Report for 2005VI53B: Assessing the Sediment Retention Function of Salt Ponds on the US Virgin Islands – Implications for Management

Publications

- There are no reported publications resulting from this project.

Report Follows

Problem and Research Objectives

Salt ponds and the specialized salt-tolerant vegetation communities that they support perform a variety of biological, hydrologic and water quality functions with benefits to both wildlife and humans. In the case of sediments in surface water runoff, salt ponds act as a retention basin (Brody et al., 1970; Hodge, undated; Brin et al., 2003) and facilitate deposition of particles within the pond or among the dense root systems of the plants fringing the pond.

Methodologies that use a functional approach to habitat assessment are considered to give a balanced perspective of the attributes wetlands provide not only to wildlife but also to society on a sustainable basis (Adamus and Field, 2001). Unfortunately these methodologies are limited, in part, due to a lack of understanding of wetland formation and maintenance processes, particularly in highly altered landscapes (Adamus and Field, 2001).

The goal of this study was to evaluate the effectiveness of the sediment retention function of salt ponds and the pond watersheds (salt pond systems) in the US Virgin Islands. To attain this goal, the following objectives were carried out:

1. Identify and evaluate the features of salt pond systems that are important in contributing to the effectiveness of sediment retention;
2. Evaluate historical changes and trends to the functional capacity of USVI salt pond systems to retain sediments in order to enable sound regulatory and land-use management decisions that will help to ensure a high functional performance;
3. Evaluate remote sensing as a management tool to predict and monitor the performance of sediment retention in salt pond systems.

Methodology

The methodology involved seven distinct tasks:

1. Rainfall data between the years 2000 and 2005 were reviewed for a number of stations located on St. Thomas, St. John and St. Croix. Rain events exceeding 1.0 inch (2.5 cm) of daily precipitation and major storm events in which daily rainfall exceeded 4 inches (10 cm) were identified in order to help focus the search for appropriate remote sensing imagery that would document near-shore coastal sedimentation from terrestrial sources. Average annual rainfall patterns across the islands were also examined to aid in the evaluation of site-specific conditions.
2. Functional assessment methodologies were reviewed to identify pond and watershed parameters considered to be important in contributing to the ability or the effectiveness of a salt pond to trap and retain sediments. An initial set of 40 parameters was identified, and from this, a sub-set of 13 was selected based on i) identification by the local survey team as being applicable to salt ponds in the US Virgin Islands and ii) ability to easily and rapidly collect the information.
3. Site visits to 25 salt ponds were made in order to identify salt pond systems that represented a range of conditions of both natural and human-induced origins. Of the 25 sites initially visited,

17 salt pond systems were selected for further data collection. These were grouped into high, medium or low disturbance categories based on specific land-use criteria.

4. Department of Planning and Natural Resources (DPNR) permits and Environmental Assessment reviews were examined for any development applications affecting the selected 17 ponds. Aerial photographs from 1947-1999 were identified and examined for changes that have occurred over time to the salt pond features.
5. Data for 13 different parameters were obtained through either field collection or through the use of maps. Field collection of data took place between March and December 2005 for parameters that could not be obtained from available maps. The remaining parameters were calculated using GIS-based digital orthophotography.
6. Analysis of the data included justification of parameter inclusion based on literature documentation; analysis of the data with respect to documented performance criteria, site variability and disturbance levels; and evaluation of site-specific features. A conclusion was formulated as to whether the parameter provided evidence of the functioning condition of the salt pond systems. Values of the measured parameters were shown in bar-graph form with each of the disturbance categories (H, M, L) grouped together to facilitate analysis and discussion. The assumption inherent in the analysis was that the selected parameter played an important role in sediment retention.
7. An evaluation was carried out on the use of remote sensing imagery as a tool for monitoring sediment in the nearshore water column. This included an assessment of both Landsat satellite imagery and aerial photography.

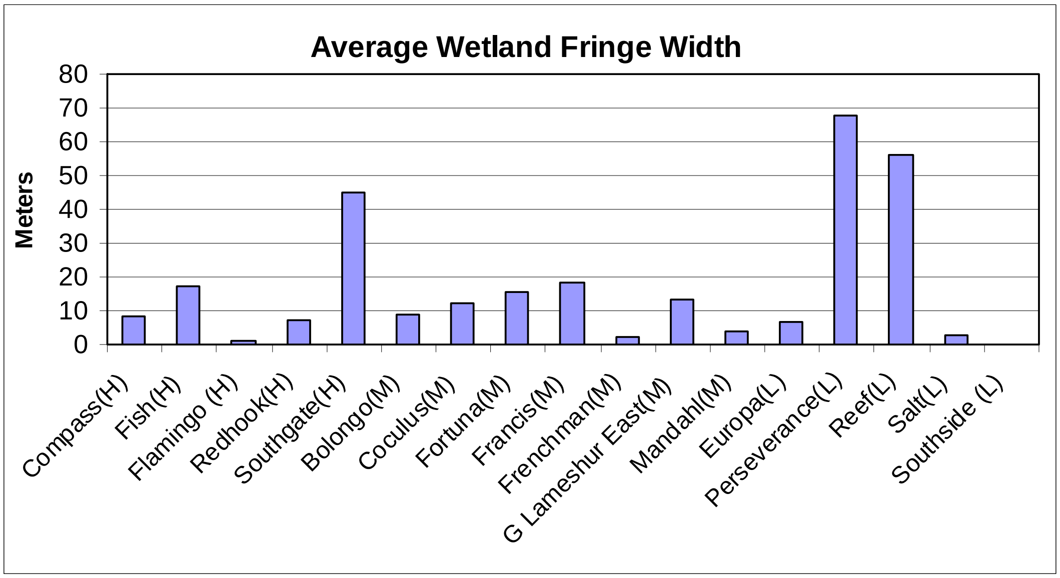
Principal Findings and Significance

Variability in Sediment Retention Characteristics

Salt pond systems are highly variable in their potential to retain sediment. For this reason, pond systems must be evaluated individually in order to determine their sediment retention effectiveness. Specific wetland or watershed features often play a role in sediment retention in conjunction with other features, and it is this combination, which can differ between ponds, that leads to effective or non-effective functional performance.

Pond systems with the least human-induced disturbance reflect the most natural environmental conditions, however as shown in this study, this does not necessarily indicate the most effective functional performance for sediment retention. Wetland fringe width, for example, is an important determinant in sediment retention effectiveness, yet a number of undisturbed ponds on St. John have a very narrow wetland fringe while the highly disturbed Southgate watershed supports a wide wetland fringe around the pond. Slope, climate and other factors, both natural and human-induced, play a role. An example of the wetland fringe data analysis is shown in Figure 1.

Figure 1. Average wetland fringe width for the 17 salt ponds under study



Another important determinant in sediment retention effectiveness is the amount of wetland area within a watershed, and this feature also showed a wide variability between the salt pond systems. Other studies have indicated that a watershed containing 10% wetlands can optimize sediment retention. Eleven of the 17 salt ponds and surrounding wetlands in this study comprised less than 10% of their watershed (Table 1). Wetlands comprising less than 10% of the watershed or having a watershed:wetland ratio greater than 15 suggests sub-optimal performance. The Perseverance salt pond system is shown in Figure 2.

As a consequence, developing standards of reference based on a 'best performance' basis is not possible for most of the features analyzed in this study. However, using the data collected for each pond system as a guide to the variability of each parameter provides a valuable reference for assessing parameters of other pond systems or for monitoring changes to the pond systems studied in this investigation. The condition of the pond as a result of human disturbance is not a reliable indication of sediment retention effectiveness.

Table 1. Ponds exhibiting sub-optimal size within their watershed for effective sediment removal/retention.

Pond	Wetland Area as Percent of Watershed	Watershed:wetland ratio
Bolongo	1.32	76:1
G. Lameshur East	1.54	65:1
Fortuna	2.50	40:1
Perseverance	4.36	23:1

Pond	Wetland Area as Percent of Watershed	Watershed:wetland ratio
Southgate	4.69	21:1
Fish	5.64	18:1
Frenchman	6.04	17:1
Coculus	6.80	15:1
Mandahl	7.92	13:1
Reef	8.47	12:1
Francis	8.52	12:1

Figure 2. Perseverance salt pond and its contributing watershed (salt pond system)

Key Parameters as Indicators of Salt Pond System Functional Effectiveness

Data analyses of the thirteen parameters led to a number of conclusions of salt pond system functional effectiveness for sediment retention based on the evidence collected and documented literature (Table 2). No salt pond system is expected to function effectively with respect to all parameters, however the role of a pond and its watershed in carrying out the sediment retention function increases with the more parameters noted as effective in Table 2. Perseverance (6), Salt (5) and Southgate (5) were identified as being more effective for a particular parameter most often; Compass Point (6), Flamingo (4), Fortuna (4) and Mandahl (4) were found to be less effective.

The results of this study indicated that the function of sediment retention is most effective in Perseverance, Salt and Southgate pond systems. Changes to landscape features from natural or human-induced modifications that result in decreased effectiveness could compromise this functional performance. This does not mean that salt pond systems noted as being effective for fewer parameters are not playing an important role in sediment retention, however it does imply that these systems and the nearshore coastal waters they protect could be more vulnerable to increased sediment flow, should this occur. Compass Point, Flamingo, Fortuna, and Mandahl pond systems were found to be ineffective for different reasons, however the underlying cause of these reasons can be attributed to human-induced changes.

Table 2. Locations where key parameters contribute to functional effectiveness

Feature	More Effective	Less Effective	Not Important or Not Determined
Berm elevation	Europa, Fortuna, Great Lameshur East, Salt	Reef, Fish	Flamingo, Mandahl, Compass Point
Outlet	Bolongo, Coculus, Europa, Fish, Fortuna, Francis, Frenchman, Great Lameshur East, Perseverance, Redhook, Reef, Salt , Southside	Mandahl, Flamingo	
Pond depth		Flamingo, Compass Point	
Submerged aquatic vegetation	Compass Point, Flamingo, Perseverance		Europa, Redhook
Water/woody veg interspersion	Compass Point, Fish, Fortuna, Francis, Perseverance, Reef, Southgate		Europa, Redhook
Fringe vegetation density	Perseverance	Compass Point, Salt	Southside

Feature	More Effective	Less Effective	Not Important or Not Determined
Fringe width	Perseverance, Reef, Southgate	Bolongo, Compass Point, Flamingo, Mandahl, Redhook	Southside
Flood plain area	Southgate	Bolongo, Compass Point, Flamingo, Mandahl, Redhook	
Gut presence	Bolongo, Flamingo, G. Lameshur East, Mandahl, Perseverance, Redhook, Salt, Southgate		
Land use	Europa, Great Lameshur East, Reef, Salt	Compass Point, Fish, Fortuna, Coculus, Mandahl, Southgate	Flamingo
Slope	Fish, Southgate	Europa, Fortuna, Frenchman Great Lameshur East, Perseverance, Southside	Flamingo
Soil erosion potential	Francis, Mandahl	Coculus, Compass Point, Fortuna, Southgate	Flamingo
Wetland to watershed ratio	Compass, Europa, Redhook, Salt, Southside	Bolongo, Coculus, Fish, Fortuna, Frenchman, Great Lameshur East, Perseverance, Southgate	Flamingo

Salt Ponds Systems at Risk

A number of conclusions can be drawn from the findings in this study with regard to the potential risk for salt pond systems on the USVI to perform a sediment retention function effectively.

1. Sediment trapping ability will decline as wetlands fill in or if vegetation dies due to flooding or to other disturbances. Although guts that empty to ponds are noted as an effective sediment retention feature, these salt ponds are also more at risk from infill should vegetation removal in their respective watersheds result in increased sedimentation flow to the pond via the gut. Reducing the amount of sediment washing off the hills from human activity is key to ensuring a pond's natural evolution. Guts and the vegetation contained in and around them should be protected against development and modification.

2. Compass Point, Southgate and Fish ponds have low depth:area ratios suggesting that these ponds are receiving or have received abnormally high sediment loads in the past. This has implications for the longevity of the ponds as depressional basins and could compromise their ability to retain sediments in the long-term. Actions to prevent increased sediment loads to these systems should be given high priority.

3. Although there is no information on the trigger level for human disturbance beyond which a negative impact might be expected on steeper gradients, watersheds where land modification has exceeded 10% of steep slopes should be monitored for sediment flow to the lower watershed. These include Southgate, Compass Point, Fortuna, Coculus and Mandahl on St. Thomas and Fish on St. John.

4. The greater proportion of roads to other land-use categories in the Fish, Redhook and Frenchman pond watersheds suggests that these watersheds may experience a loss of vegetated slopes to development in the near future which could further stress the effectiveness of sediment retention. Actions to protect the lower watershed from increased sediment loads should be given high priority.

5. Pond systems with a high Kf-factor that are outside the development protection afforded by the Virgin Islands National Park system will be more at risk from land-use changes and consequently have more potential for erosion. These include Bolongo, Coculus, Compass Point, Fortuna, Frenchman and Perseverance ponds on St. Thomas and Fish and Southside ponds on St. John. Actions to limit removal of vegetation in these watersheds should be given high priority.

6. The causeway separating Southgate Pond from the marina appears to be at an adequate height to preserve sediment retention functional performance in the reduced pond, however changes to the historical pond configuration and land-use activities in the upper watershed may be causing reduced sediment retention within the adjacent East Gut with potential damage to nearshore coastal waters. Measures to improve flow reduction, sediment retention and sediment filtering capacity of the East Gut should be implemented.

7. Perseverance and Southgate pond systems are noted as functioning effectively for a number of key parameters, however, these ponds are also noted as being small relative to their watershed. As a consequence, small land-use changes in the watershed could negatively impact the functional performance of these ponds and threaten the sensitive nearshore coastal resources beyond. Protection of existing vegetation cover and limiting further development or road construction in these watersheds should be given high priority.

Functional Assessment in Management

The sustainable management of coastal wetland resources is fundamental to the protection of nearshore coastal resources. Sustainable management is brought about by sound land-use and regulatory decisions, which in turn are limited by the quality of information available to the decision makers.

Land managers should ensure that effects from changes to land use do not result in changes to the key parameters that are outside the limits of its range, after evaluating site-specific considerations. This will help to ensure that salt pond systems continue to function effectively with respect to sediment retention so that sensitive downstream resources are not damaged.

A number of recommendations are likely to be of interest in management decisions. These include:

- Deep, straight channels behind the beach berm, such as found at Reef pond, may cause earlier or more frequent breaching of the berm than would occur naturally. This would reduce sediment retention effectiveness and warrants further investigation.

- The ratio of pond depth to surface area is a good indicator for identifying a potentially impacted condition.

- The extensive root network of the mangrove community in the wetland fringe creates a high frictional resistance to water flow, aiding in the trapping and retention of sediment. The presence of a dense mangrove community is a good indicator of effective sediment retention. Measures to increase mangrove density should be applied where appropriate.

- Where conditions allow the development of a wetland fringe, the greater the fringe width, the more effective the functional performance of sediment retention will be. Land-use decisions that could hinder the development of the wetland fringe or reduce the wetland fringe should be avoided.

- Human disturbance in the watershed is an important factor affecting the potential functional effectiveness of sediment retention. To help protect the function, land-use modification should not exceed 25% of the pond watershed, however conditions in the watershed may warrant less than this amount.

- The flood plain is an important contributor to sediment retention, and development within the flood plain should be avoided.

- The berm creates an extremely effective impoundment which is arguably the most important sediment retention feature; creating an opening in the berm will reduce the functional effectiveness of a pond and should be avoided.

Remote Sensing as a Management Tool

Monitoring turbidity events in the nearshore coastal zone will provide evidence to the effectiveness of sediment retention features in the adjacent watershed. Landsat images can be used to illustrate suspended sediment in inshore waters but routine use of Landsat imagery to detect and monitor suspended sediment in the coastal waters of the USVI is unfeasible. Although personal observations of the authors of this report and others indicate that suspended sediment plumes are to be found in the nearshore waters of the USVI, we were able to find no evidence of suspended sediment associated with salt ponds and only limited evidence of suspended sediment at any location in the USVI in the Landsat imagery we examined. This limited evidence of suspended sediment was only associated with extreme precipitation events, more than 23 cm (9 inches) of rain over two to three days.

Our inability to find evidence of sediment in coastal waters of the USVI may be due to a number of factors. First, small volcanic islands with a thin layer of topsoil and no perennial streams or rivers produce limited quantities of sediment to be carried into the nearshore waters. The sediment that is carried to coastal waters may be detrimental to susceptible marine organisms in the inshore environment, but it is much less in quantity than might be carried by perennial rivers draining larger land masses. This is evident in the comparison between sediment plumes derived from the September 15-17, 2004 precipitation event in Puerto Rico (Figure 3) versus those that occurred in the USVI (Figure 4). Of obvious interest would be the condition of coral reefs of the north coast of Puerto Rico subsequent to the observed sediment plumes of September 2004.

Second, the orbital repeat time of 16 days is often too long to try to correlate with ephemeral events such as precipitation periods. In two of the three events analyzed in this report, the imaging took place from two to four days after precipitation ended. For precipitation events that are low to moderate in their severity, this may be sufficient time for much of the sediment to either disperse or to fall out of the water column. Even when an event occurs in temporal proximity to remotely sensed imaging, there is no guarantee that image will be available because of mission objectives and cloud cover.

Finally, the suspended sediment plume evident in the aerial photography of the USVI is small enough spatially that, at best, it would occupy only a few pixels in a Landsat scene, possibly too few to be picked up in analysis.

Given these pessimistic conclusions, two courses of action could be pursued in the future if remote sensing is to be considered as a management tool. One is to continue to evaluate the feasibility of recently launched remote sensing satellites for monitoring suspended sediment in nearshore waters. Perhaps a more feasible technique might be to employ small planes or helicopters to obtain imagery through hand-held digital cameras. This approach would have the advantage of being able to document sediment plumes immediately after precipitation events, but it also suffers from a number of problems arising from the oblique rather than vertical camera angle that normally is associated with hand-held imaging. Nevertheless, if the objective is simply to qualitatively document nearshore sediment plumes and their relationship to land-use activities or coastal features, this approach seems to be the most feasible.

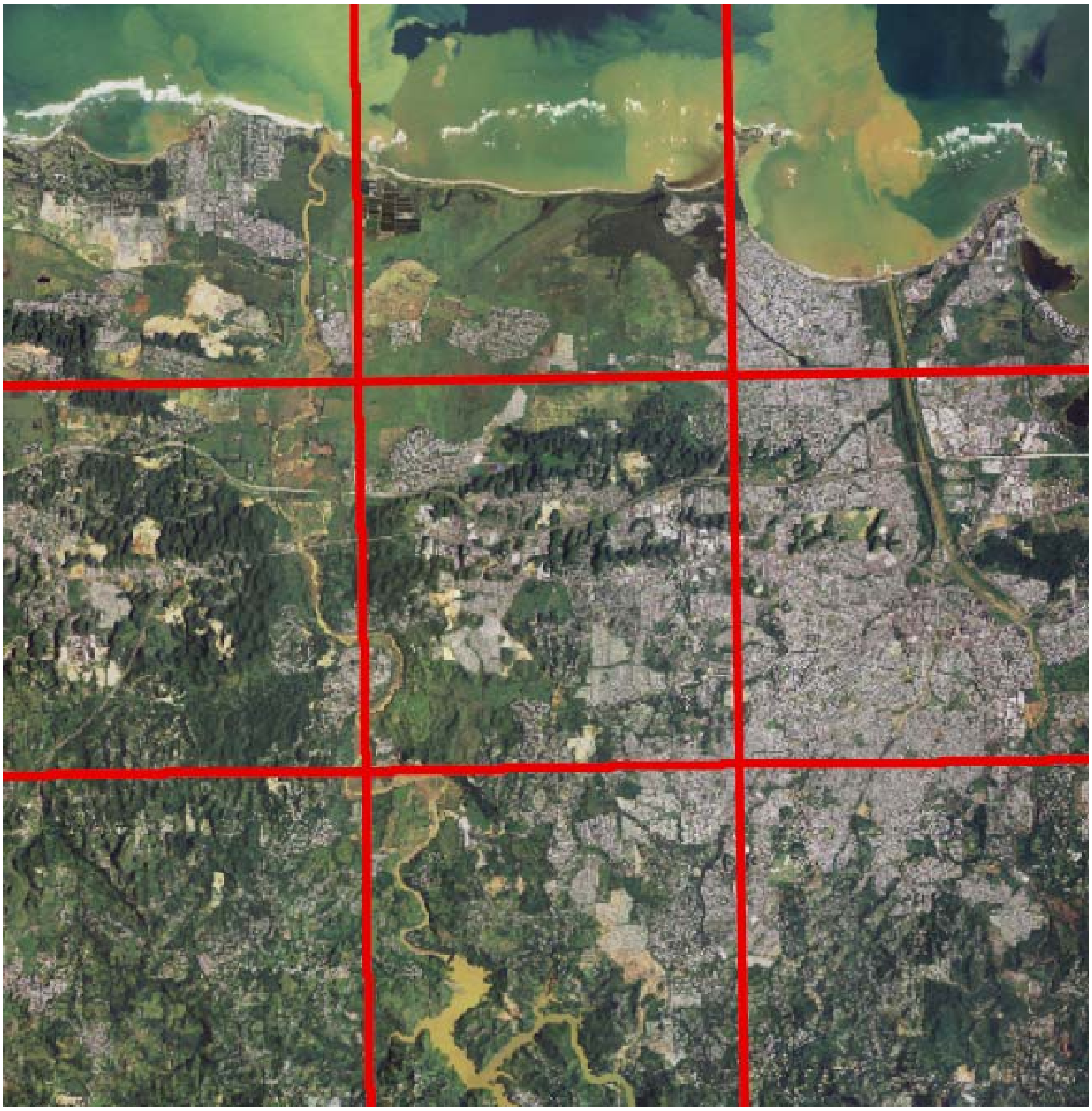


Figure 3. North central coast of Puerto Rico, San Juan area. September 21, 2004. West -- Rio de la Plata, East -- Rio de la Bayamon. Sediment plumes are evident at the mouths of both rivers.

Source: Imagery courtesy of USDA-Natural Resources Conservation Service (Tony Kimmet, George Rohaley) and the US Army Corps of Engineers.

Figure 4. Lerkenlund Bay (in Magens Bay, north coast of St Thomas, USVI. September 21, 2004. The yellowish plume immediately off the beach is a sediment plume.

Source: Imagery courtesy of USDA-Natural Resources Conservation Service (Tony Kimmet, George Rohaley) and the US Army Corps of Engineers.

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