

During this period the data components for the study were further evaluated and the principal impervious surface categories were assessed in ERDAS Imagine 8.7. The data components consist of:

- Cloud free IKONOS image from 2006;
- Overlays of watershed boundaries, shoreline, and roads;
- High resolution aerial photographs from 1994 (1 ft)

The main categories of impervious surfaces in the Coral Bay watershed have been identified from remote sensing images to be the following:

- Roads
- House roofs (which catch water)
- Bare rock
- Cleared land. In the Coral Bay watershed the thin, bare soil is volcanic in origin and has a fast runoff potential due to steep slopes. Agriculture is insignificant, and lawns are infrequent due to water scarcity.

Analysis of the IKONOS image has shown that impervious surfaces are bright and vegetation is dark. The blue band of IKONOS provides the cleanest distinction between vegetation and impervious surfaces. The IKONOS pan reinforces the blue band but has much more variation due to its panchromatic spectral responsivity. We also continued to examine the Normalized Difference Vegetation Index (NDVI) for the IKONOS image.

A brochure to educate homeowners on simple actions that can be taken to minimize the effects of impervious surfaces has been completed. The brochure provides information about the project and highlights the main actions that homeowners can take to minimize the impacts from impervious surfaces.

Diversity of Freshwater Fish and Invertebrates of St. Thomas Watersheds and its Relationship to Water Quality as Affected by Residential and Commercial Development

Basic Information

Title:	Diversity of Freshwater Fish and Invertebrates of St. Thomas Watersheds and its Relationship to Water Quality as Affected by Residential and Commercial Development
Project Number:	2006VI73B
Start Date:	3/1/2006
End Date:	7/30/2007
Funding Source:	104B
Congressional District:	N/A
Research Category:	Biological Sciences
Focus Category:	Ecology, Water Quality, Education
Descriptors:	
Principal Investigators:	Donna Nemeth

Publication

1. None as yet.

PROBLEM AND RESEARCH OBJECTIVES

St. Thomas has limited freshwater resources, represented by a small number of guts that drain the island's 13 watersheds. Despite extensive current work surveying, characterizing, and mapping the watersheds and riparian vegetation of the Virgin Islands (IRF, CDC, and DPNR 2004), the *aquatic* portion of that freshwater and brackish habitat remains poorly surveyed. The majority of these guts carry water only seasonally, and flows vary dramatically with changing rainfall. Despite the often temporary nature of the freshwater habitat, several species of fishes and shrimps persist in these guts, including several introduced species.

From a management perspective, these freshwater habitats form a vital connection between terrestrial activities and the marine habitat downstream. The discharge of fresh water into the sea also creates a brackish habitat (e.g. mangrove swamps and salt ponds) used by many commercially and recreationally important marine fish species as a nursery. The current research emphasis in the Virgin Islands on the problems of non-point source pollution and sedimentation from terrestrial erosion affecting the coral reef and other marine organisms has largely ignored the watershed habitat through which these pollutants are transported. With no record of faunal diversity of this ephemeral aquatic habitat, there exists no baseline for evaluating the potential effects of current and future land-use practices.

From an educational perspective, we see a need to inform residents as to the function and value of these ecosystems. With a greater understanding of how human activities and development impact the local environment, the community may make more informed decisions regarding land use and management. Specifically, the training of young scientists in the methodology used to study local environments will contribute to the development of a local workforce for assessment and management.

The objectives of this project were to:

- determine if St. Thomas gut streams varied in water quality, and if that correlated with the level of human impact in the surrounding watershed.
- identify all aquatic species found in the gut stream habitats, and to look for distribution patterns with respect to among-gut differences in water quality and human impact.
- train two UVI undergraduates in research methods and field work
- communicate our findings to the community through a display at Coral World Ocean Park.

METHODOLOGY

We sampled three gut streams in St. Thomas that had been previously categorized as being in areas of low, mid, and high levels of human development. Each gut was visited at least three times over a 9 month period. A portable multiparameter meter (IQ 170) was used to measure pH, salinity, conductivity, total dissolved solids & temperature in 5 pools of each gut per visit. Total Kjeldahl Nitrogen (TKN), Total Phosphorous (TP), and the presence of *E. coli* in the stream water were evaluated on two different dates for all three guts. All animals were identified and their abundance estimated.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Five species of native shrimp, two species of native fish, and two species of introduced fish were identified in three gut streams.

Most water quality measures (pH, salinity, conductivity, total dissolved solids & temperature) were found to be highly variable and showed no clear pattern with respect to different guts or human impact.

The gut streams in the areas with mid and high human disturbance had, relative to the stream with low human disturbance:

- Fewer native shrimp and fish species
- Elevated total phosphorous concentration
- introduced fish species

In one gut, we identified a residential sewage discharge that provided a reference point for comparison of conditions upstream and downstream. Directly downstream of that input,

- Total Phosphorous concentration increased nearly 10-fold and TKN doubled.
- Pool substrate changed from gravel, to a thick layer of anoxic sludge.
- Native species of shrimp and fish were absent, with only introduced guppies and trumpet snails persisting.

Land development of small island states introduces non-point source pollution that flows through watersheds to the marine environment. The impact of this pollution on the aquatic wildlife in the gut streams is poorly understood. Our preliminary findings suggest that streams in areas with greater human impact may be less habitable by native species, or be altered by the introduction of non-native species (Tilapia, guppies, and trumpet snails). Introduced species have the potential to prey on native wildlife and/or compete with them for resources.

One of the most satisfying successes of this project was in stimulating interest and future research, among students, conservation biologists, and the general public, both local and visitors. The research and our findings appealed to many different groups trying to understand the importance of this natural resource to recreation, conservation, control of invasive species, nutrient cycling in ecosystems, and the importance of connectivity with the marine environment. It perhaps contributed to or stimulated further research on guts funded by the VI-WRRI, to Lloyd Gardner and Toni Thomas.

Freshwater ‘Guts’ of the Virgin Islands

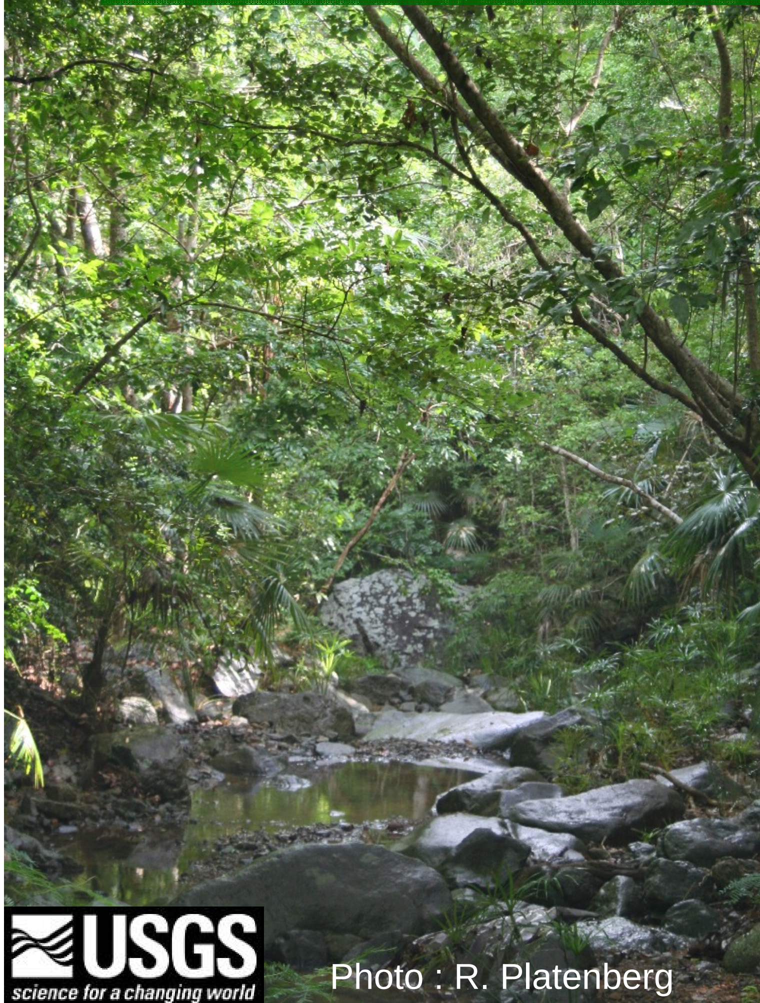

Photo : R. Platenberg

St. Thomas has no permanent streams or lakes. Narrow gullies, or ‘guts’, channel water down the steep slopes after it rains. Small pools may persist year-round.

Five kinds of shrimp and two kinds of native fish are found in St. Thomas gut pools.
All spend their larval life in the sea, before returning to a freshwater stream.

Xiphocaris shrimp

Atya shrimp

Macrobrachium shrimps

Sirajo Goby

Mountain Mullet

The rainy season turns the guts into dramatic waterfalls

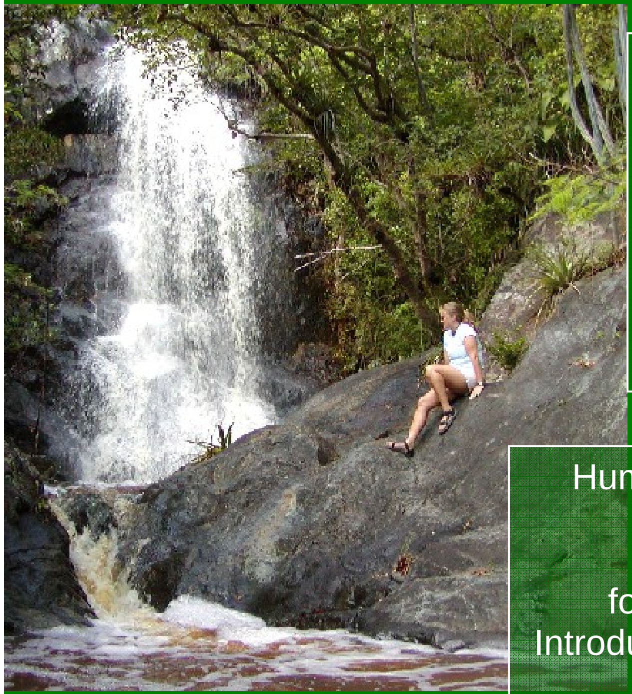

Photo : S. Herzlieb

When land is cleared for development,
rushing water carries topsoil, sewage, and pollutants down to sea.
These damage fragile coral reefs.

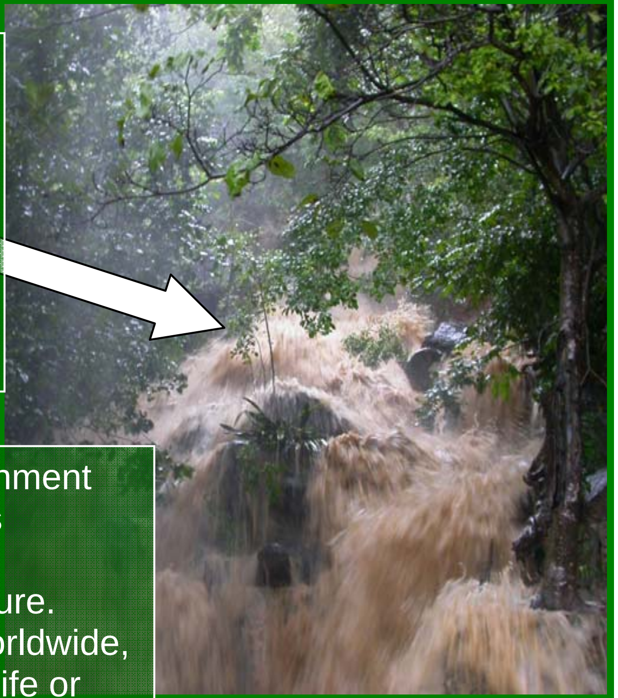

Photo : D. Morton

Humans have changed the environment by introducing exotic species
–-guppies & Tilapia–
for mosquito control or aquaculture.
Introduced species are a problem worldwide, as they may eat native wildlife or compete with them for food.

USGS
science for a changing world

University of the Virgin Islands scientists are studying the impact of human activity and development on the animal communities in the guts.

Water Usage and Papaya Growth in Double−Row Systems Established During the Dry Season

Basic Information

Title:	Water Usage and Papaya Growth in Double−Row Systems Established During the Dry Season
Project Number:	2007VI85B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	N/A
Research Category:	Biological Sciences
Focus Category:	Agriculture, Drought, Irrigation
Descriptors:	
Principal Investigators:	Thomas W. Zimmerman

Publication

1. None as yet.

PROBLEM AND RESEARCH OBJECTIVES

The crop farms in the U.S. Virgin Islands are mainly comprised of small farmers. The average amount of land for a crop farmer is 4.7 acres (National Agricultural Statistics, 2000). Though this average includes livestock farmers, the crop farmers are less than 2 acres. The small size limits the investment the farmer can make to produce a crop. They have to see a strong benefit to a technology before they invest in it and adapt it to their farming practices. New technologies are being developed for papaya production. Papaya requires nine months from seed, in the early varieties, to have a marketable crop. To have fruits available during the holiday season and peak tourist season, papayas need to be planted in late February through March. However, February through August are normally the driest months of the year in the US Virgin Islands.

Plant spacing from the past project indicated that growth and production were not influenced by plant spacing. The plant spacing was 9’ x 9’, 6’ x 9’ and a double-row 3’ x 9’. The double-row provided a higher planting density and a more efficient use of space and irrigation water.

Drip irrigation technology permits the resourceful use of water and can help maximize the use of semiarid lands for agricultural use. This technology is particularly suited to widely spaced crops as papaya. Though multiple field trials have shown the economic beneficial use of drip irrigation on vegetable and herb production in the Virgin Islands limited information is available on the use of drip irrigation for papaya production. It has been suggested that the water needs for papaya in Hawaii are ideally supplied with 100 mm of rainfall each month. This amount is seldom encountered in the semiarid climate of the Virgin Islands where erratic rainfall patterns and extended dry periods are the norm. Also, the local preference is for large, greater than two pounds, red papayas while most papaya research from Hawaii has focused on small, yellow one pound or smaller fruit. Not only are the varieties different between the Virgin Islands and Hawaii but also the soil. The soils of the Virgin Islands are calcareous, having a high pH around 8 versus volcanic base in Hawaii. Breeding and selection of papayas at the University of the Virgin Islands has resulted in early bearing varieties that meet the fruit preferences of the Virgin Islanders.

Water is most often the limiting factor to crop production in the U.S. Virgin Islands. The municipal source of water is from desalination of ocean water. Due to the cost of the desalinated municipal water, farmers use the water sparingly. The most efficient use of water can result in economical gains for the local farmers. We wish to develop for farmers proficient ways to manage water usage throughout papaya establishment to ensure quality production during the greatest demand for the product. By establishing the beneficial influence drip irrigation, mulch and plant spacing has on papaya production, the small scale farmers will be encouraged to grow papayas and apply the irrigation technology to the situation and incorporate sustainable production practices, water conservation and improve soil stewardship. The expected benefit to the small scale minority farmer is not only the use of environmentally sound farming practices but also increase real income from production. The results will be applicable to small scale farmers in the tropical regions both domestic and foreign. This research project expanded on the double-row concept to include closer double-row spacing to determine the best intensive plant spacing for the most efficient use of water for fruit set.

The objectives of this research were to develop a commercial papaya producing field plot that incorporates drip irrigation and mulch for growing selected papaya varieties at multiple double-row spacing regimes and determine water usage during the dry season in the U.S. Virgin Islands. Specifically to integrate water conservation through drip irrigation and mulching into papaya production, determine water requirements of papaya grown under multiple double-row plant spacing regimes and determine the growth and production potential of papaya as influenced by spacing under drip irrigation and biodegradable mulch.

METHODOLOGY AND PRINCIPAL FINDINGS

Papaya plants were established in double-row spacings during February from greenhouse grown seedlings. Water usage was recorded over a six month period which corresponds to the annual dry season from March through August with the assistance of a prebaccalaureate student. Tensiometers were used to record soil moisture levels and determine when irrigation water needed to be applied.

To study the integrate water conservation through drip irrigation and mulching into papaya production, papaya were established from seed in a greenhouse one and a half months prior to transplantation to the field at the University of the Virgin Islands Agricultural Experiment Station on St. Croix. The three varieties used were 'Maradol', 'Tainung 5' and 'Yuen Nong 1'. 'Maradol' is a compact variety producing red 4-5 lb fruit. 'Tainung 5' and 'Yuen Nong 1'are standard sized trees that produce large red and yellow fruit respectively.

A double-row plant spacing regime was followed. A nine foot distance was between double-rows to allow for tractor cultivation until the plants attain three feet. Each double-row was three feet apart. The distance between each plant within a row of the double-row varied from three feet, six feet or nine feet which corresponds to 2,400, 1,200, or 800 plants per acre respectively. Each plant spacing was replicated three times and had ten plants of each variety per replication. Guard rows were planted on both sides of the field and between replications. Guard plants were also planted at the end of each row.

One drip line of irrigation was installed at the time of transplanting six-eight inch tall seedlings into the field. The spacing of the orifices in the linear irrigation tubing was three feet and exude one gallon per hour. The drip lines were placed near the plant base and moved outward to a distance of 1.5 feet from the base of the plant. A final drip line was added between the double rows when the plants were at three feet in height. The double rows then had a drip line outside of each row and one between the double-rows for a total of three lines per double-row. Hay mulch was applied to the whole field after the third drip line was installed. The drip lines were under the mulch and in contact with the soil. The hay mulch was spread to a depth of the three inches between plants and rows. The straw/hay was obtained from the VI Department of Agriculture as large round bales.

To determine water requirements of papaya grown under double-row plant spacing regimes soil moisture tensiometers were placed throughout the plots at a depth of 15 cm and 30 cm. The tensiometers were used to determine soil moisture content. Water meters were installed for each plant spacing plots and the amount of water applied recorded over time. Rainfall information was obtained from the IVI-AES weather station.

During the initial six month growth of the papaya plot corresponding to the dry season, data was collected on plant height, height to first flower, height to first set fruit, stem diameter at three feet from the soil surface and number of fruit set when the first fruit was ripening. This growth and production data was obtained to determine the influence of spacing and drip irrigation on papaya yield.

A prebaccalaureate student assisted in data collection and entered the data into a computer spread sheet. The student was involved in all aspects of the research and was an integral part throughout the project.

Papaya were established under field plot conditions in early 2007 from seeds germinated in a greenhouse. The first six months of 2007, during the establishment of the papaya plot, a typical dry season was experienced on St Croix (Figure 1). Low rainfall started in January and when plant establishment occurred in early February, the soil was dry. There was a spike in rainfall during April. Heavy rains were received that lasted a week and provided seven inches of rainfall. The soil moisture content was at field capacity during these heavy rains causing the tensiometer to read zero for ten days (Figure 2). The soil tensiometers' readings increase in value as the soil dries. When the soil is saturated the readings decrease to zero. Figure 2 also indicates that plant spacing did have an influence on soil moisture available to the plants. The same dripline, with three foot emitters, was used for all spacing treatments and the 3' x 3' double row spacing configuration had drier soil before and after the heavy April rains. The closer the plant spacing results in more competition from the plants roots for the water available in the soil. The papaya plants in the 3' x 3' spacing competed more for the available water, reducing the soil moisture quicker, then was observed for either the 3' x 6' or 3' x 9' double row spacing.

During the initial six months of papaya establishment and growth, water was applied as indicated in Figure 3. The wet soils from the heavy April rains resulted in less water being applied to the papayas in April. The mulch was very effective in controlling weeds, conserving soil moisture and protecting the soil from erosion during sudden short heavy tropical rains. However, the straw mulch absorbs the light showers preventing the water from reaching the soil. Most light showers have minimal effect on the soil and availability to plants due to the high evaporation rate. The total amount of water given to each plant was 62 gallons over seven and one half months for the 3’ x 6’ plant spacing during which plant establishment, floral induction and fruit set occurred.

Plant spacing did have an influence on the height of ‘Maradol’ plants over time. After two months of growth, the 3’ x 3’ spacing caused the plants to be taller then the more distant spacings (Figure 4). ‘Maradol’ is a compact papaya variety that has a slower rate of growth but the close plant spacing caused it to stretch to have a difference of 50 cm by the forth month. ‘Maradol’ grew at the same rate for the 3’ x 6’ and 3’ x 9’ plant spacing.

Both ‘Tainung 5’ and ‘Yuen Nong 1’ are standard sized papaya trees. However, the close 3’ x 3’ spacing had taller plants after one month (Figures 4 and 5). The leaves start interacting with each other after a month’s growth at the close plant spacing. As the plants became taller with age, the close spacing caused the plants to grow outwards resulting in a ‘V’ shaped double row. This leaning outward was not observed in the 3’ x 6’ or 3’ x 9’ spacing which grew perpendicular to the soil.

The stem diameter can have an influence on the plants ability to support a column of fruit as well as have tolerance to wind. Thinner stemmed plants tend to snap in wind when carrying a heavy fruit set. These varieties are grown because they are able to set 30-50 fruits. For all three varieties the close plant spacing had the thinnest stems (Table 1). The 3’ x 9’ plant spacing resulted in significantly thicker stems then the 3’ x 3’ spacing. With ‘Tainung 5’ both the 3’ x 9’ and 3’ x 6’ spacing had significantly thicker stems then the 3’ x 3’ spaced plants.

The height to first flower and height of the first set fruit indicate how low the fruit is set on the stem. These three varieties were chosen because they set fruit early. Flowers are present between the first and second of field establishment. Papaya trees that set fruit early have a lower center of gravity and less prone to high winds. Both the 3’ x 6’ and the 3’ x 9’ spaced plants had earlier flowering and fruit set lower to the soil surface for all varieties then the 3’ x 3’ plants (Figure 7). Lower fruit set also allows more fruit to be within reach for a longer period of time.

The main reason for growing papaya is for production. The number of fruit set on a papaya stem column was recorded when the first fruit ripened and indicates expected production for the tree. For all three varieties, the 3’ x 3’ double row spacing set significantly less fruit then either the 3’ x 6’ or 3’ x 9’ double row spacing (Figure 7). This indicates that the close plant spacing can’t hold as many fruit and may be influenced by the water availability to the plant previously discussed. The 3’ x 6’ and 3’ x 9’ double spaced plants were not significantly different for fruit set. The 3’ x 6’ double row spacing was the most efficient for water usage and land area to produce the most fruit.

The papaya plants for ‘Maradol’, ‘Tainung 5’ and ‘Yuen Nong 1’, grown in a 3’ x 3’ double row system were taller, had thinner stems and significantly fewer fruit set then the 3’ x 6’ or 3’ x 9’ double row spacing regime during a normal dry season of six months for plant establishment and growth. The 3’ x 6’ double row grown papaya were similar to the 3’ x 9’ double row plants for height, stem diameter and fruit set. The 3’ x 6’ double row growing system is recommended to increase production where space and water are limiting factors. A grass/hay mulch is very effective in controlling weeds, conserving soil moisture and protecting the soil from erosion during sudden short heavy tropical rains.

SIGNIFICANCE

Significant findings from this study was that the grass/hay mulch conserves and hold moisture in the soil following sudden heavy tropical rains and prevents erosion causing run-off. Tensiometers were able to follow soil moisture over time and usage by the papaya plants. A 3’ x 3’ double row spacing depletes the soil moisture quicker, results in thinner stemmed plants with fruit set higher from the soil surface then the 3’ x 6’ or 3’ x 9’ double row spacing. The 3’ x 6’ double row spacing, allows for 1,200 plants per acre, and production similar to a 3’ x 9’ double row spacing of 800 plants per acre. Using a grass/hay mulch and the 3’ x 6’ double row spacing is the most efficient papaya plant spacing for water usage and fruit production in the Virgin Islands.

Table 1. Diameter of papaya stems taken at a one meter height for three varieties as influenced by plant spacing in a double row system.

	Spacing (ft)*		
Variety	**3x3**	**3x6**	**3x9**
Maradol	**6.70 a**	**7.80 ab**	**9.01 b**
Tainung 5	**6.49 a**	**8.67 b**	**9.36 b**
Yuen Nong 1	**7.01 a**	**8.35 ab**	**9.86 b**

*Mean separation within rows conducted using LSD P=0.05

Table 2. Number of fruit set at the time of the first ripe fruit for three papaya varieties as influenced by plant spacing in a double row system.

	Spacing (ft)*		
Variety	**3x3**	**3x6**	**3x9**
Maradol	**23.3 a**	**35.9 b**	**38.8 b**
Tainung 5	**27.9 a**	**46.1 b**	**49.0 b**
Yuen Nong 1	**23.1 a**	**36.5 b**	**39.1 b**

*Mean separation within rows conducted using LSD P=0.05

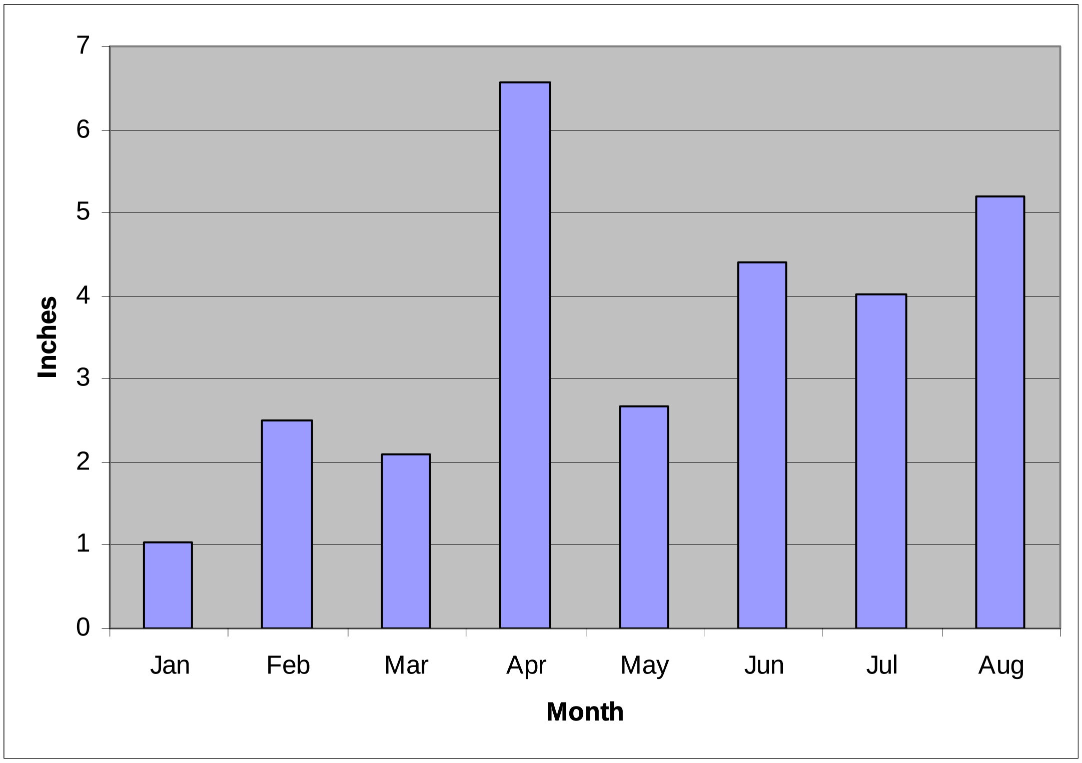

Fig. 1. Average monthly rainfall during 2007.

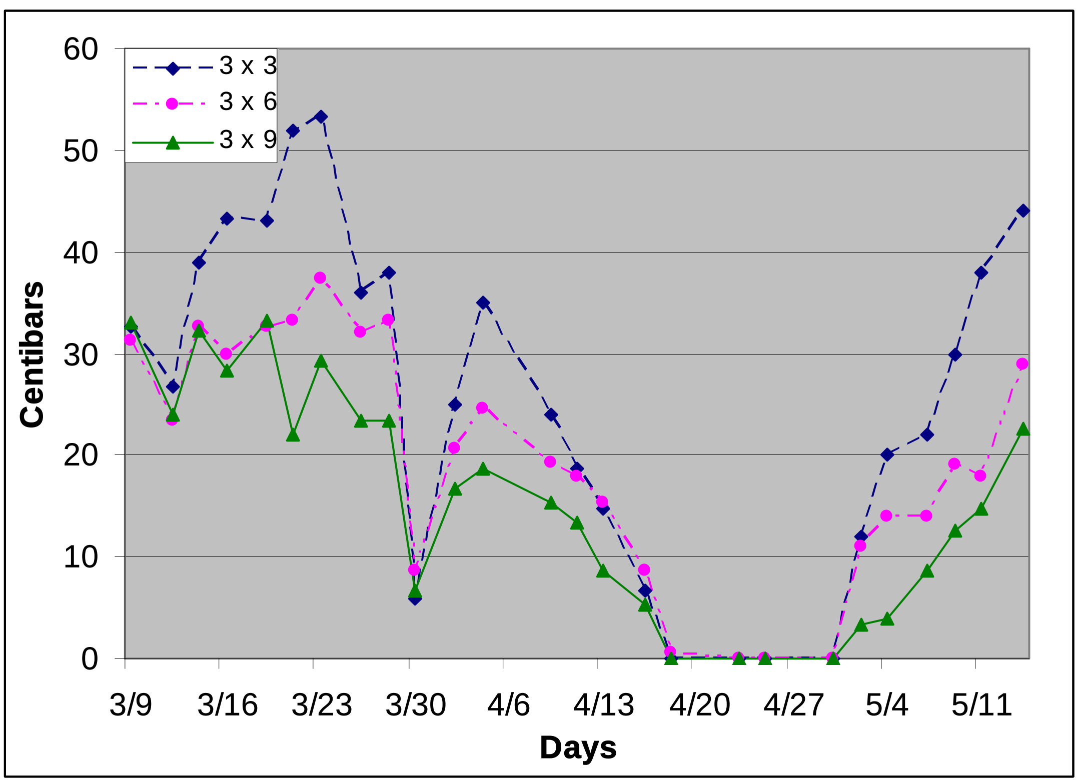

Fig. 2 Soil tensiometer readings, in centibars, over time for each papaya spacing.

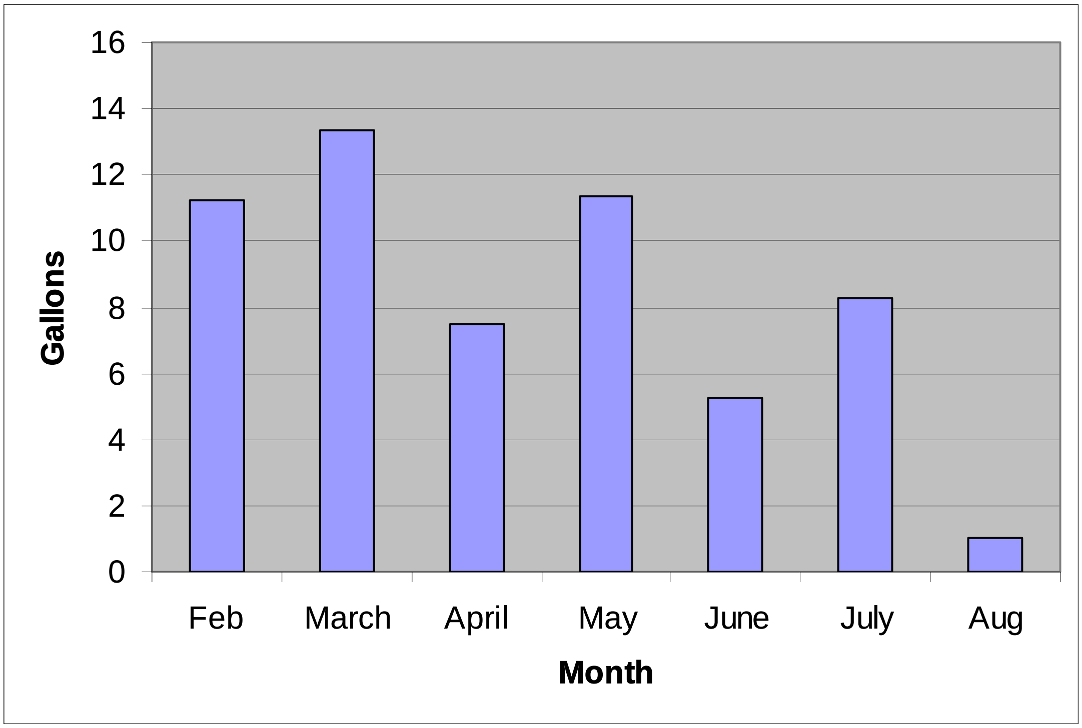

Fig. 3. Average gallons of water applied to each papaya plant.

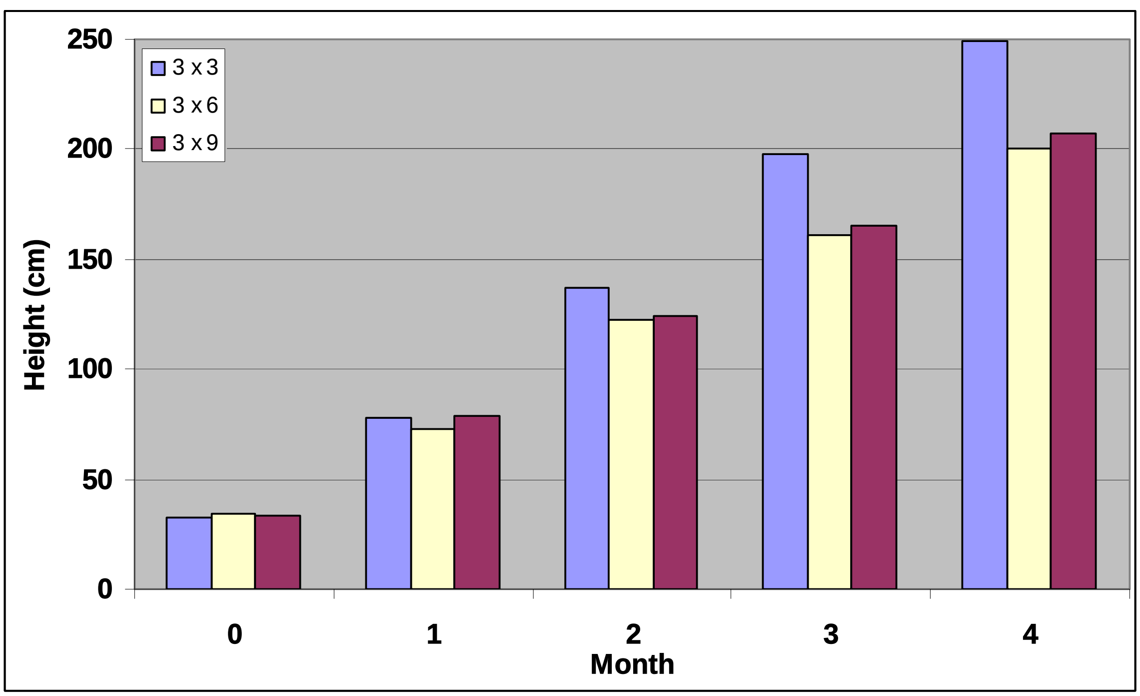

Fig. 4. Plant height of the 'Maradol' papaya plants during the first four months.

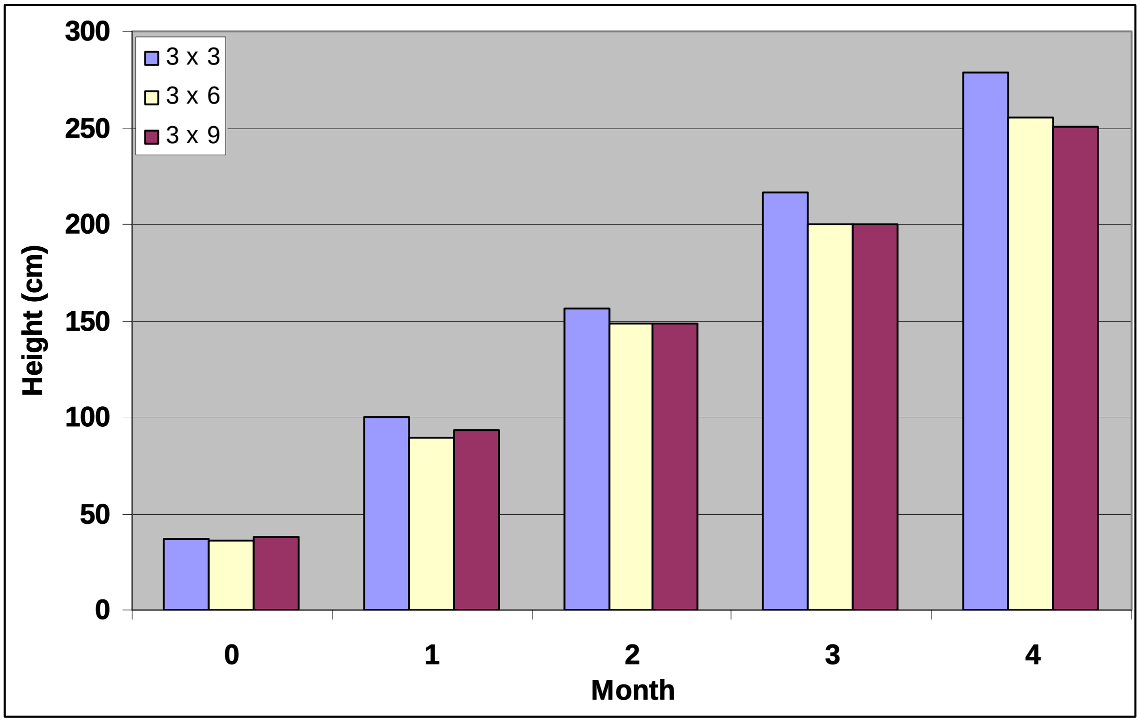

Fig. 5. Plant height of the 'Tainung 5' papaya plants during the first four months.

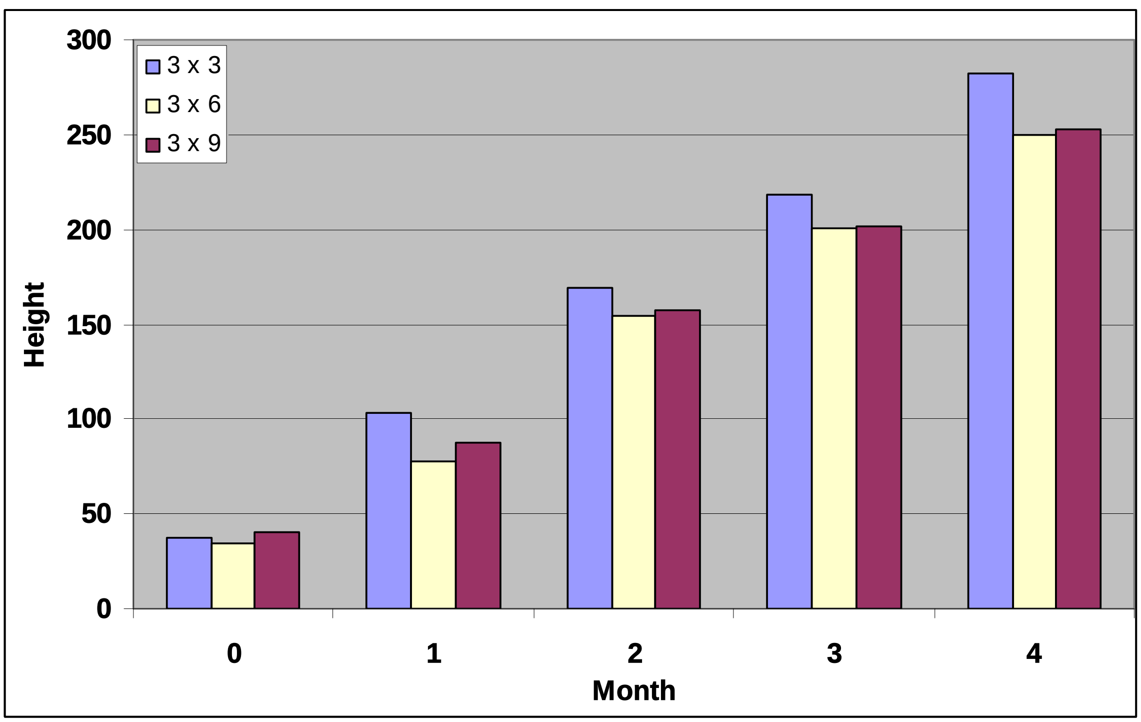

Fig. 6. Plant height of the 'Yuen Nong 1' papaya plants during the first four months.

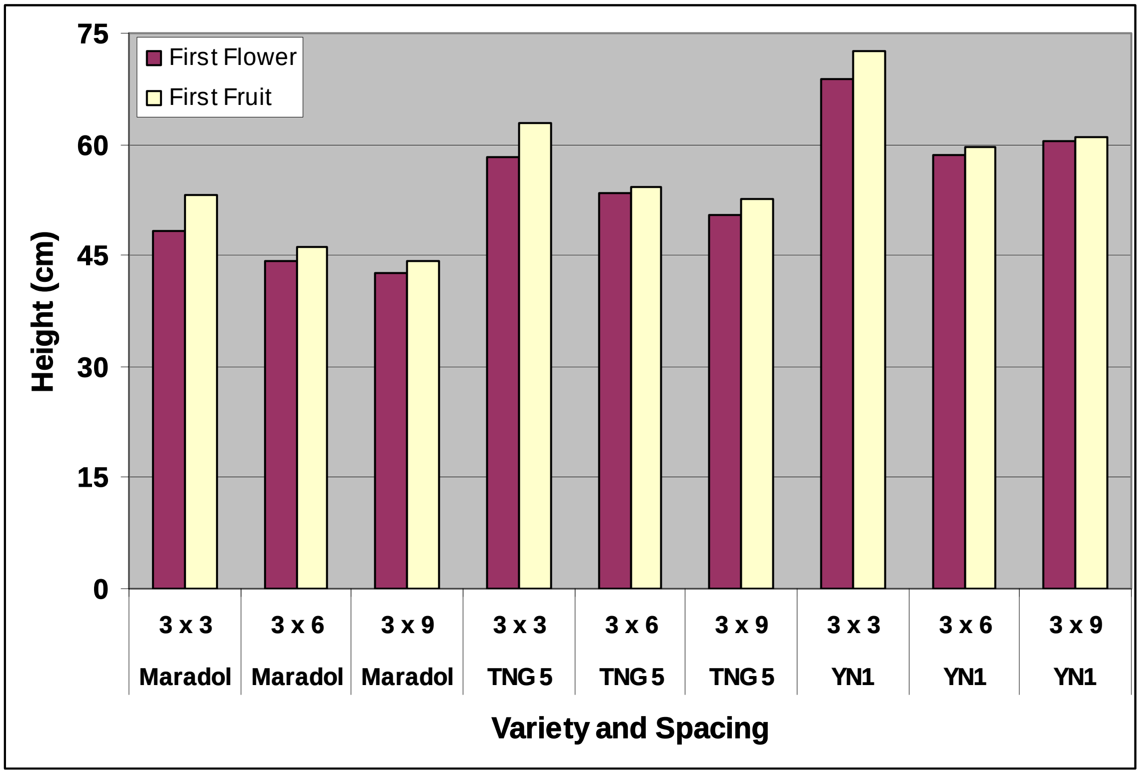

Fig. 7. Effect of plant spacing on the initiation of the first flower and setting of the first fruit for three papaya varieties.

Response to Uncertain Irrigation Supplies Through Recovery and Application of Aquaculture Wastewater for Agronomic Crops Cultivated in the U.S. Virgin Islands.

Basic Information

Title:	Response to Uncertain Irrigation Supplies Through Recovery and Application of Aquaculture Wastewater for Agronomic Crops Cultivated in the U.S. Virgin Islands.
Project Number:	2007VI90B
Start Date:	3/1/2007
End Date:	2/1/2008
Funding Source:	104B
Congressional District:	N/A
Research Category:	Biological Sciences
Focus Category:	Agriculture, Irrigation, Water Use
Descriptors:	
Principal Investigators:	Jason James Danaher, Kathryn M Lincoln

Publication

1. None as yet.

PROBLEM AND RESEARCH OBJECTIVES

Improving water use efficiency is critical to most Caribbean islands where there is low per capita freshwater availability. Concerns for water conservation in the U.S. Virgin Islands have promoted the development of intensive, recirculating fish production systems. These systems treat and reuse a major portion of their production water, but rely on the removal of nutrients and organic matter through biological and mechanical processes to ensure system sustainability. Discharged aquaculture effluent is comprised of organic matter and high levels of nitrogen and phosphorus which can pose an environmental threat; thus increasing waste production through intensification will require novel methods for managing aquaculture effluent. To abate the environmental impact new management practices need to be adopted to reuse the nutrients and water.

Integrating recirculating aquaculture systems with the production of other valuable agronomic crops to recycle nutrients and reuse water could provide a viable solution to sustainable food production in semi-arid regions. Experiments have demonstrated aquaculture effluent to be an excellent nutrient source for agronomic plants; thus, effluents should be treated as a resource management and not as a disposal problem. One major constraint to the integration process has been clogging of irrigation systems due to high levels of organic matter. Technology that is capable of separating the solid fraction from the liquid portion of fish effluent would give farmers increased options for integrating aquaculture and vegetable production.

Geotube® technology now exists and creates a more flexible approach for the integration of aquaculture effluent with agronomic crops. A Geotube® is constructed from a high strength woven geotextile fabric that can be filled repeatedly with aquaculture effluent and allowed to dewater for a period of time. This process could possibly create options and opportunity for the agricultural operator by allowing the solid fraction retained in the Geotube® to be used as a fertilizer and the filtrate exiting the Geotube® to be used as a water source for agronomic crops.

Objectives

1. Evaluate geotextile material (Geotube®) for the recovery and reuse of solids, wastewater, and dissolved nutrients from aquaculture effluent for use on agronomic crops.
2. Evaluate the efficacy of drip irrigation systems delivery of Geotube® filtrate.
3. Evaluate the nutrient content of Geotube® retained solids, establish its quality for amending soils in agronomic crop plots, and establish if the filtrate is a nutrient source based on plant response.

METHODOLOGY

Experiment A

Objective 1 and objective 2 were assessed through experiment A. A 150-m3 lined, storage pond was the source of the fish effluent. A Geotube® measuring 7.6m × 2.3m was installed adjacent to the storage pond. A 3/4-Hp vertical lift aerator and horizontal mixer were used to agitate the fish effluent prior to each pumping event. A 1/3-Hp pump, pumped effluent at a rate of 114 liters/minute. Prior to entering the Geotube® the effluent was treated with a polymer, Hyperfloc® CE 854, (Hychem, Inc., Tampa, FL) at a concentration of 14.2 mg/L and allowed to mix by passing through a series of 90-degree PVC elbows.

The first two pumping events occurred on 29 November and 14 December 2007. The final occurred on 17 January 2008. On each sampling date three pond sludge (PS) samples were collected directly adjacent to the pump at a depth of 30 cm. A 250-mL aliquot of the samples was sent for water quality analysis of PS. On each sampling date three samples of Geotube® filtrate (GF) were also taken from different locations where filtrate was weeping from the Geotube® during filling. A 250-mL aliquot of the samples was sent for analysis of GF. A sample of retained solids (RS) in the Geotube® was taken on 17 January prior to the final pumping event and analyzed for pH, organic matter, moisture content, and nutrient concentrations. Water samples of PS, GF, and RS were sent to Micro Macro International, Inc. (Athens, GA) for analyses of micro- and macronutrient concentrations.

Over a four-week period GF was pumped through a T-tape® irrigation system to determine if clogging occurred.

Experiment B

This is an on-going project evaluating objective 3. The study is evaluating RS and GF as nutrient sources compared to a commercial inorganic, slow release fertilizer (Osmocote®). The experiment consists of three treatments with three replicates (28-m^2) each. The control is a slow-release 12-12-12, inorganic fertilizer [Osmocote®] with rainwater. Treatment two is RS with rainwater and treatment three is RS with GF. A Randomized Block Design was used for the experimental design and data will be analyzed using ANOVA

Based on an initial soil test of the growing area a recommended fertilization application was applied. Each fertilizer was applied and rototilled in on 1 April. Osmocote was applied at the equivalent of 880 kg/ha and RS (83 % moisture) was applied at the equivalent of 5 mt/ha. Cucumber (*Cucumis sativus* v. Eureka) were seeded in the greenhouse 8 April. On April 21st a Geotube was filled and filtrate was collected for irrigation purposes. A sample of the filtrate and rainwater was sent for nutrient analysis. A T-tape® irrigation system was installed to deliver water. On 21 April a soil test was performed at the beginning of the experiment and another will be performed at the end of the experiment to compare soil pH, buffer pH, NO_3-Nitrogen, Ca, Mg, K, P, B, Cu, Fe, Mn, Na, S, Zn, organic matter, calculated cation exchange capacity (CEC), and base saturation %. Transplants were planted on the 22 April. Spacing between rows is 0.37 m and plant spacing within each row is 0.19 m. Straw mulch was added on 25 April.

PRINCIPAL FINDINGS AND SIGNIFICANCE

Experiment A

Table 1. Averages of water quality parameters and nutrient concentrations measured during experiment for pond sludge (PS), geotube filtrate (GF), and geotube retained solids (RS).

	Pond Sludge Mean ± S.D.	**Geotube Filtrate** Mean ± S.D.	**Percent Removal**	**Geotube Solids**
pH	7.6 ± 0.3	7.7 ± 0.4		8.1
Temperature	24.5 ± 0.5	24.5 ± 0.5		
Alkalinity (mg/L)	860.0 ± 34.6	801.3 ± 90.5		
TSS (mg/L)	22,525.0 ± 3,892.2	115.0 ± 68.7	99	
Macronutrients (mg/L)				
NPK (%)	0.09 **:** 0.15 **:** 0.03	0.02 **:** 0.04 **:** 0.03		3.6 : 6.0 : 0.2
Total Nitrogen	898.7 ± 27.3	244.5 ± 59.7	73	36,400.0
Phosphorus	670.3 ± 550.1	155.7 ± 207.5	77	60,026.0
Potassium	248.4 ± 151.1	225.8 ± 151.3	9	1,852.0
Calcium	3,404.5 ± 2,878.4	417.3 ± 333.4	88	136,242.0
Magnesium	127.0 ± 62.1	66.3 ± 69.4	48	2,447.0
Micronutrients (mg/L)				
Iron	33.3 ± 14.1	14.5 ± 19.9	56	2,028.0
Copper	8.0 ± 7.0	8.3 ± 10.5	- 4	112.0
Zinc	23.8 ± 22.0	22.3 ± 15.9	6	1,195.0
Boron	5.5 ± 3.7	13.5 ± 19.1	- 73	48.0
Manganese	13.0 ± 9.0	5.8 ± 10.8	55	773.0
Molybdenum	7.3 ± 9.0	13.3 ± 20.0	- 82	0.0

Results are presented in Table 1. The Geotube® technology reduced TSS concentration 99%. The T-tape® drip irrigation system did not clog using GF. All macronutrient concentrations decreased, while micronutrient concentrations were found to either increase or decrease in GF samples. The pH of RS was higher than the average PS or GF readings. Results found RS contained substantially higher NPK levels than either the PS or GF. Comparison of PS and RS showed the Geotube® concentrated macronutrients and micronutrients by factors ranging from 7 - 40x and 0 - 60x, respectively. Analysis of RS showed it was composed of 59.3% organic matter with 86.4% moisture content after four weeks of dewatering.

Geotube® technology was highly effective in reducing the concentration of TSS in fish effluent. The GF contained a dilute nutrient concentration and a total of 1,230 liters of GF was shown to pass through standard, commercial irrigation systems without clogging or need for further filtration. The GF and RS from the Geotube® would allow an integrated farming system to utilize aquaculture effluent on agronomic crops during seasonal water shortages or persistent droughts.

Experiment B

This is an on-going project evaluating objective 3. Data will be obtained and results will be analyzed for total yield, marketable yield, and individual fruit length and width. It is hoped that dependence on inorganic fertilizers could possibly be reduced by applying dilute GF and/or concentrated RS to agronomic field plots. Thus, improving the on-farm nutrient cycle for small farmers.

Selection of Sediment Transport Functions for St. Thomas Island Guts

Basic Information

Title:	Selection of Sediment Transport Functions for St. Thomas Island Guts
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Focus Category:	Geomorphological Processes, Sediments, Hydrology
Descriptors:	
Principal Investigators:	Walter F Silva

Publication

1. Silva−Araya, W., Ruiz, R., Rodriguez, A., 2007, “Field Reconnaissance in Turpentine Creek”, Poster presented at the Seventh Caribbean Islands Water Resources Congress, University of the Virgin Islands, St. Croix, US Virgin Islands.
2. Silva−Araya, W., Garcia−Medina, G. and Ruiz, R., Submitted for November 17−20, 2008, “Selection of Sediment Transport Functions for St. Thomas Guts”, AWRA 2008 Annual Water Resources Conference, Louisiana, New Orleans.

PROBLEM AND RESEARCH OBJECTIVES

Very little is known about sediment transport processes in the Caribbean Islands. Although there are no perennial streams in the Virgin Islands, *guts* become the main channel for transporting water and sediments during runoff conditions. Suspended and bed sediment discharge into the coastal areas impact the coral reefs and marine life. Same as in perennial streams, aggradation in guts changes the channel capacity and reduce the effective area for flow conveyance, increasing the probability for flooding conditions. Conversely, guts degradation increases bed erosion and deepens the channel. The net effect in both cases is channel instability.

Sediment transport during flow discharge periods is usually estimated by using *sediment transport functions.* The common approach to select the most appropriate sediment load equation for a particular stream is to analyze a series of measured values of suspended and/or bed load in order to find the function that best fit the field data. This approach requires a long period of historic measurements and usually this information is not available; therefore, this methodology cannot be applied in many streams

This research selected sediment transport functions for Turpentine Run watersheds, which is the largest watershed in St. Thomas, US Virgin Islands. The proposed methodology does not require long periods of sediment discharge measurements. Instead, it uses grain size distributions, geometric and hydraulic parameters of the water course to identify those sediment transport functions more appropriate for the existing conditions.

METHODOLOGY

The methodology followed in this research was divided in the stages described next.

Field Reconnaissance

A field reconnaissance and data collection visit was done in Turpentine Run watershed from September 10 to 15, 2007. Three days were dedicated to a field reconnaissance of the creek, including collection of sediment samples, surveying of cross sections and longitudinal profiles of the thalweg; as well as, observation of the geomorphic characteristics. Topographic and soil data will be used to construct a hydraulic and sediment transport model to estimate potential sediment rates for this watershed.

Development of the Hydrologic Model

Turpentine Run's hydrologic analysis objective is to determine the discharge produced by a given rainfall event. The U.S. Army Corp of Engineers model Hydrologic Modeling System (HEC-HMS 3.0.1) was used in this analysis. In order to develop the model; rainfall events, soil abstractions, rainfall storage in underground tanks, travel time and channel routing were determined.

Rainfall Events

Design storms represent the rainfall distribution for a given probability of occurrence (named recurrence interval) and duration. The rainfall data for US Virgin Islands was obtained from

NOAA's Atlas 14 (http://hdsc.nws.noaa.gov/hdsc/pfds/pr/vi_pfds.html) using the coordinates of the centroid of Turpentine basin: 18.333 N 64.897 W. Table 1 presents the storm depth for different storm durations and return periods used in the hydrologic model. A power regression for each return period was adjusted to data from Table 1. Hyetographs were developed using a rainfall distribution where the highest amount of rainfall occurs at the center of the storm duration. Other rainfall increments were distributed alternatively in both sides from the center of the storm duration. This rainfall distribution pattern is similar to that recommended by the National Resources Conservation Service (NRCS) in Technical Release 55 (TR-55) for 24 hrs design events in the United States Virgin Islands (Type II rainfall distributions) and produced a hyetograph similar to the one shown in Figure 1.Storms were computed for durations of 6, 12 and 24 hours and recurrence periods of 1, 2, 5, 10, 25, 50 and 100 years.

Table 1 Precipitation Frequency Estimates (inches)

ARI (years)	5 min	10 Min	15 Min	30 Min	60 min	120 Min	3 hr	6 hr	12 hr	24 hr	48 hr
1	0.32	0.44	0.56	0.91	1.34	1.72	1.90	2.29	2.67	3.08	4.06
2	0.41	0.56	0.73	1.16	1.72	2.22	2.48	3.04	3.62	4.19	5.56
5	0.51	0.70	0.90	1.44	2.14	2.89	3.25	4.22	5.29	6.30	8.32
10	0.59	0.81	1.03	1.66	2.46	3.41	3.86	5.20	6.67	8.11	10.59
25	0.69	0.94	1.21	1.94	2.87	4.11	4.68	6.57	8.66	10.77	13.91
50	0.77	1.05	1.34	2.15	3.19	4.67	5.32	7.68	10.31	13.04	16.68
100	0.84	1.15	1.48	2.36	3.50	5.23	5.99	8.86	12.06	15.51	19.64

Geospatial Analysis

Hydrological characteristics including watershed area calculation, watershed area delineation, sub watershed area delineation, longest flow path and watershed slope was done by using geospatial analysis. The ArcHydro Tool calculates the watershed boundaries, the longest flow path, watershed slope and watershed area. This tool use a digital elevation model (DEM) as an input to calculate all the variables. Turpentine Run watershed was divided into six (6) sub-watersheds using geospatial analysis delineation as shown in Figure 2 .Table 2 present the corresponding area. Other data obtained from the geospatial analysis is included in different tables along this report, where it was required.

Curve Numbers

GIS techniques were applied for the curve number calculation. The curve number is associated with the hydrologic soil group cover and land use. To calculate a curve number we use the NRCS soil layer with the hydrological groups and a land use cover. A general land use was created using NOAA's 1999 two meter resolution aerial photography, topographic quadrangles and rectified with field recognition. To be more accurate it was compared with the Google Earth's images. These two layers were intersected and a curve number was assigned. To assign the corresponding curve number a CN table was previously created with the different land use and hydrological soil group cover. Curve numbers for every sub-basin are shown in Table 2.

Hydrologic Abstractions

Once the curve numbers are obtained the initial abstractions due to water absorption by the soil are computed. The National Resources Conservation Service methodology outlined in its Technical Release 55 was used. Initial abstractions are defined as the losses before runoff begins. Initial abstractions were determined for every sub basin, as shown in Table 2.

Table 2. Watershed Characteristics, Curve Numbers and Initial Abstractions

Sub Basin	Averaged CN	Area Km^2	Area Ft^2	Area mi^2	S	Initial Abstraction (in)
Sub-T1	82	1.000	10762830.696	0.386	2.195	0.439
Sub-T2	79	0.891	9588974.169	0.344	2.658	0.532
Sub-T3	79	2.361	25415608.184	0.912	2.658	0.532
Sub-T4	81	1.626	17498032.301	0.628	2.346	0.469
Sub-T5	86	1.298	13973132.664	0.501	1.628	0.326
Sub-T6	82	1.208	13000642.041	0.466	2.195	0.439

Effects of rainfall collection reservoirs

Water captured by the storage tanks beneath St. Thomas houses doesn't become runoff. This particular effect was considered as an initial abstraction in the hydrologic model. According to regulations, a minimum of 10 gallon of storage capacity should be provided per square foot of roof area, the following analysis was done. An average roof area and the total roof-cover over the basin were estimated. The corresponding storage volume was computed and converted into an initial abstraction. Fifty (50) randomly selected structures were chosen and their roof area was measured from high resolution satellite images and Arc-GIS 9.1. A total of 1827 square ft area resulted. The number of houses in each sub-basin was determined using the satellite image. The volume of water trapped in the reservoirs was normalized using each sub-basin's area. The results are shown in Table 3. Table 4 presents the comparison between retention volumes with and without the storage tanks effect.

It can be noted that, for sub-basins 4, 5 and 6, which are the more populated areas, the water tank volume is larger than the natural initial infiltration volume. This is due to the predominance of soil with small infiltration rate (mostly hydrologic type D) which is reflected in a high value of the Curve Number. If all tanks were emptied at the beginning of a storm event, the initial abstractions due to this effect will be larger than the initial abstraction for the natural soil conditions.

Time of Concentration

Time of concentration is defined as the time required for a particle of water to flow hydraulically from the most distant point in the watershed to the outlet or design point. In order to obtain the time of concentration, the longest flow path of every sub-basin was found using ARC-GIS 9.1. This parameter was obtained for every sub-basin using the TR-55 method. Each flow path was segmented according to slope and geomorphology. Time of concentration is the algebraic sum of the travel times for each segment in the longest flow path. The TR-55 method requires that lag time be an input instead of the time of concentration; lag time for a given flow path is the 60% of the time of concentration for a given flow path. Each Sub-Basin's Time of Concentration is found in Table 5.

Hydrologic Model

A hydrologic model was created for Turpentine Run using HEC-HMS 3.0.1 developed by the United States Corps of Engineers. This model's main purpose is to determine the total discharge at the beginning of the channelized section given different rainfall events. The model consists of the six sub basins two reaches and three junctions; this will simulate the water behavior. Two independent models were developed, one considers the storage effect due to underground tanks and the other one doesn't.

Frequencies include 100, 50, 25, 10, 5, 2, and 1 year with 6, 12 and 24 hour periods, values are shown in the design storms section. The model results are summarized in Figures 3 and 4. These figures present the peak discharges for different storm durations and return periods with and without considering the storage tank effects. Discharges correspond to the beginning of the channelized section before the mangrove lagoon. Results provided by the model were used in the sediment transport analysis.

Table 3. Estimated storage in rainfall water storage tanks for Turpentine sub-basins

Sub Basin	Houses	Basin Area (ft^2)	Storage (gal)	Abstractions (in)
Sub-T1	83	10762830	1516410	0.22
Sub-T2	0	9588974	0	0.00
Sub-T3	40	25415608	730800	0.046
Sub-T4	616	17498032	11254320	1.03
Sub-T5	657	13973132	12003390	1.387
Sub-T6	484	13000642	8842680	1.091

Table4. Combined effect of soil abstractions and rainfall collection reservoirs.

Sub Basin	Soil (in)	Storage (in)	Abstractions (in)
Sub-T1	0.439	0.226	0.665
Sub-T2	0.532	0.000	0.532
Sub-T3	0.532	0.046	0.578
Sub-T4	0.469	1.032	1.501
Sub-T5	0.326	1.378	1.704
Sub-T6	0.439	1.091	1.530

Table 5. Time of Concentration and Lag Time for each sub-basin

Sub-Basin	Time of Concentration (hr)	Lag Time (min)
T-1	1.13	40.5
T-2	1.84	66.2
T-3	2.50	89.8
T-4	3.26	117.4
T-5	1.25	45.0
T-6	0.28	9.9

Hydraulic Analysis

The hydraulic analysis was done using SAM-HYD to calculate Turpentine Run's normal depth. SAM-Hyd requires water temperature, energy slope, water surface elevation and geometry data. Water temperature was assumed 80 degrees Fahrenheit, energy slope was obtained from the trigonometric leveling performed on the creek and water surface elevation and geometry data was obtained from the survey data. This module provides an output file that was used as input for the SAM-Sed module for sediment transport analysis.

Geometric Data

Eighteen (18) cross sections were measured in a 1.13 km reach from a sediment trap dam located near Tutu to a channelized reach near the downstream end. Cross sections were measured using a Total Station System, and the data was processed using Autodesk's Auto-Cad. Measurements were made whenever the river geometry changed significantly. Longitudinal profile along the thagweg was also obtained. Among the measured cross sections, three cross sections were selected as representative sections to be used in the sediment transport capacity analysis.

Hydraulic Model

Full bank flow was computed for three representative cross-sections assuming uniform flow conditions with Manning's equation. Flows of 152 cfs, 185 cfs and 253 cfs were determined to be full bank flows for sections 100, 1000, and 1600 respectively. The discharge capacity of the cross sections increases in the downstream direction. The hydraulic model was run for full bank flow conditions and flows were corresponding to 1, 2, 5, and 10 year of return period and 6 hours of rainfall durations considering the effect of the storage tanks.

Sediment Transport Analysis

Sediment transport calculations in Turpentine Run Creek were performed using USCOE's SAMwin Hydraulic Design Package Version 1.0. The objectives in this part of the project are to find which sediment transport equations are adequate to predict sediment transport on the creek and to determine the sediment transport capacity and concentration for the creek. SAM-Sed is a module that computes sediment transport capacity and concentration. Its required input are discharge, velocity, depth, top width, energy slope, water temperature and bed material data. Bed data is obtained from the soil samples collected on field and the other parameters are obtained from SAM-Hyd output file. Sediment transport equations were chosen based on recommendations made by SAM-Aid. SAM-Aid is a database that identifies the sediment transport equations that best fits the river to be studied. Its input requirements are D50 in millimeters, slope, velocity, top width and depth. SAM-Aid then displays the equations that best fit the project. The equations chosen match three of the parameters for every section; since no equation satisfied four or five parameters.

Soil Sample Gradation

Soil samples were gathered at every cross section, and include samples from the banks and from the bottom of the creek. A sieve analysis was performed on every 500 g sample. Data from section 100, 1000 and 1600 was used to develop the sediment transport model. If more than one data was obtained from a given section it was averaged, weighted by the length of each section contributing to the wetted perimeter. It is necessary to have only one soil gradation because SAMwin works only with one type of soil for each cross section.

Sediment Transport Function Selection

with similar characteristics. Van Rijn Sediment transport function selection was made using SAM-Aid module. This module uses SAM-Hyd output and soil gradation data to recommend a sediment transport functions. SAM.aid is based on the premise that a sediment transport function that accurately predicts measured sediment in a gaged stream would be an appropriate predictor in an ungaged stream formula is the best match for each of the representative sections. Other functions that could be used with caution are Yang and Ackers'White. Turpentine Run flow velocity, depth and soil's median diameter are within the formula's domain. Van Rijn published both parts of the equation in the series of papers "Sediment Transport" (see Ref. 2 & Ref. 3) where he validated the formula by experimentation and comparison to other existing sediment transport equations. This equation proved to yield good results for particles that ranged from 0.1 to 2 millimeters. Soil analysis shows that around 70%, 35% and 63% of the soil sampled for sections 100, 1000 and 1600 respectively, satisfy the formula's recommended domain. Van Rijn's formula is based on particle dynamics in which the sediment's trajectory is predicted using a vector force analysis.

Sediment Transport Analysis

Sediment transport capacity was evaluated using SAM-Sed. This model requires SAM-hyd's input, soil gradation and the selected sediment transport functions. Sediment transport was evaluated using two maximum particle sizes, 5mm and 9.5mm, in order to evaluate the capacity's sensitivity to maximum particle size. The 5 mm maximum particle size was chosen randomly while the 9.5 mm maximum sediment size corresponds to the size of the next sieve larger than sieve 4. Results indicate that maximum particle size is not an important criterion when computing sediment transport capacity. Full ban flow and flows corresponding to 1, 2, 5, and 10 year 6 hour rainfall events considering rainfall storage tanks were considered in this analysis. A result summary for full bank flow is shown in Table 6-7 through Table 6-9.

Table 8. Sediment Transport Capacity at different cross sections using Van Rijn equation

Van Rijn	Capacity Tons/day	
Cross Section	Max Sed Size	
	5 mm	9.5 mm
100	2,868.22	2,852.46
1000	6,006.10	5,910.67
1600	86,381.36	84,971.20

PRINCIPAL FINDINGS AND SIGNIFICANCE

The most relevant findings found in this research are summarized as:

1. Sediment transport functions for Turpentine Run in the St. Thomas USVI were selected. The most recommended function, based in SAM Database criteria, is Van Rijn formulation. Other formulations that fulfilled at least three criteria but not at all cross sections were Yang and Ackers White. These functions are recommended for use only within the limits of the main channel or for high frequency floods. The model do not provide for spatial variation of sediment size characteristics across the cross-sections.

2. Sediment transport rates increased downstream along the watershed. Near the sediment trap located in Tutu, an estimate of 2,800 tons/day was obtained. This amount increases to approximately 85,000 near the beginning of the downstream canal. As with any sediment transport analysis, these estimates could be subject to significant errors; however, they represent the best estimation available at present.

3. Several hydrologic characteristics of Turpentine watershed were obtained; including: watershed sub-basins, soil characteristics and travel time. The hydrologic model provided peak discharges for storm durations from 6 to 24 hours and return periods of up to 100 years. However, the sediment transport analysis is limited to events up to 6 hours and 10 years due to limitations of one-dimensional models.

4. The storage tanks for rainfall water collections could have a significant effect in peak flow reductions for high frequency events. In several occasions, particularly if they are at low levels, it could mitigate the effects of flash floods effects occurring in the Island.

Figures

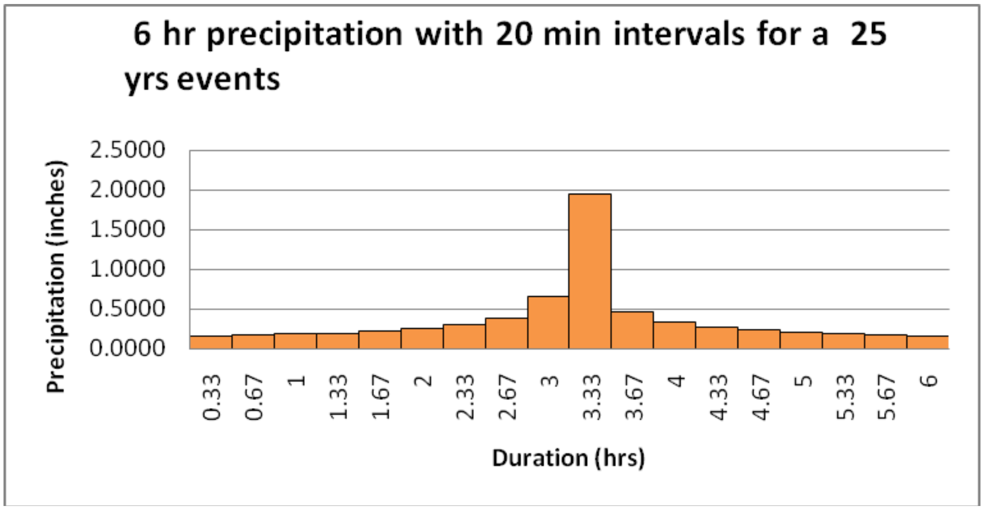

Figure 1. Typical Rainfall Distribution for Hydrologic Analysis

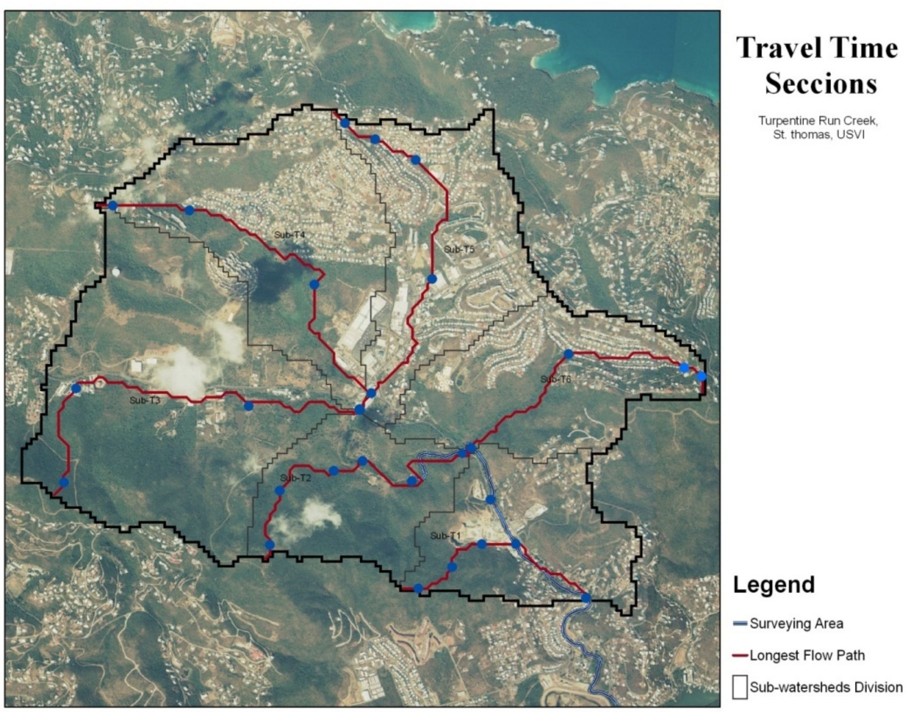

Figure 2. Turpentine watershed sub-basins

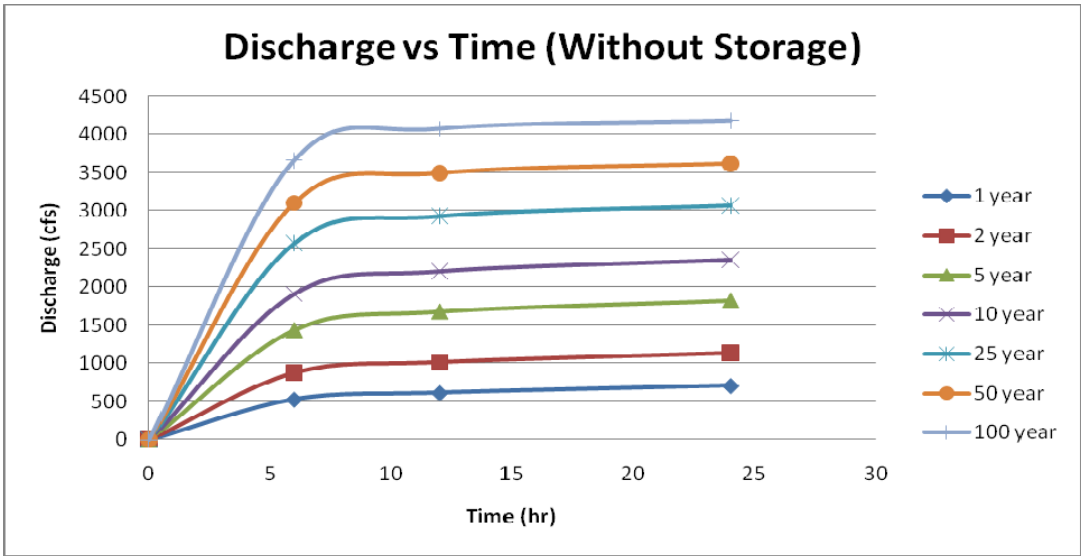

Figure 3. Discharges at the beginning of the channelized section

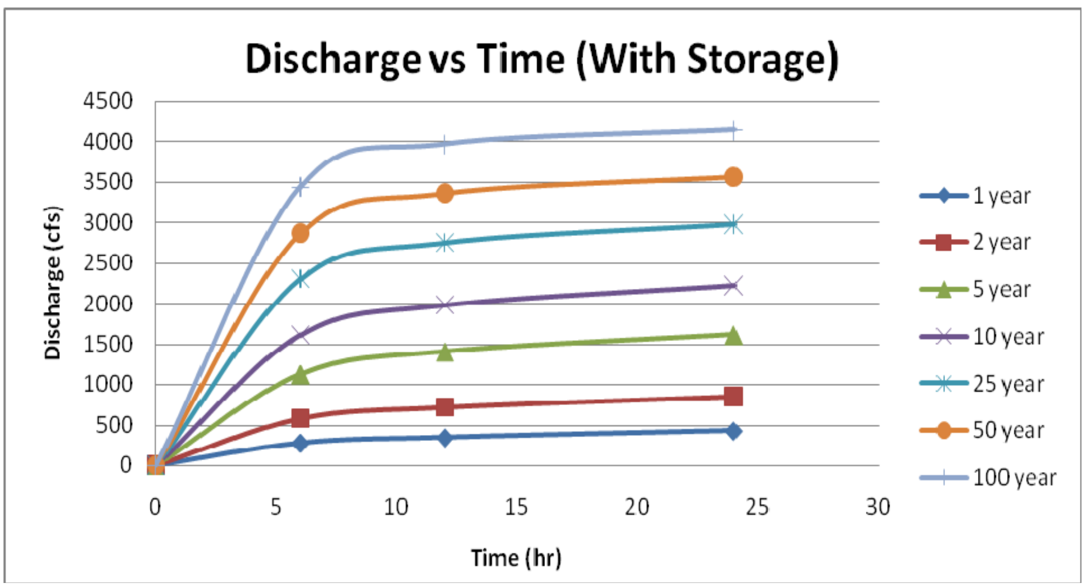

Figure 4. Discharges at the beginning of the channelized section

Revitalization of Guts as Urban Recreational Spaces in the U.S. Virgin Islands

Basic Information

Title:	Revitalization of Guts as Urban Recreational Spaces in the U.S. Virgin Islands
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Principal Investigators:	Lloyd S. Gardner, Stevie Henry, Toni Thomas

Publication

1. None as yet.

PROBLEM AND RESEARCH OBJECTIVES

Watercourses in the U.S. Virgin Islands are important resources, providing ecological, recreational, economic, and community development services. Yet those watercourses, or guts as they are commonly called, are threatened by the impacts of development activity. The Virgin Islands Code protects watercourses through a prohibition on cutting of vegetation within 30ft. of the center of a natural watercourse, or 25ft. from the edge, whichever is greater. Despite the legal protection, guts continue to be degraded through clearing of vegetation, changing drainage patterns, pollution inputs, and physical alterations. These development impacts result in the impairment of coastal water quality, the degradation of gut resources, and reduction of the amenity value of such areas.

In addition to the provision of water for domestic, agricultural, and commercial purposes, streams and watercourses (guts) have traditionally been used for recreational purposes in the U.S. Virgin Islands. In addition to the use by individuals, community groups conduct hikes to selected guts. Such hikes are used not only as a form of recreation, but also to share knowledge of natural and historical resources with school children, residents, and visitors.

Periodic studies have noted that the guts represent one of the few remaining areas where canopy forest can be found in the U.S. Virgin Islands, and which encompass potentially higher levels of biological diversity. Additionally, guts are increasingly being used for teaching, general recreation, research, and as a source of water for agriculture. However, there is no estimate of the demand for gut resources.

There is no program that translates the protection afforded by the law into actual protection strategies or that offers protection of guts through the development control process. For example, the wildlife strategy for the U.S. Virgin Islands, prepared by the Division of Fish and Wildlife-Department of Planning and Natural Resources (2005), does not include guts in the classification of wetlands, and does not offer any direction for protection of this ecosystem. A comprehensive program to promote awareness and protection of guts has not been formally adopted by community groups or the Department of Planning and Natural Resources, the primary natural resource management agency in the Territory.

This project was designed on the assumption that greater attention would be given to streams/guts if they were promoted not only as environmental resources to be protected, but also as recreational spaces for residents and visitors.

The project attempted to determine whether guts and associated resources are still important in the development of the U.S. Virgin Islands, to ascertain the current policy and legal protections, to ascertain relevant programming by local institutions, and identify the main issues relevant to guts and associated resources. That information was then used to design a management framework within which a gut protection program can be established by the relevant natural resources management agencies and research institutions in the U.S. Virgin Islands. The specific objectives were listed as:

(a) Determination of the state of knowledge concerning guts in the U.S. Virgin Islands;
(b) Review of the current programming relevant to guts/streams;

(c) Preparation of a draft policy and plan for gut management;
(d) Endorsement of the draft gut management program by the relevant public sector and research institutions, and
(e) Development of demonstration activities involving one site each on St. Croix and St. Thomas.

METHODOLOGY

The project commenced on November 1, 2007, and the first two months were spent contacting individuals and institutions known to have an interest in the subject matter. A Project Fact Sheet was prepared during this initial period, and circulation of the Fact Sheet continued throughout the project.

A review of the literature (research papers, natural history notes from noted naturalists, project reports, laws, etc.) was used as the basis for determination of the past uses and benefits of guts to the U.S. Virgin Islands. The information gathered from the literature was supplemented by information compiled from the websites of the public sector regulatory agencies, as well as interviews with a number of public sector and civil society institutions. The information gathered through this process was used to prepare the report on the current state of knowledge concerning guts.

The project also included a consultation process that started in November 2007, and which continued for the duration of the project. An attempt was made early during this process to inform the wider community of the existence of the project, and to invite their participation therein. This was done by having two members of the project team participate in the Afternoon Mix, a one-hour radio show aired on WVWI 1000 AM. The session on guts was aired on December 11, 2007. The consultation process included interviews with personnel in public sector agencies and civil society institutions, as well as two “public” meetings.

Information was circulated on an ongoing basis by email to a list of persons identified as having interest in issues relevant to guts. Additionally, a Yahoo-based listserv was established to support communication between interested individuals during the project. A number of the project documents and relevant reports were posted on the website.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The main findings of the project are:

(a) Guts continue to provide goods and services that are used in the social and economic development of the U.S. Virgin Islands. The increased use of gut resources for tourism and education will place greater pressure on those resources. This, coupled with the increased impacts from development activity, is likely to raise the focus on guts by the environmental professionals in the Territory.

(b) There are a number of programs in several public and civil society institutions that have an impact on guts, directly and indirectly.

(c) The policies relevant to guts need to be revised to address policy and legislative gaps, as well as ensure program integration across agencies.

(d) There is no institutional framework that currently supports inter-agency planning and consultations on environmental management strategies, including guts. An appropriate institutional framework was recommended in the draft management plan.

(e) The data to support decision making relative to guts is inadequate, especially as it relates to biodiversity functions of guts, impact of storm water management plans on guts, and changing drainage patterns in the watersheds.

(f) A strategy for management of guts in the U.S. Virgin Islands is needed. Participants in the two public sessions agreed that such a management strategy should support the development of a more cohesive policy and management framework for watersheds management.

Information Transfer Program Introduction

As part of its program of disseminating information to the public, the Virgin Islands Water Resources Research Institute collaborated with the Puerto Rico Water Resources and Environmental Research Institute at the University of Puerto Rico and the Caribbean District Office of the U. S. Geological Survey and hosted the Seventh Caribbean Islands Water Resources Congress. This conference not only assisted in disseminating information on work done previously at the VI−WRRI, the PRWRERI and the USGS and other entities on island hydrology but provided a forum for identification of water resources research and outreach needs for the region.

Seventh Caribbean Islands Water Resources Congress

Basic Information

Title:	Seventh Caribbean Islands Water Resources Congress
Project Number:	2007VI95B
Start Date:	3/1/2007
End Date:	2/28/2008
Funding Source:	104B
Congressional District:	Not Applicable
Research Category:	Not Applicable
Focus Category:	Education, Management and Planning, Water Supply
Descriptors:	None
Principal Investigators:	Henry H. Smith

Publication

1. Hwang, Sangchul, 2007, Proceedings of the Seventh Caribbean Islands Water Resources Congress, Virgin Islands Water Resources Research Institute, University of the Virgin Islands, St. Thomas, Virgin Islands, 110 pages.

PROBLEM AND INFORMATION DISSEMINATION OBJECTIVES

In the U. S. Virgin Islands, responsibility for management of the water resources is split between several agencies. However, there is no provision for facilitation of the synergy that could occur due to these agencies sharing information and lessons gained in a meaningful, systematic manner. Organizations in many cases are not aware of each others existence and collaborations might occur in a piecemeal opportunistic fashion. It is not unusual for these units to at times be competing for the same resources to execute programs that have a common worthy goal. There is need for local discussion among groups with water resources interests to share information, develop priorities and possibly develop plans for ongoing collaboration.

The problem of insularity is further compounded because while the local agencies may benefit from their associations with related agencies at the national level within the United States, they do not interact with similar agencies and groups in the neighboring Caribbean Islands with whom they might have more in common. This situation might be brought on by political affiliations and the associated difficulties of restrictions imposed by funding sources. For example, a researcher at the Virgin Islands Water Resources Research Institute in St. Thomas conducting work funded through a U. S. Geological Survey project, might travel around the globe to engage in consultation with a researcher thousands of miles away in Guam. However, in order to travel ten miles to consult with a researcher in the British Virgin Islands, special permission must be sought from the U. S. Geological Survey. An opportunity for regional dialogue on water resources is needed.

RESULTING ACTIVITY

The Seventh Caribbean Islands Water Resources Congress was held on the St. Croix campus of the University of the Virgin Islands October 25 – 26, 2007 to address the issues described above. It was co-sponsored by the Virgin Islands Water Resources Research Institute, the Puerto Rico Water Resources and Environmental Research Institute at the University of Puerto Rico and the Caribbean District Office of the U. S. Geological Survey. The First Caribbean Islands Water Resources Congress was held in the Virgin Islands in 1984 and subsequent meetings were held in San Juan and Mayaguez, Puerto Rico and the Virgin Islands also as collaborative efforts between the University of the Virgin Islands, the University of Puerto Rico and the U. S. Geological Survey. This conference then has a long history and is highly regarded. Significant support for the conference was also provided by the University of the Virgin Islands' Cooperative Extension Service, the Virgin Islands Experimental Program to Stimulate Competitive Research and the V. I. Department of Tourism.

The conference took place over a two-day period. Twelve papers on water resources issues applicable to the Caribbean area were presented as part of panel discussions under the topics "Watershed Management", "Advances in Water Sanitization", "Surface and Ground Water Quality" and "Management of Limited Freshwater Resources". There were also two luncheon presentations. These topics allowed the general information sharing that was planned as an objective of the conference. The conference's feedback form indicated that participants were pleased with the wide range of topics covered and their opportunity to interact with other conference participants for discussions on management responsibilities, research activities and implementation of highly successful practices. A copy of the final program of technical presentations appears on the following page.

The conference was intended for a wide range of persons including government officials, researchers, NGO's and private interests as well as students. The attendance roster indicated that this target audience participated. The conference met the objective of providing a forum in which persons in the U. S. Virgin Islands and the Caribbean region could exchange ideas and develop understandings and relationships that could promote better water resources management in the region.

Final Program of Technical Presentations

		25-Oct-07		26-Oct-07	
Time		Watershed Management (Moderator: Walter Silva_UPRM)	Advances in Water Sanitization (Moderator: San Hwang_UPRM)	Surface and Ground Water Quality (Moderator: Pedro Diaz_USGS_PR)	Management of Limited Freshwater Resources (Moderator: Adrian Cashman_U. West Indies)
8:00	8:20	*Welcoming (Henry H. Smith, Congress General Chair), Opening Remarks (Dr. LaVerne E. Ragster, UVI President), and On-site Registration*			
8:20	9:00	Plenary Talk: Matthew Larsen (USGS)		*Welcoming (Jorge Rivera-Santos, Congress Co-Chair), and On-site Registration*	
9:00	9:30	"Caribbean Water Management Implications of Potential Climate Change" by A. Cashman et al. (U. West Indies)		"Groundwater Levels in Puerto Rico, 1987-2006" by R. Richards (USGS_PR)	
9:30	10:00	"Numerical Simulation of Rivers in Floodplains" by W. Silva and A. Rojas (UPRM)		"Effects of Aquifer Development and Changes in Irrigation Practices on the Groundwater Discharge to the Jobos Bay National Estuarine Research Reserve, South-Central, Puerto Rico" by J. Rodriguez and J. Rodriguez (USGS_PR)	
20-min Coffee Break		Poster Presentations and Exhibitions (REC Room # 133)			
10:20	10:50	"The Role of a Community-based Nongovernmental Organization in promoting Active Research and Stewardship of Water and Other Environmental Resources in the US Virgin Islands" by S. Coldren (GBCC, VI)		"Nutrient Load Estimation at Lago Dos Bocas, Puerto Rico" by C. Villata et al. (UPRM)	
10:50	11:20	"Effect of Spatial and Temporal Resolution Uncertainty on Predicted Best Management Practice (BMP) Efficiency" by R. Miskewitz et al. (Rutgers U., USA)		"Use of Stable Isotopes to Determine Potential Sources of Nitrate and Contribution of Surface Water to Aquifer Recharge in the Salinas Area, South Coastal Plain Alluvial Aquifer, Puerto Rico" by J. Rodriguez (USGS_PR)	
Lunch		Luncheon Talk: Ferdinand Quinonez (Puerto Rico)		Luncheon Talk: Aaron Hutchins (VI Department of Planning and Natural Resources)	
1:00	1:30	"Sediment Production from Natural and Disturbed Surfaces in Dry Tropical Areas of La Parguera, PR, 2003 - 2005" by C. Ramos (U. Texas_USA)			"*Title: To Be Announced*" by May Adams Cornwall (VI Waste Management Authority)
1:30	2:00	"The Caribbean Water Initiative (CARIWIN)" by A. Suchorski et al. (McGill U., Canada)			"Impacts of Watershed Development on Diversity of Freshwater Fish and Crustaceans on St. Thomas, U.S. Virgin Islands" by D. Nemeth et al. (UVI)
20-min Coffee Break		Poster Presentations and Exhibitions (REC Room # 133)			
2:20	2:50		"Hydraulic and biochemcial characteristics of Coal Combustion Byproducts Aggregates as Alternative Daily Cover for Landfills" by A. Fonseca et al. (UPRM)		"Effectiveness of Mandatory Law of Cistern Construction for Rainwater Harvesting on Supply and Demand of Public Water in U.S. Virgin Islands" by H. Solomon and H. Smith (UVI)
2:50	3:20		"Telemetry Monitoring of Small Water Supply" by S. Sanchez et al. (UPRM)		"Hydrologic Studies using Vflo in Western Puerto Rico" by A. Rojas and E. Harmsen (UPRM)
3:20	3:50		"Innovative on site Wastewater Disposal Systems Outreach and Demonstration Project" by R. Davila (UPR)	Closing Remarks (Pedro L. Diaz, Congress Co-Chair)	
4:20	5:00	Poster Presentations and Exhibitions (REC Room # 133)			

Poster Presentations

1 "Evaluation of the adsorption behavior of tetracycline onto crumb rubber in aqueous solution" by J. Lopez et al. (UPRM)

2 "Use of recycled tires crumb rubber to remove ethylbenzene, toluene and xylene in single componebt, multi-components systems and gasoline from aqueous solutions" by L. Alamo et al. (UPRM)

3 "Removal of lead, copper, and cadmium ions from aqueous solutions using waste tire crumb rubber" by D. Sanchez et al. (UPRM)

Student Support

Student Support					
Category	**Section 104 Base Grant**	**Section 104 NCGP Award**	**NIWR−USGS Internship**	**Supplemental Awards**	**Total**
Undergraduate	6	0	0	0	6
Masters	1	0	0	0	1
Ph.D.	0	0	0	0	0
Post−Doc.	0	0	0	0	0
Total	7	0	0	0	7

Notable Awards and Achievements