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Hazard Assessment and Mapping for St. Kitts and Nevis

Summary Reports:

Beach Erosion
Inland Flooding
Drought (Nevis)
Inland Erosion (St. Kitts)

Post-Georges Disaster Mitigation Project in Antigua & Barbuda and St. Kitts & Nevis

July 2001

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An Assessment of Beach Erosion Hazards in St. Kitts and Nevis: Summary Report

OAS/USAID Post-Georges Disaster Mitigation Project

Implemented by the Organization of American States, Unit for Sustainable Development and Environment for USAID-Jamaica/Caribbean Regional Program

January 2001

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Acronyms

COSALC Coast and Beach Stability in the Caribbean
ESRI Environmental Systems Research Institute
IMF International Monetary Fund
GIS Geographic Information Systems
NHCS Nevis Historical and Conservation Society
OAS Organization of American States
PGDM Post-Georges Disaster Mitigation
UNESCO United Nations Educational, Scientific and Cultural Organization
UPR-SGCP University of Puerto Rico Sea Grant College Program
USAID United States Agency for International Development

Non-Technical Summary

Purpose

This coastal erosion hazard study for St. Kitts and Nevis was completed as part of the Organization of American States/U.S. Agency for International Development (OAS/USAID) Post-Georges Disaster Mitigation (PGDM) project. The goals of the coastal erosion hazard study were to: a) map the relative erosion hazards along the coastline of St. Kitts and Nevis; and, b) identify areas for future research. Geographic information system (GIS) technology and mean annual beach change rate information were used to prepare these maps.

Coastal Erosion Hazard in St. Kitts and Nevis

Coastal Erosion Phenomena: Most people are familiar and concerned with the beach since it is the portion of the coast where human activities are concentrated (Davis, 1996). This being the case, this report focuses on beaches and the term 'coastal erosion' refers to beach erosion.

Beach erosion occurs when sediment is removed from beaches at a rate that exceeds its replacement and is influenced by both natural processes and human factors. The most important natural process of concern to Caribbean islands is high energy waves during storms which cause dramatic erosion of their shorelines. For example, studies show that after the passage of Hurricane Luis in 1995, the average beach size shrank by 28 percent on seven Caribbean islands (Cambers, 1996), although it is important to note that some beach recovery did take place after the hurricane.

Another important natural factor is sea level rise. Surveys of beaches around the world show that sand loss from beaches and consequent landward movement of coastlines is very widespread (Clayton, 1995). Other factors are: a) loss of vegetation, such as seagrass, from the nearshore zone, grasses from coastal dunes, and mangroves, all of which provide sediment stability especially during severe erosion events; b) winter swells with high energy waves; and c) human factors (e.g. damming and diverting rivers, sand mining and construction of coastal structures).

Coastal Erosion Hazard: Like other Caribbean islands, coastal erosion hazards will continue to affect the economic and social sectors in St. Kitts and Nevis. Together the islands cover an area of 104 sq. miles and have a combined population of some 44,000. Their economy depends heavily on the tourism industry, which is still very much beach-oriented. According to the International Monetary Fund (IMF, 2000), ongoing investments in the hotel industry in 2000 should spearhead a pick-up in economic activity, with real Gross Domestic Product (GDP) growth projected at 3¾ percent. Of critical importance is the threat of beach erosion to the majority of existing and potential tourism facilities sited in areas located near the coastline (e.g. Pinneys Beach - Nevis; Frigate Bay, Basseterre, and the Southeast Peninsula - St. Kitts).

The impacts of coastal erosion have already been felt in recent years. As Barrett and Huggins (1997) noted, in September 1995, Hurricane Luis caused dramatic shoreline erosion at most west coast beaches in Nevis and also extensive damage to coastal infrastructure. Also in 1998, Hurricane Georges caused $ 445 million in damage, which included destruction of the main berthing platform on Port Zante in Basseterre, and damage to several major hotels (USAID, 1999). The big challenge is to implement hazard mitigation strategies that will minimize or eliminate the degree of risk to human life and property from coastal erosion hazards. This study makes a key step toward meeting this challenge by utilizing existing coastal erosion information to identify and map coastal erosion hazard areas in St. Kitts and Nevis.

Preparation of Coastal Hazard Maps

The method used to assess the coastal erosion hazards and the preparation of hazard maps is summarized below.

To create maps showing relative coastal erosion hazards, it was necessary to create relative erosion hazard rankings for each coastal area. The assessment of coastal erosion hazard is an estimation of a coastal area's susceptibility to erosion based on a number of factors such as historical coastal changes, geomorphology, wave and current patterns and human activities. In this study, because of time limitations, only mean annual beach change rate information was used. This

data was provided by the Department of the Environment in St. Kitts, and by the Nevis Historical and Conservation Society and the Physical Planning Department in Nevis. These agencies have measured beach changes at 35 beaches (21 in St. Kitts; 14 in Nevis) on a quarterly basis over a 9 year period in St. Kitts and an 11 year period in Nevis. These beach monitoring programs were established as part of a regional beach monitoring project 'Coast and beach stability in the Caribbean' (COSALC) which is sponsored by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and the University of Puerto Rico Sea Grant College Program (UPR-SGCP).

Beach profiles are measured, from which various information can be extracted. In this study, profile width is used, this is the width of the beach, measured from the vegetation line into the sea. Variation in the beach width is used to calculate mean annual beach change rates. If the beach width decreases over time, this is interpreted as an erosion rate while if the beach width increases, this is an accretion rate.

The method adopted in this study takes the maximum and minimum mean annual beach change rates for each island and subdivides this range into equal intervals. The five relative erosion hazard categories defined were: Very High, High, Moderate/Medium, Low and Very Low. The very high category would identify those beaches with highest erosion rates. Results are presented in Table 1.

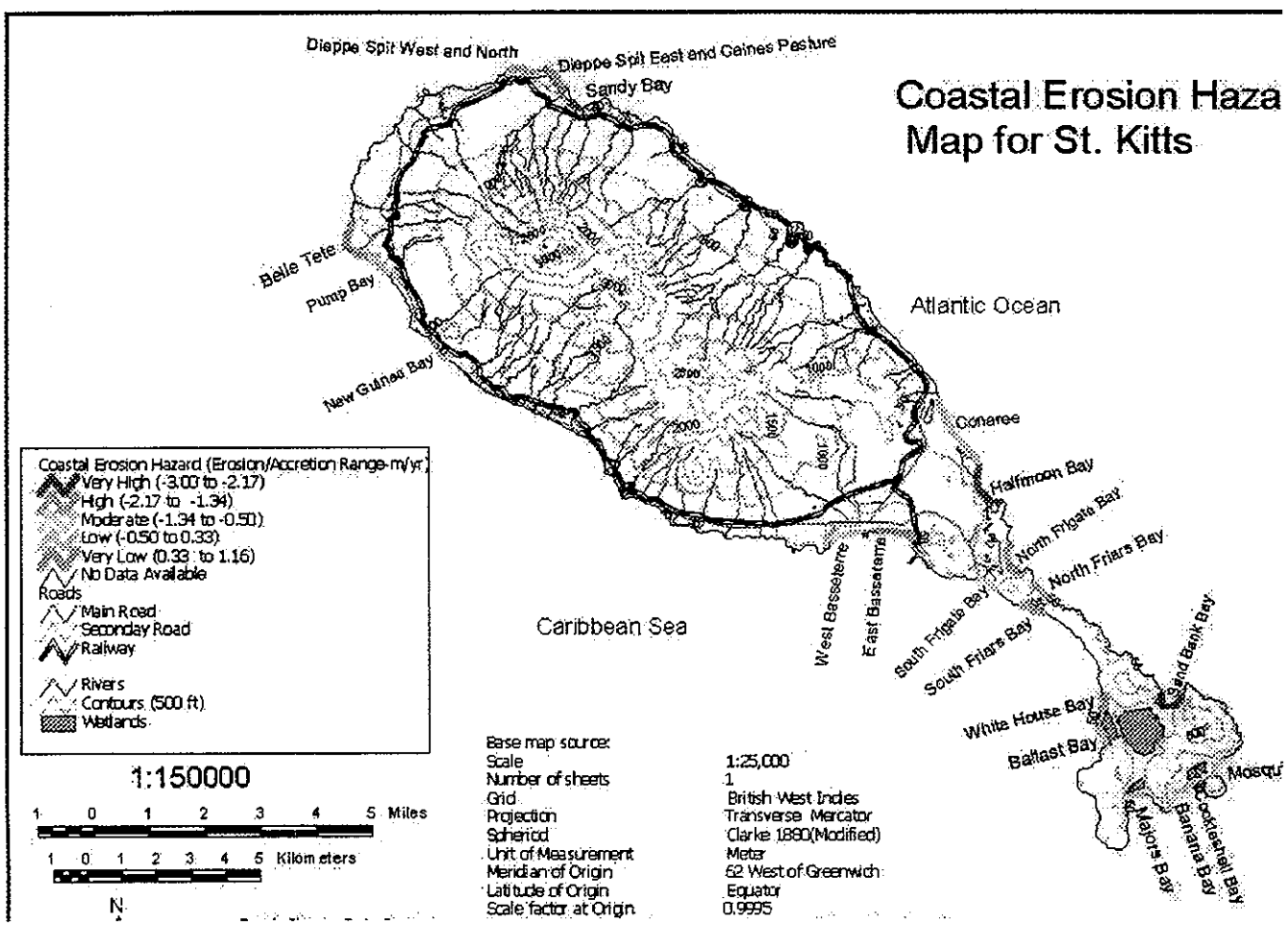
In this study, Environmental Systems Research Institute's (ESRI) state-of-the-art ArcView (GIS) software was used to produce island-wide coastal erosion hazard maps. OAS, with the assistance from the University of the West Indies, provided the coastline and other reference GIS layers (e.g. roads, contours, and rivers). These layers were generated from topographic maps of St. Kitts and Nevis at scale 1:25,000.

Coastal erosion hazard maps have been prepared for both islands at scale 1:50,000. Sample hazard maps are shown in Figures 1 and 2. These maps convey information on coastal erosion hazards in St. Kitts and Nevis in a format for technical (e.g. Planners, Engineers) and non-technical (e.g. landowners, general public) users.

Island	Erosion Hazard Categories:Erosion(-)/Accretion(+) Ranges [m/yr]	Beach	Mean Annual Beach Change Rate: Erosion(-)/Accretion(+) [m/yr]	Erosion Hazard Ranking
St. Kitts	Very High: -3.00 to -2.17	Basseterre East	0.92	Very Low
		Basseterre West	-0.37	Low
	High: -2.17 to -1.34	New Guinea Bay	-0.17	Low
		Pump Bay	-0.32	Low
	Moderate: -1.34 to -0.50	Belle Tete	1.16	Very Low
	Low: -0.50 to 0.33	Dieppe Spit West and North	-1.55	High
		Dieppe Spit East and Caines Pasture	0.46	Very Low
	Very Low: 0.33 to 1.16	Sandy Bay	-3.00	Very high
		Conaree	-0.03	Low
		Halfmoon Bay	-2.95	Very high
		North Frigate Bay	0.73	Very Low
		North Friars Bay	-1.88	High
		Sand Bank Bay	-2.88	Very High
		Mosquito Bay	-0.78	Moderate
		Cockleshell Bay	-0.05	Low
		Banana Bay	-0.53	Moderate
		Majors Bay	-1.02	Moderate
		Ballast Bay	0.09	Low
		Whitehouse Bay	0.36	Very Low

		South Friars Bay	-1.77	High
		South Frigate Bay	-0.56	Moderate
Nevis	Very High: -2.41to -2.31	Gallows Bay	-1.72	High
		Pinneys Beach Hotel	-2.31	Very High
	High: -2.31 to -1.38	Pinneys Golden Rock	-1.25	Moderate
	Moderate: -1.38 to -0.8	Pinneys Jessup	-1.38	High
		Pinneys Mariners	2.03	Very Low
	Low: -0.8 to 0.05	Pinneys Cotton Ground	-2.41	Very High
	Very Low: 0.05 to 2.03	Cades Bay	0.005	Low
		Mosquito Bay	1.01	Very Low
		Hurricane Hill	-1.24	Moderate
		Newcastle	-0.80	Moderate
		Nisbett	-0.86	Moderate
		Longhaul Bay	1.04	Very Low
		White Bay	-1.08	Moderate
		Indian Castle Bay	-1.21	Moderate

Table 1: Coastal Erosion Hazard Rankings for St. Kitts and Nevis



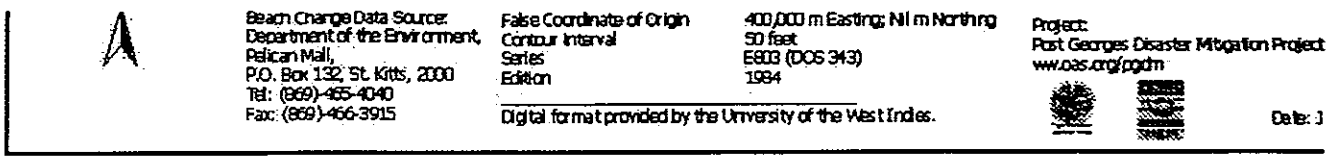


Figure 1: Coastal Erosion Hazard Map for St. Kitts

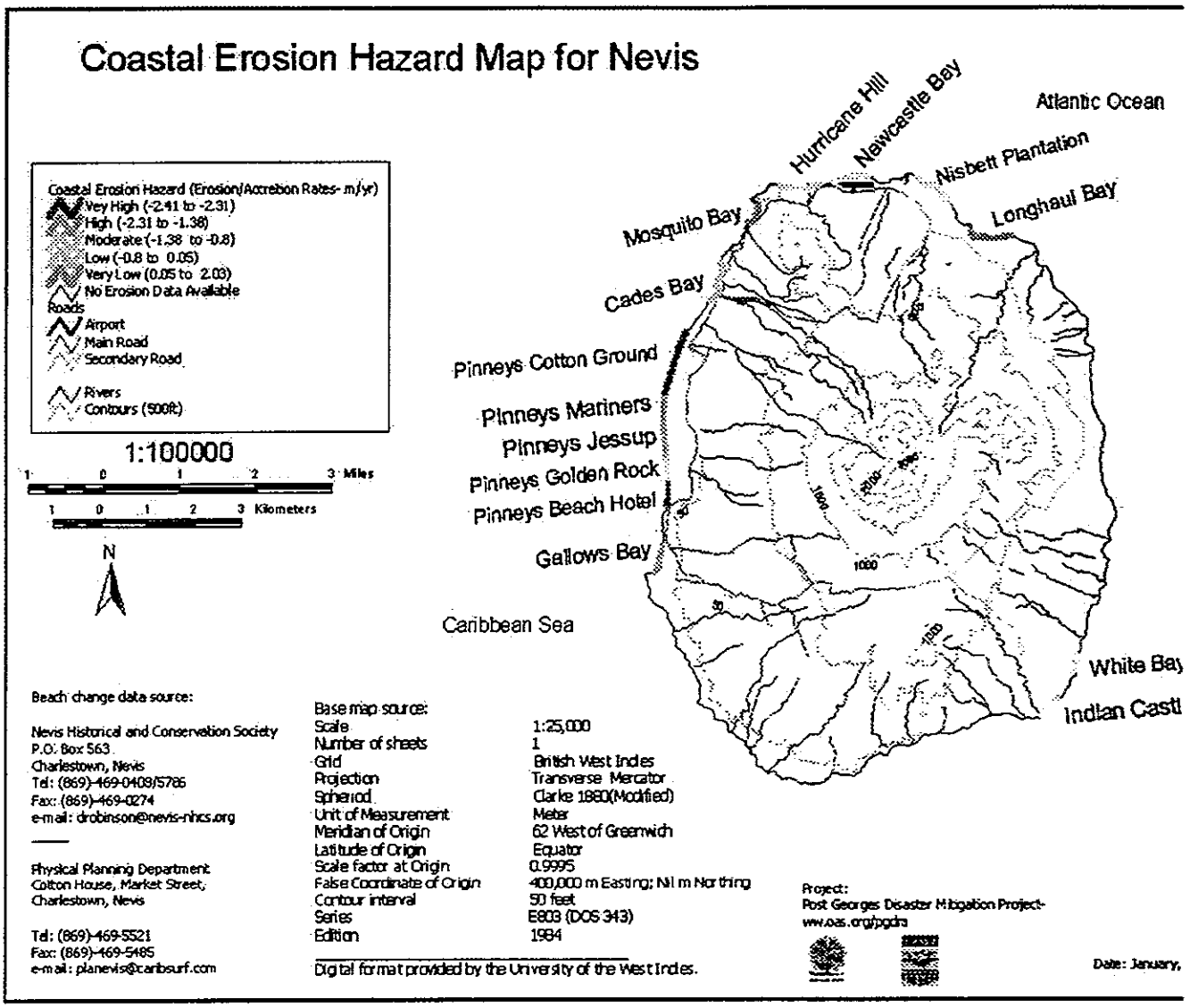


Figure 2: Coastal Erosion Hazard Map for Nevis

The majority (5 of 6) beaches assigned very high and high hazard ratings in St. Kitts are located on the Atlantic coast. The second pattern revealed is that the majority (7 of 9) of beaches on the Caribbean coast have a low or very low hazard rating. These results are not surprising and support the theory that the higher the wave, the more energy exists for moving coastal sediment. As Cambers (1998) notes, in the Caribbean waves approach predominantly from the easterly direction and generate the highest waves, averaging over 1m (3 ft), on the windward or Atlantic coast. While on the leeward or Caribbean coast, average wave height is usually less then 0.3m (1ft).

On the Nevis coastline, the results are different. Here, the coastal areas with very high and high hazard rankings are located along the west or Caribbean coast, especially Pinneys Beach. But even then, not all of Pinneys Beach experiences high erosion hazard ranking. The section near the Mariners Inn has a very low ranking and the beach here is getting wider. It is interesting to note that in both islands, beaches near the northwest corner, Belle Tete in St. Kitts and Mosquito Bay in Nevis, show accretion and very low hazard ranking. These maps highlight the coastal areas that

appear to present the high erosion hazards. They also emphasize the fact that each beach is unique in its behavior and it is therefore difficult and perhaps unwise to try and generalize.

Use of Coastal Erosion Hazard Maps

These maps can be used as tool to:

a. Perform preliminary selection of coastal areas for sand mining, tourism and housing development, coastal structures (e.g. docks) and infrastructure development.
b. Identify coastal areas that have shown historical patterns of erosion and are likely to display similar patterns in the future.
c. Sensitize the general public about coastal erosion and associated impacts.
d. Assist with the development of strategies for addressing the problems that may arise because of coastal erosion. For example, illegal sand mining is a major issue facing coastal planners today. With the information presented in the maps, it is possible to prioritize beaches for mining. Additional investigation of seasonal erosion and accretion patterns can also guide the development of a rotation system for sand mining.
e. Prioritize the allocation of resources for erosion defense, increased monitoring and/or further research of coastal dynamics.
f. Display the spatial relationship of coastal hazard areas with existing coastal developments and infrastructure. During episodic erosion events, it is important to be able to identify the developments located near coastal areas that are susceptible to erosion.

Map Limitations

This study suffered from limited data on one key GIS layer- settlements. The absence of this reference layer limits the user's ability to spatially orient existing settlements relative to the coastline and identify those communities at potential risk from coastal erosion. The lack of data on factors influencing coastal erosion also restricts the utility of the hazard method used. In addition, the roads layer was generated from a 1984 topographic map (Opadeyi, 2000). Consequently, the roads layer does not represent the current road network especially in the southeastern peninsula area.

The method used to produce the erosion hazard categories makes the assumption that these historical rates will continue in the future. However, the coastal erosion process is complex and other factors should be considered when defining relative erosion hazards. Therefore, the user must keep this in mind when using these maps.

It is also important to highlight existing limitations of the method used to calculate the beach change rate information. The drawback with using mean beach change rate information is that it may not tell the true story as average values tend to cover up severe erosion during episodic events. Therefore, there is no distinction between long term erosion trends and erosion resulting from short-term events.

In addition, erosion patterns over a period of time at fixed profile monitoring sites may be local and do not represent the entire beach. The problem here is that the two or three profiles located on beaches with lengths up to 1000 meters, may not always fully capture the entire beach changes over a period of time.

Notwithstanding the above limitations, the results provide a broad picture and general understanding of the erosion patterns and hazards on both islands.

Further Research

It is recognized that the method used in this report is computationally simple and does not incorporate all the factors that influence coastal erosion. To take the work completed under this study forward, the following key areas are presented for further research. The writer has started research in some of these areas.

1. Mapping Coast and Marine Features: New satellite images, IKONOS, with higher resolution became available in December 1999. Research is needed to evaluate the use of these new images and global positioning systems as a source of GIS data, which can be utilized for coastal mapping, GIS application development. Additional information on coastal

features can also be used in a more rigorous coastal erosion hazard.

*2. **Coastal Erosion Modeling:*** Beach erosion models provide the ability to better understand beach dynamics and predict beach erosion/accretion patterns under different coastal conditions. Research is needed to test/calibrate existing beach erosion models with beach profile data collected under the regional COSALC Project.

*3. **Coastal Management and Analysis System:*** It is recommended that geographic information system (GIS) be used to integrate data collected under the beach monitoring program with corresponding spatial information to generate thematic maps, and perform spatial, and other advanced analyses. A summary of the recommended analyses is presented below.

> *Erosion/Accretion Data Analysis:* Routines for the analysis would allow users to: a) identify and locate sensitive beaches with a specified erosion rate; b) calculate erosion and accretion rates over a specified period for a particular beach or category of beaches; c) compare erosion and accretion rates between beaches or categories of beaches over a specified period; and d) calculate beach sand volume changes over a specified period for a particular beach.
>
> *Risk Analysis*: Routines for the analysis would allow users to evaluate the potential risk coastal erosion poses to existing coastal development and infrastructure.
>
> *Setback Analysis:* Routines for the analysis would allow users to calculate individual setback distances for new buildings from the active beach zone.
>
> *Scenarios:* Routines for the analysis would allow users to study the potential impacts of coastal erosion or implementing coastal planning policies (e.g. setback distances).
>
> *Coastal Information Dissemination via the Internet*: These tools would facilitate the effective sharing and disseminating of coastal information using state-of-the-art Internet GIS technology.

Glossary

Accretion: accumulation of sand or other beach material due to the natural action of waves, currents, wind; a build-up of sand.

Beach: an accumulation of unconsolidated sediment that is transported and molded into characteristic forms by wave-generated water motion.

Beach erosion: the removal of sediment from beaches at a rate that exceeds its replacement. The removal of sediment can be a natural process or man induced.

Beach Profile: a side view of a beach extending from the top of the dune line into the sea.

Geographic Information Systems (GIS): a computer technology that combines geographic data (the location of man-made and natural features on the earth's surface) and other types of information (names, classifications, addresses, and much more) to answer queries, perform analyses, and generate visual maps and reports.

Hazard: the occurrence of a phenomenon (e.g. coastal erosion) which has the potential for causing damage to or loss of buildings, natural ecosystems and infrastructure.

Hazard mitigation: the set of activities implemented to minimize or eliminate the risk to property and human life from a hazard.

Risk: the frequency of incidents and their associated consequences. Coastal erosion risk is the combination of the frequency of erosion along the coastline and the magnitude of associated impacts on coastal development, natural ecosystems and infrastructure.

Topographic map: a map type showing a limited set of features but including, at the minimum, information about elevations or landform. These maps are common for navigation and for use as reference maps.

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St. Kitts Inland Erosion Hazard Assessment, Mapping and Mitigation Summary Report

Post-Georges Disaster Mitigation Project in Antigua & Barbuda and St. Kitts & Nevis

April 2001

This report was prepared under contract with the OAS by David Lang (Dominica).

Erosion hazards– what are they?

1. Kinds of erosion

'Erosion' is natural forces at work. The word erosion is an inclusive term for:

- wearing away and removal of soil or rock material by the effect of:
  - rainfall: water washing across the land or a rivulet or stream wearing away its bed or its banks, and depositing its load somewhere else, on land, in the stream bed or at sea, the processes that are thought of as 'normal' erosion
  - wind: wind-driven loose particles scouring the land surface and blowing away to be deposited against the nearest obstacle– perhaps a clump of bushes or a house – common only where the surface is bare and very dry and the wind is strong
  - percolating water dissolving rock: solution – especially in limestones and young volcanic ash, but difficult to analyse. This type of erosion is omitted in this report.

- rock falls and landslides slips etc, which are together called 'mass movements', and which are like any movement of unsecured objects under gravity

Erosion by running water is usually divided into several phases, some of which have names which are reasonably well known:

sheetwash describes erosion where water flows across land more or less in a sheet, and picks up particles of soil and carries them away. Its effects are often not very obvious to casual observation and it grades into

rilling is where flowing water makes very shallow sometimes broad channels across land and also picks up and wears away soil. Both sheetwash and rilling leave patches of deposited material wherever the gradient slackens and the slower flow will not carry all the load. When there is heavy rain and a large load is carried, deeper deposits form, often where the flow crosses a flat track or road and so becomes

much more obvious.

gullying is where quite deep and relatively narrow channels are formed, by water running off the land. These may become very deep and large like the St. Kitts ghauts, and cut below the soil into underlying soft rocks. Gullies sometimes develop from the joining of rills but more often start because the existing natural drainage system has become overloaded as a result of a change of land use or a massive burn etc. Gullies usually start short, but may lengthen quickly with the head of the gully moving back up slope. At the lower end gullies may produce a deep fan of outwash material.

stream cutting: established streams have courses which change all the time. For long periods there may appear to be very little change but whenever the river flows really full—full to the top of its banks or overflowing—it will scour its bed and cut away at bends.

All of these are normal natural processes, but human activity often multiplies them greatly, both in frequency and size. Sheetwash and rilling are not common under natural vegetation in these islands, except where fire or hurricane has bared the land, but they have become very common on certain soils when farmed. Gullying is uncommon under natural vegetation but where vegetation has been disturbed by hurricane or burned off, which can happen naturally in volcanic territory and may explain the ghauts, gullying will occur.

Mass movement—landslide and rock fall—is relatively common under natural vegetation in the steeper landscapes of the Lesser Antilles. There are several different types of landslide, partly dependent on the kind of materials involved, but we can generalise by saying that most landslides (not rock falls) occur when, or just after, a mass of porous material is saturated or super-saturated with water. Prolonged heavy rain brings landslides. Rock falls may be triggered by rain in the odd case, but seismic events and gradual loosening under weathering are more common causes. However human activity once again multiplies the frequency and size of these events.

Wind erosion, where the wind picks up and carries light small soil particles (especially organic matter) and bounces or rolls larger particles along the land surface, cannot occur under a vegetation cover and is only found naturally in the formation of dunes in dry sandy beach or desert areas, or where some other factor has left a bare surface.

2. Impact of human activity on erosion hazard

Human activity is usually effective in the following main ways:

- reducing the rate at which water enters the soil, and thereby promoting rapid runoff, by cultivation, and more especially by covering land with impervious material– houses, roads etc., or compacting soil. More and more rapid runoff leads to greater erosive power of water, and greatly increased erosion, up to more than a thousand times increase
- making drainage systems which concentrate runoff water but do insufficiently control outflow, which then causes erosion, often in the form of gullies
- making excavations which leave unstable slopes which may slide or fall, providing loose material to be washed away

3. The nature of the hazards to human communities

The hazards caused by erosion include those caused by the deposition of eroded material, which can have a greater impact on land use and human activity or at least a more obvious impact than the loss of soil.

Rill and sheetwash erosion is mainly of consequence for farmers. Surface erosion mainly affects the part of the soil most valuable for farming, the organic topsoil. Losses of one or two centimetres—the maximum likely loss over a few years under normal conditions here—will probably not bother anyone else, but make a critical difference for farmers.

Deposition of fine materials (mud) at the foot of a slope on a farm may destroy crops and make tillage more problematic. By contrast a float of mud on a road may mean a few hours of inconvenience and some work for a machine—hardly a major problem.

Gully erosion could be more serious for other land users than for farmers, through the need for costly controls to avoid further expansion and the disruption of works already underway. Roads for example may be cut. Farmers may be able to contain gullies by using simple bush dam structures, filling and covering with vines etc., but for construction sites some kind of well-planned diversion may be required.

Mud and sand deposits at the outfalls of gullies, probably at the foot of a slope where the angle suddenly becomes more gentle, may be deeper than those from rills and gullies and more difficult to deal with.

Stream bank erosion need not be a great problem—it is simply natural adjustment to the course of the river—unless structures are built within the banks of the river or very close to them. It is a problem for some bridge footings, which must be built near the banks of rivers and streams. The effects of deposits from stream bank erosion should be insignificant, since they will either occur within the stream course, on natural levees or as shallow deposits on terraces, for which farmers at least are prepared. If a meandering river cuts a new course, on its flood plain, the area at hazard is somewhat more extensive. However it should be clear that such areas are subject to flood damage even apart from new stream courses. For any infrastructure construction in these areas, there needs special justification and planning.

Wind erosion is usually very damaging to young farm crops, because of the cutting action of particles whipped along by the wind. Tall, well-developed crops provide their own defence, to a great extent. Deposition is governed by wind direction and may take place anywhere. Probably in our conditions only a little material 'flies' in suspension and most 'bouncing' and rolling particles will be halted by the nearest bush or building. On the whole, the consequences are not likely to be very large.

Landslides and rock falls can be dangerous. Landslides have engulfed villages and killed people on many occasions in the Lesser Antilles, and there have also been many narrow escapes. Most landslides and rock falls contain relatively small quantities of material which moves only a short distance, but they can still present a threat to life. In steeper lands where there is potential for long distance travel, a long fall may provide the momentum to ride up an opposing slope. Flow slides, which are primarily found in allophane soils and little-weathered pumiceous ash, can travel long distances down quite gentle slopes. In areas where the more dangerous sorts of landslide / rockfall are possible (part of the areas of highest hazard class), it will be worthwhile to check whether buildings are in a potential landslide or rock fall path and monitor them. The hazard should promote caution but not be allowed to cause an excessive reaction. Many buildings in Dominica, a much more landslide-prone island than either Antigua or Barbuda, which appear to be prime candidates for landslide damage have existed with the potential threat for many years.

Mitigating erosion hazards

General

The best mitigation takes the form of avoiding, as far as possible, the practices which are conducive to erosion, and using defences only where that is not practical.

The maintenance of a good vegetation cover, preferably forest, is the best insurance against rainfall-based erosion and landslides. Dense grass cover, if tall, is nearly as good, unless it is tussocky like lemon grass, but it offers little protection from landslides. The most vulnerable conditions of the land are where extensive hillsides are completely cleared, something that occasionally happens when a major land use change takes place, but which can be very largely mitigated if standard conservation measures are used.

Attention needs to be paid to land use management. Farmers may or may not need to be instructed in conservation, but more investment in ensuring that good conservation practices are employed is necessary, to minimise both loss of fertility and the problems created by sedimentation.

Attention also needs to be given to Town and Country Planning. Concern expressed over reworking of stream banks, and natural excavation of stream courses by the stream in spate, indicate that planning has been neglected. Building roads across an occasional stream without providing adequate culverts and permitting house construction within a gully or on the edge of vertical stream banks in weak materials is not good practice. Mitigation of earthquake-induced rock falls and landslides also requires more careful recognition of potential recipient sites during Town and Country

planning.

Specific

Mitigation of water erosion: sheet erosion, rilling, gullying

1. *Plan adequate drainage systems*
2. *Take action in response to land use change*

The main problem with dealing with water erosion is that land use is changed without appropriate conservation measures being taken. For example, converting a piece of land under bush to dwelling house lots results in a marked reduction in infiltration (the way water enters the soil) and a marked increase in runoff. The surface drainage of the area needs to be considered and linked to existing drainage in such a way that the drains will accommodate the flows produced by storms under the changed land use. This is a matter where planners need to enforce some rules. The proposed exit of St Kitts from the sugar industry will present an enormous problem unless land use change is well planned, as the soils presently protected by sugar cane have a high potential for erosion. The second problem relates to the design of drainage systems in general. Drainage systems need to be planned to deal with a whole sub-catchment. Those that do not, and do not integrate all factors, can cause more trouble than no system at all. Although no particular problems were evident during field visits to St. Kitts, except the case of the road to the southeast peninsula often mentioned previously, the alignment and construction of roads and particularly the provision for road drainage can provide long term instability problems and have been the initiator of major landslides and gullying throughout the Windwards. Again, this is a matter of planning, in which the planners need to ensure that developers including Public Works and farmers have given the matter adequate consideration.

There is no lack of knowledge within government departments of the means—planning, specific conservation measures—by which rainfall-induced erosion can be mitigated. But, for want of urgency, it is being neglected.

Mitigation of problems produced by wind erosion

1. *Retain windbreaks, avoid large areas of exposed soil, use vegetation strips*

Wind erosion is only serious where literally bare soil is exposed to strong wind. The serious examples in Europe and North America ("dust-bowls") have occurred where large expanses of soil have been completely bare. In Europe, areas that had grown grains in fairly small fields without real problems were badly damaged by wind after the removal of hedges. Here any form of strip cultivation (provided it is not continuous over long distances, so as to provide a funnel), should be effective. This is a problem for agriculturists to tackle, but one which will affect others, so planners should be involved.

Mitigation of mass movement induced problems

1. *Monitor and avoid areas at hazard*
2. *Provide cut-off drains*
3. *Use stabilising techniques (a costly last resort)*

Mass movement under gravity is not something which can be easily stopped. Some land use practices increase the hazard of mass movement– removal of trees and loading weak slopes (with buildings or roads) for example– and should be proscribed as a matter of common sense, since we all have to pay for the resulting damage. Building on sites in the recipient area of such movements should be discouraged and would normally be a matter for rejection where Environmental Impact Assessments (EIA) are required. Again, planners should be able to minimise these problems.

Rock falls, simply a movement of loosened lumps of material under gravity, can only be mitigated by:

- minimising damage:
  - quarantining the predicted receiving site
  - identification and regular monitoring of potential falls, and provision of a catch site or barricade if that appears likely to be cost effective

    - terracing—this is costly and not particularly effective / appropriate where a vertical cut has higher land behind
- minimising the likelihood of a fall:
    - identification and artificial protection – such as sealing cracks where infiltrating water may remove some material or assist slipping

Landslides, (and some rock falls) may be mitigated by:

- minimising the likelihood of a slide:
    - reducing lubrication to the slide by cutting ditches above the likely slide site to carry water away from the slide plane
- avoiding loss of tree cover from such a site
- minimising damage:
- monitoring likely areas and minimising use

Mitigation of problems caused by stream bank erosion / stream reworking / new courses

1. *Keep drainage ways clean of impediments– do not fill with solid waste etc*
2. *Avoid using potentially endangered land for permanent structures*
3. *Use structures to deflect damage to sites or reduce reworking effects (a costly last resort)*

Stream courses can be canalised, as they often are where they pass through towns, but to prevent the adjustments which are natural processes of stream development will often be unreasonably expensive elsewhere and sometimes very difficult in most cases in St. Kitts, except perhaps downtown. It might be less difficult in Antigua but would still be costly and rarely giving a beneficial return commensurate with cost. The task is for planners to provide the right information.

These problems can really only be mitigated for the long term by:

- avoiding the likely sites of reworking which are easily predictable from channel shape
- canalisation of a long stretch of the stream— this is not likely to be cost effective in St. Kitts.
- finding a means of reducing maximum flows (e.g. dams)

Temporary protection can be effected by:

- providing walls supporting the attacked site
- baffles, deflecting the stream flow

But it is unlikely that these will be cost effective except in a few instances.

Mapping the hazards

Because of the tendency of most agriculture to accelerate natural erosion processes, erosion has been the subject of observation in relation to agriculture. Observations have been of two kinds:

- surveys, for example, of the effects of rain or wind storms on soils
- studies of sample plots

These observations have led to the development of mathematical models used to estimate erosion losses or potential erosion. The main concepts are that each identified soil type has an intrinsic susceptibility to erosion (erodibility), that each rainstorm has a specific capacity to erode (erosivity) which can be assessed, and that land cover / vegetation has a major modifying effect on erosion potential.

As a land forming process, however, erosion is also very important in geomorphology, for its role in the development of slopes and stream courses and thus of natural landscapes.

The models used in this study have been developed using the general understanding that has developed of the processes involved and the role of various land characteristics in these processes. They are simple models using the following land characteristics as variables to estimate the effects of the apparent processes:

- Topography: slope, aspect, etc.
- Physical geology: tectonics / lithology
- Geomorphology
- Soils: physical and chemical
- Rainfall
- Wind
- Present and antecedent Land Use / Vegetation
- Current status of erosion / landslide
- Hydrology

Models similar to these are widely used in the absence of local experiment and the kind of local data which engineers might provide.

The data used in these models is often a simpler version of what appears to be the appropriate data, which are used because they are available and the "better" data are not. Some better data can and should be obtained.

Hazard maps

1. Single feature maps

1. Simple models were used to produce hazard scores for each land unit. The score is an estimate of the relative likelihood of the hazard at the land unit, but it has no physical meaning, like 'days per year' or 'tons per acre', etc.
2. To make the scores more useable, they have been classified. For each hazard, the scores have been divided into 5 classes having equal land area (representing very low, low, medium, high and very high groupings)
3. Combining the effect of different types of hazard would be likc adding apples and pears, with no common element like calorific value to use. Adding classes rather than scores reduces this problem. Composite maps were produced by adding classes and then reclassifying.

2. Composite maps, choosing the most appropriate classes for defining land-based erosion hazard for development sites

Erosion hazards are most commonly defined in relation to open land either under agricultural use or intended for an agricultural use. The application to development sites where some kind of construction is intended is related to localised incidents rather than a general picture. This emphasises the need for data at a more appropriate scale, which are not available at present.

1. Overall, *rill and sheet erosion* should be given little importance in assessing possible impacts on building development sites, while gullying is important.
2. The natural evolution of *streams* means that bank erosion is inevitable without canalisation of the stream course. Overall the stream bank erosion / stream adjustment effect could be important for development sites.
3. *Wind erosion*, although it can cause problems in certain circumstances, is unlikely to affect a building site seriously at the levels at which it is probable in the present circumstances of the island.
4. *Mass movement*, on the other hand, both the site from which the movement takes place and the destination of material, can produce major difficulties for building development.

The final map for St. Kitts combines gullying and mass movement (landslides and rock falls) and, where possible, an indicator of the probability of stream bank erosion. This is done by adding together the land unit by land unit values for gullying and mass movement and indicating separately those catchments in which stream bank erosion is highly likely.

3. Individual hazard maps and composite maps presented

The two final maps comprise a main map which is a composite and a supplementary , derived from the whole set of individual "erosion" process maps for each island. The full set, shown below and available as larger maps, comprises:

St. Kitts

Composite Maps: 1) Composite erosion hazard classes (gullying and landslide / rock fall hazard of bare soil areas except in the area of the Forest Reserve, where the hazard under vegetation is taken). 2) Stream bank erosion hazard , to be used as an annotation to map (Wind erosion and sheet and rill erosion are not considered of importance in building development in St Kitts)

1. Landslides in the absence of cover, classes
2. Stream bank erosion hazard, classes
3. Hazard of rill erosion in absence of cover, classes
4. Hazard of rill erosion under land cover, classes
5. Hazard of wind erosion under land cover, classes
6. Hazard of gullying (overlay to bare soil rill), classes

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Nevis Drought Hazard Assessment and Mapping Summary Report

Post-Georges Disaster Mitigation Project in Antigua & Barbuda and St. Kitts & Nevis

April 2001

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INTRODUCTION

This document, which summaries the results of a drought hazard assessment and mapping study for Nevis, was commissioned by the Organization of American States (OAS) as part of its Post-Georges Disaster Mitigation Project (PGDM).

One of the major objectives of the PGDM is the "development of national goals, objectives and actions to reduce the vulnerability of Nevis ... to the effects of natural hazards."

There were two major component products of the study, namely:

- A drought hazard assessment technical report and;
- Island-wide drought hazard data maps which were used to identify areas of different categories of risk to drought.

Data for map preparation and for drought assessment were collected from secondary sources, reports, maps, personal communication and limited field observations. Maps were first manually prepared and then digitized, using GIS application, Arc View.

DEFINITION OF DROUGHT

Drought is a recurrent feature of Nevis' climate. It occurs when there is an extended period of deficiency in precipitation (relative to what is considered normal). Drought has three critical but inter-related components:

- Meteorological drought, which has been defined to occur when rain falls below 39.1 inches per year, which is 15% less than the annual average of 46 inches.
- Agricultural drought, where extended dryness reduces moisture in the soil to the point that plants and crops are adversely affected;

- Hydrological drought, where the reduction of water levels in wells, surface reservoirs and dams severely affect livestock or where water must be rationed to households, hotels and other sectors.

Land use practices, such as clearing of vegetation, overgrazing by livestock and farming without trying to conserve soil and moisture make the island more vulnerable to all forms of drought. Vulnerability can be reduced by changes to such practices.

PAST DROUGHTS AND THEIR EFFECTS

Historic Drought

Based on rainfall records obtained from the Department of Agriculture, three (3) periods of drought have been identified for the last decade, namely:

1990 – 1991
1993
1997

The year 2000 may also turn out to be one of below average rainfall – the average rainfall from January to November being 32.51 inches.

In 1990, average rainfall was 46.77 inches but 15.11 inches was recorded for the month of October. For the rest of the year rainfall was 31.66 inches and for the months of January to September only 24.37. Even with the 15.11 inches of rain recorded for October 1990, the average rainfall for the two-year period was 37.07.

In 1993, average rainfall was 37.10 inches and in 1997, 34.06 inches.

Actual yearly rainfall figures before 1990 were not obtained but 1974 was said to be perhaps the worst period of drought in recent times (Richard Lupinacci, Hermitage Hotel, pers. comm.) Lupinacci said that the dryness and wilting of vegetation in 1974 was the most severe experienced in recent times even in higher elevations such as Hermitage, where average rainfall is about 55 inches/year.

DROUGHT IMPACTS

Environmental Impacts

a) Vegetation and Landscape

Drought impacts were particularly severe in watersheds where plants with shallow root systems on shallow soils were among the first to be affected by deficiencies in soil water.

No studies were made of soil conditions during the 1990-91 drought. However, it is assumed that moisture deficiencies during this and other droughts gradually lead to the reduction in soil fertility. Plant growth and crop yield is affected as a result.

Leaf and stem loss in herbaceous and woody plants were followed by plant mortality in certain species in the 1974 drought (R. Lupinacci, pers. comm.). As plants wilted and died, canopy cover decreased in wooded areas and the landscape generally became visibly brown, dusty and harsh looking.

Soil exposure due to overgrazing makes more land vulnerable to accelerated erosion with each drought. Soil loss is therefore a major environmental impact from drought particularly on the east, northeast and southeast coastal areas that are very exposed to wind.

b) Habitat

In Nevis, wildlife habitats are sometimes also used for grazing by livestock. Such areas may have a combination of scrub, grass and woody plants with sufficient canopy cover to attract species of birds. Irrespective of plant characteristics, ecosystems require adequate moisture to function reliably as habitats for wildlife. Inadequate moisture during the droughts created conditions that were stressful to bird, reptile (lizards) and amphibian (frogs) species.

Stressful conditions are exacerbated by competition for resources and space from goats and other livestock. Livestock population densities in some areas are in excess of what is considered sustainable for such ecosystems.

One constraint in assessing habitat impacts is the absence of detailed listings of plant species preferred by goats. Unlike cattle and sheep, goats browse (rather than graze) normally on various herbaceous plants and woody shrubs, along with ornamental plants if they get access to household gardens.

Since biomass production of grass used by livestock in Nevis declines faster relative to many species used by goats, grazing livestock are likely to reach the critical threshold of nutritional stress earlier than goats.

Economic Impacts

a) Agriculture

In 1975 31% of the land in Nevis was under agriculture (IRF, Nevis Country Environmental Profile). The preliminary findings of the 2000 agricultural and fisheries census indicates that there were 3,278.5 acres of land in agricultural holdings representing 14% of total land area in Nevis. It is instructive however that only 5% of the land is devoted to what the census terms "agricultural purposes". What is termed "common grazing lands" is not included in the acreage of agricultural holdings given by the census. The figures nevertheless suggest a significant decline in lands used for cultivation.

The relationships of holdings to water resources (aquifers, wells) and infrastructure (storage reservoirs) could not be determined. Such relationships are helpful in making assumptions about past impacts on droughts geographically or spatially, where data is lacking and more importantly in trying to determine agricultural areas vulnerable to future droughts.

For example, the parish of St. George has five (5) reservoirs with total capacity of 1,155,500 imperial gallons located at various areas within its borders that could allow for gravity flow to farm areas. It also has six (6) wells with total yield of 442,080 IGPD.

However, farming in the parish remains mainly rain-fed because of the cost of domestic water. Here vulnerability to drought could be reduced if a way could be found to subsidize the purchase of water.

Farmers in the Cades area of St. Thomas on the other hand benefit from free (subsidized) water supplied by government dams located in the spring Hill/Westbury area. These farmers remain vulnerable to drought since they use irrigated water from dams totally dependent on rainfall.

In response to request for information, a written summary was received from the Department of Agriculture on the impact of drought on the agricultural sector. This summary is provided below as given, namely:

a. The period of time water is available in open dams becomes limited;
b. Farmers have to reduce their scale of operations as a direct result;
c. Farmers use more domestic water, which is at a higher cost;
d. Due to a decrease in local production, more vegetables and fruits are imported – loss of revenue to farmers and loss of foreign exchange;
e. The quality of certain vegetables, for example lettuce, watermelon and cucumber, is severely affected;
f. Smaller and poorer quality feed for livestock;
g. Poorer quality meats;
h. Deterioration of conditions of animals resulting in less returns;
i. Overgrazing, which impacts on agriculture and the environment;

j. Increase in the mortality rate of animals.

Dams

Agricultural dams in Nevis are located in:

Cades Bay
New River
Potworks
Matters

Farms in the Cades Bay area are gravity fed from the dams at higher elevations with a total capacity of 3.5 million gallons. Potworks farms benefit from a dam with the storage capacity of 600,000 gallons, while dams supplying farms at New River have a total capacity of only 16,000 gallons.

According to the Department of Agriculture, drip irrigation is the most common method of irrigation in these areas but sprinkler systems are also used.

The initial impact on farmers during times of drought is monetary. When dam sources dwindle or dry up farmers are forced to use domestic water bought at the cost of EC$25 per 1000 gallons. Water cost becomes then a major factor in the ability of farmers to keep crops supplied with the level of moisture required to achieve normal yields, particularly where drought conditions result in higher temperatures and evaporation rates.

The quantification of effects from drought relative to the availability of water and the understanding of future vulnerability are hindered by:

- Absence of rainfall stations at dam locations; rainfall stations exist at estates fed by the dams (Cades, Potworks, New River) but the stations at Cades Bay and Potworks Estate are not routinely monitored, hence regular monthly data is not available;
- Absence of reliable evaporation records from the dams;
- Failure to meter dam water supply to farms.

Reduction in Farm Operations

The Department of Agriculture's conclusion that farmers reduce the scale of their operations when water in dams becomes limited is understandable. There is however no data readily available to determine quantitatively:

- Reduced acreage of land farmed in any of the drought periods and for what period of time;
- Reduced crop yield per acre;
- Reduction in volume of crop produce;
- Cost to farmers.

Use of Domestic Water

A monetary impact on the use of domestic water by farmers as a substitute for dam water could easily be determined if supply from dams was metered. Metered dam water supply would also allow authorities to estimate additional demands for water from farms during drought periods.

Increased Importation of Vegetables and Fruits

Based on number of holdings and acreage under cultivation, sweet peppers, sweet potatoes, tomatoes, cabbages, pumpkins, carrots, chive, tannia, yams and cucumbers are major annual crops on Nevis.

Among permanent crops, bananas, mangoes and coconuts have relatively large holdings (between 355 and 461 acres), while breadfruit, sugar apples, soursop, avocado pears, limes, golden apples, guavas and guinep have holdings ranging

between 150 and 200 acres.

Bananas are moisture-loving plants, whose growth and yield is readily affected adversely by extended periods of dry weather. Coconuts on the other hand use a lot of water but are less vulnerable to drought particularly where located in areas with high water table.

Thus, rarely would there be a need to import coconuts, while the tendency is to import bananas at the first indication that local production is down.

The same is true for vegetables in relatively high demand such as carrots, tomatoes and sweet peppers.

Quality of Vegetables

Water-loving vegetables such as lettuce, cucumber and watermelon and fruits such as bananas, decline in quality when they experience moisture stress. The impact is most severe for farms without access to dam or domestic water.

Impact is also relative to space requirements of crops. For example, lettuce can be intensely grown in small parcels thus moisture requirements are more easily managed than for plants requiring more space per plant.

Quality of Livestock Feed

When there is a deficit of rainfall biomass productivity among species of grass used by grazing livestock drops relatively quickly. This is true for managed livestock ranges (labeled grazing on the land use data map) and unmanaged livestock ranges (labeled rough grazing).

Animal Health

The droughts affected the health, weight (hence marketability) and productivity of livestock. Hot weather caused heat stress, which is said to reduce fertility through sperm damage. Hot weather also affects libido in male animals, decreases milk production in cows and kills chickens (Dr. Paul Cadogan, 2000).

Animals also suffered from dehydration caused by shortages of water.

Livestock Mortality

Death of livestock caused by drought was confirmed by the Department of Agriculture after consultation with the Veterinary Division. However, drought related mortality figures were not available.

Economic Impacts

The economic impacts could be summarized as:

- Setbacks to the development of small and large herds due to drought effects on the productive capacities of animals;
- Reduction in weight and hence marketable volume of meat because of under-nourishment;
- Reduced marketability of animals and their products due to the malnourished appearance of animals;
- Reduction in the supply of local meats, creating more dependency on imported meat products;
- Significant income loss to livestock farmers.

Absence of Drought Insurance

The economic impacts on agriculture from drought were compounded by the absence of drought insurance for crops and livestock. Insurance is lacking for three key reasons:

- Insurers do not perceive this as a feasibly investment of resources, given the relatively small sizes of farms and

livestock herds;
- Even if crop and livestock insurance for drought was available, small farmers most likely would not have seen the need; with the small size and subsistence nature of many operations, paying insurance premiums would have been considered an additional financial burden;
- Crop insurance is not integral to the small farm culture in Nevis.

In the absence of being able to file claims for crop damages and/or loss, farmers had to absorb their own financial losses. The experience was difficult and stressful for many farmers and in some cases it dampened the enthusiasm for future investment in agriculture.

b) Tourism

Nevis has 478 rooms divided between hotels/resorts, condominiums/villas, plantation inns and guesthouses.

A number of the plantation inns and guest houses are located south of Nevis Peak within the rainfall "shadow", where temperatures are relatively more comfortable and conditions for plant growth better.

Most of the hotel rooms are on the west coast. A few of the plantation inns and guesthouses are located on the relatively exposed north coast. Fortunately, none are sited on the lower elevations of the east coast where exposure and dryness in periods of drought make vacations less comfortable.

Landscape, Product and Climate

Nevis' tourism is promoted on the strength of its climate, sea and beaches. Several ground tours are designed around its ecology and scenic landscape.

Drought adversely affects the quality of the biological landscape (that is the living landscape of plants and animals) and the physical (non-living) landscape; the latter due mainly to the heat and dust associated with extended periods of low precipitation.

During the droughts the general quality of the visitors' experience was affected by relatively hotter and drier conditions and a landscape stressed from heat and moisture deficiencies.

Property Landscape

One impact from droughts was the loss of plants on hotel property. Hotels did not have to purchase water from other than normal sources but indications were that some rationing of water occurred on properties.

At an average cost of EC$25 per 1000 gallons, some hoteliers view water as expensive. Consequently, although water was available from the local water authority, water was sparingly used on plants. As a result, a property such as Hermitage reported a loss of plants.

Local Produce

During previous droughts, hotels had difficulties securing local fresh fruits and vegetables. Hermitage reported difficulties in purchasing local bananas, melons and other fruits, lettuce and various other vegetables.

Effects on Workers

Unlike Antigua, where a number of properties laid off workers due to a decline in tourism sector, hotels in Nevis did not lay off workers as a direct consequence of the droughts.

Impact on Natural Attractions

Natural attractions of vegetation and scenic interests lose their visual appeal due to moisture deficiency.

The Nevis Island Development Plan 1996-2005, Volume 1, Island Profile Survey lists the following natural attractions:

- Nevis Peak National Park
- Gallows Bay Bog
- Saddle Hill
- Round Hill/Hurricane Hill
- Nelson Spring
- Pinney's Beach and Wetland
- New Castle Bay
- Indian Castle.

It is not known if the volume of visitor trips to any of these attractions was affected by drought conditions. Even if there were a reduction in visitor volumes, it would have been difficult to obtain supporting data because the infrastructure to record visitor trips to most, if not all, of these attractions does not exist.

Settlements

The effect of past droughts on settlements has not been documented. However, it is assumed that settlements on the east, northeast and southeast coasts because of the relative exposure to prevailing winds and location within the lower rainfall belt would have been more severely affected. Settlement elevation in relation to booster pumps and water storage reservoirs was evaluated during the assessment. The findings indicate that relatively few residences are located higher than their supply reservoirs and the Water Department confirmed that for the most part settlements were adequately served by its water distribution network. Data on the number of households connected to mains supply was not secured. Households without connection would normally be vulnerable and would perhaps become more so during droughts.

FUTURE VUILNERABILITY

Agriculture

The agricultural sector remains highly vulnerable to future droughts for several reasons, namely:

Location of crops. Crops located in areas where rainfall is below the national yearly average will remain vulnerable to drought if rain continues to be the main source of water for plants. Vulnerability can be reduced if water for irrigation is made available at reduced or subsidized rates.

Vegetable crops grown in shallow soils on relatively steep slopes will also remain vulnerable unless water and soil conservation measures are applied. Depending on the level of constraints posed by shallow soils and steep slopes, soil and water conservation measures could be very costly and may prove to be uneconomical in some applications. Cultivation practices that cannot be sustained can be considered economically vulnerable.

Cost of water. Although the number of farms with access to water for irrigation is increasing, irrigation remains uneconomical for most small farmers because of the cost of water. As a result, even if farms have access to potable water, cost could prove a deterrent to its use in meeting irrigation requirements.

Overgrazing. High livestock population density will continue to adversely affect the landscape, soil, habitat and plant growth unless radical policy interventions are made to mitigate these impacts. If mitigation does not occur, large sections of the island's landscape will remain vulnerable to drought.

Better control of livestock populations will be necessary to reduce and eventually eliminate crop damage from goats and sheep, which increases during periods of drought.

Tourism

Recent increases in water supply will reduce the impacts of meteorological drought on the hotel sector. Where dry

weather conditions persist long enough to drastically reduce ground water yield, water rationing would be required and this would affect hotels.

Growth in the hotel sector, along with the construction of any additional golf courses, would significantly increase demand to the point where supply could become inadequate. For this reason, growth in water demand should be anticipated and investment made to increase supply to reduce vulnerability to drought.

Settlements

Settlements have become less vulnerable to droughts because water supply and distribution has improved in recent years. A few settlements are affected by low water pressure because of water transmission and supply problems.

The majority of settlements are not expected to suffer major water shortages for household use unless rainfall deficiencies remain long enough to affect ground water yields. However, households headed by farmers that are dependent on agriculture for all or part of their incomes will remain vulnerable to meteorological droughts, where costs prohibit irrigation of crops.

Certain characteristics that may suggest the need for mitigating the vulnerability of settlements to drought can be identified, namely:

- Residential areas without potable water supply;
- Villages or areas where household connections to potable water are below the national average;
- Areas in high elevations relative to storage reservoirs;
- Areas supplied by inadequate storage, pumping or distribution infrastructure, resulting in periodic water shortage problems;
- Villages overly dependent on subsistence farming;

Understanding and Applying the Concept of Risk

Drought risk for the purposes of this analysis is considered as having two (2) contributing factors, namely:

- Recurring environmental or meteorological events or natural physical characteristics beyond the control of man;
- Human practices (policy or land use) that make the population vulnerable to natural events and characteristics.

In addition, existing policy may also contribute to the island's vulnerability to drought. Vulnerability could be reduce if policy interventions are made in the following areas:

- Cost of water for irrigation;
- Regulation of livestock grazing and livestock population densities;
- Incentives for water and soil conservation practices;
- Drought insurance;
- Drought relief programs;

Areas at Risk to Drought

Drought Risk Criteria for Mapping

Mapping of areas on the basis of their risk to drought, namely, low, moderate, high, very high was based on a set of criteria. Each criterion is given a value of one (1) and the total value of an area determines its rank:

Low drought risk 3-4
Moderate drought risk 5-6
High drought risk 6-7
Low drought risk 8-10

The listing of drought risk criteria is shown below:

Environmental Meteorological

- Rainfall < 45 inches
- Exposure (wind)
- Strong marine influence
- Shallow soils
- Slopes >10 degrees
- Cactus scrub and agricultural vegetation
- Absence of moist forest
- Absence of dry evergreen forest
- Absence of dry woodland forest

Hydrological/Infrastructural

- Absence of wells, springs
- Absence of storage reservoirs (ponds, dams)

Human/Landuse

- Grazing
- Cultivated crops
- Settlements

Areas

The assessment confirms, what perhaps is already known, that the central mountain area of moist forest has the lowest risk to drought. Moderate risk areas include the northwest and north of the island.

High-risk areas include the Charlestown water zone and the Butlers/Mannings water zone on the east of the island. The south and southeast section of the island is considered to be of very high risk to drought.

It is suggested that additional work be undertaken to confirm these drought risk designations. The work should include field observations to update the data maps where necessary.

Emphasis should also be placed on identifying more appropriate boundaries for water resources and drought management. A thorough analysis of drainage basins on the island could provide the basis for the delineation of the management boundaries.

Follow-up should also involve the refinement of the methodology used for drought risk ranking. Selective merging of drainage basins into units for managing drought would require re-evaluation and adjustment to the drought risk zones.

MAP USE AND LIMITATIONS

Use and limitations of the data maps and drought risk maps are described in the technical report. Difficulties in gathering data for mapping were key constraints in the assessment. Updating of the data maps should therefore be considered as new information becomes available.

INDICATORS FOR FUTURE IDENTIFICATION OF DROUGHTS

This section summarizes and describes indicators that suggest approaching or actual drought conditions. These indicators are discussed under the following categories:

- Meteorological/Environmental;
- Hydrological
- Agricultural
- Socio-economic

a) Environmental Indicators

Reduction in biomass production of common grass species. Early warning is wilting, as grass roots become progressively damaged by lack of soil water; Grass cover becomes patchier as fallen leaf debris is blown away by wind in exposed areas. Home owners find no need to use lawn mowers on lawns;

Leaf fall and litter in Forests. The increase in leaf fall and litter (detritus) on the forest floor can be used as one indicator of drought. Since leaf fall varies between species, measurement would need to be correlated with plant associations.

Damage to "indicator" plant species. Some types of xerophytes, (succulents, such as cacti and agaves) utilize stored water in dry periods without noticeable damage. In fact, such plants can survive for weeks when uprooted, so that signs of damage (dried leaves or broken stems) may be an indication of negative water balance resulted from extended drought.

b) Hydrological

Reduction in Ground Water levels. Ground water levels at various well fields are an indicator of hydrological drought.

There is a time lapse between meteorological and agricultural drought conditions and hydrological drought as indicated by ground water levels. The latter occurs later but the time lapse cannot be accurately predicted in the absence of rainfall data that could be correlated with rates of pumping and recharge, for the drainage basins in which the well fields occur.

Recovery from meteorological and agriculture droughts occurs in advance of the replenishment of ground water to average levels. Again, the data does not exist to accurately predict the gap in time between these events.

Reduction of Water Levels at Agricultural Reservoirs. Receding water levels at agricultural reservoirs is another drought indicator. Indicator levels at selected reservoirs could be determined over a period of time by monitoring to consistently measure meteorological and hydrological data, including, rainfall, temperature, wind speed, evaporation and seepage.

Water Rationing. The Water Department rations water before ground water levels recede to critical points. In fact, the decision to begin rationing water appears to be influenced by perceived meteorological and agricultural drought conditions.

Agricultural

Livestock

Goats adapt well to drought by using physiological measures to conserve water. Despite this, they and other livestock will show signs of stress during extended drought, including:

- Weight loss
- Higher incidence of disease
- Unusual high incidence of miscarriage among pregnant females

Crops

Indicators may include:

- Negative water balance, as evidenced from wilting and ultimately death of plants in extended droughts;
- Unusually high incidence of disease as plants are unable to obtain needed moisture and nutrients from the soil;

c) Socio-economic

Socio-economic indicators include changes in water use practices by households and businesses:

- Storage of water in existing or temporary storage facilities as a result of water rationing;
- Reduction of water used for landscaping of household and hotel gardens;
- Trucking of water to meet water deficit due to rationing;
- Higher incidence of respiratory ailments due to excessive dust in a very dry landscape. Respiratory ailments related to drought are not recorded for Nevis but are generally considered a drought related health impact.

Who's Right And Who's Wrong?

The duality of right versus wrong does not have to exist. There can instead be a continuum of "rightness", predicated on our knowledge and perception of possible outcomes. People must learn to listen to one another's ideas, not as points of debate but as different and valid experiences in a collective reality, in order to have new experiences and broaden their understanding. Then they can fully participate **In Search Of Common Ground**.

At the same time, we must be willing to accept a challenge to our ideas in the spirit of learning, rather than as an invitation to combat. The greatest triumphs in science are not, after all, triumphs of facts but rather triumphs of new ways of seeing, of thinking, of perceiving, and of asking questions. Since I do not know for sure who is more right than whom, I must in fairness accept that everyone is right from her or his own point of view, and each point of view is different -- not wrong, only different -- regardless of what the discussion is about. Through communication, our many individual perceptions are coordinated and integrated into a collective vision of reality.

It is extremely important in human interactions to keep each person's dignity, which means I will protect their dignity so they can protect mine. Dignity's emotional foundation rests on the perceived ability to make choices, which in turn provides a sense of hope. Although I cannot convince you that you are wrong without somehow attacking your dignity, I can give you new data, which raises the value of your making a new decision based on new information. In this way, I can be patient while maintaining your dignity intact. Remove the sense of choice that has to do with one's determination of one's own destiny and you remove hope as well, and human dignity withers.

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Inland Flood Hazard Mapping for St. Kitts and Nevis: Summary Report

OAS/USAID Post-Georges Disaster Mitigation Project

Implemented by the Organization of American States, Unit for Sustainable Development and Environment for USAID-Jamaica/Caribbean Regional Program

May 2001

This report was prepared by Vincent Cooper, University of the West Indies, Trinidad.

Note: The final maps that accompany this report are available online: St. Kitts | Nevis

1. Introduction

This report describes the approach to mapping the natural hazard of inland floods on St. Kitts/Nevis. It first presents a summary of the main cause of flooding on the islands. This is due not only to extreme rainfall, which provides the potential water for inundation, but also depends on the condition of the watersheds at the time of the event. The detrimental effects of flooding are then presented, which on the islands are mainly health hazards in terms of drowning and the contraction of diseases (to a small degree), and damage to economic systems including public infrastructure and private property. The data needs and adequacy for flood quantification are then discussed. For its quantification three sets of data are required, and they include rainfall data for characterizing the rainfall with potential to cause floods, the physical properties of the watershed which determine the volume and time-distribution of runoff onto low-lying areas, and the geometric features of the drainage channel which may or may not have sufficient capacity to accommodate the runoff from the watersheds. The two approaches used for flood mapping are described, followed by the presentation of the methodology implemented for producing the maps. A general summary of the findings for each island concludes this report. Among other things, it suggests what are necessary to improve the accuracy of the maps, which given the limited data must be regarded as only preliminary maps.

2. Causes of flood

The nature of inland flooding being investigated on St. Kitts/Nevis is described by the following definition: "Flooding is a general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland waters or from the usual and rapid runoff of surface waters from rainfall." In these islands, the major trigger of this inundation is extreme rainfall on the watersheds. These extreme events are sometimes associated with hurricanes that

produce significant quantities of rainfall during their passage over the islands, the slower the movement over the islands, the greater the quantity of rainfall. Widespread flooding may also occur from rainfall associated with the Intertropical Convergence Zone (ITCZ) weather system. However, most extreme events have been from violent thunderstorms occurring mainly because of the high relief of the watersheds. These are generally very localized rainfall events.

Whether or not floods occur within a watershed, on the occurrence of an extreme rainfall event, depends on the characteristics of the watershed. Most watersheds in St. Kitts/Nevis have the following properties:

i. Soils that are very permeable and highly erodible. The soils can permit significant infiltration amounts and has potential to significantly reduce runoff volumes;
ii. Very steep watersheds causing rapid flow of water, permitting little infiltration and causing significant soil erosion;
iii. Forested areas in the upper portion of the watersheds;
iv. Expanding urbanization (especially in St. Kitts) in the foothills that is generally replacing sugarcane plantations and thereby replaces pervious areas with impervious surfaces such as roofs and roadways; and
v. grazing by livestock on Nevis that compacts soils and reduces infiltration rates, and removes vegetative cover leaving the soil surface exposed to full impact of the rainfall drops and vulnerable to soil erosion.

Mainly because of the steep slopes, there is reduced infiltration and little flow retardation of the travel of the flood volume toward the low-lying areas. Thus watersheds in St. Kitts and Nevis are susceptible to flooding. Fortunately, watersheds are small, in the order of a few square kilometers, and so the volume of runoff would be relatively small even for very extreme rainfall.

3. Effects of floods

Floods may have detrimental effects on three aspects of the human condition—health, agriculture, and economic systems. In terms of human health, floods can cause death by drowning, impact or exposure. In St. Kitts and Nevis, fast flowing waters may sweep persons and vehicles away toward the sea as happened recently in both islands. The main danger is at various road-crossings where ghauts may overtop the culverts and bridges and flow over the road. Unaware of the danger of fast-flowing water, several lives have been lost by persons attempting to negotiate across the swift floodwaters. In St. Kitts, persons living along Lower College Street are exposed to the danger of swift moving water when the College Street Ghaut is flowing full. Likewise on Nevis, for persons in the lower Bath Ghaut area. Numerous physical injuries are possible as well, and a common effect of flooding is disease and disease transmission. Diseases commonly are associated with disruption of fresh water supply; contact with floodwaters contaminated by septic tank and wastewater treatment plant overflows; the creation of appropriate habitat conditions for certain rodents, insects and organisms that transmit diseases. Detrimental effects in Nevis on agriculture are mainly due to loss of livestock due to drowning or becoming dispersed. Destruction of crops, seeds, and stored food stocks during inundation is limited as agriculture occurs on the foothills and not on floodplains. Public infrastructure and private property may be damaged with inundation and deposition of significant quantities of silt. For Basseterre and Lower Bath Ghaut, initially ground floors of buildings and residences may be affected with rising flood stage. But with increasing stage and flow velocities, buildings and loose property can be swept away. An additional danger with such steep sloped watersheds is caused by boulders transported by the swift currents and floating debris such as cars and logs that can increase damage as they impact structures downstream. Properties on riverbanks may be in danger if riverbanks erode and trigger bank failure. Extreme examples of bank erosion exist along the College Street Ghaut, around Monkey Town, and Cayon Ghaut.

Major disruptions of the road network may affect productivity as the workforce is delayed in reaching their workplaces.

4. Characteristics of Flood Prone Areas

Areas prone to flooding have the following characteristics:

- gentle slopes that are perhaps poorly drained because their drainage channels also have very gentle slopes;
- constricted natural drainage owing to, for example, heavily vegetated areas such as mangrove forests, meandering streams, or tidal influences. If communities are located around the outlet, then the hydraulic structures, such as bridges and culverts, may constrict flows owing to poor designs or because they become

blocked with debris, and thus may further limit the natural carrying capacity of the channels;
- large watershed areas (relative to their area) contributing runoff from rainfall;
- so positioned within the watershed that runoff from the surrounding lands concentrate at the flood prone area;
- contributing areas having large runoff coefficients due to impervious soils, impervious ground cover, steep slopes, or/and limited abstraction losses by vegetative cover.

5. Data Needs and Adequacy for Quantifying Floods

Data needs for flood quantification can be grouped into three categories: data for describing the meteorological event which may trigger the flood; data about the watershed which are used for determining the fraction of the rainfall that would run off the land and how it would be distributed in time; and data for describing the geometry of the drainage channels, which may or may not be able to convey all of the runoff within its banks, depending on their water carrying capacity.

The Critical Storm: The definition of a critical storm is somewhat subjective and its description may vary depending on the purpose of the investigation. In all cases it is defined by four features:

i. rainfall depth;
ii. duration;
iii. the time-distribution of the rainfall depth over the duration of the storm; and
iv. the spatial distribution or the area over which the features in (i) to (iii) remain unchanged.

Historical daily rainfall records collected within the watersheds are vital to obtaining the rainfall depth. From the application of appropriate statistical analyses on these records, the depth of rainfall of certain return periods (see definition below) can be found. Daily rainfall records are normally available in plenty supply but more often than not there is little information to describe how that depth of rainfall occurs over the 24-hour period. The resulting runoff is very much dependent on this time distribution, and it is not sufficient to average the rainfall over the 24 hour period. Standard time distribution curves have been developed for the United States and some of these curves have been successfully used in the Caribbean (and indeed in other parts of the world). In the absence of time varying rainfall data collected from within the watersheds, these curves can be used. The storm duration is related to a characteristic of the watershed known as the time of concentration. The time of concentration, T_c, depends on the physical characteristics of the watershed. It represents the time required for water from the furthest point in the watershed to reach the place where the hydrograph is being measured. For maximum runoff generation, the critical storm must have a duration at least equal to the T_c of the watershed. The variation in space also must be considered in developing the critical storm. The amount and timing of rainfall vary considerably from one place to the other for the same storm. Therefore, the capturing of such variability requires finding a weighted average of rainfall measured at several raingauges set up throughout the watershed. The use of one raingauge may not be truly representative of the rainfall over an entire area, but in many cases, only one gauge is available.

For St. Kitts, twenty-three years of daily rainfall from seven stations distributed over the entire island were used to produce seven critical storms, one for each station. Rainfall depths for the 100-year return period for each station were obtained from the statistical analysis. These daily rainfall depths were chosen for the critical storms and the Type III time distribution curve—a designation used to describe one of the standard curves in which most of the rainfall occurs within a small fraction of the 24 hour period—was used to distribute the rainfall in time, at each station. The island was then divided into seven zones, each zone having a raingauge station at its centre. It was assumed that rainfall characteristics within a zone was everywhere the same and was identical to the critical storm formulated at the rainfall station within the zone.

Runoff: Having defined the critical storms, it would then be possible to estimate runoff properties from the surrounding watersheds. The amount of water available as runoff from the rainfall and the distribution of this runoff in time are controlled by the features of the watershed. The important features are:

- Size of the watershed;
- Soil infiltration rates and depth of storage;
- Land cover;
- The total length of all the rivers and their tributaries within the watershed;

- Shape, slope and ruggedness of the watersheds.

The first three features control the amount of water available as runoff onto the flood prone areas. The other features control the timing of the hydrograph peak. Most of the required data are available on standard maps. Most are natural conditions, but the land cover and, to some extent, the length and characteristics of the rivers and tributaries can be altered depending on the human activities occurring within the watersheds.

All required data can be extracted from standard maps and land capability reports, and these were all readily available, some in digital format.

Geometric Features of the Drainage Channels The geometric properties of the drainage channels and the nature of their lining determine the flow rate that can be accommodated within their banks. Meanders on channels reduce their capacity, so too would reduced slopes. Capacity is also reduced with increasing roughness of the channels. Carrying capacity is affected by man-made hydraulic structures, such as bridges, weirs, and sluice gates culverts, that may be constructed within the channels.

Normally, detailed surveys are required to gather the geometric data for describing the drainage channels. Some surveys were carried out within the College Street Ghaut and Wash Ghaut watersheds on St. Kitts, and the Bath Ghaut and the Camps River watersheds in Nevis.

6. Approaches to Flood Mapping

Two approaches to flood mapping, differing mainly in the degree of accuracy in mapping floodwater levels, were applied. The first approach was done at the floodplain scale and the results, though still approximate for lack of sufficient data, provide information on flood levels within the plain. This traditional approach required hydrological inputs and detailed hydraulic data. It is concerned with bank overflow as it considers the carrying capacity of the drainage facilities on the flood prone areas and the extent to which water from surrounding watersheds remains as "within-bank" flow. For the results to be meaningful careful analysis on the hydraulics of the floodplain is needed and the analyst must take into account all the significant features within the flood prone area that could affect water levels.

If all required information is available, and most importantly if floodwater levels have been collected from actual flood events, then the hydraulic analysis can be fine-tuned by making adjustments to uncertain inputs until the water levels from the analysis match the levels from the recorded flood events. Typically, the accuracy is within 150 mm (6 inches).

The second approach was applied because of lack of detailed information about channel geometries in other flood prone areas not subject to detailed surveys. Whereas the same runoff information as above is needed to quantify the amount of water within the flood prone area, this approach does not attempt any hydraulic analyses. Instead, the method estimates a flood depth over the entire flood prone area, which is essentially an average value derived from a simple division of the total volume of water from all runoff flowing into the flood prone area over its surficial area. This depth does not provide any information about how water depths vary within the flood prone area as it assumes that the area has the same mild slope throughout. Furthermore, this value may overestimate actual flood levels in some places, and underestimate them in other places. Such approaches may be necessary when the type of information required in the first approach is missing or unavailable, but the approach is very useful for providing basic ranking of the extent to which flood prone areas over the island is susceptible. Its approximations must be well understood so that it can be properly used. Most of the requirements can be extracted from standard topographical maps.

7. Methodology

Island-wide Scale Mapping:

i. Identify areas, called flood prone areas, having mild slopes. This can be done either via manual inspection of topographical maps or with the aid of DEMs and computer software;
ii. for each flood prone area, demarcate the watershed draining into the area and then determine the ratio between the watershed area and the flood prone area (from (1) above);
iii. for a particular 24-hour return period rainfall, generate runoff hydrographs discharging into the flood prone

area, based on the shape, the drainage network, the soil properties and the landuse;

iv. from the hydrographs, determine the volume flowing into the flood prone area and estimate an average discharge rate over the hydrograph period;

v. estimate a discharge rate from the flood prone area and use it to determine the maximum volume of water (expressed as depth of water) that is likely to be stored on the flood prone area;

vi. determine the hazard category of each flood prone area according to water depth within the plain from the 100 year return period storm using the following classification:

Table 1 Hazard classification according to mean depth of water.

Water Depth (mm)	Hazard
>600	Very High
600-630	High
300-150	Moderate
150-50	Low
<50	Very Low

The categorization of the hazard in this way provides a measure of the magnitude of flooding to be expected from such an event. It also provides a measure, certainly by rank if not in absolute terms, of the severity of flooding among the identified zones.

For detailed flood mapping:

- Perform statistical analyses on the daily rainfall data and obtain amounts for various return periods.
- Derive the critical storm for a 24-hour duration, using standard time curves, and assuming that the rainfall was the same throughout the watershed;
- Obtain contour maps of St. Kitts and Nevis and demarcate the watersheds draining into the four areas—Lower College Street Ghaut, Wash Ghaut, Lower Bath Ghaut, and Camp River—conduct field trips to confirm the boundaries;
- Determine the existing land use within the watersheds from topographical maps and field visits;
- Obtain soils maps of St. Kitts/Nevis;
- Digitize information from the map and field visit;
- Conduct interviews with residents within the four areas to determine specific information about recent floods—the highest water level reached, the direction from which the flood waters came, the time it reached its highest level, the length of time it stayed at that level, the time it took to subside to some remembered level;
- Survey the river or drain from which the reported flooding originated, paying attention to: (i) any natural constrictions such as a narrowing of the river cross-section, or manmade constrictions due to hydraulic structures such as culverts and bridges, or to construction of property within the waterway; (ii) the free clearance of hydraulic structures and bends; (iii) the lining of the channels; (iv) the level of maintenance of the channels (v) the nature of the flood prone area from the river bank in terms of its coverage—pastures, wooded, urbanized;
- Identify critical river sections based on its impact on flooding with potential for significant losses;
- Conduct detailed surveys of these areas at critical cross-sections, hydraulic structures and any other important features.
- Examine the discharge point of the section to determine outlet control conditions—whether, for example flow was unhindered or under the influence of tides.
- Perform detailed hydraulic analyses using appropriate computer software.
- Produce a flood map showing variation of water depths within the flood prone area.

7. Summary Results

St. Kitts

- The watersheds are mountainous and they frequently experience high intensity localized rainfall. Runoff from these watersheds are flashy as their times of concentration are very short, in all cases being less than one hour.

Several watersheds are undergoing some developmental pressure especially in the foothills, which are currently used for sugarcane cultivation. Generally, however, the watersheds are well covered with vegetation especially in the headwaters, which comprise largely primary forests. Soils are very erodible and are washed away by runoff where they are deposited in the ghauts, especially at road crossings via bridge or culvert. Flooding often occurs at these crossings owing to infrequent clearing of the silt. In some instances flooding has occurred due to reduction of the waterway by encroachment of residential property within the waterway area of the ghauts. To a lesser extent, flooding is caused by obstruction of the waterway due to dumping of solid waste in the ghauts.

- The most extensive flooding occurs in the lower reaches of College Street Ghaut where it passes through Basseterre. The potential for major damage is great because the flooding occurs within the commercial centre.
- Detailed survey data picked up within the lower College Ghaut watershed and Wash Ghaut provided sufficient information for conducting detailed flood plain mapping.
- An adequate database of daily rainfall exists, which includes records from gauges covering the entire island. The twenty-three years of records provided for the project were used for estimating the 100-year return period storm. No continuous rainfall records were available and so use was made of standard time distribution curves for determining peak flows of the catchments.
- Limitations in river flow data prevented full-scale calibration of the model output of water levels within College Street and Wash ghauts. The limited data acquired from field data provided validation of the output, but recommendations for improving the reliability of the output are provided within the technical report.
- Erosion is a major problem within the vicinity of the ghauts and should be addressed. Some preliminary consideration has been given to it but further information needs to be gathered for generating accurate maps.

Nevis

- Similar to St. Kitts, the watersheds in Nevis also are mountainous, well vegetated in the headwaters, have very short times of concentration and therefore have flashy responses to rainfall. They also will be subject to random, violent rainfall. Their soils are highly erodible and heavy silt deposition blocks culverts and bridges at road crossings. Infrastructure is inadequate owing to poor design and construction and infrequent maintenance. Very little attention is given to enforcing land use zoning and this has been the sole cause of flooding in several areas of the island.
- The two years of daily rainfall records provided for the project were insufficient for producing reliable rainfall frequency curves and so records from St. Kitts were used in the interim to generate the rainfall frequencies. The one year of Nevis rainfall data that overlapped with records from St. Kitts could not be used to do any reliable rainfall comparison.
- Detailed flood maps were produced for the lower Bath Ghaut using detailed survey data. The output, however, should only be regarded as representative until a rainfall frequency analysis using Nevis data has been complete, and water levels acquired from within the catchment are available for validating the water levels shown in the map.
- Urgent attention is required at addressing the drainage inadequacies around Newcastle Airport, and so avoid frequent closure of the airport due to flooding on the runway.

Definitions

Flood: A general and temporary condition of partial or complete inundation of normally dry land areas from overflow of inland waters or from the usual and rapid runoff of surface waters from rainfall.

Hydrograph: A flood wave passing a particular place in the river. It represents how the stage (water elevation) or the flow in a river changes with time.

Return Period: This is an expression of the probability of a particular rainfall depth of a given duration occurring. The rainfall depth corresponding to a specified return period will be equaled or exceeded at a probability equal to the inverse of the return period, that is the relation can be expressed as follows: *Return Period = 1 / (Probability of Occurrence).* For a 10 year return period: So the probability that the rainfall depth for a 10-year return period will be equaled or exceeded is 0.1 (1/10)

Critical Storm: The rainfall input used for producing the hydrograph. It represents what is viewed by the analyst to be most important in predicting the effects of the rainfall on runoff. The rainfall depth, the duration of the storm, the type of distribution of the rainfall depth in time and the uniformity of the distribution of the storm over the watershed must

all be specified for complete specification of the critical storm.

Time of Concentration: The time elapsed between the start of the rain and the runoff from the most remote point in the watershed to reach the place where the hydrograph is being measured.

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