Culebrinas River Flood Control Project

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Executive Summary

The U.S. Army Corps of Engineers, Jacksonville District, is planning a flood control project for an associated river mouth drainage of the Culebrinas River, Caño Madre Vieja. During high flood events, the Culebrinas River overflows its channel upstream of highway PR-2 and at the first meander curve just downstream of PR-2. The flood waters enter Caño Madre Vieja flooding out the southwestern sectors of Aguadilla and the northeastern portion of the community of Espinar.

The preferred alternative would place two dikes east and west of the Caño to maintain the flood waters within this floodway. To accommodate the eastern levee, a double meander of flowing stream in the Caño would be eliminated via a cut-off channel. The western levee would cross a mangrove forest and channel near the mouth of the Caño, directly impacting some mangroves and indirectly affecting the existing hydrology that supplies tidal flow to the mangrove forest that would be left outside the flood dikes.

The Service's major concern centers around the potential indirect and secondary impacts for the mangrove forest and other wetlands that would remain outside the flood levee. The section of the mangrove forest where the west levee would pass through lies within Coastal Barrier unit PR-75. Our understanding is that this precludes the use of Federal funds for projects, including flood control projects authorized after the date of the inclusion of the Coastal Barrier unit. Another concern is for the section of river to be eliminated. The Service believes that ample opportunities exist in the area for appropriate mitigation, however, there has been no specific mitigation plan discussed to this point.

Introduction

The Río Culebrinas is the fifth largest watershed in Puerto Rico with a total drainage area of approximately 103 square miles. The river flows at a relatively low gradient out of the central mountain region in a northwesterly direction, emptying into Aguadilla Bay southwest of the town of Aguadilla. Historically the river has meandered throughout the valley (C type meandering stream, Rosgen hydrogeomorphic classification), and the mouth of the river has periodically migrated. Caño Madre Vieja, to the north of the Culebrinas River, is considered to be an abandoned river mouth that now carries only localized drainage except during flood stages on the Culebrinas. The beach in this area receives moderate to high energy sea conditions, and the coastline is subject to erosion. The beach between the Culebrinas River and Caño Madre Vieja has a low berm, and is backed by herbaceous and mangrove forest wetlands with a direct hydrological connection to the Caño.

One of the major island highways, PR-2, crosses the Culebrinas River in a north/south direction. The highway is elevated above the surrounding floodplain, although the river is capable of going over the highway during flood stage (Figure 1). The highway bridges the Culebrinas River and culverts maintain flow in the upper part of Caño Madre Vieja. When the Culebrinas exceeds bank-full flows, it floods over the first large meander below PR-2, and into the drainage for Caño Madre Vieja, flooding both the Espinar Community and the southwestern low-lying portions of Aguadilla. In higher flood stages, it overflows above PR-2, also draining towards the Caño.

The river has no major impoundments, but does have a small low head dam (Photos 1 and 2) built in the early part of the century to provide a water diversion for the Coloso Sugar Mill. This diversion is still used to provide process water for the mill. In 1998, the Puerto Rico Aqueducts and Sewers Authority (PRASA) along with the Commonwealth Infrastructure Agency (AFI) developed a surface water intake for potable water using the impoundment from this dam. The dam is located several hundred meters upstream of PR-2, and the pump house is located on an elevated stand next to the diversion dam (presumably above the 100 year flood stage). The raw water is currently pumped up to the Aguadilla treatment plant, but AFI is considering the creation of an off-river reservoir/ sedimentation lake near the damsite to supply additional firm yield and reduce the very high sediment load in the raw water extracted from the river. Because of its narrow design, it is likely that the existing dam serves as a constriction creating overflow into the floodplain above PR-2 during flood stage.

The dam acts as a partial barrier for fish and shrimp migration upstream, and juvenile shrimp can generally be seen migrating upstream on the cement bulkhead of the weir in the wetted zone above the water flow (Photo 3). Native fish (approximately 6 species) and shrimp (as many as 14 species) are compulsory migrators, requiring a portion of their life cycles in estuarine or marine waters. At least six species of shrimps are large enough to be fished for human consumption, one species reaching very large sizes (Photo 4). Most of these species are also likely to occur in Caño Madre Vieja along with estuarine fish such as snook, tarpon, mullet, mojarra, and jacks; and crustaceans such as blue crabs and land crabs. Fishermen of the area

Figure 1. USGS Topographic quadrangle enlargement showing the lower Culebrinas River and Caño Madre Vieja. Coloso diversion dam location shown.

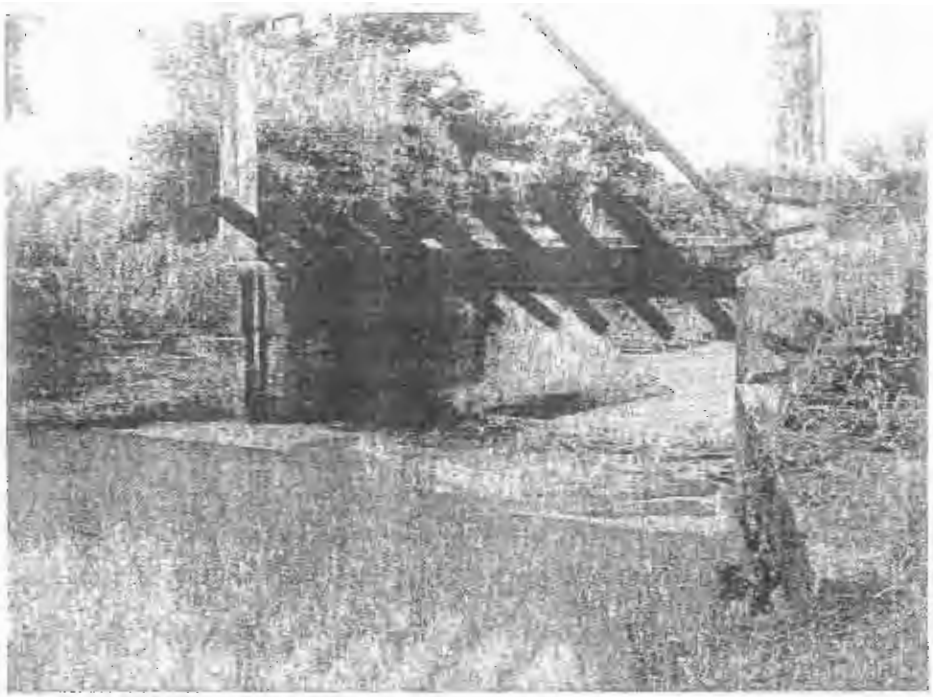

Photo 1. Coloso diversion dam from the upstream side. Note that the opening is very narrow and topped by a road.

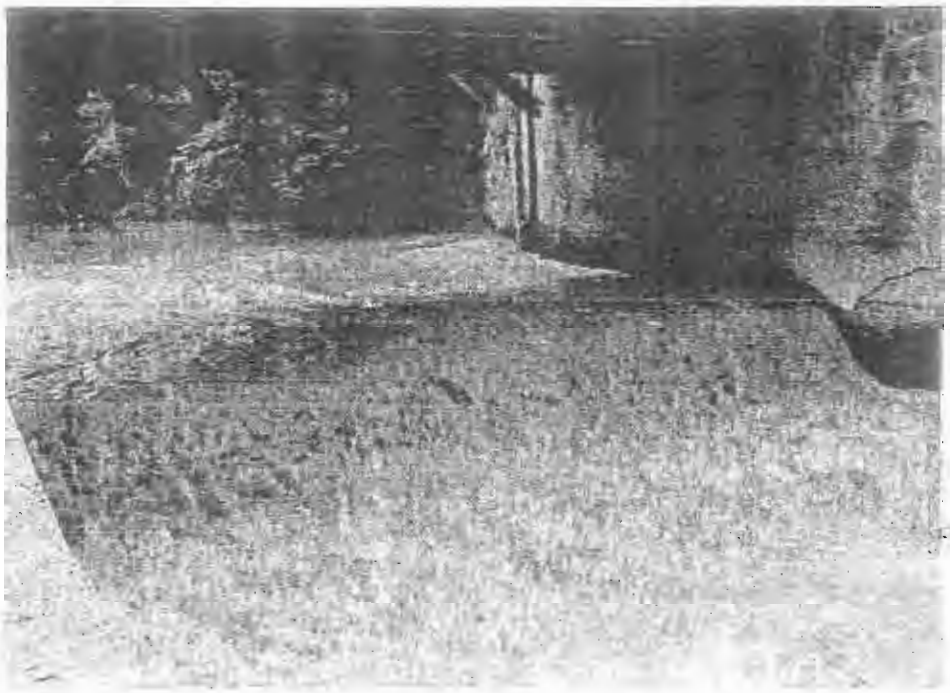

Photo 2. Downstream side of the Coloso dam. Drop during lower flows (photo condition) approximately 2 meters including a lower step not shown in the photo. Note that the vertical sidewalls have a wetted zone.

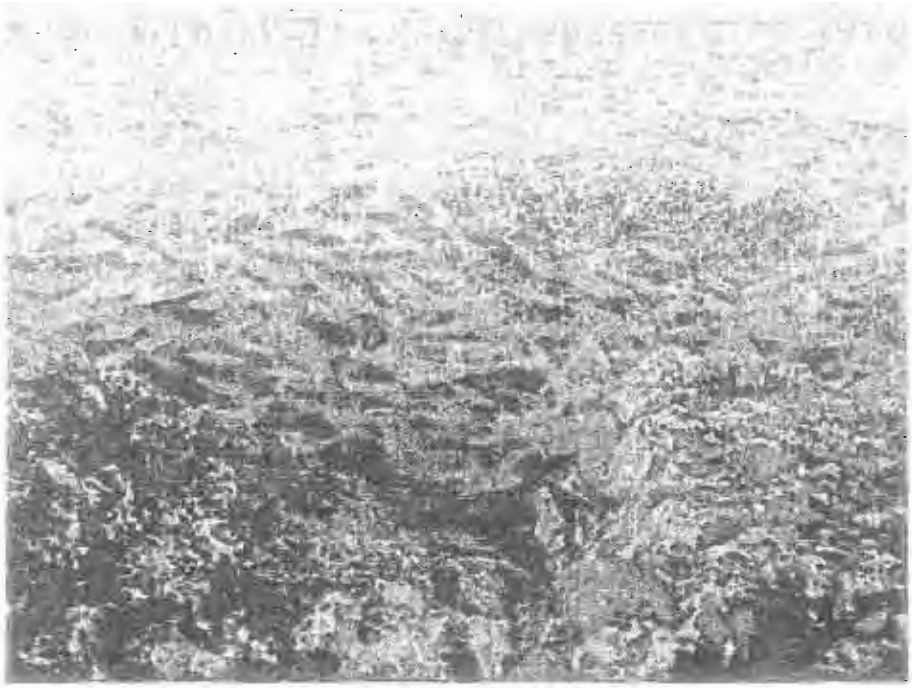

Photo 3. Juvenile shrimps, approximately 1 cm long, migrating upstream in the wetted (splash zone of the dam side walls.

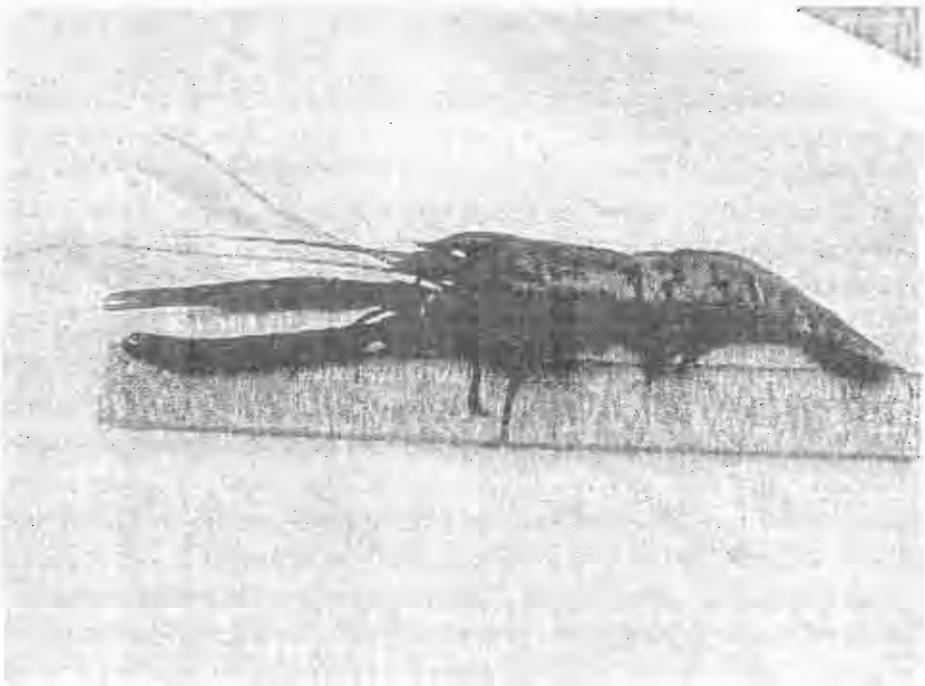

Photo 4. A specimen of *Macrobrachium carcinus*, the largest species of freshwater shrimp. This species can reach overall lengths of 18 inches and a pound in weight. This, and four other species of shrimp are actively fished.

have commented that they catch fish and the larger species of shrimp from both the Culebrinas and the Caño and its canals for consumption. The Service is participating in a fishway project for the Coloso Mill dam with AFI and PRASA.

A large wetland area, the Cayures marsh, lies south of the Culebrinas River near the Coloso sugar mill. This wetland area is a DNER designated Critical Coastal Wildlife Area providing habitat for a number of waterfowl species. The marsh consists of some interconnected ponding areas associated with overflow from the river. This wetland area will not be discussed further as the preferred alternative would not impact this marsh. In addition to the Cayures marsh, herbaceous wetlands occur on the south side of the Culebrinas River and are directly associated with the river.

From documents provided by the Corps, we understand that a number of alternatives have been considered to provide some Flood Hazard Mitigation for already developed portions of the community of Espinar and the southwestern communities of Aguadilla. The first alternative proposed was to construct a single flood levee from PR-2, just southwest of Caño Madre Vieja extending along the south side of Espinar, tying into a hill to the west to isolate the Caño from the floodwaters of the Culebrinas River (Figure 2). This would have provided flood protection for the western communities of Aguadilla, greatly reduced the floodplain of Caño Madre Vieja, and protected portions of the Espinar community. It would have raised flood levels in the Culebrinas River, however, thus affecting other portions of the Espinar community along the Culebrinas River. It also would have reduced the frequency of high flows that help maintain the channel and mouth of Caño Madre Vieja and encouraged development in much of the currently uninhabited floodplain along the Caño, violating E.O. 11988 for the protection of floodplains. To be effective, this plan would have to include channelization of the lower Culebrinas River to minimize the flood levels on its course, eliminating the river meanders and associated wetlands, and increasing maintenance costs for the floodway channel. Channelization of the lower Culebrinas River would have been likely to affect hydrology in the neighboring associated Cayures marsh. Our understanding is that this alternative has been discarded due to high costs and environmental considerations.

Alternative 2 from the original Reconnaissance Report (Figure 3) would provide two flood levees: one along the eastern side of Caño Madre Vieja north of PR-2 to protect southern Aguadilla, and a flood ring levee on the west side of the Caño. The original design would also have included a continuation of this levee on the north side of Espinar. Various permutations of Alternative 2 have been considered by the Corps as additional alternatives, mostly as variations to the western levee. In addition to the levees, the various permutations of this alternative also require the elimination of a double meander of Caño Madre Vieja via a short cut-off channel to accommodate the eastern levee. A modified version of Alternative 2 is the currently preferred alternative described as "Plan 1" in the Detailed Project Report (Figure 4). The western levee of this plan was altered to include the Iglesia de Espinar, a historic church for that community, in the protected area. The portion of the levee behind the beach berm and just north of Espinar community was eliminated, and the end of the levee was tied into the beach berm on the west side of the mouth of the Caño. One-way drainage structures are to be incorporated into the levee at strategic points. This last alternative has been further modified to include a two-way culvert

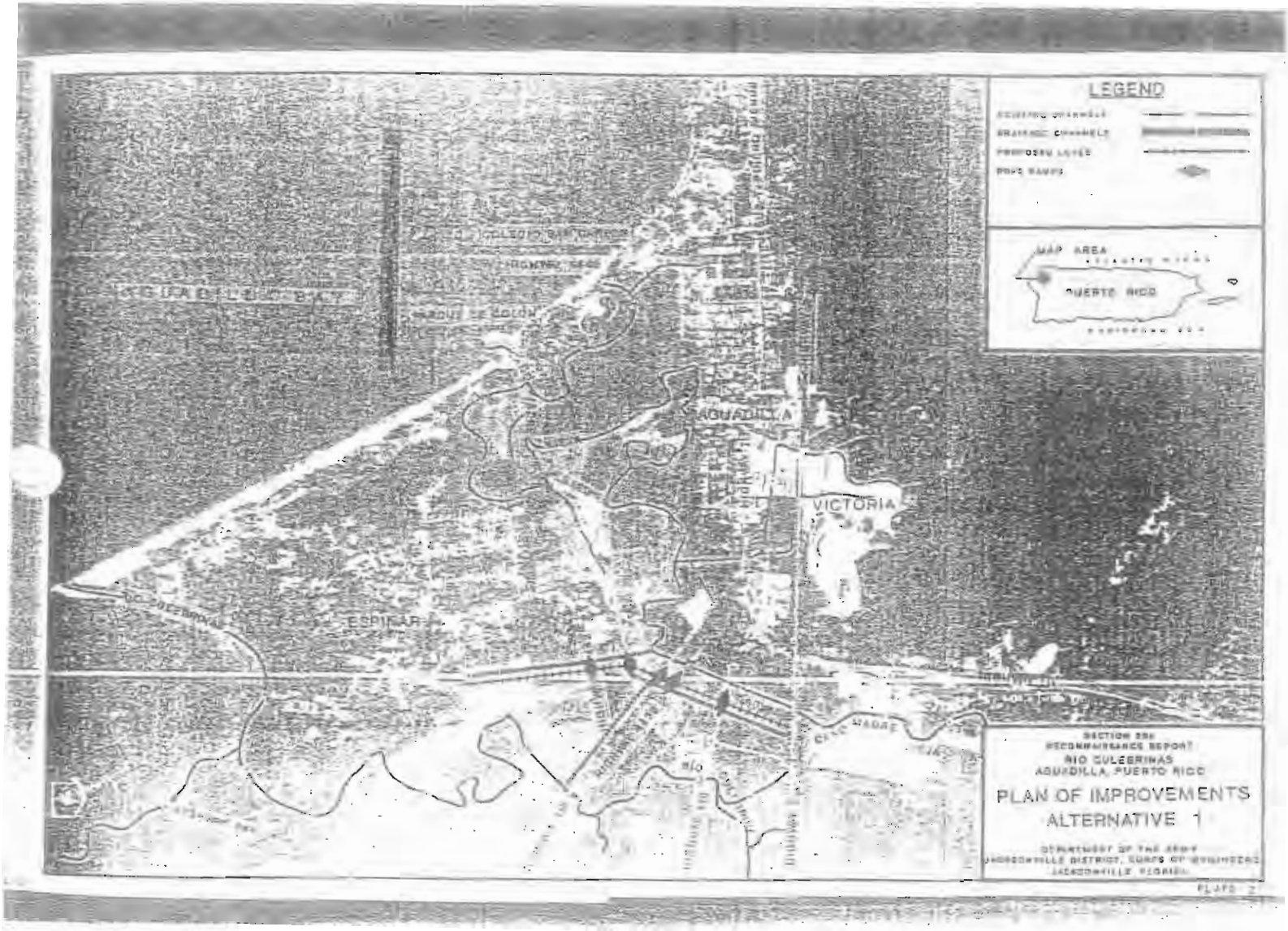

Figure 2. Original alternative 1 from Section 205 Reconnaissance Report, 1992.

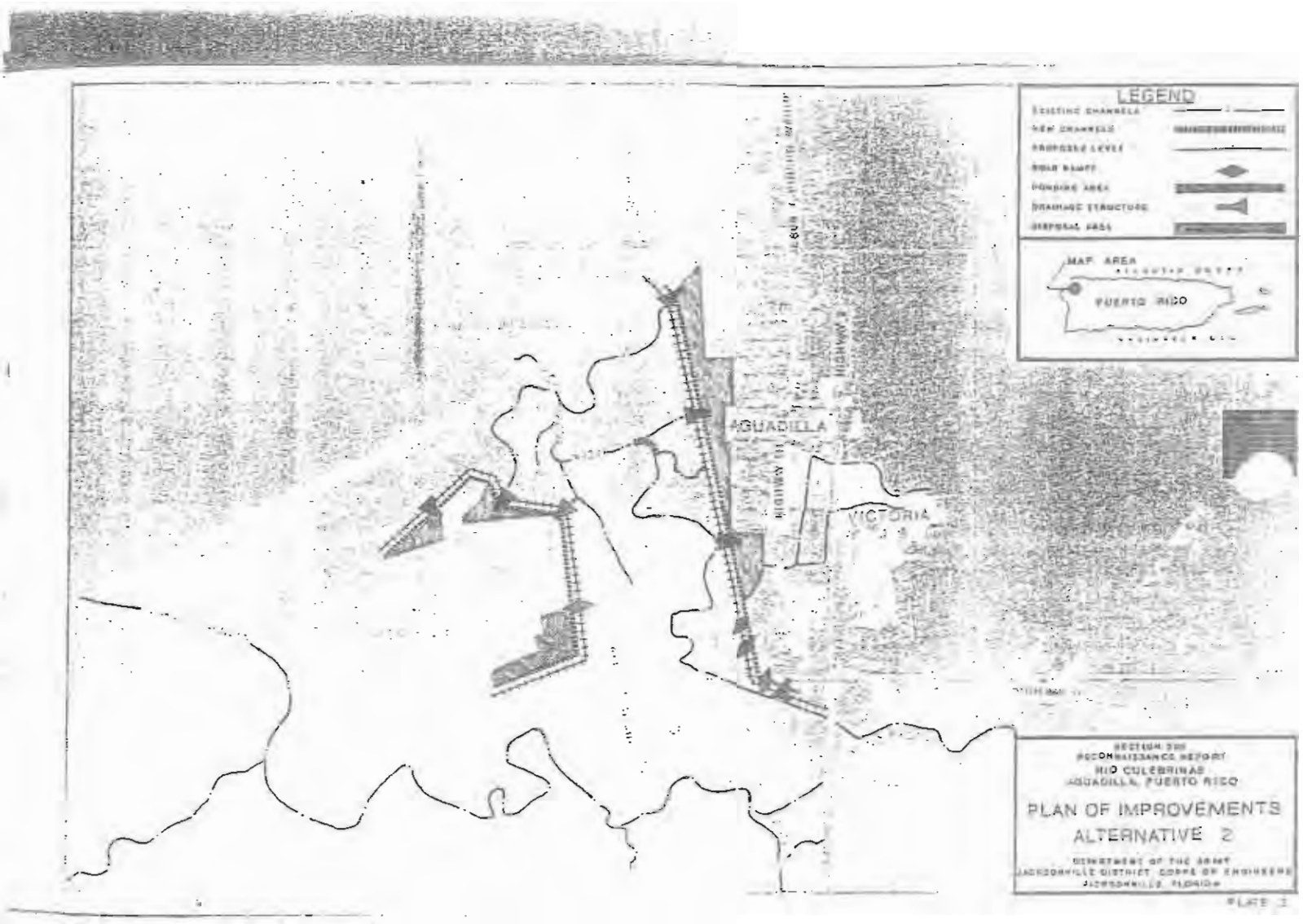

Figure 3. Original Alternative 2 from Section 205 Reconnaissance Report, 1992.

Figure 4. Currently favored alternative with the modified west levee.

to provide hydrology to the mangrove forest channel that runs on the north and east sides of the Espinar community.

Fish and Wildlife Trust Resources

Evaluation of the fish and wildlife trust resources for this CAR focus strictly on the Caño Madre Vieja area that would be affected by the currently favored alternative. Both the Cayures marsh and the low-head dam discussed above are outside of the immediate project area, but should be evaluated if further alternatives outside the lower Caño Madre Vieja area are considered. The lower Culebrinas River valley includes areas of herbaceous and forested (mostly mangrove) wetlands. Most of the forested wetlands in the immediate project area are located near the mouth of Caño Madre Vieja.

On the east side of the Caño, Aguadilla developed a public park with recreational facilities, a boat ramp, and an athletic field and track. The beach front road on the west side from the town to the park is protected in most areas by rip-rap. The mouth of the Caño is protected by breakwater/groins, the larger one lying on the east side of the mouth (Photos 5 and 6). These help maintain the mouth open and provide some protection for small boats entering and leaving the mouth. Our understanding is that the municipality of Aguadilla may also periodically provide maintenance to keep the mouth open, and that no new alterations are planned for the mouth the the Caño. The eastern side of the Caño mouth lies within Coastal Barrier unit PR-75P, while the western side of the mouth lies within Coastal Barrier PR-75 (Figure 5). On the west side of the Caño mouth is a small groin, but the beach berm is otherwise in a relatively natural condition. The western levee would tie into the beach berm within PR-75. According to the information available in our office on CBRA, the use of Federal funds is prohibited, and exempt activities do not include flood control work authorized after the date the relevant unit was included in the CBRA (in this case 1990).

While the Service has no ongoing beach monitoring projects in the area, a previous site inspection revealed the beach between Caño Madre Vieja and the Espinar community is likely to be suitable nesting habitat for the endangered hawksbill sea turtle (*Eretmochelys imbricata*) and the leatherback sea turtle (*Dermochelys coriacea*). While the project does not contemplate any alterations to the beach area, project changes that would require alterations to this beach should require consultation under Section 7 of the Endangered Species Act. This section of the beach also lies within Coastal Barrier Unit PR-75.

Soils

Caño Madre Vieja and the lower Culebrinas River lie within two major soil associations: the Coloso-Toa Association described as nearly level porous loamy soils, and the Bejucos-Jobos Association consisting of strongly leached soils with a very tight, clayey subsoil. Caño Madre Vieja lies mostly within the intersection of these two major associations. Soils in the project area are all either considered to be hydric soils or non-hydric soils with hydric inclusions (Figure 6). Those considered to be hydric soils include Bajura clay (Ba), Iguadad clay (Ig), and Tidal swamp (Td). The non hydric soils with hydric inclusions include Toa silty clay-loam (ToA),

Photo 5. A view of southwestern Aguadilla from PR-2 above the town. The jetty visible in the middle of the coastline is the eastern jetty of Caño Madre Vieja.

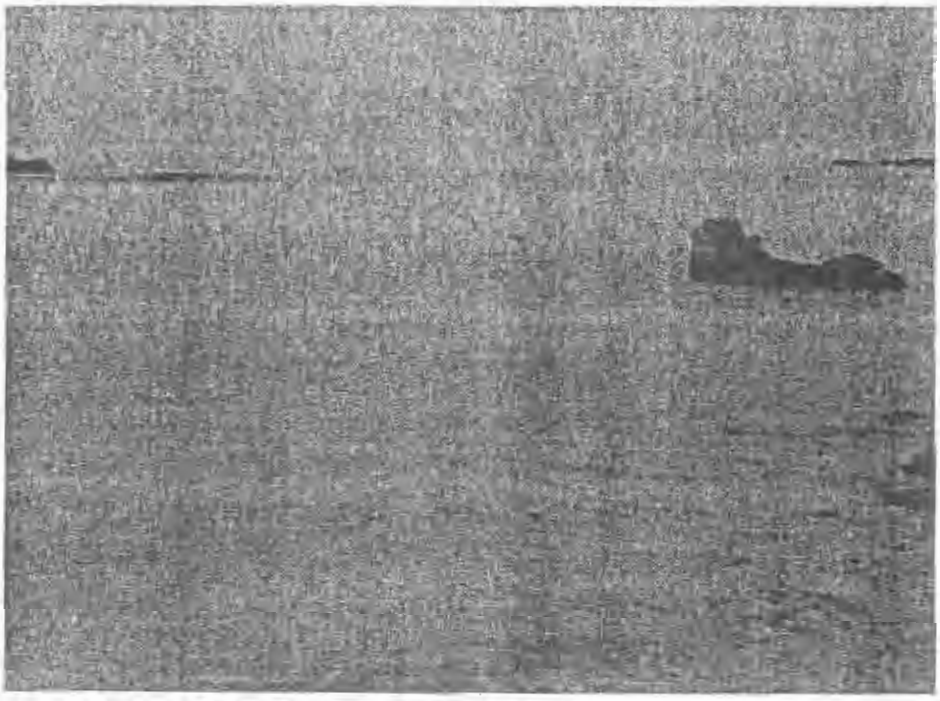

Photo 6. Open mouth of Caño Madre Vieja from Parque Colón on the east side. The tip of the small western jetty is visible on the left side of the picture.

Figure 5. Showing Coastal Barrier Resource Units PR-75 and PR-75P.

Figure 6. Enlarged soil map showing Caño Madre Vieja.

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

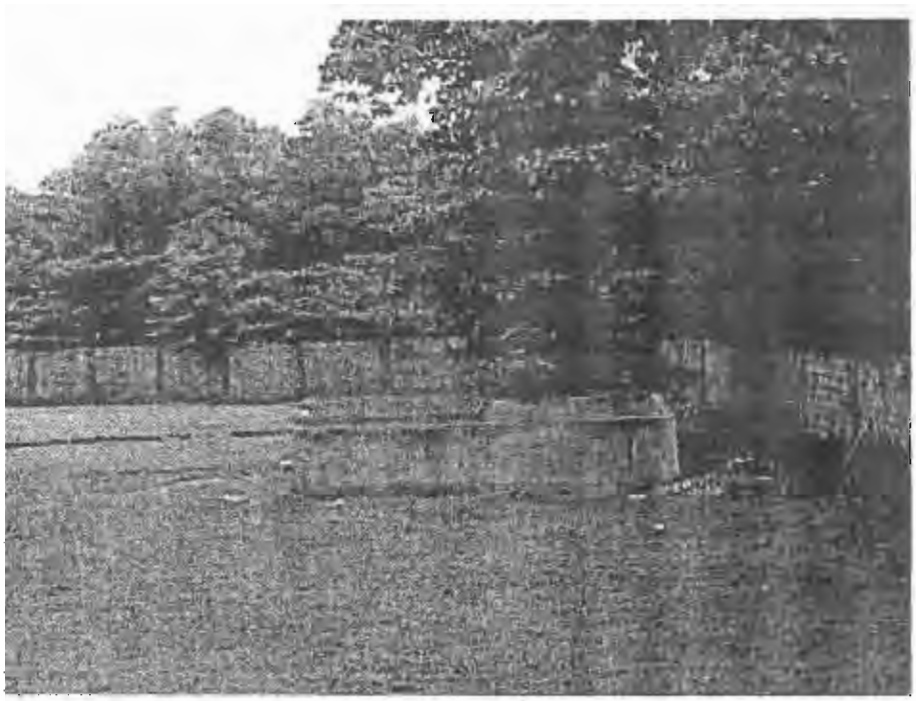

Photo 7. Colegio San Carlos school yard with the forested drainage behind it. The eastern levee would pass through part of the school yard and forest.

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*,

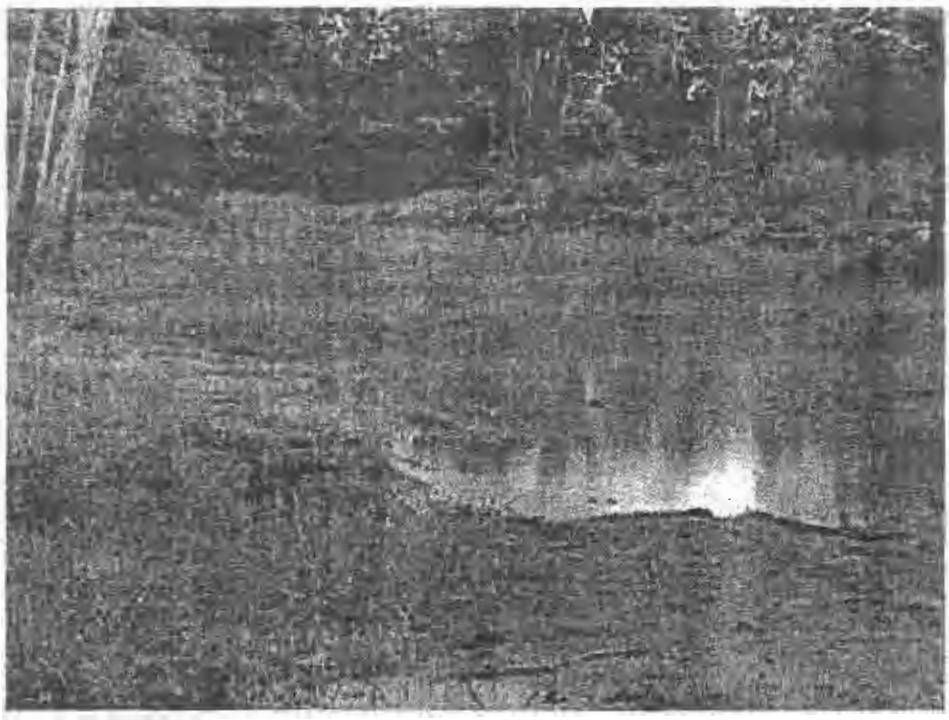

Photo 9. Recently disturbed wetland area behind the beach berm to the west of Caño Madre Vieja. Note the piles of cleared vegetation and soil deposited in wetlands towards the mangrove forest.

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

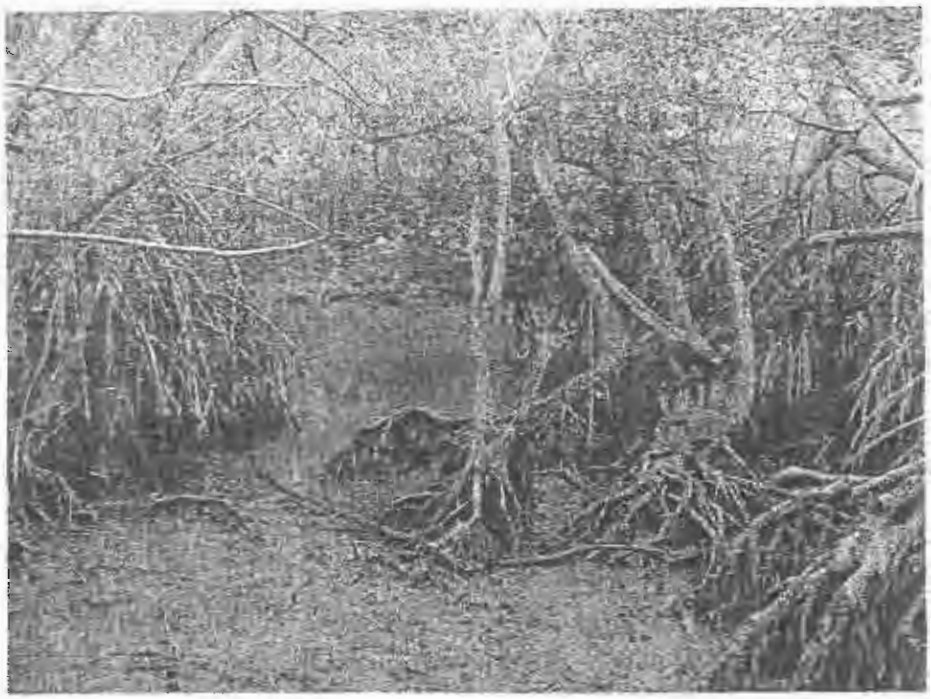

Photo 11. Predominantly red mangrove forest in the area where the western dike would cross and near the narrow point of the channel. The tide was moving out and at low stage.

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
Environmental Quality Section
USACOE - Jacksonville District

Date

Signed: — 7/5/95

Ivan Acosta, Environmental Engineer
Environmental Quality Section
USACOE - Jacksonville District

Date

Reviewed By:

Signed: — 7/6/95

James McAdams, Chief Environmental
Quality Section
USACOE - Jacksonville District

Date

Approved By:

Signed: Kenneth R. Dupp for — 7/6/95

Hanley K. Smith, Chief Environmental
Resources Branch
USACOE - Jacksonville District

Date

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.

COMMONWEALTH OF PUERTO RICO
OFFICE OF THE GOVERNOR
PUERTO RICO PLANNING BOARD

Minillas Governmental Center, North Bldg.
De Diego Ave; Stop 22
P. O. Box 41119, San Juan, P. R. 00940 - 1119

June 4, 1991

A. J. Salem, Chief
Planning Division
Department of the Army
Jacksonville District
Corps of Engineers
P.O. Box 4970
Jacksonville, Florida 32232-0019

Att: Environmental Studies Section

Dear Mr. Salem:

I write in reference to your request for comments on the reconnaissance-level report for the Río Culebrinas and Caño Madre Vieja flood protection project, south of the Municipality of Aguadilla. Historical records show that the area west of Highway PR-2 has been affected by floods of both Río Culebrinas and the Caño.

According to FEMA's panel number 720000-0009B and our Flood Zones Map number 1D, Urb. García, Urb. Victoria and the Public Housing Project José Aponte were affected by the 100 year-flood, and were classified within the floodway. Urban development was restricted because of the floods, as shown in dotted lines, in our Land Use Plan for Aguadilla, (corresponding parts included). The Plan also proposes that the lands located northeast and adjacent to the mouth of Caño Madre Vieja be used for recreational uses.

Any additional information that you may need will be furnished on request.

Cordially,

Patria G. Custodio
Chairperson

Enclosure


VICTORIA
PARQUE

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 Rat Pre-treatment 2.5 Berms

6
18

EVALUATION SUMMARY

Without Proj

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.
2	Water Quality Inputs and Treatment:	LU= 2.5(.5)+ 2(.5) = 1.25 + 1.0

6 2.25 + 1.75 4

Land Use 50% high d
vegitation; 50% pas
Pre-treatment 1 dry ret
2.5 Berms

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 ... 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
DRAFT 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

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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

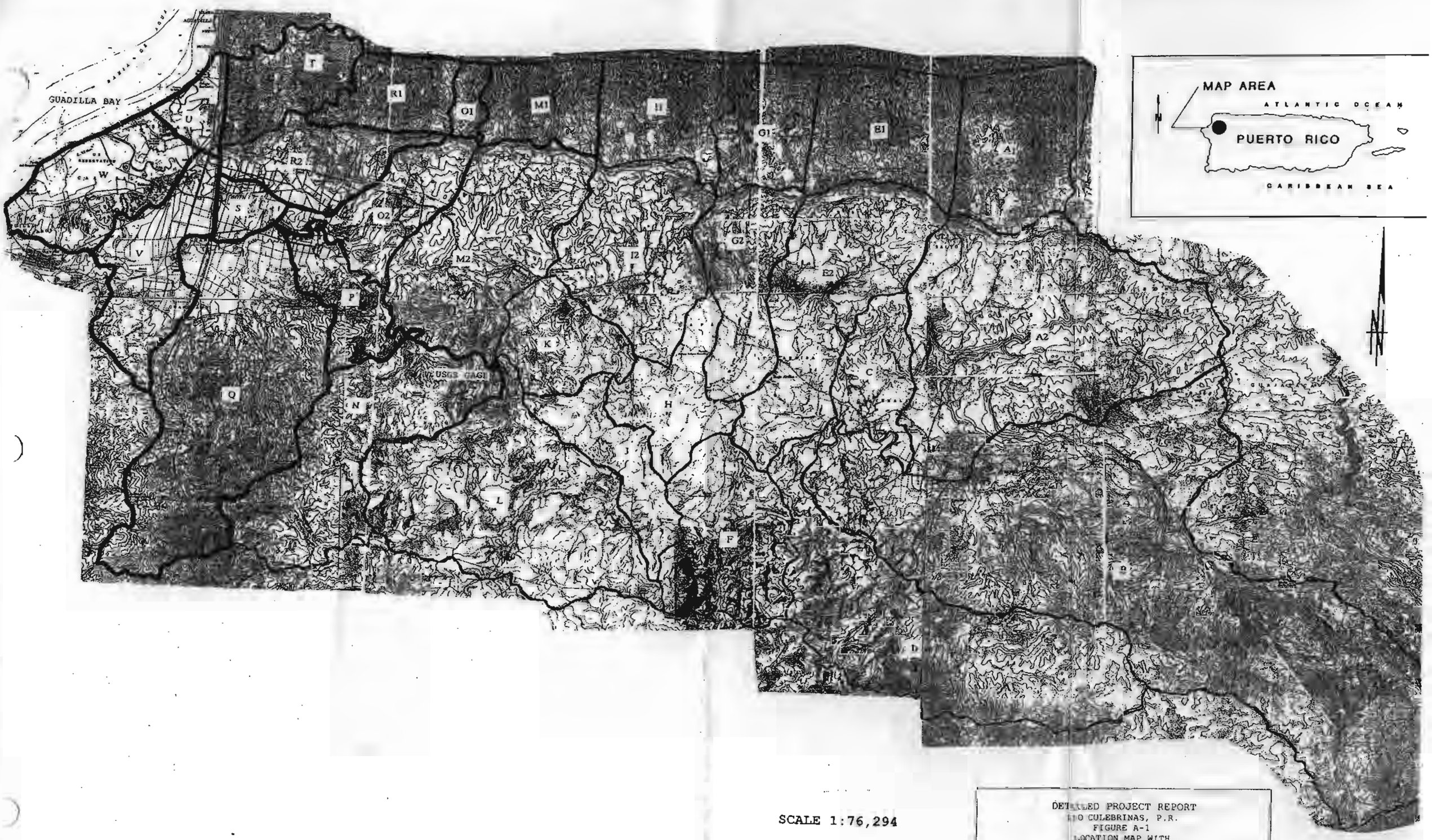
exceed the design capacity are rare but could occur. In the event of a flood greater than design discharges overtopping of one or both levees could occur. Each levee would be provided with a 50 meter long overtopping segment with a lower levee crest elevation. Paragraph C.5. provides a description of 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 ponding 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 ponding areas are an essential part of the interior drainage plan for each levee segment.

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 ponding 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. Ponding stages related to a 10-year event would also impact the eastern side of the community of Espinar. Plate A-3 shows the interior flooded areas for the 10-year event.



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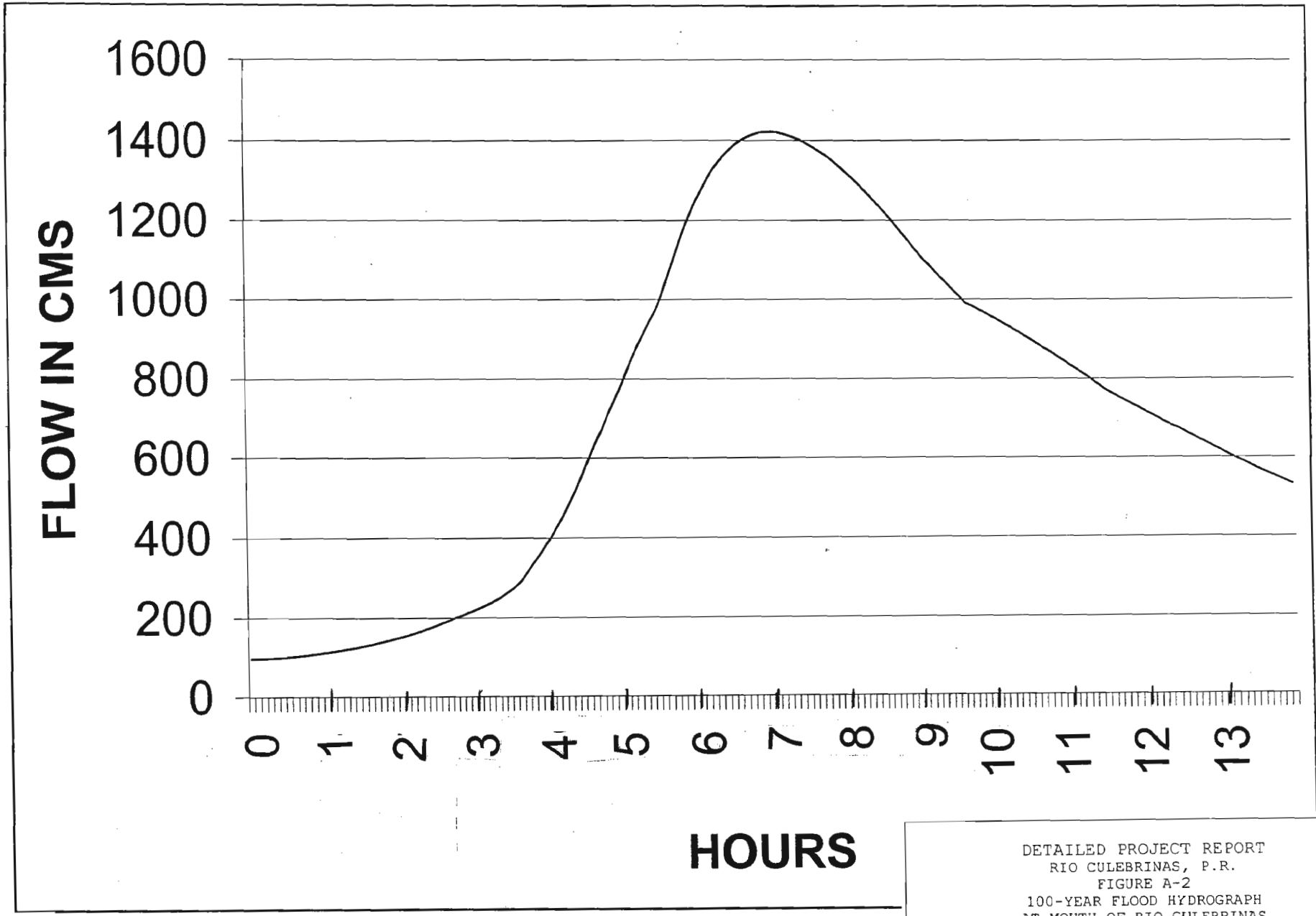
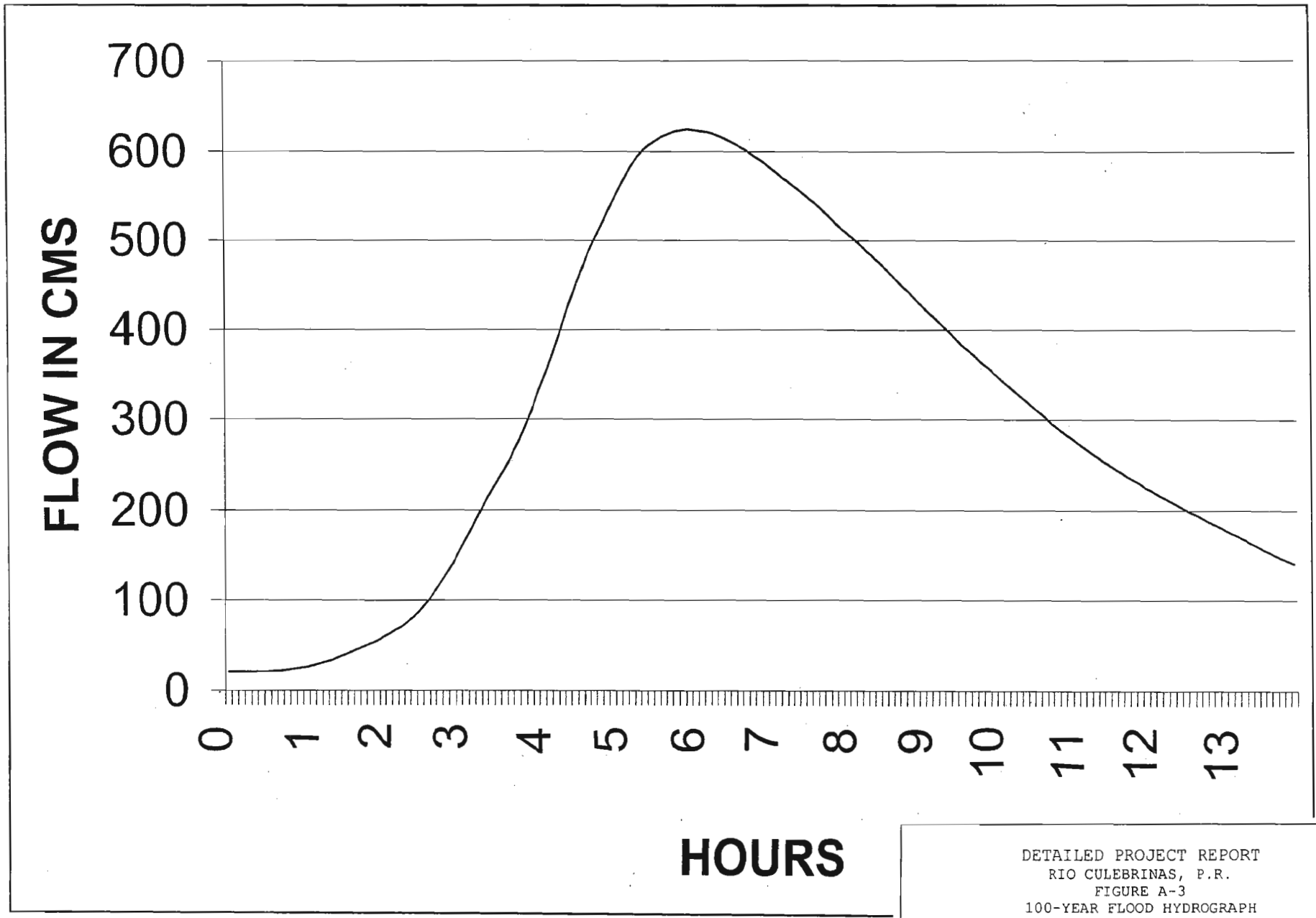
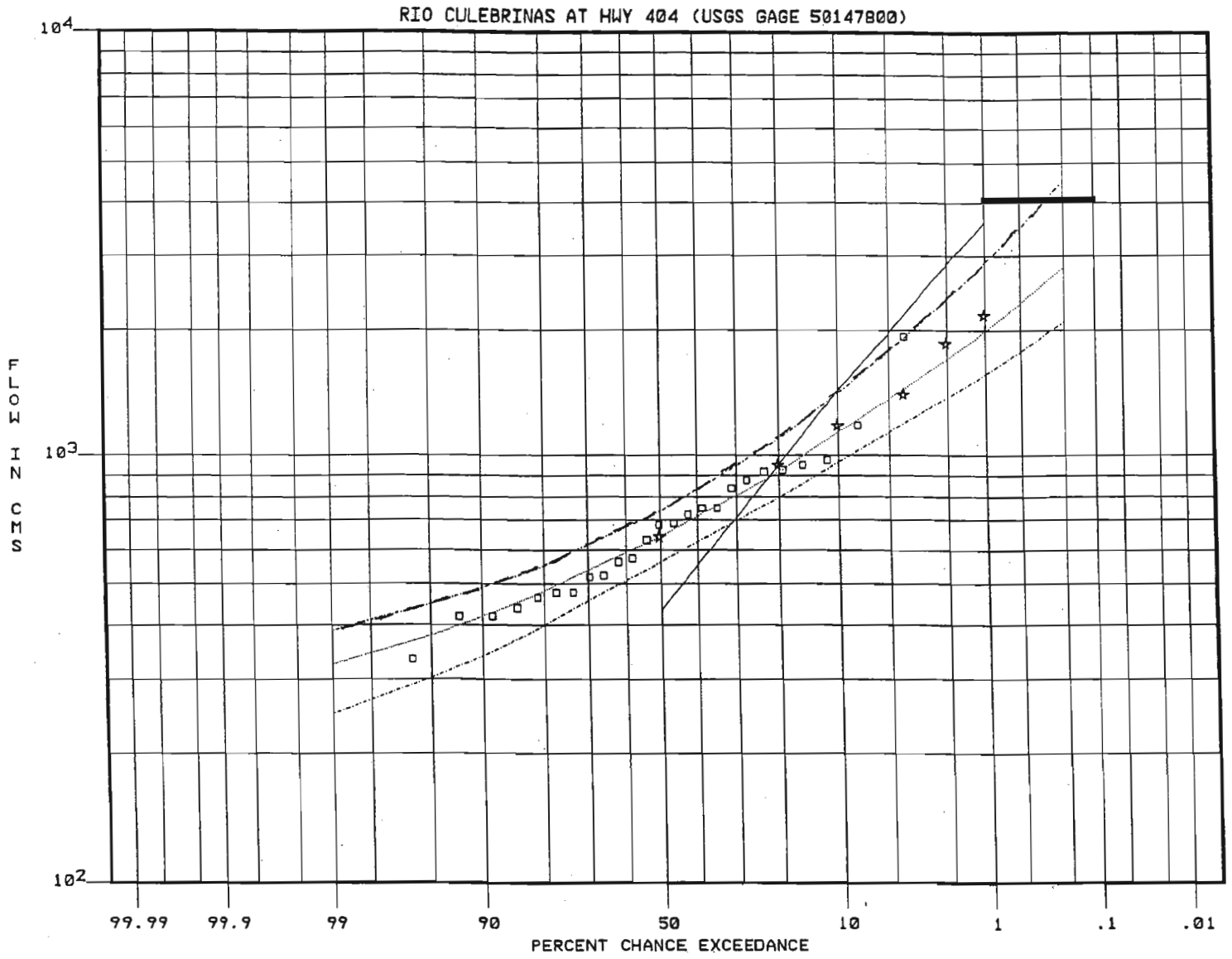
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-1
LOCATION MAP WITH
BASIN AND SUB-BASINS
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



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



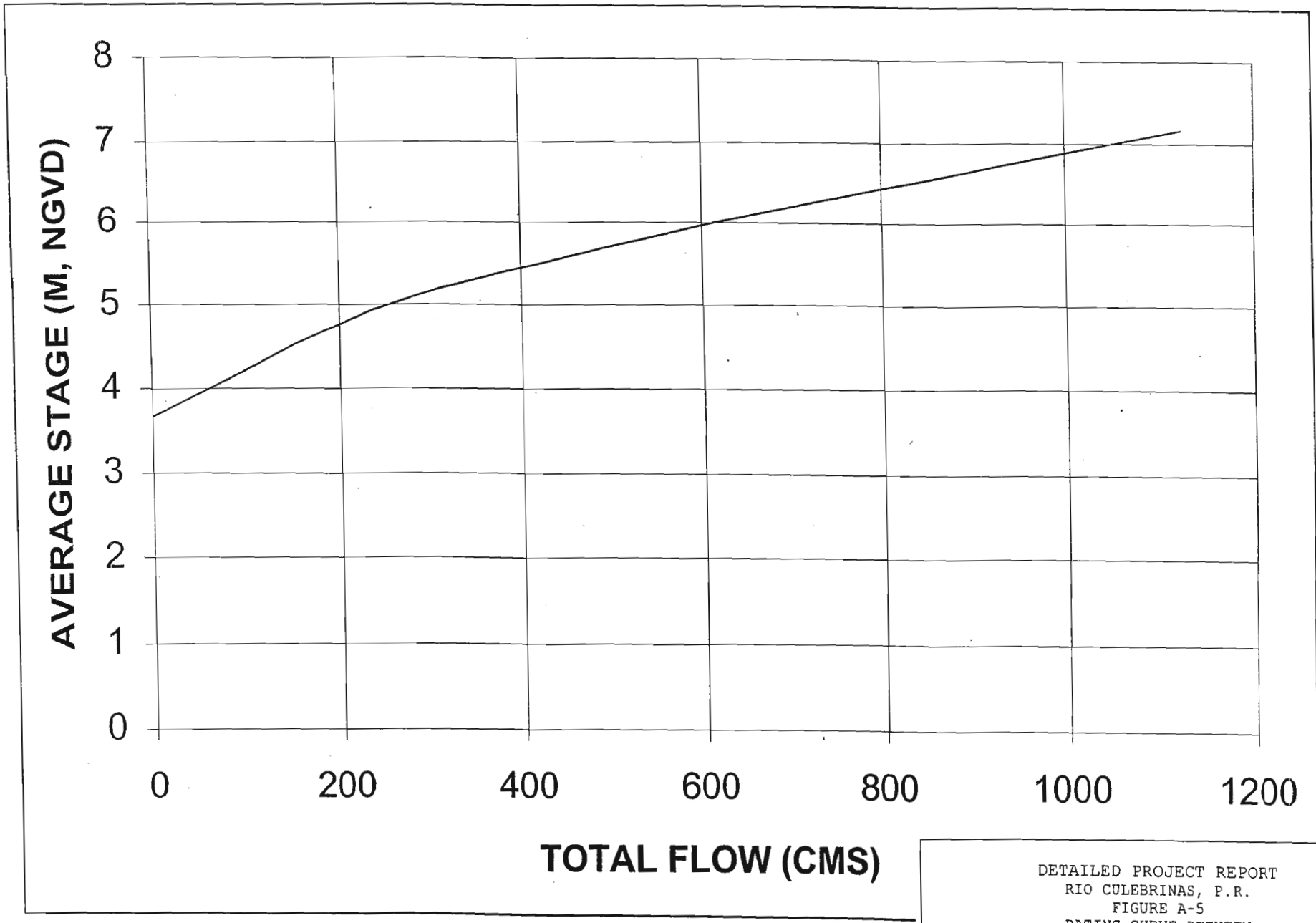
DETAILED PROJECT REPORT
RIO CULEBRINAS, P.R.
FIGURE A-3
100-YEAR FLOOD HYDROGRAPH
AT MOUTH OF CANO MADRE VIEJA
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA



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 AF
JACKSONVILLE DISTRICT, CORPS (NGINEERS
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

TABLE A-6

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

	BRIDGE	CROSS SECTION	MILE	2-YEAR		5-YEAR		10-YEAR		25-YEAR		50-YEAR		100-YEAR		SPF	
				WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	EXISTING CONDITIONS	WITH PROJECT	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	3.8
		74	0.05	1.71	1.79	2.07	2.23	2.29	.47	2.51	2.69	2.80	3.06	2.94	3.15	3.52	
		17	0.01	1.53	1.64	1.86	2.05	2.06	.28	2.26	2.55	2.59	2.86	2.72	2.97	3.28	.59

NO... 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 + 00.00	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

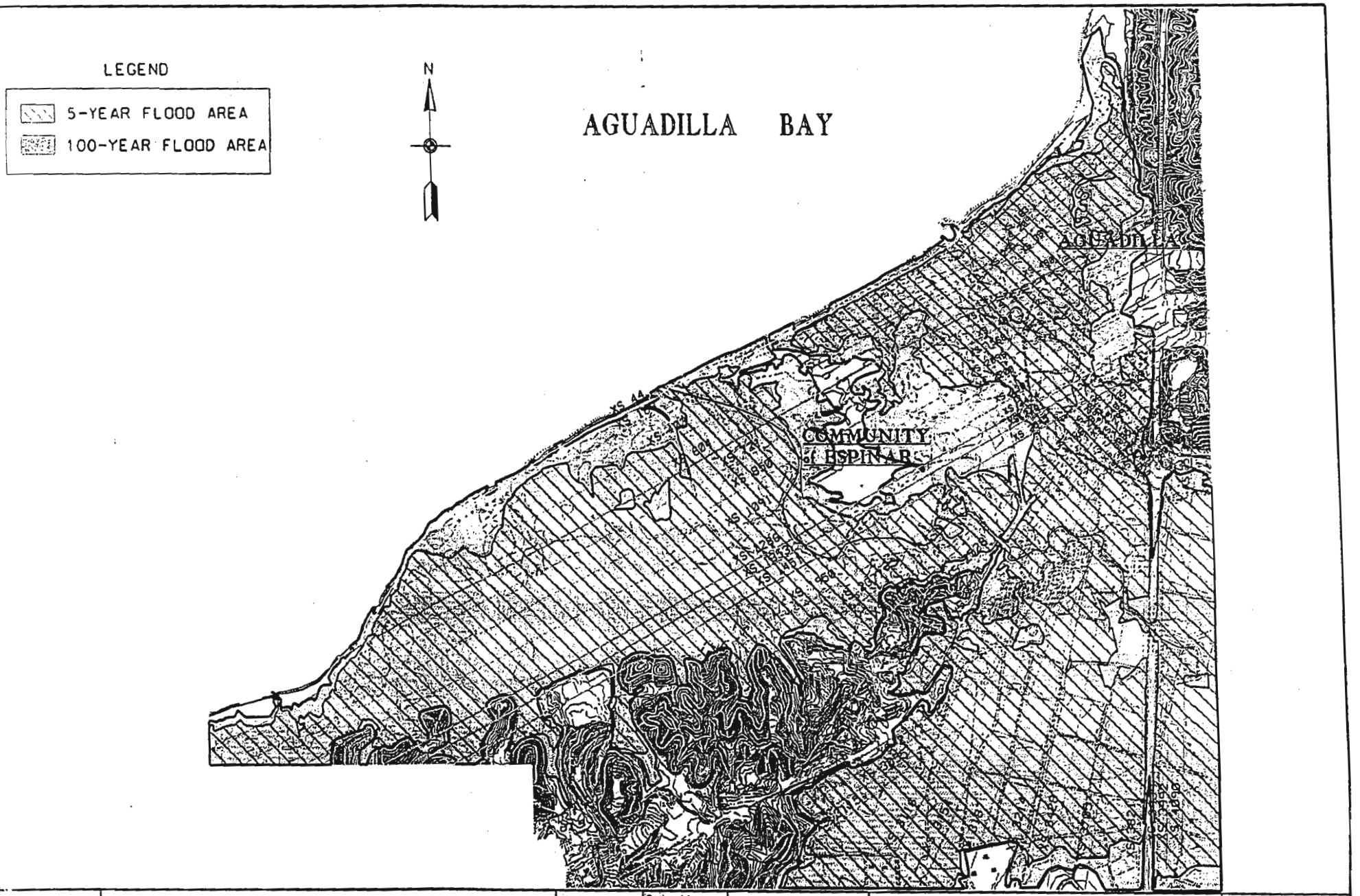


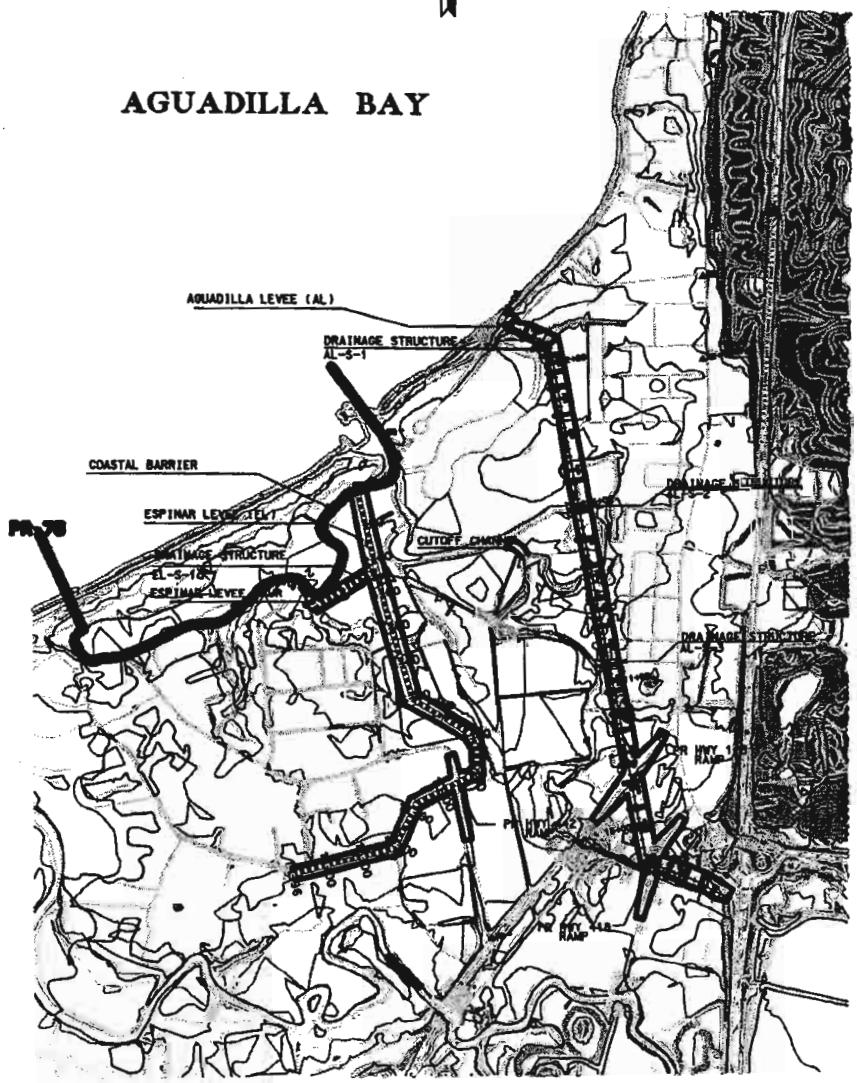
PLATE
A-1

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

File name:
Reference files:
Designed by:
Drwn by:
Chkd by:
Scale:
Plot date:
Plot scale: 7.00ft.
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



RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO

DETAILED PROJECT REPORT
RECOMMENDED PLAN

File name:
Reference files:

Designed by:
Drn by:
Ckd by:

Scale:
Plot date: ----
Plot scale: 400:1

Dated: JULY 1999
D.O.FILE NO.

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

US Army Corps of Engineers
Jacksonville District

PLATE
A-2

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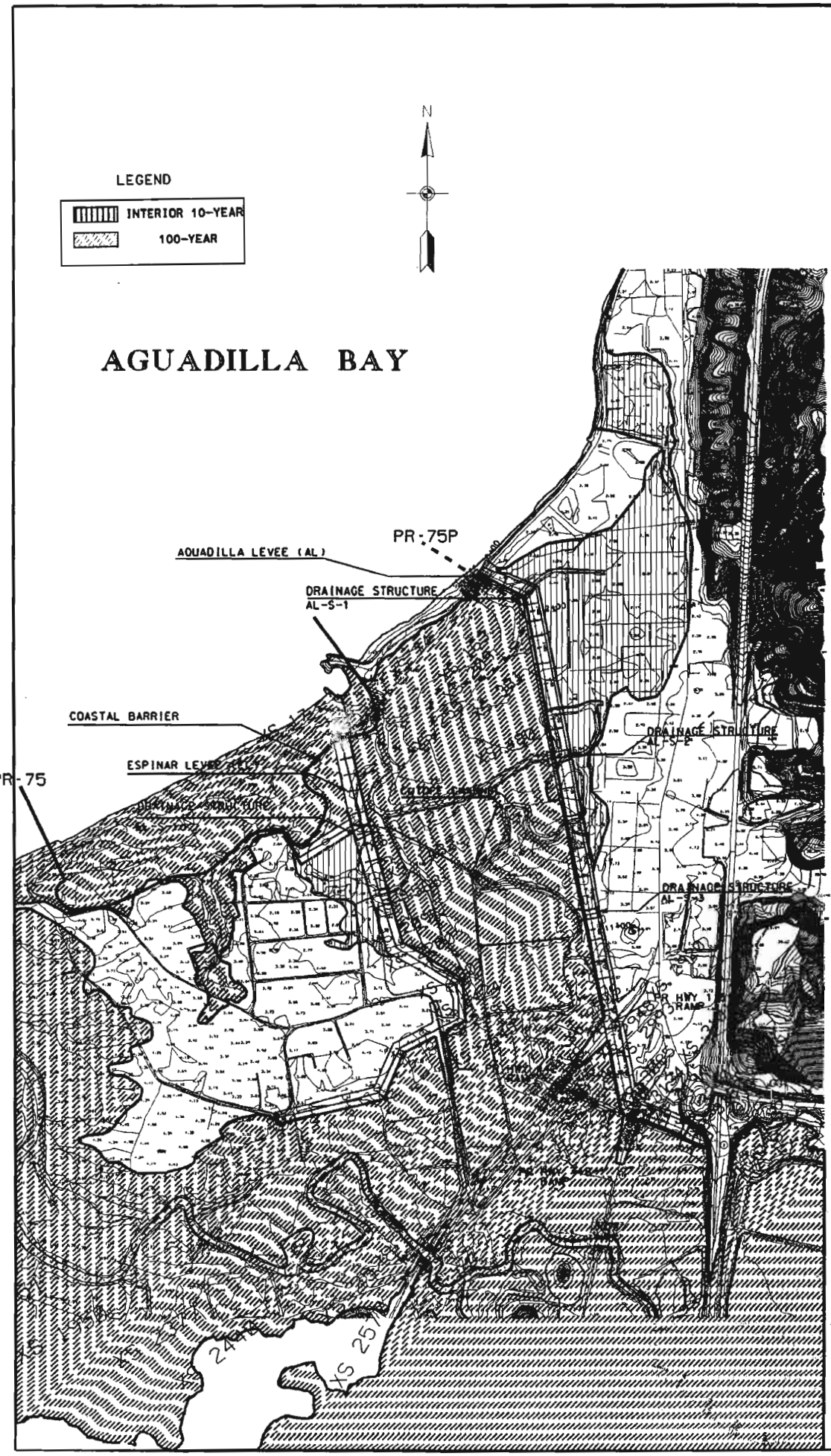


US Army Corps of Engineers
Jacksonville District

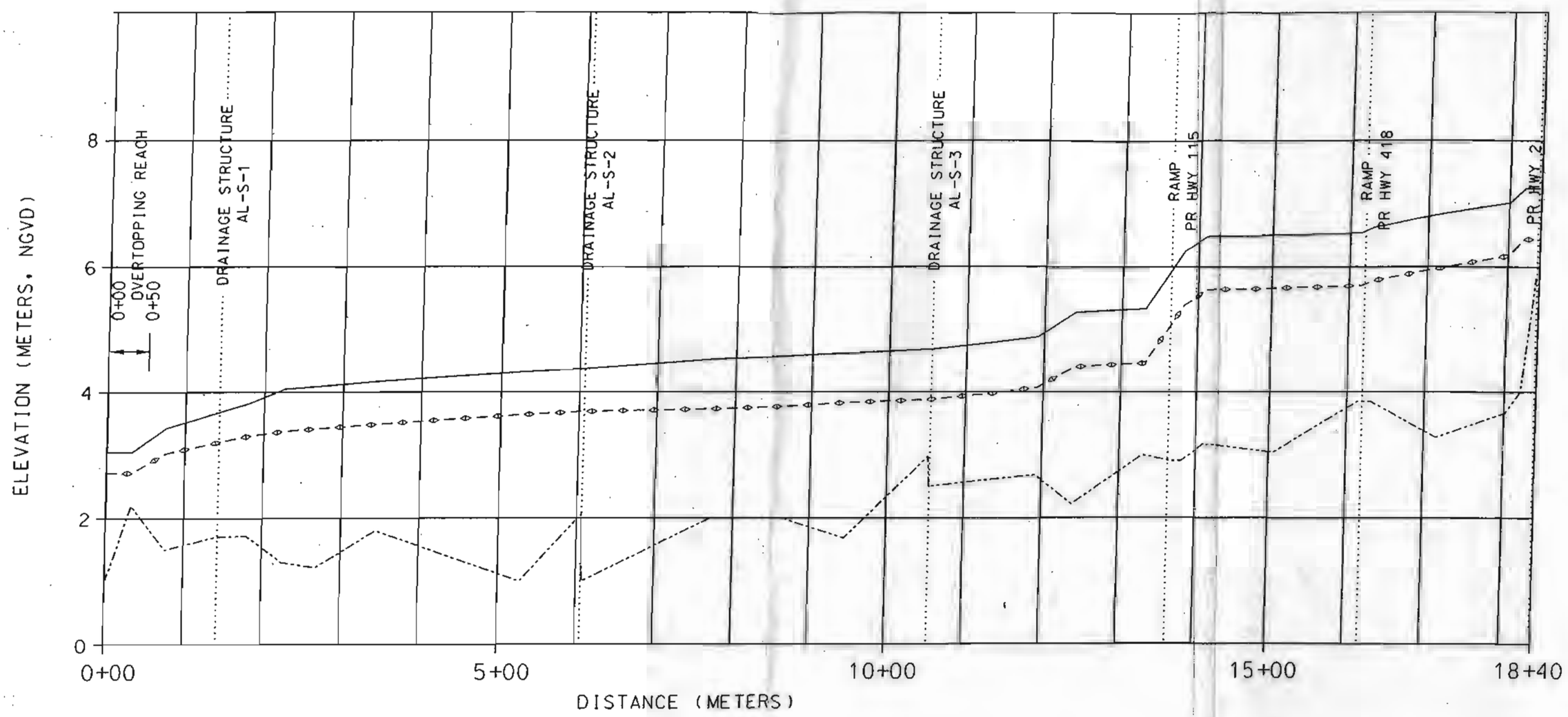
DEPARTMENT OF THE ARMY
JACKSONVILLE DISTRICT, CORPS OF ENGINEERS
JACKSONVILLE, FLORIDA

RIO CULEBRINAS AT AGUADA/AGUADILLA
PUERTO RICO

DETAILED PROJECT REPORT
RESIDUAL FLOODED AREA

File name:
Reference files:
Designed by:
Dwn by:
Ckd by:
Scale:
Plot date:
Plot scale: 4.00:1.
Dated: JULY 1999
D.O.FILE NO.

PLATE
A-3



LEGEND

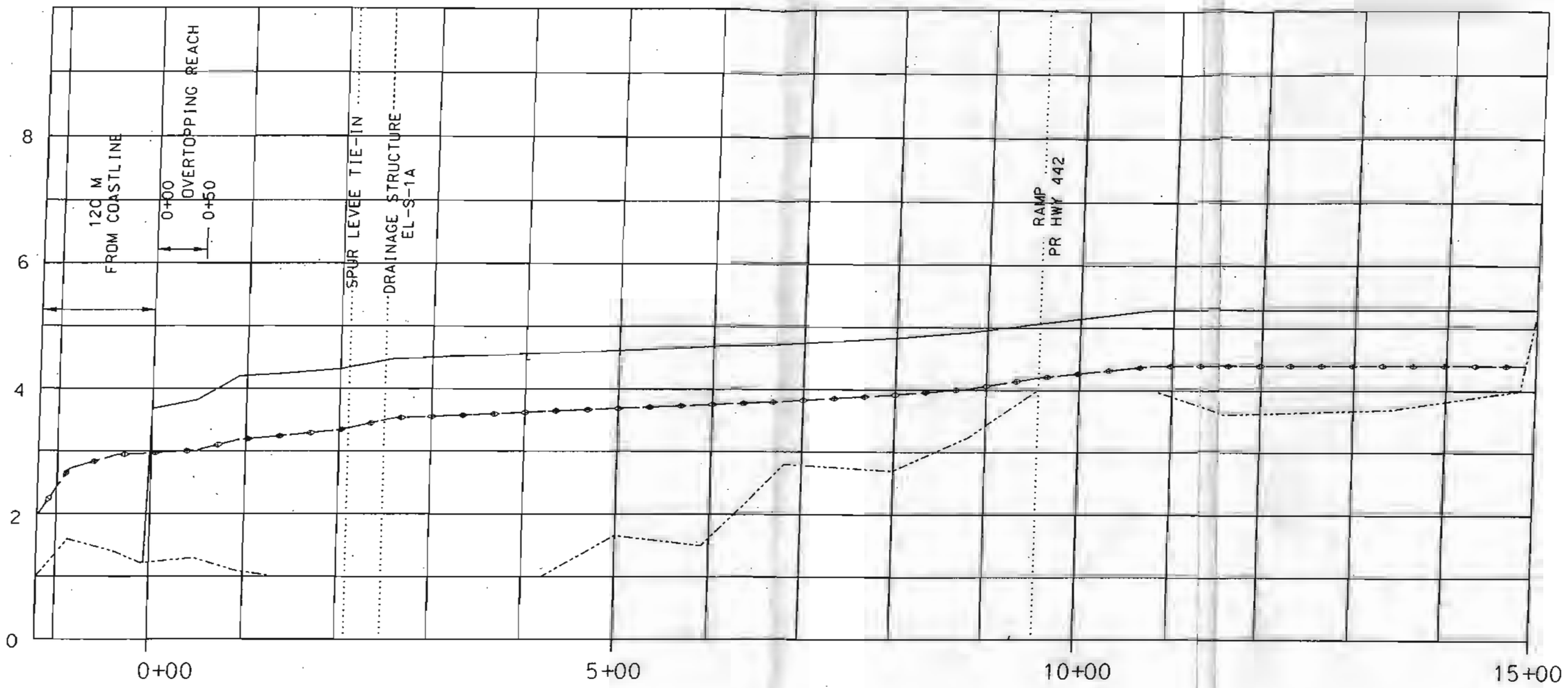
EXISTING GROUND ELEVATION

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:

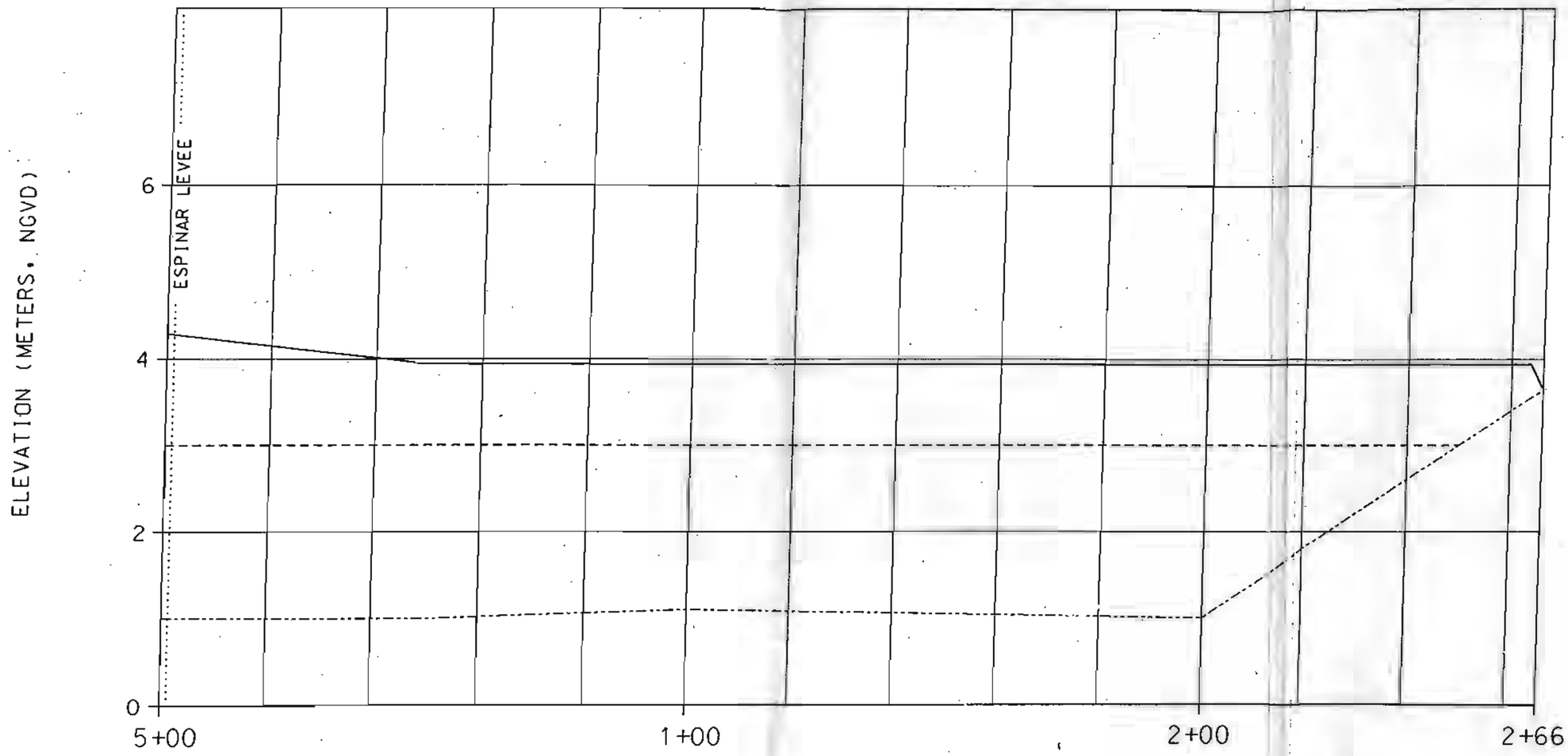
DESIGN ENG.:
CHECKED BY:
DRAWN BY:

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

AQUADA/AQUADILLA, PUERTO RICO

RIO CULEBRINAS
ESPINAR LEVEE PROFILE
100-YEAR

INV. NO.
DATED:
SIZE
DWG. NO.
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