7 LIFELINES

This report presents findings of earthquake damage to lifeline facilities. Topics included are dams, water supply, sewage, power, communications, liquid fuels, and general transportation. Port facility structural and geotechnical aspects of the earthquake are discussed in Chapter 5—Industrial Facilities Performance of bridges is discussed in Chapter 6—Bridges.

TRANSPORTATION

Highway and railroad bridge, road, and railroad failure had a significant impact on emergency response and restoration of services. It further affected businesses by blocking shipments of bananas to market.

Much of the road between Siquerres and Limon is located on an alluvial plain that underwent significant liquefaction and lateral spreading. In many places the road was constructed on fill, built up one to three meters above the surrounding plain. When the underlying material liquefied, the fill settled and developed severe cracks. The road was reopened after bulldozers graded it, filling in the cracks. The resulting gravel road will not be as serviceable as the paved road, particularly during the pending rainy season. By April 25, the highway had been reopened to emergency and four-wheel drive vehicles. By May 27, it was open to general traffic.

The road south of Limon was damaged in a similar manner to that between Limon and San Jose, and had gaping cracks resulting from lateral spreading. The reconnaissance team gained access along a dirt road through the mountains crossing the Estrella River on a single-lane cable stay bridge. The route would not carry significant supplies.

Because significant vehicular access was cut off south of Limon, emergency supplies were being flown in by helicopters on loan from both the United States and Nicaragua.

As a result of the road closure, coupled with damage to the narrow gauge railroad running along the coast, an estimated $250,000 in banana exports was being lost daily. Trucks and four-wheel drive vehicles were fording some of the smaller rivers where bridges had collapsed. Even that would probably not be possible when the rainy season begins.

Costa Rica should give consideration to providing multiple transportation systems and/or corridors, particularly on key routes. This consideration is over and above mitigation of earthquake effects on transportation structures, such as bridges

DAMS

Locations of the four largest dams in Costa Rica and the epicenter of the April 22 earthquake are shown in Figure 7-1. Table 7-1 contains general information on the dams and their distances from the epicenter. The general information is from the registry of the International Commission on Large Dams (1988). The dams are the principal source of electric power for the nation. None of the dams was damaged by the earthquake.

Arenal dam has a height of 80m and impounds a world class reservoir. The dam is rockfill with an impervious core and was built on alluvium (Figure 7-2). The dam is about 210 km from the epicenter of the earthquake, a distance at which the attenuated motions apparently did not trigger the strong motion instruments in the region.

La Garita, a gravity dam 20m in height, has only a small impoundment and is 145 km from the epicenter. Shaking in the area can be judged by the Alajuela record (ALJ), in which the maximum horizontal motion is about 0.1g (strong motion record is shown as Figure 2-15 in Chapter 2—Seismology and Tectonics).

Cachi dam is a concrete arch structure 80m in height and is located 86 km from the epicenter. Figure 7-3 shows the appearance of the structure from upstream. Figure 7-4 shows a view of Cachi dam from downstream, including the spillways

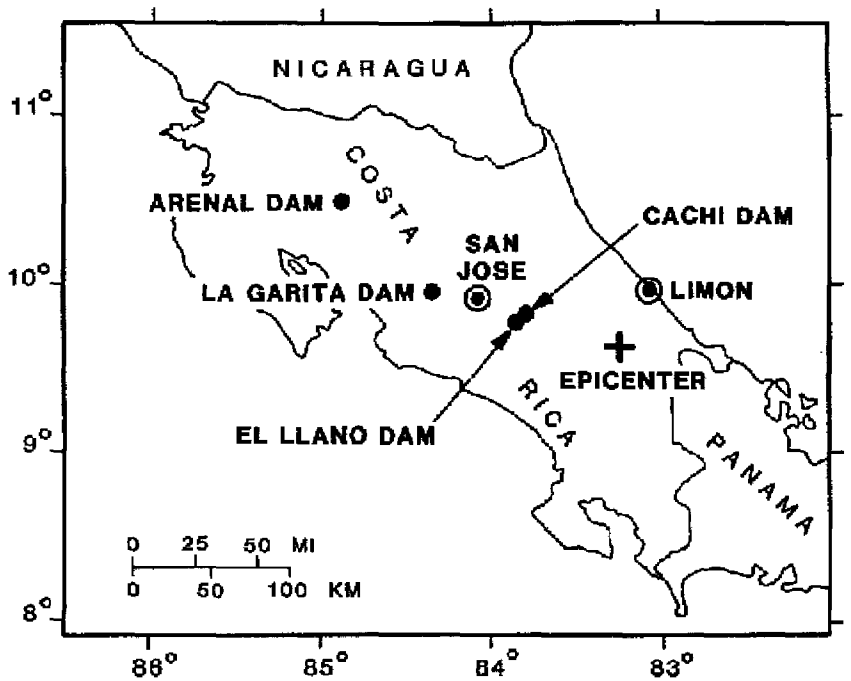

Figure 7-1 Location map of large dams in Costa Rica and the epicenter of the April 22, 1991 earthquake.

TABLE 7-1 Major Dams in Costa Rica

Name of Dam	*Year*	*Type*	*Position of Sealing Element*	*Foundation*	*Height (m)*	*Length of Crest (m)*	*Gross Capacity of Reservoir (10^3 m^3)*	*Purpose*	*Discharge Capacity of Spillway (m^3/s)*	*Type of Spillway*	*Distance from epicenter 4-22-91 Egk km*
La Garita	1958	Gravity	Homogeneous	Rock	20	59	—	Hydroelectric	1,7500	Uncontrolled	145
El Llano	1963	Earth	Internal core	Soil	20	380	400	Hydroelectric	34	Uncontrolled	90
Cachi	1966	Arch	Homogeneous	Rock	80	70	51,000	Hydroelectric	3,500	Uncontrolled	86
Arenal	1978-82	Rockfill	Internal core	Soil	70	900	2,200,000	Hydroelectric and irrigation	160	Uncontrolled	210

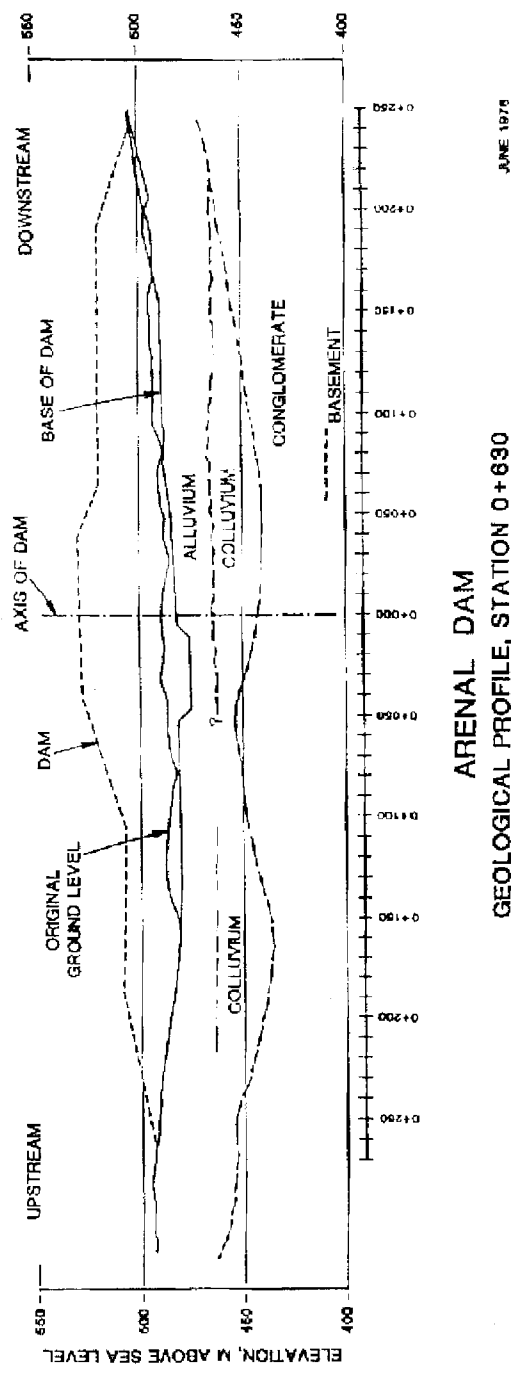

Figure 7-2 Cross section of Arenal dam and of the foundation materials on which it is built.

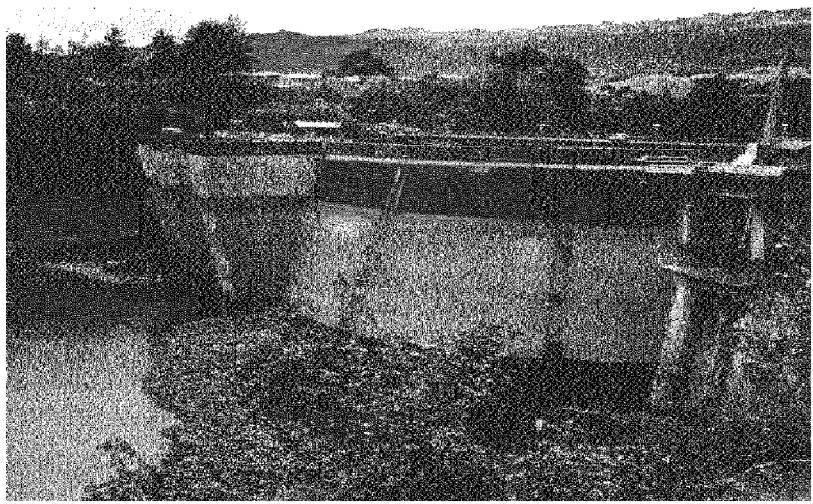

Figure 7-3 View of Cachi dam from upstream.

The dam is built in a narrow gorge of the Rio Reventazon, seen in Figure 7-5, in which the restriction appears to have been caused by thick lava flows laid over indurated conglomerates. The structural association and lithology of the rocks into which the valley was incised is shown in Figure 7-6. The site is composed of strongly indurated conglomerates over which are thin, discontinuous alluvial and lacustrine deposits overlain the sheet-like coverings of lavas and tuffs.

Cachi dam had one strong motion instrument in a gallery. The gallery is 82m below the crest of the dam and extends laterally into the indurated conglomerate as shown in Figure 7-6. The instrument was said to be about 10m within the gallery. The indurated conglomerate is the material classed as "rock" in Table 7-1. The instrument was triggered by the earthquake and registered a peak horizontal acceleration of 0.149g. The relevant accelerograms are presented in this report under Station Code CCH.

El Llano dam is a relatively small earth structure, 20m high, built upstream from Cachi dam on the Rio Reventazon. Its appearance from the left abutment is shown in Figure 7-7. The earthquake produced no visible effects on the dam.

At the Cachi dam site there is no power station and no generation of electricity. The water is sent to a power station 12 km away where water also is received from the Llano reservoir. The power station suffered a temporary disruption of power generation due to shifting of transformers.

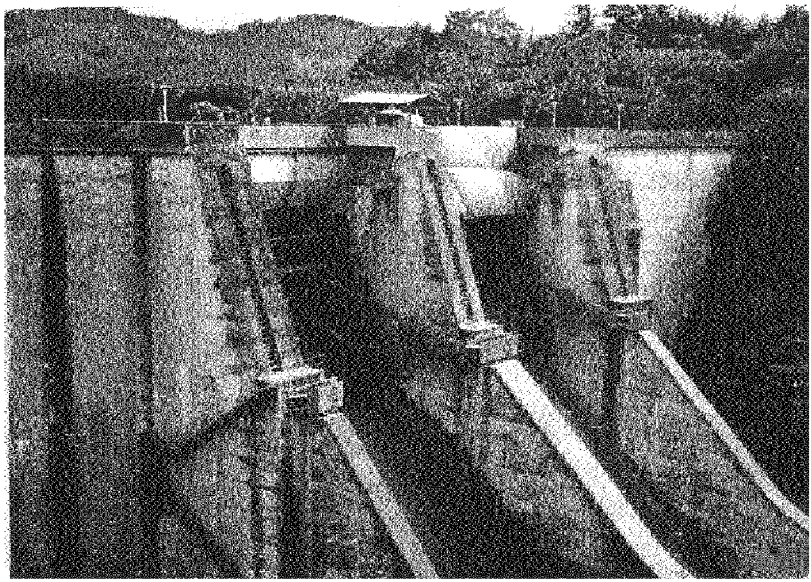

Figure 7-4 View of Cachi dam and its spillways from downstream.

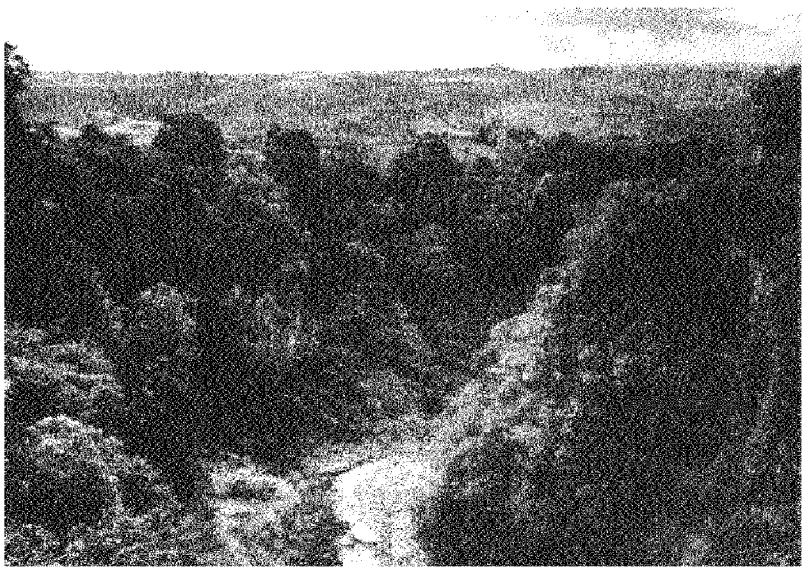

Figure 7-5 The narrow gorge of the Rio Reventazon below Cachi dam.