Maintain and Improve Aging and Failing Gray and Green Infrastructure that Negatively Impacts Water and Bottom Sediment Quality

Sanitary Sewer Infrastructure

Baseline

Sanitary sewer infrastructure within the San Juan Bay Estuary (SJBE) system is critical for maintaining water quality and public health, yet it faces significant challenges. Aging systems and capacity limitations are compounded by vulnerabilities related to sea level rise and increased storm events and intensity. Effective wastewater management is essential to prevent pollution and protect aquatic habitats.

The discharge of raw sewage into the SJBE presents a health risk to surrounding communities, estuary users, and living resources (Estuario, 2000). Untreated sewage discharges introduce high levels of nutrients, pathogens, and other pollutants, which harm aquatic ecosystems, threaten public health, and impair the potential for recreational and economic activities (USACE, 2016). Public health impacts are a significant concern associated with inadequate wastewater management. The state of sanitary sewer infrastructure directly affects the risk of waterborne diseases and other health issues, particularly among vulnerable populations in the region.

The absence of proper sanitary sewer coverage in densely populated sectors, such as Juana Matos, Cucharillas, and Puente Blanco in Cataño, contributes significantly to the degradation of water quality within the SJBE and its tributaries. Additionally, communities such as Cantera, Marina, Buena Vista, Israel, and Bitimul were established on the eastern banks of the Caño Martín Peña by filling its waters and wetlands with debris and other types of refuse (Sepúlveda-Rivera and Carbonell, 1988). This housing was developed without sanitary sewers, leading to the discharge of untreated sewage into improvised gutters or directly into the Caño Martín Peña. Similar conditions can be found in other communities within the SJBE system, including Palo Seco in Toa Baja; Vietnam and Amelia in Guaynabo; Playita, El Checo, Sierra Maestra, Villa Clemente, and Plebiscito 1, 2, and 3 in San Juan; and La Torre and Piñones in Loíza. In some areas, residents have built on-site septic systems to dispose of wastewater instead of discharging it directly into the estuary, its tributaries, or other related surface waters. However, the use of underground septic tanks is inappropriate in these low-lying areas, which are prone to flooding and seepage.

Low-lying coastal regions, including those within the SJBE, are particularly susceptible to sea level rise, which can lead to flooding and increased risks for subsurface infrastructure, including sanitary sewer systems. Groundwater levels can rise as sea levels increase, impacting the functionality of both centralized and decentralized systems. Approximately 35%–40% of Puerto Rico's population relies on septic systems for domestic wastewater disposal, and these systems can contribute to water quality issues, especially when poorly maintained or located near waterbodies (USEPA, 2019). Communities such as Juana Matos and Puente Blanco are particularly vulnerable, facing risks from flooding that can lead to sewage overflow and contamination of local waterways.

Sanitary sewer systems in the SJBE have historically faced significant challenges. The Clean Water Act, enacted in 1972, established regulations to control the discharge of pollutants. The National Pollutant Discharge Elimination System (NPDES) was established in 1987 to monitor compliance with water quality standards. Despite these regulatory frameworks, the current wastewater treatment systems, including the Carolina Regional, Bayamón Regional, and Puerto Nuevo Wastewater Treatment Systems, have a history of poor maintenance and frequent overflows (USEPA, 2011). These systems specifically, which collectively handle an average flow of 177 million gallons per day, are exempt from secondary treatment requirements under Section 301(h) of the Clean Water Act. This exemption under Section 301(h) is due to Puerto Rico’s

unique geographic, economic, and infrastructural challenges that make full secondary wastewater treatment difficult to achieve or maintain (U.S. Environmental Protection Agency [USEPA], 2011).

Illicit discharges from unauthorized sources further complicate water quality challenges in the SJBE. These discharges can originate from industrial activities, informal systems, and stormwater runoff, complicating monitoring and enforcement efforts. Effective identification and response to illicit discharges require collaboration among local agencies and community education and involvement, which is often hampered by limited resources. As the population in the watershed continues to grow and the existing wastewater infrastructure ages and becomes inadequate, there is a pressing need to invest in new infrastructure and technology to provide reliable and higher levels of wastewater treatment.

There are frameworks and plans in place to help address the current challenges associated with sanitary sewer infrastructure. Puerto Rico Aquifer and Sewer Authority (PRASA) is implementing an extensive capital improvements program across the island, with 67 projects currently underway in the study area. These projects range from replacing outdated pipes to rehabilitating entire sanitary sewer systems. Furthermore, the Caño Martín Peña Comprehensive Infrastructure Master Plan represents a proactive approach to addressing the unique challenges faced by communities around Caño Martín Peña. This plan emphasizes community agency and incorporates extreme events risk analysis to develop strategies for improving water quality and public health.

The SJBE Illegal Discharges Detection & Elimination Task Force (IDDE) Task Force is a working group assembled in 2014 by Estuario that meets periodically to discuss and implement solutions for the elimination of illegal and unauthorized sewage discharges in the SJBE watershed. The IDDE Task Force includes members from the state and federal environmental agencies, municipalities, academia, and stakeholders. After the IDDE Task Force was created in 2014, Estuario received a grant from the Puerto Rico Environmental Quality Board (now Department of Natural and Environmental Resources [DNER]) through the State Revolving Funds and Section 319 of the Clean Water Act to identify raw sewage and other pollutant discharges in the SJBE watershed. After a careful and rigorous selection process, Estuario contracted the University of Puerto Rico's Agriculture Experimental Station to perform the study. The study's findings are discussed through the IDDE Task Force; therefore, this group became the platform to implement and monitor corrective actions.

Ultimately, the successful elimination of illegal commercial and residential sewage discharges relies on a multifaceted approach that combines routine monitoring, community engagement and education, regulatory enforcement, and infrastructure enhancement. The SJBE faces significant challenges related to wastewater management stemming from aging infrastructure, growing population density, and environmental pressures.

Objectives

- Eliminate illicit discharges from sanitary sewer infrastructure.
- Optimize existing septic systems.

Actions

MI-01 Design and construct a sanitary sewer system for the communities fringing the eastern section of Caño Martín Peña and other areas that lack an adequate system. Adaptation

ACTIVITIES

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Implement the priority sanitary sewer improvements recommended in the Caño Martín Peña Infrastructure Master Plan to improve water quality and system performance.	Reduce pollutants to the SJBE system from sanitary sewer systems in these communities.	Added sanitary sewer systems for the communities along the Caño Martín Peña.	Lead: PRASA Implementing partners: DNER, Municipality of San Juan, regulatory agencies	On Track	5+ years	TBD	USEPA, State Revolving Fund, PRASA, DNER, municipalities, Federal Emergency Management Agency (FEMA), Community Development Block Grant (CDBG), U.S. Army Corps of Engineers (USACE)
2. Use the Caño Martín Peña Infrastructure Master Plan to develop a sanitary sewer management plan for the Caño Martín Peña communities (Barrio Obrero San Ciprián, Buena Vista Santurce and Israel – Bitumul).	Identify priority areas for sanitary sewer infrastructure improvements and construction.	Identified priority areas for sanitary sewer infrastructure improvements.	Lead: PRASA Implementing partners: DNER, municipalities, academia, scientific community, community groups, Estuario	Pending	3-5 years	TBD	USEPA, DNER, municipalities, FEMA, CDBG, USACE
3. Conduct a needs assessment in conjunction with the communities to identify additional areas that currently lack sanitary sewer systems.	Complete a needs assessment report identifying areas without sanitary sewer coverage.	Completed assessment.	Lead: PRASA Implementing partners: DNER, scientific community, municipalities, community groups, Estuario	Pending	0-2 years	TBD	USEPA, DNER, municipalities, USACE
4. Develop designs and plans of identified areas and secure funding to support the construction and maintenance of new sewer systems.	Complete design plans and successful acquisition of funding commitments.	Finalized designs and secure funding.	Lead: PRASA Implementing partners: DNER, scientific community, municipalities, Estuario	Pending	3-5 years	TBD	USEPA, DNER, municipalities, USACE

5. Develop a wastewater management plan for the San Juan Metropolitan Region that includes infrastructure upgrades, regulatory compliance measures, pollution reduction strategies, emergency response protocols, and funding sources.	Complete a comprehensive wastewater management plan addressing upgrades, compliance, pollution reduction, and emergency response.	Developed and implemented the wastewater management plan.	Lead: PRASA Implementing partners: DNER, municipalities, private utilities, regulatory agencies, academia	Pending	3-5 years	TBD	USEPA, DNER, municipalities
6. Construct and achieve fully operational status for new sanitary sewer systems and monitor effectives and compliance.	Construct new sanitary sewer systems and verify that they are fully operational.	Completed construction and achieved full operational status.	Lead: PRASA Implementing partners: DNER, municipalities	Pending	5+ years	TBD	USEPA, DNER, municipalities, USACE

Regulatory and Policy Requirements

Raw sewage discharges into surface waterbodies result in a violation of DNER's Water Quality Standards and USEPA issued NPDES permits and their implementing regulations. A compliance plan must be developed, funded, and enforced.

MI-02 Implement infrastructure retrofits to support the reduction of raw sewage discharges into the SJBE. Adaptation

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Eliminate overflows and bypasses through adequate operation and maintenance of systems.	Improve collection system and pump station maintenance to reduce discharges.	Reduced the number of overflow incidents per year.	Lead: PRASA Implementing partner: DNER	On Track	5+ years	TBD	PRASA, State Revolving Fund, USACE
2. Identify and work with private utilities to improve private sewage collection and treatment systems.	Improve collection system and pump station maintenance to reduce discharges.	Established partnerships with private utilities to reduce discharges.	Lead: Private utilities Implementing partners: USEPA, Estuario	Pending	0-2 years	TBD	USEPA, State Revolving Fund, USACE

3. Identify and address locations of unregulated/ unauthorized sewer outflows and conduct enforcement.	Reduce pollutants from wastewater in stormwater outflows.	Reduced pollutant concentrations from combined sewer outflows through compliance.	Lead: DNER Implementing partner: USEPA	Pending	3-5 years	TBD	USEPA, State Revolving Fund, USACE
4. Prioritize and implement correction programs for unresolved or high-risk contamination sites such as Juan Méndez Creek North, El Cinco, Fairview (16th Street), and Country Club.	Identify and prioritize high-risk contamination sites for remediation.	Developed and approved remediation plans for prioritized sites, initiating corrective actions.	Leads: PRASA, private utilities Implementing partners: DNER, USEPA	Pending	3-5 years	TBD	USEPA, State Revolving Fund, USACE
5. Ensure redundancies in the system are in place to improve performance.	Number of redundancies incorporated into the system to enhance reliability and performance, such as automatization and electricity backup.	Designed and implemented redundancies covering critical system components.	Leads: PRASA, private utilities Implementing partners: DNER, USEPA	Pending	3-5 years	TBD	USEPA, State Revolving Fund, USACE
6. Facilitate discussion and participation in the IDDE Task Force.	Number of IDDE Task Force meetings held and level of stakeholder participation.	Conducted IDDE Task Force meetings.	Lead: Estuario Implementing partners: PRASA, DNER, USEPA, municipalities, academia	Pending	0-2 years	TBD	USEPA, USACE

Regulatory and Policy Requirements

Wastewater treatment and discharge are regulated by the NPDES permit program, Clean Water Act, and applicable PRASA rules and regulations. Unauthorized raw sewage discharges and bypasses into surface waterbodies result in a violation of DNER water quality standards. A compliance plan should be developed and enforced.

MI-03 Eliminate illegal commercial and residential sewage discharges into the stormwater sewer system.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Identify all residential, commercial, and industrial sanitary connections to the storm sewer system that eventually discharge into the SJBE.	Improve illicit discharge reporting and tracking.	Documented and mapped identified sanitary connections to the storm sewer system.	Leads: DNER, PRASA Implementing partners: municipalities	Ongoing	0-2 years	TBD	DNER, municipalities, PRASA, USEPA, State Revolving Fund, USACE
2. Connect illicit discharges to the sanitary sewer system and conduct enforcement for any violators who do not connect.	Reduce the number of illicit discharges.	Identified violators and connected them to the sanitary sewer system or conducted enforcement .	Leads: PRASA, municipalities, DNER Implementing partner: USEPA	Ongoing	0-2 years	TBD	DNER, municipalities, PRASA, State Revolving Fund, USACE, USEPA
3. Construct sanitary sewer systems in unserved high-risk areas, using discharge location data.	Number of sanitary sewer systems constructed in identified high-risk, unserved areas.	Completed construction in high-risk areas.	Leads: PRASA, municipalities Implementing partner: DNER	Pending	5+ years	TBD	DNER, municipalities, PRASA, State Revolving Fund, USACE

Regulatory and Policy Requirements

Unauthorized raw sewage discharges and bypasses into surface waterbodies result in a violation of DNER's water quality standards and applicable provisions, NPDES permits, Clean Water Act, and applicable PRASA rule and regulations. A compliance plan must be developed and enforced.

**NEW* MI-04 Collaborate with local industry to improve wastewater infrastructure and treatment levels using the best available technology. Adaptation*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Identify deficiencies in current treatment plants regarding nutrient removal capabilities and areas needed upgrades.	Complete an evaluation report identifying nutrient removal deficiencies and upgrade needs at treatment plants.	Completed evaluation for all identified treatment plants.	Lead: PRASA Implementing partners: private utilities, regulatory agencies	Pending	0-2 years	TBD	USEPA, DNER, municipalities, private utilities, USACE

2. Develop partnerships with industry to identify viable wastewater treatment technologies with higher treatment efficiencies and modify wastewater treatment standards to require higher pollutant removal.	Improve treatment of wastewater.	Established partnerships to identify innovate treatment technologies and revised treatment standards.	Leads: PRASA, private utilities, DNER Implementing partners: local industries, Estuario, USEPA	Pending	3-5 years	TBD	PRASA, private utilities, local industries, DNER, USEPA
3. Implement identified technologies with higher treatment levels at major wastewater facilities.	Improve treatment of wastewater resulting in reduced pollutants discharged to the SJBE system.	Installed and operated treatment technologies.	Leads: PRASA, private utilities Implementing partners: local industries	Pending	3-5 years	TBD	USEPA, State Revolving Fund, local industries

Regulatory and Policy Requirements

Modification of local standards to require higher wastewater treatment levels and implementation through facility NPDES permits.

**NEW* MI-05 Create and manage an integrated public system for reporting the resolution of illicit discharges, as opposed to each agency and municipality handling its own in private.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Establish protocols and workflows for coordination and response between agencies and partners.	Develop and implement formal protocols and workflows for inter-agency coordination and response.	Approved coordination protocols with key agencies.	Lead: Estuario Implementing partners: DNER, USEPA, PRASA, Department of Transportation and Public Works (DTOP), private utilities, municipalities	Pending	0-2 years	TBD	DNER, USEPA
2. Implement data-sharing agreements among agencies and partners to facilitate transparency and comprehensive tracking.	Number of data-sharing agreements executed and active among agencies and partners.	Established data-sharing agreements with key agencies.	Lead: Estuario Implementing partners: DNER, USEPA, PRASA, DTOP, private utilities, municipalities	Pending	0-2 years	TBD	DNER, USEPA

3. Develop a training curriculum for responding to and reporting wastewater overflows and collaborate with public and private utilities to conduct workshops.	Define a process to respond to and report wastewater spills and educate staff to better track wastewater overflows.	Trained personnel and citizens to respond to and report wastewater overflows.	Leads: DNER, USEPA Implementing partners: PRASA, private utilities, DTOP, Estuario	Pending	3-5 years	TBD	DNER, USEPA
4. Design, build, test, and publish the integrated public system and dashboard and encourage community participation in reporting illicit discharges.	Increase engagement and provide a system for illicit discharge reporting.	Published the integrated public system and dashboard.	Lead: Estuario Implementing partners: DNER, USEPA, PRASA, DTOP, private utilities, municipalities	Pending	3-5 years	TBD	DNER, USEPA

Regulatory and Policy Requirements

Currently, each agency and municipality manage complaints separately. However, citizens do not know to which agency or municipality they should make the complaint. The Puerto Rico Innovation and Technology Service could develop an integrated system for receiving, managing, and providing updates on complaints to reduce confusion and provide accountability.

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Stormwater Infrastructure

Baseline

Stormwater runoff, whether from extreme weather events or typical rainfall, has an impact on the SJBE system. Urban land use and land cover are intrinsic to stormwater management and runoff generation. According to Webb and Gómez Gómez (1998), approximately 60% of the rainfall in the region is converted to runoff that flows into the estuary. The stormwater systems in Puerto Rico are primarily the responsibility of the municipalities; however, DTOP and DNER also play significant roles in planning, regulating, and maintaining stormwater infrastructure, particularly in coordination with municipal authorities and PRASA. This multi-agency responsibility can complicate management and maintenance efforts due to overlapping jurisdictions (Bauzá-Ortega, 2015).

Figure 1. Stormwater System Management

The presence of combined wastewater and stormwater pipeline networks presents unique challenges. In a settlement in 2023, PRASA agreed to increase transparency with the public regarding the combined sewer overflows.

The SJBE watershed is predominantly urban, with 60.3% classified as “urban land” (Government of Puerto Rico, 2015). However, this classification oversimplifies a larger problem: the high level of urbanization leads to significant increases in impervious surfaces, such as rooftops, roads, and parking lots, which drastically reduce natural infiltration and increase stormwater runoff volume and velocity. This intensifies flooding risks and accelerates pollutant transport to waterbodies. Furthermore, urban infrastructure often lacks sufficient capacity or design to manage these altered hydrological patterns, contributing to frequent flooding events and environmental degradation (Santos Flores and Martínez-Rodríguez, 2020; Burgos-López, 2025). This high level of urbanization results in high volumes of stormwater runoff, particularly in areas such as the San José Lagoon, whereabout 90% of the freshwater inflows are attributed to urban runoff. (Santos Flores and Martínez-Rodríguez, 2020). Approximately 70% of the rainfall was converted into inflows to Torrecilla, San José, and Piñones, which increased the waterbody levels to a point that they did not return to normal levels during the sampling period (Santos Flores and Martínez-Rodríguez, 2020).

These waterbodies gather pollutants from the watershed and can export these pollutants during high rainfall events and flow reversal periods. Specifically, during heavy rainfall and flow reversal, these lagoons and estuarine waterbodies can export accumulated nutrients, pathogens, sediments, and other contaminants downstream into coastal waters and the Atlantic Ocean, potentially affecting marine ecosystems and coastal water quality. This export process increases the spatial extent of pollution beyond the estuary and can cause harmful algal blooms and other ecological disturbances in coastal zones (Ramírez et al., 2012). Understanding these pollutant dynamics is critical for effective watershed and coastal management.

The Cucharillas Marshland in Cataño plays a role in flood protection and water quality improvement, acting as a sponge to absorb high levels of runoff. The Cucharillas Marshland consists of mostly herbaceous wetlands, mangroves, and open water. Its hydrology is influenced by stormwater, tidal cycles, and runoff

from urban areas and a pump station operated by DNER to minimize flooding during heavy rainfall events in surrounding communities (Ramírez et al., 2012). Obstructions and backflow of raw sewage at points of discharge can be seen when extreme weather and flooding events occur (Bauzá-Ortega, 2015). Additionally, flooding has become a more prominent concern throughout the SJBE watershed, exacerbated by urban expansion, upstream deforestation, impermeabilization and sea level rise, among other stressors. A key project addressing flooding is the Río Puerto Nuevo Flood Damage Reduction Project, which involves channelizing over 17 kilometers of the Río Piedras in San Juan to reduce flood risks in densely urbanized areas (USACE, 2023). Engineered flood control projects that integrate structural and non-structural components are vital complements to comprehensive stormwater management efforts.

Urbanization and land use patterns significantly influence stormwater generation and pollutant transport in the SJBE watershed. The replacement of natural infiltration zones with impervious surfaces, such as rooftops and roadways, exacerbates runoff volumes and sedimentation, leading to higher pollutant loads entering the estuary. Consequently, these pollutants can enter the SJBE and affect its ecological functions for months or even years (Lugo and Bauzá Ortega, 2024). Current planning tools, such as the Puerto Rico Land Use Plan fail to recognize the hydrological and ecosystem contributions of pervious surfaces, categorizing them uniformly as "urban land" (Burgos-López, 2025). This oversimplification neglects their critical role in stormwater infiltration, urban cooling, and exacerbating environmental challenges. The role of transportation infrastructure also cannot be overlooked, as roads and highways significantly contribute to stormwater runoff and environmental degradation. As highlighted Burgos-Lopez's findings, "transportation infrastructure also plays a significant role in shaping urban dynamics," underscoring the need for integrated planning that includes green infrastructure solutions (2025).

In light of these challenges, updating and enhancing comprehensive drainage maps of the SJBE watershed is essential for effective water management and flood mitigation strategies. Accurate and detailed drainage maps provide critical information about the existing stormwater infrastructure, including drainage patterns, flow paths, and areas prone to flooding. Enhanced drainage maps can facilitate better planning and decision-making processes. The process of updating drainage maps should involve community engagement and input from local stakeholders. Involving residents, community organizations, and businesses in the mapping process can provide valuable insights into local drainage issues and enhance public awareness of stormwater management challenges.

In addition, there are significant areas within the SJBE watershed that lack adequate infrastructure altogether. These areas often rely on informal drainage systems or have no stormwater management solutions in place, leading to increased vulnerability during heavy rainfall and extreme events. The Caño Martín Peña Special Planning District suffers from degraded channel conditions and informal community development, which contribute to chronic flooding issues. Many areas lack formal stormwater sewer systems and have poorly maintained water infrastructure, leading to frequent inland flooding and direct wastewater discharges into canals. The existing systems are often clogged or improperly functioning, posing additional environmental and health risks (Proyecto ENLACE, 2022). In addition, communities within the San Juan Metropolitan Region, that are part of SJBE watershed, face significant challenges due to inadequate or nonexistent stormwater infrastructure. Many neighborhoods, particularly those in low-lying or rapidly urbanizing areas, lack proper drainage systems to effectively manage stormwater runoff. This deficiency leads to frequent flooding, property damage, and increased public health risks from waterborne

contaminants during rain events. Moreover, the absence of effective comprehensive stormwater management contributes to the degradation of water quality in local waterways.

Without proper infrastructure, stormwater runoff can overwhelm natural drainage pathways. Adequate infrastructure includes well-designed and maintained drainage channels, culverts, retention basins, and storm drains capable of handling local runoff volumes. Insufficient maintenance practices, such as failure to remove debris, sediment, and vegetation that can block drainage and cause localized flooding, are also an issue for stormwater management. Effective maintenance is essential to ensure stormwater infrastructure functions properly and reduces flood risks (Bauzá-Ortega, 2015). Improper stormwater infrastructure not only threatens the ecological balance of the SJBE but also poses serious public health risks for communities that depend on the watershed's water resources for recreation and sustenance.

To improve stormwater infrastructure in the watershed a combination of gray, green, and hybrid solutions should be considered. Gray infrastructure refers to traditional, engineered systems such as stormwater drains designed to manage water flows and move stormwater away from urban areas through pipes and conduit. In contrast, green infrastructure encompasses natural systems and processes, such as wetlands and vegetated areas, to absorb, reduce, and manage stormwater while providing ecological benefits (USEPA, 2017). Recognizing the interdependence of gray and green infrastructure, the development of hybrid infrastructure solutions may be needed that integrate both approaches. By fostering collaboration between engineered systems and natural ecosystems, the resilience of water management strategies in the SJBE can be enhanced. A hybrid approach can improve water quality and promote ecosystem services, which are socially valued outputs of ecosystems dependent on self-regulating or managed ecosystem structures and processes (USACE, 2013). In the case of the SJBE, ecosystem services examples include flood mitigation, water purification, and habitat provision.

Sustainable development practices have become increasingly essential in urban regions to reduce environmental impacts, improve energy efficiency, and enhance community well-being. Green infrastructure practices such as green roofs, permeable pavements, rain gardens, and bioswales offer effective solutions for increasing permeability on private properties. These features mimic natural processes by capturing, infiltrating, and filtering stormwater onsite, thereby reducing runoff volume, mitigating flood risks, and improving water quality (USEPA, 2021). In addition, the Leadership in Energy and Environmental Design (LEED) certification provides a widely recognized framework for promoting environmentally responsible construction and operation, emphasizing energy efficiency, water conservation, sustainable materials, and indoor environmental quality (U.S. Green Building Council [USGBC], 2023). New construction projects adhering to LEED standards can substantially reduce the ecological footprint of urban development by minimizing resource use and mitigating pollution, thereby supporting the broader goals of watershed protection and climate resilience in the SJBE system.

The legal and institutional priorities guiding stormwater infrastructure in Puerto Rico are outlined in consent decrees for the Municipality of San Juan, DTOP, and DNER. These consent decrees set forth specific requirements aimed at improving stormwater management and ensuring compliance with federal water quality standards. For instance, the consent decree for the Municipality of San Juan mandates the implementation of measures to reduce combined sewer overflows, which directly impact stormwater quality and infrastructure effectiveness (Consent Decree, 2015).

The stormwater infrastructure in the SJBE watershed faces numerous challenges, exacerbated by urbanization, extreme weather events, sea level rise, and regulatory complexities. Addressing these issues requires a comprehensive approach that incorporates improved monitoring, community engagement, and adherence to regulatory policies.

Objectives

- Eliminate illicit discharges and reduce sediments and contaminants reaching the estuarine system from stormwater systems.
- Restore and strengthen green infrastructure to improve stormwater management.

Actions

MI-06 Design and construct a stormwater system for the communities fringing the eastern section of Caño Martín Peña and other adjacent communities that currently lack adequate infrastructure. ADAPTATION

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Improve the stormwater system for the communities along Caño Martín Peña to address previously identified infrastructure needs.	Reduce pollutants to the SJBE system from stormwater runoff in these communities.	Completed stormwater projects in the communities along Caño Martín Peña.	Lead: PRASA Implementing partners: municipalities	On Track	5+ years	TBD	USEPA, State Revolving Fund, PRASA, DNER, municipalities, USACE
2. Identify priority areas, analyze drainage patterns, and determine flood risks with engagement from community members and local stakeholders.	Complete a risk assessment report identifying priority areas with detailed analysis of drainage patterns and flood vulnerabilities.	Finalized analysis of priority areas.	Leads: DNER, DTOP, municipalities Implementing partners: scientific community, community groups, Estuario	Pending	0-2 years	TBD	USEPA, DNER, municipalities, DTOP, USACE
3. Develop a stormwater management plan for the SJBE watershed and implement priority recommendations.	Identify priority areas and implement projects for stormwater infrastructure improvements .	Executed priority projects from the stormwater management plan.	Leads: Estuario, PRASA Implementing partners: DNER, municipalities, academia, scientific community, community groups	Pending	3-5 years	TBD	State Revolving Fund, USEPA, PRASA, DNER, municipalities, USACE

Regulatory and Policy Requirements

Municipal separate storm sewer system (MS4) discharges are regulated under the Clean Water Act. Pursuant to this Act, USEPA issued regulations under the NPDES program which intend to minimize, reduce, control, and/or eliminate discharges of contaminated stormwater through storm sewers.

**NEW* MI-07 Design and upgrade the current infrastructure to support stormwater management in the San Juan Metropolitan Region. ADAPTATION*

ACTIVITIES

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Assess existing infrastructure to identify deficiencies, aging components, and areas prone to flooding or pollution with input from community members and stakeholders.	Complete a detailed infrastructure assessment report identifying deficiencies, aging components, and vulnerable areas.	Finalized assessment for all critical infrastructure.	Leads: DNER, DTOP, municipalities Implementing partners: scientific community, community groups, Estuario	Pending	3-5 years	TBD	USEPA, DNER, municipalities, DTOP, USACE
2. Conduct an hydrologic and hydraulic assessment of the Río Piedras watershed to identify priority areas.	Complete an hydrologic and hydraulic assessment report identifying priority areas for intervention.	Finalized hydrologic and hydraulic assessment and made the information publicly available.	Leads: DNER, PRASA, scientific community Implementing partners: Municipality of San Juan, La Alianza, Coalición Comunitaria, Estuario, USACE	Pending	3-5 years	TBD	USEPA, DNER, PRASA, USACE
3. Develop retrofit designs with a focus on green infrastructure with involvement from local communities and stakeholders.	Complete retrofit design plans emphasizing green infrastructure solutions with community and stakeholder input.	Finalized green infrastructure retrofit designs	Leads: DNER, PRASA, Municipality of San Juan, Estuario Implementing partners: Scientific community, La Alianza, Coalición Comunitaria, Para La Naturaleza USACE, DTOP, PRASA, academia, USACE	Pending	3-5 years	TBD	USEPA, DNER, PRASA, USACE

4. Secure funding and regulatory approvals to then implement construction and installation.	Secure funding and obtain regulatory approvals for project implementation.	Secured required funding and regulatory approvals.	Leads: DNER, DTOP, municipalities Implementing partners: scientific community, community groups	Pending	5+ years	TBD	USEPA, DNER, municipalities, DTOP, USACE

Regulatory and Policy Requirements

Regular monitoring, emergency preparedness, and infrastructure redundancy measures must be implemented to meet regulatory performance and reliability standards.

**NEW* MI-08 Develop and implement a stormwater management plan at the watershed level for the San Juan Metropolitan Region. Adaptation*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Conduct a study on flow reversals to understand their causes, frequency, and impacts on water quality and flooding.	Complete a comprehensive study detailing causes, frequency, and impacts of flow reversals on water quality and flooding.	Finalized study and provided actionable recommendations.	Lead: Estuario Implementing partners: DNER, PRASA, DTOP, municipalities, scientific community, community groups	Pending	3-5 years	TBD	USEPA, DNER, municipalities, DTOP
2. Update drainage and land cover maps for the San Juan Metropolitan Region and create a georeferenced map of the stormwater management system.	Complete updated drainage, land cover, and stormwater system maps incorporating recent data and field verification.	Delivered updated maps to stakeholders.	Lead: Estuario Implementing partners: DNER, PRASA, DTOP, municipalities, scientific community, community groups	Pending	3-5 years	TBD	USEPA, DNER, municipalities, DTOP
3. Develop the stormwater management plan with community participation in identifying main stressors and priorities.	Improve stormwater management.	Gathered community input to improve stormwater management.	Lead: Estuario Implementing partners: DNER, PRASA, DTOP, municipalities, scientific community, community groups	Pending	5+ years	TBD	USEPA, DNER, municipalities, DTOP

Regulatory and Policy Requirements

Adherence to MS4 permit requirements and Regulation 40.

**NEW* MI-09 Design and implement the necessary stormwater infrastructure retrofits in the Río Piedras watershed to support the river's natural capacity to manage stormwater and prevent floods. ADAPTATION*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Conduct an hydrologic and hydraulic assessment of the Río Piedras watershed to identify priority areas.	Complete an hydrologic and hydraulic assessment report identifying priority areas for intervention.	Finalized hydrologic and hydraulic assessment and made the information publicly available.	Leads: DNER, PRASA, scientific community Implementing partners: Municipality of San Juan, La Alianza, Coalición Comunitaria, Estuario, USACE	Pending	3-5 years	TBD	USEPA, DNER, PRASA, USACE
2. Develop retrofit designs with a focus on green infrastructure with involvement from local communities and stakeholders.	Complete retrofit design plans emphasizing green infrastructure solutions with community and stakeholder input.	Finalized green infrastructure retrofit designs	Leads: DNER, PRASA, Municipality of San Juan, Estuario Implementing partners: Scientific community, La Alianza, Coalición Comunitaria, Para La Naturaleza USACE, DTOP, PRASA, academia, USACE	Pending	3-5 years	TBD	USEPA, DNER, PRASA, USACE
3. Expand monitoring to gather additional data on water level flows pre- and post-project.	Additional information to evaluate the project benefits.	Implemented expanded monitoring in the project area.	Lead: DNER Implementing partners: Municipality of San Juan, USACE, Estuario	Pending	5+ years	TBD	DNER, USACE
4. Maintain infrastructure to allow for proper stormwater conveyance.	Improved stormwater conveyance.	Added regular maintenance of the stormwater system.	Lead: Municipality of San Juan Implementing partner: DNER	Pending	3-5 years	TBD	Municipality of San Juan, DNER

Regulatory and Policy Requirements

None.

MI-10 Restore and enhance connectivity of riparian corridors along the SJBE tributaries. ADAPTATION

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Conduct a baseline assessment of existing riparian corridor conditions, identify gaps, and characterize flora species to develop planting plans.	Identify corridors for restoration based on existing conditions assessment.	Identified riparian corridors suitable for restoration.	Leads: DNER, United States Forestry Service (USFS), NRCS Implementing partners: municipalities, Estuario	Pending	0-2 years	TBD	DNER, USFS, NRCS
2. Develop enhancement and restoration measures and maintenance plans based on the condition of selected riparian corridors.	Improve condition of riparian corridors.	Created and implemented a restoration and maintenance plan for riparian corridors.	Leads: DNER, USFS, NRCS Implementing partners: municipalities, Estuario	On Track	3-5 years	TBD	DNER, USFS, NRCS, municipalities

Regulatory and Policy Requirements

Strengthen land-use regulations to prevent under permitted development in these regions. Enforce Bill 1439-24, which widens protected areas for riparian corridors.

**NEW* MI-11 Restore and maintain the natural flow regimes of tributaries to maximize stormwater management potential ADAPTATION*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop and implement restoration plans that prioritize the reestablishment of natural channel morphology and floodplain connectivity and monitor the flow recovery, stormwater benefits, and ecological health.	Complete and approve restoration plans focused on natural channel morphology and floodplain connectivity.	Developed plans and implemented restoration activities.	Leads: DNER, PRASA, scientific community, Estuario Implementing partners: municipalities, private utilities	Pending	3-5 years	TBD	USEPA, DNER, PRASA
2. Remove or retrofit existing barriers that disrupt natural flow patterns.	Number of barriers removed or retrofitted to restore natural flow patterns.	Removed or retrofitted identified flow-disruption barriers.	Leads: DNER, PRASA, private utilities Implementing partners: municipalities	Pending	5+ years	TBD	USEPA, DNER, PRASA, State Revolving Fund

Regulatory and Policy Requirements

None.

MI-12 Develop and issue NPDES permits to regulate stormwater discharges in urbanized areas of the SJBE watershed, such as Condado Beach, that contribute stormwater point source discharges to the system and its tributaries.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Conduct a stormwater system assessment to identify gaps and maintenance needs.	Complete a comprehensive stormwater system assessment report detailing infrastructure gaps and maintenance requirements.	Finalized assessment of the stormwater system.	Leads: PRASA, municipalities Implementing partners: DNER private utilities, Estuario	Pending	2-3 years	TBD	USEPA, State Revolving Fund, DNER
2. Support jurisdictions in designing stormwater infrastructure using best management practices (BMPs) and green infrastructure techniques.	Reduce pollutants through BMPs and green infrastructure.	Provided technical support to jurisdictions to result in BMPs and green infrastructure designs being adopted.	Lead: DNER Implementing partners: PRASA, municipalities, private utilities, Estuario	Pending	3-5 years	TBD	USEPA, State Revolving Fund, DNER
3. Develop and issue NPDES permits for MS4s within the SJBE watershed.	Number of NPDES permits issued and compliance rate among operators.	Increased permit compliance within the watershed.	Lead: DNER Implementing partners: PRASA, municipalities, private utilities	Pending	3-5 years	TBD	USEPA, DNER
4. Facilitate regional collaboration for shared resources.	Number of regional collaboration meetings held and shared resource agreements established.	Organized collaboration meetings.	Leads: Estuario, DNER Implementing partners: PRASA, municipalities, private utilities	Pending	2-3 years	TBD	USEPA, State Revolving Fund, DNER

Regulatory and Policy Requirements

MS4 discharges are regulated under the Clean Water Act. Pursuant to this act, USEPA issued regulations under the NPDES program to minimize, reduce, control, and/or eliminate discharges of contaminated stormwater through storm sewers. Permit compliance is needed to reduce stormwater impacts.

MI-13 Validate and implement the Master Plan for Green Infrastructure in the SJBE Watershed. ADAPTATION

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Validate the Green Infrastructure Master Plan.	Complete a validation report confirming the accuracy, feasibility, and stakeholder acceptance of the Green Infrastructure Master Plan.	Conducted validation activities.	Lead: Estuario, PRASA, municipalities Implementing partners: DNER, academia	Pending	3-5 years	TBD	USEPA, State Revolving Fund, DNER, USACE
2. Develop and distribute technical guides and resources on installing and maintaining green infrastructure features.	Number of technical guides developed and distributed, and user engagement metrics.	Produced and distributed comprehensive technical guides.	Leads: DNER, Estuario Implementing partners: municipalities, scientific community, academia, local community groups	Pending	0-2 years	TBD	USEPA, DNER
3. Conduct education and outreach campaigns to inform private property owners about the benefits of green infrastructure practices.	Number of education and outreach events held, and quantity of informational materials distributed to private property owners.	Conducted outreach events.	Leads: DNER, Estuario Implementing partners: municipalities, scientific community, academia, local community groups	Pending	0-2 years	TBD	USEPA, DNER
4. Establish financial incentives or assistance programs to incentivize green infrastructure installation.	Number of financial incentive programs established, and amount of funding allocated for green infrastructure installations.	Launched financial incentive programs.	Leads: Legislature, DNER, Estuario Implementing partners: municipalities, scientific community, academia, local community groups	Pending	3-5 years	TBD	USEPA, DNER

5. Assess current urban and agricultural practices and develop a plan for implementation of traditional and nature-based BMPs in urban and agricultural areas with the greatest need.	Prioritize list of traditional and nature-based BMPs.	Created a list of BMPs for urban and agricultural areas.	Leads: Puerto Rico Department of Agriculture (PRDA), United States Department of Agriculture (USDA), Estuario Implementing partners: Academia, scientific community, agricultural landowners, municipalities	Pending	3-5 years	TBD	USEPA, municipalities, PRDA, USDA
6. Implement BMPs in identified high priority areas.	Reduce stormwater runoff impacts in the SJBE watershed.	Installed BMPs in priority areas.	Leads: PRDA, USDA Implementing partners: Municipalities	Pending	5+ years	TBD	USEPA, PRDA, USDA
7. Evaluate the watershed to identify key urban locations to increase vegetative cover and prepare a reforestation plan that identifies locations, accepted tree types, and care requirements.	Identify locations for tree canopy needs.	Completed an assessment to identify key urban locations with insufficient tree cover.	Leads: DNER, USFS, NRCS Implementing partners: municipalities, academia, local organizations, Estuario	Pending	3-5 years	TBD	DNER, USFS, NRCS
8. Implement the plan by planting trees in identified priority locations in coordination with local organizations.	Increase tree canopy in the urban areas.	Planted trees in identified priority locations.	Leads: DNER, USFS, NRCS Implementing partners: Municipalities, local organizations	Pending	5+ years	TBD	DNER, USFS, NRCS, USEPA

Regulatory and Policy Requirements

Modifications may be needed to local codes and ordinances to allow for the implementation of more innovative and green stormwater BMPs and to incentivize the planting of native trees.

**NEW* MI-14 Work with the legislature, agencies, municipalities, and private developers to spur the development of LEED-certified developments.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Increase the number of LEED-accredited individuals in the SJBE region.	Number of new LEED-accredited professionals certified within the SJBE region.	Increased LEED-accredited individuals.	Lead: DNER Implementing partners: municipalities, developers, academia, scientific community	Pending	5+ years	TBD	DNER, academia
2. Collaborate with planning and regulatory agencies to integrate LEED requirements into zoning and code requirements and provide incentives to encourage developers to pursue LEED certifications.	Engage planning and regulatory agencies to adopt LEED requirements and incentives into zoning and building codes.	Collaborated with key agencies and implemented incentive programs.	Leads: DNER, Estuario Implementing partners: municipalities, developers, academia, scientific community	Pending	3-5 years	TBD	USEPA, DNER, State Revolving Fund, municipalities
3. Coordinate efforts, share best practices, and provide technical assistance for stakeholders regarding LEED project development.	Number of coordination meetings held, best practices shared, and technical assistance sessions conducted for stakeholders.	Conducted coordination meetings.	Leads: DNER, Estuario Implementing partners: municipalities, developers, academia, scientific community	Pending	0-2 years	TBD	USEPA, DNER, State Revolving Fund, municipalities

Regulatory and Policy Requirements

Adherence to local zoning ordinances, building codes, and permitting processes is needed.

**NEW* MI-15 Conduct a study to evaluate the frequency and duration of flow reversals due to stormwater runoff to improve mass balance estimates and to update drainage maps. Adaptation*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop a stormwater flow reversals study, collect additional data, and share a report with findings and recommendations for potential projects.	Improve data to evaluate stormwater flow reversal impacts.	Completed a stormwater flow and reversals study and reported on potential projects.	Lead: Estuario Implementing partners: Academia, scientific community, local organizations	Pending	3-5 years	TBD	USEPA, DNER
2. Implement project recommendations from study.	Reduce impacts to the SJBE system from stormwater flow reversals.	Executed priority project recommendations from the study.	Leads: DNER, DTOP Implementing partners: municipalities	Pending	5+ years	TBD	USEPA, State Revolving Fund, DNER

3. Gather existing drainage maps and data, conduct surveys to verify data and collect new information, and create a geodatabase.	Comprehensive database of existing drainage information.	Compiled database.	Leads: PRASA, DNER Implementing partners: Academia, scientific community, municipalities, Estuario	Pending	0-2 years	TBD	DNER, PRASA, municipalities, USACE
4. Publish updated maps and findings.	Share knowledge for decision making on stormwater management.	Created and distributed findings report to stakeholders.	Leads: PRASA, DNER Implementing partners: Academia, scientific community, municipalities, Estuario	Pending	3-5 years	TBD	DNER, PRASA, municipalities, USACE

Regulatory and Policy Requirements

None.

**NEW* MI-16 Add the De Diego Flood Control Pumping Station discharge point to the impaired waters list.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Add the De Diego FCPS Costa- PREC13 East Side of Condado Bridge to Punta Las Marías segment to the 303(d) list of impaired waters.	Add waterbody segment to the 303(d) impaired waterbodies list.	Listed waterbody segment as impaired.	Lead: DNER Implementing partners: DNER, Estuario	Pending	0-2 years	TBD	DNER
2. Determine appropriate biological response and nutrient standards for this segment.	Set biological and nutrient standards for the impaired segment.	Established biological and nutrient standards.	Lead: DNER Implementing partners: DNER, Estuario	Pending	0-2 years	TBD	DNER
3. Evaluate the extent of the mixing zone for the discharge location.	Establish a mixing zone for the discharge point.	Established mixing zone.	Lead: DNER Implementing partners: DNER, Estuario	Pending	5+ years	TBD	DNER

Regulatory and Policy Requirements

USEPA approval is required to include the De Diego FCPS in the NPDES permit modification.

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Infrastructure to Mitigate Erosion and Sediment Transport

Baseline

Sediment transfer to estuaries is a natural process; however, erosion, which is the detachment and movement of soil or rock particles by water, wind, or other natural forces, is a key factor influencing sediment generation and transport (USDA, 2017). In urban settings, erosion is often accelerated by human activities that disturb the land surface, making it highly relevant to sediment management in the SJBE. Anthropogenic influences have dramatically altered both the quantity and quality of sediments entering the SJBE.

Rivers, streams, surface runoff, and point source discharges contribute sediments to the SJBE. When excessive sedimentation occurs in a waterbody, the functional values of the system may become impaired. Sediments are capable of modifying the water column in ways that inhibit important biological functions (photosynthesis, nitrogen fixation, and migration). It is therefore important to evaluate the role that sediments play in determining the productivity and diversity of the system. Sediments suspended in the water column attenuate light transmission while reducing or inhibiting the primary productivity of the system. When excessive sediment loads enter estuary waters, corals, seagrasses, and algae become buried and die off. The detritus from this process forms sediments that consume oxygen and release the nutrients back into the water column, causing harmful algal blooms and leading to a decline in overall system health.

Land use and land cover changes, particularly urbanization characterized by highly altered urban features such as impervious surfaces, drastically modifying natural hydrological processes. These changes reduce infiltration, increase surface runoff, and enhance erosion and sediment transport into waterbodies. Hundreds of millions of dollars are proposed for dredging to restore the SJBE waters as a result of sediments and trash discharges (Coto, 2024). This is the most expensive way to address sediment transport. The least expensive method is to eliminate sediments from being discharged through stabilization and maintenance. Street sweeping to remove sediments before they reach the stormwater system is another BMP that reduces the need for higher cost maintenance within stormwater systems before sediments are discharged to the SJBE, where they are most impactful to the environment and most costly to remove. Stormwater management practices governed by regulations such as Puerto Rico's Regulation 40 play a critical role in controlling erosion and sedimentation by mandating BMPs that mitigate runoff and soil loss (DNER, 2019). Integration of these regulatory frameworks with land use planning is essential to control sediment generation at its source.

The proliferation of impervious surfaces, such as roads and buildings, exacerbates these issues by increasing runoff and reducing the natural absorption of rainfall, leading to accelerated erosion and sediment transport. In addition, the lack of adequate stormwater management infrastructure coupled with altered land use and land cover intensifies soil erosion and sediment delivery to the estuary, undermining ecosystem health and increasing flood risks.

Urbanization, topographic modifications, and deforestation have significantly increased the deposition of organic materials, nutrients, heavy metals, and other contaminants, diminished water clarity and adversely impacting aquatic life. These pollutants create conditions detrimental to the growth of seagrass, shellfish, and benthic invertebrates, resulting in mucky sediments that can consume oxygen and release nutrients back into the water column. This nutrient flux contributes to harmful algal blooms, hypoxic conditions, and

fish kills particularly under anaerobic conditions where orthophosphate, nitrates, and trace metals may enter the water. This occurs because in the absence of oxygen, chemical and biological processes in sediment change, leading to the release of these substances. These processes increase the bioavailability of nutrients and trace metals, exacerbating eutrophication and toxicity risks in the estuary. In addition, recently available heavy metal concentration data from SJBE sediments show decreases in concentrations of most metals, although both arsenic and chromium increased, and the composite sample from sediment above the clay interface at the San Antonio extension (near Condado) had higher concentrations of copper, mercury, nickel, and silver (Anamar Environmental Consulting, Inc., 2021). Addressing these contaminants requires targeted cleanup efforts to mitigate their impact on the estuary's ecosystems.

The SJBE has suffered from severe degradation, exacerbated by rapid urbanization since the mid-20th century. Historically, urban development in Puerto Rico was marked by rapid expansion with limited environmental oversight, resulting in widespread deforestation, soil disturbance, and poorly planned infrastructure (Martinuzzi et al., 2007). Many communities developed informally without adequate stormwater and erosion control measures, leading to increased sediment loads in waterways. This legacy continues to impact erosion and sediment transport dynamics in the watershed today

The construction of substandard housing in sensitive mangrove wetlands has led to the accumulation of sediment, debris, and waste, obstructing the hydraulic flow between the San José Lagoon and the San Juan Bay. The eastern half of the Caño Martín Peña, once historically 200 to 400 feet wide, is now severely compromised, clogged with sediments and pollutants that hinder its ecological function (Brodine, 2017).

Updating the land use map for the SJBE is a critical step in effectively managing the ecological health of the system. The Puerto Rico Land Use Plan (2015) is the planning instrument that governs public policy on land use, development, and conservation in Puerto Rico for a term of ten years. As established by law in Article 12, this plan divides land according to its existing and potential characteristics and values into three basic categories established in the Municipal Code (Law 107-2020): urban land, developable land, and rural land. The Land Use Plan serves as a framework for realigning and improving the plans, programs, and procedures of state agencies to achieve their goals and objectives. Collaborating with local partners is vital to ensure that the updated land use maps accurately capture recent development. Collaboration can facilitate the collection of data sources and local knowledge, leading to a more comprehensive understanding of how land use changes affect hydrology, sediment dynamics, and forested lands in the SJBE watershed.

In addition, using and building upon existing models will help to inform decision-making related to sediment management. From 2020 to 2024, Dr. Luís Pérez Alegria from the University of Puerto Rico at Mayaguez modeled sediment and nutrient loads within the SJBE watershed based on soil particles and nutrients. The model uses the USACE Hydrologic Modeling Center's Hydrologic Modeling System (HEC-HMS), which simulates precipitation and runoff processes from watersheds such as those contained in the SJBE (Kamal et al., 2022). The Environmental Fluid Dynamics Code (EFDC)/ Three-Dimensional Hydrodynamic Eutrophication Model (HEM3D) coupled hydrodynamic and water quality models have also been applied to quantify the potential water quality from flows of stormwater, industrial discharges, and other flows. The USEPA-supported EFDC/HEM3D includes features and capabilities that make it superior and more applicable to shallow estuarine environments than other models (Florida Institute of Technology, 2023). Effective management of erosion and sediment transport is essential for maintaining the ecological function of the SJBE. This approach is vital for restoring the channel's capacity to transport sediments and contaminants

effectively, thereby enhancing water quality and habitat conditions across the estuary. There is a connection between urban development patterns, stormwater management effectiveness, and erosion and sediment transport within the watershed. Poorly managed urban runoff can increase erosion rates, which in turn can elevate sediment loads entering the estuary, degrading water quality and aquatic habitats. Effective stormwater management, including erosion control measures, is therefore crucial to breaking this cycle and promoting estuarine restoration and resilience.

Objectives

- Manage sediments and contaminants reaching the estuarine system from topographical modifications, increased impervious areas, and deforestation.
- Reduce topographical modifications, impervious areas, and deforestation.

Actions

MI-17 Minimize sediment loading into the SJBE. ADAPTATION

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Assess current sediment sources and sedimentation rates within the SJBE boundary.	Improve information on sources and mass.	Assessed identified sediment sources and sedimentation rates.	Leads: DNER, Estuario Implementing partners: Academia, scientific community	On Track	0-2 years	TBD	DNER, USEPA
2. Collaborate with stakeholders to develop BMPs for erosion control measures and increase sweeping of municipal streets.	Reduce sediment loads to SJBE.	Established a set of BMPs for erosion control and increased street sweeping.	Leads: DNER, Estuario, municipalities Implementing partners: Academia, scientific community	Pending	0-2 years	TBD	DNER, USEPA, municipalities
3. Implement regulations and establish guidelines to reduce sediment runoff during construction and agricultural activities.	Improve erosion control and enforcement at construction sites.	Ensured compliance with regulation and guidelines.	Leads: DNER, USEPA, PRDA, USDA Implementing partners: Academia, scientific community, Estuario	Pending	3-5 years	TBD	DNER, USEPA, PRDA, USDA

Regulatory and Policy Requirements

Modifications to local codes and ordinances to incorporate erosion control BMPs may be required.

MI-18 Update the Puerto Rico Land Use Plan every ten years.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Conduct a comprehensive review of existing land use data, including the land cover map in the stormwater management plan.	Identify discrepancies in data or outdated information or data gaps.	Identified key areas where data gaps are present and are a priority to address.	Leads: DNER, Estuario Implementing partners: municipalities, academia, scientific community	Pending	0-2 years	TBD	USEPA, DNER
2. Share findings with the updated Land Use Plan and gather feedback from stakeholders and community members.	Update land use plan created through collaboration and partnership with key stakeholders.	Distributed the updated Land Use Plan to key stakeholders.	Leads: DNER, Estuario Implementing partners: municipalities, academia, scientific community	Pending	3-5 years	TBD	USEPA, DNER

Regulatory and Policy Requirements

Modifications to local development regulations and codes may be required if land use categorizations change with the update of the Land Use Plan.

**NEW* MI-19 Evaluate technologies and approaches for the beneficial use and disposal of dredged material in the SJBE.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Identify sediment locations with high nutrient concentrations and/or contamination in the SJBE system and determine techniques and technologies for each priority location.	Improve application of dredging, capping, and beneficial use techniques.	Completed a feasibility study for priority locations.	Leads: USACE, DNER, Estuario Implementing partners: municipalities, academia, scientific community	Ongoing	3-5 years	TBD	USEPA, DNER, USACE, Water Resources Development Act (WRDA)
2. Implement a project using selected technologies and techniques to address priority sediment locations.	Improve sediment health in the SJBE system.	Implemented sediment remediation projects at priority locations.	Leads: USACE, DNER Implementing partners: municipalities, academia, scientific community	Pending	5+ years	TBD	USEPA, DNER, and WRDA

Regulatory and Policy Requirements

USACE and other permitting may be required to install monitoring devices and perform monitoring activities. The data gathered will drive policy changes towards more efficient and sustainable dredging, capping, and beneficial use strategies to improve sediment in the SJBE.

**NEW* MI-20 Nutrient and sediment modeling in the SJBE watershed. Adaptation*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Review and analyze existing nutrient and sediment modeling data and gather data to fill in gaps.	Collect nutrient and sediment load data from the SJBE study area.	Identified data gaps and filled those gaps to improve analyses.	Lead: DNER Implementing partners: municipalities, academia, scientific community, Estuario	Pending	0-2 years	TBD	USEPA, DNER, USACE
2. Update models based on collected data and make results publicly available for decision-making.	Improve and update nutrient and sediment load models.	Achieved a correlation between modeled and observed nutrient and sediment loads and made results available.	Lead: DNER, Estuario Implementing partners: municipalities, academia, scientific community	Pending	3-5 years	TBD	USEPA, DNER, USACE
3. Engage with stakeholders on management strategies based on updated model findings.	Stakeholders identified and discussion to propose new strategies.	Conducted stakeholder and community engagement events.	Lead: DNER Implementing partners: municipalities, academia, scientific community, Estuario	Pending	0-2 years	TBD	USEPA, DNER, USACE

Regulatory and Policy Requirements

Amendments to DNER's Regulation for the Control of Erosion and Sedimentation may be needed based on the results of modeling efforts and new data.

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Drainage and Water Exchange Infrastructure

Baseline

The SJBE system has undergone significant anthropogenic modifications, including dredging, filling, and sedimentation. Until recently, these changes were solely for economic benefit and quality of human life. Many of these changes to the landscape have resulted in significant ecological impacts. Approximately 85% of the landscape in the SJBE watershed has been altered by man, going back thousands of years ago (Seguinot-Barbosa, 1983). To understand the present state of the drainage and water exchange infrastructure and further understand changes necessary for the current environmental and economic conditions of the area of the SJBE, the hydrology and historical changes to the system must be understood.

Hydrology is the movement of water and its relation to land. Changes to the land under or adjacent to the water can result in significant changes to the hydrology and upset the delicate balance of an estuary. The earliest changes to the SJBE were made by indigenous populations that deforested coastal areas for agricultural and homesteads resulting in significant erosion, but the major changes began with the arrival of Ponce de Leon and the development of San Juan Bay in the early 1500s (Seguinot-Barbosa, 1983). Since this time, management of the hydrology of the SJBE system has been to mine the waters and wetlands for the earth below, engineer and control the banks of the waterbody, and fill and develop the changed shoreline. This management approach has created deep dredge holes, new environments, and limited the capacity of the system to buffer flows of water and the pollutants and resources it carries. The restricted flows in the canals east and west of San Jose Lagoon have isolated the once tidally influenced San Jose Lagoon, which no longer flows as freely with the changing tides and is dominated by episodic storm events that can reverse the tidal flows. This altered system has created increasing flood events, limited natural flushing, contributed to nutrient imbalance (eutrophication), and changes to the flora and fauna beyond the estuary itself.

The San Juan Bay has a mouth to the Atlantic Ocean and a second inlet at the northwest end of the Condado Lagoon, resulting in limited restriction of flow (Bunch et al., 2000). The large area and extensive navigational dredging in the SJBE have made it the center of marine commerce in Puerto Rico since the 1500s. Navigational dredging for the San Juan Bay also extends east into the Caño Martín Peña.

Caño Martín Peña connects the San Juan Bay to the San Jose Lagoon. This system was once a wide and winding estuarine channel with wetlands that reached far north and south of the channel. In the eastern end of the Caño Martín Peña, the natural sinuous flow of the channel remains, but the nearly half mile wide floodplain and associated wetlands have been reduced to a narrow buffer (where present) between the filled and developed former mangroves and the channel. Many of the areas are filled with waste, creating additional challenges to restoration. The channel is choked with trash and debris, limiting the tidal exchange between San Juan Bay and the San Jose Lagoon. The low-lying areas are frequently flooded as a result of old storm sewer system that includes combined sewer flows, discharge from the Juan Mendez Creek, and storm surge flowing through the Suarez Canal and San Jose Lagoon. This frequent flooding of contaminated waters results in direct impacts to human health in the low-lying areas (ENLACE and USACE, 2016).

To the west, the sinuous flow of the natural channel has been replaced by an unnatural straight-lined channel. While this area has also been challenged with filled mangroves and development, mangroves have reestablished on both sides of the channel. In 2003, the area was designated as a Natural Reserve to protect the area from further development. To the east the natural flow of the channel may remain, but

development and pollution of trash, stormwater, and sanitary waste have created extensive damage to the system. With the damage to the Caño Martín Peña, the Caño Martín Peña Ecosystem Restoration project is underway and is further described in this section.

The San Jose Lagoon has also suffered from hardened shorelines and encroaching development, but most significant to the hydrology is the dredging from a depth of approximately six feet on average to up to 32 feet deep in dredge holes in the eastern section. The volume of the San José lagoon was increased by more than 30%, which also increased the time required to exchange the water volume in this already isolated and restricted waterbody. The deep depressions formed from dredging result in areas of denser salt water from the ocean running deep below the freshwater entering through the Caño Martín Peña, eliminating the mixing of fresh and saltwater that define an estuary and result in the unique balancing between the fresh and marine environments (ENLACE and USACE, 2016).

The San José Lagoon is divided into two sections named Los Corozos Lagoon to the northwest and the San José Lagoon, to the southeast. There is no direct connection between this lagoon and the ocean. Ocean waters have access to the San José Lagoon via the Caño Martín Peña connecting it to the San Juan Bay and the Suárez Canal, which connects to La Torrecilla Lagoon. The Suarez Canal is an artificial connection from the San Jose lagoon to the La Torrecilla Lagoon by dredging the canal in 1920s and 1930s. The Suarez Canal is constricted in its middle section, where the Román Baldorioty de Castro Expressway Bridge crosses the canal. La Torrecilla Lagoon connects to the ocean through the narrow channel of the Boca de Cangrejos outlet. Stormwater is supplied through creeks draining the surrounding urban areas, including Juan Mendez and San Anton. Paved and unpaved canals also drain urban areas including the Luis Muñoz Marín International Airport. The San José Lagoon also receives combined sewer overflows and stormwater from pump stations (ENLACE and USACE, 2016).

With the development in and around the SJBE, the natural balance of the system has been severely disturbed. The mangrove wetlands and floodplains are now channelized and developed, leaving no place for floodwaters to go and increasing the discharge of nutrients and sediments. Clean freshwater streams entering the estuary are now polluted with trash, sanitary waste, and sediment. The shallow but open channels connecting the waters of the SJBE have been replaced by channelized flows of varied depths, limiting the tidal exchange and vertically isolating fresh and salt waters.

Building on the understanding of the hydrological challenges facing the SJBE, it is crucial to examine the ongoing and planning restoration efforts aimed at addressing these issues. Several projects have been initiated or proposed to restore natural flows, improve water quality and enhance ecological and community health throughout the estuary system.

The Caño Martín Peña Ecosystem Restoration project (CMP-ERP) is the first major restoration project designed to have a large-scale improvement to the environmental conditions of the SJBE. It seeks to restore the hydraulic connection between the eastern and western portions of the SJEB by dredging and channelizing approximately 2.2 miles of the Caño Martín Peña. The CMP-ERP will improve dissolved oxygen levels, increase biodiversity by restoring fish habitat and benthic conditions, and enhance the functional value of mangrove habitat within the SJBE. The CMP-ERP is authorized by Section 5127 of WRDA 2007, as amended. The lead federal agency is USACE, and the non-federal cosponsors are ENLACE and DNER. In May 2016, the Assistant Secretary of the Army for Civil Works approved the Feasibility Study and Environmental Impact Statement, developed by ENLACE and USACE, deeming the CMP-ERP technically feasible, cost-

effective, environmentally justified, in accordance with environmental statutes, and in the public interest. In January 2022, after years of organized community advocacy, the federal government allocated $163.8 million to begin the construction phase through the Bipartisan Infrastructure Act of 2021. Following the allocation of federal funds, in July 2022, ENLACE, USACE, and DNER executed the Project Partnership Agreement, initiating the construction phase. The progress made on this project have been led by ENLACE, Project, Group of Eight Communities Surrounding the Caño Martín Peña, Inc., and Caño Martín Peña Land Trust.

USACE contracts for restoration of the eastern Caño Martín Peña began in 2023 and are scheduled for completion in 2031. USACE issued Contract 1 of the Caño Martín Peña project in June 2023, and the removal of vegetation and 15,000 tons of solid waste from approximately 36 acres was completed in October 2023. Contract 2 was awarded in September 2024 and included the excavation of 25,000 cubic yards of material from the western end of the channel. The project also includes the construction of a 115-foot-wide channel at the western bridges, installation of riprap in the channel bottom and side slopes, and sheet pile wall installation at the eastern end. This contract is estimated for completion in October 2026. Contract 3 will be awarded in three phases, with awards anticipated in September 2025 and January 2028. The scope of work for this contract will include 1.8 miles of channel dredging, 2 miles of access channel dredging, bank stabilization, Barbosa Bridge scour protection, 35 acres of mangrove/wetland restoration along the entire channel, and construction of recreation facilities. Disposal pits ae proposed in the former dredge holes in the San Jose Lagoon (USACE, 2024).

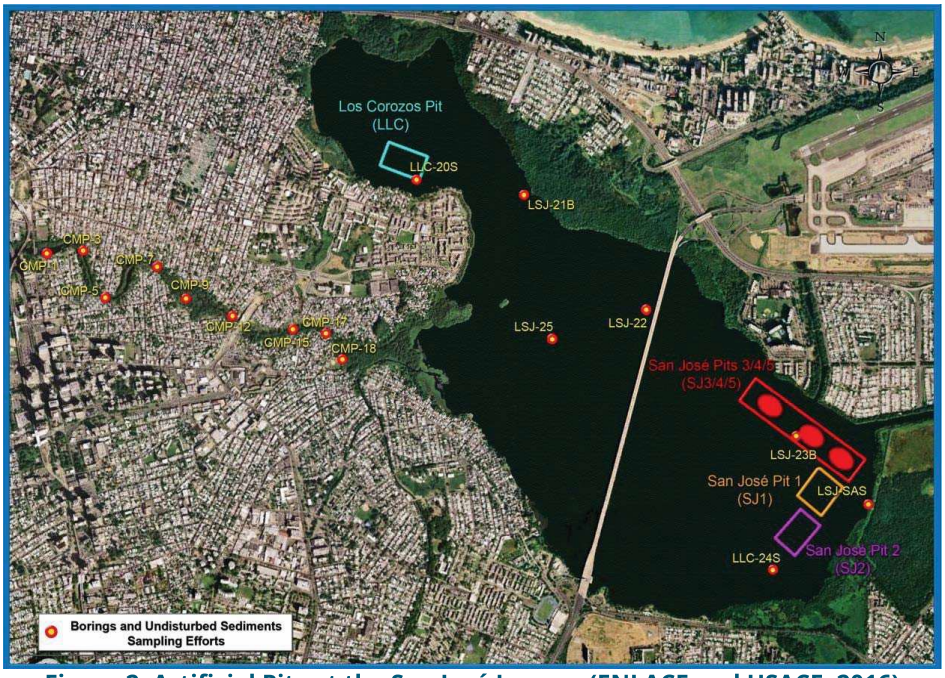

Figure 2. Artificial Pits at the San José Lagoon (ENLACE and USACE, 2016)

The latest dredging projects and the Caño Martín Peña Environmental Restoration project have provided many bathymetric data sets; however, a comprehensive bathymetry dataset of the waterbodies in the SJBE system needs to be updated and compiled. These data will inform the hydrological and mass balance studies required to fully understand the SJBE restrictions to flow, residence times, and circulation patterns.

In 2021, USACE published a coastal storm risk management study for the San Juan Metro Area and the back bay areas. The back bay refers to the interior, low-lying estuarine and flood-prone areas located behind the main San Juan Bay shoreline, which are particularly vulnerable to storm surge and flooding. With a focus on coastal flood risks from storm surge, waves, tides, and sea level changes, the plan recommends several structural and nature-based features. The recommended plan provided by USACE includes levees (1.5 miles), a series of breakwaters over 0.7 miles along the Cataño shoreline, seawalls/floodwalls (6.5 miles), elevated living shoreline (0.7 miles), a discharge structure on the Malaria Canal, and associated inland hydrology features (pumps and culverts) to allow continued rainfall runoff drainage (2021). This comprehensive back bay project aims to reduce coastal flooding and enhance resilience for vulnerable communities in the interior flood-prone areas of the San Juan metropolitan region by combining engineered infrastructure with natural habitat restoration.

Objectives

- Increase water circulation and intertidal water exchange in Caño Martín Peña, between La Esperanza Peninsula Cove and the San Juan Bay, and across Isla de Cabras for better flushing capacity in the estuarine system.

Actions

**NEW* MI-21 Conduct a comprehensive hydrologic assessment of the estuarine system to prioritize water exchange restoration efforts. ADAPTATION*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Compile recent bathymetric studies and flow dynamics to identify data gaps and needs.	Attain a bathymetric map of all areas of the SJBE.	Completed a comprehensive bathymetric survey map of SJBE.	Lead: USACE Implementing partners: U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Proyecto ENLACE, DNER	Ongoing	2 years	TBD	WRDA, NOAA, USACE
2. Identify restrictions to tidal and surface current flows; quantify water residence time dynamics, including impacts from sea level rise and extreme rainfall events; and model circulation dynamics.	Complete models to identify flow restrictions, residence times, and circulation patterns.	Identified restrictions, residence times, and circulation patterns.	Lead: USACE Implementing partners: USGS, NOAA, Proyecto ENLACE, DNER	Pending	5+ years	TBD	WRDA, USACE

3. Publish a comprehensive report of hydrologic conditions that includes challenges and opportunities.	Compile bathymetric data; models; and summary of data gaps, flow restrictions, residence times, circulation patterns, challenges, and opportunities.	Publish report.	Lead: Estuario Implementing partners: USGS, NOAA, Proyecto ENLACE, DNER	Pending	5+ years	TBD	WRDA, USACE

Regulatory and Policy Requirements

None.

MI-22 Improve flow in Caño Martín Peña and relocate families living adjacent to the Caño Martín Peña.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Western bridges scour protection in Caño Martín Peña, Tren Urbano, and Luis Muñoz Rivera (USACE Caño Martín Peña Restoration Contract 2).	Protect the bridge from scour by dredging the west end of Caño Martín Peña channel, and installation of sheet piles and riprap to secure slopes.	Excavated 25,000 cubic yards of material from the western end of the channel, constructed 115-foot-wide by 6.5-foot-deep channel located at western bridges, installed riprap at the channel bottom and the side slopes, and installed steel sheet pile walls at the eastern end.	Leads: USACE, Proyecto ENLACE Implementing partner: DNER	On Track	0-2 years	TBD	WRDA
2. Channel excavation and stabilization (USACE Caño Martín Peña Restoration Contract 3).	Remove flow restrictions in the Caño Martín Peña, stabilize the banks, restore mangroves and wetlands, and provide recreational facilities.	Dredged 1.8 miles of channel, dredged 2 miles of access channel from staging area to eastern end of Caño Martín Peña, stabilized bank including sheet pile, added Barbosa Bridge scour protection, restored 35 acres of mangrove/wetland for entire channel, and added recreation features.	Leads: USACE, Proyecto ENLACE Implementing partner: DNER	On Track	5+ years	TBD	WRDA
3. Establish a plan and schedule for maintenance dredging.	Maintain improved flows in Caño Martín Peña over time.	Continued maintenance, as needed, to maintain flows in Caño Martín Peña.	Leads: USACE, Proyecto ENLACE Implementing partner: DNER	Pending	5+ years	TBD	WRDA
4. Conduct an assessment and mapping initiative of households to identify relocation needs and priorities.	Develop a map identifying households needing relocation with prioritized rankings.	Prioritized list for relocation.	Lead: Proyecto ENLACE Implementing partners: DNER, municipalities, community groups	Pending	0-2 years	TBD	USEPA, DNER, municipalities, FEMA

5. Develop a community engagement and communication plan to inform residents about options, timelines, and available support services for relocation. Track relocation progress and address any challenges or concerns.	Complete community engagement and communication plan with outreach strategies and materials.	Coordinated with residents in target communities.	Lead: Proyecto ENLACE Implementing partners: DNER, municipalities, community groups, Estuario	Pending	3-5 years	TBD	USEPA, DNER, municipalities

Regulatory and Policy Requirements

Congress authorized projects in 2007 through Section 5127 of WRDA. The approval of the project's viability study in 2018 has allowed USACE and Proyecto ENLACE to work on the pre-construction phase, engineering, design, and early phases of construction. The project will need continued support of the U.S. Congress to ensure funding of the final phases. Policy may be needed to help with relocation assistance for people who need to move.

MI-23 Fill artificial depressions at the Suarez Canal and at Los Corozos, San José, and La Torrecilla Lagoons.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Fill dredge depressions in the Suarez Canal.	Restore or approach more consistent historic depth to improve flushing and mixing of marine and freshwaters.	Achieved a maximum canal depth of --14 feet.	Lead: USACE Implementing partner: DNER	Delayed	5+ years	TBD	WRDA
2. Fill dredge depressions in the Los Corozos Lagoon.	Restore or approach more consistent historic natural depth to improve flushing and mixing of marine and freshwaters.	Achieved a maximum lagoon depth of -6 feet.	Lead: USACE Implementing partner: DNER	Delayed	5+ years	TBD	WRDA
3. Fill dredge depressions in the San Jose Lagoon.	Restore or approach more consistent historic natural depth to improve flushing and mixing of marine and freshwaters.	Achieved a maximum depth of -16 feet.	Leads: USACE, Proyecto ENLACE Implementing partner: DNER	Pending	5+ years	TBD	WRDA
4. Fill dredge depressions in the La Torrecilla Lagoon.	Restore or approach more consistent historic natural depth to improve flushing and mixing of marine and freshwaters.	Achieved a maximum depth of 14 feet outside of the navigation channels.	Lead: USACE Implementing partner: DNER	Delayed	5+ years	TBD	WRDA

Regulatory and Policy Requirements

Congress authorized the project in 2007 through Section 5127 of WRDA. The approval of the project's viability study in 2018 has allowed USACE and ENLACE Project Corporation for Caño Martín Peña to work on the pre-construction, engineering, design, and early phases of construction. The project will need continued support from U.S. Congress to ensure funding of the final phases. Additional funding will be required to evaluate, engineer, and complete the filing of dredge holes in the construction of the Suarez Canal, Los Corozos Lagoon, and La Torrecilla Lagoon.

MI-24 Improve the flow of water between La Esperanza Peninsula Cove and San Juan Bay.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Continue dredging to remove shoaling and improve flushing in the cove.	Improve flushing and tidal exchange between the La Esperanza Peninsula Cove and San Juan Bay.	Increased in number, width, and/or depth of openings.	Lead: USACE Implementing partner: DNER	Stalled	5+ years	TBD	WRDA, USACE
2. Conduct monitoring to evaluate project effectiveness and nearby habitat.	Gather information on project benefits and minimize impacts.	Monitored to evaluate hydrological improvements.	Lead: USACE Implementing partner: DNER	Pending	5+ years	TBD	USACE, DNER

Regulatory and Policy Requirements

U.S. Congress previously authorized the dredge project under the WRDA 1986 authorization. Bids were solicited for the project in 2015. The engineering, design, and permitting will need to be reevaluated. The project will need continued support of the U.S. Congress to ensure funding of the project.

MI-25 Assess the feasibility of opening the causeway to Isla de Cabras to increase water flow.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Evaluate the need to increase the flow of water between San Juan Bay and Ensenada Boca Vieja and select the location and size of the new opening.	Conduct needs assessment to determine where flow levels need to be restored and their priority status.	Completed the needs assessment identified a location for a new opening.	Lead: DNER Implementing partners: USACE, Estuario	Pending	2-5 years	TBD	DNER, USEPA, USACE

2. Begin construction once necessary permits have been granted.	Develop construction plan and apply for necessary permits.	Finalize permits finalized and complete construction.	Lead: DNER Implementing partners: USACE, PRPA	Pending	5+ years	TBD	DNER, USPEA, State Revolving Fund, USACE

Regulatory and Policy Requirements

A Clean Water Action Section 404 permit and associated coastal zone and water quality certifications should be obtained.

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Ports and Vessels Infrastructure

Baseline

The SJBE is a vital component of Puerto Rico's maritime landscape, balancing significant economic benefits with complex environmental and safety challenges. With a growing network of harbors, ports, and marinas, the SJBE system serves as a pivotal hub for marine transportation, which is vital for both commercial activity and tourism. The harbors within the SJBE are typically larger facilities designed to accommodate commercial vessels, including cargo ships and cruise ships. The San Juan Bay, for instance, is notable as the 17th largest port facility in the world and the second busiest container port on the east coast of the United States (Estuario, 2000). These facilities and use of San Juan Bay as safe harbor date back to the original Spanish settlement and have played a fundamental role in trade and tourism, with the Port of San Juan handling a significant portion of the island's cargo and cruise ship traffic.

In 2019, more than 30 million cruise ship passengers visited the Caribbean, with Puerto Rico as a key destination. The growth in cruise tourism, which had been nearly 10% annually before the COVID-19 pandemic, reflects the high demand for maritime travel and the vital role of the SJBE in supporting this industry (Runde and Sandin, 2021). To maintain the growth of the industry and modern-day vessels, dredging was completed in the San Juan Bay in 2024 to deepen and widen the navigation channel. The project included the removal of 3 million cubic yards of material to make room for larger vessels.

Public safety and environmental protection play essential roles in the development and operation of port facilities. Law 125-1942, as amended, established the Puerto Rico Port Authority in 1942 and mandated the creation of the General Security Office for the Puerto Rico Port Authority in the amendment presented in Law in 2024. The General Security Office must also comply with the Maritime Transportation Security Act. This act was a response to the terror attacks on September 11, 2001, and directed the Federal Department of Transportation to develop security measures to protect domestic ports and vessels. The act had a particular focus on security threats, cargo vessels, and dangerous cargo, but also addressed workplace safety and environmental concerns. DNER, through the Navigation Commissioner's Office, seeks to minimize the environmental impact from recreational watercraft. The four components of this office are vessel registration, marine education, marine safety, and Laws and Regulations.

Under the Puerto Rico Port Authority Act, the General Security Office is mandated to take all necessary actions for the administration, internal organization, and maintenance of its assets. Crucially, the Authority is required to prepare and periodically review a Safety, Protection, and Vigilance Plan, which is executed in coordination with local and federal security agencies. This plan serves as the foundation for safeguarding port operations, protecting public safety, and preventing environmental incidents that could compromise water quality in the SJBE (Law No. 125-1942). However, despite this clear legal mandate, there is currently no publicly available evidence or documentation confirming the existence or active implementation of such a plan by the Puerto Rico Ports Authority. In 2024, the U.S. Coast Guard conducted a Ports and Waterways Safety Assessment (PAWSA) workshop for the Port of San Juan, focusing on the estuary's complex maritime environment. The PAWSA process engaged local experts and stakeholders in a structured risk assessment to identify waterway safety hazards that impact both environmental and public health (U.S. Coast Guard, 2024). The PAWSA workshop and resulting report represent a significant step forward in addressing the safety and environmental vulnerabilities of the SJBE port infrastructure. This progress is critical to ensuring

that safety and vigilance measures effectively protect the estuary's water quality, thereby upholding the Clean Water Act's goals.

In accordance with 33 CFR 151.10, when a vessel is within 12 nautical miles of the nearest land, any discharge of oil or oily mixtures into the sea from a ship other than an oil tanker or from machinery space bilges of an oil tanker is prohibited with a few exceptions. Oily-water separators capable of limiting discharges of oil to less than 15 ppm may be used. Discharges of untreated sanitary waste and from marine sanitation devices from vessels also contribute to nutrient loading in the SJBE. Improvements to port facilities for bilge water collection and sanitary waste pump outs could significantly reduce waste discharges from vessels in the SJBE. Extreme weather events present a growing threat to the SJBE's maritime infrastructure. Extreme weather events, such as hurricanes, have caused extensive damage to the infrastructure, disrupting commercial and recreational maritime activities. As changing conditions continue to exacerbate weather events, the resilience of the SJBE's infrastructure is increasingly jeopardized, challenging economic stability, recovery efforts, and tourism opportunities (United Nations Trade and Development, 2017).

The Vessel Incidental Discharge Act (VIDA), enacted in 2018, provides a uniform national framework for regulating discharges incidental to the normal operation of commercial vessels under the Clean Water Act Section 312(p). VIDA aims to prevent or reduce pollutant discharges from vessels into U.S. waters by consolidating and streamlining the previously fragmented patchwork of federal, state, and local regulations. Under VIDA, USEPA is responsible for developing national standards of performance for incidental discharges, while the U.S. Coast Guard develops the corresponding enforcement regulations. The Act covers various types of vessel discharges, including bilge water, and provides specific state petition processes to address local concerns (USEPA, 2025).

Bilge water discharges from vessels pose a significant environmental challenge in the SJBE system. Bilge water often contains oil, grease, chemicals, and other pollutants that, if discharged untreated, can degrade water quality and harm aquatic ecosystems. Regulations such as those outlined in VIDA and 33 CFR 151.10 seek to limit oil content in bilge water discharges and mandate the use of oily-water separators to reduce pollution. However, compliance and infrastructure limitations, such as inadequate bilge water collection facilities at ports, remain issues that contribute to pollutant loading in the SJBE. Enhancing port facilities for bilge water collection, improving monitoring and enforcement, and increasing awareness among vessel operators are critical steps toward minimizing the environmental impact of vessel discharges in the estuary.

In addition to bilge water, in-water maintenance activities (such as hull cleaning and painting) and fueling operations also contribute to water quality degradation through the release of pollutants including antifouling agents, fuels, and oils into the estuary. These activities can result in the discharge of hazardous substances directly into the water if not properly managed. Idle discharges, or the release of wastewater while a vessel is stationary, can further contribute to pollutant loading in the SJBE.

In addition to maritime activities, airports within the SJBE watershed contribute to water quality pollution through stormwater runoff, de-icing operations, fuel handling, and other airport-related activities. Ensuring that all airports in the SJBE comply with the Clean Water Act is vital for protecting the estuary's water quality and supporting broader conservation and restoration goals. Airports are complex operational environments where pollutants such as hydrocarbons, heavy metals, de-icing chemicals, and other contaminants can enter stormwater and ultimately discharge into nearby waterbodies if not properly managed. These

discharges can degrade aquatic habitats, impair water quality, and threaten public health. Developing and implementing a comprehensive compliance plan tailored to the unique challenges of airports in the SJBE region will facilitate better coordination among airport authorities, environmental agencies, and community stakeholders.

There is a growing recognition of the need to work more closely ports, vessels, and airport authorities as key stakeholders in the estuary's watershed to reduce pollutant discharges and enhance compliance with federal water quality regulations.

Objectives

- Reduce spills and discharges from ports, marinas, fishing villages, and vessels infrastructure.

Actions

**NEW* MI-26 Develop and implement an infrastructure plan to ensure all seaports support water restoration and conservation efforts.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Evaluate seaport infrastructure to research and evaluate existing information and/or plans and conduct a needs analysis.	Conduct an inspection of all port stormwater, sanitary sewer, shoreline protection, and wharf structures and identify critical infrastructure requiring maintenance or replacement.	Completed inspections and evaluation and improved the performance or longevity of infrastructure.	Lead: Puerto Rico Ports Authority Implementing partners: Marinas, boating groups and organizations	Pending	5+ years	TBD	WRDA
2. Review and update BMPs in the Stormwater Pollution Prevention Plan (SWPPP).	Ensure all stormwater infrastructure is inspected, maintained, and in compliance to ensure proper flood protection and water treatment.	Completed inspections and maintenance per the SWPPP schedule.	Lead: Puerto Rico Ports Authority Implementing partners: DNER, USEPA	Pending	0-2 years	TBD	Puerto Rico Ports Authority
3. Develop the Safety, Protection, and Vigilance Plan for compliance with the Clean Waters Act.	Complete plan.	Developed plan.	Lead: Puerto Rico Ports Authority Implementing partner: , DNER, U.S. Coast Guard, USEPA	Pending	0-2 years	TBD	WRDA

Regulatory and Policy Requirements

Need to ensure compliance with the Clean Water Act and the guideline established by Law No. 125-1942 when developing the plan.

MI-27 Create a Port Advisory Council to monitor docks and other watercraft facilities within the SJBE system and ensure regulatory and permit compliance.

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Create a Port Advisory Council of stakeholders to make recommendations on measures to control the proliferation of docks and other watercraft facilities within the SJBE system.	Develop and enforce stormwater management systems that prevent runoff pollution, improve infrastructure to prevent illegal discharges, implement training programs, and develop emergency preparedness plans for oil/diesel spills, vessel evacuation under extreme events.	Created Advisory Council to develop necessary measures and plans.	Lead: Estuario Implementing partners: DNER, USEPA, United State Fish and Wildlife Service (USFWS), municipalities, marinas, boating groups and organizations	On Track	0-2 years	TBD	DNER, USFWS, USEPA
2. Recommend enforcement action against illegal structures.	Reduction of illegal structures that are impacting the SJBE system.	Took enforcement action.	Lead: DNER Implementing partners: Municipalities, marinas, boating groups and organizations	Pending	0-2 years	TBD	DNER
3. Recommend the development of public docks and other facilities in areas where the natural resources will not be adversely impacted.	Improve siting of facilities to serve the community while protecting natural resources.	Recommended facility locations.	Lead: DNER Implementing partners: USEPA, USFWS) municipalities, marinas, boating groups and organizations	Pending	0-2 years	TBD	DNER

Regulatory and Policy Requirements

To be determined based on the findings of the task force.

**NEW* MI-28 Develop guidelines for marina construction and retrofits to incorporate sustainable design features.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Conduct a comprehensive review of existing marina design standards and best practices in sustainable development.	Compile database of practices for more sustainable marina development.	Compiled database.	Lead: DNER, Implementing partners: USFWS, marinas, boating organizations, academia	Pending	0-2 years	TBD	DNER, USFWS, municipalities, marinas
2. Implement requirements for sustainable designs in marina construction and retrofit projects.	Improve sustainability of infrastructure and protection of natural areas.	Adopted regulation.	Lead: DNER Implementing partners: USFWS, marinas, boating organizations	Pending	3-5 years	TBD	DNER, USFWS, municipalities, marinas
3. Construct and deploy artificial reef habitats under marinas and harbor facilities.	Increase in reef habitat to increase benthic resources and assist in sustaining fisheries resources.	Created reefs.	Lead: DNER Implementing partners: USFWS, marinas, boating organizations	Pending	3-5 years	TBD	DNER, USFWS, municipalities, marinas

Regulatory and Policy Requirements

Modifications may be needed to local codes and ordinances to allow for implementation of the recommended guidelines.

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Transportation and Mobility Infrastructure

Baseline

There are more roads than rivers in the SJBE watershed, and the road infrastructure in the watershed conveys water into the SJBE. By implementing robust safety measures to ensure the coexistence of cyclists and motorists, alternative and clean modes of transportation can be incorporated into the road system. This includes the continued establishment of clear signage, dedicated bicycle lanes, and comprehensive public awareness campaigns. By addressing safety concerns, the region can mitigate risks and promote a more secure environment for all transportation users. This includes green infrastructure such as trees for traffic calming, but also bio-retention swales, rain gardens, flow through planters, and permeable surfaces to reduce impacts from stormwater runoff (DTOP, 2018).

Preparing a comprehensive map of the road system within the SJBE watershed can help manage water quality by identifying locations where runoff pollution needs to be controlled and/or mitigated. A detailed map of the road network, including drainage systems and surrounding topography, can help visualize where road runoff and associated pollutants flow to nearby waterbodies. The map can also be used to identify where road segments or infrastructure features are major sources of pollution, such as areas with high traffic volume, inadequate drainage systems, or construction sites, which can impact aquatic ecosystems and drinking water sources.

Communities within the SJBE system have also raised concerns regarding repaving efforts that inadvertently block sewer inlets and disrupt effective stormwater management. Proper slope and grading during road repavement are critical to ensuring that stormwater is efficiently directed toward drainage systems, preventing localized flooding, sewer overflows, and environmental contamination. When repaving projects neglect appropriate grading standards, they can cause water to pool on road surfaces or clog sewer inlets, exacerbating water quality issues within the estuary.

In 2023, Puerto Rico DTOP lead the creation of the Puerto Rico Multimodal Long Range Transportation Plan. This plan identifies organizational structure, outlined a vision for transportation in Puerto Rico, and evaluated financing for projects with a planning timeframe through the year 2050. The plan was put in place to align with federal requirements outlined in the Intermodal Surface Transportation Efficiency Act of 1991 and Fixing America's Surface Transportation (FAST) Act. This plan also recognizes San Juan as a Transportation Management Area, and a separate plan was also established for San Juan. The goals and objectives for the San Juan Plan focused on four general topics, or the four E's: Efficiency, Environment, Effectiveness and Economy. Of particular concern for the Estuario Plan are the Environment Objectives:

- B.1 To promote transportation infrastructure that preserves balanced ecosystems minimizing adverse impacts to the Island's natural environment by conceding a preponderant weight to rehabilitation and improvement of existing infrastructure alternatives.
- B.2 Reduce greenhouse gas emissions, energy consumption, and carbon footprint emittance; promote "smart growth," livable communities and improve air quality by implementing sustainability strategies and environmental management methodologies.
- B.3 Support integrated transportation and land use planning by attempting to maintain consistency with existing and planned land uses.

- B.4 Improve alternative modes of transportation and travel demand strategies by implementing and improving pedestrian access, bikes lanes, public transportation plan, recharge ports for electric vehicles, among other environmentally sustainable alternatives, that reduce motorized vehicles dependency and enhance alternative modes of transportation.
- B.5 Reduce transportation infrastructure's vulnerability for it to withstand extreme weather events
- through resilient infrastructure.
- B.6 Improve physical and mental health by promoting and increasing active modes through interventions or new project with proper infrastructure (DOTP, 2023).

The Multimodal Long Range Transportation Plan and the Plan and Design Guide for Complete Streets in Puerto Rico prepared by Puerto Rican Planning Society provide a roadmap for the modern streets in the SJBE watershed. By building on these efforts and improving stormwater management through the use of proper BMPs and green infrastructure, the road system can provide sustainable management of runoff to protect the SJBE.

Objectives

- Reduce sediments and contaminants reaching the estuarine system from the transportation and mobility infrastructure.
- Increase options available for alternative transportation means, such as walking and biking.

Actions

**NEW* MI-29 Develop a comprehensive system map of federal, state, and local roads.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Compile stormwater infrastructure information.	Gather stormwater infrastructure information for federal, state, and local roads, as well as port and airport facilities.	Gathered information on Infrastructure locations.	Lead: Estuario Implementing partners: Puerto Rico Ports Authority, DNER, municipalities	Ongoing	0-2 years	TBD	DNER
2. Prepare a GIS database and map of stormwater infrastructure in the SJBE watershed.	Integrate federal, state, and local infrastructure into a single database.	Created GIS database and map that is shared to Estuario's website.	Lead: Estuario Implementing partners: Puerto Rico Ports Authority, DNER, municipalities	Ongoing	0-2 years	TBD	DNER

Regulatory and Policy Requirements

The comprehensive map will provide information to identify regulatory and policy changes that may be required to better manage pollutant contributions from the road system to improve water quality.

**NEW* MI-30 Ensure repaving efforts maintain proper slopes and grading to effectively manage stormwater and prevent blockage of sewer inlets. Adaptation*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Establish permitting, construction BMP, and inspection criteria.	Permitting and inspection criteria documented existing and proposed elevations, ensuring proper construction BMPs are in place, and evaluated direct impacts to storm sewers.	New permitting and inspection criteria practiced.	Lead: DNER Implementing partners: municipalities	Pending	0-2 years	TBD	DNER
2. Establish a repavement inspection task force for inspections and implement noted fixes to ensure proper grading.	Created a task force for inspections to ensure roads are properly graded when repaved to improve water quality.	Created the task force and ensured proper road grading.	Lead: Estuario, DNER Implementing partners: municipalities	Pending	3-5 years	TBD	DNER
3. Prepare a guidance document for approaches to regrading and BMPs to protect water quality.	Prepare a guidance document for pavement projects.	Implemented proper grading and treatment of roads.	Leads: DNER Implementing partners: municipalities	Pending	0-2 years	TBD	DNER

Regulatory and Policy Requirements

Efforts to maintain proper drainage of sewer inlets should follow local and federal regulations.

**NEW* MI-31 Collaborate with municipalities and planners to include alternative transportation infrastructure, such as bicycle lanes, sidewalks, and public transit access points.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop guidelines for incorporating alternative transportation infrastructure into development plans.	Better information on how to add alternative transportation for SJBE communities.	Developed guidelines.	Lead: DTOP Implementing partners: Metropolitan Bus Authority, Transit Safety Commission, municipalities	Pending	0-2 years	TBD	DTOP, Metropolitan Bus Authority, Transit Safety Commission, municipalities

2. Advocate for the inclusion of alternative transportation infrastructure in local zoning codes and development regulations.	Remove barriers to including alternative transportation in development projects.	Removed barriers.	Lead: DTOP Implementing partners: Metropolitan Bus Authority, Transit Safety Commission, municipalities, local advocacy groups	Pending	0-2 years	TBD	DTOP, Metropolitan Bus Authority, Transit Safety Commission, municipalities
3. Implement alternative transportation projects in key areas of the SJBE watershed.	Improve access throughout the watershed.	Completed alternative transportation projects.	Lead: DTOP Implementing partners: Metropolitan Bus Authority, municipalities	Pending	3-5 years	TBD	DTOP, Metropolitan Bus Authority, Transit Safety Commission, municipalities

Regulatory and Policy Requirements

Modifications to local development codes and regulations may be required to provide incentives for developers to include alternative transportation infrastructure. These local code modifications may be currently required to comply with DTOP, FAST Act, and other recently enacted requirements.

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Collaborative Water and Bottom Sediment Quality Monitoring and Data Reporting

Baseline

Creating a comprehensive monitoring network for the SJBE system water quality, benthic sediments quality, and biological resources is important to determine current conditions and evaluate restoration projects and programs. A robust dataset will provide information on historical conditions to better understand interactions between pollutant sources from the watershed and responses within the estuary. Sediment quality monitoring is a key component of these efforts, as sediments act both as sinks and potential sources of pollutants affecting aquatic ecosystems (Otero & Meléndez, 2011). The monitoring program's focus on sediment contaminants is critical because contaminants in the sediments of the SJBE reflect both historical and ongoing inputs from industrial, urban, and municipal sources (Otero & Meléndez, 2011).

Estuario is leading efforts to gather data in the system. Since 2008, Estuario's Volunteer Water Quality Monitoring Project has been engaging local citizens in water quality monitoring. This project collects water samples that are evaluated for 12 parameters including nutrients (nitrogen and phosphorus), bacteria (fecal coliforms and enterococcus), oils and fats, conductivity, pH, dissolved oxygen, and turbidity. Data are collected monthly from 26 stations across 13 waterbodies that represent the diverse aquatic systems within the watershed (Lugo and Bauzá Ortega, 2024). To date, Estuario has trained over 400 scientific citizens to conduct this sampling (Estuario, 2025).

Estuario has also funded a monitoring project that samples 32 drainage outlets, including 19 subbasins from the SJBE watershed and 13 from the Río Grande de Loíza below the dam, through close to 200 diagnostic stations. The project focuses on nutrient sampling to identify locations of sewage discharges with those categorized as impaired and critical indicating an ongoing major sanitary discharge (Martínez Rodríguez, 2024). In addition, Estuario staff collect samples for fecal enterococcus in estuarine waters. The samples are analyzed in Estuario's in-house laboratories, and the results are published weekly on their website and social media accounts through a GIS map (see example in Figure 3). This effort started in 2014 with the Laguna del Condado Natural Reserve and was extended after Hurricane María to the northern coast of Estuario's study area and to weekly sampling (Estuario, 2025).

The current monitoring activities provide ways for citizens to participate in data collection and access results in a timely manner using GIS maps. The data collected can also be used in models to evaluate changes in water quality within the estuary and major tributaries in response to changes within the watershed. Expanding data collection efforts to monitor other parameters and in additional locations will provide a more robust dataset for mapping, modeling, decision-making, and public outreach. Monitoring of sediments has revealed elevated concentrations of heavy metals, including lead, mercury, and cadmium, at multiple locations, which poses potential toxicity risks to benthic organisms and risks through bioaccumulation (Otero & Meléndez, 2011). Additionally, organic contaminants and nutrient levels in sediments contribute to the degradation of sediment quality and exacerbate eutrophication processes in the estuary (Otero & Meléndez, 2011).

Figure 3. Example of Weekly Bacteria Monitoring Results

Estuario convened potential partners and identified the need for collaborative regional monitoring efforts to develop a watershed-scale water quality monitoring effort to establish baseline conditions and document the impact of anticipated large-scale infrastructure projects. Through this regional water quality monitoring network, known as the Collaborative Water Quality Monitoring Network, Estuario collaborates with partners to carry out the water quality monitoring objectives. This monitoring will help to leverage additional funding to collect water quality data more frequently and efficiently, ensure quality assurance, and enable quick turnaround on interpretation and reporting for corrective measurements. In addition, collaborative monitoring efforts will provide more visibility and make data more accessible so that the different sectors can establish trends and make science-based decisions. The integration of sediment contaminant data with water quality and biological indicators provides a comprehensive understanding of estuarine conditions and informs management decisions (Otero & Meléndez, 2011).

The monitoring program should be expanded to gather information on contaminants of emerging concern, which include pharmaceuticals, personal care products, and hormones that have been detected at increasing frequencies (Rodríguez-Sierra et al., 2025). The need for a comprehensive monitoring and research program is imperative to assess the occurrence of these contaminants and evaluate their potential risks to aquatic life and human health. A robust monitoring program should establish a network of stations throughout the SJBE to collect data on the presence and concentration of contaminants of emerging concern. This systematic approach will help identify hotspots and trends, providing crucial information for effective management. In addition, research should focus on understanding the sources and pathways of contaminants of emerging concern entering the estuary. Investigating the roles of wastewater treatment

facilities, stormwater runoff, and illicit discharges is vital to provide information to advocate for advanced treatment technologies that effectively reduce these contaminants.

In addition, harmful algal blooms are becoming an increasing concern and should be further evaluated. Harmful algal blooms are the rapid growth of algae or cyanobacteria in water, which can harm people, organisms, and/or the environment (Centers for Disease Control and Prevention [CDC], 2024). An increase in nutrients in waterbodies can feed the algae, causing them to rapidly grow in a bloom. Some blooms produce toxins, and the blooms can deplete oxygen in the water when they die off, which can lead to fish and other wildlife kills. Therefore, reducing the occurrence of harmful algal blooms is an important measure for the health of the SJBE system. A study was completed in 2013 to evaluate the SJBE system's vulnerabilities to changing conditions. It found that harmful algal blooms are likely to be more extensive in the estuary system within 15–30 years (Jacobs and Pérez, 2013). Reducing the occurrences of harmful algal blooms requires that protective measures and an early detection system are developed. To successfully model and predict harmful algal blooms, data are needed on climatic and environmental variables (e.g., atmospheric temperature, wind, solar radiation), hydrodynamics (e.g., water levels, salinity, water temperature, column stratification), water quality (e.g., nutrient inputs, photic depth, pH, dissolved oxygen), and phytoplankton community structure (e.g., species composition, competition between species, and grazing effects). Additional information will need to be gathered, and an appropriate predictive tool identified and developed for the SJBE system.

Estuario will develop a data dashboard to support the collection, evaluation, and presentation of data to the public. The data dashboard will provide more visibility across different sectors and enable the ability to make science-based decisions.

Objectives

- Measure the effectiveness of water infrastructure investments based on measured water quality data.
- Identify and track spatial and temporal changes and trends in water quality and living resources associated with waterbodies.
- Strengthen communication of progress in restoring and conserving water quality.

Actions

MI-32 Continue and strengthen Estuario's monitoring efforts including its public-science component, paying particular attention to the Río Piedras, Juan Méndez Creek, San Antón Creek, and their tributaries. ADAPTATION

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources

1. Continue to support the Volunteer-led Water Quality Monitoring Project and look for opportunities to expand the monitoring locations and frequency.	Increase the number of volunteers and water quality data collected.	Increased volunteers and data collected.	Lead: Estuario Implementing partners: USEPA, DNER, community organizations	Ongoing	0-2 years	TBD	USEPA, municipalities
2. Develop, maintain, and update the data dashboard and continue to publish data on the Estuario website.	Readily-accessible water quality data for public use.	Dashboard to increase data visibility.	Lead: Estuario	Ongoing	0-2 years	TBD	USEPA
3. Continue to provide the Report on the Condition of the SJBE.	Readily-accessible water quality data for public use.	Readily-accessible data.	Lead: Estuario Implementing partners: USEPA, DNER, community organizations	Ongoing	0-2 years	TBD	USEPA, municipalities
4. Continue leading the Collaborative Water Quality Monitoring Network.	Continue data from the Collaborative Water Quality Monitoring Network.	Led the Collaborative Water Quality Monitoring Network.	Lead: Estuario	Ongoing	0-2 years	TBD	USEPA

Regulatory and Policy Requirements

None.

**NEW* MI-33 Establish a monitoring and research program about the occurrence and potential risk of contaminants of emerging concern in the SJBE system. ADAPTATION*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop a monitoring framework to facilitate the assessment of contaminants of emerging concern concentrations, sources, and trends over time.	Collect comprehensive data on contaminants of emerging concern concentrations and identify trends.	Annual report summarizing contaminants of emerging concern data with recommendations on management actions.	Leads: DNER USEPA Implementing partners: PRASA, private utilities, academia, Estuario	Pending	3-5 years	TBD	DNER, USEPA
2. Conduct data analysis to assess ecological risks from contaminants of emerging concern and develop policy.	Develop informed policies and regulations addressing contaminants of emerging concern management.	Created risk assessments of key species in the SJBE.	Lead: DNER Implementing partners: USEPA, PRASA, private utilities, academia	Pending	3-5 years	TBD	DNER, USEPA

Regulatory and Policy Requirements

Update of local policies and regulations to recognize the dangers of contaminants of emerging concern in the system and support their regulation in entering the watershed.

**NEW* MI-34 Develop a predictive platform for the early detection of harmful algal blooms. ADAPTATION*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Identify gaps in water quality, hydrological, and weather data and opportunities to fill those gaps to gather the information needed to better predict harmful algal blooms.	Fill gaps in monitoring to better predict harmful algal blooms.	Filled harmful algal blooms data gaps.	Leads: USEPA, DNER Implementing partners: municipalities, academia, research organizations	Pending	0-2 years	TBD	USEPA, DNER
2. Determine an appropriate harmful algal bloom modeling platform, including evaluation of existing tools, and develop the tool for coordination and collaboration to reduce harmful algal blooms and provide rapid response.	Tool to better manage watershed and estuary conditions to reduce harmful algal blooms and to help with response when harmful algal blooms occur.	Reduced harmful algal blooms through better management.	Leads: USEPA, DNER Implementing partners: municipalities, academia, research organizations, Estuario	Pending	3-5 years	TBD	USEPA, DNER

Regulatory and Policy Requirements

None.

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Impacts to Water Quality from Sources Beyond the Current Study Area

Baseline

Leading up to and during development of this Estuario Plan revision, the need to better understand all the contributions to the SJBE system was identified by the Estuario Management Conference and Board of Directors. While the current Estuario study area encompasses the areas immediately adjacent to the estuary, the watersheds associated with the major rivers and streams (río Grande de Loíza, río Bayamón, and their tributaries) that flow into the estuary are currently excluded.

The discharge from río Grande de Loíza reaches Boca de Cangrejos during extreme floods and affects mangrove populations from Vacía Talega westward. Río Bayamón was diverted away from the estuary; however, some of its tributaries still flow into the estuary system (Lugo and Bauzá Ortega, 2024). The connection between these areas and the estuary as well as the effects of the pollutant sources in these watersheds on the estuary are not fully understood. Additional sewage discharges, septic systems, and stormwater sources are located in the expanded study and may contribute pollutant loads to the estuary. In addition, water is brought into the estuary watershed through outside sources. Examples include a super aqueduct that carries about 70 million gallons per day of freshwater to San Juan from outside the municipality, and the Sergio Cuevas Water Filtration Plant that pulls water from the río Grande de Loíza at the dam in Barrio Carraízo of Trujillo Alto (USEPA, 2019). Additional studies, monitoring, and coordination with the municipalities are needed to determine whether the Estuario programmatic boundary should be expanded in a future plan revision.

Figure 4 shows the expanded study area that will be investigated as part of this Estuario Plan revision. The expanded study area includes approximately 1,833 square kilometers of watershed and encompasses all or parts of 29 municipalities, as compared to the current study area of approximately 221 square miles and 8 municipalities. In addition, this expanded study area removes the current northern boundary to include the coastal systems that are influenced by land-based activities and interact with the estuary.

The goal of expanding the programmatic boundary is to provide a more comprehensive approach to managing the SJBE system, its watershed, and connected waterways. This expansion will also provide an opportunity to better influence enforcement and regulatory requirements that would benefit the estuary.

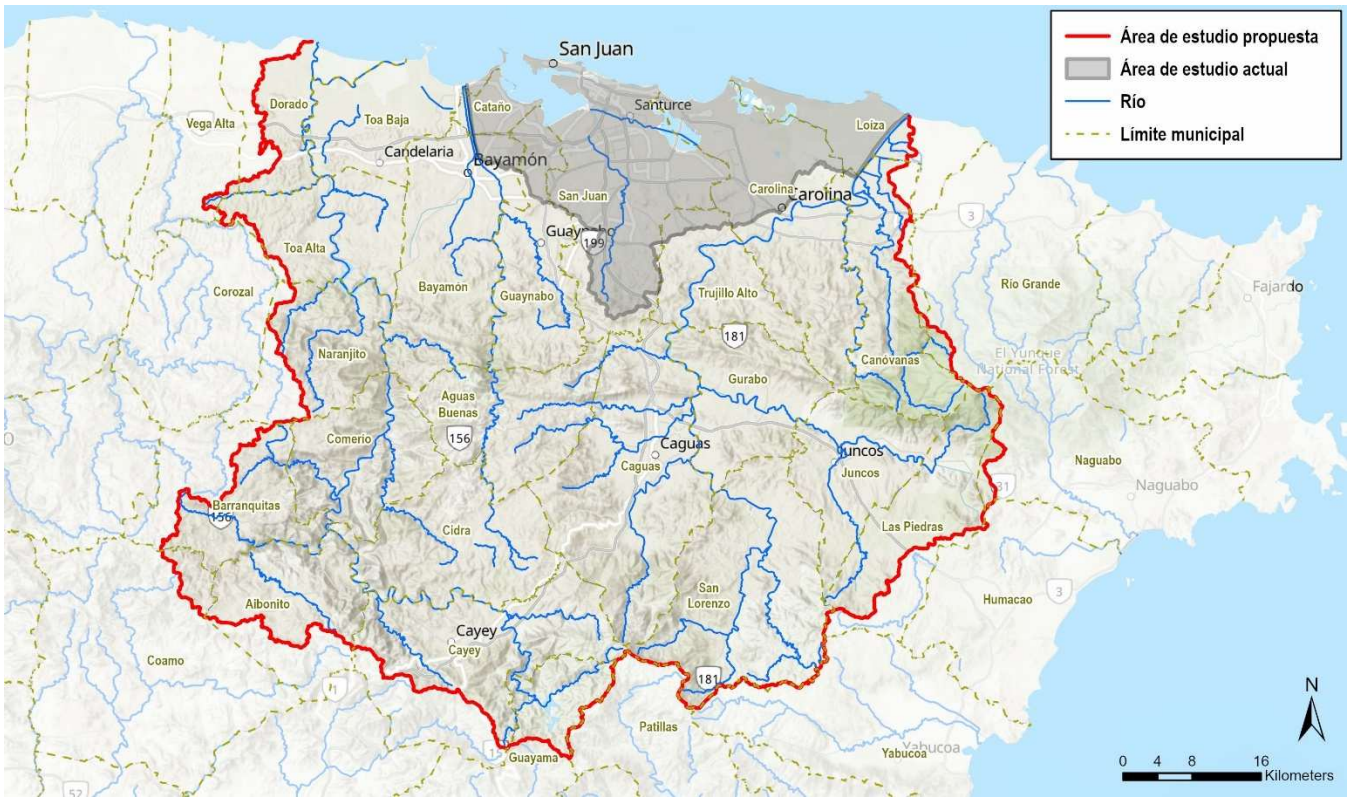

Figure 4. Current Estuario Study Area Boundary and Expanded Area for Evaluation

Objectives

- Assess the potential impact from point and non-point sources of contaminants to the estuarine system from regions beyond the current study area.

Actions

**NEW* MI-35 Determine the areas of highest sewage discharge in the expanded study area*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Establish and implement research protocols for identifying locations of sewage discharges and evaluating compliance with NPDES permits in the expanded study area.	Improve information on sewage discharge locations and permit compliance.	Developed protocol for identifying sewage discharge locations and findings from the compliance analysis.	Lead: Estuario Implementing partners: Scientific community, academia, municipalities, DNER	Pending	0-2 years	TBD	Academia, municipalities, DNER

2. Evaluate public health issues in the areas with the greatest sewage discharges in the expanded study area.	Information on greatest contributions of sewage in the expanded study area.	Evaluated data on greatest sewage contributions.	Lead: Estuario Implementing partners: Scientific community, academia, municipalities, DNER	Pending	3-5 years	TBD	Academia, municipalities, DNER
3. Develop maps showing the results of the sewage discharge analysis in the expanded study area for posting on Estuario's public dashboard.	Improve information on sewage discharge locations.	Prepared maps showing sewage contribution locations,	Lead: Estuario Implementing partners: Scientific community, academia, municipalities, DNER	Pending	3-5 years	TBD	Academia, municipalities, DNER
4. Use the study results to identify projects to eliminate sewage discharges in the expanded study area.	Plan to reduce the number of sewage discharges.	Developed a project list to eliminate the sewage discharges with the greatest impacts.	Lead: DNER Implementing partners: Municipalities, utilities	Pending	5+ years	TBD	USEPA, State Revolving Fund, DNER, municipalities, utilities

Regulatory and Policy Requirements

None for the study. The results will help inform regulatory and policy needs in the future.

**NEW* MI-36 Evaluate Septic System and Groundwater Sources in the Expanded Study Area*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Establish and implement research protocols for identifying septic system leaks and groundwater contamination in the expanded study area.	Improve information on septic system and groundwater contamination locations.	Identified septic system and groundwater contaminatio n locations.	Lead: Estuario Implementing partners: Scientific community, academia, municipalities, DNER	Pending	0-2 years	TBD	Academia, municipalities, DNER
2. Develop maps showing areas with the greatest contribution of pollutants from septic systems and groundwater sources in the expanded study area.	Improve information on septic system and groundwater sources with the highest pollutant contributions.	Developed maps showing septic system and groundwater source contribution locations.	Lead: Estuario Implementing partners: scientific community, academia, municipalities, utilities, industry	Pending	3-5 years	TBD	DNER, USEPA
3. Use the study results to identify projects to improve septic system and groundwater management in the expanded study area.	Plan to address wastewater sources with the highest pollutant contributions.	Completed a plan with hotspot locations and potential projects.	Lead: DNER Implementing partners: municipalities, utilities	Pending	5+ years	TBD	USEPA, DNER, State Revolving Fund, municipalities

Regulatory and Policy Requirements

None for the study. The results will help inform regulatory and policy needs in the future.

**NEW* MI-37 Investigate urban and agricultural stormwater sources in the expanded study area.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop and implement a study to gather data on stormwater sources in the expanded study area.	Information on stormwater pollutants, volumes, and locations in the expanded study area.	Completed a study to identify stormwater sources.	Lead: Estuario Implementing partners: Scientific community, academia, municipalities, agricultural landowners, DNER, PRDA, USDA	Pending	0-2 years	TBD	USEPA, DNER, USDA
2. Develop maps showing the results of the stormwater evaluation in the expanded study area.	Improve information on areas with the greatest pollutant concentrations from stormwater.	Developed maps showing stormwater contribution locations.	Lead: Estuario Implementing partners: scientific community, academia, municipalities, agricultural landowners, DNER, PRDA, USDA	Pending	3-5 years	TBD	USEPA, DNER, USDA
3. Use the study results to identify stormwater management and treatment projects in the expanded study area.	Reduce pollutant and volume loading from stormwater sources in the expanded study area.	Prepared a project list to reduce stormwater pollution.	Leads: DNER Implementing partners: Municipalities, agricultural landowners, DNER, PRDA, USDA	Pending	5+ years	TBD	USEPA, DNER, USDA, State Revolving Fund, municipalities

Regulatory and Policy Requirements

None for the study. The results will help inform regulatory and policy needs in the future.

**NEW* MI-38 Estimate inputs from water sources into the expanded study area.*

Activities

Activity	Performance Measures	Milestones	Responsible Stakeholder(s) and Partner(s)	Status	Timeframe	Estimated Costs	Potential Funding Sources
1. Develop a study to gather data on nutrient and pollutant concentrations in water sources being brought into the expanded study area.	Information on nutrient and pollutant concentrations in water sources.	Completed a study to identify pollutants in water sources.	Lead: Estuario Implementing partners: Scientific community, academia, PRASA, DNER	Pending	0-2 years	TBD	USEPA, DNER, PRASA

2. Identify nutrient and/or pollutant concentrations of concern in the water sources being brought into the expanded study area.	Data on high nutrient and pollutant concentrations.	Identified contaminants with high concentrations.	Lead: Estuario Implementing partners: Scientific community, academia, PRASA, DNER	Pending	3-5 years	TBD	USEPA, DNER, PRASA
3. Coordinate with PRASA on necessary treatment projects to reduce pollutants in water sources being brought into the expanded study area.	Reduce pollutant concentrations entering the expanded study area.	Reduced pollution from water sources.	Lead: DNER Implementing partner: PRDA	Pending	5+ years	TBD	USEPA, DNER, PRASA, State Revolving Fund

Regulatory and Policy Requirements

None for the study. The results will help inform regulatory and policy needs in the future.

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