

Appendix 1

Terms of Reference

September 18th, 1995

**TO STUDY THE EFFECTS OF HURRICANE LUIS
ON THE BUILDINGS AND OTHER STRUCTURES
OF THE ELECTRICITY SECTION OF APUA**

1.0 GENERAL:

This study will be an addition to the body of work that now exists within the CARILEC membership on the vulnerability of the electric utility facilities, and the remedial actions that should be taken on existing facilities which will be applicable to future construction.

Such studies now exist on the facilities of BL&P and LUCELEC. Additional risk management studies in respect of windstorms will be undertaken by the CARILEC membership this year in the Risk Management Survey which is part of the Risk Management Project being done by IDB/CDB and CARILEC.

The findings of this study will be included as part of the above project, and will have the special importance that can be placed on data and analysis done immediately after such an event.

2.0 FACILITIES TO BE EXAMINED:

The following facilities will be examined:-

- Power stations at Crabbs, Friars Hill and Cassada Gardens
- Five 66/11 kV substations
- Transmission and Distribution lines (general comments on the structures and foundations within the competence of the Consultant).
- Control Room

EFFECTS OF HURRICANE:

Where applicable, the consultant shall analyse and comment on the effects of high wind, flying debris, storm surge and abnormal rainfall, stating the vulnerability and corrective actions that can be taken with existing and future facilities.

3.0 SCOPE OF WORK:

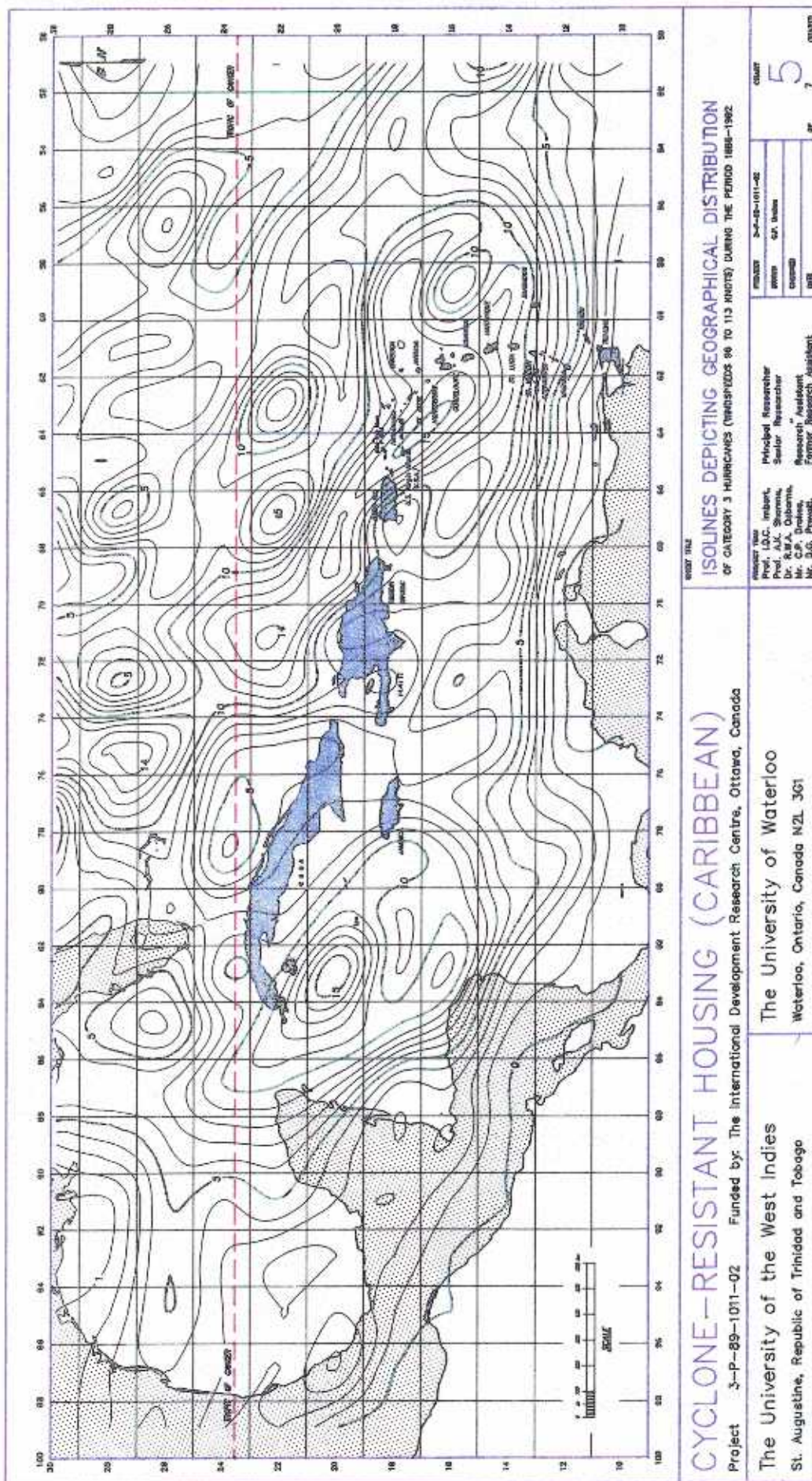
- 3.1 The consultant shall carry out inspection of the facilities listed under Section 2.0 to determine the damage caused by Hurricane Luis.
- 3.2 Prepare a description of the repairs required, taking into account a reasonable standard of protection against future disasters. This description shall be general in nature and will not be used as detailed instructions to a contractor undertaking repairs to the damage.
- 3.3 Draw conclusions from investigations in respect of inadequate design, where damage can be prevented by timely maintenance, failure of materials, and where the use of appropriate standards could have limited the damage.
- 3.4 Prepare budgetary cost estimates for the repair of damage to the buildings and structures.
- 3.5 Prepare comparative analyses, using examples of buildings that resisted the hurricane and those that sustained damage.
- 3.6 Where possible, identify the reasons - technical and otherwise - for the different levels of damage sustained.
- 3.7 Take photographs to illustrate the inspection, comments and analyses.

4.0 DELIVERABLES:

A report shall be submitted which will include inspection data, conclusions and recommendations. The report shall contain information and be of a format consistent with the reports previously done on BL&P and LUCELEC, and will add to or reinforce conclusions and recommendations that are specific to the affected utility and be applicable generally to other Caribbean electric utilities.

Appendix 2

Figures



The Chart shown here is derived from a detailed study of the frequency of occurrences of Category 3 hurricanes during the period 1888-1992. The isolines shown above are lines which connect points representing a particular frequency of occurrence of Category 3 hurricanes. These lines are similar to contour lines on a topographical map, the interval representing one frequency of occurrence. The heavy coloured lines represent 3 frequencies of occurrence in ascending order, as shown by the numbering on the Chart. The isolines are used to determine the average number of hurricanes which have affected the location during the period. Thus, a two-degree square box appropriate to that location is chosen and the isoline(s) nearest to that location is/are found. The numbers appropriate to those isolines provide the average number of Category 3 hurricanes which have affected the location during the period. For example, the islands of St. Kitts/Nevis are located within a box bounded by 17 to 19 degrees latitude and 62 to 64 degrees longitude and have an isoline with the number 13 going through them. Thus, the average number of Category 3 hurricanes affecting those islands during the period was 13, giving a return period of approximately 8 years.

Figure 1

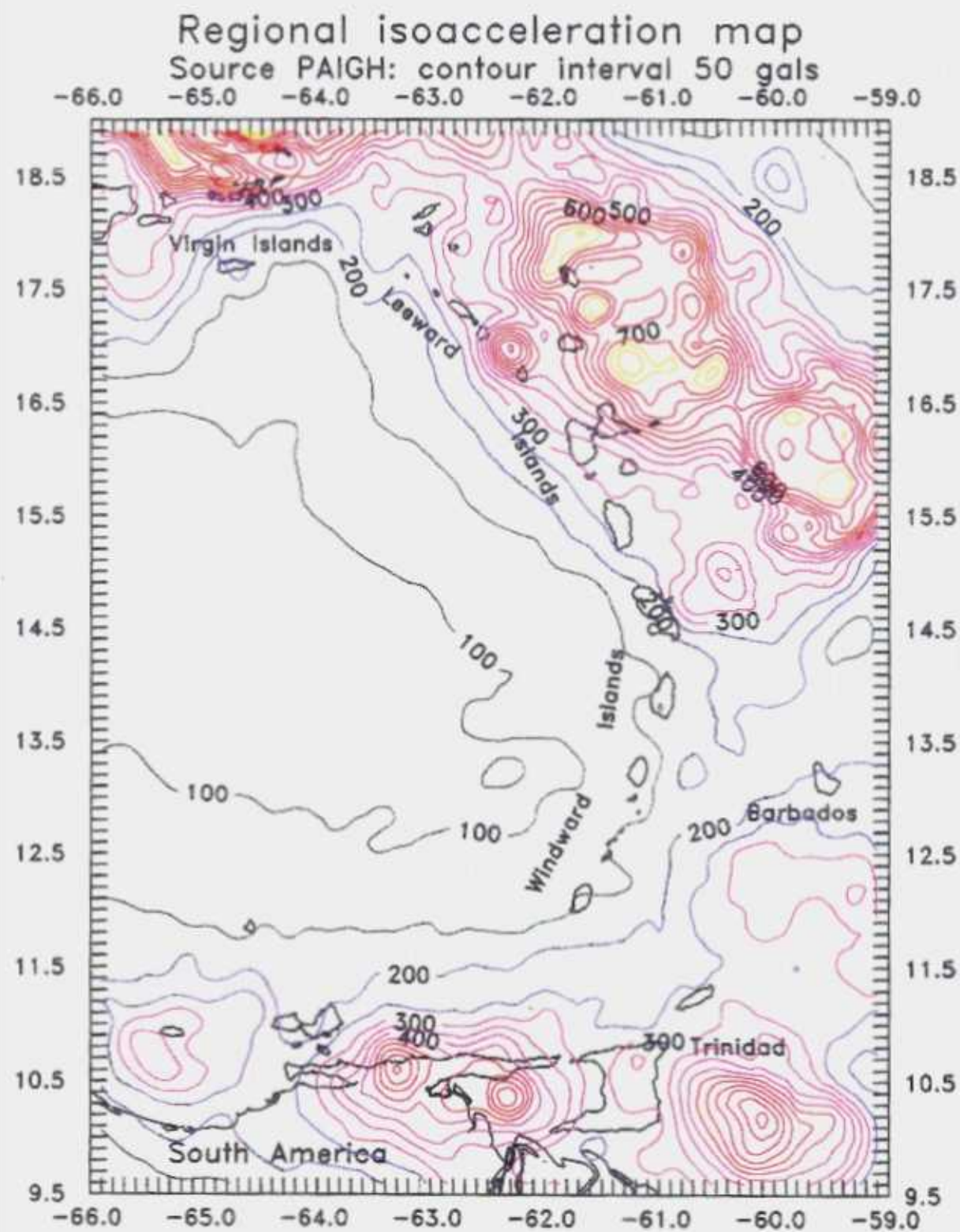


Figure 2

CONTINUOUS LOAD PATH

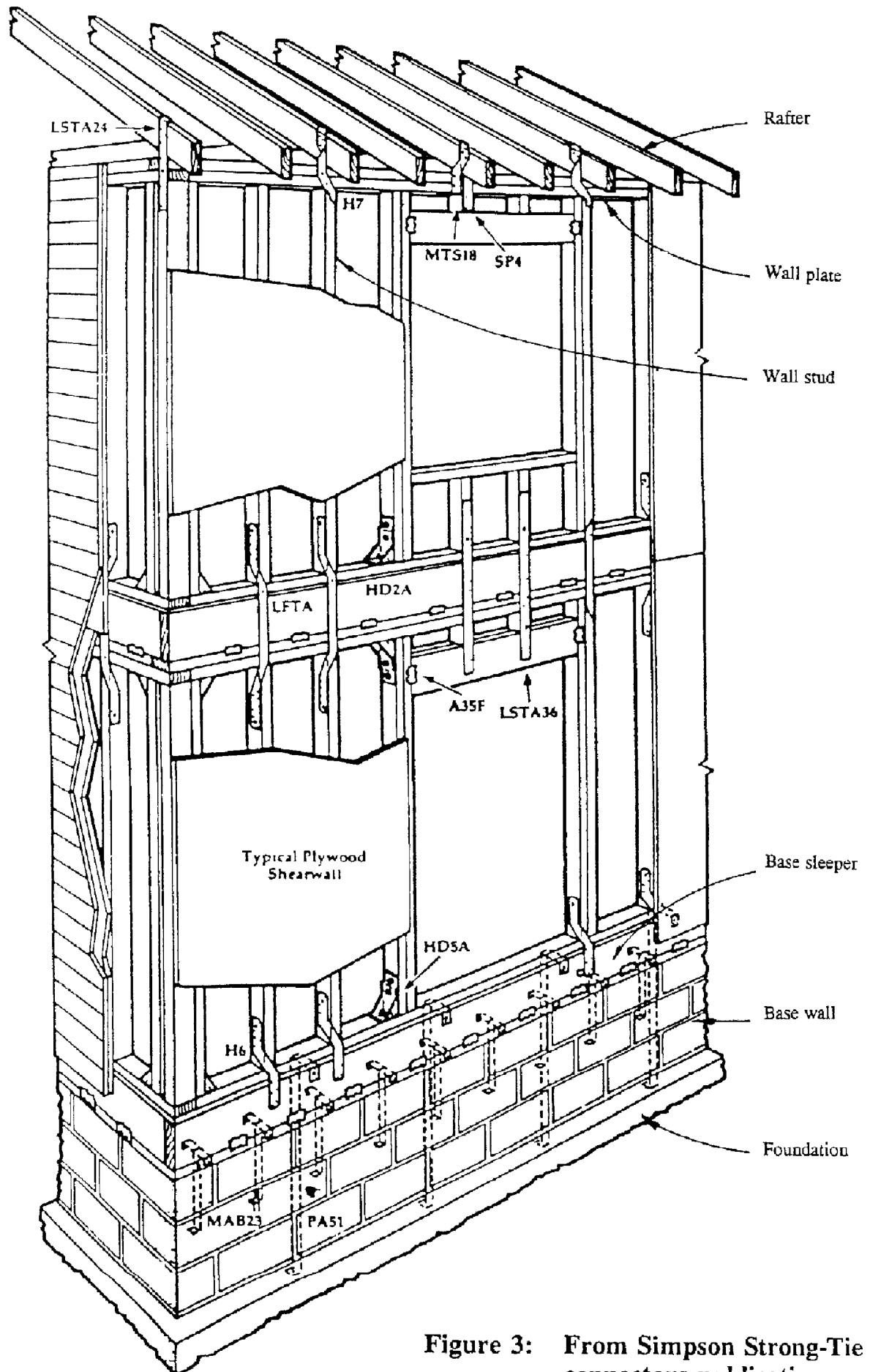


Figure 3: From Simpson Strong-Tie connectors publication

Appendix 3

Tables

Building	Element	Activity	Estimate	Subtotal
Generator Building	Sheeting	Roof and side sheeting	\$10,000	\$10,000
Control Building	Roofing Ceiling Vinyl tiling Painting	Replace corroded sheets Replace tiles Replace tile in affected rooms Paint interior and exterior	\$10,800 \$9,200 \$1,800 \$28,100	\$50,000
Canteen	Demolition Roofing Walls Carpentry Painting Tiling Electrical	Remove remaining walls Rebuild roof and ceiling Rebuild Cupboards, windows and doors Paint interior and exterior Retile in 12"x12" tiles Re-wire building	\$7,200 \$94,300 \$92,000 \$27,700 \$25,100 \$44,000 \$28,700	\$319,000
Transmission and Distribution	Roofing Siding Ceiling Tiling Painting Electrical	Replace damage sheeting Replace corroded sheets Replace damage ceilings Relay loose vinyl tiles Paint siding to match new Lighting to new ceiling	\$8,100 \$9,900 \$5,400 \$14,400 \$18,000 \$1,800	\$57,000
Total				\$436,000

Notes: No allowance is made for mechanical equipment
No allowance is made for electrical re-wiring of the buildings

**Cost Estimates for Repairs to Buildings
Cassada Gardens Complex**

Table 1a

Building	Element	Activity	Estimate	Subtotal
Site	Fencing	Re-erect as necessary	\$40,200	\$40,200
Generator Building	Roofing	Re-sheet roof	\$116,700	\$315,300
	Siding	Repair side sheeting	\$53,900	
	Sliding doors	Rebuild	\$43,100	
	Masonry	Patch masonry as required	\$3,600	
	Carpentry	Re-build ceilings	\$39,500	
	Tiling	Relay vinyl tiles	\$4,600	
	Painting	General redecoration	\$53,900	
Office and Warehouse	Roofing	Repair corroded sheets	\$26,900	\$62,500
	Siding	Repair corroded sheets	\$9,900	
	Masonry	Patch where necessary	\$3,000	
	Carpentry	Rebuild ceilings	\$3,600	
	Tiling	Relay vinyl tiles	\$4,700	
	Painting	General redecoration	\$14,400	
Industrial Workshop	Roofing	Re-sheet roof	\$175,500	\$317,500
	Walls	Side sheeting	\$89,000	
	Carpentry	Windows and doors	\$38,000	
	Painting	General redecoration	\$15,000	
Total				\$735,500

Notes: No allowance is made for mechanical equipment
No allowance is made for electrical re-wiring of the buildings

Cost Estimates for Repairs to Buildings
Friars Hill Power Station

Table 1b

Building	Element	Activity	Estimate	Subtotal
Site	Fencing	Re-erect fencing	\$32,300	\$32,300
Generator Building	Roofing Siding Masonry Tiling Carpentry Doors Ventilators Painting	Re-sheet N-S generator hall Repair siding Repair blockwall Relay vinyl tiles Repair doors , louvres etc Roller shutters Replace General redecoration	\$140,000 \$59,300 \$2,400 \$25,100 \$82,400 \$71,800 \$32,300 \$11,800	\$425,100
Machine Shop	Roofing Masonry Carpentry Miscellaneous Painting	Replace Repair Blockwall Windows and doors General repairs General redecoration	\$35,900 \$1,800 \$21,500 \$43,100 \$6,700	\$109,000
Administration and Control building	Roofing Miscellaneous	General repairs General repairs	\$18,000 \$53,900	\$71,900
Total				\$638,300

Notes: No allowance is made for mechanical equipment
No allowance is made for electrical re-wiring of the buildings

**Cost Estimates for Repairs to Buildings
Crabbs Complex**

Table 1c

Substation	1	2	Feeder 3	Number 4	5	6	Total
			Number of Poles				
Swetes		96	559	119			774
Union Road		146		182			328
Friars Hill	423	74	189	278			964
Cassada Gardens	249	131		253	242		875
Crabbs				386			386
Livingston	193	372	347	269			1181
Belmont		247	558				805
Total	865	1066	1653	1487	242	0	5313
Total number of poles on 11 kV system =							5313
Add 2% for poles planted after count =							106
Total =							5419
Damage to 11 kV system:							
Broken poles =				440	% =		8.12
Leaning poles =				322	% =		5.94
Broken conductors =				160			
Detached conductors =				364			
Total number of poles on 69 kV system =							200
Total numbr of towers on 69 kV system =							?
Damage to 69 kV system:							
Broken poles =				6	% =		3.00
Leaning poles =				45	% =		0.83
Damaged towers =				0	% =		?

Damage to Transmission and Distribution Systems

Table 2

Substation	Feeder Number	Planned Start	Planned Finnish	Planned Days	% Done
Cassada Gardens	1	11-Sep-95	18-Sep-95	7	100
Cassada Gardens	2	06-Sep-95	12-Sep-95	6	100
Cassada Gardens	3	18-Sep-95	27-Sep-95	9	0
Cassada Gardens	4	08-Sep-95	15-Sep-95	7	75
Cassada Gardens	5	18-Sep-95	27-Sep-95	9	85
Belmont	2	18-Sep-95	23-Sep-95	5	0
Belmont	3	14-Sep-95	27-Sep-95	13	0
Swetes	2	23-Sep-95	07-Oct-95	14	0
Swetes	3	23-Sep-95	07-Oct-95	14	0
Swetes	4	28-Sep-95	19-Oct-95	21	0
Lavington	1	11-Sep-95	12-Sep-95	1	100
Lavington	2	12-Sep-95	27-Sep-95	15	60
Lavington	3	27-Sep-95	03-Oct-95	6	0
Lavington	4	21-Sep-95	27-Sep-95	6	10
Crabbs	4	13-Sep-95	22-Sep-95	9	0
Five Islands	2	27-Sep-95	29-Sep-95	2	0
Five Islands	4	17-Sep-95	24-Sep-95	7	50
Friars Hill: St John's Central		11-Sep-95	15-Sep-95	4	100
Friars Hill: St John's South		11-Sep-95	23-Sep-95	12	100
Friars Hill: St John's West		16-Sep-95	22-Sep-95	6	100
Friars Hill: St John's North		22-Sep-95	03-Oct-95	11	5
Friars Hill/WIOC Interconnector		11-Sep-95	11-Sep-95	0	100
Friars Hill/Garden Interconnector		11-Sep-95	13-Sep-95	2	100
Baker/Tango Interconnector		08-Sep-95	10-Sep-95	2	100

Hurricane Luis Feeder Restoration Schedule

Table 3

Appendix 4

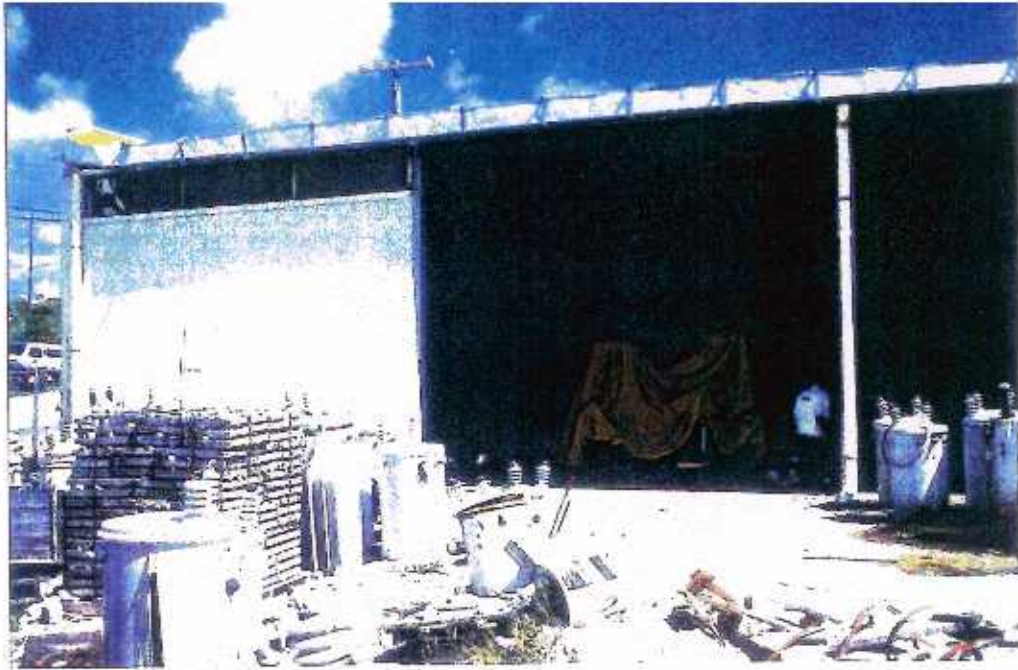
Photographs



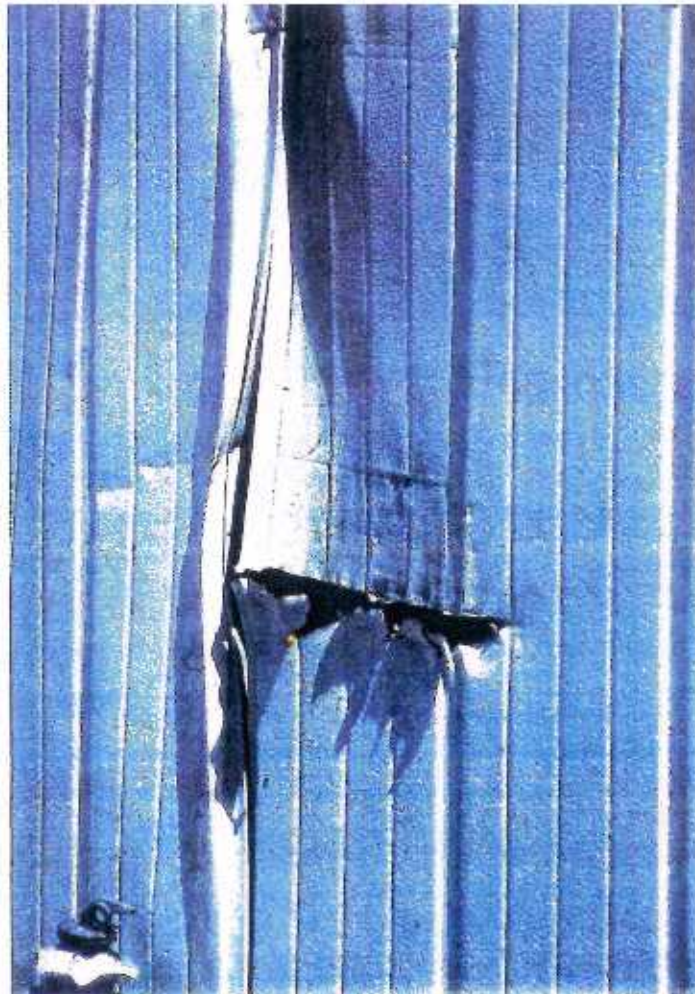
1 Cassada Gardens Complex - overall aerial view



2 Cassada Gardens Complex - Note the badly rusted but undamaged Old Power Station and the destroyed Canteen/Workshop.



3 Cassada Gardens Stores Building



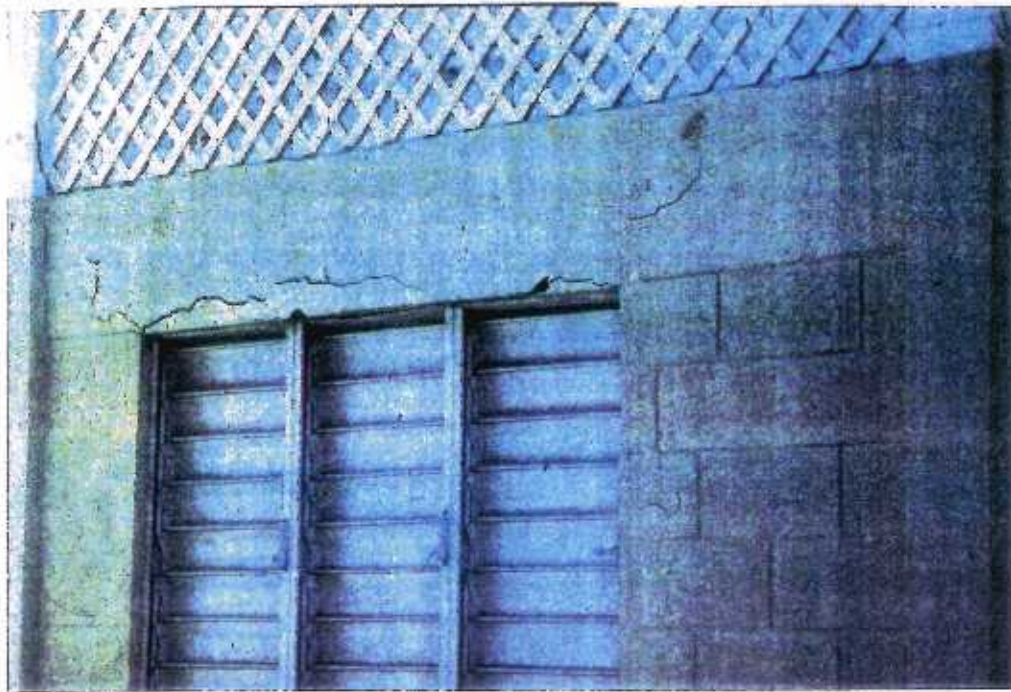
4 Cassada Gardens Stores Building - impact damage to the siding



5 Cassada Gardens Canteen - roof structure completely removed; ceiling structure badly damaged, but in place.



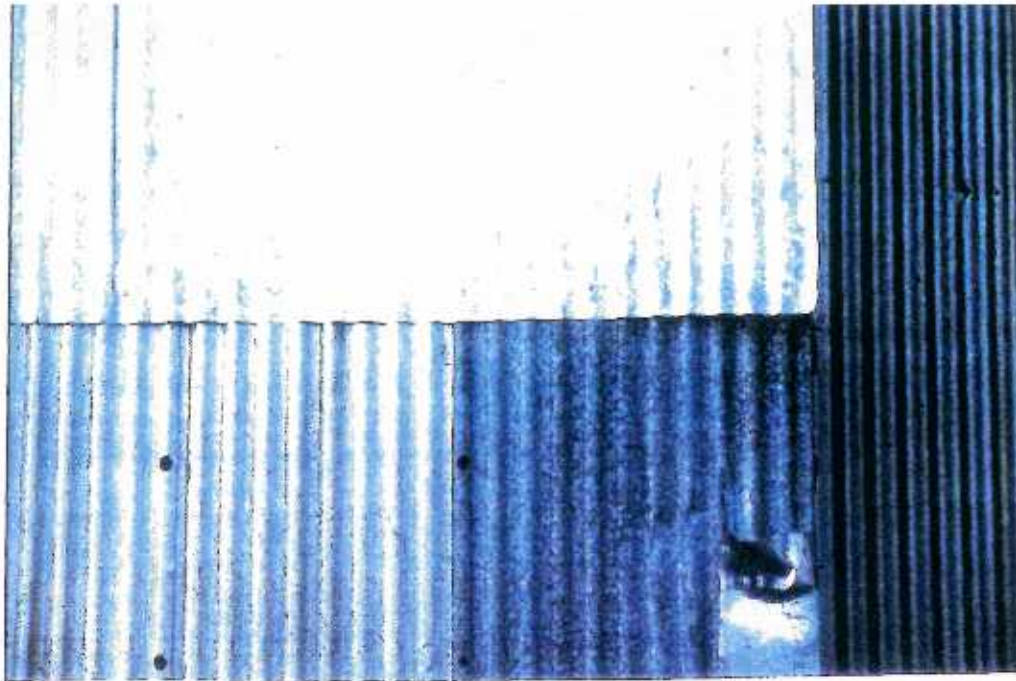
6 Cassada Gardens Canteen - removed roof trusses on the ground



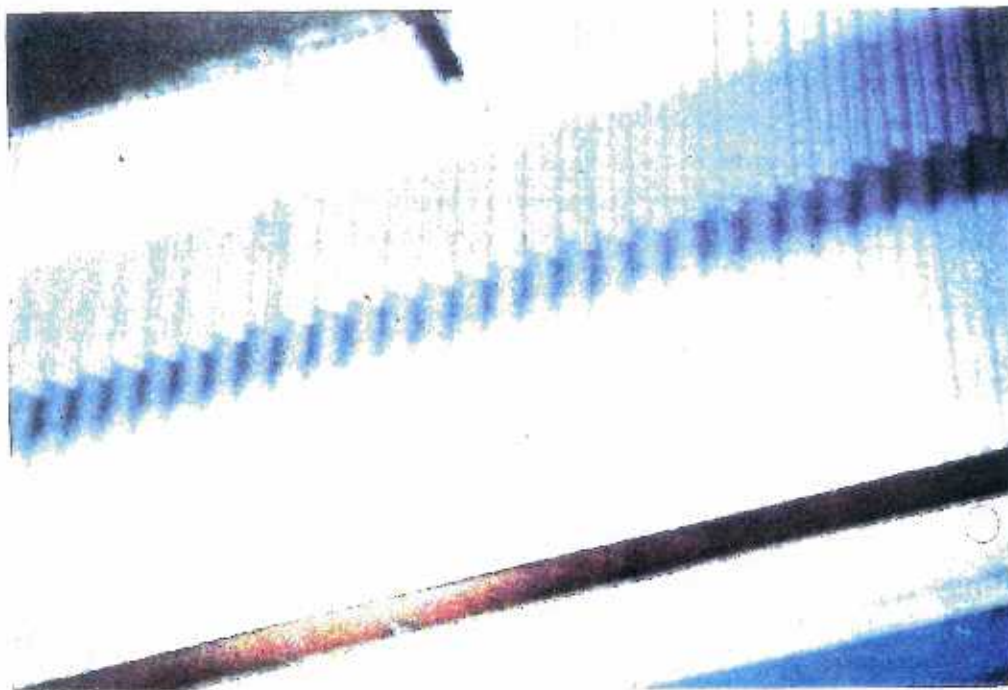
7 Cassada Gardens Canteen - cracked walls



8 Friars Hill Power Station
- the south gable-end cladding has been replaced since the hurricane.



- 9 Friars Hill Power Station - the south gable-end cladding showing repairs after Hugo (1989) and Luis (1995) - note that the latest repairs are not even as well secured as those which failed in Luis.



- 10 Friars Hill Power Station - Repairs to sidings show the absence of horizontal rails at the overlap of sheeting. This would lead to inevitable failure in the next hurricane.



11 Friars Hill Workshop, Stores and Office Building



12 Friars Hill Workshop



13 Friars Hill Workshop



14 Friars Hill Workshop - note the torn corrugated steel sheets