Caribbean Disaster Mitigation Project

Organisation of American States

Caribbean Electric Utility Services Corporation

Vulnerability Audit
St Lucia Electricity Services Ltd
Final Report

August 1995

CEP

Consulting Engineers Partnership Ltd

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Our Ref: CEP/20249

3 July, 1995

Mr Jan Vermeiren
Department of Regional Development and Environment
Organisation of American States
1889 F Street, N W, Room 340-R
WASHINGTON, DC 20006
U S A

Dear Sir,

LUCELEC Vulnerability Audit

We submit herewith our final report on the above-captioned exercise. The report is cognizant of comments made in your fax dated 23 June and seeks to provide additional information and/or clarification on those topics which may not have been dealt with completely in the draft issue Should you have any comments or queries regarding any aspect of the document please direct them to the undersigned.

Yours faithfully,

Stephen Sandiford B Eng (Hons), MBAPE

cc: CARILEC

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12 June, 1995

Mr Jan Vermeiren
Organisation of American States
17th Street & Constitution Avenue, NW
WASHINGTON, DC 20006
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Dear Sir,

LUCELEC Vulnerability Audit

Pursuant to the issue of the Inception Report (September 1994), supplementary field surveys and other investigations were undertaken during the first half of 1995. The additional data obtained has been incorporated into a Draft Final Report which is attached hereto for your review Also included are estimates of retrofitting costs and proposed design criteria.

There are still outstanding items for which further information is awaited For this reason, we propose to re-issue the Final Report at the end of June The final version will not only contain information currently not available but will hopefully also include your comments on this draft. As you may be aware, Mr Tony Gibbs is currently off-island. You are therefore asked to direct any queries you may have regarding the contents of the report to the undersigned

Once again we wish to express our appreciation for the efforts of yourself, various members of staff of CARILEC and LUCELEC and others in assisting with the compilation of this report.

Yours faithfully,

Stephen Sandiford (B Eng (Hons), MBAPE)

cc CARILEC

CONTENTS

1.0 SUPPLEMENTARY INVESTIGATIONS

1.1 Summary

The Inception Report indicated the need for further investigation in several areas. These are outlined below:

- Castries: Whether the design of the Administrative Office Building considered the potential for liquefaction of the soil sub-strata under the building

  Fixing details for the external ceramic wall cladding on the Administrative Office Building.

- Cul-de-Sac: Strength of the main roller shutter door on Power Station.

  Construction of the fuel and water tanks.

  Design of the Peak Lopping Station

- Union: Stability of cliff face behind the Sub-station

  Inspection of the Sub-station (named the "Auxiliary Plant Building" in the Inception Report)

- Storm Surge: Effects of this hazard on coastal sites and more accurate information on the elevations of buildings at these sites relative to mean sea level (msl).

Additional information on most of these items was obtained during a follow-up visit to St Lucia by Mr. Stephen Sandiford in mid-February and through subsequent enquiries. For some items, it has not been possible to obtain definitive information. The majority of these issues are dealt with in sub-section 1 3, while the effects of storm surge are outlined in sub-section 1 2.

In light of the passage of tropical storm (TS) Debbie in September 1994 a review of the torrential rain hazard (particularly at Union) was also undertaken. Further discussion of the effects of the storm is provided in sub-section 1 2 2

1.2 Review of Natural Hazards

The following review of selected hazards is undertaken as a result of the receipt of further information on these topics.

1.2.1 Storm Surges

Figure 1 is taken from a CDMP/OAS computer model of the 1-in-100 year storm surge event for St Lucia. The model makes use of satellite imagery and data from the National Hurricane Centre on all tropical weather systems that have passed through the Caribbean region since 1886 to estimate the maximum coastline storm surges that would be generated by storms with return periods of 50 and 100 years.

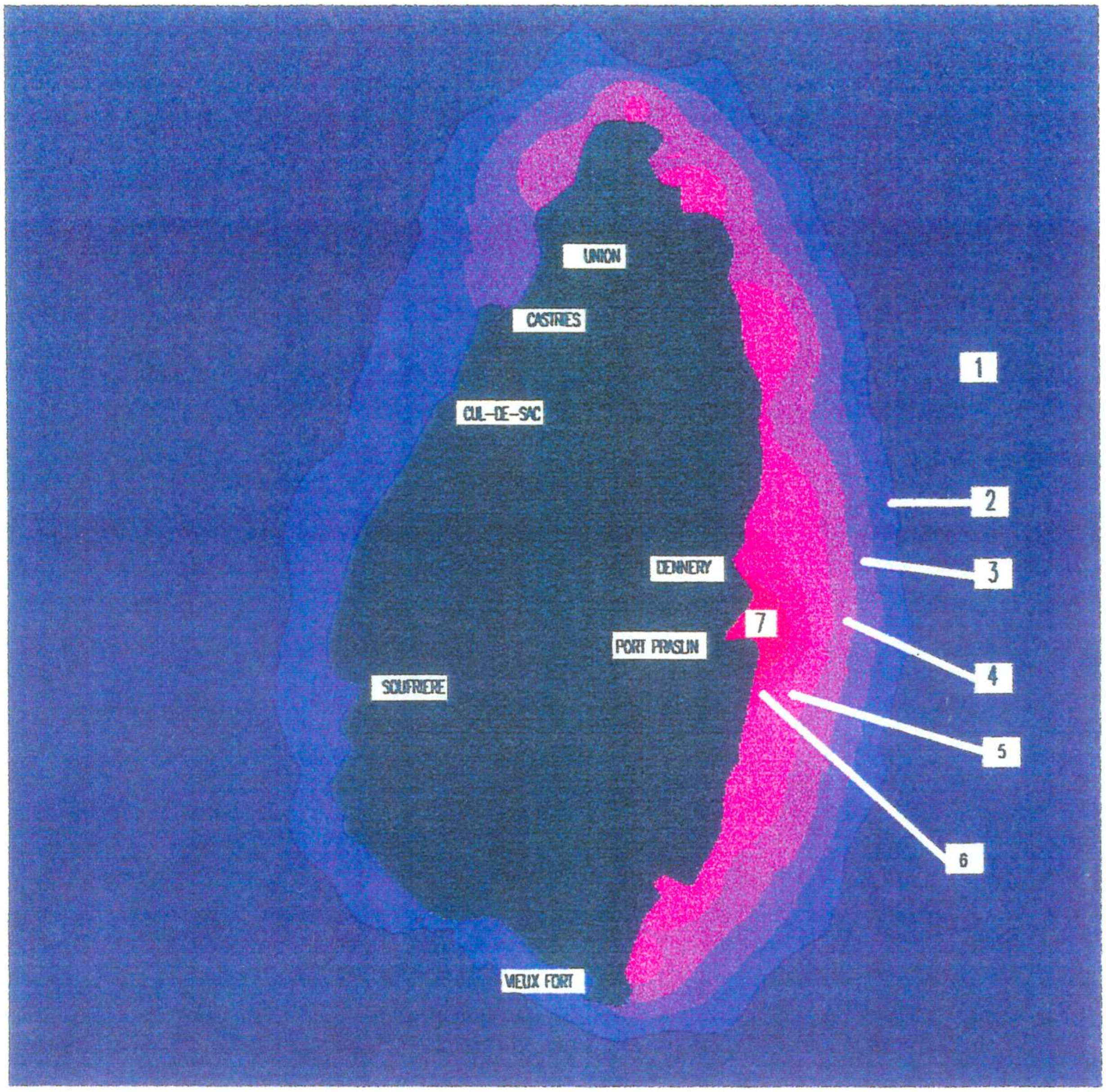

Figure 1

OAS/CDMP Data for 1-in-100 year Storm Surge Event

Key: Surge heights in metres for areas indicated on map

1 : 0.5m - 0.75m	4 : 1.5m - 1.75m
2 : 1.0m - 1.25m	5 : 1.75m - 2.0m
3 : 1.25m - 1.50m	6 : 2.0m - 2.25m
4 : 1.50m - 1.75m	7 : 2.25m - 2.5m

For St Lucia, the model indicates that the greatest surge heights can be expected on the east coast of the island, with a maximum of 2 to 2.5m around Port Praslin The value given for the area around Castries (1 25 to 1 5m) is approximate as the effect of the topography of Castries harbour is not given detailed consideration in the model.

Table 1 lists the approximate heights above mean sea level of the various sites. These were obtained from 1:2500 Ordinance Survey (OSD) maps. Only facilities at Castries are likely to be affected by the 1-in-100-year storm surge event.

OSD Map Ref.	**Location**		**Approx. height above msl of site**	**Comments**
0849	Castries	Admin. Bldg	~1.5m	Near the coast in Castries harbour
0848		Sub-Station	~ 1.5m	Located about 200m inland. Floor level raised a further 0.9m above ground level
1050	Union	Sub-Station & Power Station	7 5m to 9m	1 5 km inland. Power Stn floor ~ 1.5m above Sub-Stn floor.
1216	Vieux-Fort:	Power Station	~3m to 4.5m	On south-west coast
1020		Sub-Stn	16m to 16 5m	About 1.75km inland.
0231	Soufriere	Sub-Stn.	16m to 24.5m	About 2km inland
-	Cul-de-Sac site		18m to 24.5m	-

Table 1

(Abbreviations: Stn = Station, bldg. = building)

1.2.2 The Effects of Tropical Storm (TS) Debbie

TS Debbie affected St Lucia between 9 and 10 September 1994. In addition to other damage, torrential rains associated with the storm caused widespread disruption of the transmission and distribution system, minor flooding at Cul-de-Sac and near inundation of the sub-station at Union (see LUCELEC report in Appendix A)

Meteorological data indicate that the total rainfall experienced over a 24-hour period varied from around 230mm (9") to 350mm (13.75"). At Union Agricultural Station, less than half a mile from the power station and sub-station site, about 290mm (11.25") of rain fell during that period. The 1-hour rainfall intensity for this same site peaked at around 85mm (3 35") These latter figures indicate rainfall in excess of the 1-in-13 year design storm (and probably in excess of the 1-in-20 year storm) for Union (ref figures 8 & 9 in the Inception Report). The severity of TS Debbie is still under discussion, having been considered a 1-in-1 000 year event by some

It should be noted that intensity duration graphs used in design are limited by the length (in years) of the available reliable records of rainfall amounts. The longer the period of observation, the more reliable the estimate of intensities for various return periods In particular, it is difficult to accurately estimate the intensities of rainfalls with large recurrence intervals from relatively short periods of records.

Although rainfall in the vicinity of Union was in excess of the likely design criteria, this would not completely explain the observed levels of flooding at the site. Most of the observed flooding in low-lying areas occurred as a result of runoff from heavy rainfall at higher elevation Increased runoff at higher elevation may be the result of inappropriate land development

Further discussion of the Union site is contained in sub-section 1.3.3.

1.3 Vulnerability of Existing Facilities (Addendum)

1.3.1 Castries

No significant flooding was reported at either of the Castries facilities as a result of TS Debbie However, the access road east of the sub-station was reported to be temporarily under about 12" of water (photos 1 & 2).

1 3 1.1 Administrative Offices

Discussions were held with Mr. T.R. Walcott, the structural design engineer for the building Mr Walcott related that Canadian National Building Code earthquake criteria had been employed but there had been no consideration of earthquake-induced liquefaction of the underlying soils. It is known that saturated fine sands are very susceptible to liquefaction with loss of foundation support, localised subsidence, and damage to piles as possible consequences

From construction reports, it has been determined that the sub-soil was mostly sand, that the material in the SW section of the site was softer than elsewhere, and that about 20% of the piles needed to be driven further (as much as 100% further) than originally expected.

Copies of the borehole logs (see Appendix B) and soils investigation (obtained from Trintoplan Ltd) indicate that the sub-soil is predominantly a gravely-sand with significant amounts of silt and traces of organic matter to a depth of about 15-ft. This layer overlays dense weathered rock. Ground water was noted at between 2-ft to 6-ft down.

A detailed analysis of the liquefaction potential of the site does not fall within the ambit of this report. However, despite the presence of large amounts of gravel in the sub-soil, there is clearly some potential for damage as a result of this phenomenon in *strong* earthquakes. However, it is not felt that the cost of further investigations and the nature of any remedial work that could be attempted to forestall liquefaction effects under severe earthquake events can be justified.

The external wall cladding (3/8" thick, glazed, ceramic tiles) on the Administrative Offices was fastened using an adhesive cement. It is likely that there will be some loss of tiles under earthquake conditions. This could cause personal injury and damage to glazing and equipment.

1.3 2 Cul de Sac

As mentioned previously, no significant flooding was reported at the Cul de Sac compound during TS Debbie. Previous problems with flooding had occurred as a result of the blockage of cut-off drains on the hill-side above the compound. The Chief Engineer, Mr C J Mitchell, noted that there had been recurring problems with groundwater (possibly an underground spring) in the area to the SW of the main building. Boreholes done for the peak lopping station had indicated groundwater at only 4' below the surface in this area Care should be taken to ensure that basements are of watertight construction, especially where pipes, etc , penetrate the walls

(See Appendix A for a description of the damage caused by TS Debbie at Cul-de-Sac)

1.3.2 1 Main Building/Power Station

The roller shutter door here is about 6m high x 4m wide. The guide wheels (placed at about 18" c/c along the longer edges) are held in place by shallow (1" to 2" deep) channel sections fixed to the adjacent wall. There was no channel or other fixing at the bottom of the door

Although sturdily constructed, the lack of positive restraints may result in the door being pulled out of its tracks during a hurricane. This may readily be avoided by the provision of storm bolts/stays at the base and sides.

In the Inception Report, the opinion was given that the power station exhaust stacks are adequately constructed and fixed down to resist Category 3 hurricanes. No further investigation of these aerodynamic structures has been carried out. Such an exercise would be warranted if it is imperative that these stacks remain intact in the aftermath of a Category 4 or 5 hurricane.

1.3.2.2 Peak Lopping Station

The members used in the steel frame for this building were substantially smaller than those used in other buildings on the site. The design criteria required a 3-second gust wind speed of 54m/s and stipulated that ridge ventilators were to be used. Steelwork design was to be in accordance with British Standard Code of Practice BS5950.

The supplier's calculations (Appendix E) were carried out using the methodology of the 1981 BAPE/NCST/OAS Code of Practice for Wind Loads for Structural Design. The "BAPE" code defines a 1-in-50 year, 3-second gust (i.e. basic wind speed) for St Lucia as 58 m/s Thus, although the stipulated design criterion of 54 m/s falls within the Saffir-Simpson range (ref Inception Report, Sect. 2 3) for Category 3 hurricanes (50 to 58 m/s) it lies 7% below the "BAPE" requirement

In addition, the supplier used a partial safety factor of 1 2 for the steelwork design, rather than the 1 4 recommended by BS5950, for wind loading This represents a reduction of about 14% in the partial safety factor for wind. This reduction in load factor is unorthodox and unreasonable.

CEP analysed the building using the "BAPE" and BS5950 provisions It was found that the existing structural frame will resist Category 3 winds (58 m/s (3-second gust) basic wind speed) unless a dominant opening occurs (e g , loss of door(s) or large expanse of side sheeting) In such a case, the increase in pressures may lead to the failure of some members The original design criteria did not specify strength requirements for the doors, nor were these items actively considered in the supplier's design. The actual strength of these elements is not known.

1.3.2.3 Fuel & Water Tanks

Oral information obtained from the Hess Oil Company, St Lucia, indicated that the tanks had been designed in accordance with the recommendations of the American Petroleum Institute and that allowances had been made for high winds. It is unknown whether these allowances are adequate. No further details on the design of these tanks has become available. However, the tanks warrant further consideration There are examples of catastrophic failure of fuel tanks in the Caribbean under both hurricane and earthquake conditions.

1.3.3 Union Site

The power station and sub-station at Union are located slightly downstream of the narrowest point of the surrounding Choc River valley at perhaps 10 to 12-ft above the river bed (photos 3 to 7) The valley itself drains a substantial portion of the surrounding area: from Morne Serpent in the north to as far away as Bocage and Babonneau in the south During TS Debbie water levels as high as 5-ft to 6-ft were reported at the power station and sub-station site. Apparently, large amounts of water only entered the sub-station building after the latch on the main metal doors failed However, neither the doors nor windows were specifically designed to be water tight The power station floor is about 5-ft higher than that of the sub-station and the equipment there was not affected

Although the rainfall during the storm appeared to be higher than the likely design criteria, this in itself would not explain the observed water levels The importance of the valley as a catchment for the area north of Castries and the location of the sub-station near the outfall were contributing factors. This site is therefore at higher risk of flooding than other locations

Remedial measures to be considered for the protection of the sub-station against flooding might include:

- the construction of flood protection and/or additional drainage structures,
- installing water tight windows and doors,
- raising critical equipment above floor level,
- relocation of the building

Regarding the stability of the cliff face to the south of the site, geotechnical data obtained from pre-construction investigations indicate that the water table is at 3 to 4-ft below the surface of the power station site and that the underlying material is predominantly clayey to a depth of 30-ft below which a dense rock (probably basaltic) is encountered However, no definitive statement is possible on the stability of the nearby cliff face without further extensive site investigation. In the absence of evidence of rock falls or mud slides further investigation may well not be economically justified This issue should be revisited if unstable slope conditions develop

1.3 3 1 Sub-Station

Visual inspections of the sub-station (previously referred to as the Auxiliary Plant Building) and stores buildings at Union were carried out. The sub-station is of similar construction to the Castries sub-station (ref section 4 2.2 of the Inception Report) and can be expected to show equally good resistance to earthquakes and Category 3 storms.

1 3 3.2 Stores

The old stores building at Union is not normally used to stockpile any important items, however equipment destined for use at the Castries sub-station had been stored there and had been damaged by flood waters during TS Debbie. The building is composed of "trussed" steel stanchions with blockwork walls and piers. There are ventilation blocks at the eaves. The lightweight, metal roof sheeting has a favourable slope for hurricane resistance but is fixed using J-bolts. As mentioned in the Inception Report, J-bolts have a tendency to straighten out under repeated uplift loads.

If the building is to be used as a storage facility in future, it is recommended that this type of fixing be supplemented with self-tapping screws. Overall, the building is expected to show fair resistance to hurricanes and fair to good resistance to earthquakes

1 3.4 Soufrière

The new sub-station under construction in the Soufrière area is a small, light-weight, metal-framed structure (about the size of a commercial shipping container) clad with profiled steel sheet. It was not possible to see the actual structural framing. However, given the observed wall thickness and frequency of cladding fixings, this building might be expected to perform poorly during a Category 3 hurricane.

The building is located on a hillside about 8-ft to 12-ft above the nearby road. Flooding is not expected to be a problem at this site (Photos 8 & 9)