Coloso silty clay-loam (Cn), Cataño sandy clay-loam (Ce), and Cataño sand (Cd). In general, the unmapped inclusions may be small units of the above listed known hydric soils, or would be described as "unnamed inclusions". These unnamed inclusions generally have a lot of the characteristics of the surrounding soils and may lack obvious hydric indicators, but are often ponded. In the case of soils with heavy clay content, hydric indicators may not be obvious, and inclusions are usually within depressional wetland areas where the hydrology is maintained by ponding rather than flooding. NRCS has noted that the hydric soil indicators in such soils are good for saturation only and may not be present in ponding situations. Drainage channels have been dug on both sides of the Caño in various places, and while some have been maintained others have not, making the hydrology of the area complex.

Existing Conditions

The National Wetland Inventory Map (Figure 7) of the area indicates relatively extensive wetlands in the Caño Madre Vieja area. While wetlands east of Caño Madre Vieja may be over-estimated in the maps, some areas marked as uplands within the proposed levees may be in the process of reverting to wetlands. The mouth of Caño Madre Vieja is mapped as Cd on the soil map, and is a classic small stream opening on a dynamic beach. The beach berms, while considered to be uplands are relatively narrow. On the eastern side of the Caño, as mentioned above, the beach berm has been elevated for the coastal road and further altered with groins and rip-rap to protect the park development, the public road, and the school. The beach berm on the western side of the Caño mouth has retained more natural characteristics with some forest of coconut palms and portia tree (*Thespesia populnea*), and West-Indian almond (*Terminalia catappa*).

Typically small rivers form sand bar sills in the river mouths during low flows and may even close during very low flows. As mentioned above, this channel is generally maintained open by the groins and occasional maintenance. Both east and west of the mouth, the beach berm is backed by the two side drainages that enter into the Caño near the mouth. These drainages are mapped as Tidal swamp (Td) and contain the riverine mangrove associations commonly found in small drainages where water accumulates behind the river mouth bar. Red mangroves (*Rhizophora mangle*) generally occur as fringes immediately adjacent to the channels, while black mangroves (*Avicennia germinans*) dominate in the saturated areas away from the open channel. On the beach side of this channel, red mangrove on the channel is backed by white mangrove (*Laguncularia racemosa*), and indication that soils are not hypersaline in this area. Leather ferns (*Achrosticum* spp.) are also commonly found in this association.

The eastern forested wetlands have been reduced since the NWI maps were made by the park development, particularly the athletic track and by the western edge of the school (Colegio San Carlos). The remaining wetlands still retain mangroves and other wet tolerant trees such as west-indian almond (*Terminalia catappa*), and palms (Photos 7 and 8). The seaward edge of the east dike would pass through the edge of the school yard, possibly cutting off a small segment of this drainage and wetland forest.

The western drainage divides with one arm passing just behind the beach berm directly west,

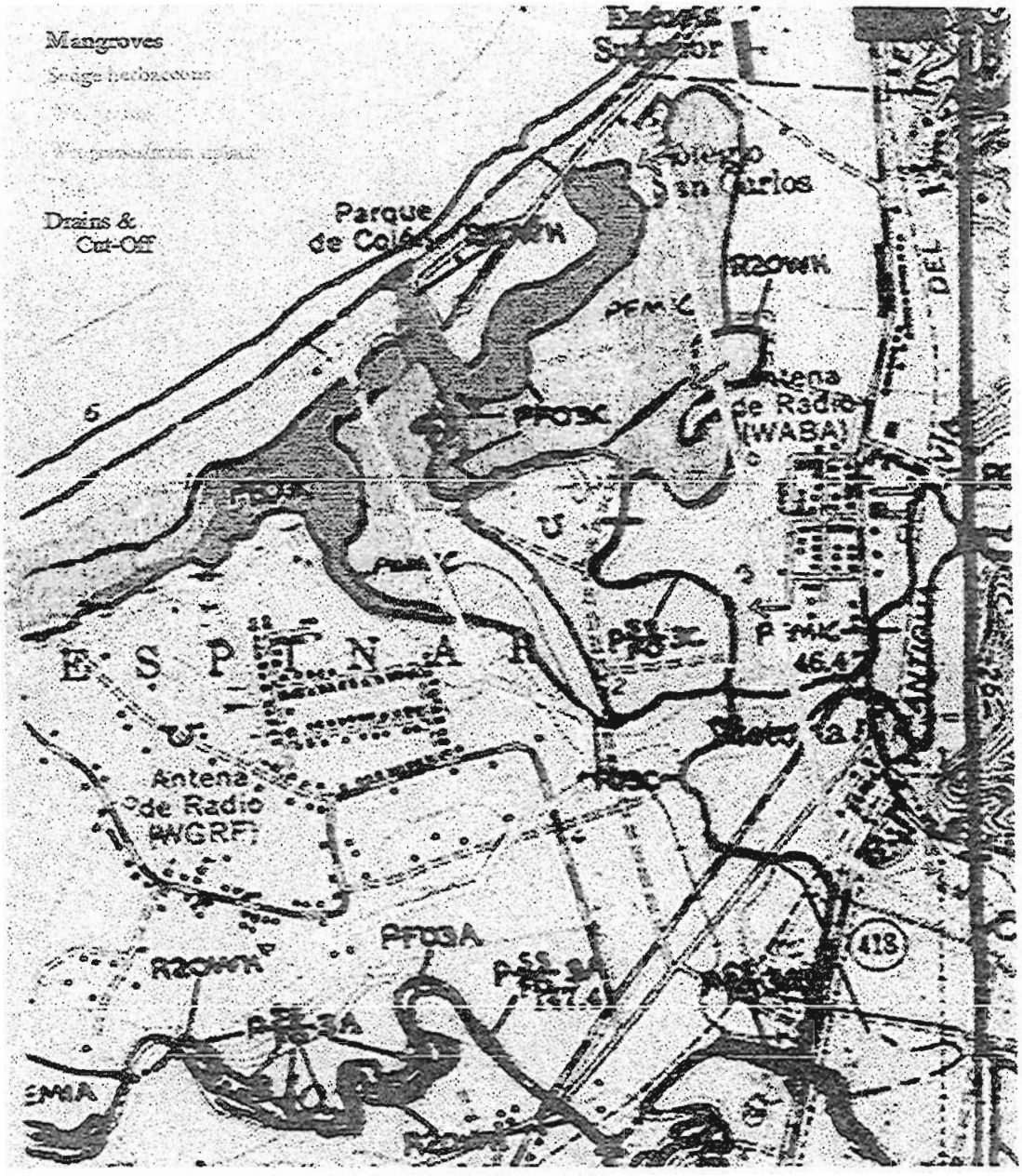


Figure 7. NWI map of the project with the dike layout and rough approximation of wetland types

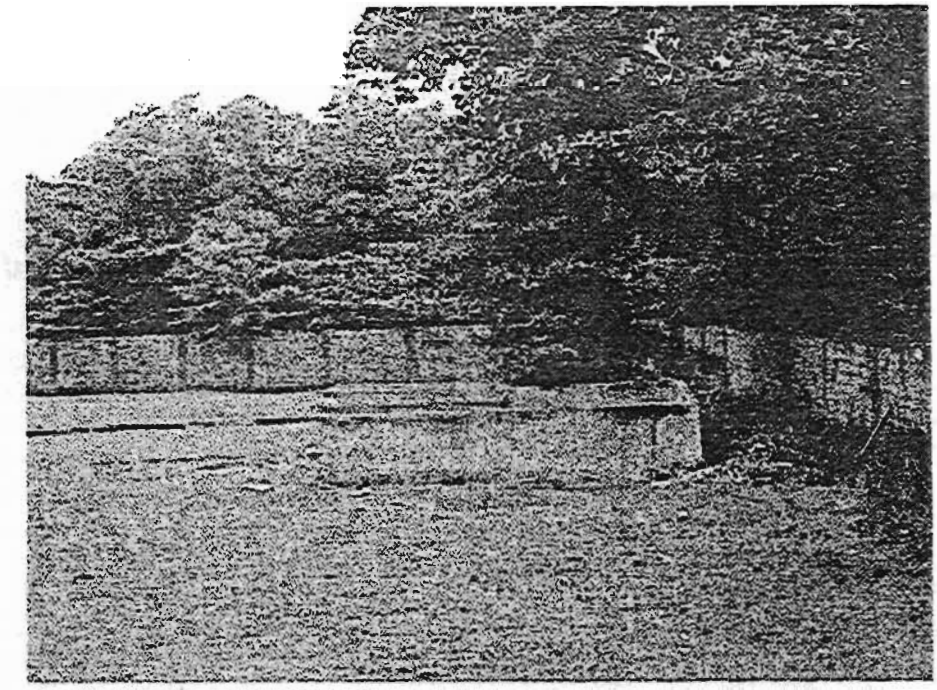


Photo 7. Colegio San Carlos school yard with the forested drainage behind it. The eastern levee would pass through part of the school yard and forest.

Photo 8. The forested drainage from the road just west of the school. Upland trees are in the foreground on the road levee and mangroves are in the background.

and the other arm meandering south on the edge of Espinar community. The mangrove forest along the southern portion of this drainage next to the Espinar community is well developed with some trees exceeding 30 feet in height. The channel is also connected to an intermittent drainage lying on the north side of Espinar, just behind the beach berm. The wetlands behind the beach berm are dominated by cattail (*Typha domingensis*) and other herbaceous vegetation to the west, probably a result of past (and current) land clearing and sand extraction. A previous wetland violation was noted in that area, and these wetlands were recently disturbed by land clearing activities (Photos 9 and 10). It appears that most of the cleared wetlands consisted of cattail (Typha domingensis) mixed with sedges and salt grass. The western dike would cut across the mangrove channel to tie into the existing beach berm just to the west of the mouth of Caño Madre Vieja. While the current plan calls for a two-way culvert to maintain tidal flow into this channel, the size of the culvert is critical in maintaining the hydraulic capacity of this channel. At the narrowest point in the vicinity of the proposed dike, the channel is approximately five feet in width and at least a foot in depth (Photos 11 and 12). Our understanding is that the Corps is currently considering a 2' diameter two-way culvert which appears to be considerably below the existing hydraulic capacity of the channel.

The east side of the Caño, south of the mangrove channel and park, lies between the side channel and a large curve in the main channel. It is mapped as Cataño sandy clay-loam (Ce) just south of the channel, shifting to Coloso silty clay-loam (Cn) and Igualdad clay (Ig) to the east. Probably reflecting these mixed soil associations, the plant community is patchy, varying between FACU and FACW herbaceous plant species. Most of the area is in grasses classified as FACU (*Panicum maximum*) with patches including sedges and FACW grasses such as *Brachiaria purpurascens*. The plant association shifts to cyperids and leather fern as the wetland forest is approached to the north, and the soils shift to Cataño sandy clay-loam. Much of the area on the eastern side of the Caño near the existing community could be considered as uplands, however, small changes in topography promote the wetland plant species in shallow depressions. The area is complex, and should be considered to be a mixture of wetlands and uplands that perform a number of wetland functions including filtration and sedimentation.

On the west side of Caño Madre Vieja, south of the mangrove channel, the soils are mapped as Cataño sandy clay-loam (Ce), grading into Bajuras clay. The plant community in this area strongly reflects the hydric soils, being dominated by wetland grasses and sedges (Photos 13 and 14). The ground in this area was completely saturated, with ponded water in places during the October 12 site visit. This area is bordered on the west by the mangrove lined channel adjacent to Espinar community. The dike would pass through this area.

Further south, in the vicinity of the double meander that would be impacted by the project (see below), the soils shift from Coloso silty clay-loam (Cn) on the east bank and within the meander area to Toa silty clay-loam (ToA) further west. Some small forest stands of geno-geno (Lonchocarpus domingensis) lie on or near the Caño meanders to be cut off by the levee (Photo 15 and 16). This tree is often found associated with drainages in drier areas and is considered to be a FACW tree. Some of the trees lie within a meander channel below bankfull levels, and fiddler crabs were abundant in the area indicating the liklihood of occasional estuarine conditions. Otherwise, the east bank area is dominated by guinea grass (*Panicum maximum*,

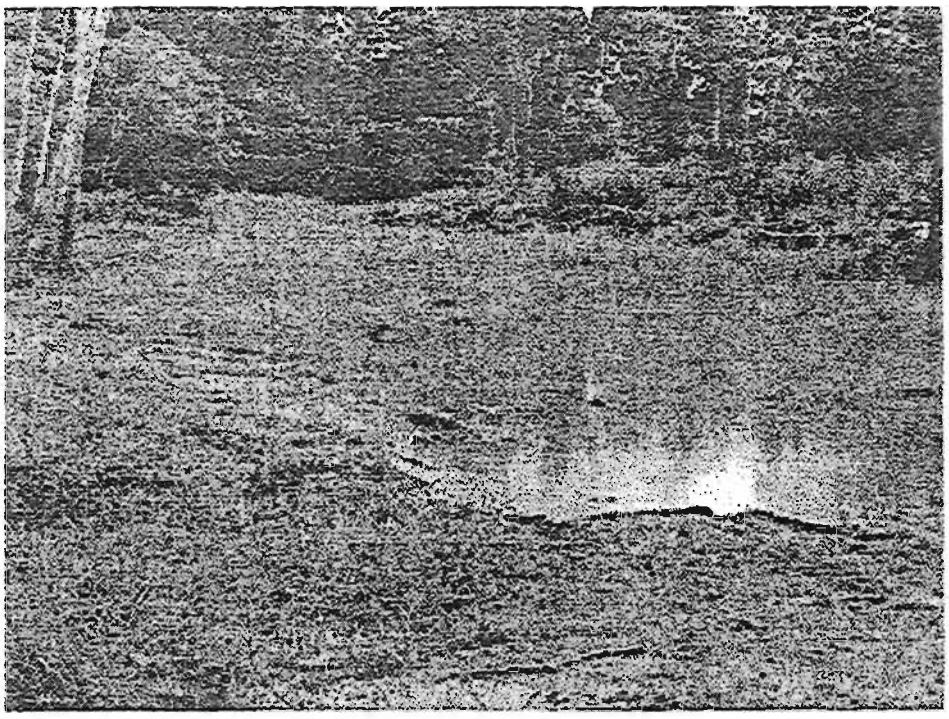


Photo 9. Recently disturbed wetland area behind the beach berm to the west of Caño Madre Vieja. Note the piles of cleared vegetation and soil deposited in wetlands towards the mangrove forest.

Photo 10. Cleared wetland area behind beach berm west of the Caño showing piled debris that includes some trees.

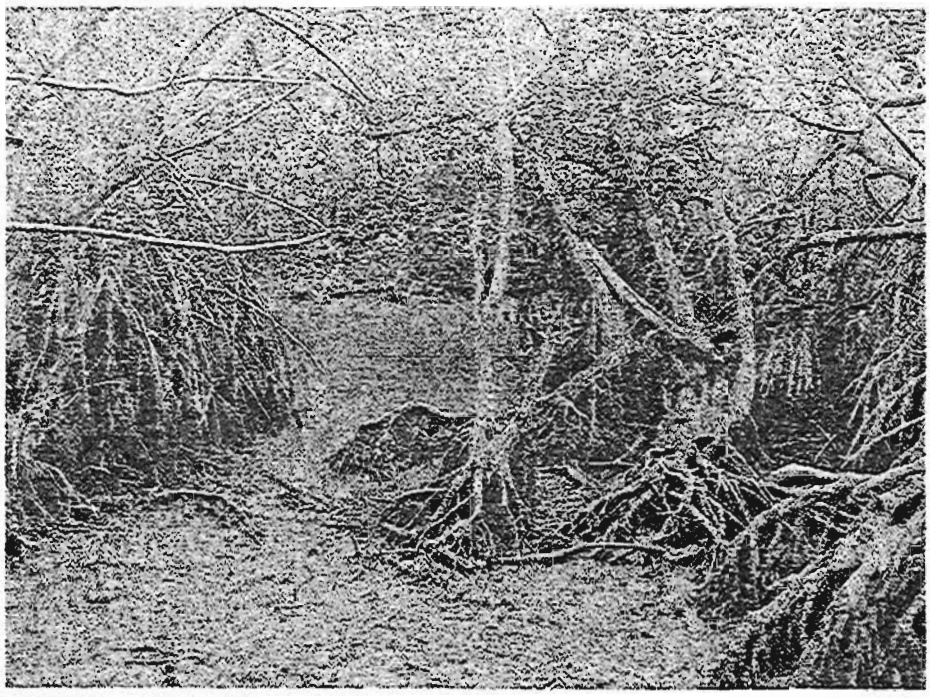


Photo 11. Predominantly red mangrove forest in the area where the western dike would cross and near the narrow point of the channel. The tide was moving out and at low stage.

Photo 12. Mixed red and white mangroves along the mangrove channel area behind the beach berm west of the Caño.

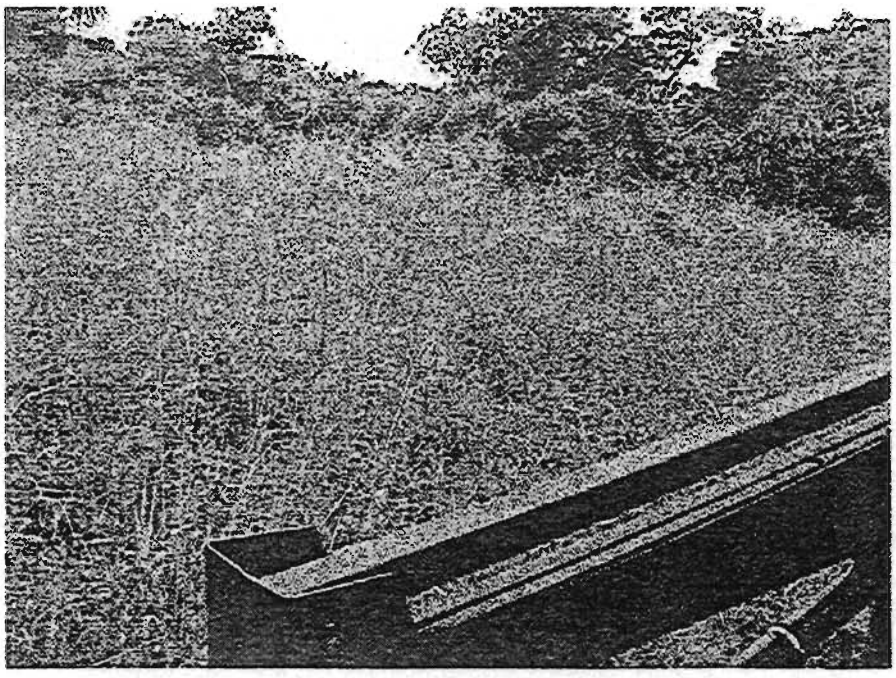


Photo 13. Sedge dominated wetlands on the west side of the Caño, south of the mangrove channel (visible in background). The ground was ponded with several inches of water during this visit.

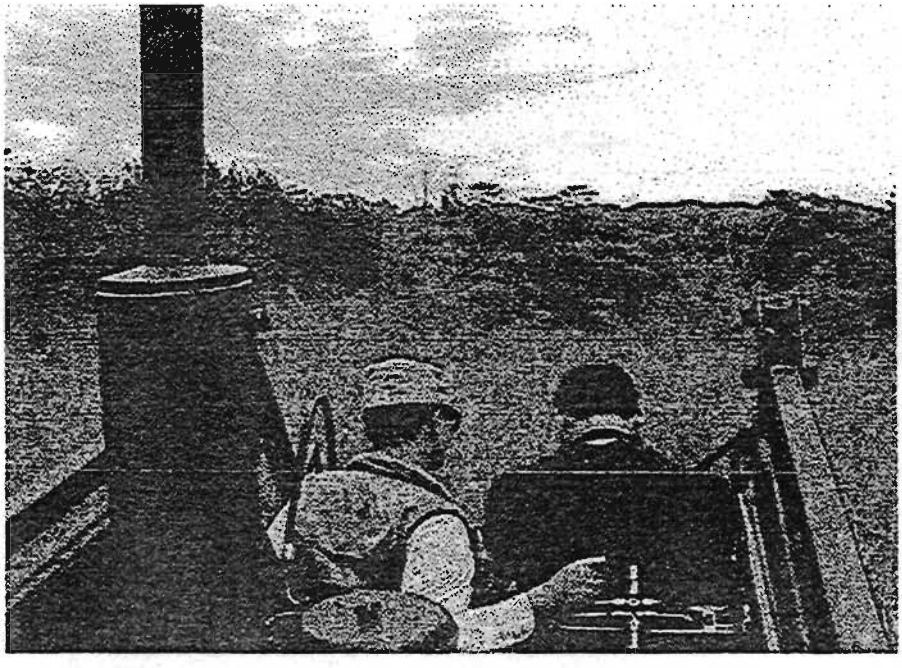


Photo 14. Another view of sedge/wetland grass dominated area. The entire area on the west side of the channel was too wet to enter with conventional 4 wheel drive vehicles and could only be accessed on foot or by tractor.

Photo 15. Mixed uplands and wet prairie area on the eastern side of the Caño, near the meanders that would be impacted. The larger trees are geno-geno (*Lonchocarpus domingensis*), and the herbaceous plants are mostly guinea grass (*Panicum maximum*) mixed with cyperids and *Brachiaria purpurascens.*

Photo 16. Geno-geno trees next to the river. Fiddler crabs were in abundance around the roots of the trees in this area.

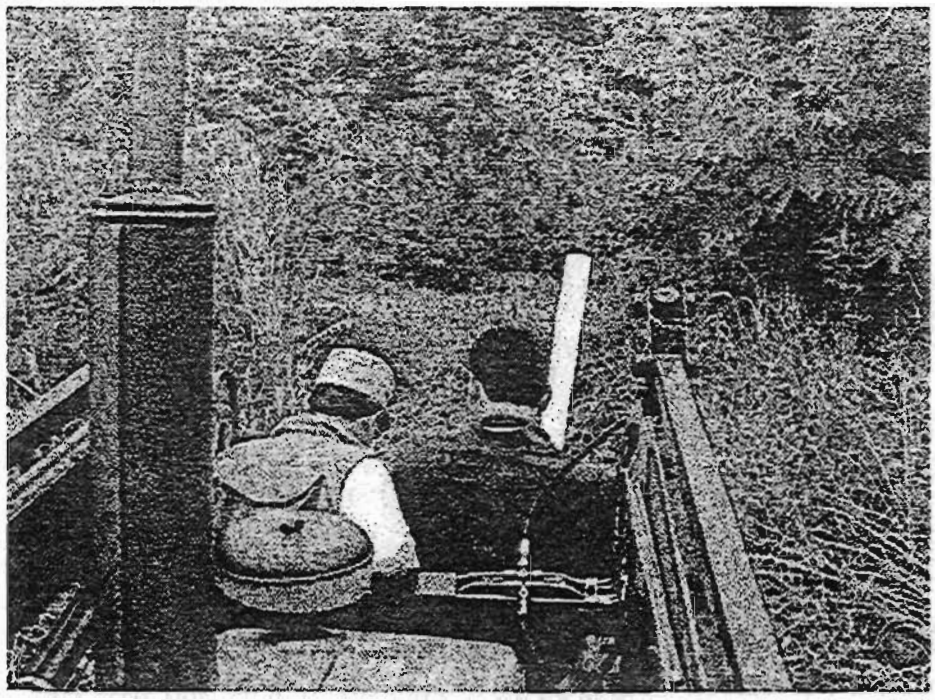


Photo 17. Western side of the Caño, approaching the edge. Note upland trees on the top of the river bank. Many of the grasses are FACW such as *Brachiaria purpurascens* and *Paspalum millegrana*.

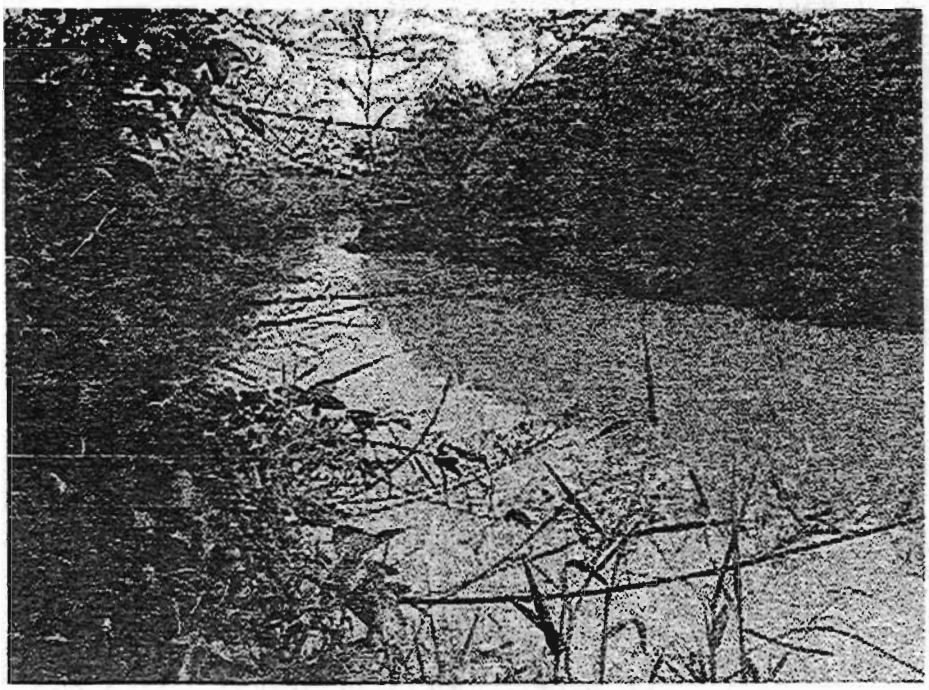


Photo 18. View downstream of the Caño from the west bank just downstream of the meanders. Trees near the water-line are mangroves (red and some white). Most are under 10 feet in height.

FACU), and the southern Aguadilla communities have developed up to the edges of the meanders at some points. The west bank is still largely in sugarcane production, with very deep furrows made to help drain the soils. Depressional areas have sedges and FACW grasses moving in. A drainage channel coming from the edge of Espinar community divides this area from the sedge dominated areas further north.

Small mangroves still occur on the Caño banks just downstream of the double meander (Photos 17 and 18). The size of the mangroves probably reflect the last time this Caño was mechanically cleaned out. While the Corps does not intend further alteration to the cut-off meander, the hydrology would be highly altered from an estuarine to a fresh-water ponding condition. Some of the trees would be eliminated, though it appears that most would be outside the immediate footprint of the levee.

Further upstream, to the southeast, the eastern dike would pass through a forested area and over two roads (Figure 4). The forest in this area has some mature mango trees, but is heavily dominated by *Albizia procera*, an introduced legume that colonizes old cane fields and disturbed areas. *Albizia* tends to form monocultures and provides little wildlife habitat value. While this species is often found in relatively wet soils on the edges of wetlands, it is considered to be an upland species.

Wildlife seen in the Caño Madre Vieja included a number of herons and egrets, smooth-billed anis (*Crotophaga ani*), and the red bishop (*Euplectes orix*). The presence of fiddler crabs in the vicinity of the double meander indicates that estuarine conditions occur at least that far upstream. Other likely fauna would include mongoose, rats, the cane toad (*Bufo marinus*), and other common amphibians, reptiles, and birds in the less disturbed areas with trees. The aquatic freshwater species of fishes and shrimps should occur in the Caño as well as the Culebrinas River.

Potential Project Impacts and Recommendations

The draft Environmental Assessment for the project estimates a wetland loss of approximately 0.5 acres of mangroves (under worst case scenario), and approximately 1.5 acres of wet prairie. It would also eliminate approximately 980 meters of active stream (meander to be cut off). The EA emphasizes that these are strictly estimates of direct impacts from the footprint of the levee, and do not include indirect or secondary impacts likely to occur in wetlands outside of the flood levees. The EA does not consider the fragmentation of wetlands by the dike and associated construction (including the small pilot channel and land to be disturbed during the construction phase). Estimated impact width for the levee footprint includes: a side access on the inside of the levee (5m), the levee footprint (approximately 21m with side slopes), access between the levee and small pilot channel (9m), pilot channel on the outside of levee (7m), and 4m of disturbed area outside of the pilot channel. The total width of the disturbed area would be approximately 46m or 150 feet. Permanent impacts would likely be less, but should include at least the levee footprint to the pilot channel (approximately 21 m).

Indirect and secondary impacts should receive careful consideration as they are likely to be

greater and have longer term impacts on the Caño's wetlands than the direct impacts. Indirect effects would be likely to include hydrology modifications to wetlands lying outside the flood levee and meander wetlands to be cut off by the diversion channel within the flood levees. Secondary impacts would include the liklihood that wetlands remaining outside of the levees would be filled for urban expansion.

Much of the alignment of the eastern levee would lie within uplands, except where it passes in the vicinity of the mangrove wetlands near the school and where it cuts off the Caño meanders. The eastern levee would impinge on the edge of the mangrove fringed channel between the track and Colegio San Carlos, and the impact area is likely to be small as this is a much more restricted forested wetland area than the mangrove channel next to Espinar. The major impact to the meander to be cut off would be due to the cut-off channel within the levee. The tendency over time should be for this meander to fill with sediment since the only hydrology would be provided by the one-way drainage structure through the dike. At the least, the character of the channel and any associated wetlands would change.

The western dike, as currently contemplated cuts across a small portion of the mangrove forest and channel near Espinar and bisects the relatively large herbaceous (sedge dominated) wetland south of the mangroves. The hydrology currently supporting the mangroves is likely to be altered. As mentioned above, the seaward end of the dike, including the mangrove channel crossing, lies within Coastal Barrier PR-75. The two-way culvert being proposed for maintaining hydrology to the Espinar mangrove channel is only 2 feet in diameter. Heavy flood waters moving down this channel would be drained through additional one way drainage structures. Our understanding is that the sizing of the two-way culvert was based on a need to prevent back-flow flooding into the side channel as the flood stage rises on the main channel within the dikes. Apparently this is also based on the assumption of continued partial closing of the Caño, forcing flood levels to as high as 2 meter near the mouth of the Caño. Heavy flooding has traditionally opened this mouth, and the mouth rarely closes now due to the groin/breakwater modifications and periodic maintenance by the municipality.

The original version of the two-levee alternative (Figure 3) included a flood ring levee immediately adjacent to the south, east and north sides of Espinar community. The variation to include the church could still be used within this alternative. That alternative would have impinged on the mangrove channel immediately adjacent to the northeast part of Espinar community, but would have remained south of the back-berm herbaceous and forested wetlands and Coastal Barrier Unit PR-75 and it would have avoided impacts to the sedge dominated wetlands south of the mangroves. The mangroves that would be impacted could be mitigated by relocating the portion of the channel to be impacted slightly eastward and replanting mangroves.

If the currently favored alternative can still be developed under the Coastal Barriers Resources Act, we strongly recommend that the Corps consider installing a larger two-way culvert to maintain tidal flows in the mangrove channel. Reducing the hydraulic capacity of this channel would be likely to encourage sedimentation upstream of the culvert. While the general tendency of flows in the existing mangrove channel is seaward, the persistence of mangroves far upstream along this channel indicates that seawater moves in as a tidal salinity wedge, at least during

spring tides (or normal tides in low rainfall periods). Maintaining adequate two-way flow may be critical to maintaining this system. The additional one-way flood-plain culverts should be slightly elevated above the two-way culvert to encourage the normal flows to continue passing through the principal two-way culvert, and to maintain the existing hydrology in the wetlands upstream.

Wetlands outside of the dike are supposed to be maintained as ponding areas to reduce community flooding, and allow these areas to drain out as flood levels recede within the flood dikes. The Corps should stipulate how these ponding areas would be maintained. Considerations for maintaining these areas as wetlands should include careful evaluation of the elevations of the one-way drainage structures through the dikes. If these ponding areas are not protected through acquisition and posting, they area likely to be developed in a piece-meal fashion through incidental filling and should be considered as part of the secondary impacts of the project.

For wetland impacts that cannot be avoided, we believe that significant opportunities exist within the flood levee dikes for wetland restoration, and possibly some creation. The presence of young mangroves far up the channel of Caño Madre Vieja indicates that the area has probably been periodically altered through channel clearing. Mangroves could be planted, and to some degree, allowed to naturally colonize the Caño margins. Post-project conditions within the dike floodway area may preclude the little agricultural use currently occurring there. Without maintenance of existing drainage channels, more of the area would be likely to revert to wetlands. This obviously depends on the future plans for agricultural use and sand/earth extraction in the area.

The sedge dominated area on the west side of the Caño near the mangrove forest would be particularly suitable for estuarine and freshwater forested wetland restoration. Since this area would lie mostly outside the flood levee, protection of this area from future development would be critical. If no use restrictions are put on these wetlands, they should be considered to be part of secondary project impacts. The upstream portions of this area may be capable of supporting fresh-water wetland trees such as swamp apple (*Annona glabra*), (*Maechaerium lunatum*), and swamp bloodwood *(Pterocarpus officinalis*). Freshwater forested wetlands in similar positions on the landscape used to be quite abundant in Puerto Rico, but were largely eliminated by clearing for agriculture early in this century. A *Pterocarpus officinalis* forest (Caño Boquilla) occurs on a similar small drainage associated with the Añasco River to the south and is in the process of becoming a Natural Reserve.

In summary, we recommend that the preferred alternative be re-evaluated to avoid impacts within Coastal Barrier PR-75. If the Corps determines that the project can still proceed as proposed under CBRA, careful consideration should be given to the capacity of the two-way culvert to maintain hydrology to the mangrove channel. The wetland areas outside of the flood dikes would also have to be protected in some manner and the drainage culvert elevations would be critical to maintaining these wetlands. Mitigation needs could be met through development of additional estuarine and freshwater forested wetlands within the flood levees.

C. CLEAN WATER ACT SECTION 404 (b)(1) EVALUATION AND MITIGATION PLAN

The proposed levees will impact through fill deposition a 0.2-acre red mangrove area, a 1.5-acre emergent prairie area, and 35.55 acres of wet prairie within the projected footprint. These are currently used as pastureland. Hydrologic flow through the area comprised between both planned levees will be unaltered.

The work should not result in violations of water quality standards. Water quality will not be adversely impacted by this project, and Commonwealth water quality standards will be met. Contaminants will not be introduced by clean fill material that may become suspended or dissolved in the river water during the construction operations. Short-term increases in the turbidity are expected during the construction phase of the project; however, the system will re-establish itself as a productive part of the overall ecosystem. No long-term surface water quality problems will result.

Full compliance will be achieved with issuance of a water quality certificate (WQC) from the Environmental Quality Board of Puerto Rico. WQC issuance is expected, but Commonwealth procedures require application to begin after NEPA coordination is completed, not before.

CESAJ-PD-EE (200) 13 July 1995

MEMORANDUM FOR Chief, Environmental Studies Section

SUBJECT: Rio Culebrinas Water Quality (404), Air Quality, and HTRW Input

1. Enclosed is a copy of the water quality, air quality, and HTRW Civil Works Report for subject project for your use. The report is summarized below.

2. Water Quality. Water Quality will not be adversely impacted by this project, and Commonwealth water quality standards will be met. Contaminants will not be introduced by clean fill material that may become suspended or dissolved in the river water during the construction operations. Short term increases in turbidity are expected during the construction phase of the project; however, the system will re-establish itself as a productive part of the overall ecosystem. No long-term surface water quality problems will result.

3. Air Quality. No adverse effects on air quality will result from the implementation of the proposed project. Fugitive dust may be generated by excavation and deposition of fill material, as in the construction of levees. All dust and pollution suppression measures and equipment required under Federal and Commonwealth laws and regulations will be utilized during project construction.

4. Hazardous Toxic and Radiological Wastes (HTRW). Preliminary research (background information, literature search, etc.) revealed that no known sources of HTRW materials exist in the directly impacted portions of the project corridors. A civil works audit as defined in ER-1165-2-132 for HTRW materials was conducted in May of 1995. The following signs of potential HTRW problems were not identified: landfills, dumps, and disposal areas; burning or burned areas; tanks; vats, lagoons, ponds, and basins sludge pits; pits, quarries, and borrow areas; wells; containers of unidentified substances; spills, seepage, and slicks; odors; dead or stressed vegetation; water treatment plants; ditches, trenches, or depressions; mounds and dirt piles; transport areas, such as boat or rail yards, harbors, airports, and truck terminals; and abandoned buildings. No sites with potential for contamination with HTRW were found. Additional trip reports, photos, and other documentation are on file in the CESAJ District office.

5. POC for this work is Mr. Ivan Acosta at X1693.

Encl

JAMES J. MC ADAMS
Chief, Environmental
Quality Section

WATER QUALITY, AIR QUALITY AND HTRW CIVIL WORKS REPORT FOR RIO CULEBRINAS AT AGUADILLA, PUERTO RICO.

1. HAZARDOUS TOXIC RADIOLOGICAL WASTE (HTRW) INITIAL ASSESSMENT (Reconnaissance Phase). An initial HTRW assessment was conducted for a Section 205 Flood Control project to be located along Rio Culebrinas at Aguadilla, Puerto Rico. (see attachments 1 and 2 for location and vicinity maps). This assessment also included an investigation of the water quality and air quality potential impact in the project area. The assessment addresses the existence of, or potential for, HTRW contamination on lands, structures and submerged lands in the study area, or external HTRW contamination which could impact or be impacted by the proposed project. Contamination problems will be considered in determining whether to proceed to the feasibility phase. The assessment will help identify and develop the level of effort to be undertaken in the feasibility phase.

a. Level of effort. Consideration of HTRW in the initial assessment phase involves the same level of detail given to other engineering, economic, real estate, and environmental aspects of the project. This initial HTRW assessment of the project area relied primarily on existing documents, interviews, and observations gathered during the conduct of a site visit.

b. Procedures. The following was documented.

i. Land Uses: The predominant land usage in the project area consists of agriculture and poses little or no HTRW threat. The proposed work will be carried out from Highway 2 to high ground at Espinar community.

ii. Adjacent Problems: In an interview with Felix Lopez, US Fish and Wildlife Services representative, it was indicated that the area presented no adverse impacts or HTRW threat.

iii. Soils: The principal soil types found in the Rio Culebrinas basin area are the Valdora-Moca, Colinas-Soler, Caguabo-Mucara, and the Consumo-Humatas in the uplands and the Coloso-Toa and Bejucos-Jobos in the lower flood plain. These soils are predominantly of the "D" type, indicating high runoff potential. Type "B" soils, indicating moderate drainage potential, are also found within the basin. The principal soil type surrounding the proposed work site Coloso-Toa.

According to the U.S. Weather Bureau climatological zone designations, the upper part of the basin lies within the western interior zone; the northern part and flood plain are in the northern slopes zone.

iv. Photos: Current and historical photographs have been studied and compared to assist in identifying potentially contaminated sites/structures (see attachment 3). No evidence of contaminated sites was found.

v. History: The Rio Culebrinas flood control project is located on the northwestern coast of Puerto Rico at Aguadilla, approximately 130 kilometers (81 miles) from the city of San Juan. The river flows in a westerly direction through the municipalities of Lares, San Sebastian, Moca, Aguada, and Aguadilla to discharge into the Aguadilla Bay. The basin is bordered on the north, south, and east by other river basins, and on the west by the bay.

Since the turn of the century, there have been at least 38 damaging floods on the Rio Culebrinas Basin. The largest flood of record occurred on September 16, 1975. This flood had an estimated recurrence interval of approximately 25 years. The discharge associated with this flood was estimated at 1,954 cms (69,000 cfs), and stages just downstream of Highway 2, where ground elevation averages about 4.0 meters, reached about 7.2 meters (23.6 feet) above mean sea level. Other large floods in the Rio Culebrinas for which records are available occurred in October 1972, May 1980, October 1981, May 1985, May 1986 and August 1988. The dates of these events, elevations above mean sea level (msl), and their respective peak discharges in cubic meters per second (cms) as determined by the United States Geologic Survey (USGS) at the Moca gaging stations are shown on Table 1 of the Reconnaissance Report dated March 1992.

vi. Records Search: Appropriate available records, such as community right-to-know records have been reviewed. Also contacted was the U.S. Fish and Wildlife Service and the Puerto Rico Environmental Quality Board (EQB), with the same results as mentioned above. No problems were identified.

vii. Anecdotal Evidence: To obtain additional information, long-time local residents or workers were interviewed about past land uses, potential contamination, and any history of HTRW problems. No HTRW problems were identified.

viii. Agency Coordination: Federal, State, and local regulatory or response agencies were consulted for license/permit actions, for any violations, enforcement actions, and/or litigation against property owners, and for general information about local HTRW problems such as illegal dumping and past contamination, etc. No other problems were found.

ix. Site Visitation Sheet: A visual survey of the proposed project site was made to determine the potential for HTRW. No evidence of surface contamination or partially buried containers, discolored soil, seeping liquids, films on water, abnormal or dead vegetation or animals, suspect odors, dead-end pipes, abnormal grading, fills, or depressions were observed.

a. An experienced Environmental Engineer was part of the team doing field visits and made record searches, interviews, and on-site visual evaluation for possible HTRW contamination.

b. Results. A preliminary assessment was conducted in May 1995 to address the existence or potential for occurrence of HTRW contamination on lands, including structures and submerged lands, in the Rio Culebrinas project/study area in Aguadilla, Puerto Rico. The preliminary assessment for the project/study area included a project review, site literature/document review, and site reconnaissance. During each assessment, the following signs of potential HTRW problems were looked for:

Landfills, dumps, disposal areas
Burning or burned areas
Tanks (underground surface)
Vats, lagoon, ponds or basins sludge pits
Excavations (pits, quarries borrow areas)
Wells
Containers of unidentified substances
Spills, seepage, slicks

Odors
Dead or stressed vegetation (brown, spotted curled or withered leaves)
Water treatment plants
Ditches, trenches, depressions
Mounds and dirt piles
Transport areas (i.e. boat yards, harbors, rail yards, airports, truck terminals)
Abandoned buildings

c. There is refuse floating on the canal, (see attachment 3 for photographs of the area). The components of the refuse are garbage, food wastes, and rubbish which includes glass, tin cans and paper. This could present a direct threat to human health in the future. The relationship between solid wastes and human diseases should be apparent. Improper disposal of solid wastes is a definite health hazard, which can serve as the catalyst for the spread of at least 22 human diseases. The most important vectors (vectors are means by which disease organisms are transmitted) of human diseases in regard to solid wastes are rats and flies (water, air and food can be factors). The fly is a prolific breeder (70,000 flies can be produced in 1 cubic foot of garbage) and a carrier of many diseases, e.g., bacillary dysentery. Rats destroy property and can cause infection by direct bite; they are also dangerous as carriers of insects which can also act as vectors. Refuse is unsightly, unhealthy, and damaging to the wildlife.

The refuse appears to be primarily municipal solid waste and debris rather than excavatable dirt. We recommend that the refuse be removed from the Rio Culebrinas and properly disposed of in a sanitary landfill. Also is recommended that a public awareness campaign (newsletter, signs, etc.) be developed in the project area and vicinity to avoid further contamination and to address the impact to human, wildlife, and aquatic environments.

d. Resolution of HTRW issues. No issues were found.

e. Sponsor's commitment. The Feasibility Cost Sharing Agreement (FCSA) will state that the development of a response plan for dealing with any HTRW discovered is a 100 percent non-Federal cost as stated in Engineering Regulation 1165 -2- 132 "Water Resources Policies and Authorities - HTRW Guidance for Civil Works Projects", dated June 1992.

2. WATER QUALITY. The EQB has designated the waters of Rio Culebrinas as class SD. According to USGS, the water from Rio Culebrinas is of good quality and suitable for most purposes. Short term local increases in water turbidity are expected due to construction activities. All appropriates measures required by EQB regulations would be adopted. It is believed that conditions will return to normal soon after construction activities have terminated. A data base analysis of the historical data available was performed on the EPA STORET system and the USGS Water Resources Data-Puerto Rico and U.S. Virgin Islands, with the following results; one station was reported to collect data from the vicinity of the proposed area between 1968 to 1989. This station collected samples to test for inorganic and bacterial constituents in water. Two stations upstream from the proposed work site were also studied. These stations collected samples to test for organic, inorganic, and bacterial constituents in water. The values reported from these stations comply within the EQB Parameters for waters with the SD classification, with certain exceptions. Fecal contamination may be the most serious water quality problem. In addition, the data reflected concentrations of lead greater than EQB specifications.

Hydrologist, Senen Guzman, USGS Puerto Rico, suggested that these elevated levels were most likely due to urban runoff from the city of San Sebastian and were fairly typical of the area.

3. AIR QUALITY. The air quality in the Rio Culebrinas area is good due to the presence of either on-, or off-shore coastal breezes. The EQB, Air Quality Division has classified the Rio Culebrinas project area as an attainment area. No appreciable decrease in air quality is expected in the future because of the presence of either on-, or off-shore coastal breezes. Fugitive dust can be generated by excavation and deposit of fill material, as in the construction of levees. All appropriate measures required by EQB regulations will be adopted during construction.

STATEMENT OF WORK

Prepared By:

Signed: Brenda W. Stamps — 5 July 1995
Brenda W. Stamps, Biologist — Date
Environmental Quality Section
USACOE - Jacksonville District

Signed: — 7/5/95
Ivan Acosta, Environmental Engineer — Date
Environmental Quality Section
USACOE - Jacksonville District

Reviewed By:

Signed: — 7/6/95
James McAdams, Chief Environmental Quality Section — Date
USACOE - Jacksonville District

Approved By:

Signed: Kenneth R. Dragg — 7/6/95
for Hanley K. Smith, Chief Environmental Resources Branch — Date
USACOE - Jacksonville District

SECTION 404(b) EVALUATION

Flood Control Project
Río Culebrinas
Aguada and Aguadilla, Puerto Rico

I. Project Description

a. Location. The proposed work will be performed Caño Madre Vieja and Río Culebrinas, between the municipalities of Aguada and Aguadilla, Puerto Rico.

b. General Description. The proposed plan calls for the construction of two flood control levees to separate the last downstream segment of Caño Madre Vieja from adjoining residential communities. Other project features are: a short cutoff channel, to connect two meanders of the stream where the Aguadilla Levee will interrupt it, four drainage structures, interior drainage channels, and a commercial borrow area located in Aguada.

c. Authority and Purpose. This study and proposed project were developed under the authority of Section 205 of the 1948 Flood Control Act, as amended.

d. General Description of Dredged or Fill Material.

(1) General Characteristics of Material. Clean, toxic contaminant-free fill will be used.

(2) Quantity of Material. Approximately 110,000 cubic yards of fill. And 1,000 cubic yards of spoil fill.

(3) Source of Material. Approximately 30,000 cubic yards would come from the cutoff and drainage channels and the rest from the commercial borrow site at nearby Tablonal Quarry.

e. Description of the proposed Discharge Site.

(1) Location. Most spoil fill will be disposed of within the right-of-way of the levees, on top or on the sides slopes as topsoil. Any spoil fill or debris that cannot be disposed of in that manner will be disposed of in the municipal landfill in use by the Municipalities of Agüadilla and Aguada at the time the work takes place.

(2) Size. The approximately 19.6 acres. Area of the levee footprints. And the minimal debris and spoil found to be unsuitable will go in the existing landfills.

(3) Type of Site. Mostly uplands pastureland.

(4) Type of Habitat. Footprint of the levees

(5) Timing and Duration of Discharge. Duration of the actual levee construction.

f. Description of Disposal Method. Transportation over existing roads, using commercial trucks. Deposition at existing municipal sanitary landfills.

II. Factual Determinations

a. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. Both levees would have an average structural height of 2.5 meters, 1 on 2.5 side slopes, an average levee base of 16 meters, and a levee crest width of 3 meters.

(2) Sediment Type. Sandy silt.

(2) Dredge/Fill Material Movement. Material to be excavated by backhoe and carried to final destination using dump trucks.

(4) Physical Effects on Benthos. No effect is expected on the Benthic habitat.

b. Water Circulation, Fluctuation and Salinity Determination.

(1) Water Column Effects. These are Class SD waters. No changes are expected.

(2) Current Patterns and Circulation. Existing fast water flow patterns for the Culebrinas River will remain unchanged.

(3) Normal Water Level Fluctuations and Salinity Gradients. No changes are expected.

c. Suspended Particulate/Turbidity Determinations.

(1) Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Disposal Site. None expected. The disposal site is the footprint of the levee and the municipal landfill, no permanent turbidity level changes are

expected during deposition. The acceptable turbidity levels in the Culebrinas River (50 NTUs) will not be exceeded.

(2) Effects on the Chemical and Physical Properties of the Water Column.

(a) Light Penetration. Since no significant changes in turbidity are expected, no significant changes in light penetration are expected, either.

(b) Dissolved Oxygen. The amount of dissolved oxygen 5.0 mg/L (PPM) is not expected to vary.

(c) Toxic Metals, Organics, and Pathogens. No increase expected in these parameters.

(d) Aesthetics. The earthen levees will be re colonized by the existing vegetation, blending with the surroundings

(3) Effects on Biota.

(a) Primary Productivity and Photosynthesis. No effect.

(b) Suspension/Filter Feeders. No effect.

(c) Sight Feeders. No effect.

d. Contaminant Determinations.

e. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. None.

(2) Effects on Benthos. None.

(3) Effects on Nekton. None.

(3) Effects on the Aquatic Food Web. None.

(5) Effects on Special Aquatic Sites.

(a) Hardground and Coral Reef Communities. Doesn't apply.

(b) Sanctuaries and Refuges. Not applicable.

(c) Wetlands. The project will impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands, and having a total biological value of 1 unit in accordance with the Wetlands Rapid Assessment Procedure Methodology (WRAP). Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie.

(d) Mud Flats. Not applicable.

(e) Vegetated Shallows. Not applicable.

(f) Riffle and Pool Complexes. Not applicable.

(6) Endangered and Threatened Species. No endangered species was identified in the work area.

(7) Other Wildlife. Not applicable.

(8) Actions to Minimize Impacts. The design and footprint of the project were modified to avoid work inside the wetlands of Coastal barrier PR-75.

f. Proposed Disposal Site Determinations.

(1) Mixing Zone Determination. Not applicable.

(2) Determination of Compliance with Applicable Water Quality Standards. Fill deposition will occur within the footprints of the levees on existing pasturelands. Other deposition will be in contained, approved municipal landfills. The Corps has thus determined that the proposed work complies with Applicable Water Quality Standards.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supplies. Not applicable.

(b) Recreational and Commercial Fisheries. Not applicable.

(c) Water Related Recreation. Not applicable.

(d) Aesthetics. No aesthetic changes are foreseen, the levees will be re-colonized by the local vegetation.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves. Not applicable.

g. Determination of Cumulative Effects on the Aquatic Ecosystem. None expected.

h. Determination of Secondary Effects on the Aquatic Ecosystem. None expected.

III. Findings of Compliance or Non-compliance with the Restrictions on Discharge.

a. No significant adaptations of the guidelines were made relative to this evaluation.

b. No practicable alternative exists which meets the study objectives that does not involve discharge of fill into waters of the United States.

c. After consideration of disposal site dilution and dispersion, the discharge of fill materials will not cause or contribute to, violations of any applicable State water quality standards for Class III waters. The discharge operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

d. The construction of the levees and associated canal cut will not jeopardize the continued existence of any species listed as threatened or endangered or result in the likelihood of destruction or adverse modification of any critical habitat as specified by the Endangered Species Act of 1973, as amended.

e. The placement of fill material will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreational and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic species and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values will not occur.

f. On the basis of the guidelines, the proposed disposal site for the discharge of dredged material is specified as complying with the requirements of these guidelines.

SECTION 404(b) EVALUATION

Flood Control Project
Río Culebrinas
Aguada and Aguadilla, Puerto Rico

I. Project Description

a. Location. The proposed work will be performed Caño Madre Vieja and Río Culebrinas, between the municipalities of Aguada and Aguadilla, Puerto Rico.

b. General Description. The proposed plan calls for the construction of two flood control levees to separate the last downstream segment of Caño Madre Vieja from adjoining residential communities. Other project features are: a short cutoff channel, to connect two meanders of the stream where the Aguadilla Levee will interrupt it, four drainage structures, interior drainage channels, and a commercial borrow area located in Aguada.

c. Authority and Purpose. This study and proposed project were developed under the authority of Section 205 of the 1948 Flood Control Act, as amended.

d. General Description of Dredged or Fill Material.

(1) General Characteristics of Material. Clean, toxic contaminant-free fill will be used.

(2) Quantity of Material. Approximately 110,000 cubic yards of fill. And 1,000 cubic yards of spoil fill.

(3) Source of Material. Approximately 30,000 cubic yards would come from the cutoff and drainage channels and the rest from the commercial borrow site at nearby Tablonal Quarry.

e. Description of the proposed Discharge Site.

(1) Location. Most spoil fill will be disposed of within the right-of-way of the levees, on top or on the sides slopes as topsoil. Any spoil fill or debris that cannot be disposed of in that manner will be disposed of in the municipal landfill in use by the Municipalities of Agüadilla and Aguada at the time the work takes place.

(2) Size. The approximately 19.6 acres. Area of the levee footprints. And the minimal debris and spoil found to be unsuitable will go in the existing landfills.

(3) Type of Site. Mostly uplands pastureland.

(4) Type of Habitat. Footprint of the levees

(5) Timing and Duration of Discharge. Duration of the actual levee construction.

f. Description of Disposal Method. Transportation over existing roads, using commercial trucks. Deposition at existing municipal sanitary landfills.

II. Factual Determinations

a. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. Both levees would have an average structural height of 2.5 meters, 1 on 2.5 side slopes, an average levee base of 16 meters, and a levee crest width of 3 meters.

(2) Sediment Type. Sandy silt.

(2) Dredge/Fill Material Movement. Material to be excavated by backhoe and carried to final destination using dump trucks.

(4) Physical Effects on Benthos. No effect is expected on the Benthic habitat.

b. Water Circulation, Fluctuation and Salinity Determination.

(1) Water Column Effects. These are Class SD waters. No changes are expected.

(2) Current Patterns and Circulation. Existing fast water flow patterns for the Culebrinas River will remain unchanged.

(3) Normal Water Level Fluctuations and Salinity Gradients. No changes are expected.

c. Suspended Particulate/Turbidity Determinations.

(1) Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Disposal Site. None expected. The disposal site is the footprint of the levee and the municipal landfill, no permanent turbidity level changes are expected during deposition. The acceptable turbidity levels in the Culebrinas River (50 NTUs) will not be exceeded.

(2) Effects on the Chemical and Physical Properties of the Water Column.

(a) Light Penetration. Since no significant changes in turbidity are expected, no significant changes in light penetration are expected, either.

(b) Dissolved Oxygen. The amount of dissolved oxygen 5.0 mg/L (PPM) is not expected to vary.

(c) Toxic Metals, Organics, and Pathogens. No increase expected in these parameters.

(d) Aesthetics. The earthen levees will be re colonized by the existing vegetation, blending with the surroundings

(3) Effects on Biota.

(a) Primary Productivity and Photosynthesis. No effect.

(b) Suspension/Filter Feeders. No effect.

(c) Sight Feeders. No effect.

d. Contaminant Determinations.

e. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. None.

(2) Effects on Benthos. None.

(3) Effects on Nekton. None.

(3) Effects on the Aquatic Food Web. None.

(5) Effects on Special Aquatic Sites.

(a) Hardground and Coral Reef Communities. Doesn't apply.

(b) Sanctuaries and Refuges. Not applicable.

(c) Wetlands. The project will impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands, and having a total biological value of 1 unit in accordance with the Wetlands Rapid Assessment Procedure Methodology (WRAP). Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie.

(d) Mud Flats. Not applicable.

(e) Vegetated Shallows. Not applicable.

(f) Riffle and Pool Complexes. Not applicable.

(6) Endangered and Threatened Species. No endangered species was identified in the work area.

(7) Other Wildlife. Not applicable.

(8) Actions to Minimize Impacts. The design and footprint of the project were modified to avoid work inside the wetlands of Coastal barrier PR-75.

f. Proposed Disposal Site Determinations.

(1) Mixing Zone Determination. Not applicable.

(2) Determination of Compliance with Applicable Water Quality Standards. Fill deposition will occur within the footprints of the levees on existing pasturelands. Other deposition will be in contained, approved municipal landfills. The Corps has thus determined that the proposed work complies . with Applicable Water Quality Standards.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supplies. Not applicable.

(b) Recreational and Commercial Fisheries. Not applicable.

(c) Water Related Recreation. Not applicable.

(d) Aesthetics. No aesthetic changes are foreseen, the levees will be re-colonized by the local vegetation.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves. Not applicable.

g. Determination of Cumulative Effects on the Aquatic Ecosystem. None expected.

h. Determination of Secondary Effects on the Aquatic Ecosystem. None expected.

III. Findings of Compliance or Non-compliance with the Restrictions on Discharge.

a. No significant adaptations of the guidelines were made relative to this evaluation.

b. No practicable alternative exists which meets the study objectives that does not involve discharge of fill into waters of the United States.

c. After consideration of disposal site dilution and dispersion, the discharge of fill materials will not cause or contribute to, violations of any applicable State water quality standards for Class III waters. The discharge operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

d. The construction of the levees and associated canal cut will not jeopardize the continued existence of any species listed as threatened or endangered or result in the likelihood of destruction or adverse modification of any critical habitat as specified by the Endangered Species Act of 1973, as amended.

e. The placement of fill material will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreational and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic species and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values will not occur.

f. On the basis of the guidelines, the proposed disposal site for the discharge of dredged material is specified as complying with the requirements of these guidelines.

D. COASTAL ZONE MANAGEMENT ACT COORDINATION – Certification of Compliance with PR Coastal Management Plan and Application for Concurrence from PR Planning Board.

At this time the study and recommended plan have been determined to be in compliance with the major programs and objectives of the Puerto Rico Coastal Management Program. Concurrence from the Puerto Rico Planning Board (PRPB) will be sought when the public comment period on this EA has closed.

E. SITE VISIT MEMORANDUM AND WRAP SCORE SHEETS

Project completion will directly impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands and 0.2-acre of Red mangrove swamp. These were assessed to have a total biological value of 1 unit, using the Wetlands Rapid Assessment Procedure Methodology (WRAP). The score was 0.48 for the pasture and 0.56 for the Red mangrove. Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie. The USACE estimates that project completion will also result in the construction of drainage channels parallel to the levees. These will have an average width of approximately 7 meters (21feet) and will run for the entire length of the levees. This will create approximately
21 x 9,723 = 204,183 square feet or 4.69 acres of habitat for fish and amphibian species.

Assuming creation of at least 13 meters (40 feet) of shallow littoral area on both banks of each channel, an additional 8.93 acres of wetlands would be created. The USACE believes that the wetlands and waters of the United States created by the project would avoid a net loss of wetlands.

Present during the October 12, 1999 site visit: Beverly Yoshioka USFWS; Ana Román, USFWS; Jorge M. Tous, USACE; Esteban Jimenez, USACE.

CESAJ-PD-ES 12 October 1999

MEMORANDUM FOR RECORD

SUBJECT: Culebrinas River Flood Control (Aguadilla & Espinar Levees) Project Site Visit

1. Going west to east along the Aguadilla levee footprint (24.2 acres or 98,095 square meters including levee, drainage channel, ramps, and right of way), the start is an approximately 35% urban developed area. It continues along fields use for horses grazing. Sawgrass predominates with few depressional wetlands. Functional wetlands are 10% or less of the total footprint area of the proposed Aguadilla levee. These are found mostly halfway along the footprint.

2. A similar situation is seen along the Espinar levee proposed footprint (17.5 acres or 70,861 square meters including levee, drainage channel, ramps, and right of way). Upland herbaceous species and sawgrass predominate. Mangroves and cattail (*Typha spp.*) are found in 10% or less of the footprint area. The most impressive wetland vegetation is seen in an approximately 100-foot by 70-foot section of coastal barrier vegetated over 90% by climax red mangroves with a height over 50 feet . This exists in the margins of the drainage channel, which exist parallel to the coastline in a south-north attitude, no more than 500 feet inland and connecting to the estuary at the mouth of the Culebrinas River. Considerable sediment extrusion into the bay is seen at the Culebrinas River estuary.

3. For the projected cut at the central area approximately halfway between the two projected levees: The area currently includes drainage channels with flowing water, supporting mature white mangrove populations with approximately 90% coverage for some 25 feet from the existing channel margins. An mangrove juvenile and *Typha* understory dominates.

////////////////////////nothing follows//

ESTEBAN JIMENEZ
Biologist

EVALUATION SUMMARY

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.78

Evaluator(s): E. Jimenez

Project/Site: R. Culebrines (Espinor Levee at Coastal Barrier)
Permit Number:
Wetland ID:
Wetland Type: Saltwater Swamp
Land Use: Coastal Barrier and Run off channel

SCORE **NOTES**

2 Fish and Wildlife Utilization:

Slight human impact due to adjacent beach and area habitation.
Debris seen. No fish seen.
Crustacean burrows.

2.5 Overstory/Shrub Canopy:

Mature Red Mangrove > 90%

1.5 Ground Cover:

Juvenile Mangrove and Typha 40%

2.5 Upland/Wetland Buffer:

> 30', < 300'

2.5 Field Indicators of Wetland Hydrology:

Flowing water in channel.
Adequate hydroperiod.

3 Water Quality Inputs and Treatment:

Land Use 3 unimprov
natural

Pre-treatment 3 unimprov
natural

14
18

EVALUATION SUMMARY

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.33

Evaluator(s): E. Jimenez

Project/Site: R. Culebrinas (Espinor Levee)
Permit Number:
Wetland ID:
Wetland Type: Emergent (Freshwater Flat) prairie
Land Use: Agricultural Use

SCORE **NOTES**

0.5 Fish and Wildlife Utilization:

Cattle and associated bird species
No fish seen.

0.5 Overstory/Shrub Canopy:

Upland Spp. ~ 80%

0.5 Ground Cover:

~ 10% Cattail (Typha). Predominant upland Spp.

1.5 Upland/Wetland Buffer:

>30'. Connection to wildlife corridors

0.5 Field Indicators of Wetland Hydrology:

Altered wetland hydrology would require scrapedown.

2.5 Water Quality Inputs and Treatment:

Land Use 2.5 Ran

6/18

Pre-treatment 2.5 Berms

EVALUATION SUMMARY

Without Proje

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.33

Evaluator(s): E. Jimenez

Project/Site: Rio Culebrinas (Aguadilla Levee following Cano Madre Vieja)
Permit Number:
Wetland ID:
Wetland Type: Freshwater Flat (emergent prairie
Land Use: Horse/Cattle pasture

SCORE		NOTES
1	Fish and Wildlife Utilization:	Birds associated with cattle (i.e. egrets). No fish seen. Various crab burrows.
0	Overstory/Shrub Canopy:	No nesting. <10% in some depressional areas.
0.5	Ground Cover:	Typha and Buttonwood 10%
1.5	Upland/Wetland Buffer:	30'> x <300'. Wildlife corridor connections.
1	Field Indicators of Wetland Hydrology:	Transitional vegetation indicating interference with hydrology.
	Water Quality Inputs and Treatment:	Land Use 50% high de vegitation; 50% past Pre-treatment 1 dry rete 2.5 Berms

LU = 2.5(.5) + 2(.5)
= 1.25 + 1.0
= 2.25

6/12 2.25 + 1.75 = 4/2 = 2

EVALUATION SUMMARY

Without Project

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.76

Evaluator(s): E. Jimenez

Project/Site: R. Culebrinas (Planned cutoff between Espinar and Aguadilla)
Permit Number:
Wetland ID:
Wetland Type: Mangrove forest and existing channel.
Land Use: Undeveloped.

SCORE		NOTES
2	Fish and Wildlife Utilization:	No fish seen. Birds (crane) seen. Rodents crabs and burrows.
3	Overstory/Shrub Canopy:	Over 90% mature mangrove (white)
2	Ground Cover:	Wetland spp., Mangrove juveniles.
2	Upland/Wetland Buffer:	30' > x < 300', undeveloped. Connected to possible wildlife corridors.
2	Field Indicators of Wetland Hydrology:	Standing water with high hydroperiod. Supports wetland vegetation.
2.75	Water Quality Inputs and Treatment:	Land Use 3 Open = a Pre-treatment 2.5 wet de swales.

$\frac{13.75}{18} = 0.76$ $\frac{3+2.5=5.5}{2 \quad 2} = 2.75$

RIO CULEBRINAS AT AGUADILLA AND AGUADA, PUERTO RICO
SECTION 205
FINAL DETAILED PROJECT REPORT
AND ENVIRONMENTAL ASSESSMENT

APPENDIX A
HYDROLOGY AND HYDRAULICS

RIO CULEBRINAS
AGUADA/AGUADILLA, PUERTO RICO
DETAILED PROJECT REPORT

APPENDIX A
HYDROLOGY AND HYDRAULICS

TABLE OF CONTENTS

I. INTRODUCTION. A-1

II. DRAINAGE BASIN INFORMATION. A-1

A. Location. A-1
B. Topography. A-1
C. Geology, Soils and Vegetation A-1
D. Climate A-2
E. Main Streams and Tributaries. A-2
F. Available Hydrologic Data A-2
G. Historical Floods A-2
H. Flood Flow Frequency Analysis A-3
I. Rainfall. A-3

III. HYDROLOGIC ANALYSIS A-4

A. Computer Programs A-4
B. Formation of HEC-1 and UNET Models. A-4
1. Drainage Area A-4
2. Curve Numbers A-4
3. Lag Times A-4
4. Rainfall. A-5
5. Flood Routings. A-5
6. Discharge for Existing Conditions with Future Land Uses A-5
C. Hydrology of Interior Flooding. A-6
D. Other Sources of Flooding A-6

IV. HYDRAULICS. A-7

A. Existing Conditions A-7
1. Hydraulic Model A-7
2. Survey Data A-7
3. Roughness Coefficients. A-7
4. Starting Conditions A-7
5. Model Verification. A-8
6. Flood Stages. A-8
B. Sediment Assessment A-8
1. Existing Conditions A-8
2. With Project Conditions A-8

V. HYDRAULIC DESIGNS A-9

A. Hydraulic Design Criteria A-9
B. Design Objective. A-9
C. Levees. A-9
1. Aguadilla Levee A-10
2. Espinar Levee A-10
3. Side Slopes A-10
4. Levee Crest Elevation A-10
5. Levee Overtopping Analysis. A-11
6. Reliability Analysis of the Selected Levees. A-12
D. Channels. A-12
1. Cutoff Channel. A-12
2. Interior Drainage Channels. A-13
E. Drainage Structures A-13
1. Aguadilla Levee A-13
a. AL-S-1. . . . . A-13
b. AL-S-2. . . . . A-13
c. AL-S-3. . . . . A-13
2. Espinar Levee A-14
a. EL-S-1a A-14
F. Road Ramps. A-14
G. Borrow Area A-14
H. Performance A-14
1. Levee Design Protection A-14
2. Residual Flooding A-15
3. People at Risk. A-16

LIST OF FIGURES

TITLE	FIGURE NO.
Location Map with Basin and Sub-Basins	A-1
100-Year Flood Hydrograph at Mouth of Rio Culebrinas	A-2
100-Year Flood Hydrograph at Mouth of Cano Madre Vieja	A-3
Flow Frequency at United States Geological Survey (USGS) Gage No. 50147800	A-4
Rating Curve Between Rio Culebrinas and Cano Madre Vieja	A-5

LIST OF TABLES

TITLE	TABLE NO.
Historical Flood Data for Rio Culebrinas	A-1
Rainfall for Various Frequencies and Durations	A-2
Watershed Parameters	A-3
Summary of Peak Discharges	A-4
Wave Run-up and Wind Set-up.	A-5
Existing and With Project Water Surface Elevations	A-6
100-Year Levee Crest Elevations.	A-7
Hydraulic Design Data Interior Drainage Structures	A-8
Hydraulic Design Data Interior Drainage Channels	A-9
Hydraulic Design Data Cutoff Channel	A-10
Interior Flood Hydrology	A-11
Interior Drainage - Residual Flood Elevations.	A-12
Reliability Analysis at Levee Cross Section 1568	A-13

LIST OF PLATES

TITLE	PLATE NO.
Existing Conditions Flooded Areas (5 and 100-yr)	A-1
Recommended Plan	A-2
Residual Flooded Areas	A-3
Aguadilla Levee Profile 100-Year	A-4
Espinar Levee Profile 100-Year	A-5
Espinar Levee Spur Profile 100-Year.	A-6

I. INTRODUCTION

This appendix presents the basic hydrologic data and analyses used to define the flooding conditions for the Rio Culebrinas Detailed Project Report.

II. DRAINAGE BASIN INFORMATION

A. Location

The Rio Culebrinas basin is located in the northwestern part of the island of Puerto Rico, about 130 kilometers from the City of San Juan. The basin is bordered to the north and east by the Rio Guajataca basin, to the south by the Rio Culebra and Rio Grande de Añasco basins, and to the west by Aguadilla Bay. There are no impounding reservoirs within the river basin. The drainage area of the watershed is about 322.6 square kilometers. Figure A-1 shows where the study area is located in Puerto Rico along with the basin and subbasins of Rio Culebrinas.

B. Topography

The basin is considered a fairly gently sloping basin with elevations ranging from sea level at Aguadilla Bay, to over 300 meters near Juncal, at the basin divide between Rio Culebrinas and Rio Guajataca. A prominent feature of the basin is a 100-meter high limestone escarpment that extends along its northern boundary.

C. Geology, Soils and Vegetation

The principal soil associations found in the Rio Culebrinas watershed area are the Voladora-Moca, Colinas-Soler, Caguabo-Mucara, and the Consumo-Humatas, in the uplands and the Coloso-Toa and Bejucos-Jobos in the lower flood plain. These soils are mostly of the D type with a high runoff potential. Type B soils with moderate degree of drainage potential are also found in this basin. The flood plain is composed of alluvial deposits of sands silts, clays and gravels of various sizes.

The forest and pasture areas are located in the eastern hilly part of the watershed and the urban area is located near the ocean. Land use within the flood prone area is urban with commercial and light industrial areas.

D. Climate

The climate in this area is characteristically tropical. Mean annual temperature in this region varies from approximately 21 degrees centigrade to 26 degrees centigrade. Mean annual precipitation for the region varies from 115 to 205 centimeters. The annual pattern of rainfall in the basin is such that the wettest period of the year is the hurricane season, which occurs in the latter part of the summer and the early part of fall.

E. Main Streams and Tributaries

The Rio Culebrinas originates in the western part of the Cordillera Central (the central mountain range of Puerto Rico) at an elevation of about 300 meters above mean sea level and flows in a westerly direction through the towns of San Sebastian and Moca to discharge into the Aguadilla Bay. The major tributaries for Rio Culebrinas are Rio Guatemala, Rio Cano, Rio Sonador and Quebrada Grande. The total length of Rio Culebrinas is about 44 kilometers.

The Cano Madre Vieja is a distributary of Rio Culebrinas and is about 2.1 kilometers long. This is an old river outlet that flows across the study area and discharges into the Aguadilla Bay. This small intermittent stream is the boundary dividing the municipality of Aguadilla to the east from the community of Espinar to the west.

F. Available Hydrologic Data

The US Geological Survey (USGS), in cooperation with local and other federal agencies, collects and maintains a large amount of water resources data in Puerto Rico. There is one USGS gage recording peak flows and/or peak stages in Rio Culebrinas. This USGS gaging station numbered 50147800 is located at PR Hwy 404 near Moca, Puerto Rico. Approximate location is shown in Figure A-1.

G. Historical Floods

Since the turn of the century there have been at least 38 damaging floods in the Rio Culebrinas Basin. The largest flood of record occurred on September 16, 1975. This flood had an estimated recurrence interval of approximately 25 years. The discharge associated with this flood was estimated at 1,954 cubic meters per second (cms) and stages just downstream of PR Hwy 2 were 7.2

meters, mean sea level (msl), about 3.2 meters of water depth.

The most outstanding recent floods in the Aguadilla area for which stream gaging station records exceeded 850 cms were those which occurred during October 1972, May 1980, October 1981, May 1985, May 1986 and August 1988. There are twenty-three other large floods in the Rio Culebrinas for which records at the stream gaging station exceeded 566 cms. These are indicated in Table A-1.

H. Flood Flow Frequency Analysis

A log-Pearson Type III frequency analysis was performed on the 35-years of annual peak discharge data listed in Table A-1. The US Army Corps of Engineers computer program Flood Frequency Analysis (FFA) was used for the analysis. The estimated discharge-frequency curve is shown in Figure A-4 along with the expected probability adjustments. The plotting positions of the discharge data are included in the figure for comparison. The frequency curves corresponding to the 5% and the 95% confidence limits are also shown in Figure A-4.

I. Rainfall

The National Weather Service (NWS) operates several rain gages in Puerto Rico. The NWS Technical Paper No. 42 (TP-42) shows generalized estimates of the Probable Maximum Precipitation (PMP) and rainfall depth-frequency data for Puerto Rico and the US Virgin Islands. Contained in the report are isopluvial maps of precipitation contours for selected frequencies. The maps indicate rainfall increases toward the central mountain region of Puerto Rico. Point rainfalls representing Rio Culebrinas basin were obtained from TP-42 and are listed in Table A-2.

The Standard Project Storm (SPS) is defined as the most severe flood-producing rainfall depth-area-duration relationship and the isohyetal pattern of any storm that is considered reasonably characteristic of the region.

The PMP is defined as the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year. The SPS was assumed to be 50 percent of the PMP.

III. HYDROLOGIC ANALYSIS

A. Computer Programs

The US Army Corps of Engineers HEC-1 computer program was used to calculate the flood hydrographs for various sub-basins. The HEC-1 estimates surface runoff resulting from synthetic or observed storm events. Several choices of estimating the rainfall-runoff relationships are available in HEC-1. The Soil Conservation Service (SCS) runoff curve number methodology was selected for the Rio Culebrinas basin. Runoff curve numbers are functions of soil types, land uses and Antecedent Moisture Conditions (AMC).

Flood routings were performed for the Rio Culebrinas by the Hydrologic Engineering Center computer program entitled UNET. The UNET is a one-dimensional unsteady flow model that can simulate dendritic and network (looped) system.

B. Formation of HEC-1 and UNET Models

1. Drainage Area

Available USGS quadrangle maps on a scale of 1 to 20,000 were used to delineate drainage boundaries for the Rio Culebrinas basin. Surveys collected in February and March 1995 were also used. The watershed was divided into 30 sub-basins as shown in Figure A-1.

2. Curve Numbers

Runoff curve numbers were estimated for each sub-basin by considering soil types, land uses, and the AMC, appropriate for the rainfall frequency events. AMC I conditions were used for 50, 20, and 10 percent chance flood; AMC II conditions for 4 and 2 percent chance floods; AMC III conditions were adopted for 1 percent and events rarer than 1 percent. Estimated curve numbers for various sub-basins and AMC conditions are listed in Table A-3.

3. Lag Times

The lag times were computed for each sub-basin by dividing each stream into several reaches and applying the following formula:

$$L = \frac{X^{**}0.8 * (S+1)^{**}0.7}{1900 * Y^{**}0.5}$$

where

L = Lag in hours

X = Hydraulic length of watershed in feet

S = (1000/Curve Number) - 10

Y = Average watershed land slope in percent

4. Rainfall

The TP-42 point rainfall data for various durations were adjusted for the drainage area of the entire basin by HEC-1. Necessary corrections were also made to convert partial duration to equivalent annual series rainfall. Balanced storms were then generated by HEC-1 for various frequencies. Calculations were performed at 5-minute intervals.

5. Flood Routings

A UNET model was used in combination with HEC-1 generated sub-basin hydrographs for flood routing through the Rio Culebrinas valley. Cross section data were taken from surveys and available USGS quadrangle maps. Manning's roughness values and other loss coefficients were initially estimated and calibrated to historical events documented in the USGS flood atlas.

6. Discharge for Existing Conditions with Future Land Uses

The peak discharge-frequency data estimated by the HEC-1/UNET model along Rio Culebrinas and at the mouth of Cano Madre Vieja are listed in Table A-4. A flood hydrograph estimated for 24-hour storm for the 100-year event at the mouth of Rio Culebrinas and the mouth of Cano Madre Vieja are plotted in Figure A-2 and Figure A-3, respectively.

C. Hydrology of Interior Flooding

This analysis addresses the management of interior surface runoff from areas that are protected by project levees, reflecting future conditions development. Culvert outlet structures that allow for drainage of the interior areas to Cano Madre Vieja are provided through each levee segment. US Army Corps of Engineers Hydrologic Engineering Center Interior Flood Hydrology (HEC-IFH) Package was used for the analysis of the interior flooding hydrology.

HEC-IFH is a comprehensive computer program that performs all of the components of an interior flooding analysis. It is a framework on which the analyst can model rainfall-runoff, routing, interior ponding, and gravity outlet performance, as a dynamic, interactive simulation that includes changing flood conditions in the receiving stream. For this study, interior area flood elevation-frequency relationships were determined for various alternative gravity outlet configurations by using design storm event analysis in combination with interior area runoff parameters that reflect future conditions development. The resulting runoff was routed through existing interior ponding areas adjacent to the project levees, and then through gravity outlet culvert structures draining to Cano Madre Vieja. Coincident exterior flood stage 10-year hydrograph for the with-project condition was used for the tailwater boundary condition affecting each culvert.

No minimum facilities for interior drainage were identified in the pre-project condition. Existing conditions flood stages were used to define minimum gravity outlet facilities that would drain the protected areas before those stages were exceeded. Hydraulic design data for interior drainage structures are listed in Table A-8. Interior flood hydrology data and residual flood elevations are presented in Table A-11 and Table A-12, respectively.

D. Other Sources of Flooding

The detailed study area can also be flooded by hurricane tides from the ocean. Tidal flooding effects were not considered in the analysis. Tidal flood protection was not within the scope of the riverine protection project.

IV. HYDRAULICS

A. Existing Conditions

1. Hydraulic Model

Hydraulic modeling of existing conditions flood stages and post project stages were complied by using UNET.

From the upstream side of PR Hwy 2 to the coastline the area was divided into three reaches. Once floodwaters pass the PR Hwy 2 crossing, the overbank flow is divided between the outlets of Cano Madre Vieja and Rio Culebrinas. Reach 1 was identified upstream of PR Hwy 2. Reach 2 went from PR Hwy 2 to the mouth of Rio Culebrinas and Reach 3 went from PR Hwy 2 to the mouth of Cano Madre Vieja. A rating curve was used between Rio Culebrinas and Cano Madre Vieja. This rating curve is shown in Figure A-5.

2. Survey Data

The Rio Culebrinas area was surveyed in February and March 1995. Detailed topographic maps were prepared to a scale of 1 to 2,000 with a .5-meter contour interval. Detailed information of the bridges and culverts were obtained from the surveyor's field books. A site visit to the area in August 1995 also helped verify the topographic information on the maps. All elevations are referenced to the National Geodetic Vertical Datum (NGVD). The horizontal and vertical datums are referenced to the North American Datum of 1983 and 1929, respectively.

3. Roughness Coefficients

A Manning's roughness value of 0.10 was used for the overbank areas of the flow way, while a value of 0.035 was used for the channel sections. These values were based on aerial photographs, site inspection and engineering judgment.

4. Starting Conditions

Stage-discharge curves at the first cross section were computed using both normal depth and critical depth analyses. A high tide level of 0.6 meters was assumed in the Aguadilla Bay. The stage-discharge curve corresponding to the normal depth analysis was chosen for

this study based on the high water elevations listed in Hydrologic Investigations Atlas HA-457 which discusses the flood of November 27, 1968 and shows the limits of that flood delineated for the Aguada/Aguadilla area.

5. Model Verification

A flood atlas prepared by the USGS for the flood of November 27, 1968 that affected the Aguada/Aguadilla area showed high water marks and estimated flood stage contours. The USGS gage station 50147800 at PR Highway 404 recorded an estimated discharge of 850 cms. From Figure A-4 this would be less than a 10-year event.

6. Flood Stages

The existing conditions flood stages were simulated by the HEC-1 and UNET models developed for the basin. Table A-6 shows the water surface elevations under existing and with project conditions in the study area. Plate A-1 shows the flooded area for the 5 and 100-year events under existing conditions.

B. Sediment Assessment

1. Existing Conditions

Computer modeling of the existing flood plain showed that most flood flow is conveyed through the overbank areas of the floodplain. The existing channel is small and is overtopped by storms events with a 50% chance of exceedance (1 in 2-years frequency). The existing natural dominant discharge channel is very small relative to the conveyance required at design storm rates. Base flow in the existing channel is small.

Tropical and farm vegetation covers most of the floodplain and reduces sediment potential. Soils in the floodplain are a mixture of course sand, silt and clay with tropical vegetation as ground cover.

2. With Project Conditions

The average channel velocity during a 100-year event in Rio Culebrinas would range between .75 and 6.60 meters per second (mps). For Cano Madre Vieja the average channel velocity would range between .6 and 3.33 mps. Higher velocities would be expected near the bridges. The short duration of higher velocity flows and

erosion resistant nature of the channel soil type should resist large erosion related sediment movement within the channel.

The average overbank velocity along Rio Culebrinas would range between .2 and 3.75 mps. For Cano Madre Vieja the average overbank velocity would range between .46 and 2.21 mps. Vegetative cover and soil type should resist sediment movement under proposed conditions.

Sediment transport in the floodway is not expected to increase or decrease due to this project. The proposed levees would not significantly alter the current sedimentation regime within the basin.

V. HYDRAULIC DESIGNS

A. Hydraulic Design Criteria

Hydraulic design criteria and procedures used herein are in accordance with standard engineering practice and applicable provisions of Corps Engineering Manuals and the Waterways Experimental Station "Hydraulic Design Criteria" relative to design and construction of Civil Works Projects. Engineering criteria adopted to meet special local conditions are in accordance with that previously approved for similar projects.

B. Design Objective

The main flood control feature for this study consists of two levee segments and a levee spur designed for a 100-year level of protection. Each levee segment will be provided with drainage structures and all levees will have an interior drainage channel. Road ramps will be provided where the proposed levees intersect existing roads. A cutoff channel will also be provided since one of the proposed levees segments would intersect Cano Madre Vieja.

C. Levees

The 100-year level of protection with the proposed levee alignment was determined to be the most beneficial alternative. The existing condition UNET model was modified to represent the with project conditions by terminating cross sections at stations which would cross the proposed levee alignment. Plate A-2 shows the recommended plan. The two levee segments are identified as the Aguadilla levee and the Espinar levee with a levee spur.

1. Aguadilla Levee

This proposed levee segment starts at the coastline and ends at PR Hwy 2. It is approximately 1,836 meters long and has an average levee height of about 2.60 meters. There will be three drainage structures and two road ramps for this levee segment. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramps intersects the interior drainage channel. An existing concrete box culvert over Cano Madre Vieja would be impacted by one of the road ramps. This box culvert will be extended to accommodate the proposed road ramp. Plate A-2 shows the layout of the Aguadilla levee. Plate A-4 is a profile of the Aguadilla levee with the design water surface profile.

2. Espinar Levee

This proposed levee segment starts at the edge of the coastal barrier zone and ties into high grounds south of the community of Espinar. It is approximately 1,496 meters long and has an average levee height of about 2.49 meters. There will be one drainage structure through this levee and a road ramp would also be required. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramp intersects the interior drainage channel. The Espinar levee will also have a levee spur. The Espinar levee spur starts from Espinar levee Station 2+10 and ties into high grounds north of the community of Espinar. Plate A-2 shows the layout of the Espinar levee and connecting levee spur. Plates A-5 and A-6 are profiles of the Espinar levee and Espinar levee spur with the design water surface profile, respectively.

3. Side Slopes

Side slopes of the proposed levees were based on existing soil conditions, type of material used in construction and a stability analysis. The levee side slopes on the flood side and protected side would be 1 vertical to 2.5 horizontal.

4. Levee Crest Elevations

The levee crest elevations were determined by selecting the highest profile that resulted from a

worst case scenario. The 100-year water surface profile was computed with the following combinations:

a. Design discharge with the design "n" values
b. Design discharge with 20 percent increased "n" values.
c. 20 percent increased discharge hygrograph with design "n" values.

Bridge openings were reduced by 20 percent to account for debris accumulations. The 100-year water surface profile computed with a 20 percent increased discharge is slightly higher than the other profile and it was selected as the minimum levee grade.

Wave heights, periods, and durations caused by several wind speeds were computed by a shallow water wave forcasting model "SHALWAVE" described in the Coastal Engineering Research Center Instruction Report 86-2. Wave runup and wind setup calculations were performed using the Shore Protection Manual and are listed in Table A-5. A smooth levee surface was assumed in the calculations.

The 100-year levee crest elevation for the Aguadilla levee and the Espinar levee with the levee spur are presented in Table A-7.

5. Levee Overtopping Analysis

An overtopping analysis was performed on the Rio Culebrinas according to ETL 1110-2-299 dated 22 August 1986. The levees were evaluated as one system and an overtopping reach was identified for each levee segment. Overtopping water surface profiles were computed by considering the uncertainties in "n" values, bridge openings, discharge hydrographs and wind speeds.

For the Aguadilla and Espinar levees the overtopping reach is located between corresponding levee stations 0+00 and 0+50. Each overtopping reach was identified as the least critical site where initial failure would occur during severe floods. The least amount of damage in the region would be sustained if initial levee overtopping occurred at this location. Superiority is provided to insure overtopping at the proposed reach. The overtopping reach is 50 meters long and would be given 1 foot of superiority less than the remainder of the levee segment.

6. Reliability Analysis of the Selected Levees

This study was granted a waiver from doing a full risk analysis. However, a reliability analysis to determine probability of stage non-exceedance was conducted. The risk analysis computer program, available from the Hydrologic Engineering Center (HEC), was used for the reliability analysis. This analysis was conducted following ER 1105-2-101 to determine the reliability of the selected levees. Cross section 1568 was selected for this analysis, which takes into consideration the uncertainty in discharge-frequencies, stage-discharges, and cross section data. Five thousand interations were made with Latin Hypercube sampling method to determine the reliability.

The discharge-frequency data required for the reliability analysis were taken from the results of the UNET analysis. The logarithmic mean, standard deviation, and skew were determined, as per the Water Resources Council Bulletin 17B, from 1 percent, 10 percent and 50 percent chance flood events.

The stage-discharge rating curve was developed for the design "n" values from the UNET analysis. Water surface profiles were computed for possible high and low "n" values. A minimum standard deviation of 0.274 meter was required as per Table A-3 of the EC 1105-2-205.

Input data and results of the reliability analysis of the proposed levees at cross section 1568 for the SPF, 1 percent and 2 percent flood events are shown in Table A-13.

D. Channels

1. Cutoff Channel

The proposed Aguadilla Levee would intersect Cano Madre Vieja at various locations. In order to continue the flow in Cano Madre Vieja to the coastline a cutoff channel would be required. The conveyance capacity of this cutoff channel would be the same as in the existing Cano Madre Vieja channel. Hydraulic design data for the cutoff channel are shown in Table A-10.

2. Interior Drainage Channels

An interior drainage channel would be provided along the protected side of each levee segment and along the Espinar levee spur. Hydraulic design data for the interior drainage channels are provided in Table A-9.

E. Drainage Structures

There will be a total of four drainage structures as part of the recommended plan. The Aguadilla levee will have three drainage structures and the Espinar levee will have one drainage structure. The culverts at each drainage structure consist of corrugated metal pipes (CMP) with a bituminous coating and each culvert will have a flap gate on the levee flood side. Hydraulic design data of the drainage structures are indicated in Table A-8. Locations of the proposed drainage structures are shown on Plate A-2. The following describes each drainage structure:

1. Aguadilla Levee

a. AL-S-1

The drainage structure at Aguadilla levee station 1+39.5 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 15 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

b. AL-S-2

The drainage structure at Aguadilla levee station 6+05.5 consists of six-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 19 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

c. AL-S-3

The drainage structure at Aguadilla levee station 10+52.9 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length

of 20 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

2. Espinar Levee

a. EL-S-1a

The drainage structure at Espinar levee station 2+50 consists of two-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 27 meters. The two-1.52 meter diameter culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

F. Road Ramps

Road ramps would be required where PR Hwy 418 and PR Hwy 115 intersects the proposed Aguadilla levee. Another road ramp would be required where PR Hwy 442 intersects the proposed Espinar Levee. A .91 meter diameter CMP would be provided where each road ramp intersects the interior drainage channel. Hydraulic design data for the interior drainage channels is shown in Table A-9.

The proposed road ramp at PR Hwy 418 would impact an existing concrete box culvert at Cano Madre Vieja. This culvert would be extended to accommodate the flood side of this road ramp.

G. Borrow Area

For this project there will be one source for borrow material. However, suitable excavated material from the construction of the drainage structures, the interior drainage channels and the cutoff channel could also be used for the construction of the proposed levees. The proposed borrow area does not impact the drainage of the existing floodway. The location of the borrow area is indicated in the Geotechnical Appendix, Plate B-2.

H. Performance

1. Levee Design Protection

Design discharge water surface elevations within the floodway up to and including the 1% chance flood will be prevented from overtopping the levees. Events that

exceed the design capacity are rare but could occur. In the event of a flood greater than design discharges overtopping of one or both levees could occur. Each levee would be provided with a 50 meter long overtopping segment with a lower levee crest elevation. Paragraph C.5. provides a description of that design. Overtopping flows would discharge to an undeveloped area. These overtopping reaches were selected to minimize damage and provide warning that a design event has been exceeded.

2. Residual Flooding

Runoff from the protected side of the levees would collect in designated residual areas and discharge to the flood plain through culverts. The culverts at the drainage structures would be fitted with flap gate controls that would prohibit flow from the flood plain into the protected area. Analyses of various rainfall and flood events were compiled to determine the extent of residual flooding in those areas. Plate A-3 indicates the extent of the area flooded due to the 1% chance flood event in the floodway and a 10% chance flood event in the protected areas. The residual flooded areas are an essential part of the interior drainage plan for each levee segment.

The residual flooded area shown on plate A-3 was based on analyses of design rainfall levels applied to the sub-basin upstream of the levee. The rainfall runoff was routed through the sub-basin to the levee site. Runoff reaching the levee would be conveyed thorough the levee and to the floodplain by outlet structures. The size of the outlet structure is designed to drain water trapped behind the levee as quickly as possible. The structures are unusually fitted with gates that automatically close in the event that the stage in the floodplain exceeds the stage behind the levee. This prevents backflow through the inlet structure when stages in the floodway are higher than stages upstream of the levee. However, discharge to the floodway is terminated and all flow entering the area behind the levee is effectively trapped until the gates open. The trapped floodwater is called residual flooding and is a direct function of that volume of the trapped water. The area covered by trapped floodwater is called the residual flooded area.

The shaded area shown on plate A-3 represents lands that would be inundated under the existing geometry of the area. Should it become necessary or desirable for the sponsor to utilize all or part of the lands

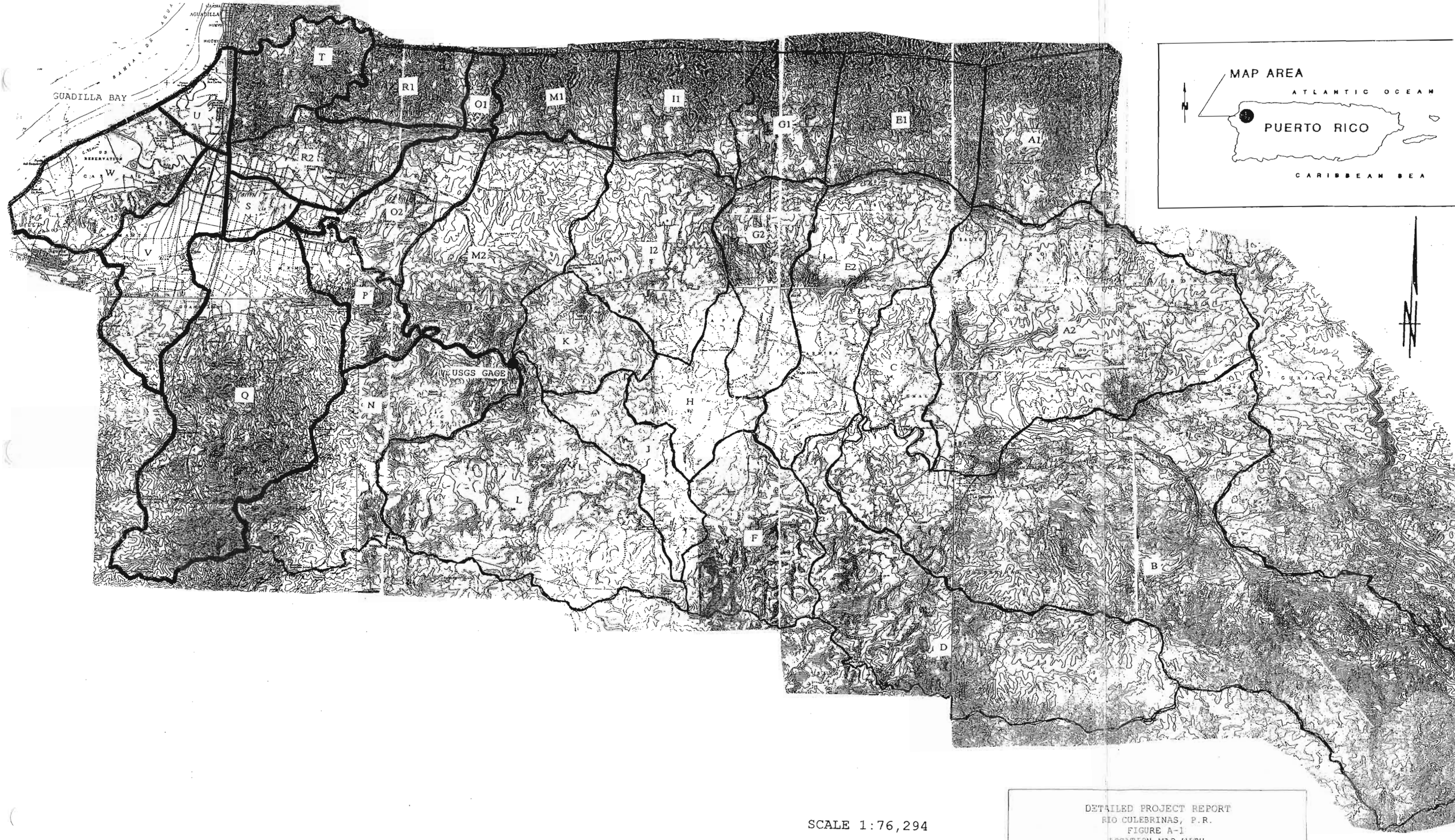
designated as the residual flooded area, the area must be studied and reevaluated. Changes in the geometry of the residual flooded area shown in the report will have a direct effect on the predicted residual flood stages, and surface area of the residual flooded area. If the originally predicted stage or land area designated for flood retention cannot be changed, engineering analyses must be performed to determine alternative means to contain the predicted flood volume without damage to adjacent properties. Measures could include larger outlet structure capacity, construction of a pump station to augment the design outlet structures, or excavation within the remaining residual flooded area to contain the design volume of floodwater at the design stage for the original residual flooded area.

3. People at Risk

Events are of a "flashflood" nature with little time available for warning people in the area. Overtopping would first occur at a designated segment of levee. Overtopping flow at the Aguadilla levee would discharge into a residual flooded area and convey along a interior drainage channel that will be connected with the other drainage structures. Overtopping flow at the Espinar levee would discharge into an uninhabited area. Peak discharges for the Rio Culebrinas basin occur within 7 hours after initial rainfall and last only about 30 minutes. Therefore overtopping is expected to be brief. However, initial water velocities as a result of overtopping could be high until the tailwater stage increase. At the north end of the Espinar levee floodwaters would flank the levee and reach the western side of the community of Espinar. Residual flooding related to a 10-year event would also impact the protected side of the community of Espinar. Plate A-3 shows the interior flooded areas for the 10-year event.

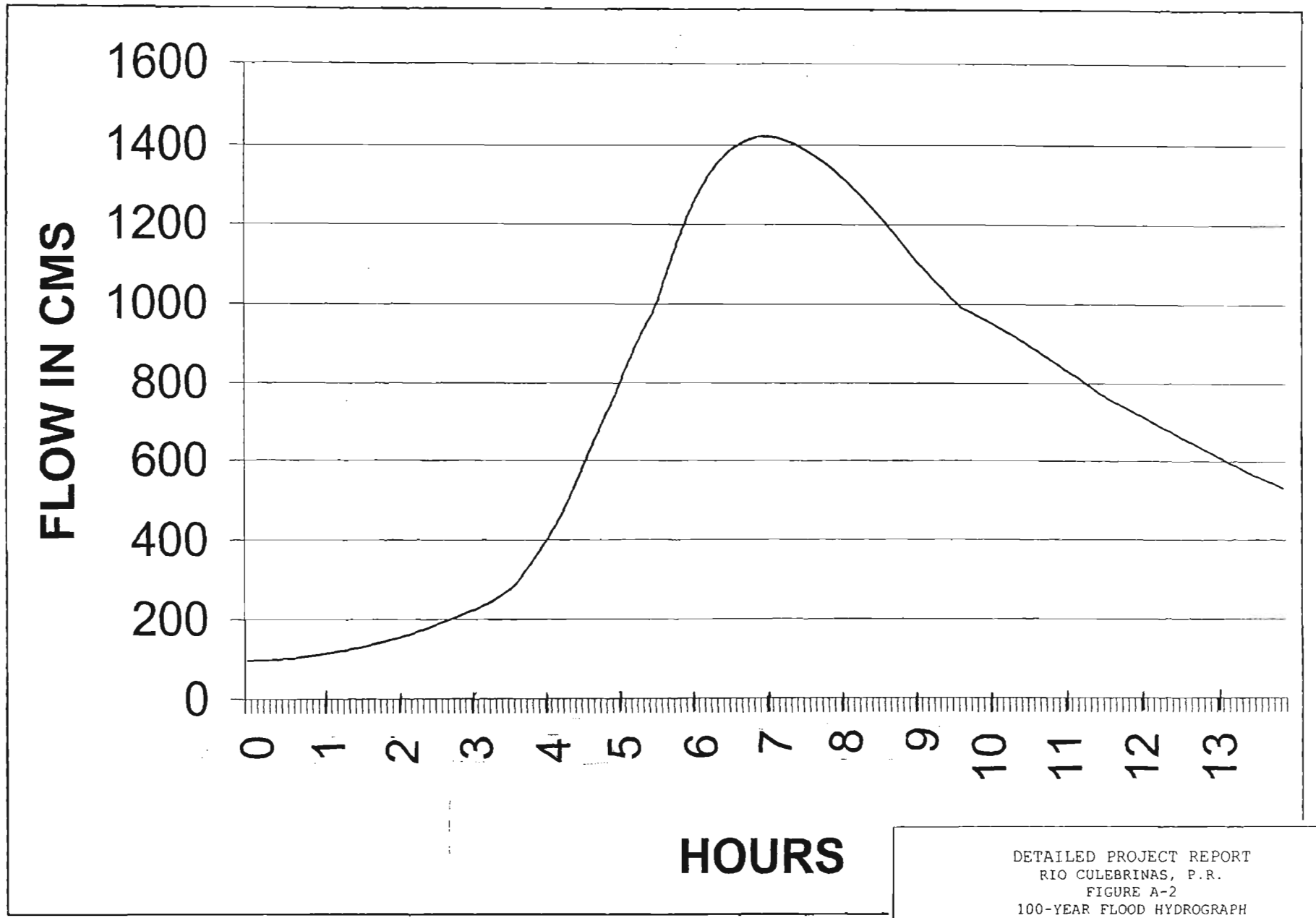
If development and/or fill were placed within the interior flooded areas the design volume of water will be displaced and the interior stage would increase. This stage increase would be above the damage elevation used for the interior drainage analysis and damages within the protected area would start to occur. Residual flooded areas are waters trapped within a protected area when the flapgates at the drainage structures are closed during a flood event. This is a design volume of water that reaches a computed stage and this stage is related to a specific rainfall event as determined from an interior

drainage analysis. Residual flooded areas are needed so that the interior drainage would function as designed.

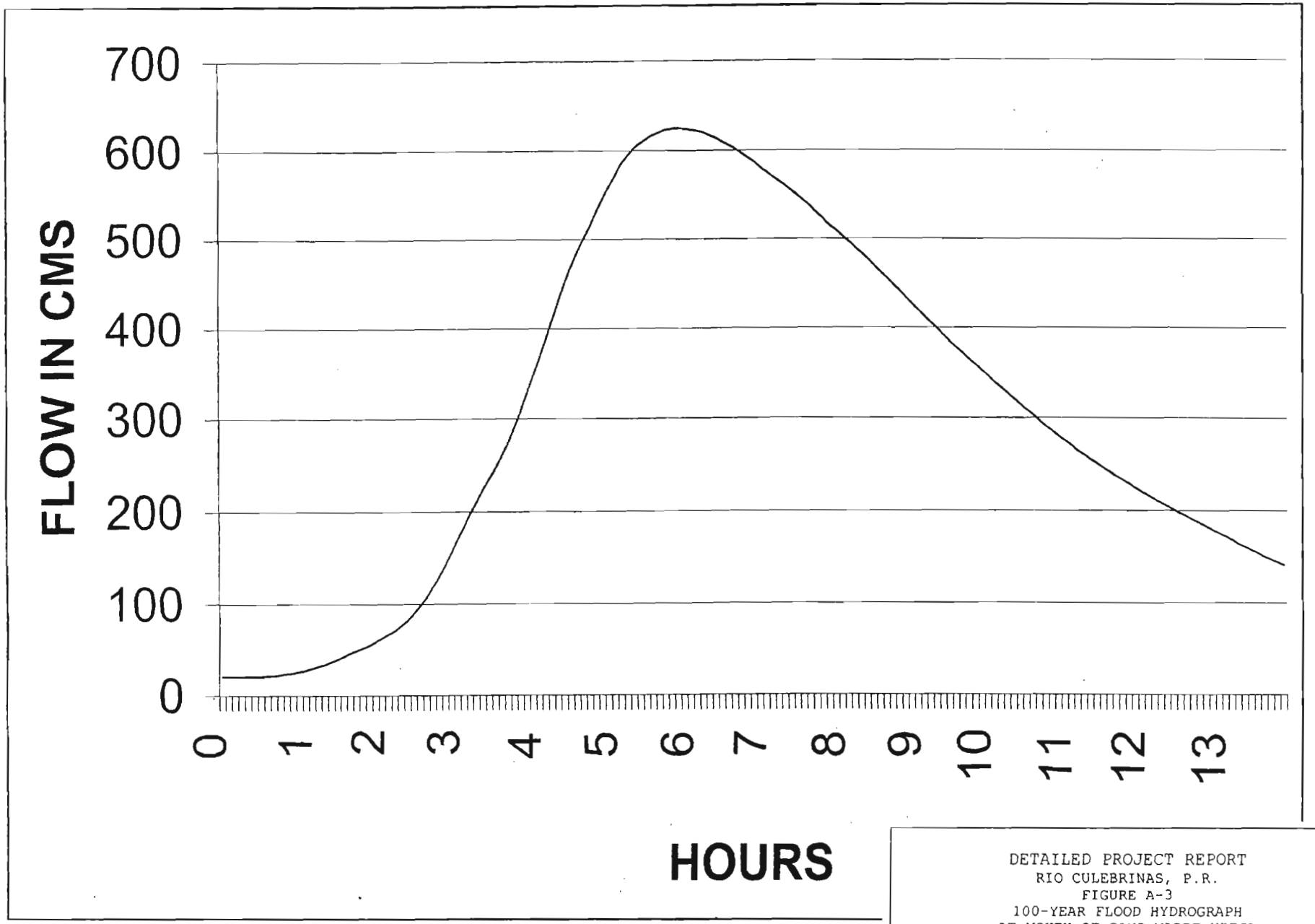


SCALE 1:76,294

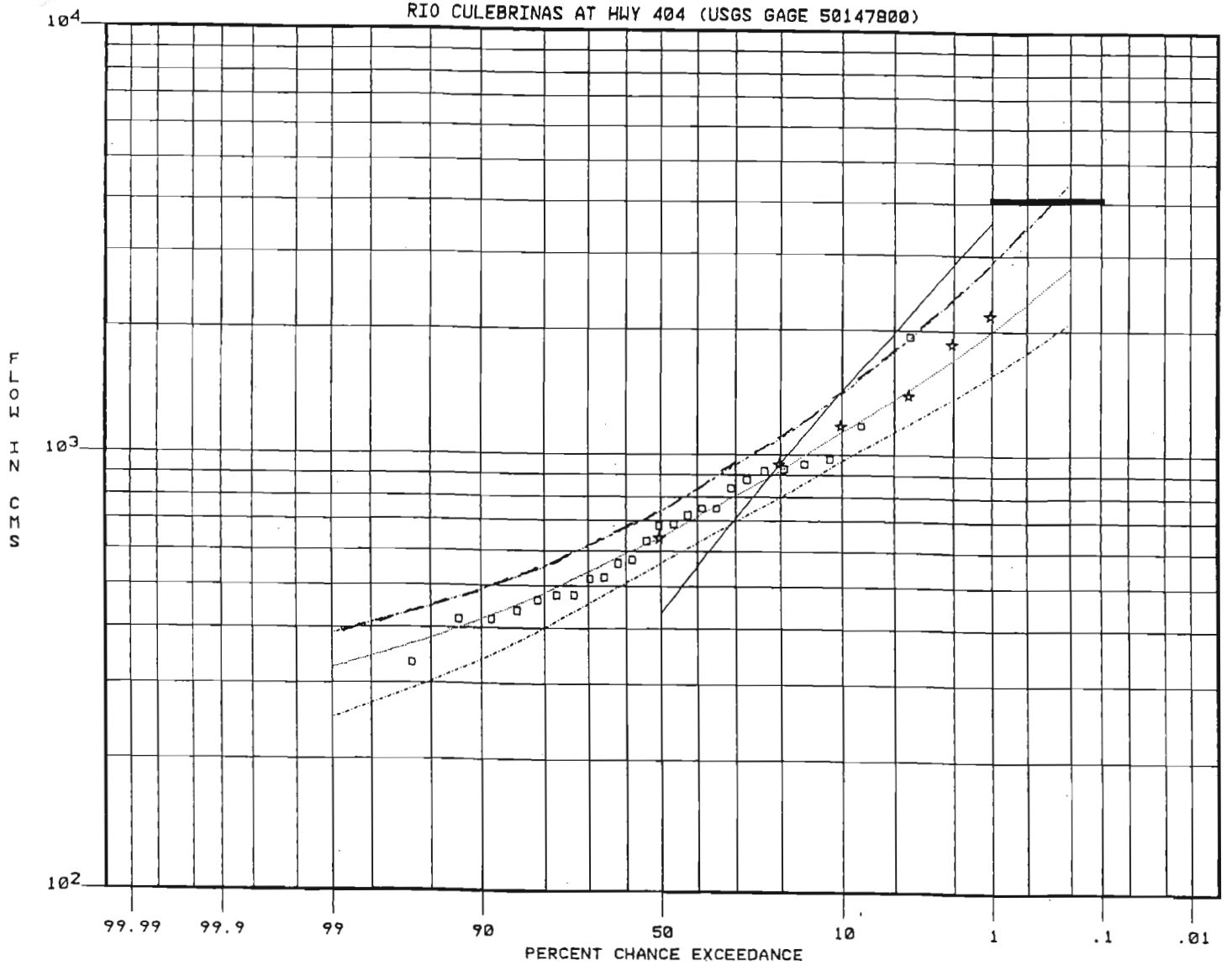
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-1
LOCATION MAP WITH
BASIN AND SUB-BASINS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-2
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF RIO CULEBRINAS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



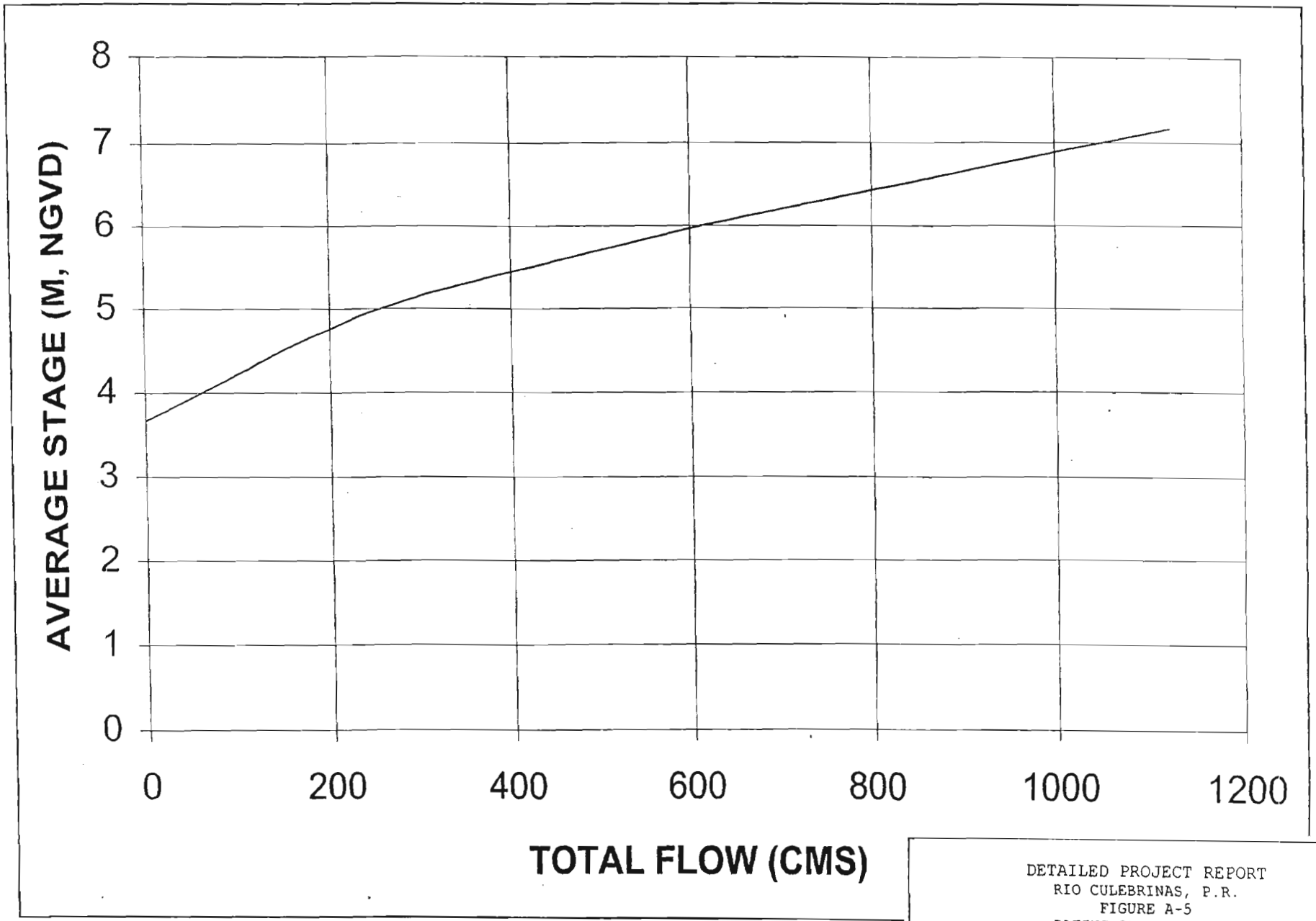
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-3
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF CANO MADRE VIEJA
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



COMPUTED
5% CONFIDENCE LIMIT
95% CONFIDENCE LIMIT
WEIBULL PLOTTING POSITION

HEC-1
SPF (HEC-1)
REGIONAL EQUATION

DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-4
FLOW FREQUENCY AT
USGS GAGE 50147800
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-5
RATING CURVE BETWEEN
RIO CULEBRINAS AND CANO MADRE VIEJA
DEPARTMENT OF THE AR
JACKSONVILLE DISTRICT, CORPS O ENGINEERS
JACKSONVILLE, FLORIDA

TABLE A-1

RIO CULEBRINAS DETAILED PROJECT REPORT
HISTORICAL FLOODS DATA FOR RIO CULEBRINAS
AT USGS GAGING STATION 50147800
AT PR HIGHWAY 404, NEAR MOCA, PUERTO RICO

DATE OF FLOOD	DISCHARGE CMS	WATER SURFACE ELEVATION METERS, NGVD
November 27, 1968	850	73.7
October 30, 1969	700	72.4
May 7, 1970	575	71.1
June 13, 1972	700	72.4
October 21, 1972	960	74.6
September 16, 1975	1955	84.6
November 4, 1977	680	72
September 23, 1978	640	71.6
September 25, 1978	730	72.6
May 19, 1980	690	72.3
May 27, 1980	890	74.3
February 15, 1981	570	71
October 24, 1981	935	74.7
July 20, 1982	685	72.3
June 5, 1984	690	72.4
September 15, 1984	760	73
October 6, 1984	675	72.2
May 18, 1985	930	74.7
May 19, 1985	705	72.5
June 25, 1985	730	72.8
October 1, 1985	580	71.1
October 7, 1985	660	72
November 3, 1985	720	72.7
April 27, 1986	780	73.2
May 3, 1986	665	72.1
May 5, 1986	985	75.1
May 6, 1986	685	72.3
May 13, 1986	845	73.9
October 18, 1986	670	72.2
October 19, 1986	660	72
December 1, 1986	635	71.8
September 11, 1987	760	73.1
October 7, 1987	730	72.8
August 24, 1988	1200	76.8
October 26, 1988	640	71.8

TABLE A-2

RIO CULEBRINAS DETAILED PROJECT REPORT
RAINFALL FOR VARIOUS FREQUENCIES AND DURATIONS

PERCENT CHANCE STORM	RAINFALL IN MM DURATION IN HOURS							
	0.083	0.25	1	2	3	6	12	24
50	14	29	53	61	72	86	104	117
20	17	36	66	79	91	107	132	155
10	19	41	72	91	104	127	146	180
4	21	45	79	104	117	150	178	198
2	24	51	91	114	127	155	191	229
1	26	55	99	124	150	180	216	249
SPF	29	61	114	203	264	381	445	508

TABLE A-3

RIO CULEBRINAS DETAILED PROJECT REPORT
WATERSHED PARAMETERS

SUB-BASIN IDENTIFICATION	DRAINAGE AREA (SQ KM)	CURVE NUMBER		LAG IN HOURS
		AMC II	AMC III	
A1	9.24	80	91	0.82
A2	28.72	80	91	0.59
B	56.51	80	91	1.40
C	4.84	80	91	0.17
D	21.85	80	91	1.02
E1	8.84	80	91	0.49
E2	14.12	80	91	0.36
F	10.31	80	91	0.27
G1	4.35	80	91	0.57
G2	7.15	80	91	0.28
H	5.80	80	91	0.08
I1	6.85	80	91	0.39
I2	11.47	80	91	0.31
J	5.10	80	91	0.27
K	5.41	80	91	0.21
L	19.63	80	91	0.28
M1	5.73	80	91	0.23
M2	15.51	81	92	0.30
N	13.86	81	92	0.30
O1	1.14	80	91	0.23
O2	6.25	81	92	0.19
P	4.41	85	94	0.04
Q	22.35	86	94	0.63
R1	4.34	84	93	0.23
R2	5.85	86	94	0.22
S	1.67	84	93	0.28
T	4.94	80	91	0.44
U	2.05	86	94	0.30
V	7.31	85	94	0.37
W	7.00	85	94	0.35
TOTAL	322.60			

TABLE A-4

RIO CULEBRINAS DETAILED PROJECT REPORT
SUMMARY OF PEAK DISCHARGES
ESTIMATED BY HEC-1/UNET ROUTING MODEL

PERCENT CHANCE STORM EVENTS	PEAK DISCHARGES IN CMS			
	USGS GAGE 50147800	UPSTREAM LIMIT OF STUDY	PR HWY 2	MOUTH
50	652	701	334	143
20	964	1036	473	240
10	1193	1313	573	312
4	1411	1587	693	397
2	1893	2102	941	536
1	2206	2508	1098	625
SPF	4111	5214	3016	1221

TABLE A-5

RIO CULEBRINAS DETAILED PROJECT REPORT
WAVE RUNUP AND WIND SETUP

LEVEE SEGMENT	LEVEE STATION	FETCH LENGTH (M)	WIND SPEED KM/HOUR	WAVE PERIOD (SEC)	WAVE HEIGHT (M)	WAVE RUNUP (M)	WIND SETUP (M)	TOTAL (M)
AGUADILLA	4 + 00	538	25	0.99	0.10	0.13	0.01	0.14
			48	1.23	0.18	0.22	0.02	0.24
	13 + 00	1003	25	1.21	0.13	0.19	0.01	0.20
			48	1.48	0.24	0.30	0.04	0.34
ESPINAR	6 + 80	991	25	1.19	0.13	0.18	0.01	0.19
			48	1.47	0.23	0.30	0.04	0.34

RIO CULEBRINAS DETAILED PROJECT REPORT
EXISTING AND WITH PROJECT WATER SURFACE ELEVATIONS

	BRIDGE	CROSS SECTION	MILE	2-YEAR WITH PROJECT	2-YEAR EXISTING CONDITIONS	5-YEAR WITH PROJECT	5-YEAR EXISTING CONDITIONS	10-YEAR WITH PROJECT	10-YEAR EXISTING CONDITIONS	25-YEAR WITH PROJECT	25-YEAR EXISTING CONDITIONS	50-YEAR WITH PROJECT	50-YEAR EXISTING CONDITIONS	100-YEAR WITH PROJECT	100-YEAR EXISTING CONDITIONS	SPF WITH PROJECT	SPF EXISTING CONDITIONS
Reach 1 EAST OF PR HWY 2			5.82	7.18	7.18	7.81	7.81	8.18	8.18	8.46	8.45	9.00	9.00	9.30	9.30	11.12	11.12
			5.07	6.91	6.91	7.50	7.50	7.83	7.83	8.09	8.09	8.60	8.60	8.90	8.90	10.92	10.92
			4.39	6.40	6.40	6.91	6.91	7.25	7.25	7.52	7.52	8.06	8.06	8.40	8.43	10.66	10.66
			3.68	5.78	5.78	6.28	6.27	6.61	6.60	6.92	6.90	7.57	7.55	7.95	8.04	10.43	10.43
		202	3.00	5.17	5.15	5.76	5.73	6.14	6.11	6.50	6.90	7.25	7.21	7.66	7.80	10.24	10.24
		104	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
Reach 2 - Rio Culebrinas		4090	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
	PR Hwy 2	3992	2.87	4.79	4.74	5.15	5.08	5.35	5.26	5.51	5.41	6.09	6.05	6.38	6.59	8.36	8.36
		3821	2.77	4.92	4.88	5.34	5.29	5.59	5.53	5.81	5.74	6.21	6.13	6.44	6.24	7.57	7.38
		3705	2.68	4.73	4.68	5.13	5.06	5.36	5.27	5.58	5.47	5.96	5.84	6.18	5.98	7.36	7.13
		3428	2.52	4.55	4.50	4.94	4.84	5.18	5.07	5.40	5.27	5.78	5.63	5.98	5.77	7.17	6.91
	PR Hwy 418	3214	2.39	4.28	4.20	4.68	4.55	4.95	4.79	5.19	5.02	5.57	5.38	5.78	5.54	6.95	7.13
		3187	2.38	4.23	4.14	4.63	4.50	4.91	4.73	5.15	4.97	5.53	5.34	5.74	5.49	6.91	6.63
		3154	2.35	4.22	4.14	4.63	4.49	4.90	4.73	5.15	4.96	5.52	5.34	5.74	5.49	6.90	6.62
		3116	2.33	4.21	4.12	4.61	4.48	4.89	4.71	5.13	4.95	5.51	5.32	5.72	5.47	6.88	6.60
		3055	2.29	4.19	4.09	4.59	4.45	4.87	4.69	5.11	4.92	5.48	5.30	5.70	5.44	6.84	6.56
		2712	2.08	4.15	4.05	4.56	4.42	4.84	4.66	5.09	4.90	5.45	5.27	5.66	5.41	6.79	6.52
		2614	2.04	4.12	4.02	4.53	4.39	4.81	4.63	5.06	4.87	5.42	5.24	5.63	5.39	6.75	6.48
	PR Hwy 115	2570	2.00	3.63	3.54	3.99	3.87	4.39	4.07	4.75	4.51	5.17	4.97	5.39	5.13	6.58	6.30
		2440	1.92	3.33	3.24	3.68	3.57	3.89	3.75	4.09	3.93	4.51	4.28	4.72	4.47	5.88	5.63
		2377	1.88	3.18	3.10	3.51	3.39	3.73	3.58	3.94	3.77	4.38	4.14	4.59	4.34	5.73	5.48
		1950	1.29	2.94	2.85	3.32	3.17	3.55	3.39	3.79	3.60	4.26	4.01	4.46	4.22	5.55	5.31
		1451	0.91	2.88	2.78	3.26	3.12	3.50	3.33	3.73	3.55	4.20	3.96	4.40	4.17	5.45	5.23
		1353	0.84	2.87	2.77	3.25	3.11	3.49	3.32	3.72	3.54	4.19	3.95	4.39	4.16	5.42	5.21
		1286	0.80	2.86	2.77	3.25	3.10	3.48	3.32	3.72	3.53	4.19	3.94	4.38	4.15	5.41	5.20
		1091	0.68	2.85	2.75	3.24	3.09	3.47	3.30	3.70	3.52	4.17	3.93	4.36	4.13	5.37	5.16
		850	0.53	2.83	2.73	3.22	3.07	3.46	3.29	3.69	3.50	4.16	3.92	4.35	4.12	5.34	5.13
		721	0.45	2.79	2.71	3.20	3.05	3.44	3.28	3.68	3.49	4.15	3.91	4.34	4.11	5.31	5.11
		604	0.38	2.74	2.65	3.17	3.01	3.41	3.25	3.65	3.47	4.13	3.89	4.31	4.09	5.27	5.08
		403	0.25	2.60	2.49	3.08	2.91	3.35	3.17	3.60	3.41	4.08	3.84	4.26	4.05	5.18	4.99
		163	0.10	2.40	2.30	2.93	2.75	3.23	3.02	3.51	3.29	4.00	3.76	4.17	3.97	5.00	4.85
		44	0.03	2.04	1.94	2.58	2.38	2.92	2.70	3.26	2.99	3.84	3.59	4.02	3.81	4.81	4.67
Reach 3 - Cano Madre Vieja		3573	2.54	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3463	2.47	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3280	2.36	4.76	4.73	5.16	5.10	5.39	5.32	5.60	5.51	5.96	5.86	6.17	5.99	7.31	7.07
		3240	2.33	4.67	4.54	5.07	4.86	5.30	5.04	5.51	5.20	5.88	5.52	6.09	5.65	7.25	6.65
		3134	2.27	4.60	4.53	4.97	4.84	5.20	5.01	5.41	5.17	5.77	5.48	5.98	5.60	7.15	6.59
	PR Hwy 418	3101	2.25	4.51	4.42	4.89	4.74	5.13	4.94	5.35	5.12	5.73	5.45	5.95	5.57	7.14	6.58
		3085	2.24	4.32	4.31	4.66	4.60	4.88	4.80	5.07	4.98	5.37	5.28	5.53	5.41	6.40	6.32
		2993	2.18	4.31	4.26	4.67	4.52	4.89	4.71	5.09	4.89	5.41	5.17	5.59	5.29	6.56	6.18
	Old Narrow Bridge	2948	2.15	4.11	3.97	4.47	4.24	4.71	4.44	4.92	4.62	5.24	4.91	5.42	5.02	6.39	5.89
	PR Hwy 115	2891	2.11	3.70	3.62	4.04	3.92	4.23	4.11	4.43	4.30	4.71	4.60	4.87	4.72	5.74	5.58
		2826	2.07	3.16	3.24	3.51	3.67	3.75	3.89	3.96	4.11	4.29	4.44	4.44	4.55	5.32	5.41
		2545	1.81	2.83	2.95	3.20	3.42	3.46	3.67	3.68	3.91	4.02	4.25	4.18	4.36	5.09	5.19
		2491	1.78	2.74	2.86	3.10	3.31	3.35	3.57	3.58	3.81	3.91	4.16	4.08	4.26	4.99	5.07
		2424	1.74	2.66	2.78	3.03	3.23	3.28	3.48	3.51	3.72	3.85	4.06	4.01	4.17	4.91	4.97
		2307	1.67	2.57	2.67	2.94	3.11	3.19	3.36	3.42	3.59	3.75	3.92	3.91	4.02	4.76	4.80
		2200	1.60	2.45	2.53	2.83	2.97	3.08	3.22	3.32	3.42	3.65	3.74	3.80	3.84	4.65	4.61
		2095	1.53	2.39	2.46	2.78	2.89	3.03	3.15	3.26	3.35	3.59	3.65	3.74	3.76	4.57	4.51
		1568	1.10	2.32	2.35	2.72	2.82	2.97	3.08	3.21	3.28	3.53	3.57	3.68	3.67	4.48	4.40
		1482	1.04	2.29	2.31	2.69	2.78	2.93	3.04	3.17	3.24	3.49	3.52	3.63	3.62	4.41	4.33
		1112	0.78	2.25	2.25	2.64	2.73	2.89	3.00	3.13	3.20	3.43	3.46	3.58	3.56	4.33	4.25
		480	0.30	2.20	2.20	2.60	2.70	2.84	2.97	3.08	3.16	3.39	3.41	3.52	3.51	4.25	4.17
		381	0.24	2.08	2.15	2.47	2.65	2.70	2.91	2.93	3.10	3.22	3.33	3.34	3.41	3.97	4.02
		255	0.16	2.02	2.10	2.39	2.59	2.62	2.86	2.84	3.05	3.13	3.27	3.24	3.34	3.83	3.94
		209	0.13	1.97	2.07	2.34	2.56	2.56	2.82	2.78	3.02	3.08	3.24	3.18	3.32	3.75	3.91
		163	0.10	1.88	2.02	2.21	2.49	2.41	2.74	2.60	2.98	2.88	3.21	3.01	3.28	3.58	3.88
		74	0.05	1.71	1.79	2.07	2.23	2.29	[illegible]	2.51	2.69	2.80	3.06	2.94	3.15	3.52	[illegible]
		17	0.01	1.53	1.64	1.86	2.05	2.06	[illegible]	2.26	2.55	2.59	2.86	2.72	2.97	3.28	[illegible]

NOTE: WATER SURFACE ELEVATIONS ARE IN METERS, NGVD

TABLE A-7

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
100-YEAR LEVEE CREST ELEVATIONS

LEVEE SEGMENT	ROAD RAMP	DRAINAGE STRUCTURE	LEVEE STATION	MINIMUM LEVEE PROFILE TO ACCOMMODATE 20 PERCENT INCREASE IN DISCHARGE OR "N" VALUE M, NGVD	WAVE RUNUP AND WIND SETUP FOR 48 KM/HOUR WIND METERS	SUPERIORITY METERS	LEVEE CREST ELEVATION M, NGVD	AVERAGE GROUND ELEVATION M, NGVD	LEVEE HEIGHT METERS	DESIGN WATER SURFACE ELEVATION M, NGVD
AGUADILLA			0 + 0.00	2.81	0.24	0.00	3.05	1.00	2.05	2.72
			0 + 32.54	2.81	0.24	0.00	3.05	2.20	0.85	2.72
			0 + 76.23	3.19	0.24	0.09	3.52	1.50	2.02	2.94
		AL-S-1	1 + 39.50	3.34	0.24	0.09	3.67	1.70	1.97	2.98
			1 + 79.72	3.43	0.24	0.15	3.82	1.72	2.10	3.01
			2 + 25.58	3.51	0.24	0.30	4.05	1.30	2.75	3.18
			2 + 68.05	3.55	0.24	0.30	4.09	1.22	2.87	3.24
			3 + 44.59	3.63	0.24	0.30	4.17	1.80	2.37	3.34
			5 + 27.92	3.78	0.24	0.30	4.32	1.00	3.32	3.52
		AL-S-2	6 + 05.50	3.83	0.24	0.30	4.37	2.06	2.31	3.58
			6 + 07.29	3.83	0.24	0.30	4.37	1.00	3.37	3.58
			7 + 71.41	3.88	0.34	0.30	4.52	2.00	2.52	3.63
			8 + 65.06	3.93	0.34	0.30	4.57	2.00	2.57	3.68
			9 + 44.83	3.98	0.34	0.30	4.62	1.68	2.94	3.74
		AL-S-3	10 + 52.90	4.04	0.34	0.30	4.68	2.98	1.70	3.80
			10 + 54.61	4.04	0.34	0.30	4.68	2.50	2.18	3.80
			11 + 28.82	4.14	0.34	0.30	4.78	2.60	2.18	3.91
			11 + 91.52	4.24	0.34	0.30	4.88	2.68	2.20	4.01
			12 + 39.36	4.63	0.34	0.30	5.27	2.22	3.05	4.40
			13 + 30.31	4.69	0.34	0.30	5.33	3.00	2.33	4.46
	PR HWY 115		13 + 66.80	5.36	0.34	0.30	6.00	2.91	3.09	5.14
			13 + 80.59	5.62	0.34	0.30	6.26	2.91	3.35	5.39
			14 + 12.01	5.84	0.34	0.30	6.48	3.18	3.30	5.63
			15 + 06.36	5.87	0.34	0.30	6.51	3.04	3.47	5.66
			16 + 13.66	5.90	0.34	0.30	6.54	3.85	2.69	5.70
	PR HWY 418		16 + 16.60	5.91	0.34	0.30	6.55	3.85	2.70	5.71
			16 + 31.19	5.99	0.34	0.30	6.63	3.85	2.78	5.78
			17 + 15.70	6.20	0.34	0.30	6.84	3.28	3.56	5.98
			18 + 00.81	6.38	0.34	0.30	7.02	3.66	3.36	6.18
			18 + 19.59	6.61	0.34	0.30	7.25	4.00	3.25	6.44
			18 + 36.00	6.61	0.34	0.30	7.25	5.82	1.43	6.44
			18 + 40.00	6.61	0.34	0.30	7.25	7.25	0.00	6.44
ESPINAR			0 + 00.00	3.30	0.34	0.00	3.64	1.23	2.41	2.97
			0 + 47.13	3.43	0.34	0.00	3.77	1.30	2.47	3.01
			0 + 91.40	3.51	0.34	0.30	4.15	1.10	3.05	3.18
			1 + 36.82	3.55	0.34	0.30	4.19	1.00	3.19	3.24
			2 + 00.64	3.63	0.34	0.30	4.27	1.00	3.27	3.34
			2 + 10.00	3.65	0.34	0.30	4.29	1.00	3.29	3.37
		EL-S-1a	2 + 50.00	3.76	0.34	0.30	4.40	1.00	3.40	3.50
			2 + 58.14	3.78	0.34	0.30	4.42	1.00	3.42	3.52
			3 + 39.73	3.83	0.34	0.30	4.47	1.00	3.47	3.58
			4 + 22.14	3.88	0.34	0.30	4.52	1.00	3.52	3.63
			4 + 99.25	3.93	0.34	0.30	4.57	1.66	2.91	3.68
			5 + 91.60	3.98	0.34	0.30	4.62	1.50	3.12	3.74
			6 + 80.98	4.04	0.34	0.30	4.68	2.80	1.88	3.80
			7 + 98.79	4.14	0.34	0.30	4.78	2.70	2.08	3.91
			8 + 81.23	4.24	0.34	0.30	4.88	3.24	1.64	4.01
	PR HWY 442		9 + 55.80	4.38	0.34	0.30	5.02	4.00	1.02	4.19
			10 + 78.67	4.60	0.34	0.30	5.24	4.00	1.24	4.38
			11 + 60.58	4.61	0.34	0.30	5.25	3.61	1.64	4.39
			13 + 41.89	4.61	0.34	0.30	5.25	3.69	1.56	4.39
			14 + 80.00	4.61	0.34	0.30	5.25	4.00	1.25	4.39
			14 + 96.00	4.61	0.34	0.30	5.25	5.25	0.00	4.39
ESPINAR LEVEE SPUR			0 + 00.00	3.30	0.34	0.30	4.29	1.00	3.29	2.97
			0 + 50.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			1 + 00.00	3.30	0.34	0.30	3.94	1.10	2.84	2.97
			2 + 00.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			2 + 66.00	3.30	0.34	0.30	3.64	3.64	0.00	2.97

re Espinar levee spur ties into Espinar levee

TABLE A-8

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE STRUCTURES

LEVEE SEGMENT	DRAINAGE STRUCTURE	LEVEE STATION	AVERAGE GROUND ELEVATION (M, NGVD)	LEVEE CROWN ELEVATION (M, NGVD)	CULVERT INVERT ELEVATION (M, NGVD)	CULVERT LENGTH* (M)	CULVERT N0. - DIA (M)	TYPE OF CONTROL
AGUADILLA	AL-S-1	1+39.5	1.70	3.67	-0.3	15	3 - 1.52	FLAPGATE
	AL-S-2	6+05.5	2.06	4.37	-0.3	19	6 - 1.52	FLAPGATE
	AL-S-3	10+52.9	2.98	4.68	-0.3	20	3 - 1.52	FLAPGATE
ESPINAR	EL-S-1a	2+ 50.0	1.00	4.40	-0.3	27	2 - 1.52	FLAPGATE

NOTE: *Computed with a levee crown width of 3.0 meters and 1V:2.5H side slopes.
Culverts are corrugated metal pipes (CMP) with bituminous coating.

TABLE A-9

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE CHANNELS

LEVEE SEGMENT	LEVEE STATION	AVERAGE GROUND ELEVATION M, NGVD	ROAD RAMP	DRAINAGE STRUCTURE	COMMENT No. - Dia. (M)	CHANNEL INVERT M, NGVD
AGUADILLA						
	0 + 0.00	1.00				
	0 + 32.54	2.20			Slope =.005	0.24
	0 + 76.23	1.50				0.02
	1 + 39.50	1.70		AL-S-1	3 - 1.52 CMP	-0.30
	1 + 79.72	1.72				-0.30
	2 + 25.58	1.30				-0.30
	2 + 68.05	1.22				-0.30
	3 + 44.59	1.80				-0.30
	5 + 27.92	1.00				-0.30
	6 + 05.50	2.06		AL-S-2	6 - 1.52 CMP	-0.30
	6 + 07.29	1.00				-0.30
	7 + 71.41	2.00				-0.30
	8 + 65.06	2.00				-0.30
	9 + 44.83	1.68				-0.30
	10 + 52.90	2.98		AL-S-3	3 - 1.52 CMP	-0.30
	10 + 54.61	2.50				-0.29
	11 + 28.82	2.60				0.08
	11 + 91.52	2.68				0.39
	12 + 39.36	2.22				0.63
	13 + 30.31	3.00				1.09
	13 + 66.80	2.91	PR HWY 115		1 - 0.91 CMP**	1.27
	13 + 80.59	2.91				1.34
	14 + 12.01	3.18				1.50
	15 + 06.36	3.04				1.97
	16 + 13.66	3.85				2.50
	16 + 16.6	3.85	PR HWY 418		1 - 0.91 CMP**	2.52
	16 + 31.19	3.85				2.59
	17 + 15.70	3.28				3.01
	18 + 00.81	3.66				3.44
	18 + 19.59	4.00				3.53
	18 + 36.00	5.82			Slope =.005	3.62
	18 + 40.00	7.25				
ESPINAR						
	0 + 00.00	1.00				
	0 + 47.13	1.60				
	0 + 91.40	1.40				
	1 + 36.82	1.22				
	2 + 00.64	1.10				
*	2 + 10.00	1.00				
	2 + 50.00	1.00		EL-S-1a	2 - 1.52 CMP	-0.30
	2 + 58.14	1.00				-0.10
	3 + 39.73	1.00				-0.01
	4 + 22.14	1.00				0.12
	4 + 99.25	1.00				0.23
	5 + 91.60	1.00				0.40
	6 + 80.98	1.66				0.56
	7 + 98.79	1.50				0.72
	8 + 81.23	2.80				0.90
	9 + 55.80	2.70	PR HWY 442		1 - 0.91 CMP**	1.08
	10 + 78.67	3.24				1.32
	11 + 60.58	4.00				1.48
	13 + 41.89	4.00				1.63
	14 + 80.00	3.61				1.88
	14 + 96.00	3.69			Slope =.002	2.04
ESPINAR LEVEE SPUR						
	0 + 00.00	1.00				
	0 + 50.00	1.00				-0.30
	1 + 00.00	1.10				-0.20
	2 + 00.00	1.00				0.00
	2 + 50.00	3.00				0.10
	2 + 66.00	3.64			Slope =.002	

* Where Espinar levee spur ties into Espinar levee.

** Corrugated Metal Pipe (CMP) at road ramps will not have a flap gate.

Channel bottom width and side slopes are 1 meter and 1V:3H, respectively.

Espinar levee spur channel will drain toward EL-S-1a

TABLE A-10

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
CUTOFF CHANNEL

LOCATION	EXISTING GR. ELEV. M-NGVD	CHANNEL INVERT M-NGVD	BOTTOM CHANNEL WIDTH (M)	SIDE SLOPE	TYPE OF CHANNEL
UPSTREAM END	5.64	0.52	15.2	1V:3.5H	EARTHEN
	3.97	0.46	15.2	1V:3.5H	EARTHEN
DOWNSTREAM END	3.61	0.36	15.2	1V:3.5H	EARTHEN

TABLE A-11

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR FLOOD HYDROLOGY

LEVEE SEGMENT	DRAINAGE STRUCTURE	DRAINAGE AREA SQ KM	PEAK FLOWS IN CMS PERCENT CHANCE FLOOD EVENTS						
			50	20	10	4	2	1	SPF
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	3.18	9	21	49	56	77	84	108
ESPINAR	EL-S-1a	0.34	1	3	7	8	13	14	17

TABLE A-12

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR DRAINAGE - RESIDUAL FLOOD ELEVATIONS

LEVEE SEGMENT	DRAINAGE STRUCTURE	RESIDUAL FLOOD ELEVATIONS IN METERS, NGVD PERCENT CHANCE FLOOD EVENTS		
		10	4	2
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	2.22	2.31	2.40
ESPINAR	EL-S-1a	1.99	2.06	2.14

TABLE A-13

RIO CULEBRINAS DETAILED PROJECT REPORT
RELIABILITY ANALYSIS
AT LEVEE CROSS SECTION 1568

LOG PEAK DISCHARGE STATISTICS

MEAN = 3.7243
STD DEV = 0.2500
SKEW = 0.2454
EVENTS = 31

STAGE-DISCHARGE RELATIONSHIP

DISCHARGE CMS	STAGE METERS
147	2.34
249	2.77
317	3.04
402	3.30
530	3.62
623	3.78
1218	4.63

STD DEV OF STAGE FLUCTUATIONS 0.274 METERS

DATA FOR LEVEE

LEVEE CREST ELEVATION = 4.57 METERS
WAVE RUNUP AND WIND SETUP = 0.34 METERS
MINIMUM LEVEE GRADE + SUPERIORITY = 3.93 METERS
DESIGN WATER SURFACE ELEVATION = 3.68 METERS

STAGE METERS	PERCENT PROBABILITY OF STAGE NON-EXCEEDANCE		
	SPF	.01 EVENT	.02 EVENT
3.50	2.54	18.21	37.14
3.93	21.87	62.95	82.92
4.50	72.82	95.64	98.71
4.57	78.34	96.59	99.13
5.00	97.59	99.62	99.85

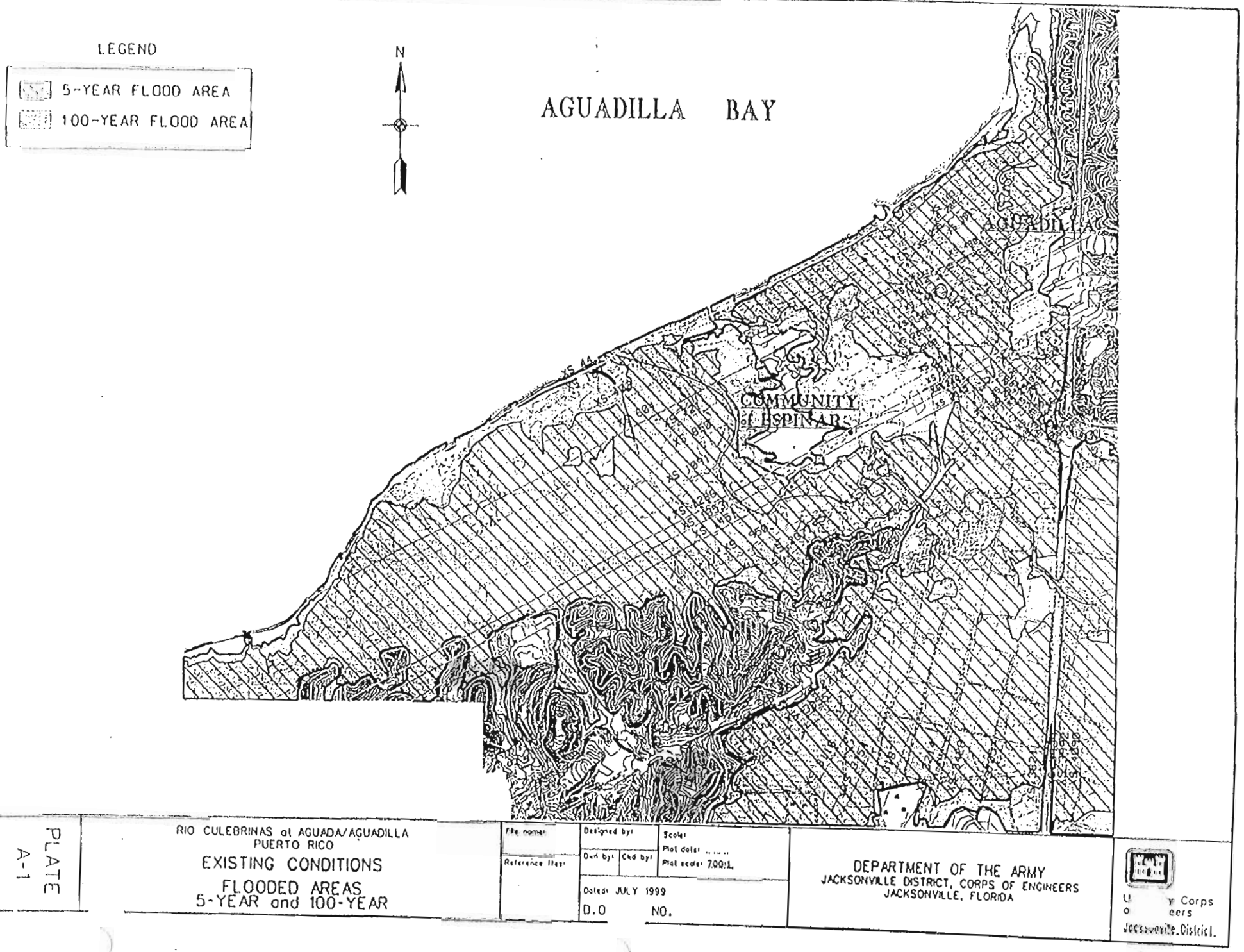


PLATE A-1

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO
EXISTING CONDITIONS
FLOODED AREAS
5-YEAR and 100-YEAR

File name:
Reference files:
Designed by:
Drawn by:
Chkd by:
Scale:
Plot date:
Plot scale: 7.00:1.
Dated: JULY 1999
D.O NO.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

U.S. Army Corps of Engineers
Jacksonville District

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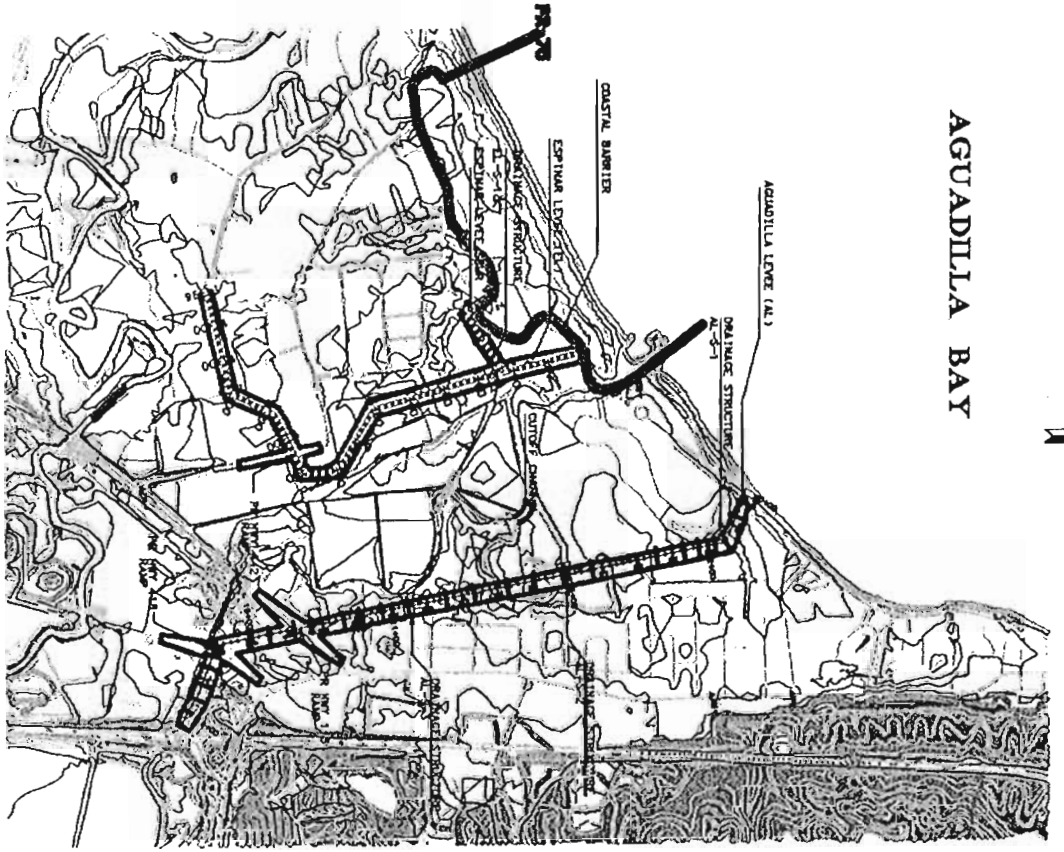


PLATE A-2

RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO
DETAILED PROJECT REPORT
RECOMMENDED PLAN

File name:
Reference files:

Designed by:
Drn by: Ckd by:
Dated: JULY 1999
O.O.FILE NO.

Scale:
Plot date:
Plot scale: 4001.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

US Army Corps of Engineers
Jacksonville District

US Army Corps of Engineers
Jacksonville District

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

File name:
Reference file:

Designed by:
Drawn by:
Checked by:

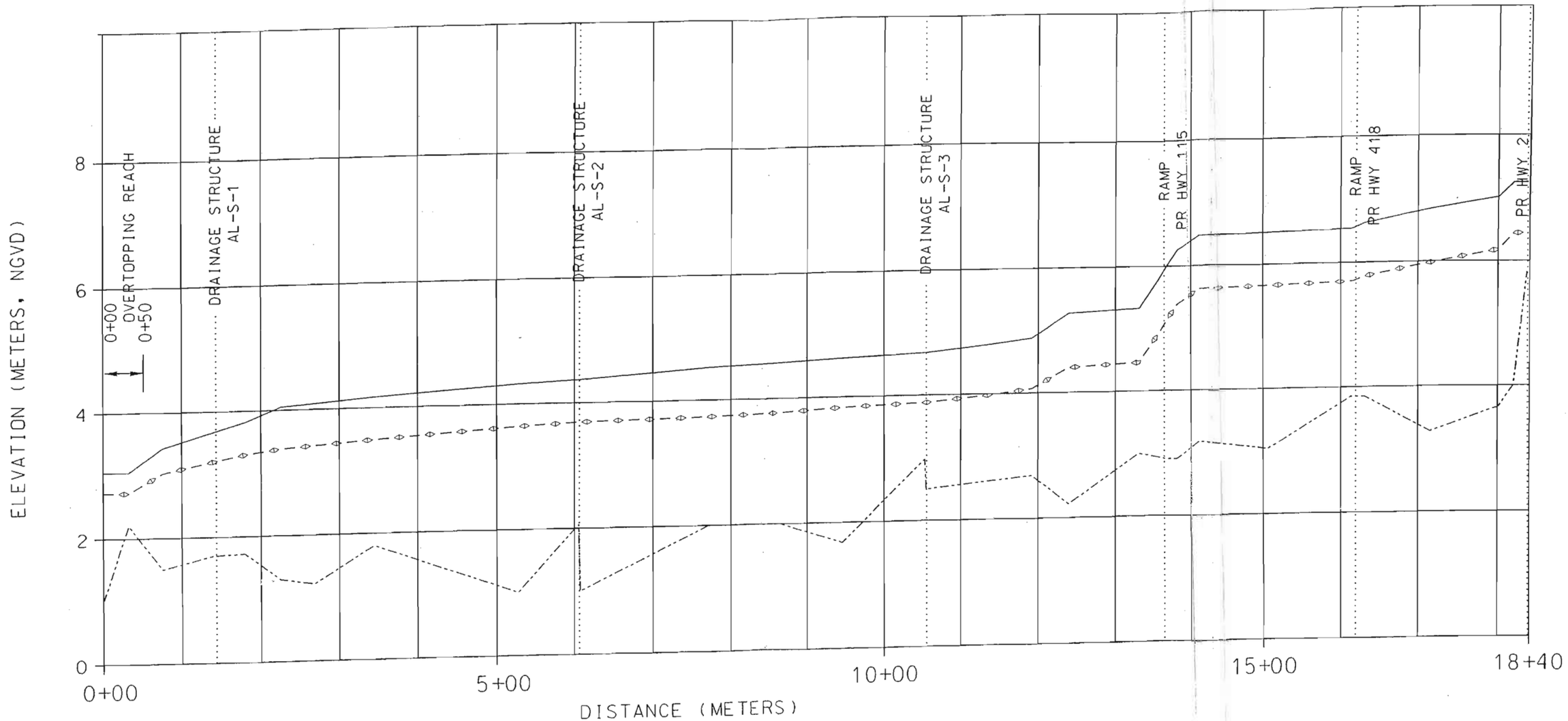
Scale:
Plot date: .....
Plot scale: 400:1

Dated: JULY 1999
D.O. FILE NO.

RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO

DETAILED PROJECT REPORT
RESIDUAL FLOODED AREA

PLATE
A-3



LEGEND

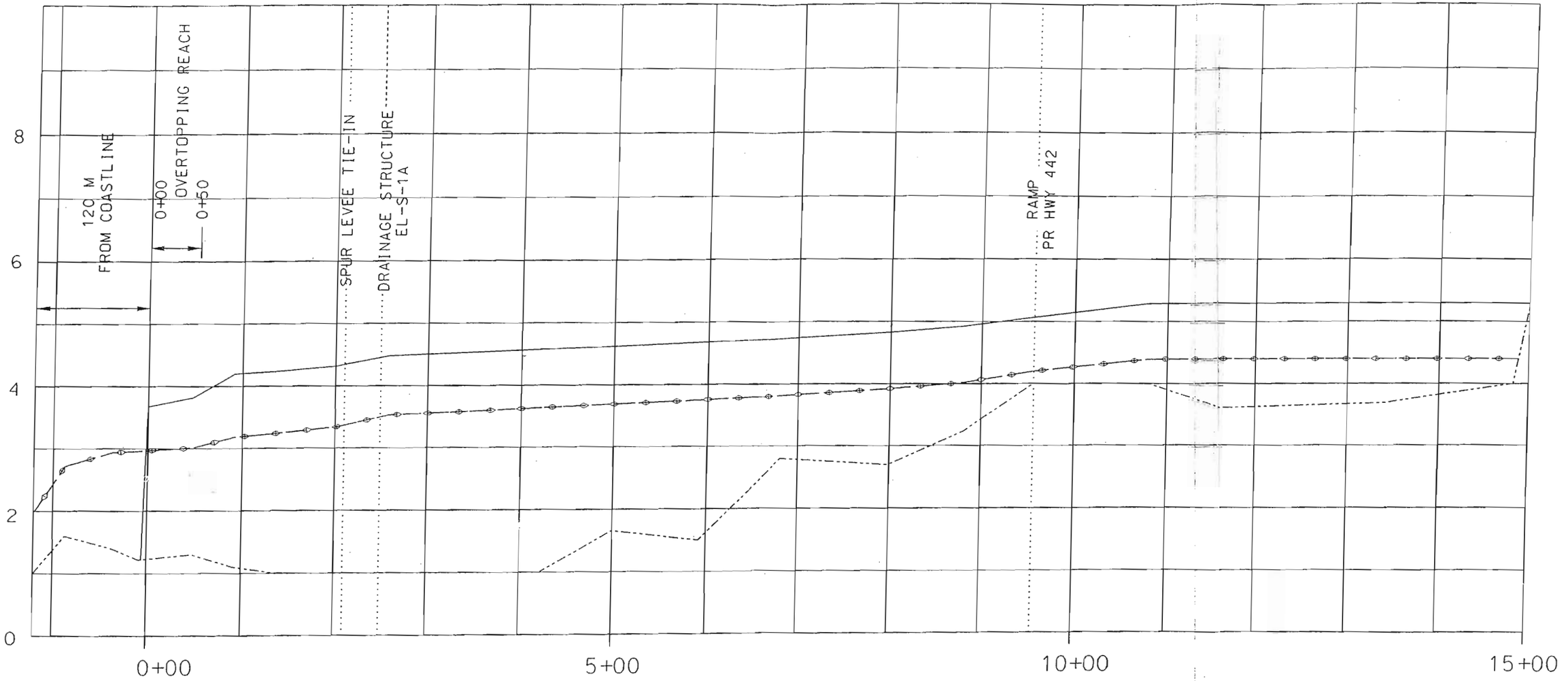
EXISTING GROUND ELEVATION

LEVEE CREST ELEVATION

DESIGN WATER SURFACE ELEVATION

NOTE: EXISTING WATER SURFACE ELEV. SAME AS DESIGN WATER SURFACE ELEV.

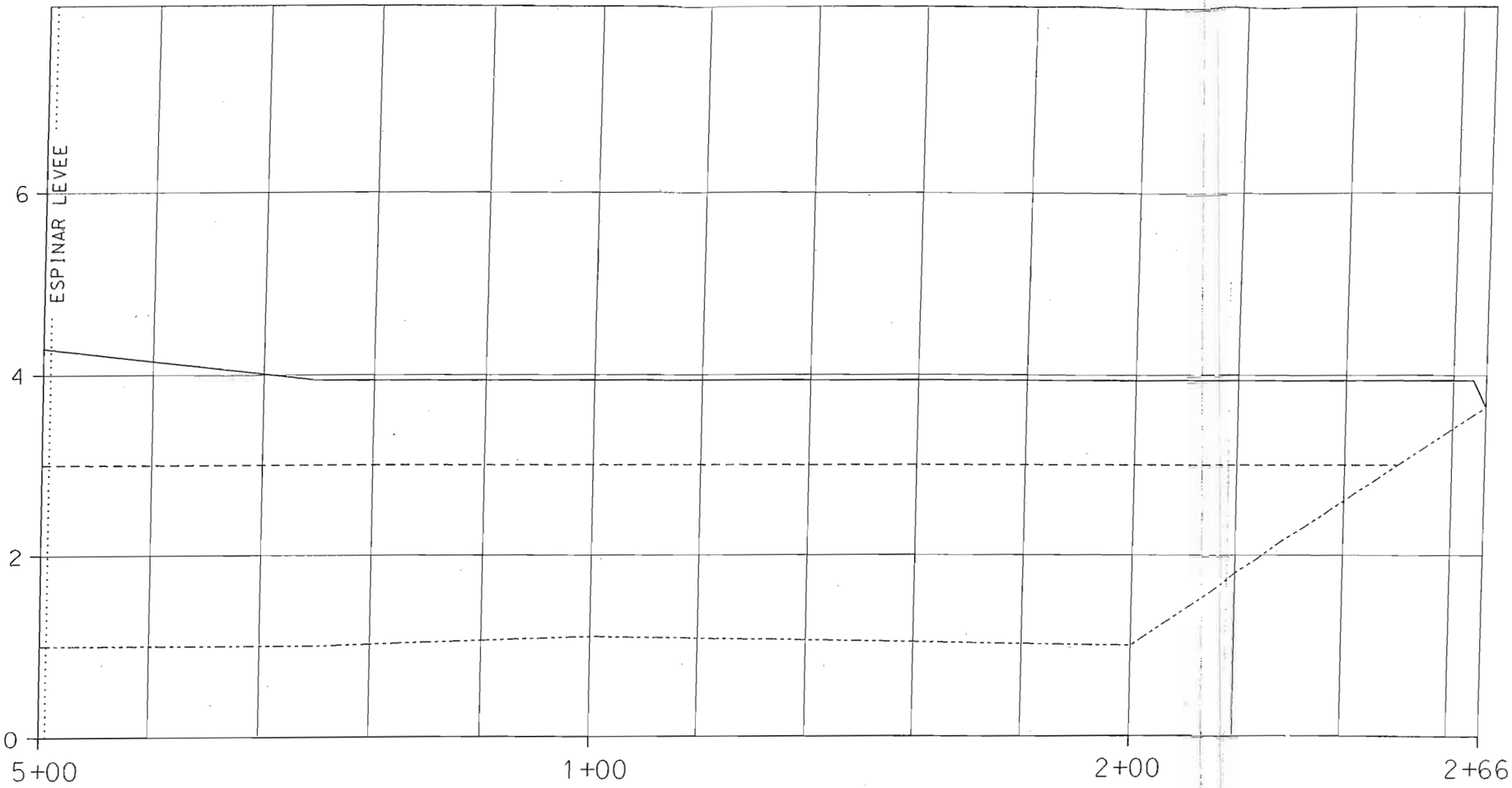
REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA		
	AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS AQUADILLA LEVEE PROFILE 100-YEAR		
DESIGN ENG.:	INV. NO.	SIZE	DWG. NO.
CHECKED BY:	DATED:		
DRAWN BY:	SCALE: AS SHOWN	DATED: JUNE, 1999	PLATE A-4



LEGEND

EXISTING GROUND ELEVATION
DESIGN WATER SURFACE ELEVATION
LEVEE CREST ELEVATION

REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA
	AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS ESPINAR LEVEE PROFILE 100-YEAR
DESIGN ENG.:	INV. NO. / SIZE / DWG. NO.
CHECKED BY:	DATED:
DRAWN BY:	SCALE: AS SHOWN / DATED: JUNE, 1999 / PLATE A-5



ELEVATION (METERS, NGVD)

DISTANCE (METERS)

LEGEND

EXISTING GROUND ELEVATION
DESIGN WATER SURFACE ELEVATION
LEVEE CREST ELEVATION

NOTE: EXISTING WATER SURFACE ELEVATION SAME AS DESIGN WATER SURFACE

REFERENCE FILENAMES:

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

AQUADA/AQUADILLA, PUERTO RICO
RIO CULEBRINAS
ESPINAR LEVEE SPUR PROFILE
100-YEAR

DESIGN ENG.:	INV. NO.	SIZE	DWG. NO.
CHECKED BY:	DATED:		
DRAWN BY:	SCALE: AS SHOWN	DATED: JUNE, 1999	PLATE A-6

SECTION 404(b) EVALUATION

Flood Control Project
Río Culebrinas
Aguada and Aguadilla, Puerto Rico

I. Project Description

a. Location. The proposed work will be performed Caño Madre Vieja and Río Culebrinas, between the municipalities of Aguada and Aguadilla, Puerto Rico.

b. General Description. The proposed plan calls for the construction of two flood control levees to separate the last downstream segment of Caño Madre Vieja from adjoining residential communities. Other project features are: a short cutoff channel, to connect two meanders of the stream where the Aguadilla Levee will interrupt it, four drainage structures, interior drainage channels, and a commercial borrow area located in Aguada.

c. Authority and Purpose. This study and proposed project were developed under the authority of Section 205 of the 1948 Flood Control Act, as amended.

d. General Description of Dredged or Fill Material.

(1) General Characteristics of Material. Clean, toxic contaminant-free fill will be used.

(2) Quantity of Material. Approximately 110,000 cubic yards of fill. And 1,000 cubic yards of spoil fill.

(3) Source of Material. Approximately 30,000 cubic yards would come from the cutoff and drainage channels and the rest from the commercial borrow site at nearby Tablonal Quarry.

e. Description of the proposed Discharge Site.

(1) Location. Most spoil fill will be disposed of within the right-of-way of the levees, on top or on the sides slopes as topsoil. Any spoil fill or debris that cannot be disposed of in that manner will be disposed of in the municipal landfill in use by the Municipalities of Agüadilla and Aguada at the time the work takes place.

(2) Size. The approximately 19.6 acres. Area of the levee footprints. And the minimal debris and spoil found to be unsuitable will go in the existing landfills.

(3) Type of Site. Mostly uplands pastureland.

(4) Type of Habitat. Footprint of the levees

(5) Timing and Duration of Discharge. Duration of the actual levee construction.

f. Description of Disposal Method. Transportation over existing roads, using commercial trucks. Deposition at existing municipal sanitary landfills.

II. Factual Determinations

a. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. Both levees would have an average structural height of 2.5 meters, 1 on 2.5 side slopes, an average levee base of 16 meters, and a levee crest width of 3 meters.

(2) Sediment Type. Sandy silt.

(2) Dredge/Fill Material Movement. Material to be excavated by backhoe and carried to final destination using dump trucks.

(4) Physical Effects on Benthos. No effect is expected on the Benthic habitat.

b. Water Circulation, Fluctuation and Salinity Determination.

(1) Water Column Effects. These are Class SD waters. No changes are expected.

(2) Current Patterns and Circulation. Existing fast water flow patterns for the Culebrinas River will remain unchanged.

(3) Normal Water Level Fluctuations and Salinity Gradients. No changes are expected.

c. Suspended Particulate/Turbidity Determinations.

(1) Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Disposal Site. None expected. The disposal site is the footprint of the levee and the municipal landfill, no permanent turbidity level changes are

expected during deposition. The acceptable turbidity levels in the Culebrinas River (50 NTUs) will not be exceeded.

(2) Effects on the Chemical and Physical Properties of the Water Column.

(a) Light Penetration. Since no significant changes in turbidity are expected, no significant changes in light penetration are expected, either.

(b) Dissolved Oxygen. The amount of dissolved oxygen 5.0 mg/L (PPM) is not expected to vary.

(c) Toxic Metals, Organics, and Pathogens. No increase expected in these parameters.

(d) Aesthetics. The earthen levees will be re colonized by the existing vegetation, blending with the surroundings

(3) Effects on Biota.

(a) Primary Productivity and Photosynthesis. No effect.

(b) Suspension/Filter Feeders. No effect.

(c) Sight Feeders. No effect.

d. Contaminant Determinations.

e. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. None.

(2) Effects on Benthos. None.

(3) Effects on Nekton. None.

(3) Effects on the Aquatic Food Web. None.

(5) Effects on Special Aquatic Sites.

(a) Hardground and Coral Reef Communities. Doesn't apply.

(b) Sanctuaries and Refuges. Not applicable.

(c) Wetlands. The project will impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands, and having a total biological value of 1 unit in accordance with the Wetlands Rapid Assessment Procedure Methodology (WRAP). Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie.

(d) Mud Flats. Not applicable.

(e) Vegetated Shallows. Not applicable.

(f) Riffle and Pool Complexes. Not applicable.

(6) Endangered and Threatened Species. No endangered species was identified in the work area.

(7) Other Wildlife. Not applicable.

(8) Actions to Minimize Impacts. The design and footprint of the project were modified to avoid work inside the wetlands of Coastal barrier PR-75.

f. Proposed Disposal Site Determinations.

(1) Mixing Zone Determination. Not applicable.

(2) Determination of Compliance with Applicable Water Quality Standards. Fill deposition will occur within the footprints of the levees on existing pasturelands. Other deposition will be in contained, approved municipal landfills. The Corps has thus determined that the proposed work complies with Applicable Water Quality Standards.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supplies. Not applicable.

(b) Recreational and Commercial Fisheries. Not applicable.

(c) Water Related Recreation. Not applicable.

(d) Aesthetics. No aesthetic changes are foreseen, the levees will be re-colonized by the local vegetation.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves. Not applicable.

g. Determination of Cumulative Effects on the Aquatic Ecosystem. None expected.

h. Determination of Secondary Effects on the Aquatic Ecosystem. None expected.

III. Findings of Compliance or Non-compliance with the Restrictions on Discharge.

a. No significant adaptations of the guidelines were made relative to this evaluation.

b. No practicable alternative exists which meets the study objectives that does not involve discharge of fill into waters of the United States.

c. After consideration of disposal site dilution and dispersion, the discharge of fill materials will not cause or contribute to, violations of any applicable State water quality standards for Class III waters. The discharge operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

d. The construction of the levees and associated canal cut will not jeopardize the continued existence of any species listed as threatened or endangered or result in the likelihood of destruction or adverse modification of any critical habitat as specified by the Endangered Species Act of 1973, as amended.

e. The placement of fill material will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreational and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic species and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values will not occur.

f. On the basis of the guidelines, the proposed disposal site for the discharge of dredged material is specified as complying with the requirements of these guidelines.

SECTION 404(b) EVALUATION

Flood Control Project
Río Culebrinas
Aguada and Aguadilla, Puerto Rico

I. Project Description

a. Location. The proposed work will be performed Caño Madre Vieja and Río Culebrinas, between the municipalities of Aguada and Aguadilla, Puerto Rico.

b. General Description. The proposed plan calls for the construction of two flood control levees to separate the last downstream segment of Caño Madre Vieja from adjoining residential communities. Other project features are: a short cutoff channel, to connect two meanders of the stream where the Aguadilla Levee will interrupt it, four drainage structures, interior drainage channels, and a commercial borrow area located in Aguada.

c. Authority and Purpose. This study and proposed project were developed under the authority of Section 205 of the 1948 Flood Control Act, as amended.

d. General Description of Dredged or Fill Material.

(1) General Characteristics of Material. Clean, toxic contaminant-free fill will be used.

(2) Quantity of Material. Approximately 110,000 cubic yards of fill. And 1,000 cubic yards of spoil fill.

(3) Source of Material. Approximately 30,000 cubic yards would come from the cutoff and drainage channels and the rest from the commercial borrow site at nearby Tablonal Quarry.

e. Description of the proposed Discharge Site.

(1) Location. Most spoil fill will be disposed of within the right-of-way of the levees, on top or on the sides slopes as topsoil. Any spoil fill or debris that cannot be disposed of in that manner will be disposed of in the municipal landfill in use by the Municipalities of Agüadilla and Aguada at the time the work takes place.

(2) Size. The approximately 19.6 acres. Area of the levee footprints. And the minimal debris and spoil found to be unsuitable will go in the existing landfills.

(3) Type of Site. Mostly uplands pastureland.

(4) Type of Habitat. Footprint of the levees

(5) Timing and Duration of Discharge. Duration of the actual levee construction.

f. Description of Disposal Method. Transportation over existing roads, using commercial trucks. Deposition at existing municipal sanitary landfills.

II. Factual Determinations

a. Physical Substrate Determinations.

(1) Substrate Elevation and Slope. Both levees would have an average structural height of 2.5 meters, 1 on 2.5 side slopes, an average levee base of 16 meters, and a levee crest width of 3 meters.

(2) Sediment Type. Sandy silt.

(2) Dredge/Fill Material Movement. Material to be excavated by backhoe and carried to final destination using dump trucks.

(4) Physical Effects on Benthos. No effect is expected on the Benthic habitat.

b. Water Circulation, Fluctuation and Salinity Determination.

(1) Water Column Effects. These are Class SD waters. No changes are expected.

(2) Current Patterns and Circulation. Existing fast water flow patterns for the Culebrinas River will remain unchanged.

(3) Normal Water Level Fluctuations and Salinity Gradients. No changes are expected.

c. Suspended Particulate/Turbidity Determinations.

(1) Expected Changes in Suspended Particulates and Turbidity Levels in the Vicinity of the Disposal Site. None expected. The disposal site is the footprint of the levee and the municipal landfill, no permanent turbidity level changes are expected during deposition. The acceptable turbidity levels in the Culebrinas River (50 NTUs) will not be exceeded.

(2) Effects on the Chemical and Physical Properties of the Water Column.

(a) Light Penetration. Since no significant changes in turbidity are expected, no significant changes in light penetration are expected, either.

(b) Dissolved Oxygen. The amount of dissolved oxygen 5.0 mg/L (PPM) is not expected to vary.

(c) Toxic Metals, Organics, and Pathogens. No increase expected in these parameters.

(d) Aesthetics. The earthen levees will be re colonized by the existing vegetation, blending with the surroundings

(3) Effects on Biota.

(a) Primary Productivity and Photosynthesis. No effect.

(b) Suspension/Filter Feeders. No effect.

(c) Sight Feeders. No effect.

d. Contaminant Determinations.

e. Aquatic Ecosystem and Organism Determinations.

(1) Effects on Plankton. None.

(2) Effects on Benthos. None.

(3) Effects on Nekton. None.

(3) Effects on the Aquatic Food Web. None.

(5) Effects on Special Aquatic Sites.

(a) Hardground and Coral Reef Communities. Doesn't apply.

(b) Sanctuaries and Refuges. Not applicable.

(c) Wetlands. The project will impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands, and having a total biological value of 1 unit in accordance with the Wetlands Rapid Assessment Procedure Methodology (WRAP). Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie.

(d) Mud Flats. Not applicable.

(e) Vegetated Shallows. Not applicable.

(f) Riffle and Pool Complexes. Not applicable.

(6) Endangered and Threatened Species. No endangered species was identified in the work area.

(7) Other Wildlife. Not applicable.

(8) Actions to Minimize Impacts. The design and footprint of the project were modified to avoid work inside the wetlands of Coastal barrier PR-75.

f. Proposed Disposal Site Determinations.

(1) Mixing Zone Determination. Not applicable.

(2) Determination of Compliance with Applicable Water Quality Standards. Fill deposition will occur within the footprints of the levees on existing pasturelands. Other deposition will be in contained, approved municipal landfills. The Corps has thus determined that the proposed work complies . with Applicable Water Quality Standards.

(3) Potential Effects on Human Use Characteristics.

(a) Municipal and Private Water Supplies. Not applicable.

(b) Recreational and Commercial Fisheries. Not applicable.

(c) Water Related Recreation. Not applicable.

(d) Aesthetics. No aesthetic changes are foreseen, the levees will be re-colonized by the local vegetation.

(e) Parks, National and Historic Monuments, National Seashores, Wilderness Areas, Research Sites, and Similar Preserves. Not applicable.

g. Determination of Cumulative Effects on the Aquatic Ecosystem. None expected.

h. Determination of Secondary Effects on the Aquatic Ecosystem. None expected.

III. Findings of Compliance or Non-compliance with the Restrictions on Discharge.

a. No significant adaptations of the guidelines were made relative to this evaluation.

b. No practicable alternative exists which meets the study objectives that does not involve discharge of fill into waters of the United States.

c. After consideration of disposal site dilution and dispersion, the discharge of fill materials will not cause or contribute to, violations of any applicable State water quality standards for Class III waters. The discharge operation will not violate the Toxic Effluent Standards of Section 307 of the Clean Water Act.

d. The construction of the levees and associated canal cut will not jeopardize the continued existence of any species listed as threatened or endangered or result in the likelihood of destruction or adverse modification of any critical habitat as specified by the Endangered Species Act of 1973, as amended.

e. The placement of fill material will not result in significant adverse effects on human health and welfare, including municipal and private water supplies, recreational and commercial fishing, plankton, fish, shellfish, wildlife, and special aquatic sites. The life stages of aquatic species and other wildlife will not be adversely affected. Significant adverse effects on aquatic ecosystem diversity, productivity and stability, and recreational, aesthetic, and economic values will not occur.

f. On the basis of the guidelines, the proposed disposal site for the discharge of dredged material is specified as complying with the requirements of these guidelines.

D. COASTAL ZONE MANAGEMENT ACT COORDINATION – Certification of Compliance with PR Coastal Management Plan and Application for Concurrence from PR Planning Board.

At this time the study and recommended plan have been determined to be in compliance with the major programs and objectives of the Puerto Rico Coastal Management Program. Concurrence from the Puerto Rico Planning Board (PRPB) will be sought when the public comment period on this EA has closed.

E. SITE VISIT MEMORANDUM AND WRAP SCORE SHEETS

Project completion will directly impact approximately 1.5 acres of emergent wet prairie currently used as pasturelands and 0.2-acre of Red mangrove swamp. These were assessed to have a total biological value of 1 unit, using the Wetlands Rapid Assessment Procedure Methodology (WRAP). The score was 0.48 for the pasture and 0.56 for the Red mangrove. Mitigation for unavoidable project impacts, if needed, would include enhancement of 1 acre of emergent wet prairie. The USACE estimates that project completion will also result in the construction of drainage channels parallel to the levees. These will have an average width of approximately 7 meters (21feet) and will run for the entire length of the levees. This will create approximately
21 x 9,723 = 204,183 square feet or 4.69 acres of habitat for fish and amphibian species.

Assuming creation of at least 13 meters (40 feet) of shallow littoral area on both banks of each channel, an additional 8.93 acres of wetlands would be created. The USACE believes that the wetlands and waters of the United States created by the project would avoid a net loss of wetlands.

Present during the October 12, 1999 site visit: Beverly Yoshioka USFWS; Ana Román, USFWS; Jorge M. Tous, USACE; Esteban Jimenez, USACE.

CESAJ-PD-ES 12 October 1999

MEMORANDUM FOR RECORD

SUBJECT: Culebrinas River Flood Control (Aguadilla & Espinar Levees) Project Site Visit

1. Going west to east along the Aguadilla levee footprint (24.2 acres or 98,095 square meters including levee, drainage channel, ramps, and right of way), the start is an approximately 35% urban developed area. It continues along fields use for horses grazing. Sawgrass predominates with few depressional wetlands. Functional wetlands are 10% or less of the total footprint area of the proposed Aguadilla levee. These are found mostly halfway along the footprint.

2. A similar situation is seen along the Espinar levee proposed footprint (17.5 acres or 70,861 square meters including levee, drainage channel, ramps, and right of way). Upland herbaceous species and sawgrass predominate. Mangroves and cattail (*Typha spp.*) are found in 10% or less of the footprint area. The most impressive wetland vegetation is seen in an approximately 100-foot by 70-foot section of coastal barrier vegetated over 90% by climax red mangroves with a height over 50 feet . This exists in the margins of the drainage channel, which exist parallel to the coastline in a south-north attitude, no more than 500 feet inland and connecting to the estuary at the mouth of the Culebrinas River. Considerable sediment extrusion into the bay is seen at the Culebrinas River estuary.

3. For the projected cut at the central area approximately halfway between the two projected levees: The area currently includes drainage channels with flowing water, supporting mature white mangrove populations with approximately 90% coverage for some 25 feet from the existing channel margins. An mangrove juvenile and *Typha* understory dominates.

////////////////////////nothing follows//

ESTEBAN JIMENEZ
Biologist

EVALUATION SUMMARY

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.78

Evaluator(s): E. Jimenez

Project/Site: R. Culebrines (Espinor Levee at Coastal Barrier)
Permit Number:
Wetland ID:
Wetland Type: Saltwater Swamp
Land Use: Coastal Barrier and Run off channel

SCORE **NOTES**

2 Fish and Wildlife Utilization:

Slight human impact due to adjacent beach and area habitation.
Debris seen. No fish seen.
Crustacean burrows.

2.5 Overstory/Shrub Canopy:

Mature Red Mangrove > 90%

1.5 Ground Cover:

Juvenile Mangrove and Typha 40%

2.5 Upland/Wetland Buffer:

> 30', < 300'

2.5 Field Indicators of Wetland Hydrology:

Flowing water in channel.
Adequate hydroperiod.

3 Water Quality Inputs and Treatment:

Land Use 3 unimprov
natural

Pre-treatment 3 unimprov
natural

14
18

EVALUATION SUMMARY

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.33

Evaluator(s): E. Jimenez

Project/Site: R. Culebrinas (Espinor Levee)
Permit Number:
Wetland ID:
Wetland Type: Emergent (Freshwater Flat) prairie
Land Use: Agricultural Use

SCORE **NOTES**

0.5 Fish and Wildlife Utilization:

Cattle and associated bird species
No fish seen.

0.5 Overstory/Shrub Canopy:

Upland Spp. ~ 80%

0.5 Ground Cover:

~ 10% Cattail (Typha). Predominant upland Spp.

1.5 Upland/Wetland Buffer:

>30'. Connection to wildlife corridors

0.5 Field Indicators of Wetland Hydrology:

Altered wetland hydrology would require scrapedown.

2.5 Water Quality Inputs and Treatment:

Land Use 2.5 Ran

6/18

Pre-treatment 2.5 Berms

EVALUATION SUMMARY

Without Proje

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.33

Evaluator(s): E. Jimenez

Project/Site: Rio Culebrinas (Aguadilla Levee following Cano Madre Vieja)
Permit Number:
Wetland ID:
Wetland Type: Freshwater Flat (emergent prairie
Land Use: Horse/Cattle pasture

SCORE		NOTES
1	Fish and Wildlife Utilization:	Birds associated with cattle (i.e. egrets). No fish seen. Various crab burrows.
0	Overstory/Shrub Canopy:	No nesting. <10% in some depressional areas.
0.5	Ground Cover:	Typha and Buttonwood 10%
1.5	Upland/Wetland Buffer:	30'> x <300'. Wildlife corridor connections.
1	Field Indicators of Wetland Hydrology:	Transitional vegetation indicating interference with hydrology.
	Water Quality Inputs and Treatment:	Land Use 50% high de vegitation; 50% past Pre-treatment 1 dry rete 2.5 Berms

LU = 2.5(.5) + 2(.5)
= 1.25 + 1.0
= 2.25

6/12 2.25 + 1.75 = 4/2 = 2

EVALUATION SUMMARY

Without Project

ESTUARINE WETLAND RAPID ASSESSMENT PROCEDURE

Date of Site Visit: 12 Oct 99

E-WRAP SCORE 0.76

Evaluator(s): E. Jimenez

Project/Site: R. Culebrinas (Planned cutoff between Espinar and Aguadilla)
Permit Number:
Wetland ID:
Wetland Type: Mangrove forest and existing channel.
Land Use: Undeveloped.

SCORE		NOTES
2	Fish and Wildlife Utilization:	No fish seen. Birds (crane) seen. Rodents crabs and burrows.
3	Overstory/Shrub Canopy:	Over 90% mature mangrove (white)
2	Ground Cover:	Wetland spp., Mangrove juveniles.
2	Upland/Wetland Buffer:	30' > x < 300', undeveloped. Connected to possible wildlife corridors.
2	Field Indicators of Wetland Hydrology:	Standing water with high hydroperiod. Supports wetland vegetation.
2.75	Water Quality Inputs and Treatment:	Land Use 3 Open = a Pre-treatment 2.5 wet de swales.

$\frac{13.75}{18} = 0.76$ $\frac{3+2.5=5.5}{2 \quad 2} = 2.75$

RIO CULEBRINAS AT AGUADILLA AND AGUADA, PUERTO RICO
SECTION 205
FINAL DETAILED PROJECT REPORT
AND ENVIRONMENTAL ASSESSMENT

APPENDIX A
HYDROLOGY AND HYDRAULICS

RIO CULEBRINAS
AGUADA/AGUADILLA, PUERTO RICO
DETAILED PROJECT REPORT

APPENDIX A
HYDROLOGY AND HYDRAULICS

TABLE OF CONTENTS

I. INTRODUCTION. A-1

II. DRAINAGE BASIN INFORMATION. A-1

A. Location. A-1
B. Topography. A-1
C. Geology, Soils and Vegetation A-1
D. Climate A-2
E. Main Streams and Tributaries. A-2
F. Available Hydrologic Data A-2
G. Historical Floods A-2
H. Flood Flow Frequency Analysis A-3
I. Rainfall. A-3

III. HYDROLOGIC ANALYSIS A-4

A. Computer Programs A-4
B. Formation of HEC-1 and UNET Models. A-4
1. Drainage Area A-4
2. Curve Numbers A-4
3. Lag Times A-4
4. Rainfall. A-5
5. Flood Routings. A-5
6. Discharge for Existing Conditions with Future Land Uses A-5
C. Hydrology of Interior Flooding. A-6
D. Other Sources of Flooding A-6

IV. HYDRAULICS. A-7

A. Existing Conditions A-7
1. Hydraulic Model A-7
2. Survey Data A-7
3. Roughness Coefficients. A-7
4. Starting Conditions A-7
5. Model Verification. A-8
6. Flood Stages. A-8
B. Sediment Assessment A-8
1. Existing Conditions A-8
2. With Project Conditions A-8

V. HYDRAULIC DESIGNS A-9

A. Hydraulic Design Criteria A-9
B. Design Objective. A-9
C. Levees. A-9
1. Aguadilla Levee A-10
2. Espinar Levee A-10
3. Side Slopes A-10
4. Levee Crest Elevation A-10
5. Levee Overtopping Analysis. A-11
6. Reliability Analysis of the Selected Levees. A-12
D. Channels. A-12
1. Cutoff Channel. A-12
2. Interior Drainage Channels. A-13
E. Drainage Structures A-13
1. Aguadilla Levee A-13
a. AL-S-1. . . . . A-13
b. AL-S-2. . . . . A-13
c. AL-S-3. . . . . A-13
2. Espinar Levee A-14
a. EL-S-1a A-14
F. Road Ramps. A-14
G. Borrow Area A-14
H. Performance A-14
1. Levee Design Protection A-14
2. Residual Flooding A-15
3. People at Risk. A-16

LIST OF FIGURES

TITLE	FIGURE NO.
Location Map with Basin and Sub-Basins	A-1
100-Year Flood Hydrograph at Mouth of Rio Culebrinas	A-2
100-Year Flood Hydrograph at Mouth of Cano Madre Vieja	A-3
Flow Frequency at United States Geological Survey (USGS) Gage No. 50147800	A-4
Rating Curve Between Rio Culebrinas and Cano Madre Vieja	A-5

LIST OF TABLES

TITLE	TABLE NO.
Historical Flood Data for Rio Culebrinas	A-1
Rainfall for Various Frequencies and Durations	A-2
Watershed Parameters	A-3
Summary of Peak Discharges	A-4
Wave Run-up and Wind Set-up.	A-5
Existing and With Project Water Surface Elevations	A-6
100-Year Levee Crest Elevations.	A-7
Hydraulic Design Data Interior Drainage Structures	A-8
Hydraulic Design Data Interior Drainage Channels	A-9
Hydraulic Design Data Cutoff Channel	A-10
Interior Flood Hydrology	A-11
Interior Drainage - Residual Flood Elevations.	A-12
Reliability Analysis at Levee Cross Section 1568	A-13

LIST OF PLATES

TITLE	PLATE NO.
Existing Conditions Flooded Areas (5 and 100-yr)	A-1
Recommended Plan	A-2
Residual Flooded Areas	A-3
Aguadilla Levee Profile 100-Year	A-4
Espinar Levee Profile 100-Year	A-5
Espinar Levee Spur Profile 100-Year.	A-6

I. INTRODUCTION

This appendix presents the basic hydrologic data and analyses used to define the flooding conditions for the Rio Culebrinas Detailed Project Report.

II. DRAINAGE BASIN INFORMATION

A. Location

The Rio Culebrinas basin is located in the northwestern part of the island of Puerto Rico, about 130 kilometers from the City of San Juan. The basin is bordered to the north and east by the Rio Guajataca basin, to the south by the Rio Culebra and Rio Grande de Añasco basins, and to the west by Aguadilla Bay. There are no impounding reservoirs within the river basin. The drainage area of the watershed is about 322.6 square kilometers. Figure A-1 shows where the study area is located in Puerto Rico along with the basin and subbasins of Rio Culebrinas.

B. Topography

The basin is considered a fairly gently sloping basin with elevations ranging from sea level at Aguadilla Bay, to over 300 meters near Juncal, at the basin divide between Rio Culebrinas and Rio Guajataca. A prominent feature of the basin is a 100-meter high limestone escarpment that extends along its northern boundary.

C. Geology, Soils and Vegetation

The principal soil associations found in the Rio Culebrinas watershed area are the Voladora-Moca, Colinas-Soler, Caguabo-Mucara, and the Consumo-Humatas, in the uplands and the Coloso-Toa and Bejucos-Jobos in the lower flood plain. These soils are mostly of the D type with a high runoff potential. Type B soils with moderate degree of drainage potential are also found in this basin. The flood plain is composed of alluvial deposits of sands silts, clays and gravels of various sizes.

The forest and pasture areas are located in the eastern hilly part of the watershed and the urban area is located near the ocean. Land use within the flood prone area is urban with commercial and light industrial areas.

D. Climate

The climate in this area is characteristically tropical. Mean annual temperature in this region varies from approximately 21 degrees centigrade to 26 degrees centigrade. Mean annual precipitation for the region varies from 115 to 205 centimeters. The annual pattern of rainfall in the basin is such that the wettest period of the year is the hurricane season, which occurs in the latter part of the summer and the early part of fall.

E. Main Streams and Tributaries

The Rio Culebrinas originates in the western part of the Cordillera Central (the central mountain range of Puerto Rico) at an elevation of about 300 meters above mean sea level and flows in a westerly direction through the towns of San Sebastian and Moca to discharge into the Aguadilla Bay. The major tributaries for Rio Culebrinas are Rio Guatemala, Rio Cano, Rio Sonador and Quebrada Grande. The total length of Rio Culebrinas is about 44 kilometers.

The Cano Madre Vieja is a distributary of Rio Culebrinas and is about 2.1 kilometers long. This is an old river outlet that flows across the study area and discharges into the Aguadilla Bay. This small intermittent stream is the boundary dividing the municipality of Aguadilla to the east from the community of Espinar to the west.

F. Available Hydrologic Data

The US Geological Survey (USGS), in cooperation with local and other federal agencies, collects and maintains a large amount of water resources data in Puerto Rico. There is one USGS gage recording peak flows and/or peak stages in Rio Culebrinas. This USGS gaging station numbered 50147800 is located at PR Hwy 404 near Moca, Puerto Rico. Approximate location is shown in Figure A-1.

G. Historical Floods

Since the turn of the century there have been at least 38 damaging floods in the Rio Culebrinas Basin. The largest flood of record occurred on September 16, 1975. This flood had an estimated recurrence interval of approximately 25 years. The discharge associated with this flood was estimated at 1,954 cubic meters per second (cms) and stages just downstream of PR Hwy 2 were 7.2

meters, mean sea level (msl), about 3.2 meters of water depth.

The most outstanding recent floods in the Aguadilla area for which stream gaging station records exceeded 850 cms were those which occurred during October 1972, May 1980, October 1981, May 1985, May 1986 and August 1988. There are twenty-three other large floods in the Rio Culebrinas for which records at the stream gaging station exceeded 566 cms. These are indicated in Table A-1.

H. Flood Flow Frequency Analysis

A log-Pearson Type III frequency analysis was performed on the 35-years of annual peak discharge data listed in Table A-1. The US Army Corps of Engineers computer program Flood Frequency Analysis (FFA) was used for the analysis. The estimated discharge-frequency curve is shown in Figure A-4 along with the expected probability adjustments. The plotting positions of the discharge data are included in the figure for comparison. The frequency curves corresponding to the 5% and the 95% confidence limits are also shown in Figure A-4.

I. Rainfall

The National Weather Service (NWS) operates several rain gages in Puerto Rico. The NWS Technical Paper No. 42 (TP-42) shows generalized estimates of the Probable Maximum Precipitation (PMP) and rainfall depth-frequency data for Puerto Rico and the US Virgin Islands. Contained in the report are isopluvial maps of precipitation contours for selected frequencies. The maps indicate rainfall increases toward the central mountain region of Puerto Rico. Point rainfalls representing Rio Culebrinas basin were obtained from TP-42 and are listed in Table A-2.

The Standard Project Storm (SPS) is defined as the most severe flood-producing rainfall depth-area-duration relationship and the isohyetal pattern of any storm that is considered reasonably characteristic of the region.

The PMP is defined as the greatest depth of precipitation for a given duration that is physically possible over a given size storm area at a particular geographical location at a certain time of the year. The SPS was assumed to be 50 percent of the PMP.

III. HYDROLOGIC ANALYSIS

A. Computer Programs

The US Army Corps of Engineers HEC-1 computer program was used to calculate the flood hydrographs for various sub-basins. The HEC-1 estimates surface runoff resulting from synthetic or observed storm events. Several choices of estimating the rainfall-runoff relationships are available in HEC-1. The Soil Conservation Service (SCS) runoff curve number methodology was selected for the Rio Culebrinas basin. Runoff curve numbers are functions of soil types, land uses and Antecedent Moisture Conditions (AMC).

Flood routings were performed for the Rio Culebrinas by the Hydrologic Engineering Center computer program entitled UNET. The UNET is a one-dimensional unsteady flow model that can simulate dendritic and network (looped) system.

B. Formation of HEC-1 and UNET Models

1. Drainage Area

Available USGS quadrangle maps on a scale of 1 to 20,000 were used to delineate drainage boundaries for the Rio Culebrinas basin. Surveys collected in February and March 1995 were also used. The watershed was divided into 30 sub-basins as shown in Figure A-1.

2. Curve Numbers

Runoff curve numbers were estimated for each sub-basin by considering soil types, land uses, and the AMC, appropriate for the rainfall frequency events. AMC I conditions were used for 50, 20, and 10 percent chance flood; AMC II conditions for 4 and 2 percent chance floods; AMC III conditions were adopted for 1 percent and events rarer than 1 percent. Estimated curve numbers for various sub-basins and AMC conditions are listed in Table A-3.

3. Lag Times

The lag times were computed for each sub-basin by dividing each stream into several reaches and applying the following formula:

$$L = \frac{X^{**}0.8 * (S+1)^{**}0.7}{1900 * Y^{**}0.5}$$

where

L = Lag in hours

X = Hydraulic length of watershed in feet

S = (1000/Curve Number) - 10

Y = Average watershed land slope in percent

4. Rainfall

The TP-42 point rainfall data for various durations were adjusted for the drainage area of the entire basin by HEC-1. Necessary corrections were also made to convert partial duration to equivalent annual series rainfall. Balanced storms were then generated by HEC-1 for various frequencies. Calculations were performed at 5-minute intervals.

5. Flood Routings

A UNET model was used in combination with HEC-1 generated sub-basin hydrographs for flood routing through the Rio Culebrinas valley. Cross section data were taken from surveys and available USGS quadrangle maps. Manning's roughness values and other loss coefficients were initially estimated and calibrated to historical events documented in the USGS flood atlas.

6. Discharge for Existing Conditions with Future Land Uses

The peak discharge-frequency data estimated by the HEC-1/UNET model along Rio Culebrinas and at the mouth of Cano Madre Vieja are listed in Table A-4. A flood hydrograph estimated for 24-hour storm for the 100-year event at the mouth of Rio Culebrinas and the mouth of Cano Madre Vieja are plotted in Figure A-2 and Figure A-3, respectively.

C. Hydrology of Interior Flooding

This analysis addresses the management of interior surface runoff from areas that are protected by project levees, reflecting future conditions development. Culvert outlet structures that allow for drainage of the interior areas to Cano Madre Vieja are provided through each levee segment. US Army Corps of Engineers Hydrologic Engineering Center Interior Flood Hydrology (HEC-IFH) Package was used for the analysis of the interior flooding hydrology.

HEC-IFH is a comprehensive computer program that performs all of the components of an interior flooding analysis. It is a framework on which the analyst can model rainfall-runoff, routing, interior ponding, and gravity outlet performance, as a dynamic, interactive simulation that includes changing flood conditions in the receiving stream. For this study, interior area flood elevation-frequency relationships were determined for various alternative gravity outlet configurations by using design storm event analysis in combination with interior area runoff parameters that reflect future conditions development. The resulting runoff was routed through existing interior ponding areas adjacent to the project levees, and then through gravity outlet culvert structures draining to Cano Madre Vieja. Coincident exterior flood stage 10-year hydrograph for the with-project condition was used for the tailwater boundary condition affecting each culvert.

No minimum facilities for interior drainage were identified in the pre-project condition. Existing conditions flood stages were used to define minimum gravity outlet facilities that would drain the protected areas before those stages were exceeded. Hydraulic design data for interior drainage structures are listed in Table A-8. Interior flood hydrology data and residual flood elevations are presented in Table A-11 and Table A-12, respectively.

D. Other Sources of Flooding

The detailed study area can also be flooded by hurricane tides from the ocean. Tidal flooding effects were not considered in the analysis. Tidal flood protection was not within the scope of the riverine protection project.

IV. HYDRAULICS

A. Existing Conditions

1. Hydraulic Model

Hydraulic modeling of existing conditions flood stages and post project stages were complied by using UNET.

From the upstream side of PR Hwy 2 to the coastline the area was divided into three reaches. Once floodwaters pass the PR Hwy 2 crossing, the overbank flow is divided between the outlets of Cano Madre Vieja and Rio Culebrinas. Reach 1 was identified upstream of PR Hwy 2. Reach 2 went from PR Hwy 2 to the mouth of Rio Culebrinas and Reach 3 went from PR Hwy 2 to the mouth of Cano Madre Vieja. A rating curve was used between Rio Culebrinas and Cano Madre Vieja. This rating curve is shown in Figure A-5.

2. Survey Data

The Rio Culebrinas area was surveyed in February and March 1995. Detailed topographic maps were prepared to a scale of 1 to 2,000 with a .5-meter contour interval. Detailed information of the bridges and culverts were obtained from the surveyor's field books. A site visit to the area in August 1995 also helped verify the topographic information on the maps. All elevations are referenced to the National Geodetic Vertical Datum (NGVD). The horizontal and vertical datums are referenced to the North American Datum of 1983 and 1929, respectively.

3. Roughness Coefficients

A Manning's roughness value of 0.10 was used for the overbank areas of the flow way, while a value of 0.035 was used for the channel sections. These values were based on aerial photographs, site inspection and engineering judgment.

4. Starting Conditions

Stage-discharge curves at the first cross section were computed using both normal depth and critical depth analyses. A high tide level of 0.6 meters was assumed in the Aguadilla Bay. The stage-discharge curve corresponding to the normal depth analysis was chosen for

this study based on the high water elevations listed in Hydrologic Investigations Atlas HA-457 which discusses the flood of November 27, 1968 and shows the limits of that flood delineated for the Aguada/Aguadilla area.

5. Model Verification

A flood atlas prepared by the USGS for the flood of November 27, 1968 that affected the Aguada/Aguadilla area showed high water marks and estimated flood stage contours. The USGS gage station 50147800 at PR Highway 404 recorded an estimated discharge of 850 cms. From Figure A-4 this would be less than a 10-year event.

6. Flood Stages

The existing conditions flood stages were simulated by the HEC-1 and UNET models developed for the basin. Table A-6 shows the water surface elevations under existing and with project conditions in the study area. Plate A-1 shows the flooded area for the 5 and 100-year events under existing conditions.

B. Sediment Assessment

1. Existing Conditions

Computer modeling of the existing flood plain showed that most flood flow is conveyed through the overbank areas of the floodplain. The existing channel is small and is overtopped by storms events with a 50% chance of exceedance (1 in 2-years frequency). The existing natural dominant discharge channel is very small relative to the conveyance required at design storm rates. Base flow in the existing channel is small.

Tropical and farm vegetation covers most of the floodplain and reduces sediment potential. Soils in the floodplain are a mixture of course sand, silt and clay with tropical vegetation as ground cover.

2. With Project Conditions

The average channel velocity during a 100-year event in Rio Culebrinas would range between .75 and 6.60 meters per second (mps). For Cano Madre Vieja the average channel velocity would range between .6 and 3.33 mps. Higher velocities would be expected near the bridges. The short duration of higher velocity flows and

erosion resistant nature of the channel soil type should resist large erosion related sediment movement within the channel.

The average overbank velocity along Rio Culebrinas would range between .2 and 3.75 mps. For Cano Madre Vieja the average overbank velocity would range between .46 and 2.21 mps. Vegetative cover and soil type should resist sediment movement under proposed conditions.

Sediment transport in the floodway is not expected to increase or decrease due to this project. The proposed levees would not significantly alter the current sedimentation regime within the basin.

V. HYDRAULIC DESIGNS

A. Hydraulic Design Criteria

Hydraulic design criteria and procedures used herein are in accordance with standard engineering practice and applicable provisions of Corps Engineering Manuals and the Waterways Experimental Station "Hydraulic Design Criteria" relative to design and construction of Civil Works Projects. Engineering criteria adopted to meet special local conditions are in accordance with that previously approved for similar projects.

B. Design Objective

The main flood control feature for this study consists of two levee segments and a levee spur designed for a 100-year level of protection. Each levee segment will be provided with drainage structures and all levees will have an interior drainage channel. Road ramps will be provided where the proposed levees intersect existing roads. A cutoff channel will also be provided since one of the proposed levees segments would intersect Cano Madre Vieja.

C. Levees

The 100-year level of protection with the proposed levee alignment was determined to be the most beneficial alternative. The existing condition UNET model was modified to represent the with project conditions by terminating cross sections at stations which would cross the proposed levee alignment. Plate A-2 shows the recommended plan. The two levee segments are identified as the Aguadilla levee and the Espinar levee with a levee spur.

1. Aguadilla Levee

This proposed levee segment starts at the coastline and ends at PR Hwy 2. It is approximately 1,836 meters long and has an average levee height of about 2.60 meters. There will be three drainage structures and two road ramps for this levee segment. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramps intersects the interior drainage channel. An existing concrete box culvert over Cano Madre Vieja would be impacted by one of the road ramps. This box culvert will be extended to accommodate the proposed road ramp. Plate A-2 shows the layout of the Aguadilla levee. Plate A-4 is a profile of the Aguadilla levee with the design water surface profile.

2. Espinar Levee

This proposed levee segment starts at the edge of the coastal barrier zone and ties into high grounds south of the community of Espinar. It is approximately 1,496 meters long and has an average levee height of about 2.49 meters. There will be one drainage structure through this levee and a road ramp would also be required. An interior drainage channel would be required along the protected side of the levee. A culvert will be provided where the road ramp intersects the interior drainage channel. The Espinar levee will also have a levee spur. The Espinar levee spur starts from Espinar levee Station 2+10 and ties into high grounds north of the community of Espinar. Plate A-2 shows the layout of the Espinar levee and connecting levee spur. Plates A-5 and A-6 are profiles of the Espinar levee and Espinar levee spur with the design water surface profile, respectively.

3. Side Slopes

Side slopes of the proposed levees were based on existing soil conditions, type of material used in construction and a stability analysis. The levee side slopes on the flood side and protected side would be 1 vertical to 2.5 horizontal.

4. Levee Crest Elevations

The levee crest elevations were determined by selecting the highest profile that resulted from a

worst case scenario. The 100-year water surface profile was computed with the following combinations:

a. Design discharge with the design "n" values
b. Design discharge with 20 percent increased "n" values.
c. 20 percent increased discharge hygrograph with design "n" values.

Bridge openings were reduced by 20 percent to account for debris accumulations. The 100-year water surface profile computed with a 20 percent increased discharge is slightly higher than the other profile and it was selected as the minimum levee grade.

Wave heights, periods, and durations caused by several wind speeds were computed by a shallow water wave forcasting model "SHALWAVE" described in the Coastal Engineering Research Center Instruction Report 86-2. Wave runup and wind setup calculations were performed using the Shore Protection Manual and are listed in Table A-5. A smooth levee surface was assumed in the calculations.

The 100-year levee crest elevation for the Aguadilla levee and the Espinar levee with the levee spur are presented in Table A-7.

5. Levee Overtopping Analysis

An overtopping analysis was performed on the Rio Culebrinas according to ETL 1110-2-299 dated 22 August 1986. The levees were evaluated as one system and an overtopping reach was identified for each levee segment. Overtopping water surface profiles were computed by considering the uncertainties in "n" values, bridge openings, discharge hydrographs and wind speeds.

For the Aguadilla and Espinar levees the overtopping reach is located between corresponding levee stations 0+00 and 0+50. Each overtopping reach was identified as the least critical site where initial failure would occur during severe floods. The least amount of damage in the region would be sustained if initial levee overtopping occurred at this location. Superiority is provided to insure overtopping at the proposed reach. The overtopping reach is 50 meters long and would be given 1 foot of superiority less than the remainder of the levee segment.

6. Reliability Analysis of the Selected Levees

This study was granted a waiver from doing a full risk analysis. However, a reliability analysis to determine probability of stage non-exceedance was conducted. The risk analysis computer program, available from the Hydrologic Engineering Center (HEC), was used for the reliability analysis. This analysis was conducted following ER 1105-2-101 to determine the reliability of the selected levees. Cross section 1568 was selected for this analysis, which takes into consideration the uncertainty in discharge-frequencies, stage-discharges, and cross section data. Five thousand interations were made with Latin Hypercube sampling method to determine the reliability.

The discharge-frequency data required for the reliability analysis were taken from the results of the UNET analysis. The logarithmic mean, standard deviation, and skew were determined, as per the Water Resources Council Bulletin 17B, from 1 percent, 10 percent and 50 percent chance flood events.

The stage-discharge rating curve was developed for the design "n" values from the UNET analysis. Water surface profiles were computed for possible high and low "n" values. A minimum standard deviation of 0.274 meter was required as per Table A-3 of the EC 1105-2-205.

Input data and results of the reliability analysis of the proposed levees at cross section 1568 for the SPF, 1 percent and 2 percent flood events are shown in Table A-13.

D. Channels

1. Cutoff Channel

The proposed Aguadilla Levee would intersect Cano Madre Vieja at various locations. In order to continue the flow in Cano Madre Vieja to the coastline a cutoff channel would be required. The conveyance capacity of this cutoff channel would be the same as in the existing Cano Madre Vieja channel. Hydraulic design data for the cutoff channel are shown in Table A-10.

2. Interior Drainage Channels

An interior drainage channel would be provided along the protected side of each levee segment and along the Espinar levee spur. Hydraulic design data for the interior drainage channels are provided in Table A-9.

E. Drainage Structures

There will be a total of four drainage structures as part of the recommended plan. The Aguadilla levee will have three drainage structures and the Espinar levee will have one drainage structure. The culverts at each drainage structure consist of corrugated metal pipes (CMP) with a bituminous coating and each culvert will have a flap gate on the levee flood side. Hydraulic design data of the drainage structures are indicated in Table A-8. Locations of the proposed drainage structures are shown on Plate A-2. The following describes each drainage structure:

1. Aguadilla Levee

a. AL-S-1

The drainage structure at Aguadilla levee station 1+39.5 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 15 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

b. AL-S-2

The drainage structure at Aguadilla levee station 6+05.5 consists of six-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 19 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

c. AL-S-3

The drainage structure at Aguadilla levee station 10+52.9 consists of three-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length

of 20 meters. All culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

2. Espinar Levee

a. EL-S-1a

The drainage structure at Espinar levee station 2+50 consists of two-1.52 meter diameter CMP. The invert of the culverts would be set at elevation -.3 meters, NGVD and have an approximate length of 27 meters. The two-1.52 meter diameter culverts would be equipped with flap gates on the levee flood side to prevent backflow in the protected area.

F. Road Ramps

Road ramps would be required where PR Hwy 418 and PR Hwy 115 intersects the proposed Aguadilla levee. Another road ramp would be required where PR Hwy 442 intersects the proposed Espinar Levee. A .91 meter diameter CMP would be provided where each road ramp intersects the interior drainage channel. Hydraulic design data for the interior drainage channels is shown in Table A-9.

The proposed road ramp at PR Hwy 418 would impact an existing concrete box culvert at Cano Madre Vieja. This culvert would be extended to accommodate the flood side of this road ramp.

G. Borrow Area

For this project there will be one source for borrow material. However, suitable excavated material from the construction of the drainage structures, the interior drainage channels and the cutoff channel could also be used for the construction of the proposed levees. The proposed borrow area does not impact the drainage of the existing floodway. The location of the borrow area is indicated in the Geotechnical Appendix, Plate B-2.

H. Performance

1. Levee Design Protection

Design discharge water surface elevations within the floodway up to and including the 1% chance flood will be prevented from overtopping the levees. Events that

exceed the design capacity are rare but could occur. In the event of a flood greater than design discharges overtopping of one or both levees could occur. Each levee would be provided with a 50 meter long overtopping segment with a lower levee crest elevation. Paragraph C.5. provides a description of that design. Overtopping flows would discharge to an undeveloped area. These overtopping reaches were selected to minimize damage and provide warning that a design event has been exceeded.

2. Residual Flooding

Runoff from the protected side of the levees would collect in designated residual areas and discharge to the flood plain through culverts. The culverts at the drainage structures would be fitted with flap gate controls that would prohibit flow from the flood plain into the protected area. Analyses of various rainfall and flood events were compiled to determine the extent of residual flooding in those areas. Plate A-3 indicates the extent of the area flooded due to the 1% chance flood event in the floodway and a 10% chance flood event in the protected areas. The residual flooded areas are an essential part of the interior drainage plan for each levee segment.

The residual flooded area shown on plate A-3 was based on analyses of design rainfall levels applied to the sub-basin upstream of the levee. The rainfall runoff was routed through the sub-basin to the levee site. Runoff reaching the levee would be conveyed thorough the levee and to the floodplain by outlet structures. The size of the outlet structure is designed to drain water trapped behind the levee as quickly as possible. The structures are unusually fitted with gates that automatically close in the event that the stage in the floodplain exceeds the stage behind the levee. This prevents backflow through the inlet structure when stages in the floodway are higher than stages upstream of the levee. However, discharge to the floodway is terminated and all flow entering the area behind the levee is effectively trapped until the gates open. The trapped floodwater is called residual flooding and is a direct function of that volume of the trapped water. The area covered by trapped floodwater is called the residual flooded area.

The shaded area shown on plate A-3 represents lands that would be inundated under the existing geometry of the area. Should it become necessary or desirable for the sponsor to utilize all or part of the lands

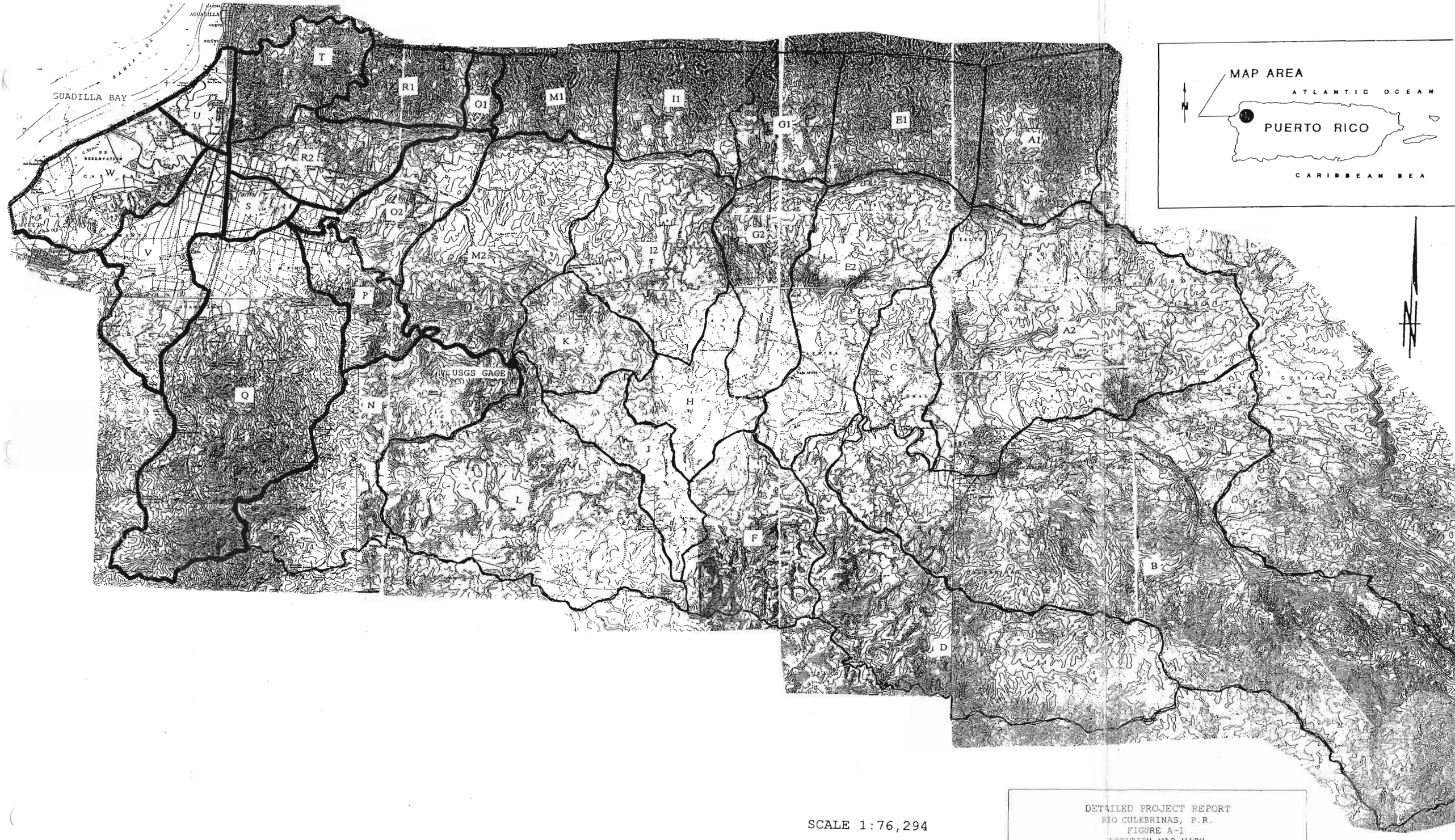
designated as the residual flooded area, the area must be studied and reevaluated. Changes in the geometry of the residual flooded area shown in the report will have a direct effect on the predicted residual flood stages, and surface area of the residual flooded area. If the originally predicted stage or land area designated for flood retention cannot be changed, engineering analyses must be performed to determine alternative means to contain the predicted flood volume without damage to adjacent properties. Measures could include larger outlet structure capacity, construction of a pump station to augment the design outlet structures, or excavation within the remaining residual flooded area to contain the design volume of floodwater at the design stage for the original residual flooded area.

3. People at Risk

Events are of a "flashflood" nature with little time available for warning people in the area. Overtopping would first occur at a designated segment of levee. Overtopping flow at the Aguadilla levee would discharge into a residual flooded area and convey along a interior drainage channel that will be connected with the other drainage structures. Overtopping flow at the Espinar levee would discharge into an uninhabited area. Peak discharges for the Rio Culebrinas basin occur within 7 hours after initial rainfall and last only about 30 minutes. Therefore overtopping is expected to be brief. However, initial water velocities as a result of overtopping could be high until the tailwater stage increase. At the north end of the Espinar levee floodwaters would flank the levee and reach the western side of the community of Espinar. Residual flooding related to a 10-year event would also impact the protected side of the community of Espinar. Plate A-3 shows the interior flooded areas for the 10-year event.

If development and/or fill were placed within the interior flooded areas the design volume of water will be displaced and the interior stage would increase. This stage increase would be above the damage elevation used for the interior drainage analysis and damages within the protected area would start to occur. Residual flooded areas are waters trapped within a protected area when the flapgates at the drainage structures are closed during a flood event. This is a design volume of water that reaches a computed stage and this stage is related to a specific rainfall event as determined from an interior

drainage analysis. Residual flooded areas are needed so that the interior drainage would function as designed.



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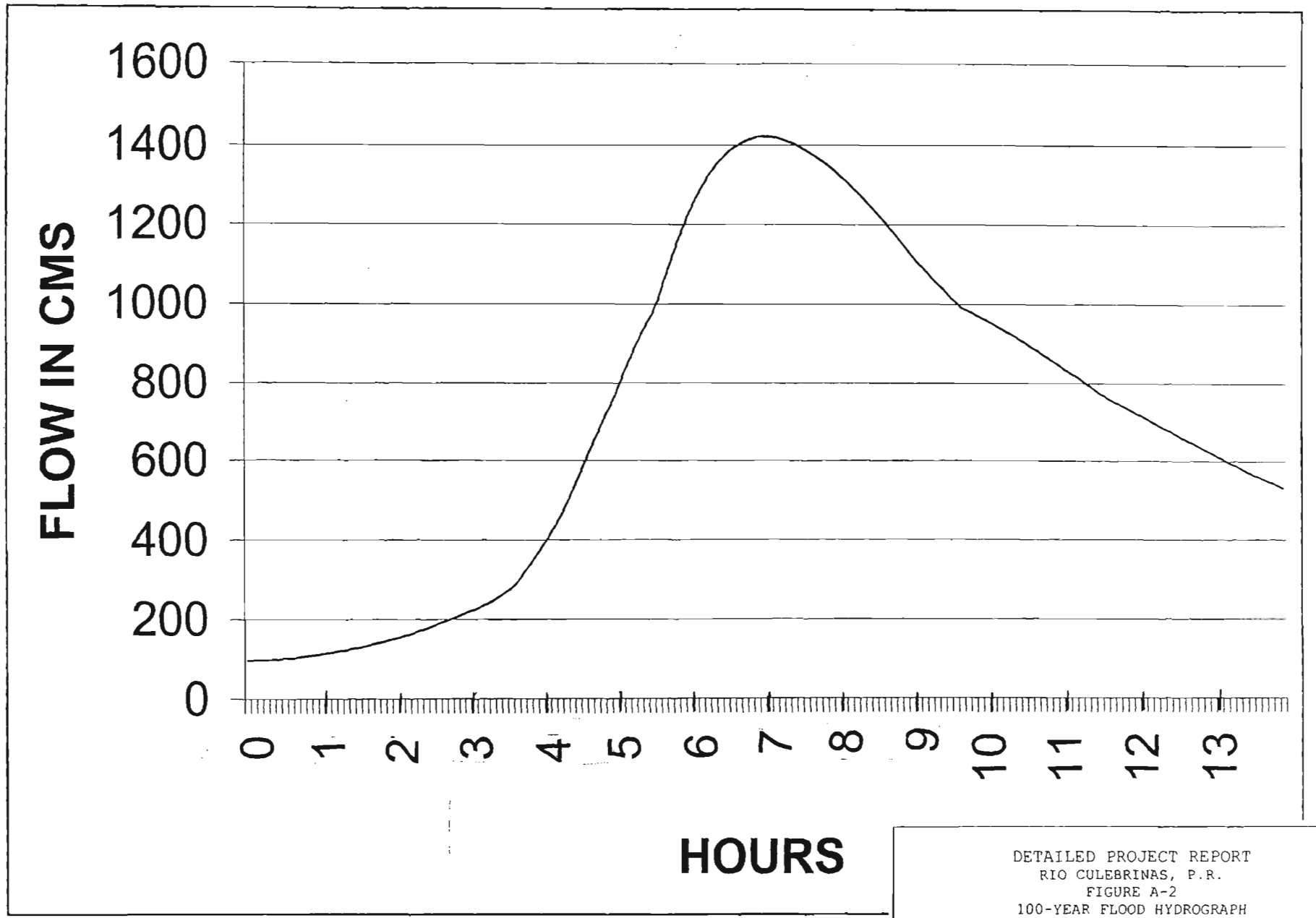
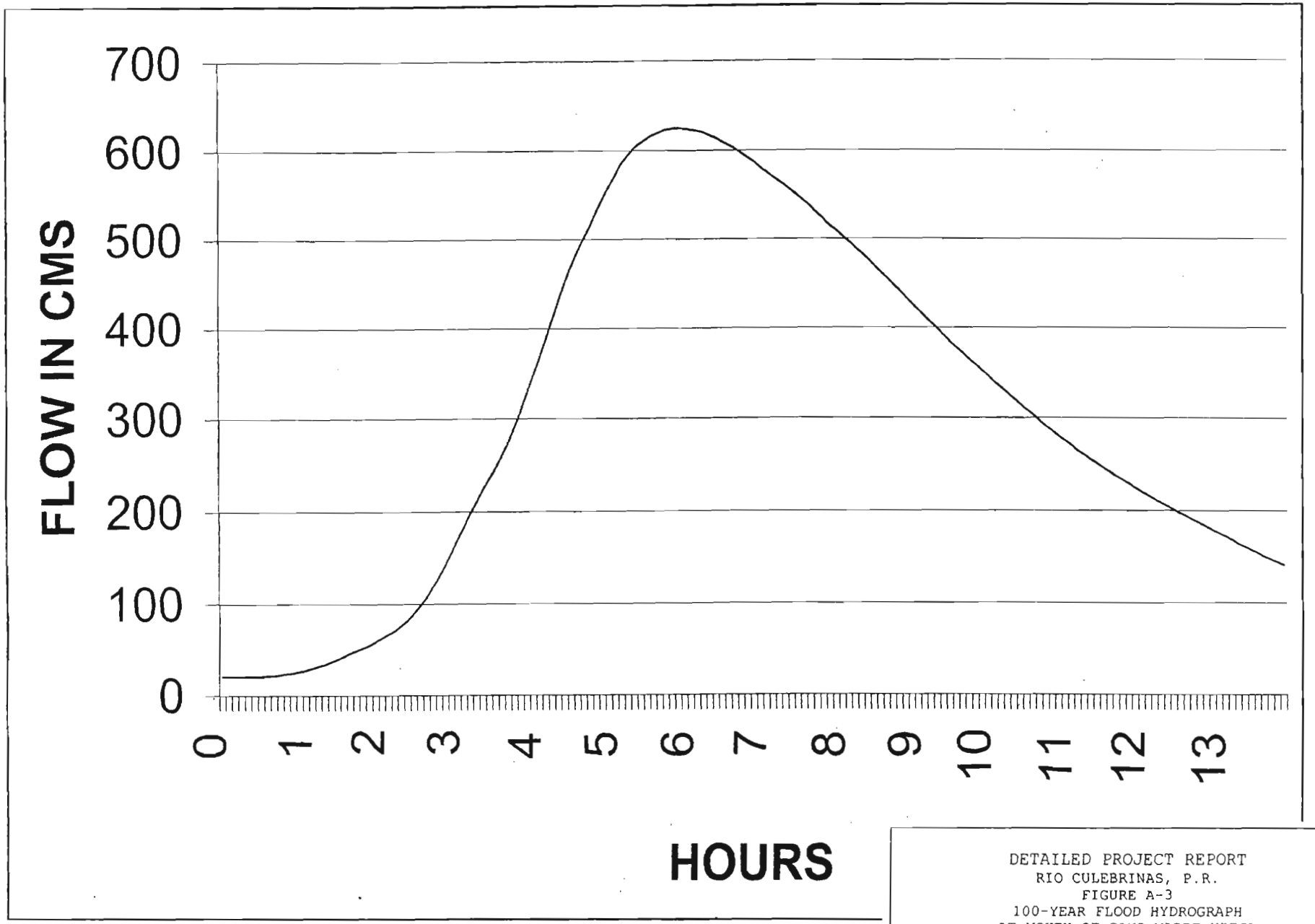
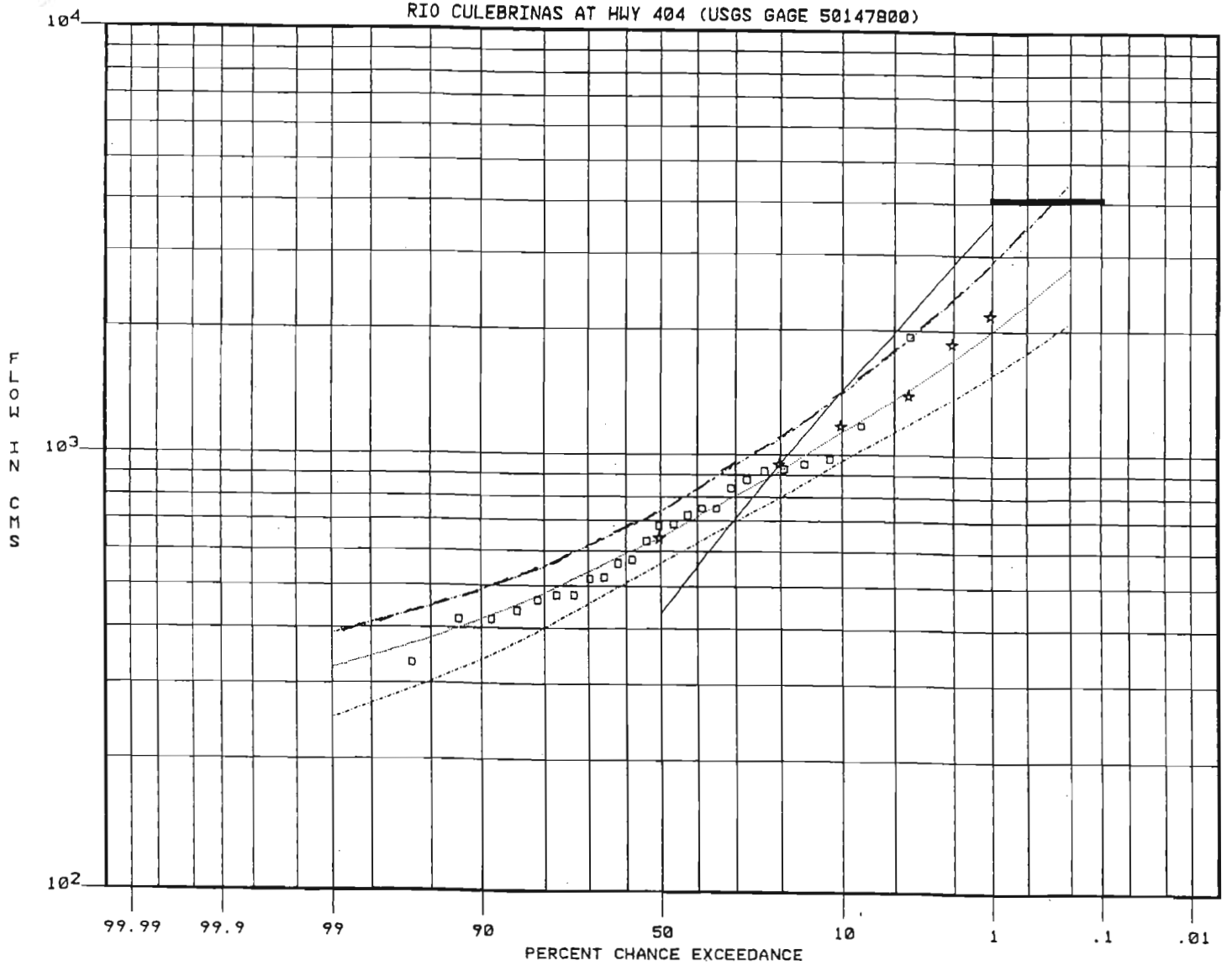
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-1
LOCATION MAP WITH
BASIN AND SUB-BASINS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-2
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF RIO CULEBRINAS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



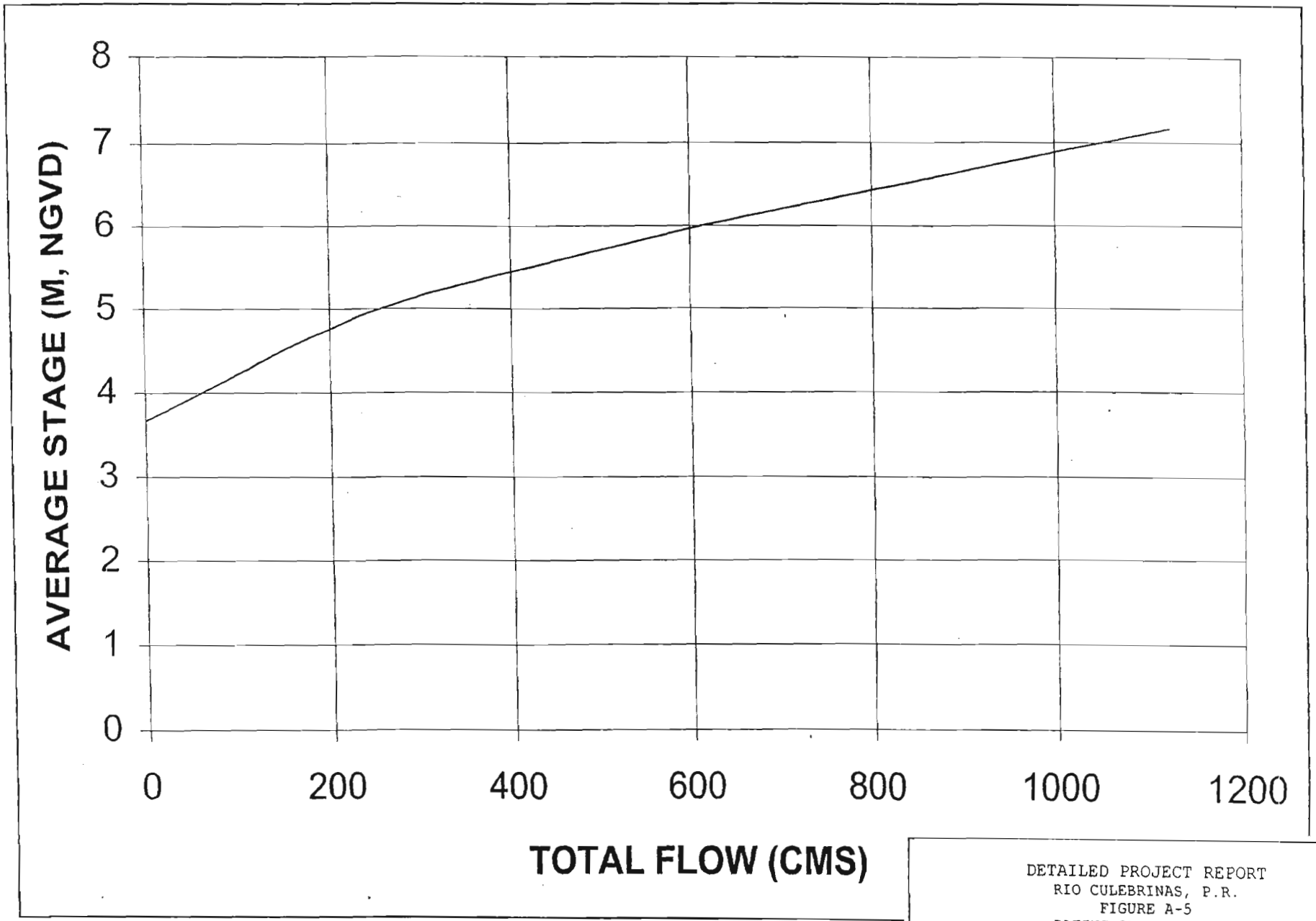
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-3
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF CANO MADRE VIEJA
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



COMPUTED
5% CONFIDENCE LIMIT
95% CONFIDENCE LIMIT
WEIBULL PLOTTING POSITION

HEC-1
SPF (HEC-1)
REGIONAL EQUATION

DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-4
FLOW FREQUENCY AT
USGS GAGE 50147800
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-5
RATING CURVE BETWEEN
RIO CULEBRINAS AND CANO MADRE VIEJA
DEPARTMENT OF THE AR
JACKSONVILLE DISTRICT, CORPS O ENGINEERS
JACKSONVILLE, FLORIDA

TABLE A-1

RIO CULEBRINAS DETAILED PROJECT REPORT
HISTORICAL FLOODS DATA FOR RIO CULEBRINAS
AT USGS GAGING STATION 50147800
AT PR HIGHWAY 404, NEAR MOCA, PUERTO RICO

DATE OF FLOOD	DISCHARGE CMS	WATER SURFACE ELEVATION METERS, NGVD
November 27, 1968	850	73.7
October 30, 1969	700	72.4
May 7, 1970	575	71.1
June 13, 1972	700	72.4
October 21, 1972	960	74.6
September 16, 1975	1955	84.6
November 4, 1977	680	72
September 23, 1978	640	71.6
September 25, 1978	730	72.6
May 19, 1980	690	72.3
May 27, 1980	890	74.3
February 15, 1981	570	71
October 24, 1981	935	74.7
July 20, 1982	685	72.3
June 5, 1984	690	72.4
September 15, 1984	760	73
October 6, 1984	675	72.2
May 18, 1985	930	74.7
May 19, 1985	705	72.5
June 25, 1985	730	72.8
October 1, 1985	580	71.1
October 7, 1985	660	72
November 3, 1985	720	72.7
April 27, 1986	780	73.2
May 3, 1986	665	72.1
May 5, 1986	985	75.1
May 6, 1986	685	72.3
May 13, 1986	845	73.9
October 18, 1986	670	72.2
October 19, 1986	660	72
December 1, 1986	635	71.8
September 11, 1987	760	73.1
October 7, 1987	730	72.8
August 24, 1988	1200	76.8
October 26, 1988	640	71.8

TABLE A-2

RIO CULEBRINAS DETAILED PROJECT REPORT
RAINFALL FOR VARIOUS FREQUENCIES AND DURATIONS

PERCENT CHANCE STORM	RAINFALL IN MM DURATION IN HOURS							
	0.083	0.25	1	2	3	6	12	24
50	14	29	53	61	72	86	104	117
20	17	36	66	79	91	107	132	155
10	19	41	72	91	104	127	146	180
4	21	45	79	104	117	150	178	198
2	24	51	91	114	127	155	191	229
1	26	55	99	124	150	180	216	249
SPF	29	61	114	203	264	381	445	508

TABLE A-3

RIO CULEBRINAS DETAILED PROJECT REPORT
WATERSHED PARAMETERS

SUB-BASIN IDENTIFICATION	DRAINAGE AREA (SQ KM)	CURVE NUMBER		LAG IN HOURS
		AMC II	AMC III	
A1	9.24	80	91	0.82
A2	28.72	80	91	0.59
B	56.51	80	91	1.40
C	4.84	80	91	0.17
D	21.85	80	91	1.02
E1	8.84	80	91	0.49
E2	14.12	80	91	0.36
F	10.31	80	91	0.27
G1	4.35	80	91	0.57
G2	7.15	80	91	0.28
H	5.80	80	91	0.08
I1	6.85	80	91	0.39
I2	11.47	80	91	0.31
J	5.10	80	91	0.27
K	5.41	80	91	0.21
L	19.63	80	91	0.28
M1	5.73	80	91	0.23
M2	15.51	81	92	0.30
N	13.86	81	92	0.30
O1	1.14	80	91	0.23
O2	6.25	81	92	0.19
P	4.41	85	94	0.04
Q	22.35	86	94	0.63
R1	4.34	84	93	0.23
R2	5.85	86	94	0.22
S	1.67	84	93	0.28
T	4.94	80	91	0.44
U	2.05	86	94	0.30
V	7.31	85	94	0.37
W	7.00	85	94	0.35
TOTAL	322.60			

TABLE A-4

RIO CULEBRINAS DETAILED PROJECT REPORT
SUMMARY OF PEAK DISCHARGES
ESTIMATED BY HEC-1/UNET ROUTING MODEL

PERCENT CHANCE STORM EVENTS	PEAK DISCHARGES IN CMS			
	USGS GAGE 50147800	UPSTREAM LIMIT OF STUDY	PR HWY 2	MOUTH
50	652	701	334	143
20	964	1036	473	240
10	1193	1313	573	312
4	1411	1587	693	397
2	1893	2102	941	536
1	2206	2508	1098	625
SPF	4111	5214	3016	1221

TABLE A-5

RIO CULEBRINAS DETAILED PROJECT REPORT
WAVE RUNUP AND WIND SETUP

LEVEE SEGMENT	LEVEE STATION	FETCH LENGTH (M)	WIND SPEED KM/HOUR	WAVE PERIOD (SEC)	WAVE HEIGHT (M)	WAVE RUNUP (M)	WIND SETUP (M)	TOTAL (M)
AGUADILLA	4 + 00	538	25	0.99	0.10	0.13	0.01	0.14
			48	1.23	0.18	0.22	0.02	0.24
	13 + 00	1003	25	1.21	0.13	0.19	0.01	0.20
			48	1.48	0.24	0.30	0.04	0.34
ESPINAR	6 + 80	991	25	1.19	0.13	0.18	0.01	0.19
			48	1.47	0.23	0.30	0.04	0.34

RIO CULEBRINAS DETAILED PROJECT REPORT
EXISTING AND WITH PROJECT WATER SURFACE ELEVATIONS

	BRIDGE	CROSS SECTION	MILE	2-YEAR WITH PROJECT	2-YEAR EXISTING CONDITIONS	5-YEAR WITH PROJECT	5-YEAR EXISTING CONDITIONS	10-YEAR WITH PROJECT	10-YEAR EXISTING CONDITIONS	25-YEAR WITH PROJECT	25-YEAR EXISTING CONDITIONS	50-YEAR WITH PROJECT	50-YEAR EXISTING CONDITIONS	100-YEAR WITH PROJECT	100-YEAR EXISTING CONDITIONS	SPF WITH PROJECT	SPF EXISTING CONDITIONS
Reach 1 EAST OF PR HWY 2			5.82	7.18	7.18	7.81	7.81	8.18	8.18	8.46	8.45	9.00	9.00	9.30	9.30	11.12	11.12
			5.07	6.91	6.91	7.50	7.50	7.83	7.83	8.09	8.09	8.60	8.60	8.90	8.90	10.92	10.92
			4.39	6.40	6.40	6.91	6.91	7.25	7.25	7.52	7.52	8.06	8.06	8.40	8.43	10.66	10.66
			3.68	5.78	5.78	6.28	6.27	6.61	6.60	6.92	6.90	7.57	7.55	7.95	8.04	10.43	10.43
		202	3.00	5.17	5.15	5.76	5.73	6.14	6.11	6.50	6.90	7.25	7.21	7.66	7.80	10.24	10.24
		104	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
Reach 2 - Rio Culebrinas		4090	2.93	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
	PR Hwy 2	3992	2.87	4.79	4.74	5.15	5.08	5.35	5.26	5.51	5.41	6.09	6.05	6.38	6.59	8.36	8.36
		3821	2.77	4.92	4.88	5.34	5.29	5.59	5.53	5.81	5.74	6.21	6.13	6.44	6.24	7.57	7.38
		3705	2.68	4.73	4.68	5.13	5.06	5.36	5.27	5.58	5.47	5.96	5.84	6.18	5.98	7.36	7.13
		3428	2.52	4.55	4.50	4.94	4.84	5.18	5.07	5.40	5.27	5.78	5.63	5.98	5.77	7.17	6.91
	PR Hwy 418	3214	2.39	4.28	4.20	4.68	4.55	4.95	4.79	5.19	5.02	5.57	5.38	5.78	5.54	6.95	7.13
		3187	2.38	4.23	4.14	4.63	4.50	4.91	4.73	5.15	4.97	5.53	5.34	5.74	5.49	6.91	6.63
		3154	2.35	4.22	4.14	4.63	4.49	4.90	4.73	5.15	4.96	5.52	5.34	5.74	5.49	6.90	6.62
		3116	2.33	4.21	4.12	4.61	4.48	4.89	4.71	5.13	4.95	5.51	5.32	5.72	5.47	6.88	6.60
		3055	2.29	4.19	4.09	4.59	4.45	4.87	4.69	5.11	4.92	5.48	5.30	5.70	5.44	6.84	6.56
		2712	2.08	4.15	4.05	4.56	4.42	4.84	4.66	5.09	4.90	5.45	5.27	5.66	5.41	6.79	6.52
		2614	2.04	4.12	4.02	4.53	4.39	4.81	4.63	5.06	4.87	5.42	5.24	5.63	5.39	6.75	6.48
	PR Hwy 115	2570	2.00	3.63	3.54	3.99	3.87	4.39	4.07	4.75	4.51	5.17	4.97	5.39	5.13	6.58	6.30
		2440	1.92	3.33	3.24	3.68	3.57	3.89	3.75	4.09	3.93	4.51	4.28	4.72	4.47	5.88	5.63
		2377	1.88	3.18	3.10	3.51	3.39	3.73	3.58	3.94	3.77	4.38	4.14	4.59	4.34	5.73	5.48
		1950	1.29	2.94	2.85	3.32	3.17	3.55	3.39	3.79	3.60	4.26	4.01	4.46	4.22	5.55	5.31
		1451	0.91	2.88	2.78	3.26	3.12	3.50	3.33	3.73	3.55	4.20	3.96	4.40	4.17	5.45	5.23
		1353	0.84	2.87	2.77	3.25	3.11	3.49	3.32	3.72	3.54	4.19	3.95	4.39	4.16	5.42	5.21
		1286	0.80	2.86	2.77	3.25	3.10	3.48	3.32	3.72	3.53	4.19	3.94	4.38	4.15	5.41	5.20
		1091	0.68	2.85	2.75	3.24	3.09	3.47	3.30	3.70	3.52	4.17	3.93	4.36	4.13	5.37	5.16
		850	0.53	2.83	2.73	3.22	3.07	3.46	3.29	3.69	3.50	4.16	3.92	4.35	4.12	5.34	5.13
		721	0.45	2.79	2.71	3.20	3.05	3.44	3.28	3.68	3.49	4.15	3.91	4.34	4.11	5.31	5.11
		604	0.38	2.74	2.65	3.17	3.01	3.41	3.25	3.65	3.47	4.13	3.89	4.31	4.09	5.27	5.08
		403	0.25	2.60	2.49	3.08	2.91	3.35	3.17	3.60	3.41	4.08	3.84	4.26	4.05	5.18	4.99
		163	0.10	2.40	2.30	2.93	2.75	3.23	3.02	3.51	3.29	4.00	3.76	4.17	3.97	5.00	4.85
		44	0.03	2.04	1.94	2.58	2.38	2.92	2.70	3.26	2.99	3.84	3.59	4.02	3.81	4.81	4.67
Reach 3 - Cano Madre Vieja		3573	2.54	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3463	2.47	5.13	5.10	5.73	5.69	6.11	6.08	6.47	6.44	7.23	7.20	7.65	7.78	10.23	10.23
		3280	2.36	4.76	4.73	5.16	5.10	5.39	5.32	5.60	5.51	5.96	5.86	6.17	5.99	7.31	7.07
		3240	2.33	4.67	4.54	5.07	4.86	5.30	5.04	5.51	5.20	5.88	5.52	6.09	5.65	7.25	6.65
		3134	2.27	4.60	4.53	4.97	4.84	5.20	5.01	5.41	5.17	5.77	5.48	5.98	5.60	7.15	6.59
	PR Hwy 418	3101	2.25	4.51	4.42	4.89	4.74	5.13	4.94	5.35	5.12	5.73	5.45	5.95	5.57	7.14	6.58
		3085	2.24	4.32	4.31	4.66	4.60	4.88	4.80	5.07	4.98	5.37	5.28	5.53	5.41	6.40	6.32
		2993	2.18	4.31	4.26	4.67	4.52	4.89	4.71	5.09	4.89	5.41	5.17	5.59	5.29	6.56	6.18
	Old Narrow Bridge	2948	2.15	4.11	3.97	4.47	4.24	4.71	4.44	4.92	4.62	5.24	4.91	5.42	5.02	6.39	5.89
	PR Hwy 115	2891	2.11	3.70	3.62	4.04	3.92	4.23	4.11	4.43	4.30	4.71	4.60	4.87	4.72	5.74	5.58
		2826	2.07	3.16	3.24	3.51	3.67	3.75	3.89	3.96	4.11	4.29	4.44	4.44	4.55	5.32	5.41
		2545	1.81	2.83	2.95	3.20	3.42	3.46	3.67	3.68	3.91	4.02	4.25	4.18	4.36	5.09	5.19
		2491	1.78	2.74	2.86	3.10	3.31	3.35	3.57	3.58	3.81	3.91	4.16	4.08	4.26	4.99	5.07
		2424	1.74	2.66	2.78	3.03	3.23	3.28	3.48	3.51	3.72	3.85	4.06	4.01	4.17	4.91	4.97
		2307	1.67	2.57	2.67	2.94	3.11	3.19	3.36	3.42	3.59	3.75	3.92	3.91	4.02	4.76	4.80
		2200	1.60	2.45	2.53	2.83	2.97	3.08	3.22	3.32	3.42	3.65	3.74	3.80	3.84	4.65	4.61
		2095	1.53	2.39	2.46	2.78	2.89	3.03	3.15	3.26	3.35	3.59	3.65	3.74	3.76	4.57	4.51
		1568	1.10	2.32	2.35	2.72	2.82	2.97	3.08	3.21	3.28	3.53	3.57	3.68	3.67	4.48	4.40
		1482	1.04	2.29	2.31	2.69	2.78	2.93	3.04	3.17	3.24	3.49	3.52	3.63	3.62	4.41	4.33
		1112	0.78	2.25	2.25	2.64	2.73	2.89	3.00	3.13	3.20	3.43	3.46	3.58	3.56	4.33	4.25
		480	0.30	2.20	2.20	2.60	2.70	2.84	2.97	3.08	3.16	3.39	3.41	3.52	3.51	4.25	4.17
		381	0.24	2.08	2.15	2.47	2.65	2.70	2.91	2.93	3.10	3.22	3.33	3.34	3.41	3.97	4.02
		255	0.16	2.02	2.10	2.39	2.59	2.62	2.86	2.84	3.05	3.13	3.27	3.24	3.34	3.83	3.94
		209	0.13	1.97	2.07	2.34	2.56	2.56	2.82	2.78	3.02	3.08	3.24	3.18	3.32	3.75	3.91
		163	0.10	1.88	2.02	2.21	2.49	2.41	2.74	2.60	2.98	2.88	3.21	3.01	3.28	3.58	3.88
		74	0.05	1.71	1.79	2.07	2.23	2.29	[illegible]	2.51	2.69	2.80	3.06	2.94	3.15	3.52	[illegible]
		17	0.01	1.53	1.64	1.86	2.05	2.06	[illegible]	2.26	2.55	2.59	2.86	2.72	2.97	3.28	[illegible]

NOTE: WATER SURFACE ELEVATIONS ARE IN METERS, NGVD

TABLE A-7

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
100-YEAR LEVEE CREST ELEVATIONS

LEVEE SEGMENT	ROAD RAMP	DRAINAGE STRUCTURE	LEVEE STATION	MINIMUM LEVEE PROFILE TO ACCOMMODATE 20 PERCENT INCREASE IN DISCHARGE OR "N" VALUE M, NGVD	WAVE RUNUP AND WIND SETUP FOR 48 KM/HOUR WIND METERS	SUPERIORITY METERS	LEVEE CREST ELEVATION M, NGVD	AVERAGE GROUND ELEVATION M, NGVD	LEVEE HEIGHT METERS	DESIGN WATER SURFACE ELEVATION M, NGVD
AGUADILLA			0 + 0.00	2.81	0.24	0.00	3.05	1.00	2.05	2.72
			0 + 32.54	2.81	0.24	0.00	3.05	2.20	0.85	2.72
			0 + 76.23	3.19	0.24	0.09	3.52	1.50	2.02	2.94
		AL-S-1	1 + 39.50	3.34	0.24	0.09	3.67	1.70	1.97	2.98
			1 + 79.72	3.43	0.24	0.15	3.82	1.72	2.10	3.01
			2 + 25.58	3.51	0.24	0.30	4.05	1.30	2.75	3.18
			2 + 68.05	3.55	0.24	0.30	4.09	1.22	2.87	3.24
			3 + 44.59	3.63	0.24	0.30	4.17	1.80	2.37	3.34
			5 + 27.92	3.78	0.24	0.30	4.32	1.00	3.32	3.52
		AL-S-2	6 + 05.50	3.83	0.24	0.30	4.37	2.06	2.31	3.58
			6 + 07.29	3.83	0.24	0.30	4.37	1.00	3.37	3.58
			7 + 71.41	3.88	0.34	0.30	4.52	2.00	2.52	3.63
			8 + 65.06	3.93	0.34	0.30	4.57	2.00	2.57	3.68
			9 + 44.83	3.98	0.34	0.30	4.62	1.68	2.94	3.74
		AL-S-3	10 + 52.90	4.04	0.34	0.30	4.68	2.98	1.70	3.80
			10 + 54.61	4.04	0.34	0.30	4.68	2.50	2.18	3.80
			11 + 28.82	4.14	0.34	0.30	4.78	2.60	2.18	3.91
			11 + 91.52	4.24	0.34	0.30	4.88	2.68	2.20	4.01
			12 + 39.36	4.63	0.34	0.30	5.27	2.22	3.05	4.40
			13 + 30.31	4.69	0.34	0.30	5.33	3.00	2.33	4.46
	PR HWY 115		13 + 66.80	5.36	0.34	0.30	6.00	2.91	3.09	5.14
			13 + 80.59	5.62	0.34	0.30	6.26	2.91	3.35	5.39
			14 + 12.01	5.84	0.34	0.30	6.48	3.18	3.30	5.63
			15 + 06.36	5.87	0.34	0.30	6.51	3.04	3.47	5.66
			16 + 13.66	5.90	0.34	0.30	6.54	3.85	2.69	5.70
	PR HWY 418		16 + 16.60	5.91	0.34	0.30	6.55	3.85	2.70	5.71
			16 + 31.19	5.99	0.34	0.30	6.63	3.85	2.78	5.78
			17 + 15.70	6.20	0.34	0.30	6.84	3.28	3.56	5.98
			18 + 00.81	6.38	0.34	0.30	7.02	3.66	3.36	6.18
			18 + 19.59	6.61	0.34	0.30	7.25	4.00	3.25	6.44
			18 + 36.00	6.61	0.34	0.30	7.25	5.82	1.43	6.44
			18 + 40.00	6.61	0.34	0.30	7.25	7.25	0.00	6.44
ESPINAR			0 + 00.00	3.30	0.34	0.00	3.64	1.23	2.41	2.97
			0 + 47.13	3.43	0.34	0.00	3.77	1.30	2.47	3.01
			0 + 91.40	3.51	0.34	0.30	4.15	1.10	3.05	3.18
			1 + 36.82	3.55	0.34	0.30	4.19	1.00	3.19	3.24
			2 + 00.64	3.63	0.34	0.30	4.27	1.00	3.27	3.34
			2 + 10.00	3.65	0.34	0.30	4.29	1.00	3.29	3.37
		EL-S-1a	2 + 50.00	3.76	0.34	0.30	4.40	1.00	3.40	3.50
			2 + 58.14	3.78	0.34	0.30	4.42	1.00	3.42	3.52
			3 + 39.73	3.83	0.34	0.30	4.47	1.00	3.47	3.58
			4 + 22.14	3.88	0.34	0.30	4.52	1.00	3.52	3.63
			4 + 99.25	3.93	0.34	0.30	4.57	1.66	2.91	3.68
			5 + 91.60	3.98	0.34	0.30	4.62	1.50	3.12	3.74
			6 + 80.98	4.04	0.34	0.30	4.68	2.80	1.88	3.80
			7 + 98.79	4.14	0.34	0.30	4.78	2.70	2.08	3.91
			8 + 81.23	4.24	0.34	0.30	4.88	3.24	1.64	4.01
	PR HWY 442		9 + 55.80	4.38	0.34	0.30	5.02	4.00	1.02	4.19
			10 + 78.67	4.60	0.34	0.30	5.24	4.00	1.24	4.38
			11 + 60.58	4.61	0.34	0.30	5.25	3.61	1.64	4.39
			13 + 41.89	4.61	0.34	0.30	5.25	3.69	1.56	4.39
			14 + 80.00	4.61	0.34	0.30	5.25	4.00	1.25	4.39
			14 + 96.00	4.61	0.34	0.30	5.25	5.25	0.00	4.39
ESPINAR LEVEE SPUR			0 + 00.00	3.30	0.34	0.30	4.29	1.00	3.29	2.97
			0 + 50.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			1 + 00.00	3.30	0.34	0.30	3.94	1.10	2.84	2.97
			2 + 00.00	3.30	0.34	0.30	3.94	1.00	2.94	2.97
			2 + 66.00	3.30	0.34	0.30	3.64	3.64	0.00	2.97

re Espinar levee spur ties into Espinar levee

TABLE A-8

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE STRUCTURES

LEVEE SEGMENT	DRAINAGE STRUCTURE	LEVEE STATION	AVERAGE GROUND ELEVATION (M, NGVD)	LEVEE CROWN ELEVATION (M, NGVD)	CULVERT INVERT ELEVATION (M, NGVD)	CULVERT LENGTH* (M)	CULVERT N0. - DIA (M)	TYPE OF CONTROL
AGUADILLA	AL-S-1	1+39.5	1.70	3.67	-0.3	15	3 - 1.52	FLAPGATE
	AL-S-2	6+05.5	2.06	4.37	-0.3	19	6 - 1.52	FLAPGATE
	AL-S-3	10+52.9	2.98	4.68	-0.3	20	3 - 1.52	FLAPGATE
ESPINAR	EL-S-1a	2+ 50.0	1.00	4.40	-0.3	27	2 - 1.52	FLAPGATE

NOTE: *Computed with a levee crown width of 3.0 meters and 1V:2.5H side slopes.
Culverts are corrugated metal pipes (CMP) with bituminous coating.

TABLE A-9

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
INTERIOR DRAINAGE CHANNELS

LEVEE SEGMENT	LEVEE STATION	AVERAGE GROUND ELEVATION M, NGVD	ROAD RAMP	DRAINAGE STRUCTURE	COMMENT No. - Dia. (M)	CHANNEL INVERT M, NGVD
AGUADILLA						
	0 + 0.00	1.00				
	0 + 32.54	2.20			Slope =.005	0.24
	0 + 76.23	1.50				0.02
	1 + 39.50	1.70		AL-S-1	3 - 1.52 CMP	-0.30
	1 + 79.72	1.72				-0.30
	2 + 25.58	1.30				-0.30
	2 + 68.05	1.22				-0.30
	3 + 44.59	1.80				-0.30
	5 + 27.92	1.00				-0.30
	6 + 05.50	2.06		AL-S-2	6 - 1.52 CMP	-0.30
	6 + 07.29	1.00				-0.30
	7 + 71.41	2.00				-0.30
	8 + 65.06	2.00				-0.30
	9 + 44.83	1.68				-0.30
	10 + 52.90	2.98		AL-S-3	3 - 1.52 CMP	-0.30
	10 + 54.61	2.50				-0.29
	11 + 28.82	2.60				0.08
	11 + 91.52	2.68				0.39
	12 + 39.36	2.22				0.63
	13 + 30.31	3.00				1.09
	13 + 66.80	2.91	PR HWY 115		1 - 0.91 CMP**	1.27
	13 + 80.59	2.91				1.34
	14 + 12.01	3.18				1.50
	15 + 06.36	3.04				1.97
	16 + 13.66	3.85				2.50
	16 + 16.6	3.85	PR HWY 418		1 - 0.91 CMP**	2.52
	16 + 31.19	3.85				2.59
	17 + 15.70	3.28				3.01
	18 + 00.81	3.66				3.44
	18 + 19.59	4.00				3.53
	18 + 36.00	5.82			Slope =.005	3.62
	18 + 40.00	7.25				
ESPINAR						
	0 + 00.00	1.00				
	0 + 47.13	1.60				
	0 + 91.40	1.40				
	1 + 36.82	1.22				
	2 + 00.64	1.10				
*	2 + 10.00	1.00				
	2 + 50.00	1.00		EL-S-1a	2 - 1.52 CMP	-0.30
	2 + 58.14	1.00				-0.10
	3 + 39.73	1.00				-0.01
	4 + 22.14	1.00				0.12
	4 + 99.25	1.00				0.23
	5 + 91.60	1.00				0.40
	6 + 80.98	1.66				0.56
	7 + 98.79	1.50				0.72
	8 + 81.23	2.80				0.90
	9 + 55.80	2.70	PR HWY 442		1 - 0.91 CMP**	1.08
	10 + 78.67	3.24				1.32
	11 + 60.58	4.00				1.48
	13 + 41.89	4.00				1.63
	14 + 80.00	3.61				1.88
	14 + 96.00	3.69			Slope =.002	2.04
ESPINAR LEVEE SPUR						
	0 + 00.00	1.00				
	0 + 50.00	1.00				-0.30
	1 + 00.00	1.10				-0.20
	2 + 00.00	1.00				0.00
	2 + 50.00	3.00				0.10
	2 + 66.00	3.64			Slope =.002	

* Where Espinar levee spur ties into Espinar levee.

** Corrugated Metal Pipe (CMP) at road ramps will not have a flap gate.

Channel bottom width and side slopes are 1 meter and 1V:3H, respectively.

Espinar levee spur channel will drain toward EL-S-1a

TABLE A-10

RIO CULEBRINAS DETAILED PROJECT REPORT
HYDRAULIC DESIGN DATA
CUTOFF CHANNEL

LOCATION	EXISTING GR. ELEV. M-NGVD	CHANNEL INVERT M-NGVD	BOTTOM CHANNEL WIDTH (M)	SIDE SLOPE	TYPE OF CHANNEL
UPSTREAM END	5.64	0.52	15.2	1V:3.5H	EARTHEN
	3.97	0.46	15.2	1V:3.5H	EARTHEN
DOWNSTREAM END	3.61	0.36	15.2	1V:3.5H	EARTHEN

TABLE A-11

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR FLOOD HYDROLOGY

LEVEE SEGMENT	DRAINAGE STRUCTURE	DRAINAGE AREA SQ KM	PEAK FLOWS IN CMS PERCENT CHANCE FLOOD EVENTS						
			50	20	10	4	2	1	SPF
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	3.18	9	21	49	56	77	84	108
ESPINAR	EL-S-1a	0.34	1	3	7	8	13	14	17

TABLE A-12

RIO CULEBRINAS DETAILED PROJECT REPORT
INTERIOR DRAINAGE - RESIDUAL FLOOD ELEVATIONS

LEVEE SEGMENT	DRAINAGE STRUCTURE	RESIDUAL FLOOD ELEVATIONS IN METERS, NGVD PERCENT CHANCE FLOOD EVENTS		
		10	4	2
AGUADILLA	AL-S-1 AL-S-2 AL-S-3	2.22	2.31	2.40
ESPINAR	EL-S-1a	1.99	2.06	2.14

TABLE A-13

RIO CULEBRINAS DETAILED PROJECT REPORT
RELIABILITY ANALYSIS
AT LEVEE CROSS SECTION 1568

LOG PEAK DISCHARGE STATISTICS

MEAN = 3.7243
STD DEV = 0.2500
SKEW = 0.2454
EVENTS = 31

STAGE-DISCHARGE RELATIONSHIP

DISCHARGE CMS	STAGE METERS
147	2.34
249	2.77
317	3.04
402	3.30
530	3.62
623	3.78
1218	4.63

STD DEV OF STAGE FLUCTUATIONS 0.274 METERS

DATA FOR LEVEE

LEVEE CREST ELEVATION = 4.57 METERS
WAVE RUNUP AND WIND SETUP = 0.34 METERS
MINIMUM LEVEE GRADE + SUPERIORITY = 3.93 METERS
DESIGN WATER SURFACE ELEVATION = 3.68 METERS

STAGE METERS	PERCENT PROBABILITY OF STAGE NON-EXCEEDANCE		
	SPF	.01 EVENT	.02 EVENT
3.50	2.54	18.21	37.14
3.93	21.87	62.95	82.92
4.50	72.82	95.64	98.71
4.57	78.34	96.59	99.13
5.00	97.59	99.62	99.85

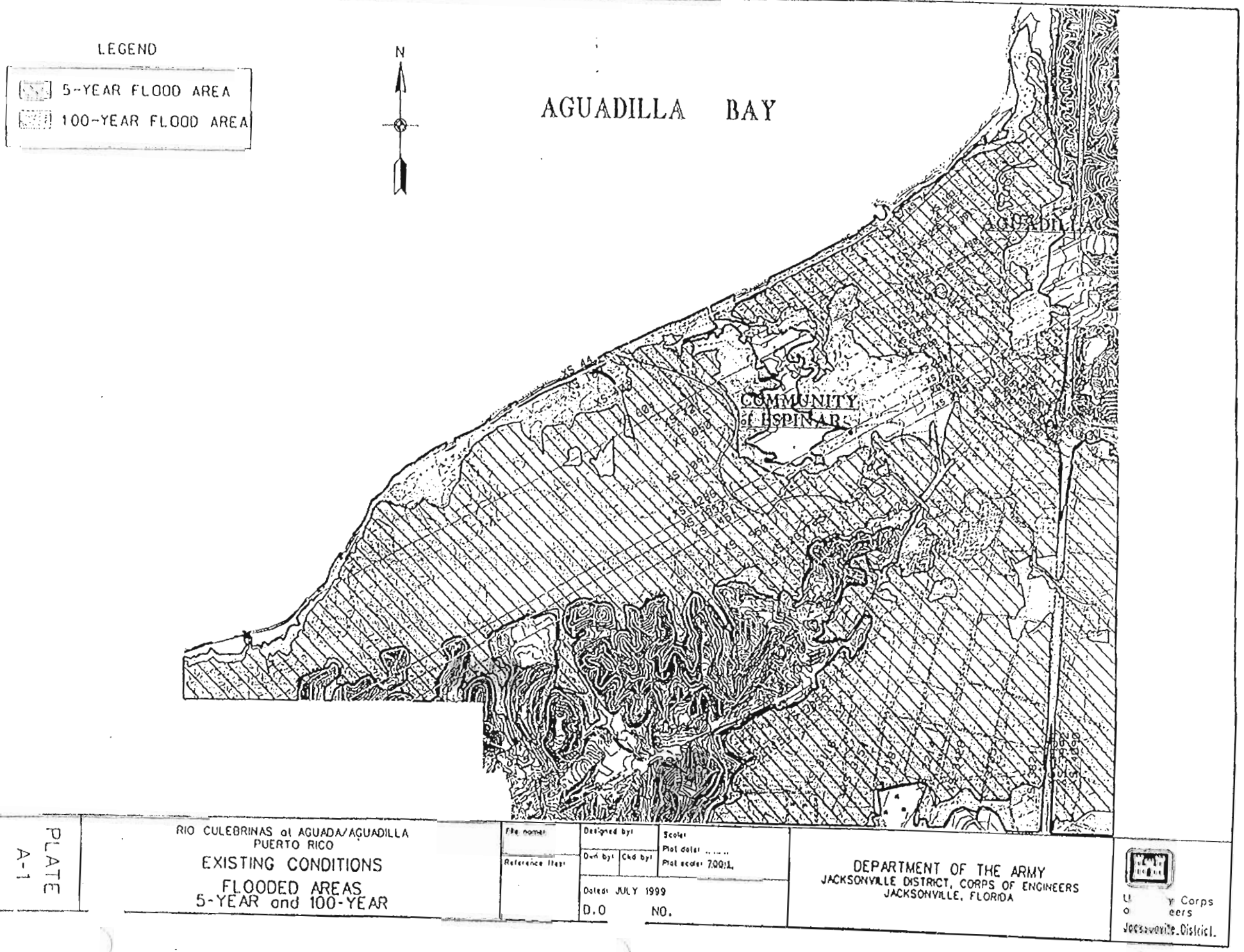


PLATE A-1

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO
EXISTING CONDITIONS
FLOODED AREAS
5-YEAR and 100-YEAR

File name:
Reference files:
Designed by:
Drawn by:
Chkd by:
Scale:
Plot date:
Plot scale: 7.00:1.
Dated: JULY 1999
D.O NO.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

U.S. Army Corps of Engineers
Jacksonville District

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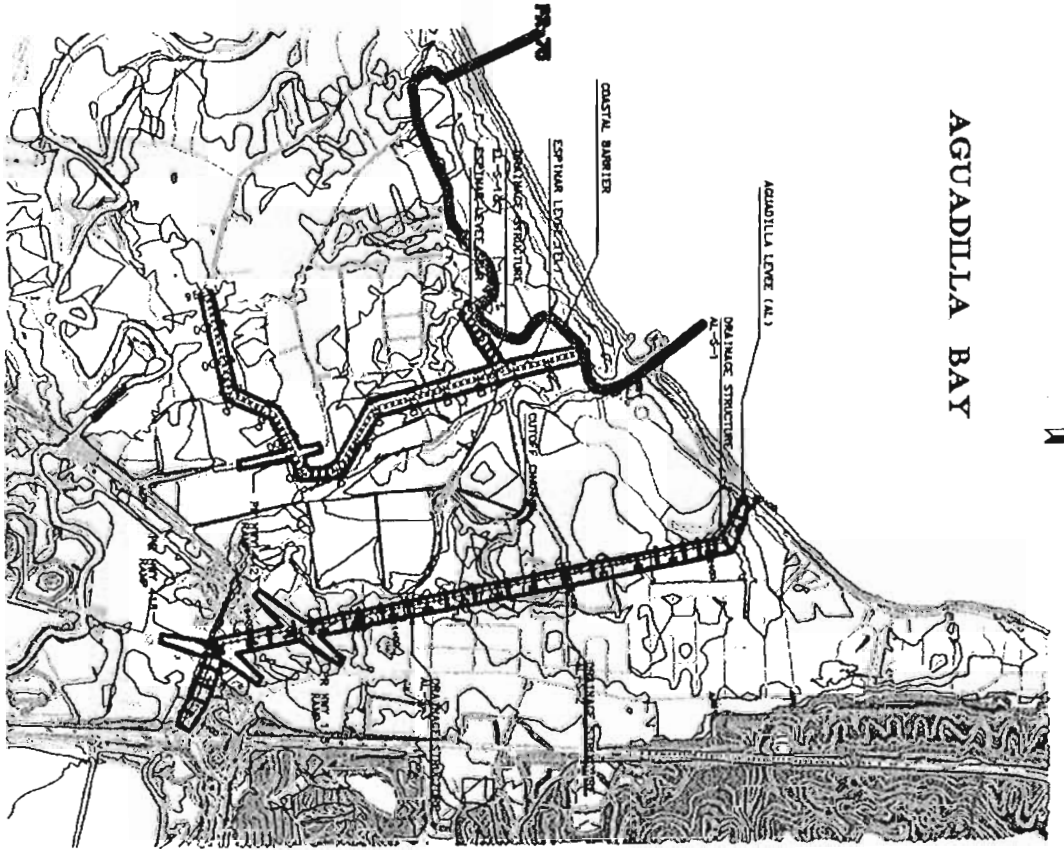


PLATE A-2

RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO
DETAILED PROJECT REPORT
RECOMMENDED PLAN

File name:
Reference files:

Designed by:
Drn by: Ckd by:
Dated: JULY 1999
O.O.FILE NO.

Scale:
Plot date:
Plot scale: 4001.

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

US Army Corps of Engineers
Jacksonville District

US Army Corps of Engineers
Jacksonville District

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

File name:
Reference file:

Designed by:
Drawn by:
Checked by:

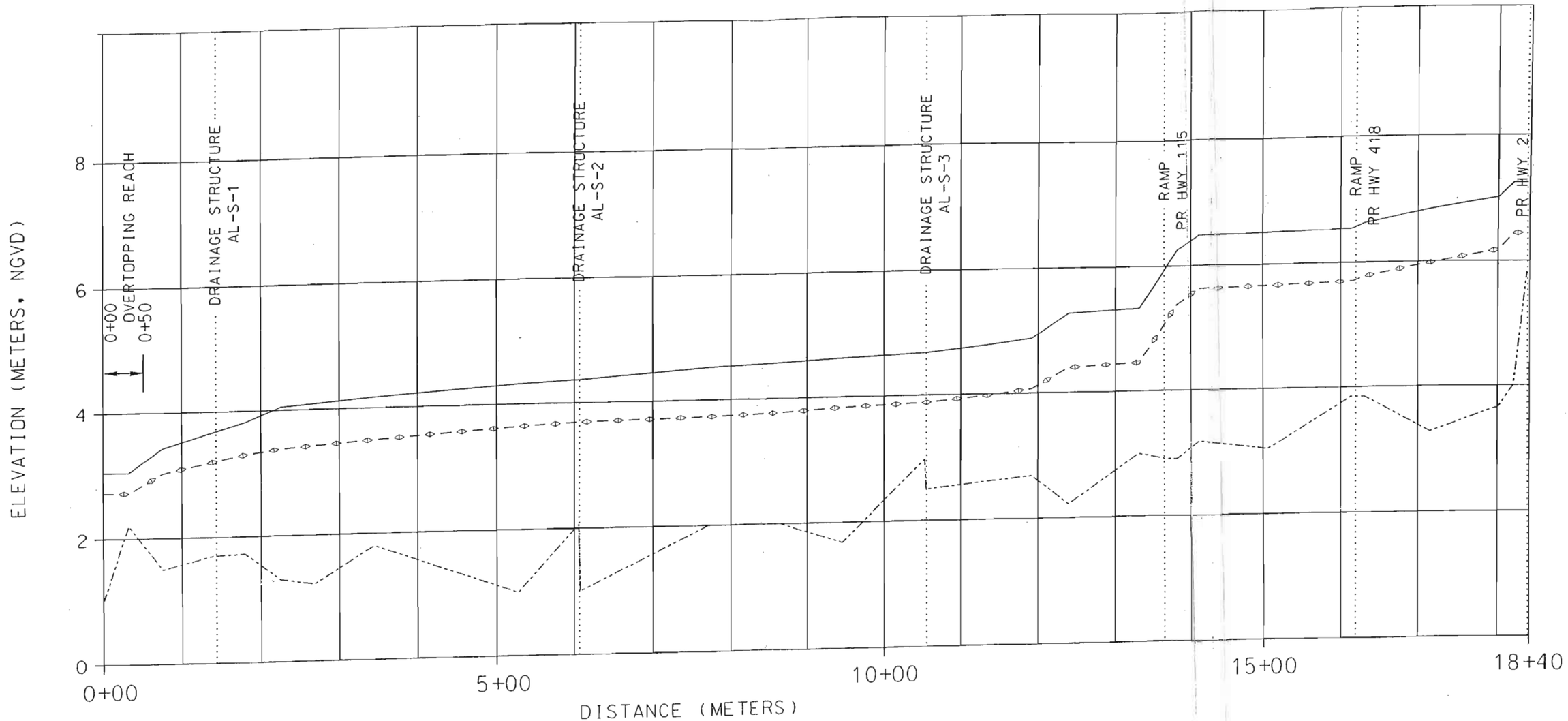
Scale:
Plot date: .....
Plot scale: 400:1

Dated: JULY 1999
D.O. FILE NO.

RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO

DETAILED PROJECT REPORT
RESIDUAL FLOODED AREA

PLATE
A-3



LEGEND

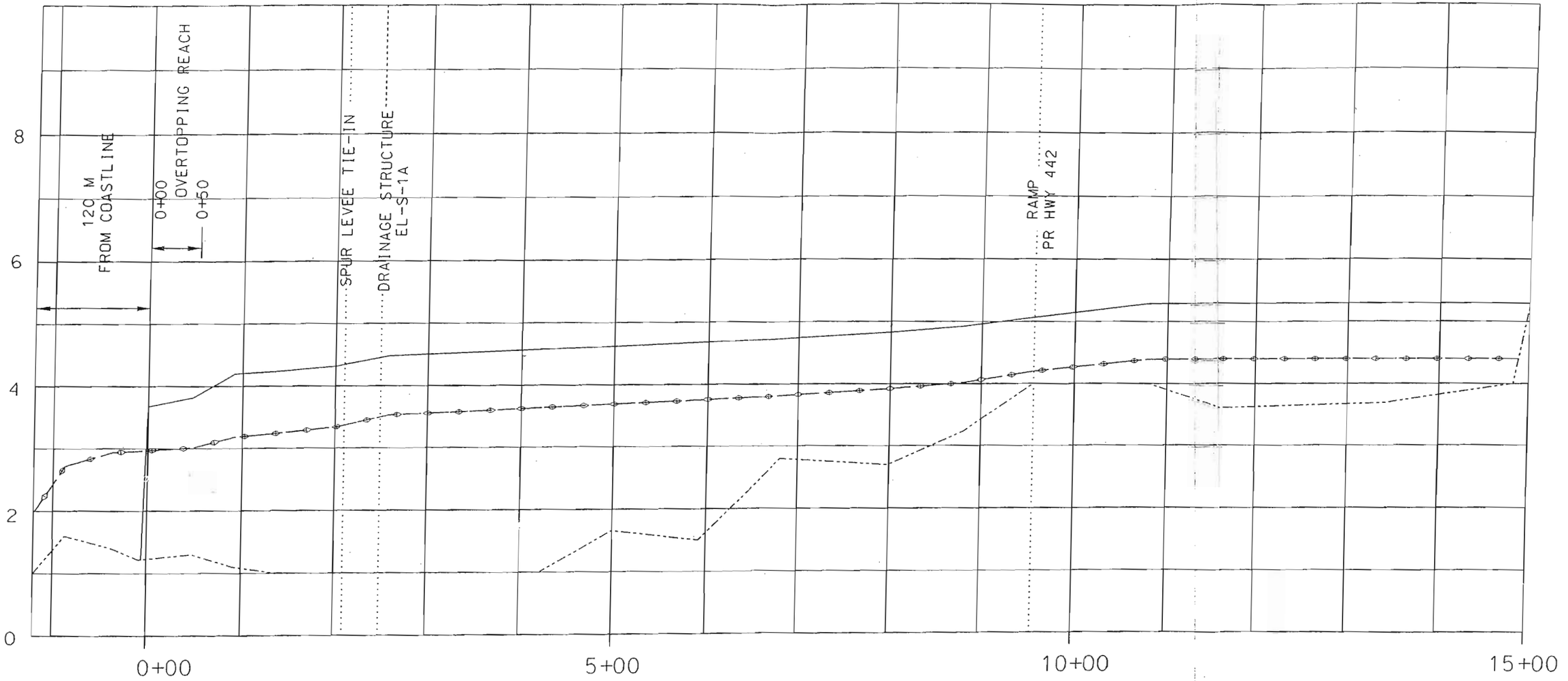
EXISTING GROUND ELEVATION

LEVEE CREST ELEVATION

DESIGN WATER SURFACE ELEVATION

NOTE: EXISTING WATER SURFACE ELEV. SAME AS DESIGN WATER SURFACE ELEV.

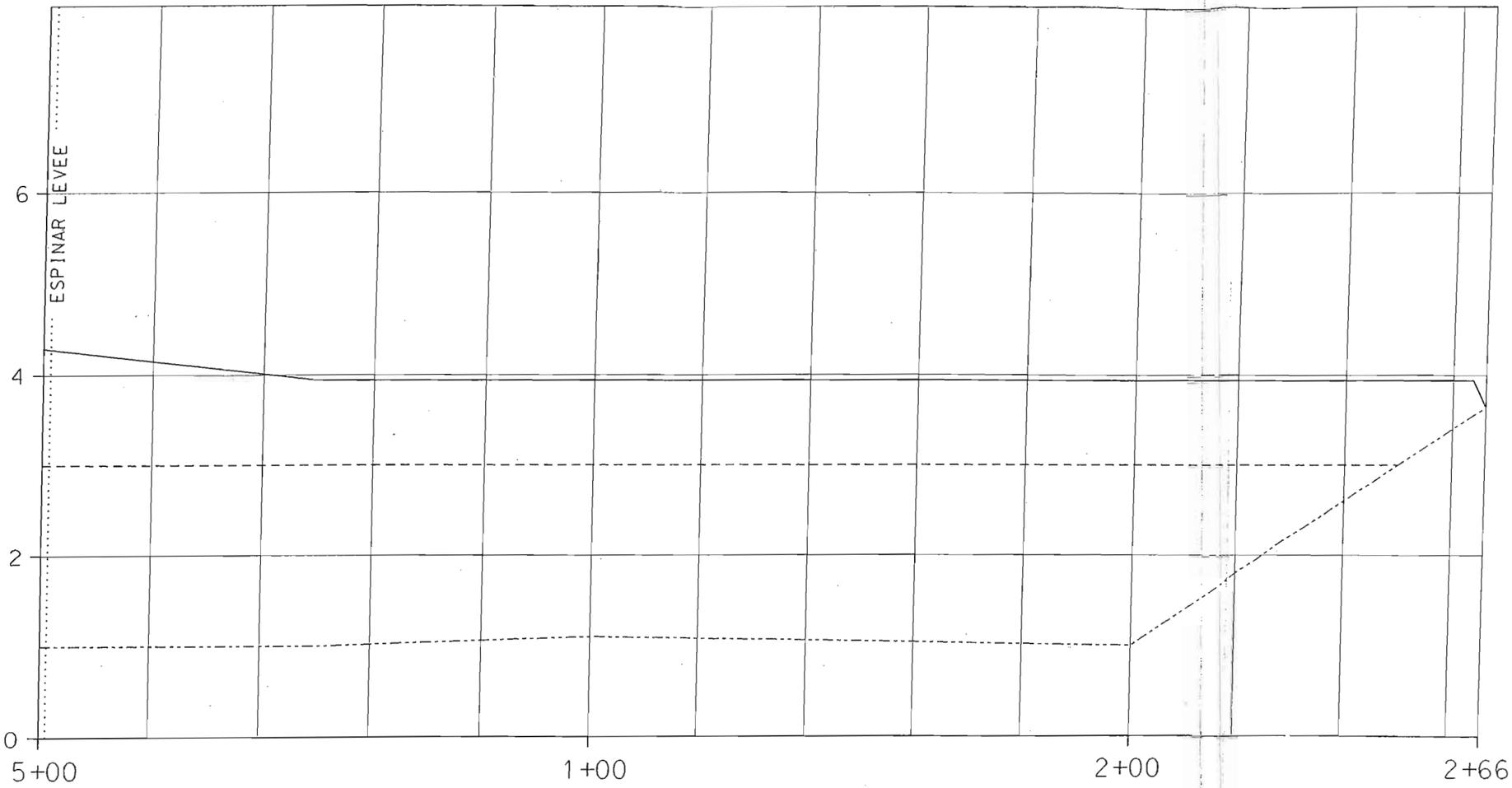
REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA		
	AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS AQUADILLA LEVEE PROFILE 100-YEAR		
DESIGN ENG.:	INV. NO.	SIZE	DWG. NO.
CHECKED BY:	DATED:		
DRAWN BY:	SCALE: AS SHOWN	DATED: JUNE, 1999	PLATE A-4



LEGEND

EXISTING GROUND ELEVATION
DESIGN WATER SURFACE ELEVATION
LEVEE CREST ELEVATION

REFERENCE FILENAMES:	DEPARTMENT OF THE ARMY JACKSONVILLE DISTRICT, CORPS OF ENGINEERS JACKSONVILLE, FLORIDA
	AQUADA/AQUADILLA, PUERTO RICO RIO CULEBRINAS ESPINAR LEVEE PROFILE 100-YEAR
DESIGN ENG.:	INV. NO. / SIZE / DWG. NO.
CHECKED BY:	DATED:
DRAWN BY:	SCALE: AS SHOWN / DATED: JUNE, 1999 / PLATE A-5



ELEVATION (METERS, NGVD)

DISTANCE (METERS)

LEGEND

EXISTING GROUND ELEVATION
DESIGN WATER SURFACE ELEVATION
LEVEE CREST ELEVATION

NOTE: EXISTING WATER SURFACE ELEVATION SAME AS DESIGN WATER SURFACE

REFERENCE FILENAMES:

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

AQUADA/AQUADILLA, PUERTO RICO
RIO CULEBRINAS
ESPINAR LEVEE SPUR PROFILE
100-YEAR

DESIGN ENG.:	INV. NO.	SIZE	DWG. NO.
CHECKED BY:	DATED:		
DRAWN BY:	SCALE: AS SHOWN	DATED: JUNE, 1999	PLATE A-6

RIO CULEBRINAS AT AGUADILLA AND AGUADA, PUERTO RICO
SECTION 205
FINAL DETAILED PROJECT REPORT
AND ENVIRONMENTAL ASSESSMENT

APPENDIX B
GEOTECHNICAL STUDIES

SECTION 205 DETAILED PROJECT REPORT
RIO CULEBRINAS
AGUADILLA, PUERTO RICO

APPENDIX B
GEOTECHNICAL

TABLE OF CONTENTS

Paragraph No.		Page No.
1.	Purpose	B-1
2.	General	B-1
3.	Investigations Performed	B-1
4.	Materials Encountered	B-3
5.	Embankment Material	B-4
6.	Stability Analysis	B-4
7.	Embankment Geometry	B-7
8.	Embankment Seepage Analysis	B-7
9.	Embankment Settlement	B-8
10.	Foundation Conditions for Structures	B-9
11.	Foundation Preparation and Embankment Construction	B-10
12.	Geotechnical Design References	B-11

List of Plates

Title	Plate No.
Site Plan and Boring Location	B-1
Site Plan and Boring Location	B-2
Geologic Section - Aguadilla Levee	B-3
Geologic Section - Espinar Levee	B-4
Slope Stability Analysis, Section No. 1	B-5
Slope Stability Analysis, Section No. 2	B-6
Slope Stability Analysis, Section No. 3	B-7

CORE BORING LOGS, TEST PIT LOGS,
AND LABORATORY TEST DATA

GEOTECHNICAL

1. Purpose. This appendix presents the results of the subsurface investigations, laboratory work, and subsequent Geotechnical analysis and design for each major feature of the Rio Culebrinas flood control project.

2. General. The study area is located on the northwest coast of Puerto Rico between the community of Espinar and the town of Aguadilla. The main feature of this flood control project will be the construction of two separate levee segments identified as Aguadilla and Espinar and the proposed drainage structures passing through them. These levees will cross three existing highways and as a result, two road ramps will be required along the alignment of the Aguadilla levee and one along the alignment of the Espinar levee. A short "cutoff" channel is also proposed to mitigate the impact of the Aguadilla levee crossing two oxbows of the Cano Madre Vieja channel. All stationing is in meters. For clarity, various measurements and other engineering properties will be reported in English units with the metric equivalent following in parentheses.

3. Investigations Performed.

a. Core Borings. For use in the design of the project features, 15 core borings were performed in June of 1998. Eight borings were drilled along the proposed Aguadilla levee alignment, six borings along the proposed Espinar levee alignment, and one boring along the proposed cutoff channel alignment. A single boring was also drilled within the limits of a potential borrow site located just to the southwest of the study area. These borings were drilled to depths ranging from 15 feet (4.57 m) to 49.5 feet (15.09 m). The average spacing between the levee borings was 800 feet (243.8 m).

Standard Penetration Tests (SPT) were performed during the drilling to determine the consistency, relative density, and approximate strength of the materials sampled. The test consists of dropping a hammer weighing 140 pounds (63.5 kg) onto the drill rod from a height of 30 inches (0.76 m). The number of blows (N) necessary to produce a penetration of 1 foot (0.3 m) is regarded as the Standard Penetration Resistance. To avoid seating errors, the blows for the first 6 inches (0.15 m) of penetration are not taken into account; those required to increase the penetration from 6 to 18 inches (0.15 to 0.46 m) constitute the N-value. The split-spoon sampler is 24 inches (0.61 m) long with an outside diameter of 2 inches (5.08 cm) and an inside diameter of 1-3/8 inch (3.49 cm). The relation between the number of blows, the

consistency of the cohesive soils, and the relative density of noncohesive soils (from Terzaghi and Peck, 1948) are as follows:

(N)	Density	(N)	Consistency
< 4	Very Loose	< 2	Very Soft
4 - 10	Loose	2 - 4	Soft
10 - 30	Medium	4 - 8	Medium
30 - 50	Dense	8 - 15	Stiff
> 50	Very Dense	15 - 30	Very Stiff
		> 30	Hard

A site plan showing the core boring locations is shown on Plates B-1 and B-2. Copies of the boring logs are included at the end of this appendix.

b. Undisturbed Sampling. Three undisturbed samples were obtained during the core drilling phase of the subsurface investigation. Each sample was obtained by pushing a 3-inch diameter (7.62 cm) Shelby Tube into the soil for a distance of two feet (0.61 m) beginning at a pre-selected depth. The site location for the sampling was within 5 feet (1.52 m) of core boring CB-CUL-05, CB-CUL-13, and CB-CUL-14.

c. Bulk Sampling. As a part of the subsurface investigation program, a potential borrow site was examined to determine the suitability of the subsurface material for embankment fill. This site is located approximately 2.45 kilometers southwest of the center of the study area. In addition to the core boring performed there, two test pits were excavated within the limits of the site and bulk samples were obtained for laboratory testing. A copy of the test pit logs is included at the end of this appendix.

d. Laboratory Testing. Laboratory tests were performed on a number of soil samples obtained at various depths from each core boring and test pit. A combination of two or more "classification" tests (moisture content, Atterberg Limits, grain size distribution, specific gravity) were performed on each sample selected for testing. Each bulk sample also received a Standard Proctor compaction test in a 6-inch (15.24 cm) diameter mold. Classification tests, triaxial shear tests, and consolidation tests were performed on each undisturbed sample obtained. One Q test (unconsolidated-undrained test) and one

consolidation test were performed on the undisturbed sample obtained next to core boring CB-CUL-13 and on the undisturbed sample obtained next to boring CB-CUL-14. One R-bar test (consolidated-undrained test with pore pressure measurements during testing) and one consolidation test were performed on the undisturbed sample obtained next to core boring CB-CUL-05. The laboratory test results are included at the end of this appendix.

4. Materials Encountered.

a. Aguadilla Levee Segment - Station 1+00 to 7+00. Core borings CB-CUL-01 and CB-CUL-03 found a layer of low-plasticity clay (with sand) overlying a deposit of well-graded sand with gravel. Core boring CB-CUL-02 encountered silty sand and well-graded sand overlying a deposit of poorly-graded sand. The consistency of the low-plasticity clay ranged from soft to medium stiff. The density of the sand layers ranged from very loose to medium.

b. Aguadilla Levee Segment - Station 7+00 to 18+00. Core borings CB-CUL-05 through CB-CUL-08 encountered interbedded layers of high-plasticity clay, clayey sand, low-plasticity clay, low-plasticity silt, high-plasticity silt, silty sand, well-graded sand, and well-graded gravel. Root and/or plant fragments were present in all silt and clay layers sampled. The consistency of these soils ranged from very soft to medium stiff. The density of the coarse-grained soils ranged from very loose to medium.

c. Proposed Channel Cut. Core boring CB-CUL-04 found a brown-and-gray layer of high-plasticity silt overlying a loose deposit of well-graded gravelly sand. The consistency of the silt ranged from very soft to medium stiff and was 2.74 meters in thickness.

d. Espinar Levee Segment - Station 0+00 to 5+00. Core boring CB-CUL-13 found a layer of brown-and-gray high-plasticity silt overlying a thin layer of low-plasticity clay and well-graded gravelly sand. The consistency of the high-plasticity silt layer was soft to very soft and was 3.66 meters in thickness. Boring CB-CUL-14 found interbedded layers of silty sand, well-graded sand, high-plasticity clay, and clayey sand overlying a layer of high-plasticity clay (1.37 m thick). Below this clay layer, the boring encountered a layer of well-graded sand with gravel to the end of the boring. The density of the sand layer ranged from loose to medium.

e. Espinar Levee Segment - Station 5+00 to 14+96. Borings CB-CUL-09 through CB-CUL-12 encountered silty sand, well-graded

sand, and clayey sand overlying a layer of poorly-graded coarse-grained sand. The coarse-grained sand contained calcite cemented sand nodules (up to gravel size) and was sampled to the end of each boring. The density of the upper sand layers ranged from very loose to dense while the density of the lower sand layer ranged from medium to dense.

f. Potential Borrow Site. Core boring CB-CUL-15 encountered slightly to thoroughly weathered limestone to the depth of the boring. The classification of the material recovered varied with depth (well-graded gravel, clayey gravel, silty gravel, low and high-plasticity silt, and low and high-plasticity clay) but was fairly uniform with respect to density (dense to very dense). Test pits TP-CUL-01 and TP-CUL-02 sampled the same limestone formation to a depth of 1.37 meters and 2.90 meters respectively. The excavated material was classified as clayey gravel and silty gravel.

A geologic section has been prepared along the proposed centerline for each levee. All applicable boring logs have been shown at their respective station locations. These geologic sections are shown on Plates B-3 and B-4. It should be noted that the sections do not indicate any specific material type limits other than that shown by the individual borings, as any reasonable interpretation made from the boring logs could at best be a poor representation of the actual subsurface conditions.

5. Embankment Material. Fill material for the proposed embankments will most likely come from a commercial borrow source located near the project site. Suitable fill for the road ramps will be limited to only course-grained soils with less than 15 percent by weight passing the number 200 sieve. Materials classified by the Unified Soil Classification System as GW, GP, GM, GC, SW, SP, SC, SM, CL, and CH may be used for levee fill. As discussed in paragraph 4f above, one potential borrow site was examined to determine the suitability of the subsurface material for embankment fill. Based on the findings from core boring CB-CUL-15 and test pits TP-CUL-01 and TP-CUL-02, material from this site may be used for the levees as long as care is taken in accurately classifying the materials excavated.

6. Stability Analysis. Slope stability analyses were performed using the UTEXAS-3 Slope Stability Program available through the U.S. Army Engineer Waterways Experiment Station, Corps Program Library. The slopes for the proposed road ramp and levee embankments and cutoff channel were analyzed under the following conditions - End of Construction and Long Term. Shear strength values for the foundation soils and overlying embankment fill were based on Standard Penetration Test (SPT) N-Values and

laboratory test results. Applicable unit weights for each soil type were determined by using laboratory test results. Two different embankment cross sections and soil profiles were modeled for stability (one Aguadilla levee section and one Espinar levee section). In each model a gravel-sand-clay/gravel-sand-silt mixture was assumed for the embankment fill while the underlying soil layers reflected those found where the section was chosen. For the cutoff channel, one cross section was modeled for stability. The shear strength values and unit weights used in each model are shown on Plates B-5 through B-7.

With the End of Construction (EOC) condition, unconsolidated-undrained shear strengths were used and a side slope of 1 vertical to 2.5 horizontal was analyzed as a starting point. The stability of the embankments and channel was also checked with a seismic event occurring at the same time. The results of the analyses were as follows:

END OF CONSTRUCTION CONDITION	Minimum Factor of Safety Computed	Minimum Factor of Safety Required*
Aguadilla Levee		
Station 13+30	1.669	1.3
Espinar Levee		
Station 2+40	1.523	1.3
Cutoff Channel	5.506	1.3
END OF CONSTRUCTION CONDITION WITH SEISMIC ACTIVITY		
Aguadilla Levee		
Station 13+30	1.023	1.0
Espinar Levee		
Station 2+40	1.005	1.0
Cutoff Channel	2.289	1.0

*Per EM-1110-2-1913, Design & Construction of Levees

As the computed factor of safety for each slope was greater than the minimum required, the EOC analyses were ended. Steepening the embankment slopes beyond 1 vertical to 2.5 horizontal would also make the operation of maintenance equipment difficult if not impossible. For each modeled section, the critical failure arc is shown on Plates B-5 through B-7.

With the Long Term (LT) condition, consolidated-drained shear strengths were used and a side slope of 1 vertical to 2.5 horizontal was again analyzed. The results of the analyses were as follows:

LONG TERM CONDITION	Minimum Factor of Safety Computed	Minimum Factor of Safety Required*
Aguadilla Levee		
Station 13+30	1.571	1.4
Espinar Levee		
Station 2+40	1.545	1.4
Cutoff Channel	1.105	1.4
LONG TERM CONDITION WITH SEISMIC ACTIVITY		
Aguadilla Levee		
Station 13+30	1.072	1.0
Espinar Levee		
Station 2+40	1.081	1.0
Cutoff Channel	---	1.0

*Per EM-1110-2-1913, Design & Construction of Levees

Under long term conditions, the embankment sections were stable but the computed factor of safety for the channel slope was less than that required by EM 1110-2-1913. As a result, the stability of the proposed channel cut was reanalyzed with a side slope of 1 vertical to 3.5 horizontal. The results were as follows:

Cutoff Channel	Minimum Factor of Safety Computed	Minimum Factor of Safety Required*
END OF CONSTRUCTION CONDITION	5.676	1.3
EOC COND. W SEISMIC ACTIVITY	2.284	1.0
LONG TERM CONDITION	1.446	1.4
LT CONDITION W SEISMIC ACTIVITY	0.971	1.0

*Per EM-1110-2-1913, Design & Construction of Levees

At a 1 vertical to 3.5 horizontal side slope, the proposed channel cut would be stable under all but the long-term condition with a seismic event. Considering the purpose and location for the cutoff channel, failure of the channel slopes into the flow-way would not threaten human life. As a result, the computed factor of safety for this condition was considered to be acceptable and the stability analyses were ended. The critical failure arc for each modeled section is shown on Plates B-5 through B-7.

Hydraulic analyses show that the effects of the 100-year event will be present on the levee slope for approximately 20 hours or less. Considering both levees, seepage through either levee section is unlikely due to the high percentage of GM/GC type material available for levee fill and the short duration of a saturating pool. Based on the above, a long-term condition with steady-state seepage was not analyzed. Partial Pool and Sudden Drawdown cases were also not analyzed as they were considered to be nonapplicable as well. Once constructed, the vegetative cover on both levees should hold most of the soil (on the slopes) in place during a high water event. Should any loss of material occur due to erosion or saturation, repairs can be made as needed.

7. Embankment Geometry. Based on the slope stability analyses, a side slope of 1 vertical to 2.5 horizontal is recommended for the road ramp and levee embankments. The crest width along both levees will be 3 meters. A maximum vertical height of 3.56 meters occurs along the Aguadilla levee alignment near station 17+15. The combined width of the travel lanes and shoulders on the road ramps will be at least 10.97 meters.

8. Embankment Seepage Analysis. While through seepage should not occur from the 100-year event in either levee, seepage *under* the embankments could occur along portions of both levees. From station 9+00 to 14+96 along the Espinar levee alignment (approx.), a layer of well-graded sand (SW) exists at and near the ground surface. This material was also encountered near the ground surface around station 3+80 along the Aguadilla levee alignment. (Where the boring logs did not show SW material at the ground surface, a layer of silty sand was present.) With a calculated horizontal permeability of 86 ft/day (26.21 meters/day), this well-graded sand could act as a conduit for the removal of embankment material during high water events. As a result, a cross section through each levee was modeled using GMS (version 2.1) for the purpose of analyzing the underseepage. With each section, a high ground water table was assumed to exist during the 100-year event. Using total-head values from program's solution file, the exit gradients (in both the horizontal and vertical direction) were calculated for a rectangular area located directly below the "landside" levee toe. The factor of safety against piping in both directions was then calculated by dividing the respective critical gradient by the respective exit gradient.

The results of the seepage analyses, shown below, indicate that the potential for loss of material due to piping is the greatest underneath the Aguadilla levee around station 3+80.

Levee	Station	Calculated Exit Gradient in the Horizontal Direction	Calculated Exit Gradient in the Vertical Direction	Factor of Safety in the Horizontal Direction	Factor of Safety in the Vertical Direction	Minimum Factor of Safety Required*
Aguadilla	3+80	0.282	0.45	1.964	2.05	2.5 -- 3
Espinar	9+60	0.0645	0.106	8.59	8.7	2.5 -- 3

* Per Cedergren 1977

Even though the duration of the 100-year event is expected to be relatively short, over time the cumulative effects of high-water events against the levee could lead to the production of seepage cavities directly below the levee. To prevent the loss of material from piping along the toe in this area, a gravel filter should be placed below the "landside" toe for a length that will be determined prior to the preparation of plans and specifications.

9. Embankment Settlement. Due to the anticipated loading from each levee upon the ground surface, long-term consolidation of the silt and clay layers located below portions of each levee is expected. As a result, settlement calculations were performed to determine the magnitude of this post-construction consolidation and the amount of overbuild that will be necessary to account for it. Settlement calculations were based on cross sections made at selected locations along both of the proposed levee alignments. Each modeled section consisted of a levee section bearing on the soils encountered by one of the project core borings. All calculations were performed by hand. The following equation from Das (see reference "b") was used to calculate the settlement.

$$S = [C_c * H/(1 + e_o)] * \log((p_o - \Delta p)/p_o) \qquad \text{(Equ. 7.20)}$$

where:

C_c = the compression index (obtained from the empirical expression $C_c = 0.30[e_o - 0.27]$)

H = initial thickness of the compressible sublayer

e_o = the initial void ratio (obtained from laboratory test results)

p_o = initial average effective overburden pressure on the compressible sublayer

Δp = increase in vertical pressure on the compressible sublayer due to the construction of the levee

The results of the settlement calculations, shown below, indicate that settlement will be the greatest where the levee alignment passes near or crosses over the Cano Madre Vieja

channel. The recommended amount of overbuild for each levee is simply the calculated amount of settlement rounded up to the nearest half-foot (15.24 cm) increment.

Levee	Modeled Station	Core Boring used for Foundation Conditions	Calculated Settlement (inches)	Recommended Amount of Overbuild (inches)	Application Range (levee station)
Aguadilla	6+00	CB-CUL-03	4.66	6	4+40 to 7+00
Aguadilla	8+30	CB-CUL-05	9.79	12	7+00 to 9+60
Aguadilla	10+50	CB-CUL-06	4.93	6	9+60 to 14+60
Aguadilla	13+40	CB-CUL-07	5.3	6	9+60 to 14+60
Espinar	---	CB-CUL-14	8.89	12	0+00 to 0+80 and 3+40 to 5+00
Espinar	2+40	CB-CUL-13	17.85	18	0+80 to 3+40

10. Foundation Conditions for Structures. Three 60-inch diameter (1.52 m) corrugated metal pipe (CMP) culverts will be placed through the Aguadilla levee at station 1+39.50 (see Plate B-1). The design invert elevation for these culverts is -0.3 meters. Based on core boring CB-CUL-01, the subgrade material below this elevation is a fine-to-medium-grained well-graded sand with a density ranging from loose to medium. The ground-water table was recorded at an elevation of -0.79 meters. Based on the above information, no special foundation preparation measures should be necessary outside of running a vibratory compactor over the cleared subgrade surface to increase the density of the existing subgrade material.

Six 60-inch diameter (1.52 m) CMP culverts will be placed through the Aguadilla levee at station 6+05.50 (see Plate B-1). The design invert elevation for these culverts is -0.3 meters. Based on boring CB-CUL-03, the subgrade material below this elevation is a well-graded sand/gravel mix to a depth of 1.37 meters. Below the well-graded sand, a 0.91-meter layer of clayey sand exists followed by a small silt layer and then another well-graded sand layer to the end of the boring. The ground-water table was recorded at an elevation of +1.97 meters. Based on the above information, dewatering may be necessary at the time of construction to insure that the backfill around the culvert is placed and compacted in the dry. A vibratory compactor should also be run over the cleared subgrade surface prior to installing the culverts.

Three 60-inch diameter (1.52 m) CMP culverts will be placed through the Aguadilla levee at station 10+52.90 (see Plate B-1). The design invert elevation for these culverts is -0.3 meters.

Based on boring CB-CUL-06, the subgrade material below this elevation is a very-soft layer of high-plasticity silt to a depth of 0.91 meters. Below the silt layer, a 3.2-meter layer of medium-dense clayey sand exists followed by a layer of well-graded sand to the end of the boring. The ground-water table was recorded at an elevation of -1.74 meters. Based on the above information, the culvert subgrade should be undercut by 1.07 meters and then backfilled with select materials (in compacted lifts) to the invert elevation.

Two 60-inch diameter (1.52 m) CMP culverts will be placed through the Espinar levee at station 2+50 (see Plate B-1). The design invert elevation for these culverts is also -0.3 meters. Based on boring CB-CUL-13, the subgrade material below this elevation will be a very-soft layer of high-plasticity silt to an elevation of -2.74 meters. Below the silt layer, a small layer of low-plasticity clay was encountered overlying a layer of well-graded gravelly sand. The ground-water table was recorded at an elevation of +0.60 meters. Based on the above information, the culvert subgrade should be undercut by 2.44 meters and then backfilled with select materials (in compacted lifts) to the invert elevation. The required excavation will most likely require dewatering in order to insure that the backfill is placed and compacted in the dry.

All of the above mentioned culverts will have a flapgate installed on the floodplain side of the levee.

11. Foundation Preparation and Embankment Construction. After all clearing and grubbing has been completed and prior to any fill placement, the foundation area for each levee should be thoroughly broken to a depth of 15 cm. This will help to insure a good bond between the first lift of fill and the existing natural ground surface. All scarifying and breaking of the ground surface should be done parallel to the proposed centerline of the levee.

Fill material selected for the levee embankments should be spread by bulldozers (or other approved means) in horizontal layers to the final grade. Prior to compaction, these layers should not exceed 1 foot (0.3 m) in thickness when coarse-grained materials are being placed and 8 inches (20.3 cm) in thickness when fine-grained materials are being placed. The levee fill should be compacted to at least 95 percent of the maximum dry density obtained at optimum moisture, as defined by the Standard Proctor Compaction Test. Compaction may be accomplished by using a sheepsfoot roller, rubber-tire roller, or other approved device well suited to the type of material being compacted.

Fill material for the road-ramp embankments should be placed in horizontal layers of loose material no greater than 8 inches (20.3 cm) in thickness. Each layer should be compacted to at least 95 percent of the maximum dry density obtained at optimum moisture, as defined by the Modified Proctor Compaction Test. Compaction may be accomplished by using a vibratory steel-wheel roller or other approved device well suited to the type of material being compacted.

12. Geotechnical Design References.

a. Das, Braja. Principles of Geotechnical Engineering. Boston: PWS Publishers, 1985.

b. Department of the Army, Office of the Chief of Engineers. Engineering Manual EM 1110-2-1913: Design and Construction of Levees, 31 March 1978.

c. Duncan, J. M., R. C. Horz, and T. L. Yang. Shear Strength Correlations For Geotechnical Engineering, Virginia Tech Department of Civil Engineering, Geotechnical Engineering. Virginia: Virginia Polytechnic Institute and State University, 1989.

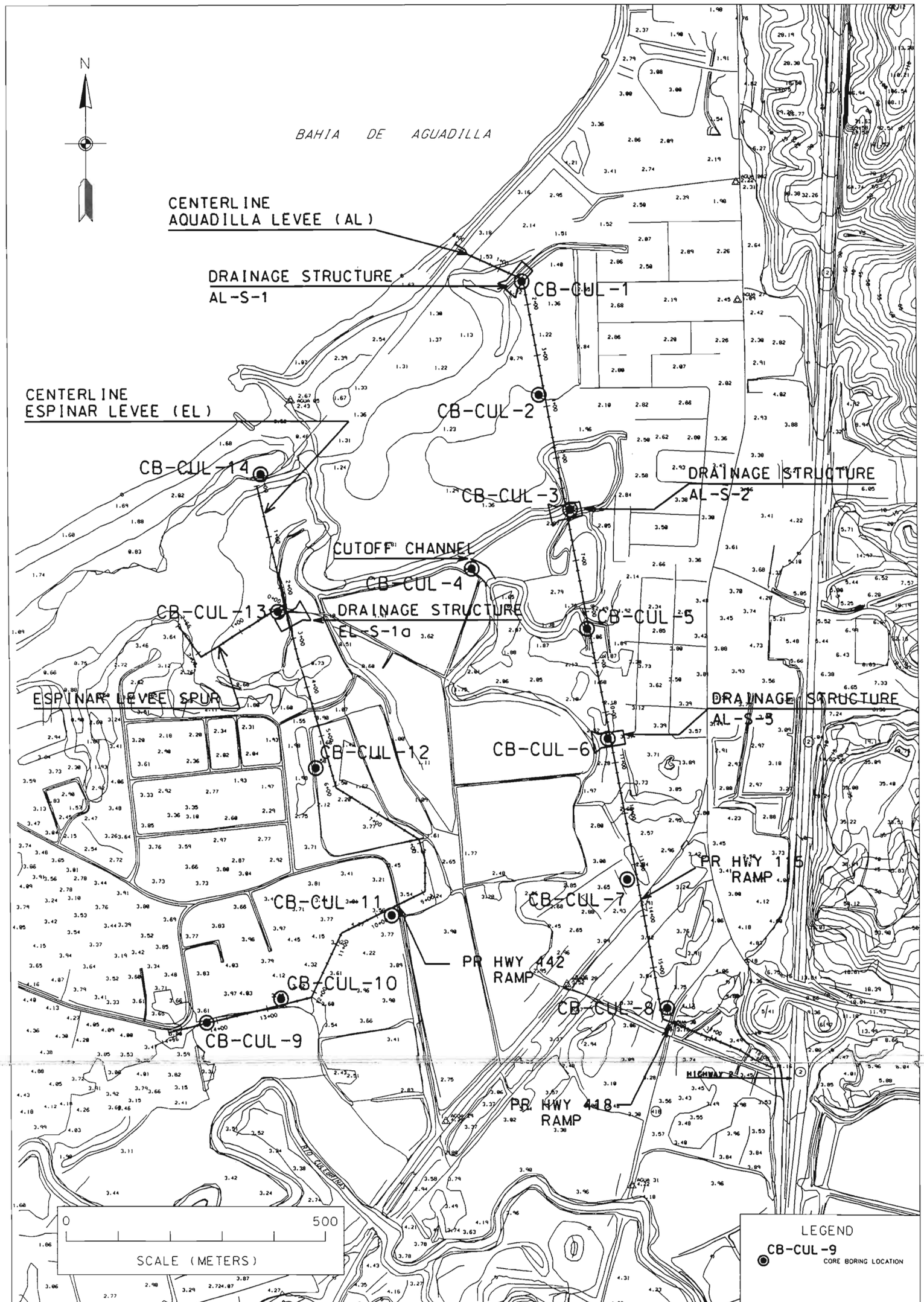


PLATE B-1

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO
SITE PLAN and BORING LOCATION

File name: PLATEBIR.DGN
Reference files:

Designed by:
Drawn by: M.W.V.
Checked by:
Scale: AS SHOWN
Plot date:
Plot scale:
Dated: April 2001
D.O.FILE NO.

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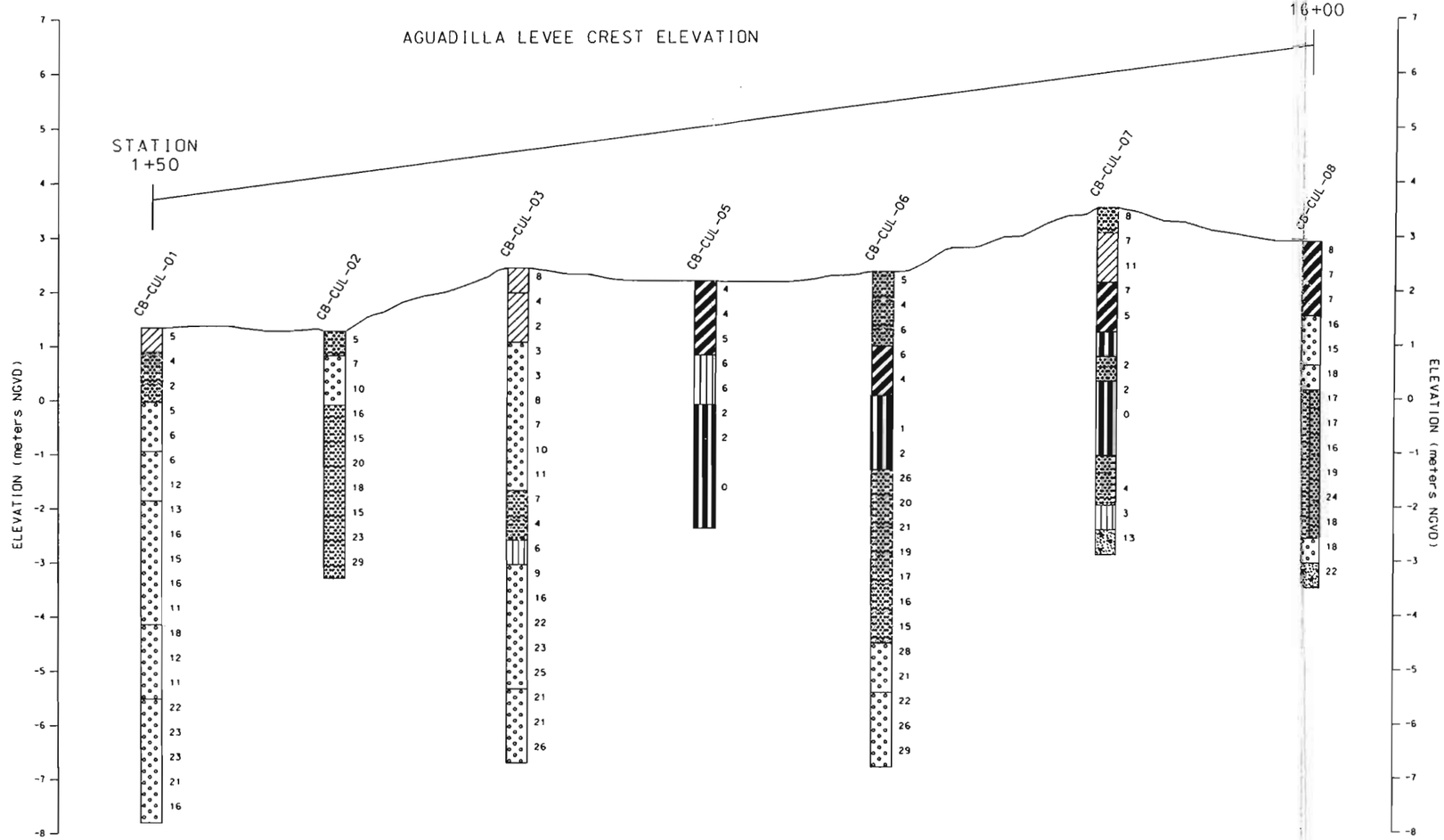
JACKSONVILLE, FLORIDA

US Army Corps of Engineers
Jacksonville District

CB-CUL-15
TP-CUL-1
TP-CUL-2
N
0
300
SCALE (METERS)
LEGEND
CB-CUL-9
CORE BORING LOCATION
TP-CUL-2
CORE BORING LOCATION
US Army Corps of Engineers
Jacksonville District
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA
Scale: AS SHOWN
Dated: April 2001
D.O.FILE NO.
RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO
SITE PLAN and BORING LOCATIONS
PLATE
B-2

AGUADILLA LEVEE CREST ELEVATION



SOIL LEGEND:

(GW) WELL-GRADED GRAVELS OR GRAVEL-SAND MIXTURES, LITTLE OR NO FINES

(SW) WELL-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES

(SP) POORLY-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.

(SM) SILTY SANDS, SAND-SILT MIXTURES

(SC) CLAYEY-SANDS, SAND-SILT MIXTURES

(ML) INORGANIC SILTS AND VERY FINE SANDS, ROCK FLOUR, SILTY OR CLAYEY FINE SANDS

(CL) INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS

(MH) INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS

(CH) INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS

NOTES:

1. THE GEOLOGIC SECTION SHOWN REFLECTS THE FIELD VISUAL CLASSIFICATION (SHOWN ON THE CORE BORING LOGS) AND LABORATORY CLASSIFICATION OF SELECTED SOIL SAMPLES.
2. NUMBERS SHOWN ON BORINGS ARE STANDARD PENETRATION TEST RESULTS IN BLOWS PER FOOT.
3. FOR A COMPLETE PLAN VIEW WITH LEGEND, SEE PLATES B-1 AND B-2.

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Dan by: M.W.V.
Ckd by:
Dated: April 2001
Scale: AS SHOWN
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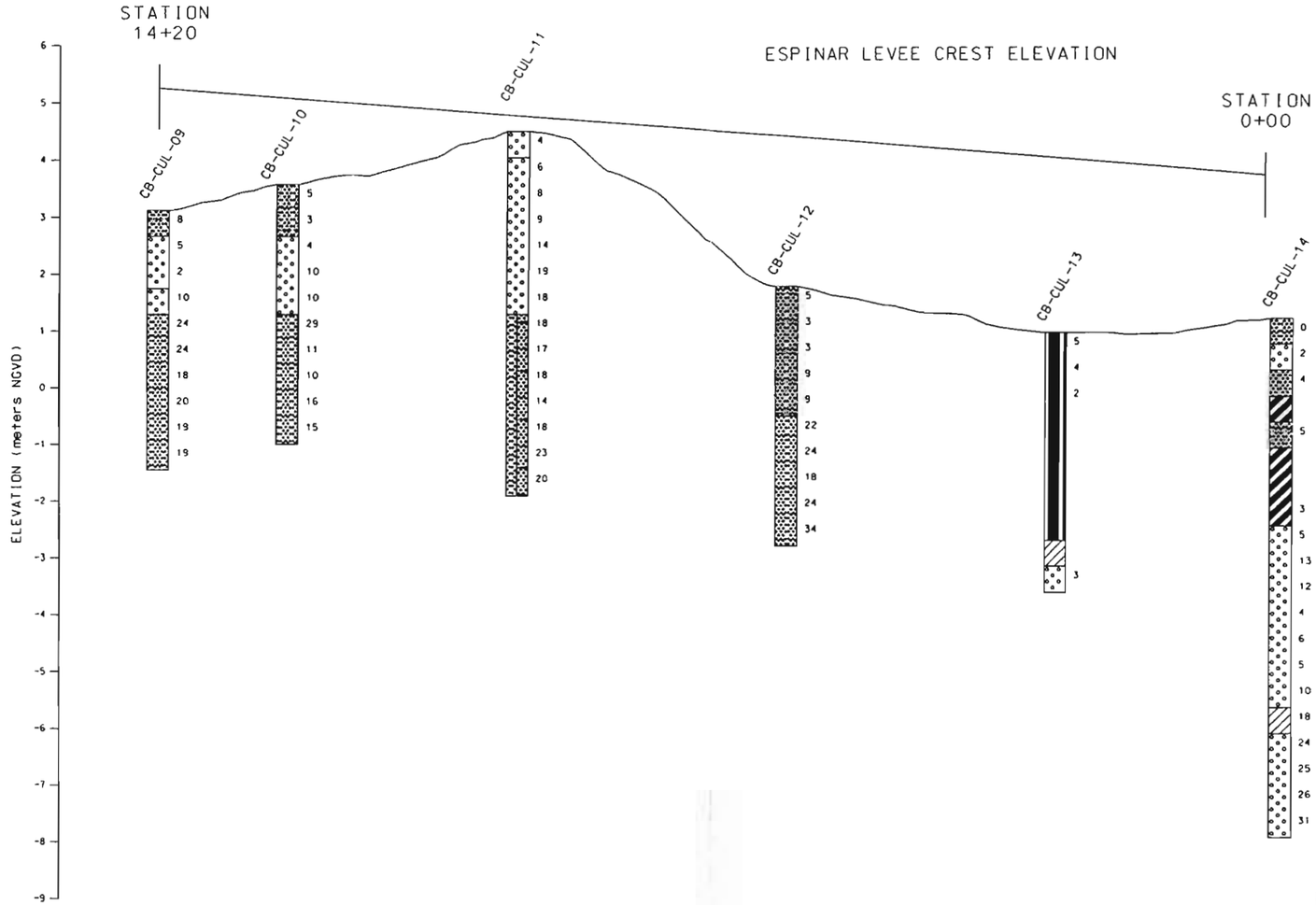
File name: PLATEB3.DGN
Reference files:
D.O. FILE NO.

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO

GEOLOGIC SECTION -- AGUADILLA LEVEE

PLATE
B-3



SOIL LEGEND:

(SW) WELL-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES

(SP) POORLY-GRADED SANDS OR GRAVELLY SANDS, LITTLE OR NO FINES.

(SM) SILTY SANDS, SAND-SILT MIXTURES

(SC) CLAYEY-SANDS, SAND-SILT MIXTURES

(CL) INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS

(MH) INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILTS

(CH) INORGANIC CLAYS OF HIGH PLASTICITY, FAT CLAYS

NOTES:

1. THE GEOLOGIC SECTION SHOWN REFLECTS THE FIELD VISUAL CLASSIFICATION (SHOWN ON THE CORE BORING LOGS) AND LABORATORY CLASSIFICATION OF SELECTED SOIL SAMPLES.
2. NUMBERS SHOWN ON BORINGS ARE STANDARD PENETRATION TEST RESULTS IN BLOWS PER FOOT.
3. FOR A COMPLETE PLAN VIEW WITH LEGEND, SEE PLATES B-1 AND B-2.

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Chk by:
Scale: AS SHOWN
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Plot scale:
Dated: April 2001
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File name: PLATEB4.DGN
Reference files:

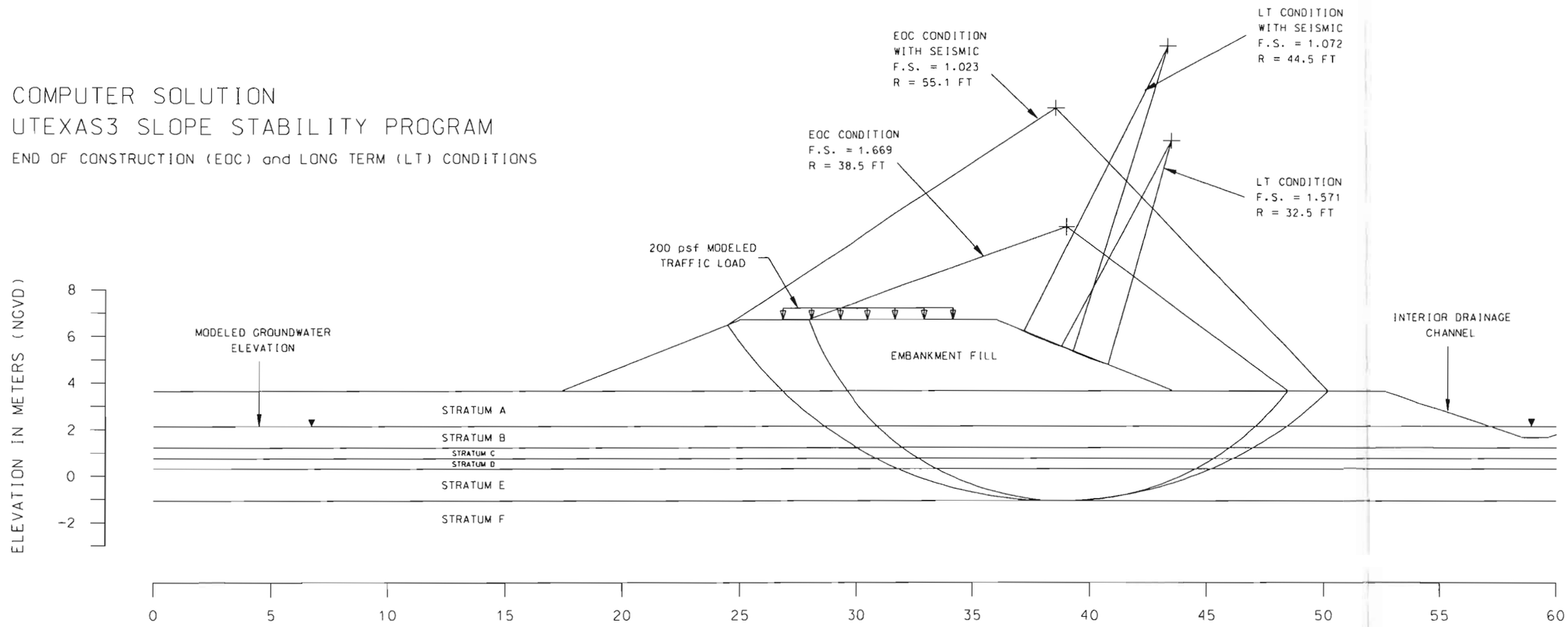
RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO

GEOLOGIC SECTION -- ESPINAR LEVEE

PLATE
B-4

COMPUTER SOLUTION
UTEXAS3 SLOPE STABILITY PROGRAM

END OF CONSTRUCTION (EOC) and LONG TERM (LT) CONDITIONS



DESIGN DATA				Q		S	
STRATUM	GENERALIZED STRATUM TYPE	MOIST WT. PCF	SATURATED WT. PCF	COHESION PSF	Ø DEGREES	COHESION PSF	Ø DEGREES
EMB. FILL	(GM/GC)	127		0	32	0	32
A	(CH)	110		500	0	0	25
B	(CH)		104	750	0	0	23
C	(MH)		92	300	0	0	30
D	(SM)		107	0	28	0	28
E	(MH)		103	300	0	0	27
F	(SM)		107	0	28	0	28

LEGEND:

F.S. = FACTOR OF SAFETY
R = RADIUS
Ø = ANGLE OF INTERNAL FRICTION
Q = UNCONSOLIDATED-UNDRAINED SHEAR STRENGTH
S = CONSOLIDATED-DRAINED SHEAR STRENGTH
WT. = WEIGHT
PCF = POUNDS PER CUBIC FOOT
PSF = POUNDS PER SQUARE FOOT

NOTES:

1. SECTION MODELED NEAR CORE BORING CB-CUL-07. SEE PLATE B-1 FOR THE CORE BORING LOCATION.
2. EMBANKMENT SIDE SLOPES ARE 1 VERTICAL TO 2.5 HORIZONTAL.

US Army Corps of Engineers
Jacksonville District

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

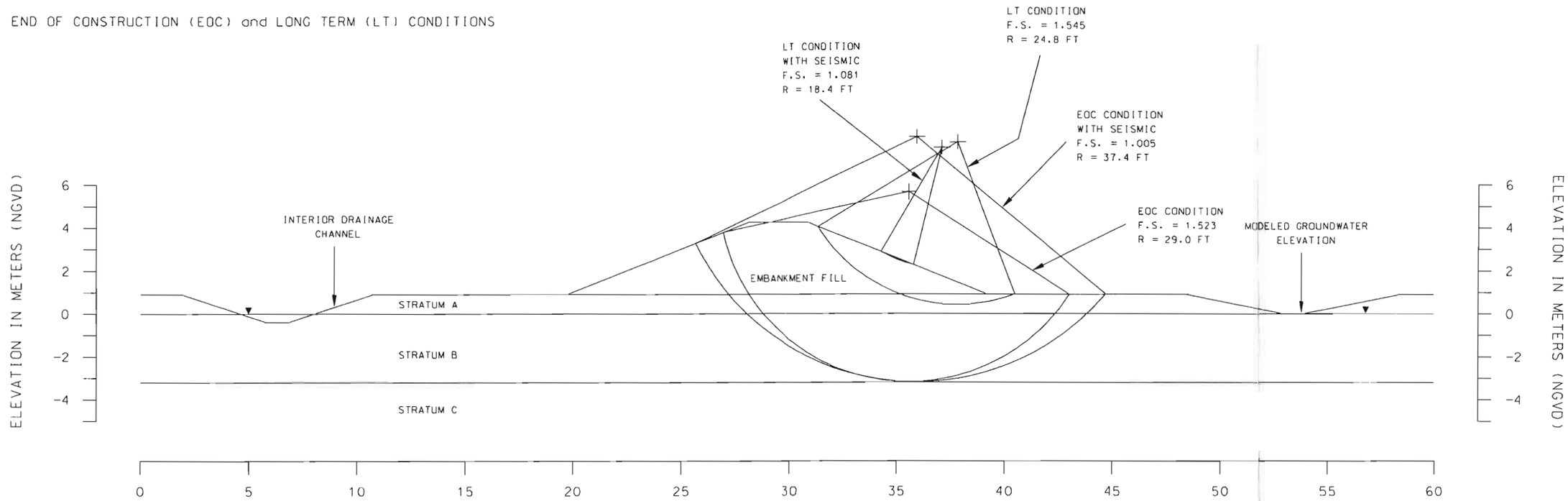
Scale: AS SHOWN
Designed by:
Drawn by: M.W.V.
Ckd by:
Dates: July 2002
D.O.FILE NO.
File name: PLATEB5R.DGN
Reference files:

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO
SLOPE STABILITY ANALYSIS - SECTION NO. 1

PLATE
B-5

COMPUTER SOLUTION
UTEXAS3 SLOPE STABILITY PROGRAM

END OF CONSTRUCTION (EOC) and LONG TERM (LT) CONDITIONS



DESIGN DATA				Q		S	
STRATUM	GENERALIZED STRATUM TYPE	MOIST WT. PCF	SATURATED WT. PCF	COHESION PSF	Ø DEGREES	COHESION PSF	Ø DEGREES
EMB. FILL	(GM/GC)	127		0	32	0	32
A	(MH)	98		500	0	0	24
B	(MH)		97	350	0	0	25
C	(SW)		125	0	28	0	28

LEGEND:

F.S. = FACTOR OF SAFETY
R = RADIUS
Ø = ANGLE OF INTERNAL FRICTION
Q = UNCONSOLIDATED-UNDRAINED SHEAR STRENGTH
S = CONSOLIDATED-DRAINED SHEAR STRENGTH
WT. = WEIGHT
PCF = POUNDS PER CUBIC FOOT
PSF = POUNDS PER SQUARE FOOT

NOTES:

1. SECTION MODELED NEAR CORE BORING CB-CUL-13. SEE PLATE B-1 FOR THE CORE BORING LOCATION.
2. EMBANKMENT SIDE SLOPES ARE 1 VERTICAL TO 2.5 HORIZONTAL.

US Army Corps of Engineers
Jacksonville District

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

Designed by:
Drawn by: M.W.V.
Ckd by:
Scale: AS SHOWN
Dates: July 2002
D.O.FILE NO.
File name: PLATEB6R.DGN
Reference files:

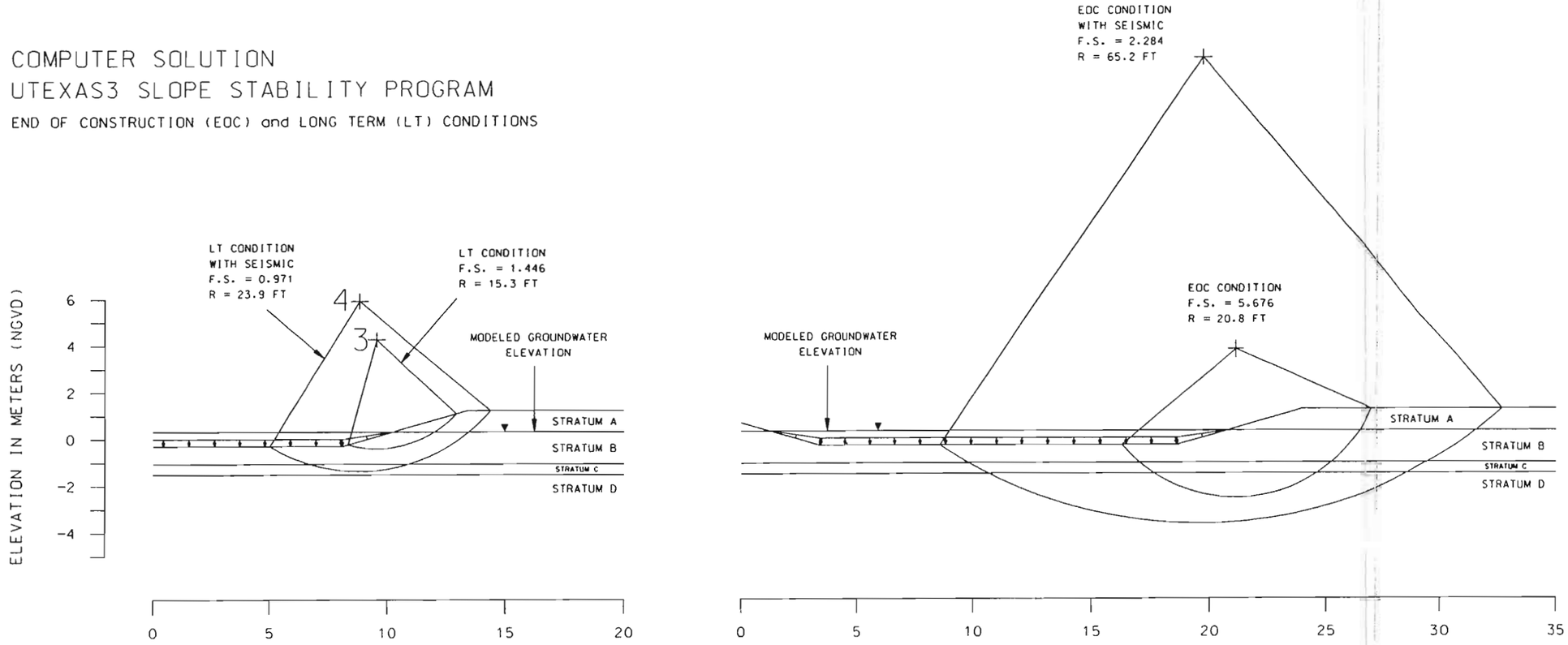
RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO

SLOPE STABILITY ANALYSIS - SECTION NO. 2

PLATE
B-6

COMPUTER SOLUTION
UTEXAS3 SLOPE STABILITY PROGRAM

END OF CONSTRUCTION (EOC) and LONG TERM (LT) CONDITIONS



DESIGN DATA				Q		S	
STRATUM	GENERALIZED STRATUM TYPE	MOIST WT. PCF	SATURATED WT. PCF	COHESION PSF	Ø DEGREES	COHESION PSF	Ø DEGREES
A	(MH)	105		750	0	0	28
B	(MH)		100	350	0	0	26
C	(MH)		110	600	0	0	28
D	(SW)		125	0	32	0	32

LEGEND:

F.S. = FACTOR OF SAFETY
R = RADIUS
Ø = ANGLE OF INTERNAL FRICTION
Q = UNCONSOLIDATED-UNDRAINED SHEAR STRENGTH
S = CONSOLIDATED-DRAINED SHEAR STRENGTH
WT. = WEIGHT
PCF = POUNDS PER CUBIC FOOT
PSF = POUNDS PER SQUARE FOOT

NOTES:

1. SECTION MODELED NEAR CORE BORING CB-CUL-04. SEE PLATE B-1 FOR THE CORE BORING LOCATION.
2. CHANNEL SIDE SLOPES ARE 1 VERTICAL TO 3.5 HORIZONTAL.

US Army Corps of Engineers
Jacksonville District

DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

Designed by:
Drawn by: M.W.V.
Ckd by:
Scale: AS SHOWN
Dated: April 2001
D.O.FILE NO.
File name: PLATEB8.DGN
Reference files:

RIO CULEBRINAS at AGUADA/AGUADILLA
PUERTO RICO

SLOPE STABILITY ANALYSIS - SECTION NO. 3

PLATE
B-7

CORE BORING LOGS

DRILLING LOG

DIVISION: South Atlantic

INSTALLATION: Jacksonville District

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=248,651 Y=212,523
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-01
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 30.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 30.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 20 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: -2.60
16. DATE HOLE STARTED: 06/18/98 COMPLETED: 06/18/98
17. ELEVATION TOP OF HOLE: 4.40 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 52.2 %
19. SIGNATURE OFENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'	
4.4	0.0					4.4		0
			Sandy CLAY, medium stiff, brown, some root and plant fragments. (CL)	55.6	1	SPLIT SPOON	1 2 3	
2.9	1.5					2.9		
			Clayey Sand, very loose, olive green. (SC)	61.1	2	SPLIT SPOON	2 2 2	2.5
			-brown			1.4		
				61.1	3	SPLIT SPOON	2 1 1	
-.1	4.5					-.1		
			Terrigenous SAND, medium dense, medium to fine-grained, subangular, gray; little beach sand. (SW)	50	4	SPLIT SPOON	2 2 3	5
			-medium-grained			-1.6		
				55.6	5	SPLIT SPOON	3 3 3	
-3.1	7.5					-3.1		7.5
			SAND, trace silt, medium to fine, loose, dark gray. (SW-SM)	55.6	6	SPLIT SPOON	2 3 3	
			-little silt, little gravel (consisting mostly of white coral fragments)			-4.6		
				44.4	7	SPLIT SPOON	3 6 6	10
-6.1	10.5					-6.1		
			Gravelly SAND, trace silt, mostly very coarse-grained, well graded, subrounded, medium dense, dark gray. (SW)	55.6	8	SPLIT SPOON	4 6 7	
			-trace silt			-7.6		
				50	9	SPLIT SPOON	6 8 8	12.5
			-as above			-9.1		
				50	10	SPLIT SPOON	4 7 8	
			-as above			-10.6		15
				55.6	11	SPLIT SPOON	6 8 8	
			-no recovery			-12.1		
				0	12	SPLIT SPOON	5 5 6	17.5
-13.6	18.0					-13.6		
			Terrigenous SAND, mostly fine-grained, medium dense, well-graded, subrounded to angular, dark gray; some beach sand. (SW)	61.1	13	SPLIT SPOON	8 9 9	
			-medium-grained			-15.1		
				55.6	14	SPLIT SPOON	4 6 6	20
			-fine-grained			-16.6		
				50	15	SPLIT SPOON	5 5 6	
-18.1	22.5					-18.1		22.5
						(continued)		

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 4.40 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
-18.1	22.5					-18.1	
			Terrigenous SAND, medium dense, well-graded, medium to coarse-grained, subrounded to angular, dark olive green; some beach sand. (SW)	55.6	16	SPLIT SPOON	1 11 11
			-medium to fine			-19.6	
				55.6	17	SPLIT SPOON	12 12 11
			-medium sand			-21.1	
				55.6	18	SPLIT SPOON	10 11 12
			-as above			-22.6	
				44.4	19	SPLIT SPOON	11 11 10
						-24.1	
				72.2	20	SPLIT SPOON	6 7 9
-25.6	30.0					-25.6	
			END OF BORING CB-CUL-01 AT 30.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec Gravity	Att. Limits L.L.	P.I.
2	33.4	2.71	50.0	24.9
6	32.4	2.77	--	--

22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50

Hole No.CB-CUL-02

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=248,795 Y=211,804
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-02
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 15.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 0.19
16. DATE HOLE STARTED: 06/17/98 COMPLETED: 06/17/98
17. ELEVATION TOP OF HOLE: 4.19 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 62.8 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
4.2	0.0					4.2	
			SAND, well-graded, some silt, some root fragments, loose, subrounded to subangular, dark brown. (SM)	83.3	1	SPLIT SPOON	1, 2, 3
2.7	1.5					2.7	
			Beach SAND, well-graded, loose, subrounded to subangular, yellowish brown. (SW)	72.2	2	SPLIT SPOON	3, 3, 4
			-medium to coarse, trace calcite cemented sand nodules			1.2	
				88.9	3	SPLIT SPOON	4, 5, 5
-.3	4.5					-.3	
			SAND, coarse-grained, medium dense, brown. (SP)	72.2	4	SPLIT SPOON	6, 8, 8
			-as above, trace silt			-1.8	
				72.2	5	SPLIT SPOON	7, 7, 8
			-little calcite cemented sand nodules			-3.3	
				66.7	6	SPLIT SPOON	8, 10, 10
			-as above			-4.8	
				50	7	SPLIT SPOON	6, 9, 9
			-coarse to very coarse-grained			-6.3	
				50	8	SPLIT SPOON	5, 7, 8
			-as above			-7.8	
				72.2	9	SPLIT SPOON	12, 11, 12
			-no recovery			-9.3	
				0	10	SPLIT SPOON	13, 13, 16
-10.8	15.0					-10.8	
			END OF BORING CB-CUL-02 AT 15.0 FEET DEPTH.				

0 / 2.5 / 5 / 7.5 / 10 / 12.5 / 15 / 17.5 / 20 / 22.5

Sample No. | Moisture Content% | Spec. Gravity | Att. Limits L.L. | P.I.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
5	27.7	2.73	--	--

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-02

Hole No.CB-CUL-03

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 2

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=248,955 Y=211,084
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-03
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 30.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 30.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 20 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 6.48 Ft.
16. DATE HOLE STARTED: 06/12/98 COMPLETED: 06/15/98
17. ELEVATION TOP OF HOLE: 7.98 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 49.4 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'	
8.0	0.0					8.0		0
			CLAY, trace silt and trace sand, stiff, dark brown; little root fragments. (CL)	77.8	1	SPLIT SPOON	2 4 4	
6.5	1.5					6.5		
			Sandy Clay, low plasticity, sand is very fine-grained, soft to medium stiff, dark gray to brown. (CL)	44.4	2	SPLIT SPOON	2 2 2	2.5
			-little very fine-grained terrigenous sand, very soft.	33.3	3	SPLIT SPOON	1 1 1	
3.5	4.5					3.5		
			SAND, some gravel, trace silt, loose, well -graded, sub-rounded, dark gray; sand and gravel consists of terrigenous sediments. (SW)	44.4	4	SPLIT SPOON	1 2 1	5
			-as above	55.6	5	SPLIT SPOON	2 1 2	
.5	7.5					.5		
			Sandy GRAVEL, subrounded, loose, dark gray. (SW)	61.1	6	SPLIT SPOON	3 4 4	7.5
			-no recovery	0	7	SPLIT SPOON	3 3 4	10
				44.4	8	SPLIT SPOON	4 5 5	
-4.0	12.0					-4.0		
			Terrigenous SAND, well-graded, trace gravel, medium dense, subrounded, to subangular, olive green, trace beach sand. (SW)	55.6	9	SPLIT SPOON	4 5 6	12.5
-5.5	13.5					-5.5		
			-sand, little gravel, little clay, loose, olive green (SC)	55.6	10	SPLIT SPOON	3 3 4	
			-no recovery	0	11	SPLIT SPOON	2 2 2	15
-8.5	16.5					-8.5		
			SILT, little clay and trace sand, medium stiff, gray to dark brown. (ML)	55.6	12	SPLIT SPOON	2 3 3	17.5
-10.0	18.0					-10.0		
			Beach SAND, coarse to very coarse, medium dense, well-graded, subrounded to subangular, brown to gray. (SW)	50	13	SPLIT SPOON	4 4 5	
			-medium to coarse-grained	83.3	14	SPLIT SPOON	7 8 8	20
			-coarse-grained	55.6	15	SPLIT SPOON	8 10 12	
						-14.5		22.5
						(continued)		

Hole No.CB-CUL-03

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 7.98 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
-14.5	22.5		~~as above~~			-14.5	
			-no recovery	55.6	16	SPLIT SPOON	10 11 12
						-16.0	
				0	17	SPLIT SPOON	11 12 13
-17.5	25.5					-17.5	
			Beach SAND, medium dense, well-graded, subrounded to subangular, gray to brown. (SW)	50	18	SPLIT SPOON	10 10 11
			-medium to coarse-grained			-19.0	
				66.7	19	SPLIT SPOON	10 11 10
						-20.5	
				100	20	SPLIT SPOON	11 13 13
-22.0	30.0					-22.0	
			END OF BORING CB-CUL-03 AT 30.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	37.9	2.86	47.8	24.9
5	18.1	2.72	--	--
10	19.9	2.72	--	--

22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50

Hole No.CB-CUL-04

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.	10. SIZE AND TYPE OF BIT: See Remarks
2. LOCATION (Coordinates or Station): X=248,336 Y=210,707	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: GEO CIM, INC.	12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-04	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
5. NAME OF DRILLER: Evaristo Santiago	14. TOTAL NUMBER OF CORE BOXES: 1
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED	15. ELEVATION GROUND WATER: 1.11 Ft.
7. THICKNESS OF BURDEN: 15.0 Ft.	16. DATE HOLE STARTED: 06/12/98 COMPLETED: 06/12/98
8. DEPTH DRILLED INTO ROCK: 0 Ft.	17. ELEVATION TOP OF HOLE: 4.11 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.	18. TOTAL CORE RECOVERY FOR BORING: 47.2 %
	19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
4.1	0.0					4.1	
			High Plasticity SILT, little root fragments, trace sand, medium stiff, dark brown. (MH)	55.6	1	SPLIT SPOON	2 3 5
			-some sand, soft to medium			2.6	
				55.6	2	SPLIT SPOON	2 2 2
1.1	3.0					1.1	
			High Plasticity, trace very fine terrigenous sand, very soft, dark gray; trace decomposing fragments. (MH)	50	3	SPLIT SPOON	1 1 1
			-no clay, no plant fragments			-.4	
				50	4	SPLIT SPOON	1 1 1
			-little terrigenous sand			-1.9	
				55.6	5	SPLIT SPOON	P P P
-3.4	7.5					-3.4	
			Sandy SILT, medium stiff, dark gray; sand consist of medium to coarse terrigenous sand. (MH)	61.1	6	SPLIT SPOON	1 2 3
-4.9	9.0					-4.9	
			Gravelly SAND, little silt, medium dense, well-graded, subrounded to subangular, coarse to very coarse, loose, dark gray; sand consists of terrigenous sediments. (SW)	50	7	SPLIT SPOON	3 4 4
			-as above			-6.4	
			-very coarse	22.2	8	SPLIT SPOON	3 4 5
						-7.9	
				33.3	9	SPLIT SPOON	4 5 5
			-as above.			-9.4	
				38.9	10	SPLIT SPOON	5 5 6
-10.9	15.0					-10.9	
			END OF BORING CB-CUL-04 AT 15.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	46.9	2.78	73.0	32.3
5	66.3	2.70	87.0	42.3

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

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PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-04

Hole No.CB-CUL-05

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=249,055 Y=210,334
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-05
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 15.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
16. ELEVATION GROUND WATER:
18. DATE HOLE STARTED COMPLETED: 06/22/98 06/22/98
17. ELEVATION TOP OF HOLE: 7.19 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 60.5 %
19. SIGNATURE OFENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
7.2	0.0					7.2	
			High Plasticity CLAY, soft to medium stiff, dark brown; some root and plant fragments. (CH)	66.7	1	SPLIT SPOON	1, 2, 2
			-little sand, brown to dark brown			5.7	
				61.1	2	SPLIT SPOON	2, 2, 2
			-medium stiff, trace gravel, trace root and plant fragments, gray to brown			4.2	
2.7	4.5			38.8	3	SPLIT SPOON	2, 2, 3
						2.7	
			SILT to Clayey SILT, medium stiff, brown to grayish brown to black, trace root fragments, trace disseminated oxides. (ML)	66.7	4	SPLIT SPOON	2, 3, 3
			-as above			1.2	
				72.2	5	SPLIT SPOON	2, 3, 3
-.3	7.5					-.3	
			SILT to Clayey SILT, very soft, dark gray, some black decomposing plant fragments. (MH)	38.9	6	SPLIT SPOON	1, 1, 1
-1.8	9.0					-1.8	
			SILT, some sand, very soft to soft, dark gray. (MH)	44.4	7	SPLIT SPOON	1, 1, 1
			-some to little sand, some wood and plant fragments			-3.3	
				44.4	8	SPLIT SPOON	1, 1/12
			-no wood fragments, trace plant fragments			-4.8	
				72.2	9	SPLIT SPOON	1/18
			-some to little clay, gray and brown			-6.3	
				100	10	SPLIT SPOON	1/18
-7.8	15.0					-7.8	
			END OF BORING CB-CUL-05 AT 15.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

Groundwater was not observed during drilling.

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	38.5	2.77	76.0	41.9
7	53.2	2.68	61.6	21.8

0, 2.5, 5, 7.5, 10, 12.5, 15, 17.5, 20, 22.5

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-05

DRILLING LOG

DIVISION: South Atlantic

INSTALLATION: Jacksonville District

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=249,180 Y=209,626
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-06
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 30.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 30.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 20 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: -5.73 Ft.
16. DATE HOLE STARTED COMPLETED: 06/22/98 06/22/98
17. ELEVATION TOP OF HOLE: 7.72 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 55.8 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
7.7	0.0					7.7	
			Clayey SAND, loose to medium dense, well-graded, mostly medium sand, black brown; some root fragments. (SC)	55.6	1	SPLIT SPOON	2 3 2
			-loose, trace gravel			6.2	
				27.8	2	SPLIT SPOON	3 2 2
			-no recovery			4.7	
				0	3	SPLIT SPOON	3 3 3
3.2	4.5					3.2	
			High Plasticity CLAY, medium stiff, brown to gray, trace root fragments. (CH)	66.7	4	SPLIT SPOON	3 3 3
			-soft, trace to little silt, little root fragments, trace sand, gray			1.7	
				77.8	5	SPLIT SPOON	2 2 2
.2	7.5					.2	
			High Plasticity SILT, traace sand, very soft, graay; some decomposing wood fragments. (MH)	94.4	6	SPLIT SPOON	1 1/12
			-as above			-1.3	
				100	7	SPLIT SPOON	1/12 1
			-little to some sand			-2.8	
				100	8	SPLIT SPOON	1 1 1
-4.3	12.0					-4.3	
			Beach SAND, some clay, medium dense, well-graded, medium to coarse, brown to gray; some decomposing plant fragments. (SC)	83.3	9	SPLIT SPOON	3 11 15
			-no clay, subangular			-5.8	
				44.4	10	SPLIT SPOON	7 10 10
			-no recovery			-7.3	
				0	11	SPLIT SPOON	5 10 11
			-medium to very coarse			-8.8	
				55.6	12	SPLIT SPOON	9 9 10
			-some calcite cemented sand nodules			-10.3	
				55.6	13	SPLIT SPOON	9 9 8
			-as above			-11.8	
				44.4	14	SPLIT SPOON	6 8 8
			-little sand nodules			-13.3	
				50	15	SPLIT SPOON	6 7 8
-14.8	22.5					-14.8	
						(continued)	

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

Hole No.CB-CUL-06

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 7.72 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
-14.8	22.5					-14.8	
			Calcite cemented Beach Sand, some loose sand, medium dense, well- graded,coarse to medium sand, brown. (SW)	55.6	16	SPLIT SPOON	14 15 13
			-medium coarse			-16.3	
				44.4	17	SPLIT SPOON	9 10 11
-17.8	25.5					-17.8	
			Beach SAND, calcite cemented sand nodules, medium dense, well-graded, fine to medium, brown. (SW)	50	18	SPLIT SPOON	10 10 12
			-as above			-19.3	
				55.6	19	SPLIT SPOON	10 13 13
			-medium to coarse			-20.8	
				55.6	20	SPLIT SPOON	11 14 15
-22.3	30.0					-22.3	
			END OF BORING CB-CUL-06 AT 30.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Groundwater level was taken during drilling.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
5	58.1	2.69	92.6	62.7
7	55.7	2.71	73.0	30.3

22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50

Hole No.CB-CUL-07

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 2

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=249,301 Y=208,733
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-07
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 21.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 21.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 14 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 10.06 Ft.
16. DATE HOLE STARTED: 06/17/98 COMPLETED: 06/17/98
17. ELEVATION TOP OF HOLE: 11.56 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 74.9 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
11.6	0.0					11.6	
10.1	1.5		FILL - Clayey SAND, some gravel and asphalt fragments, medium dense, well-graded, medium sand, dark brown. (SC)	50	1	SPLIT SPOON 10.1	3, 4, 4
7.1	4.5		FILL - CLAY, some limestone fragments, stiff, pale brown. (CL) -as above	50	2	SPLIT SPOON 8.6	4, 3, 4
				66.7	3	SPLIT SPOON 7.1	6, 6, 5
4.1	7.5		CLAY, little gravel, little sand, medium stiff, very dark brown. (CH) -medium stiff, trace gravel, trace sand, some decomposing plant fragments	83.3	4	SPLIT SPOON 5.6	3, 3, 4
				72.2	5	SPLIT SPOON 4.1	2, 2, 3
2.6	9.0		High Plasticity SILT, some fine-grained sand, some decomposing plants, very soft, dark gray. (MH)	83.3	6	SPLIT SPOON 2.6	1, 1/12
1.1	10.5		Silty SAND, some wood and plant fragments, very loose, fine, well-graded, dark gray. (SM)	83.3	7	SPLIT SPOON 1.1	1, 1, 1
-3.4	15.0		High Plasticity SILT, some sand, little wood and plant fragments, very soft, dark gray. (MH) -some root fragments -little sand, brown to dark gray (MH)	83.3	8	SPLIT SPOON -.4	1, 1, 1
				83.3	9	SPLIT SPOON -1.9	1/18
				100	10	SPLIT SPOON -3.4	P, P, P
-6.4	18.0		Silty SAND, some decomposing wood and plant fragments, very loose, well-graded, coarse, dark gray. (SM) -very coarse, loose, little decomposing wood and plant fragments	77.8	11	SPLIT SPOON -4.9	P, P, P
				83.3	12	SPLIT SPOON -6.4	1, 1, 3
-7.9	19.5		SILT, some gravel and sand, soft, dark gray; some root fragments. (ML)	50	13	SPLIT SPOON -7.9	3, 1, 2
-9.4	21.0		Gravel, some sand and silt, medium dense, well-graded, subrounded, dark gray. (GW)	83.3	14	SPLIT SPOON -9.4	3, 6, 7
			END OF BORING CB-CUL-07 AT 21.0 FEET DEPTH.				

0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 | 22.5

(continued)

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-07

Hole No.CB-CUL-07

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 11.56 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/ .5'

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
3	20.3	2.72	33.8	20.8
5	60.0	2.78	87.0	57.2
6	90.5	2.60	86.0	17.8
8	74.5	2.73	60.0	14.2
10	51.2	2.74	62.8	28.3

22.5
25
27.5
30
32.5
35
37.5
40
42.5
45
47.5
50

Hole No.CB-CUL-08

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 2

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=249,555 Y=207,932
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-08
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 21.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 21.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 14 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 5.55 Ft.
16. DATE HOLE STARTED: 06/15/98 COMPLETED: 06/15/98
17. ELEVATION TOP OF HOLE: 9.55 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 66.72 %
19. SIGNATURE OFENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
9.6	0.0					9.6	
			High Plasticity CLAY, little silt and trace sand, stiff, dark brown; some root fragments. (CH)	66.7	1	SPLIT SPOON	2, 4, 4
			-as above, some sand			8.1	
				66.7	2	SPLIT SPOON	2, 3, 4
			-some beach sand found in the lower 2 inches of penetration			6.6	
				72.2	3	SPLIT SPOON	2, 3, 4
5.1	4.5					5.1	
			Beach SAND, well-graded, medium dense, well-graded, subangular to subrounded, brown, some calcite cemented sand nodules. (SW)	83.3	4	SPLIT SPOON	5, 8, 8
			-little sand nodules			3.5	
				66.7	5	SPLIT SPOON	6, 7, 8
2.0	7.5					2.0	
			Gravelly Sand, medium dense, well-graded, subrounded to subangular, brown; gravel consist of calcite cemented beach sand nodules. (SW)	77.8	6	SPLIT SPOON	7, 9, 9
.6	9.0					.6	
			Gravelly Sand, fine to medium-grained, trace silt, light brown. (SP-SM)	72.2	7	SPLIT SPOON	7, 8, 9
			-fine to medium sand, trace silt			-.9	
				72.2	8	SPLIT SPOON	6, 8, 9
			-coarse sand, little terrigenous gravel			-2.5	
				83.3	9	SPLIT SPOON	7, 8, 8
			-little silt			-3.9	
				66.7	10	SPLIT SPOON	4, 9, 10
			-gravel consist of terrigenous rock fragments			-5.4	
				66.7	11	SPLIT SPOON	6, 11, 13
			-no recovery			-6.9	
				0	12	SPLIT SPOON	7, 8, 10
-8.4	18.0					-8.4	
			Beach SAND, medium to fine, medium dense, well-graded, subangular, brown. (SW)	100	13	SPLIT SPOON	8, 8, 10
-9.9	19.5					-9.9	
			Terrigenous GRAVEL, trace sand, medium dense, well-graded, subrounded, brown to black. (GW)	38.9	14	SPLIT SPOON	6, 10, 12
-11.4	21.0					-11.4	
			END OF BORING CB-CUL-08 AT 21.0 FEET DEPTH.				
						(continued)	

0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 | 22.5

Hole No.CB-CUL-08

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 9.55 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	31.9	2.79	61.9	33.5
8	15.7	2.77	--	--

22.5
25
27.5
30
32.5
35
37.5
40
42.5
45
47.5
50

Hole No.CB-CUL-09

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=246,627 Y=207,832
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-09
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 15.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 3.24 Ft.
16. DATE HOLE STARTED COMPLETED: 06/16/98 06/16/98
17. ELEVATION TOP OF HOLE: 10.23 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 71.1 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
10.2	0.0					10.2	
8.7	1.5		Silty SAND, loose, well-graded, dark brown, some root fragments. (SM)	72.2	1	SPLIT SPOON 8.7	1, 4, 4
			SAND, loose, little to trace silt, dark brown. (SW)	77.8	2	SPLIT SPOON 7.2	2, 2, 3
5.7	4.5		-very loose, lower 8 inches of sample consisted of clean beach sand	72.2	3	SPLIT SPOON 5.7	1, 1, 1
4.2	6.0		Beach SAND, medium dense, well-graded, subangular to subrounded, brown; trace calcite cemented sand nodules. (SW)	77.8	4	SPLIT SPOON 4.2	3, 4, 6
			-coarse-grained, little to some calcite cemented sand nodules (SP)	88.9	5	SPLIT SPOON 2.7	6, 11, 13
			-some calcite cemented sand nodules (gravel-sized)	83.3	6	SPLIT SPOON 1.2	9, 11, 13
			-as above, trace silt	83.3	7	SPLIT SPOON -.3	7, 8, 10
			-coarse to very coarse-grained	55.6	8	SPLIT SPOON -1.8	9, 9, 11
			-as above	50	9	SPLIT SPOON -3.3	8, 9, 10
-4.8	15.0		-as above.	50	10	SPLIT SPOON -4.8	8, 9, 10
			END OF BORING CB-CUL-09 AT 15.0 FEET DEPTH.				

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
7	17.3	2.70	--	--

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-09

Hole No.CB-CUL-10

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.	10. SIZE AND TYPE OF BIT: See Remarks
2. LOCATION (Coordinates or Station): X=247,099 Y=207,984	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: GEO CIM, INC.	12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-10	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
6. NAME OF DRILLER: Evaristo Santiago	14. TOTAL NUMBER OF CORE BOXES: 1
8. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED	15. ELEVATION GROUND WATER: 3.69 Ft.
7. THICKNESS OF BURDEN: 15.0 Ft.	16. DATE HOLE STARTED: 06/16/98 COMPLETED: 06/16/98
8. DEPTH DRILLED INTO ROCK: 0 Ft.	17. ELEVATION TOP OF HOLE: 11.69 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.	18. TOTAL CORE RECOVERY FOR BORING: 63.3 %
	19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
11.7	0.0					11.7	
			SAND, little silt, loose, well-graded, subangular to subrounded, dark brown, some root fragments. (SM)	77.8	1	SPLIT SPOON	2 2 3
			-very loose			10.2	
				72.2	2	SPLIT SPOON	2 2 1
8.7	3.0					8.7	
			Beach SAND, loose, well-graded, subangular to subrounded, brown. (SW)	55.6	3	SPLIT SPOON	2 1 3
			-medium dense			7.2	
				50	4	SPLIT SPOON	4 4 6
			-as above			5.7	
				50	5	SPLIT SPOON	4 4 6
4.2	7.5					4.2	
			SAND, very coarse-grained, little calcite cemented sand nodules, poorly-graded (SP)	77.8	6	SPLIT SPOON	7 16 13
			-coarse-grained			2.7	
				72.2	7	SPLIT SPOON	4 5 6
			-medium sand, trace silt, trace gravel (cemented sand)			1.2	
				72.2	8	SPLIT SPOON	4 4 6
			-coarse-grained, little calcite cemented sand nodules			-.3	
				55.6	9	SPLIT SPOON	7 8 8
			-as above.			-1.8	
				50	10	SPLIT SPOON	5 7 8
-3.3	15.0					-3.3	
			END OF BORING CB-CUL-10 AT 15.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	12.1	2.69	19.1	2.9
8	25.4	2.69	--	--

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-10

Hole No.CB-CUL-11

DRILLING LOG

DIVISION: South Atlantic

INSTALLATION: Jacksonville District

SHEET 1 OF 2

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=247,805 Y=208,506
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-11
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 21.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 21.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 14 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 5.66 Ft.
16. DATE HOLE STARTED: 06/11/98 COMPLETED: 06/11/98
17. ELEVATION TOP OF HOLE: 14.66 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 79.4 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
14.7	0.0					14.7	
			SAND, litt to some silt, well-graded, loose, subrounded, dark; little root fragments. (SW)	83.3	1	SPLIT SPOON	2 2 2
13.2	1.5					13.2	
			Beach SAND, loose, well graded, medium to fine sand, sub-rounded, brown. (SW)	72.2	2	SPLIT SPOON	2 2 4
			medium sand			11.7	
				83.3	3	SPLIT SPOON	3 4 4
			-medium to coarse-grained			10.2	
				66.7	4	SPLIT SPOON	3 4 5
			-trace calcite cemented sand nodules (gravel-sized)			8.7	
				77.8	5	SPLIT SPOON	4 6 8
			-coarse, little calcite cemented sand nodules			7.2	
				83.3	6	SPLIT SPOON	9 9 10
			-as above			5.7	
				94.4	7	SPLIT SPOON	7 8 10
4.2	10.5					4.2	
			SAND, rounded to subrounded, little gravel (cemented sand fragments), trace silt. (SP-SM)	100	8	SPLIT SPOON	6 9 9
			-as above			2.7	
				83.3	9	SPLIT SPOON	5 8 9
			-coarse to very coarse			1.2	
				88.9	10	SPLIT SPOON	6 9 9
			-as above			-.3	
				66.7	11	SPLIT SPOON	6 7 7
			-very coarse			-1.8	
				61.1	12	SPLIT SPOON	7 9 9
			-as above			-3.3	
				83.3	13	SPLIT SPOON	9 11 12
			-as above			-4.8	
				66.7	14	SPLIT SPOON	7 9 11
-6.3	21.0					-6.3	
			END OF BORING CB-CUL-11 AT 21.0 FEET DEPTH.				

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

(continued)

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

HOLE NUMBER: CB-CUL-11

Hole No.CB-CUL-11

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 14.66 Ft.

SHEET 2 OF 2

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/ .5'

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
8	14.5	2.74	--	--

22.5
25
27.5
30
32.5
35
37.5
40
42.5
45
47.5
50

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

HOLE NUMBER: CB-CUL-11

Hole No.CB-CUL-12

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.	10. SIZE AND TYPE OF BIT: See Remarks
2. LOCATION (Coordinates or Station): X=247,326 Y=209,438	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: GEO CIM, INC.	12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-12	13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
5. NAME OF DRILLER: Evaristo Santiago	14. TOTAL NUMBER OF CORE BOXES: 1
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED	16. ELEVATION GROUND WATER: 1.16 Ft.
7. THICKNESS OF BURDEN: 15.0 Ft.	18. DATE HOLE STARTED: 06/11/98 COMPLETED: 06/11/98
8. DEPTH DRILLED INTO ROCK: 0 Ft.	17. ELEVATION TOP OF HOLE: 5.66 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.	18. TOTAL CORE RECOVERY FOR BORING: 74.4 %
	19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
5.7	0.0					5.7	
			Clayey SAND, loose, dark brown; sand is medium to coarse-grained. (SC)	94.4	1	SPLIT SPOON	3 3 2
			-soft			4.2	
				83.3	2	SPLIT SPOON	2 2 1
			-as above			2.7	
				83.3	3	SPLIT SPOON	1 1 2
1.2	4.5					1.2	
			Beach SAND, some clay and little silt, loose, coarse to medium, well- graded, subrounded to subangular, gray to brown, little calcite cemented sand nodules. (SC)	72.2	4	SPLIT SPOON	2 4 5
						-.3	
				83.3	5	SPLIT SPOON	2 4 5
-1.8	7.5					-1.8	
			Beach SAND, trace silt, medium dense, medium sand, subangular, gray to brown. (SP)	72.2	6	SPLIT SPOON	7 10 12
			-no silt, medium to coarse			-3.3	
				55.6	7	SPLIT SPOON	7 11 13
			-as above			-4.8	
				83.3	8	SPLIT SPOON	6 9 9
			-coarse			-6.3	
				44.4	9	SPLIT SPOON	9 12 12
			-little to some calcite cemented sand nodules			-7.8	
				72.2	10	SPLIT SPOON	13 18 16
-9.3	15.0					-9.3	
			END OF BORING CB-CUL-12 AT 15.0 FEET DEPTH.				
			NOTES:				
			Soils are field visually classified in accordance with the Unified Soils Classification System.				
			140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)				
			X and Y Coordinates are given in feet.				

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	22.3	2.68	35.5	19.7
5	27.7	2.70	N/P	N/P

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-12

Hole No.CB-CUL-13

DRILLING LOG | DIVISION: South Atlantic | INSTALLATION: Jacksonville District | SHEET 1 OF 1

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=247,092 Y=210,444
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-13
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 15.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 15.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 10 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 1.97 Ft.
16. DATE HOLE STARTED: 06/18/98 COMPLETED: 06/18/98
17. ELEVATION TOP OF HOLE: 2.97 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 77.2 %
19. SIGNATURE OF ENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
3.0	0.0					3.0	
			High Plasticity SILT, trace sand and gravel, medium stiff, dark brown; plant fragments. (MH)	61.1	1	SPLIT SPOON	3 2 3
			-gray, no sand			1.5	
				61.1	2	SPLIT SPOON	1 2 2
			-very soft			0.0	
				66.6	3	SPLIT SPOON	1 1 1
-1.5	4.5					-1.5	
			High Plasticity SILT, trace sand, very soft, darl gray; trace decomposing roots and plant fragments. (MH)	100	4	SPLIT SPOON	P P P
						-3.0	
				100	5	SPLIT SPOON	P P P
-4.5	7.5					-4.5	
				72.2	6	SPLIT SPOON	P P P
-6.0	9.0					-6.0	
			High Plasticity SILT, very soft, dark gray. (MH)	83.3	7	SPLIT SPOON	P P P
						-7.5	
			-trace sand, little decomposing plant fragments	100	8	SPLIT SPOON	P P P
-9.0	12.0					-9.0	
			CLAY, some gravel and sand, soft, dark gray. (CL)	44.4	9	SPLIT SPOON	P P 3
-10.5	13.5					-10.5	
			Gravelly SAND, trace silt, loose, mostly very coarse, well-graded, subrounded to subangular, dark gray. (SW)	83.3	10	SPLIT SPOON	1 2 1
-12.0	15.0					-12.0	
			END OF BORING CB-CUL-13 AT 15.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
2	55.8	2.58	90.0	47.3
4	76.2	2.64	84.5	35.8
8	70.0	2.72	71.5	34.6

0 2.5 5 7.5 10 12.5 15 17.5 20 22.5

ENG FORM 1836 PREVIOUS EDITIONS ARE OBSOLETE. MAR 71

PROJECT: Rio Culebrinas Project, Aguadilla, P.R. | HOLE NUMBER: CB-CUL-13

DRILLING LOG

DIVISION: South Atlantic

INSTALLATION: Jacksonville District

1. PROJECT: Rio Culebrinas Project, Aguadilla, P.R.
2. LOCATION (Coordinates or Station): X=246,988 Y=211,306
3. DRILLING AGENCY: GEO CIM, INC.
4. HOLE NO. (As shown on drawing title and file number): CB-CUL-14
5. NAME OF DRILLER: Evaristo Santiago
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED
7. THICKNESS OF BURDEN: 30.0 Ft.
8. DEPTH DRILLED INTO ROCK: 0 Ft.
9. TOTAL DEPTH OF HOLE: 30.0 Ft.
10. SIZE AND TYPE OF BIT: See Remarks
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME-45
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: disturbed: 20 undisturbed: 0
14. TOTAL NUMBER OF CORE BOXES: 1
15. ELEVATION GROUND WATER: 2.79 Ft.
16. DATE HOLE STARTED: 06/19/98 COMPLETED: 06/19/98
17. ELEVATION TOP OF HOLE: 3.79 Ft.
18. TOTAL CORE RECOVERY FOR BORING: 65.3 %
19. SIGNATURE OFENGINEER: Jorge R. Parra, P.E.

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
3.8	0.0					3.8	
			Beach SAND, some silt, very loose, well-graded, medium sand, brown; some root fragments. (SM)	72.2	1	SPLIT SPOON	1/18
2.3	1.5					2.3	
			-no silt (SW)	72.2	2	SPLIT SPOON	2, 1, 1
.8	3.0					.8	
			-loose, little to some silt (SM)	94.4	3	SPLIT SPOON	1, 2, 2
-.7	4.5					-.7	
			High Plasticity CLAY, trace sand, very soft, dark gray; some wood and fragments. (CH)	94.4	4	SPLIT SPOON	P, P, P
-2.2	6.0					-2.2	
			SAND, some clay, loose, mostly medium sand, well-graded, dark gray. (SC)	88.9	5	SPLIT SPOON	3, 3, 2
-3.7	7.5					-3.7	
			High Plasticity CLAY, very soft, dark gray; little decomposing plant fragments. (CH)	100	6	SPLIT SPOON	P, P, P
-5.2	9.0					-5.2	
			-some sand	100	7	SPLIT SPOON	P, P, P
-6.7	10.5					-6.7	
			-little sand, soft	94.4	8	SPLIT SPOON	1, 2, 1
-8.2	12.0					-8.2	
			Terrigenous SAND, some clay, medium dense, mostly coarse-grained, well-graded, dark gray. (SW)	38.9	9	SPLIT SPOON	2, 2, 3
			-very coarse, little clay, some gravel	44.4	10	SPLIT SPOON	5, 7, 6
			-no clay			-11.2	
				83.3	11	SPLIT SPOON	4, 6, 6
			-loose, gravelly			-12.7	
				50	12	SPLIT SPOON	3, 2, 2
			-medium dense, little clay			-14.2	
				38.9	13	SPLIT SPOON	2, 2, 4
			-some clay, little gravel			-15.7	
				44.4	14	SPLIT SPOON	2, 2, 3
			-no clay			-17.2	
				55.6	15	SPLIT SPOON	3, 5, 5
-18.7	22.5					-18.7	
						(continued)	

0 | 2.5 | 5 | 7.5 | 10 | 12.5 | 15 | 17.5 | 20 | 22.5

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

HOLE NUMBER: CB-CUL-14

Hole No.CB-CUL-14

DRILLING LOG (Cont. Sheet)

ELEVATION TOP OF HOLE 3.79 Ft.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

INSTALLATION: Jacksonville District

ELEV.	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	CORE REC %	SAMPLE NUMBER	REMARKS Bit or Barrel	BLOWS/.5'
-18.7	22.5					-18.7	
-20.2	24.0		Sandy CLAY, trace gravel, very stiff, dark gray; little decomposing plant fragments. (CL)	50	16	SPLIT SPOON -20.2	4, 8, 10
			Terrigenous SAND, trace silt, mostly fine-grained, medium dense, well-graded, subangular, dark gray. (SW) subangular, dark gray.	55.6	17	SPLIT SPOON -21.7	8, 12, 12
			-as above	66.7	18	SPLIT SPOON -23.2	10, 12, 13
			-as above	61.1	19	SPLIT SPOON -24.7	9, 13, 13
			-no recovery	0	20	SPLIT SPOON -26.2	9, 15, 16
-26.2	30.0		END OF BORING CB-CUL-14 AT 30.0 FEET DEPTH.				

NOTES:

Soils are field visually classified in accordance with the Unified Soils Classification System.

140# Hammer with 30" drop used on 2.0 foot split spoon (1-3/8" I.D. x 2" O.D.)

X and Y Coordinates are given in feet.

Sample No.	Moisture Content%	Spec. Gravity	Att. Limits L.L.	P.I.
4	96.6	2.71	114.5	72.2
8	92.0	2.74	97.9	59.6

22.5 25 27.5 30 32.5 35 37.5 40 42.5 45 47.5 50

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE.

PROJECT: Rio Culebrinas Project, Aguadilla, P.R.

HOLE NUMBER: CB-CUL-14