GeoCim LUIS O. GARCIA & ASSOCIATES
GEOTECHNICAL ENGINEERING CONSULTANTS

Partners
Luis Oscar García, MSCE, CE, PE
Carlos García Echevarría, MSCE, PE
James A. Baigés, MSCE, PE

Associate
Alejandro E. Soto, MS, PG

Discovery Bay Marina Project

Geotechnical/Geological Discussion

Aguadilla, P.R.

The Discovery Bay Marina Project is located within the Espinar Ward of the municipality of Aguadilla, adjacent to the borderline with the Municipality of Aguada. This project is located within the flood plain of the Culebrinas River. The proposed project consist of the construction of an inland marina with approximately 500 slips for different sized boats and various developments providing residential, commercial, and marine facilities. The development of this project will require the construction of flood control structures to prevent the flooding of existing developments in the area; these will include the Aguadilla Levee on the east and the Espinar Levee on the west, allowing the drainage of flood waters through the new marina channel to the ocean.

Figure 1 shows a portion of the Geologic Map of the Aguadilla Quadrangle (Watson H. Monroe, 1969) published for the U.S.Geological Survey (USGS). According to the USGS, the geology of the proposed project area is dominated by Quaternary Alluvium (Qa) with a limited section at the ocean front which is identified as Quaternary Beach Deposits (Qb). The Alluvium consists of sediment deposited by the Culebrinas River and is described as *"clayey sand and sandy clay, containing scattered pebbles and cobbles of volcanic rocks in some areas; gently cross bedded and laminated; 0-10 meters thick"*. The Beach Deposits consist of recent coastal sediment that the USGS describes as *"quartz sand, shell fragments, and scattered grains of other minerals resistant to weathering; cementation to beach rock*

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common, ...". The geologic map also shows the existence of Quaternary Swamp Deposits near the mouth of Caño Madre Vieja. These deposits, described as *"sandy organic muck and peat; 0-5 +/- meters thick"*, are slackwater deposits that accumulated between a coastal sand ridge and the alluvial plain deposits.

Results of preliminary geotechnical explorations performed at the project site (ASE, 2002) are in general agreement with the information provided in the geologic map. The results of the borings drilled (within the general area mapped as Alluvium by the USGS) indicate a general subsurface profile that consist of an upper layer of alluvial clay to sandy Clay in a very soft to stiff consistency which extends to depths of approximately 5 to 15 feet from the existing ground surface underlain to the bottom of the borings (mostly to 40 feet depth) by alluvial sand with trace to some silt; the latter generally occurs in a medium dense to dense condition but the borings penetrated a few layers or pockets in a loose to medium dense condition toward the upper portions of this horizon.

Conceptual plans for the project indicate that the flood control structures will consist of the following:

Aguadilla Levee – will consist of an earth embankment or dike that will extend from the existing municipal road leading to the Parque Colón in the north end to State Road PR-2 at the south end, just south of the intersection of PR-2 and PR-111. This dike will be approximately 2,000 lineal meters in length and will be wide enough to allow the construction of a two lane roadway along its crest. The approximate location of Aguadilla Levee is shown in Figure 2. This levee will generally be about 2.5 meters in height as required by the Hydrology and Hydraulics study performed by others in order to maintain the design levee crest elevation above the design water

elevation, except at some locations where the height of the levee will be about 3 to 4 meters height such as at the crossings with the Caño Madre Vieja (where the existing ground elevations are lower) and at the south end of the levee where it will raise to the existing PR-2 level.

Espinar Levee – the Espinar Levee will extend south and then west along the marina waterfront for approximately 2,100 lineal meters as shown in Figure 2. The levee will consist of a bulkhead rising to an elevation of approximately 8 feet above mean sea level, followed by a level promenade section behind the bulkhead, followed in turn by a further raise in elevation to approximately 15 to 23 feet above sea level using retaining structures or earth embankments; refer to Figures 3, 4, and 5 for conceptual drawings of this levee. The proposed bulkhead will probably consist of a steel sheet pile wall supported at the top with tie rods and "deadman" anchors at some distance behind the wall. The soils in front of the bulkhead will be dredged to approximately 6 to 12 feet below sea level and floating docks will be attached to the bulkhead to provide the marina docking facilities.

The construction procedures for the two types of levee proposed for the project are very different and will have to take into consideration different geological and geotechnical factors. In the case of the Aguadilla Levee, the proposed dike will be constructed by first clearing and grubbing the upper topsoil layer and then placing and compacting earth fill in layers until the earth embankment is completed to the required elevation. The fill materials will be obtained from nearby borrow sources and transported to the site. At present there are several quarries in the limestone hills near the site from which borrow fill materials for roads

and general building development have been and are still being used. This same general type of fill material has been used in other projects for the same purpose such as the flood control dikes in the Barceloneta area. The borrow fill must be fully characterized for the design of the levee, including its compaction, permeability and strength properties. In general, the fill must be placed in 8 to 12 inches thick layers and each layer compacted to 95% of the maximum dry density as obtained in the Modified Proctor test (ASTM D 1557). The typical side slope inclinations for earth embankment to be used for this purpose and constructed as described above may vary from approximately 3(H):1(V) to 2(H):1(V). The levee may require the use of internal or external drainage and permeability reduction mechanisms in order to prevent instability of the structure during or immediately after flooding events when the dike will work as a water retaining structure. Erosion control methods will also be incorporated into the levee design to prevent excessive erosion of the dike surface during flood events.

The design of the proposed levee will also take into consideration the geotechnical characteristics and stability of the underlying soils with a detailed and extensive geotechnical investigation that will establish the consolidation and strength properties of the subsoils. The earth embankment to be constructed will increase the effective stresses in the underlying soils; this may cause consolidation of any underlying weak or soft clayey subsoils with resulting settlement at the ground surface and instability of the subsoils. If the design studies conclude that excessive differential and/or total settlements are likely from the construction of the levee, then different construction alternatives may have to be implemented in order to reduce or eliminate excessive post-construction settlement of the levee. Construction alternatives such as pre-consolidation by surcharging may be implemented at the site; the use

of wick drains to accelerate the consolidation could also be utilized in order to reduce the construction schedule for the surcharge.

Additionally, the liquefaction potential of the underlying sand and sandy soils during a strong motion earthquake will also be investigated. During liquefaction the effective stresses within the sand below the water table are reduced by an increase in pore pressures resulting in a loss of strength of the soil and causing a sudden collapse or settlement of the soils.

In the Espinar Levee, a bulkhead will be constructed by driving a steel sheet pile into the ground and supporting the top of the sheet pile with tie rods attached to a "deadman" anchor a certain distance behind the bulkhead. The depth of the sheetpile will depend on various considerations: the subsoil conditions encountered, the unsupported length of the wall between the upper deadman anchor and the surface of the dredged soils in front of the wall, and the spacing of the deadman anchors. The sheet piles that make up the bulkhead will be driven with impact or vibratory type pile drivers to the required depths. The design of this levee will also require that a detailed geotechnical investigation be performed along the alignment of this levee in order to establish the geotechnical properties of the subsoils and determine the stability and structural requirements of the levee. Grading behind the bulkhead and promenade will require the placement of additional fill to raise grades to elevations of 15 to 23 feet above mean sea level. The design of these facilities will also require the use of engineered fill and the determination of the geotechnical characteristics of the fill and underlying subsoils with the same geotechnical concerns and considerations described for the Aguadilla Levee, including an assessment of liquefaction potential.

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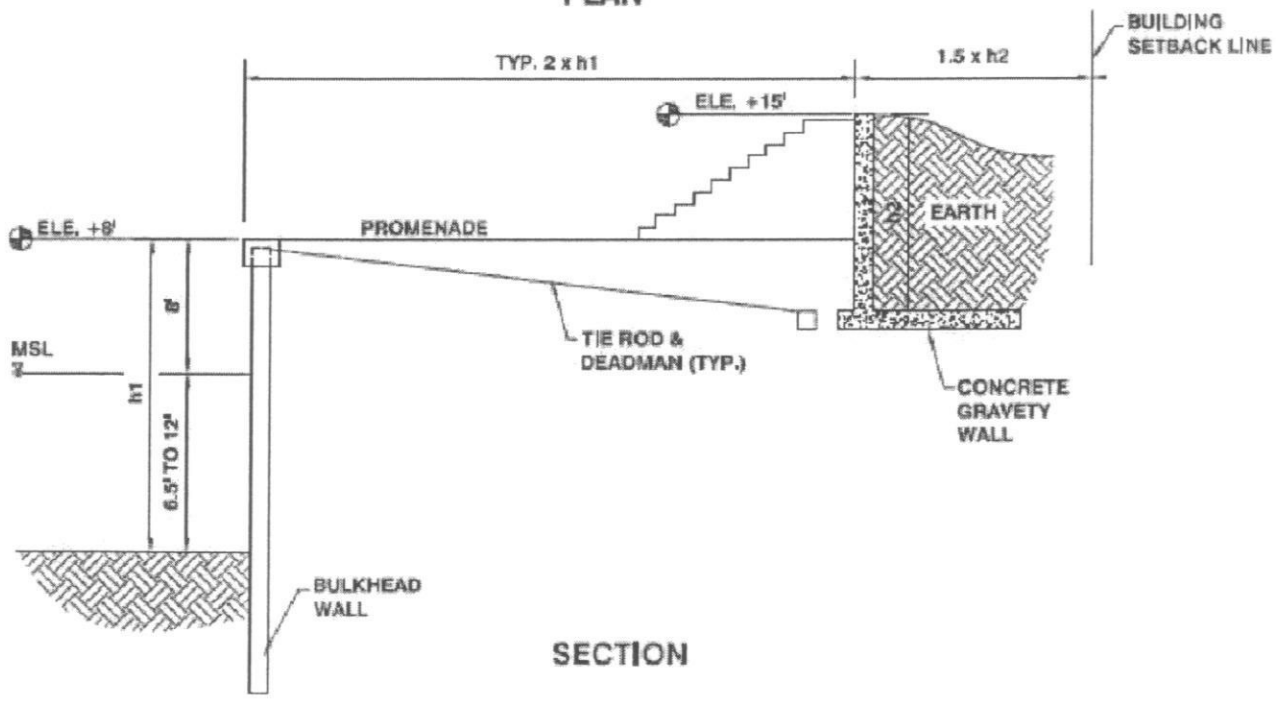
DISCOVERY BAY RESORT & MARINA

AGUADA, P.R.

DRW. BY:	CKD. BY:	SCALE:	DATE:	JOB. NO:	FIGURE NO:
G.O.G.	C.G.	N.T.S.	01/04/05	3379-05	1

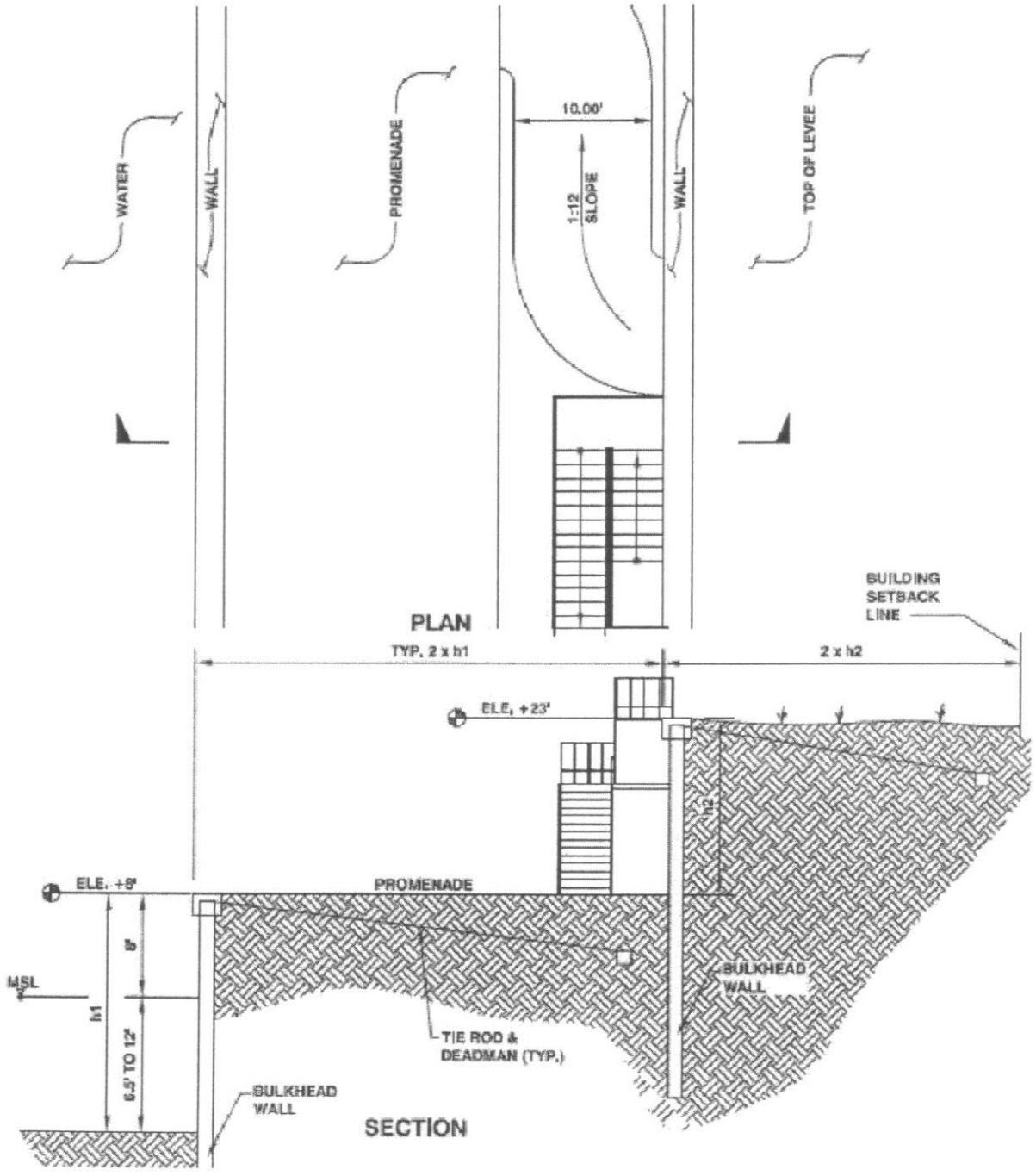
PLAN



SECTION

Giovanni: f:Autocad\drawings\Propuestos\Diques\ FIG 3 4 5

GeoCim LUIS O. GARCIA & ASSOCIATES	CONCEPTUAL DRAWING - GRAVITY & LOW LEVEL LEVEE DISCOVERY BAY RESORT & MARINA, AGUADA, P.R.					
	DRW. BY: G.O.G.	CKD. BY: C.G.	SCALE: N.T.S.	DATE: 01/20/06	JOB. NO: 3379-05	FIGURE NO: 3



Giovonni: f:\Autocad\drawings\Propuestos\Diques\ FIG 3 4 5

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CONCEPTUAL DRAWING - BULKHEAD WALL & HIGH LEVEL LEVEE
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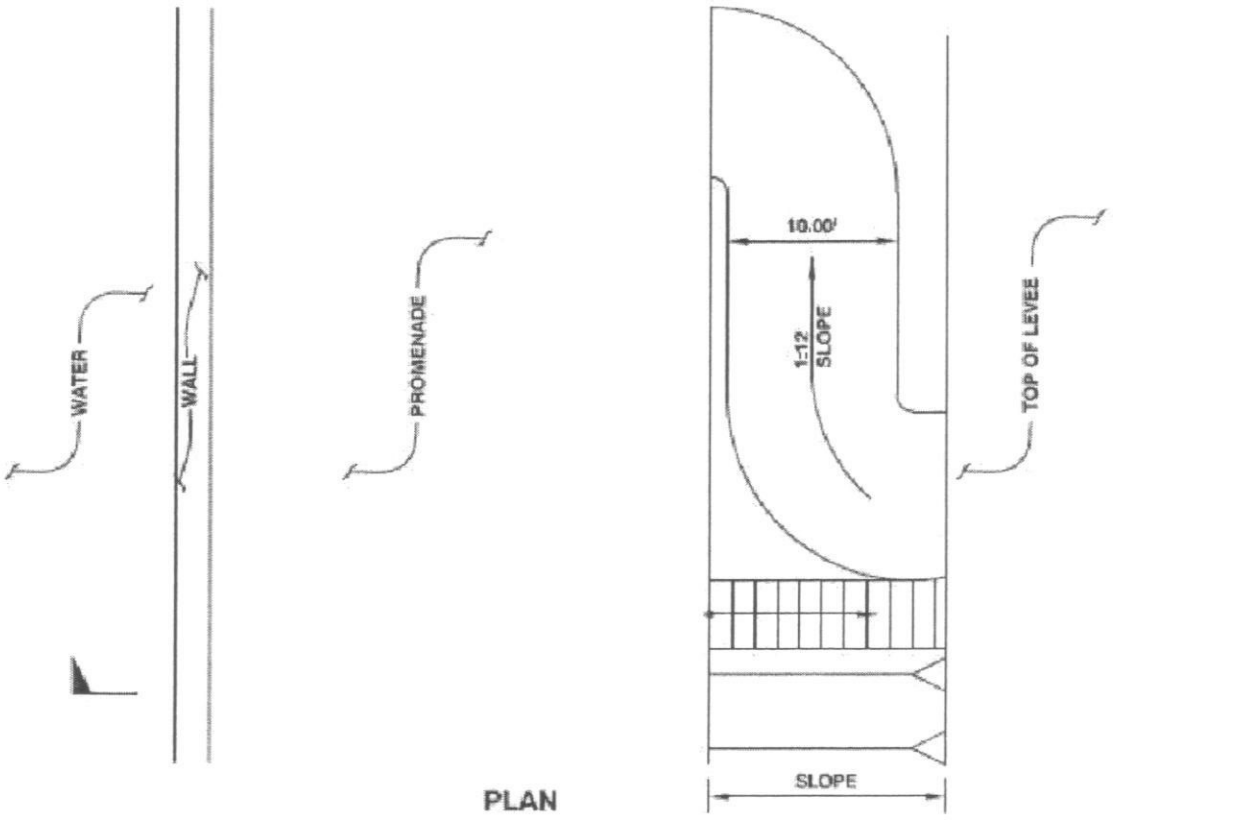
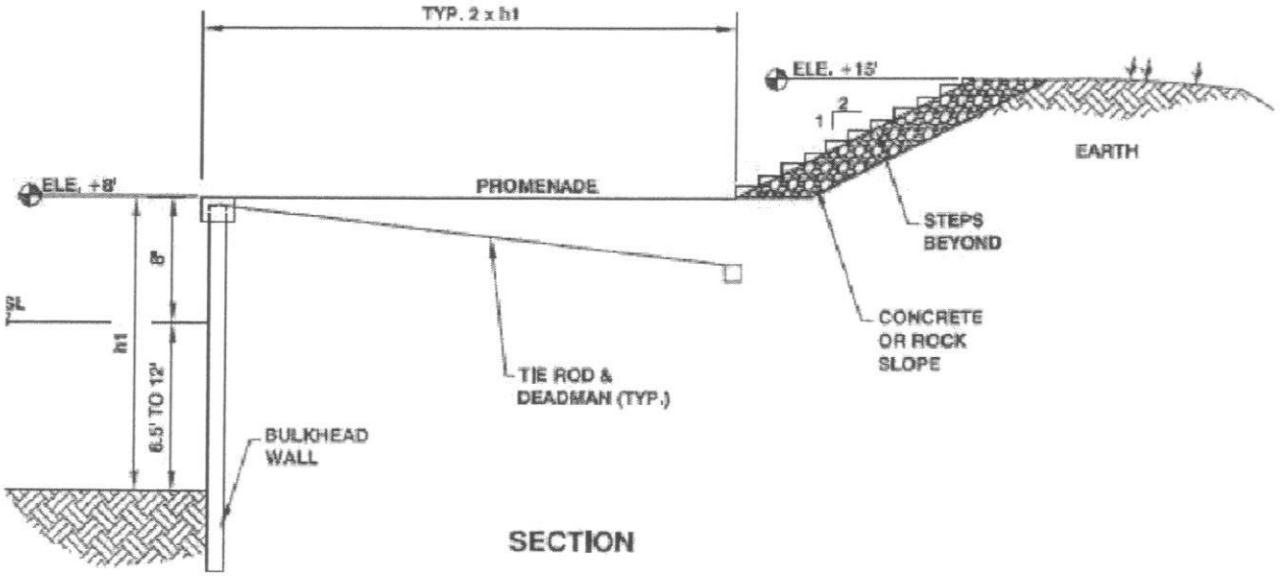
DRW. BY:	CKD. BY:	SCALE:	DATE:	JOB. NO:	FIGURE NO:
G.O.G.	C.G.	N.T.S.	01/20/06	3379-05	4



PLAN



SECTION

Giovanni: f:\Autocad\drawings\Propuestos\Diques\ FIG 3 4 5

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CONCEPTUAL DRAWING - REVETMENT & LOW LEVEL LEVEE

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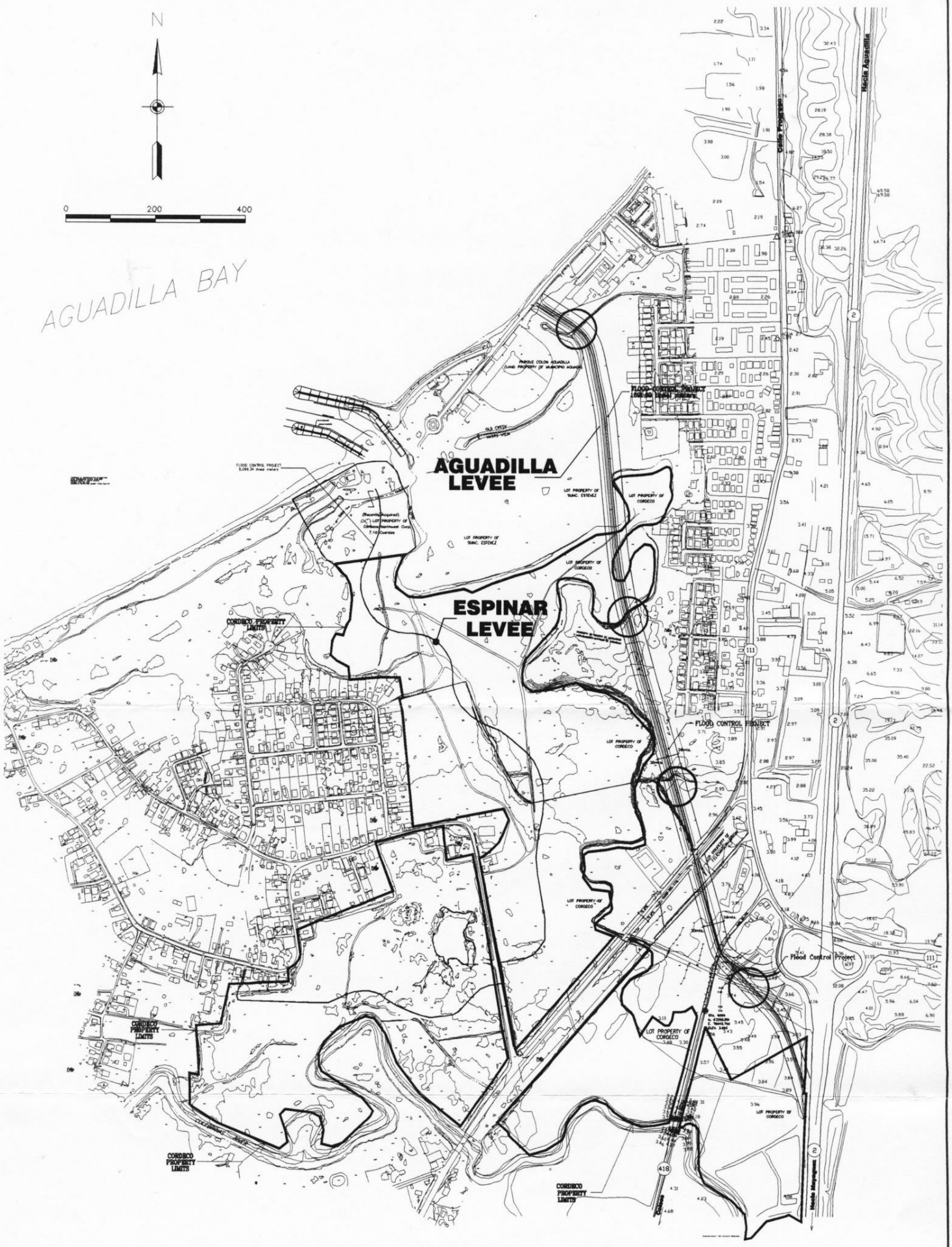
DRW. BY:	CKD. BY:	SCALE:	DATE:	JOB. NO:	FIGURE NO:
G.O.G.	C.G.	N.T.S.	01/20/06	3379-05	5



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		DATE: 01/03/05	JOB NO: .	CKD. BY. C.G.	SCALE: N.T.S.	FIGURE NO: 2