Guyana Floods

UNDAC

Geotechnical and hydraulic assessment of the East Demerara Water Conservancy dam

February 2005

Joint UNEP/OCHA Environment Unit

UNEP

Published in Switzerland, 2005 by the Joint UNEP/OCHA Environment Unit

The assessment was made possible through the kind assistance of the Ministry of Foreign Affairs of The Netherlands.

Ms. Nisa Nurmohamed and Mr. Olaf van Duin
Road and Hydraulic Engineering Institute
Ministry of Transport, Public Works and Water Management
The Netherlands

Report Coordinator: Manga Mialaret, Joint UNEP/OCHA Environment Unit
Photos: Nisa Nurmohamed,Olaf van Duin.

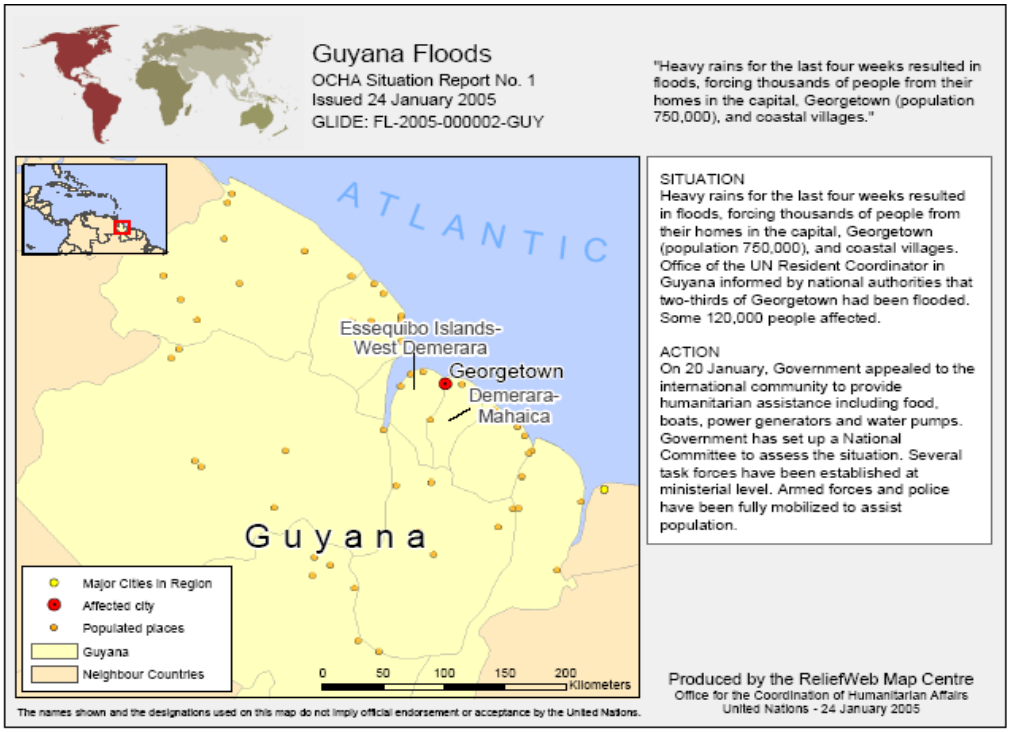
Joint UNEP/OCHA Environment Unit
Palais des Nations CH-1211 Geneva 10
Switzerland
Tel. +41 (0) 22 917 3484 - Fax +41 (0) 22 917 0257
http://ochaonline.un.org/ochaunep

Table of contents

1. Overview

Days of continued torrential rains in Guyana mid January 2005 led to extensive floods, forcing thousands of people from their homes in the capital Georgetown and coastal villages.

Upon request of the Government of Guyana, a United Nations Disaster Assessment and Coordination (UNDAC) team was deployed by OCHA on 23 January 2005. Based on initial assessments of the situation, the UNDAC team alerted the Joint UNEP/OCHA Environment Unit (Joint Unit) about a potential collapse of the East Demerara Water Conservancy (EDWC) dam, which would result in further and more extensive flooding. The Joint UNEP/OCHA Environment Unit was monitoring the situation and, in collaboration with the UNDAC team and national authorities, identified potential environmental impacts resulting from the floods. In particular, the water levels of the Demerara Water Conservancy as well as the potential collapse of the Demerara Dam were of great concern. Such an event would cause significant human and environmental impacts.



Following a request from the national authorities of Guyana, which was conveyed through the United Nations Development Programme (UNDP) Resident Coordinator, the Joint Unit mobilized assistance through the Ministry of Foreign Affairs of The Netherlands. Two experts in geotechnics, hydraulics, sea and river defense of the Ministry of Transport, Public Works and Water Management of The Netherlands were deployed to assist the UNDAC team, from 2 to 11 February 2005.

2. Introduction

2.1 Mobilization of assistance

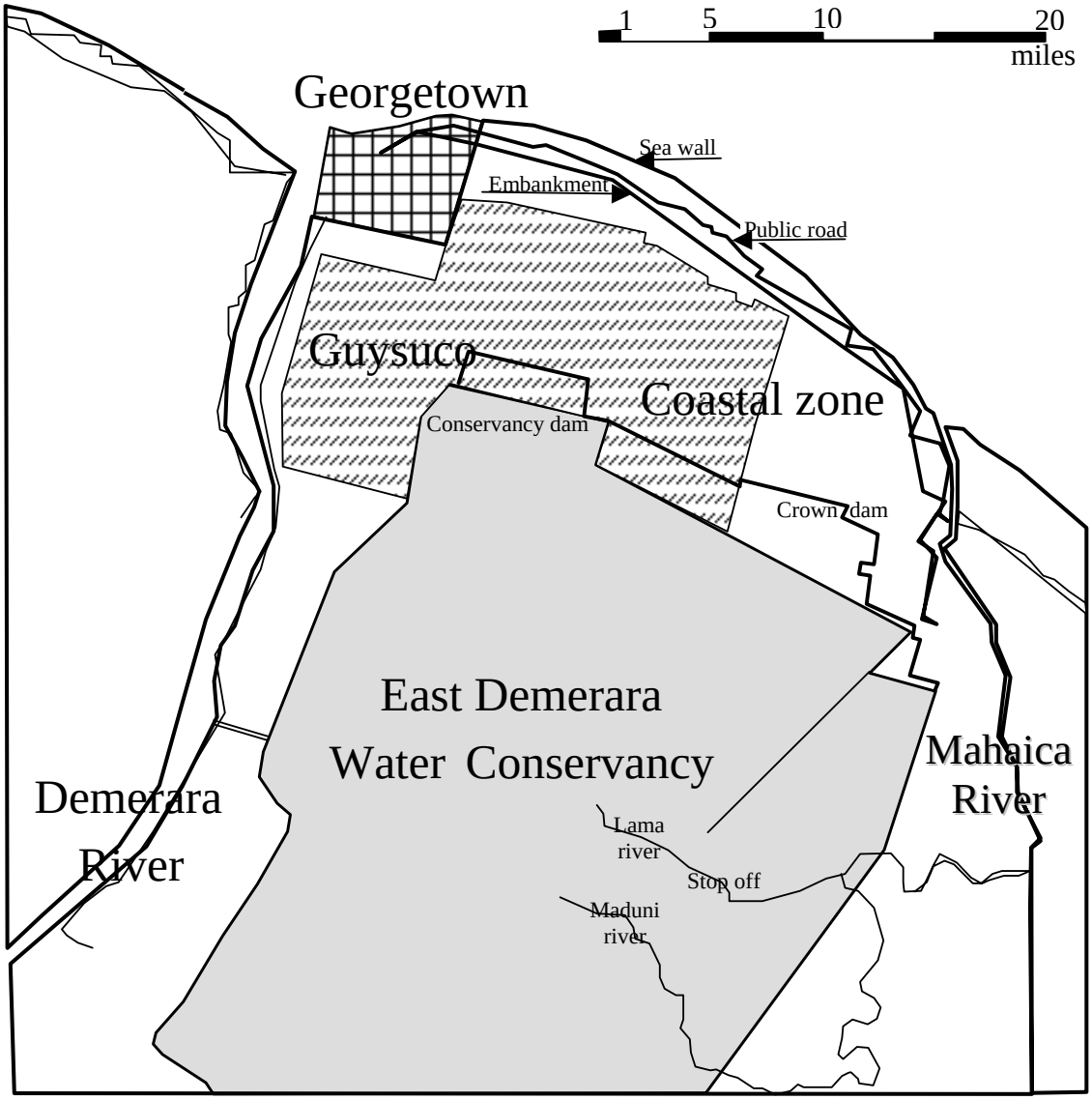
The Joint UNEP/OCHA Environment Unit (Joint Unit) functions as the United Nations mechanism to assist countries facing environmental emergencies and natural disasters with significant environmental impacts. Following the request for specialized expertise on dam safety, the Joint Unit mobilized assistance through the Humanitarian Aid Department of the Ministry of Foreign Affairs of The Netherlands. Two experts in geotechnics, hydraulics, sea and river defense of the Ministry of Transport, Public Works and Water Management of The Netherlands were deployed to assist the UNDAC team. The overall task of the UNDAC team is to carry out assessments of priority needs for assistance and supported national authorities and the UN Resident Coordinator in the coordination of international relief on-site. The experts focused on the conditions of the East Demerara Water Conservancy dam, and identified measures to reduce the chance of a dam collapse.

2.2 The East Demerara Water Conservancy

The East Demerara Water Conservancy was developed in 1880 to channel a number of water sources into a storage area. It was formed using the natural gravity water flow from the upper southern parts of the country and has a bearing capacity of more than a 100 square miles of water, herewith being the largest conservancy in Guyana.

The primary function of the Conservancy is the storage water for irrigation of sugar cane plantations, rice fields and other cash crops during periods of drought. The Northern side of the Conservancy dam also protects the land between the Conservancy and the sea (the coastal zone) against flooding by water from rainfall in the southern catchment area (see map).

Schematized map of the East Demerara Region:



The Guysuco (Guyana Sugar Company) area in the Northeast is hydraulically well managed, but does not keep the water from the residential areas along the coastline, as its infrastructure is only fitted to irrigation, internal transport by boat and releasing excess water. Water storage within the Guysuco area (otherwise than behind the crown dam and in the EDW conservancy) is not provided for.

This Conservancy dam is a man-made construction. The soil used for construction of the dam is pegasse, which is a blackish peat like acid mixture of clay in which some vegetation remains. Its properties for internal friction, cohesion and permeability vary, but are in general poor. Indeed, the material is according to engineering standards of the Dutch Ministry of Public Works (Rijkswaterstaat), unsuitable for the construction of dams. Peat provides insufficient structural strength and inadequate protection against seepage.

The crown of the dam shows a various unequal settlements, which indicate that the deformations may still be ongoing. Several breaches are repaired using sandbags and sheet piles, which is insufficient.

The southern side of the Conservancy the water level was about 58.5 G.D.[1], and the crown level was about 58.8 G.D. at the time of the mission. A detailed list of gauges readings has been kept for several years. At the other side if the dam (north) the water level has not been gauged through time. During the mission, the difference in water level at both sides of the dam was about 2 m.

3. Methodology

The experts have based their assessment on several site observations in the field, and through interviews with representatives of relevant UN agencies, Government officials and Guyanese experts. In particular, the experts met with the Ministries of Agriculture and Public Works, and the Secretary of the President's Cabinet. The experts also shared their views and experience with the Guyana Citizen's Initiative for Flood Release.

The experts have discussed their findings and recommendations with the Cabinet of the President, the UNDP Resident Coordinator, and relevant organizations, including the World Bank and the Inter-American Development Bank in order to prioritize the funds.

4. Limitations

No soil investigations, or recent survey data were available to support a detailed assessment of the conservancy dam. The findings and recommendations are based on the experience and knowledge of the persons that have been interviewed, combined with the experience of the two experts.

Furthermore, the limited duration and the urgency of the mission were one of the constraints of this assessment.

The seawall in Georgetown prospects the lower areas of the capital from the sea (I don't understand use of PROSPECTS in this context)

[1] G.D. indicates the level in feet above Georgetown Datum

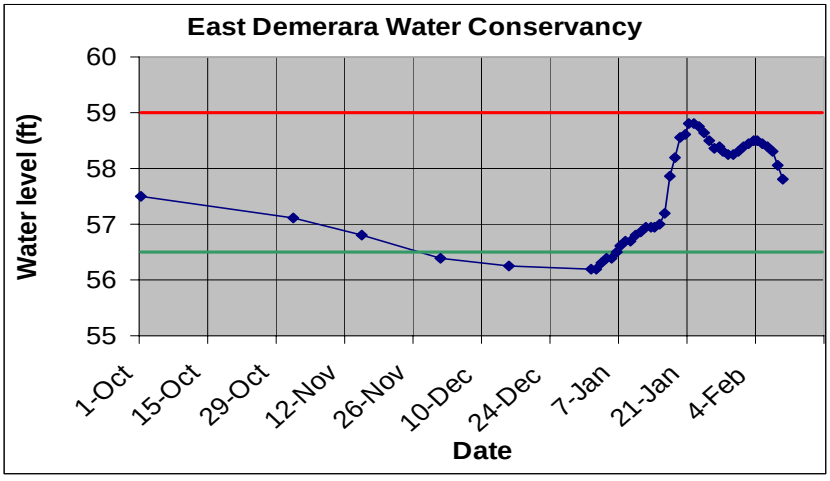
5. Main findings

The findings of the mission are divided in two parts, the distinct geographical areas of the East Demerara Water Conservancy and the East Demerara Coastal Zone. The East Demerara Water Conservancy poses a severe risk. The risk of the EDWC dam breaching and flooding the coastal zone should be minimized, in order to prevent a disaster.
At the same time, the drainage in the coastal zone is inadequate. The drainage infrastructure should be rehabilitated, to improve flood response and minimize the consequences of a breach in the EDWC dam, if it happens.

5.1 The East Demerara Water Conservancy

The East Demerara Water Conservancy (EDWC) is an essential part of the hydraulic system of the east coast Demerara. Additional elements of the hydraulic system include the intakes (outlet structures) in the Conservancy dam, the irrigation and drainage channels in the coastal zone and the outlet structures ("kokers") in the sea wall.

The diagram below illustrates the development of increased water level in the EDWC with its peak level on 21 February:

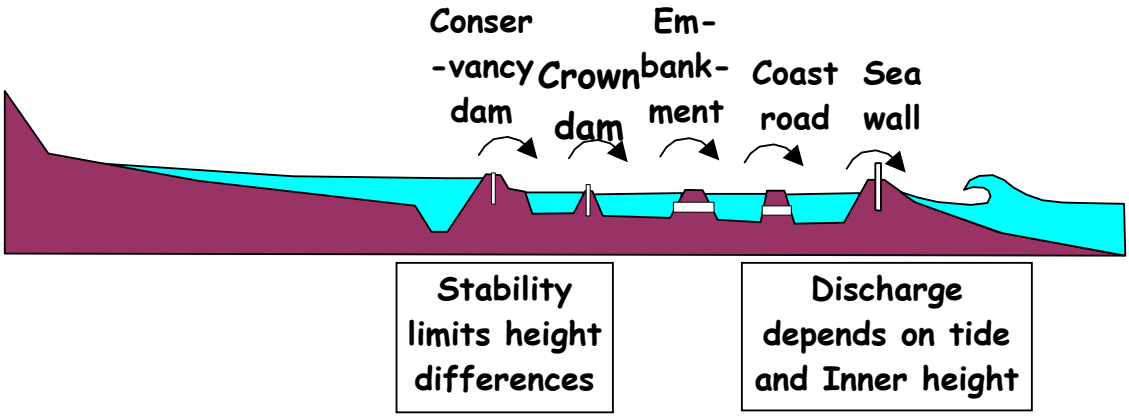


Legend:

Bleu line	-	recorded water level in the conservancy
Red line	-	top level of the Conservancy dam
Green line	-	preferred water level in the Conservancy

The gauge at Flag Staff on 6 February, reading 59.4 G.D., just inches below the top level of the dam

The flooding of the coastal zone (the area between the conservancy and the sea wall) was caused by excessive rainfall. Basically, the flooding situation can only be alleviated by discharging water through the sea wall (see cross section below). Discharge through the sea wall is effectuated by outlet structures (open during low tide and closed during high tide) and a limited number of pumping stations (see above photo).
Simultaneously, the flood water also has to be discharged through, or pumped over, the various embankments known as the public (or coastal) road, the (railway) embankment and the Crown dam (see diagram below).



However, water released from the Conservancy will add to the problems in the coastal zone. Such water release may become necessary when the difference in water level between both sides of the Conservancy dam, or overflow of this dam endanger its stability.

The EDWC-dam is a fragile construction, built on peat and clay soil layers, constructed out of the same material. The side slopes are very steep (up to 1:1). Crown widths varies from 1 to 5 feet. At several stretches the top actually consists of a row of clay-bags. Patchworks have been carried out in several places, covering ancient breaches or recent over toppings. At the eastern section of the northern dam, about 30% of the dam is in critical condition. For the rest of the northern dam and the western dam about 10% is in a poor state.

The state of the Conservancy dam is characterized by poor maintenance and patchwork and requires urgent repair

On 6 February, the water level was 58.40 G.D. If the water level rises up to 59 G.D., the overtopping would go out of control. This would have resulted in numerous breaches and the release of approximately 100 billion gallons of water into the coastal zone. This would equal a water layer of approximately 2 feet in the area from Georgetown to the Mahaica river.

In the days after 21 January, water was released from the conservancy to the Mahaica area, which caused distress to its inhabitants. However a situation was prevented whereby, the conservancy would surely have breached into the coastal zone.

Reportedly, the repair force in the conservancy consists of 20 workers in normal situations and went near 200 during the most critical period. Their primary function is to strengthen the dam at each place where they expect overtopping, using clay-filled (rice) bags. They have very little equipment available, but are capable and well lead due to years of experience with small breaches and overtopping.

A typical waterside view at the conservancy dam (the peat ridge) with green wastelands behind it

5.2 Emergency situation at the East Demerara Coastal Zone

The flooding in the coastal zone causes major distress to its inhabitants, as the floods of January-February 2005 have shown. Housing and infrastructure was damaged, stock and crops were lost and people have died due to flood related diseases. Therefore, getting the water out of this area is a first priority. The discharge can only be effectuated through the sea wall, making use of the existing outlet structures and pumping. However, some of the outlets are out of order.

6. Conclusions and recommendations

The Conservancy dam is a difficult structure to maintain and in its current condition it is unsafe. The side slopes are too steep and repair works to heighten the dam have actually undermined its foundation and thereby its stability as an earth structure. Piling more clay bags or clay on top threatens the stability against sliding. The permeability of the dam (referred to as piping) has in the past (e.g. November 2001) resulted in failure of sections.

Sealing the dam with a clay layer at the upper (reservoir) side would be the obvious response, but this will increase the pressure and may therefore induce slides. Thus the lower side requires strengthening. This can be done by the construction of a clay body at the lower side, up to a level of some two to four feet below the current top level (“berm”). At the same time the top level of the northern dam section could be filled up to a consistent 59 G.D. or better 59.5 G.D. allowing for some freeboard (the distance between the crest level of the dam and the highest water level) over its full length.

The best option would be the reconstruction of the whole dam according to a fit design, but this undertaking would imply a huge project taking hundreds of millions of US dollars and many years, which is probably not a feasible solution.

The dam, with at the conservancy swampland and at the right the coastal zone. White bags with clay and some peat are retaining the water. In the back an overtopping, sealed of with sheet piling works

6.1 Recommendations for the East Demerara Water Conservancy

6.1. a Priorities activities for the EDWC

- Reinforce the repair force (former rangers) dealing with the maintenance and strengthening of the dam, by providing them with floating equipment and supporting them with additional manpower. This will improve the most critical stretches and may create just a little extra freeboard, which may be critical in the case of more intensive rainfall.
- Strengthen first those Conservancy dam sections where (recent) patchworks have been carried out.
- Improve the drainage functions of the outfall structures in the conservancy dam and the sea wall.
- Improve the storage capacity and water flow in the conservancy, by dredging the channels in the conservancy.
- Before the coming rainy season of May-June, draft a Disaster Management Plan (DMP) for this type of situation. Such plan contains a strategic plan for the management of the relevant disaster, with contingency plans and a 'script-books' for each employee involved. For instance, the intervention levels for the EDWC are identified, with appropriate measures to be taken at each level. As the DMP is conceived in a period of rest, due consideration can be given to each step and measure, with the help of experts.
- It is explicitly recommended that this Disaster Management Plan is conceived through interaction of both Guyanese and international experts in the field of hydraulics and geotechnics, as well as managers from Guyana (in particular the government) and managers with experience in other countries with disaster management.

- The speed of small boats should be limited in the conservancy. Transport in the Conservancy should be abandoned when the water levels reach over 57.5 G.D., as their waves eat away the fragile top of the dam.

6.2.b Medium and Long Term Perspective for the Conservancy

- A review of the hydraulic system of the East Coast Demerara should take place, taking all its functions such as its security, maintainability, and efficiency and look at drainage, storage of water for irrigation, industry and domestic use into consideration. The conservancy was constructed over a hundred years ago and is unfit for the present requirements of irrigation, potable water and safety. The agriculture and population of the coastal zone have grown and new requirements are to be considered. To meet the current requirements of the coastal zone, various scenarios can be conceived. In these scenarios, a number of options exist: abandonment, demolition, less rehabilitation, replacement for all the elements of the hydraulic system, as well as adding new elements to it. An example of something new to be added, is the construction of a new spillway at the west side of the Conservancy, to discharge high volumes of water toward the Demerara, when the water level exceeds 56,5 G.D.
- Redesign and reconstruction of the hydraulic system will take some time. Therefore, in the medium term this system has to be rehabilitated the most critical parts of it, including de Conservancy dam, the outfalls, outfall channels, drainage of the Coastal zone and the outlet structures in the sea wall. This will probably cost in the order of tens of millions US dollars at the least.
- Prioritize rehabilitation works for the whole drainage system (outlets, culverts, drains and EDWC dam), in order to get – despite budget limitations - the best preparation for future flooding threats.

6.3 Recommendations for the East Demerara Coastal Zone

- Most of the malfunctioning outlets in the sea wall have been inspected. In the next chapter some customized solutions have been identified for each structure in order to facilitate discharge during low tide, while maintaining the ability for closure during high tide.

6.4 Action Plan

The rainfall had severely diminished at the time the experts were deployed, and the water level in the Conservancy was dropping. The first urgent recommendations were communicated immediately to the authorities in the first few days after the arrival of the experts.

After the emergency phase, another set of recommendations could be considered and included in an Action Plan. The implementation of such Action Plan is crucial in order to prepare for the coming rainy season of May-June 2005.

This Action Plan extends on the findings and recommendations described above and provides a basis for immediate measures aimed at protecting the East Coast Demerara against flooding from rainfall and failure of the East Demerara Water Conservancy Dam.

In addition, some notes are added concerning the rehabilitation of the whole hydraulic and drainage system over the coming years and thereafter, providing a medium and long-term perspective.

6.4.a Action Plan Summary

Area	**Short term before may 2005**	**Medium term Until 2006**	**Long term -2015**
EDWC-dam	Simple repairs to prepare	Rehabilitation of the dam up to a functional state	Redesign of the water conservancy plan
Outlets of the conservancy dam	Open up the outlets that are currently out of order[3]	Rehabilitate all structures and channels that contribute to lowering the EDWC	
Drainage outlets in the sea defense	Construct temporary fixtures to facilitate drainage of dysfunctional outlets	Rehabilitation of all the outlets	Redesign of the drainage plan for the coastal zone, involving drainage channels, ducts, kokers, outlet etc.
Drainage in the coastal zone	Repair damage by the flood	Rehabilitate of the drainage system	
Others	Draw up a Disaster Management Plan (DMP). Carry out small scale simulation exercises.	Exercise these plans according to a training schedule. Increase the capacity of staff with education and training, both locally and abroad. Extent DMPs for other potential threats in Guyana (like sea defense breaches) as well.	

For the immediate term, actions are considered that could be carried out before the following rainy season (May-June 2005) this year. The medium term relates to the rehabilitation period, after that.

It is recommended that in the second half of this year the whole infrastructure concerned with the water management is rehabilitated to a functional level and that the main flaws

[3] i.e. follow up the recommendations made by the World Bank in the meeting on February 9th at UNDP.

are taken out. In the long-term the drainage and hydraulic system of the east coast and presumably of the other regions as well, should be reconsidered entirely. It may be expected that it does not meet the requirement of Guyana today, and is also not the fit for maintenance either.

6.4.b Action Plan immediate activities

In order to recover from the recent flooding and prepare for the coming rainy season, a number of measures are to be carried out immediately. There is too little time to rehabilitate the whole hydraulic system and some measures will only mitigate the situation, while being insufficient for extreme situations.

For the activities described hereafter, there are only two months available. Therefore the following suggestions could be suggested to speed up the implementation of urgent matters:

- Tender procedures and administrative procedures (both with the government of Guyana and the donor agencies) are skipped. Contractors are appointed based on brief selection procedures, while close supervision is carried out on the jobs.
- Designs will be limited to sketches, while experienced engineers instruct contractors and other workers while works are carried out.

A number of measures have been identified from site visits and consultation with experts of Guyana and representatives of donors in the country. These are listed in the table below.

Category	Measures
1. Restore the drainage of the Conservancy	Rehabilitated culverts and outlets and dredging of canals: a. Shanks (East Coast Demerara) b. Neabaculis (East Coast Demerara) c. Diamond (East Embankment Demerara) d. Coffee (East Embankment Demerara) e. Cuna (East Embankment Demerara)
2. Strengthen the dam	Bring the whole dam to a consistent top level of 59 G.D. Strengthen the patched up areas with clay and clay bags Create or strengthen a berm at the down side of the dam in order to stabilize it
3. Upgrade the equipment of the Dam security force	Purchase a dragline, trench cleaner and two long boom excavators with appropriate pontoons
4. Provide emergency management craft	Purchase three fast boats. Because of the damage by waves from boats on the conservancy dam and the need for speed, air boats are preferred.
5. Open up the drainage within the	Dredge and widen the canals within the conservancy: a. Enmore

conservancy	b. Enterprise c. 5000 cross d. LBI e. Crag
6. Restore the function of outlets and pumps in the sea wall that are in a bad state or in disrepair	The discharge of a number of outlet structures can be improved by simple measures: a. "Plaisance" The structure is beyond repair. Excavate trenches toward the structure at both sides. Place (3) large pipes in them, going through the immobile wooden door. Discharge the water at low tide. Put a valve in the pipe to close it at high tide. b. "Buxton" and "BV/Triumph" Make use of the existing emergency slots in the sluice. Put new doors in these slots, which may be lifted by dragline or winch. Take out the remains of the old slide doors. c. "Mon Repos" The new sea wall has two outlet structures less than the old one. Install pumps there. d. "Cane" Grove Put new pumps where the old ones are broken. e. "Gove and John" Repair the existing pumping station. If need be replace pumps. f. "Greenfield" Dredge the sand in the outlet channel at the sea side.

6.4.c Action Plan medium and long-term activities

The hydraulic system of the East Coast Demerara consists of the following elements
The East Demerara Water Conservancy
A plain reservoir open at the higher south side, where it collects its water from the southern catchments areas. In the west, north and east a dam holds the water. The 60 kilometer long dam consists of peat and clay and is very fragile.

- The inhabited and cultivated coastal zone, including the East bank of the Demerara River and Mahaica Area is enclosed between the conservancy and the sea and river walls. It is drained by channels leading toward outlet structures ("kokers", "sluices") in the sea and river walls. The channels and a number of embankments (East Coast Road, the embankment Road and the Crown dam) leading parallel to the sea defense, divide this zone into several water compartments. The variation in ground levels, dimensions of drainage channels and stages of maintenance the drainage conditions in these compartments varies substantially.
- The river and sea walls protect the coastal zone against inundation. The outlet structures release the drainage water at low tide. At high tide they are closed.

About half of these structures function properly, some function only partly, others are in disrepair. The condition of the few pumping stations is similar.

At the long term, the whole concept of the hydraulic system at the East Coast should be reconsidered. The conservancy dam is hard to maintain, while replacing it would be extremely costly. Upgrading the existing conservancy dam will not lead to a satisfactory structure, while replacing it will require huge volumes of clay and sand to be transported and placed on a soft subsoil. Because of the settlements, the dam will require a substantial settlement allowance. Previous cost estimates[4] came around 50 million US$. Depending of the quality of the works, safety requirement and provisions to drive on it, these costs may go up to several hundreds of millions. The question whether such investments are worthwhile could be asked, or whether there are no other solutions, which will involve the review of water needs, threats, irrigation and drainage functions which will immediately involve flood risks of the coastal zones and the overhaul of the drainage system in that region.

Redesign of the whole hydraulic system of the East Coast - if undertaken at all - will take decennia. In the mean time, the conservancy is there and the risks associated with it too. Therefore rehabilitation of the existing hydraulic system is required. This implies dredging of drainage channels, construction of extra channels, replacement of small structures, adding extra culverts where existing culverts are too small etcetera. Such undertaking will cost several millions of US$ and it will take a few years to be carried out.

In addition to the measures mentioned above, it is recommended to compile a Disaster Management Plan (DMP). Such a disaster management plan should contain plain and simple instructions, tailored specifically for each person or function involved in the handling of disasters. It should contain telephone numbers, orders to do this or that, monitoring instructions etcetera. In order to give an idea of it, some examples of parts elements of such plan are included in Annex 1.

[4] Report on factors which led to the breach in the EDWC dam at La Bonne Mere, Georgetown March 2002

Annex 1 Elements of a Disaster Management Plan

Please know that all figures and measures are indicated as examples

Function: Gauge reader at Flag Staff (Name, telephone number)

Intervention Level (G.D.)	Actions	Status
Up to levels of 57.5	Daily recording of the water level at the gauge	Phase White
57.5	Send recent gauge records to ministry (address)	Alert
57.5 – 58.0	Twice daily recording at gauge. Convey levels to ministry after reading by phone (Name tel.#)	Phase Green
58.0	Inform department chief in the ministry (Name, tel.#)	Alert
58.0 – 58.5	Every eight hours recording at gauge. Convey levels to ministry after reading (Name tel.# and Name, tel.#)	Phase Yellow
58.5 – 59.0	Every hours recording at gauge. Convey levels to ministry after reading (Name tel.# and Name, tel.#)	Phase Orange
58.75 – 59.0	Every hours recording at gauge. Convey levels to ministry after reading (Name tel.# and Name, tel.#)	Phase Red

Please note that all figures and measures are indicated as examples

Function: Chairman of CDC (Name, telephone number)

Intervention Level (G.D.)	Actions	Status
Up to levels of 57.5	None	Phase White
57.5	Inform members of CDC about conditions	Alert
57.5 – 58.0	Send out teams for checking of all outfalls Meet with Repair Force Management ("Horse", telephone number) Order discharge from outfalls at Demerara East Embankment	Phase Green
58.0	Inform Minister of Agriculture (Name telephone number) CDC (Name tel.#)	Alert
58.0 – 58.5	Open up Lama and Maduni dam Prepare for rounding up cattle Inform inhabitants of endangered areas Verify medical stocks, staff and personnel Verify availability and status of vehicles and boats Regular meeting with CDC	Phase Yellow
58.5	Assemble Task force at ministerial level Inform Highest levels (Name telephone number)	Alert
58.5 – 58.75	Establish and verify communication network Round up cattle to higher grounds Carry out intensive inspections of dam and structures	Phase Orange
58.75	Prepare organization for evacuation	Alert
58.75 – 59.0	Prepare inhabitants for evacuation Call for emergency meeting with cabinet	Phase Red
59.0	Evacuate inhabitants of Coastal zone	Alert