
APPENDIX A1 – PLAN FORMULATION & RISK ASSESSMENT

for

RIO GUAYANILLA, GUAYANILLA, PR 2018 SUPPLEMENTAL APPROPRIATIONS FLOOD RISK MANAGEMENT STUDY



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US Army Corps
of Engineers®
Chicago District

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Flood Risk Management Study

USACE. 2020. Rio Guayanilla, Guayanilla, PR Flood Risk Management Study. Draft Final Integrated Feasibility Report Environmental Assessment. U.S. Army Corps of Engineers, Chicago District, 231 S. LaSalle Street, Suite 1500, Chicago, Illinois 60604.

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1.0 Plan Formulation

1.1 Measure Screening

Reservoirs – Constructing large reservoirs in montane river units to retain and detain rainwaters was eliminated from further consideration for the Guayanilla FRM study. Reasons for elimination are as follows:

H&H Considerations – Looking at the results of the H&H modeling, at the upstream end of the project limits the volume of water entering the watershed for a 0.01 ACE event is approximately 11,815 AC-FT (3,849,928,891 gallons) of water, this doesn't include the additional runoff volume from the town itself. Based on LRC's past experience of constructing a flood control reservoir of this size, it was determined that it would not be economically feasible. Even constructing a series of several smaller reservoirs would require pipes and mechanical equipment to get it to work properly. This would drive up the frequency and cost of O&M. The local sponsor and stakeholders have very little resources in terms of funding and manpower for larger mechanical systems that need O&M. Therefore, detention was not seen as a feasible plan for this watershed.

Fluviogeomorphic Considerations – Placing on-line detention/retention in montane segments of a catchment that has steep valley walls and high stream gradient would be quite risky to attempt due to a) the amount of alluvial material coming down stream, which would likely scour structures and pave over the basins every large event, b) at certain floods the valley here becomes a confined channel, and starts placing high forces on structures and natural features; c) these lead to high and frequent O&M costs for removing alluvial material and repairing “sand-blasted” structures. The potential for landslides increase by changing the fluviogeomorphic character here as well, both from the valley walls and down the river channel/valley.

Increased Risks to Life Safety – Any kind of feature that can retain potential energy in montane systems that reside above human occupation / activities increases risks to human safety. As described, the potential for landslide increase as well as associated discharged waters. The difficulty of reaching these for O&M would surely cause some kind of failure at some point in the early life-cycle of the project.

Human Habitation / Real Estate – Many of the points that would be suitable in terms of volume detention capabilities are typically inhabited with homes and small farms. These would need to be relocated if the land owners consented.

Environmental Considerations – Two considerations for environmental effects are for the riverine/floodplain habitats and connectivity, and the confining valley karstic slopes of Dry Subtropical Forest. Online reservoirs/basins in these segments of river would need to be significantly more robust and taller and potentially would not be able to have conservation measures applied due to the amount of alluvial materials and forces of water. There is potential for the valley to fill up to the elevation of the control structure over several storms or several years of storms depending on site size. This would equate to a loss in riverine habitat acres and flood plain habitat acres (where natural). Second, Subtropical Dry Forest would be lost via construction activities, rock removal, and post construction in changes to hydrology i.e. hydrate in Dry Tropical Forest plant communities. This would apply to all of the forested patches not cleared for habitation. The USFWS was very clear about not further disturbing this habitat type due to the amount already lost, the presences of over 20 endemic plant species and potential for up to 6 Federal T&E species; as evident from the plan formulation for the rock quarry siting. Takings and significant mitigation would most likely be required.

1.2 Alternative Screening

Table 1: Alternative Screening Criteria & Scoring

Evaluation Criteria	Quality Score	Qualifiers
Completeness		
The extent to which a given alternative plan provides and accounts for all necessary investments or other actions to ensure the realization of the planned effects. To establish the completeness of a plan, it is helpful to list those factors beyond the control of the planning team that are required to make the plan's effects (benefits) a reality.	4	Fully Complete
	3	Mostly Complete
	2	Moderately Complete
	1	Mostly Incomplete
	0	Incomplete
Effectiveness (Problems, Opportunities, Objectives, Constraints)		
The extent to which an alternative plan alleviates the specified problems and achieves the specified opportunities. An effective plan is responsive to the identified needs and makes a significant contribution to the solution of some problem or to the realization of some opportunity. It also contributes to the attainment of planning objectives. The most effective alternatives make significant contributions to all the planning objectives. Alternatives that make little or no contribution to the planning objectives can be rejected because they are relatively ineffective. Another factor that can impact the effectiveness of an alternative is whether there is substantial risk and uncertainty associated with the alternative. If the functioning or success of an alternative is uncertain, or less certain than another alternative, its effectiveness may be compromised and should be discussed.	4	POOCs Met
	3	POOCs Mostly Met
	2	POOCs Half Way Met
	1	POOCs Somewhat Met
	0	POOCs Not Met
Efficiency		
The extent to which an alternative plan is the most cost-effective means of alleviating the specified problems and realizing the specified opportunities, consistent with protecting the Nation's environment (P&G Section VI.1.6.2(c)(3)).	4	High Efficiency
	3	Medium Efficiency
	2	Low Efficiency
	1	Same as Other Alts
	0	Other Alts More Efficient
Acceptability		
The workability and viability of the alternative plan with respect to acceptance by Federal and non-Federal entities and the public; and compatibility with existing laws, regulations, and public policies. Two primary dimensions to acceptability are implementability and satisfaction. Implementability means that the alternative is feasible from technical, environmental, economic, financial, political, legal, institutional, and social perspectives. The second dimension to acceptability is the satisfaction that a particular plan brings to government entities and the public. The extent to which a plan is welcome or satisfactory is a qualitative judgment that can help planners evaluate whether to carry forward or screen out alternative plans.	4	Highly Acceptable
	3	Acceptable
	2	Moderately Acceptable
	1	Barely Acceptable
	0	Not Acceptable

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Life Safety		
The generalized change in flooding threat to a citizen's life or health, whether beneficial or adverse.	4	Reduces Risk Greatly
	3	Lowers Risk Moderately
	2	Lowers Risk Minimally
	1	Risk Remains
	0	Increases Risk
Natural Resources		
The generalized effects to physical, biological, cultural and man-made resources, whether beneficial or adverse. This includes concepts of impact magnitudes, significance thresholds, and the quality/condition of the resources in both the existing and future with and without conditions.	4	Beneficial Effects
	3	No Effects
	2	Effects Moderately Offset
	1	Effects Barely Offset
	0	Significant Adverse
HTRW		
The chance that an action will effect or be affected by the presence of hazardous, toxic and or radioactive wastes. Policy is to avoid expenditure of Civil Works funds for HTRW remediation by avoiding contaminated areas where practicable. For water resource studies, emphasis should be placed on early problem identification. Efforts to determine the existence and extent of HTRW problems will be treated as study cost and shared accordingly. Consistent with the guidance in ER 1165-2-132, the Corps will not participate in clean-up of materials regulated by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) or by the Resource Conservation and Recovery Act (RCRA).	4	Beneficial Effects
	3	No / Offset Effects
	2	Minor & Temporary
	1	Minor & Permanent
	0	Significant Adverse
Real Estate / Land Use		
The intensity of lands needed and the types of land that would be converted. The real estate component determines the amount and costs of lands needed per alternative. It also considers the complications of multiple land parcel owners.	4	Min Acres / Single Owner
	3	Min Acres / Few Owners
	2	Mod Acres or Owners
	1	High Acres / Few Owners
	0	High Acres / Many Owners
Infrastructure Relocations		
The amount / intensity of utility, road, bridge, irrigation, transportation that would be beneficially or adversely affected.	4	Minimal to None
	3	Low
	2	Moderate
	1	High
	0	Intense / Large Scale
Sustainability / O&M		
The amount of maintenance required to keep the alternative functional and operating throughout the project life. Sustainability concepts are included.	4	High Sustain / Low O&M
	3	
	2	Mod Sustain / Mod O&M
	1	
	0	Low Sustain / High O&M

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Table 2: Alternative Screening Matrix

Alt #	Alternative Name	Measure Components	Screening Scores	Completeness	Effectiveness (POOCs)	Efficiency (cost magnitudes)	Acceptability	Life Safety
0	No Action	No Action assumes the Future Without-Project Condition	NA	No plan would be implemented to support or provide completeness	Does not alleviate any study issues. All risks associated with existing and FWOP remain.	Does not alleviate any study issues; no federal dollars expended.	Unacceptable to municipality and citizens, as well as regional and state agencies. Acceptable to USFWS / NOAA.	Risk to life safety stemming from flash floods remains
1	Nonstructural Measures							
	Nonstructural	Flood Warning System Removal of Impediments to Flow	28	Certain life safety risks would remain. Would leave out protecting roads and other critical areas/facilities, which would still allow impacts to transportation and emergency routes.	Remaining risk and uncertainty due to reliance on human actions to warn and properly floodproof. Not effective at solving transportation/emergency route problems.	Minor costs compared to structural alternatives	Highly acceptable to the public. Acceptable to resource agencies.	Although a bonafide warning system would be a critical component to life safety, the risk of effects/vulnerability remains high since the hazard remains unaddressed.
2	Diversion Channel South Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	24	Would be complete and to itself, leaving minor supporting items for the non-federal partners and stakeholders to add.	Would be highly effective at meeting study/project POOCs.	Building two levees would double the cost.	Would be acceptable to municipality in terms of flood risk reduction; would be acceptable for permitting; would be unacceptable to USFWS / NOAA. Technically unacceptable because there is no need for two levees.	Risk to life safety is greatly reduced by moving the flood waters to rural lands to the west. Engineered channel produces dangerous currents and velocities.
3	Diversion Channel South Single Line Protection							
	Structural	Levees/Floodwalls Single Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	25	Would be complete and to itself, leaving minor supporting items for the non-federal partners and stakeholders to add.	Would be highly effective at meeting study/project POOCs.	Half the cost of two levees.	Would be acceptable to municipality in terms of flood risk reduction; would be acceptable for permitting; would be unacceptable to USFWS / NOAA.	Risk to life safety is greatly reduced by moving the flood waters to uninhabited lands to the west. Engineered channel produces dangerous currents and velocities.
4	Diversion Channel North Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (North) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	9	Would be complete and to itself, leaving minor supporting items for the non-federal partners and stakeholders to add.	Would be moderately effective at meeting study/project POOCs.	High costs due to alignments and crossing natural river channel several times, and robust engineering techniques and mitigation.	May be unacceptable in terms of floodway and 401 permitting; unacceptable to municipality and citizens; unacceptable to USFWS / NOAA. Technically unacceptable because there is no need for two levees.	Would increase life safety hazards with engineered channels confining flows and creating dangerous velocities in town; risk of overtopping in town; higher risk of erosion to town infrastructure
5	Diversion Channel Staged Greenway Terraces w/ Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Levees/Floodway Utility Relocation Staged Greenway Terraces Minor Nature-based Features (Channel Stabilization) Vegetation Control Invasive Species	28	Would be complete and to itself, leaving minor supporting items for the non-federal partners and stakeholders to add.	Would be highly effective at meeting study/project POOCs.	Cost similar to Alt#2; slightly more expensive due to quantity of excavated material.	Would be acceptable to municipality in terms of flood risk reduction; would be acceptable for permitting; would be acceptable to USFWS / NOAA. Technically unacceptable because there is no need for two levees.	Risk to life safety is greatly reduced by moving the flood waters to uninhabited lands to the west. Greenway channel produces much less dangerous currents and velocities due to being wider and unconfined.
6	Diversion Channel Staged Greenway Terraces w/ Single Line Protection							
	Structural	Levees/Floodwalls Single Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Levees/Floodway Utility Relocation Staged Greenway Terraces Minor Nature-based Features (Channel Stabilization) Vegetation Control Invasive Species	29	Would be complete and to itself, leaving minor supporting items for the non-federal partners and stakeholders to add.	Would be highly effective at meeting study/project POOCs.	Cost similar to Alt#3; slightly more expensive due to quantity of excavated material.	Would be acceptable to municipality in terms of flood risk reduction; would be acceptable for permitting; would be acceptable to USFWS / NOAA.	Risk to life safety is greatly reduced by moving the flood waters to uninhabited lands to the west. Greenway channel produces much less dangerous currents and velocities due to being wider and unconfined.

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Table 3: Alternative Screening Matrix (Continued)

Alt #	Alternative Name	Measure Components	Screening Scores	Natural Resources	HTRW	Real Estate	Infrastruct Relocations	Sustainability / O&M
0	No Action	No Action assumes the Future Without-Project Condition	NA	Remain in existing condition; no effects to critical T&E habitat; no effects to natural river channel habitats/species	NA	None required	None required	Natural channel riverine ecosystem remains fluviogeomorphically sustainable; no O&M required
1	Nonstructural Measures							
	Nonstructural	Flood Warning System Removal of Impediments to Flow	28	Remain in existing condition; no effects to critical T&E habitat; no effects to natural river channel habitats/species	Buyouts and floodproofing activities on high-risk properties may increase HTRW hazards.	Channel easements required for flow impediment removal.	Infrastructure would be left in place, or completely removed for buyouts.	Natural channel riverine ecosystem remains fluviogeomorphically sustainable; removal of impediments to flow is basically an O&M like activities, where it needs to be done as scheduled or responsive to events.
2	Diversion Channel South Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	24	Second largest impact to T&E critical habitat; retains required flows and connectivity in natural river channel; mitigation for critical karst habitat needed for limestone riprap mining.	Risk of encountering HTRW along alignment is low-med as project area is primarily rural/agricultural with known historic pesticide use. Risk to project implementation is low because soils are being managed onsite.	Easements and acquisition of land required for diversion channel and levee alignments. Moderate intensity/	All alternatives have seeming intense infrastructure relocations, realignments and replacements.	Natural channel riverine ecosystem is mostly fluviogeomorphically sustainable; high levels of O&M required to keep engineered diversion channel and levees free of debris, vegetation and sediment
3	Diversion Channel South Single Line Protection							
	Structural	Levees/Floodwalls Single Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	25	Third largest impact to T&E critical habitat; retains required flows and connectivity in natural river channel; mitigation for critical karst habitat needed for limestone riprap mining.	Risk of encountering HTRW along alignment is low-med as project area is primarily rural/agricultural with known historic pesticide use. Risk to project implementation is low because soils are being managed onsite.	Easements and acquisition of land required for diversion channel and levee alignments. Moderate intensity,	All alternatives have seeming intense infrastructure relocations, realignments and replacements.	Natural channel riverine ecosystem is mostly fluviogeomorphically sustainable; high levels of O&M required to keep engineered diversion channel and levees free of debris, vegetation and sediment
4	Diversion Channel North Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (North) Rehabilitate Phase I (DNER Constructed) Vegetation Control Utility Relocation Minor Nature-based Features (Channel Stabilization)	9	Largest impact to T&E critical habitat; induces higher than normal flow velocities in natural channel reaches; alters connectivity for diadromous fishes; removes additional forest habitat; could increase sedimentation rates in estuary	Risk of encountering HTRW along alignment is medium as project area is along commercial and industrial properties. Risk to project implementation remains low if soils are managed onsite.	Seemingly would require the most parcels and number of land owners to negotiate with. High intensity.	All alternatives have seeming intense infrastructure relocations, realignments and replacements.	Riverine ecosystems lose sustainability functions; Highest levels of maintenance would be needed to keep canalized reaches of river clear of debris, vegetation and sediment.
5	Diversion Channel Staged Greenway Terraces w/ Double Line Protection							
	Structural	Levees/Floodwalls Double Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Levees/Floodway Utility Relocation Staged Greenway Terraces Minor Nature-based Features (Channel Stabilization) Vegetation Control Invasive Species	28	Effects equivalent to Alt 2 except diversion channel would convert agricultural field to greenway habitat, which would further reduce rock mining needs and aid in offsetting mitigation needs for karst habitat	Risk of encountering HTRW along alignment is low-med as project area is primarily rural/agricultural with known historic pesticide use. Risk to project implementation is low because soils are being managed onsite.	Generally the same real estate requirements as Alt 3, but would need additional acres due to a much wider greenway diversion channel	All alternatives have seeming intense infrastructure relocations, realignments and replacements.	Natural channel riverine ecosystem is mostly fluviogeomorphically sustainable; low levels of O&M required to keep open natural diversion channel and levees free of debris, vegetation and sediment; diversion channel becomes self sustaining greenway habitat
6	Diversion Channel Staged Greenway Terraces w/ Single Line Protection							
	Structural	Levees/Floodwalls Single Line Protection Bridge & Conveyance Modifications Engineered Features & Bank Protection Diversion Channel (South) Rehabilitate Phase I (DNER Constructed) Vegetation Control Levees/Floodway Utility Relocation Staged Greenway Terraces Minor Nature-based Features (Channel Stabilization) Vegetation Control Invasive Species	29	Least impact alternative; diversion channel would convert agricultural field to greenway habitat, which would further reduce rock mining needs and aid in offsetting mitigation needs for karst habitat	Risk of encountering HTRW along alignment is low-med as project area is primarily rural/agricultural with known historic pesticide use. Risk to project implementation is low because soils are being managed onsite.	Generally the same real estate requirements as Alt 3, but would need additional acres due to a much wider greenway diversion channel. More real estate would be needed for additional channel width for no levee on west side.	All alternatives have seeming intense infrastructure relocations, realignments and replacements.	Natural channel riverine ecosystem is mostly fluviogeomorphically sustainable; low levels of O&M required to keep open natural diversion channel and levees free of debris, vegetation and sediment; diversion channel becomes self sustaining greenway habitat

