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Objectives

Estuario's water quality monitoring evaluates physical and chemical parameters within the San Juan Bay Estuary (SJBE) system. Current monitoring within the estuary includes data collection and subsequent analyses of environmental indicators completed by Estuario and its partners, which provides current conditions that can be compared with past measurements to observe changes through time. Additionally, possible contamination sources can be identified and addressed through the proper agencies. Estuario archives water quality monitoring data within a database for studies, as well as for education and training of volunteers (Estuario, 2020a). Over the past decade, Estuario has incrementally expanded and adapted its monitoring program in response to stakeholder and community input captured through its strategic plan. Monitoring enhancements, such as the addition of targeted sampling sites, adjustments to sampling frequency, and incorporation of new chemical and biological indicators are most recently reflected in the Estuario Plan revision.

The objective of this Monitoring Plan is to assess progress toward achieving the Estuario's vision of "thriving tropical ecosystems, healthy communities and a vibrant economy," by setting water quality targets along with other measurable goals. The Monitoring Plan integrates efforts to assess the state of the ecological systems of the estuary, quality of estuarine waters, and quality of upland waters flowing into the estuary. The Monitoring Plan builds upon acquired knowledge from past monitoring efforts so that adjustments to the program continue to improve the program's effectiveness.

This Monitoring Plan also serves as a tool for tracking the implementation of the Estuario Plan actions by documenting how environmental conditions change in response to restoration, protection, and management activities. By measuring water quality, ecological condition, and other environmental indicators over time, the monitoring helps determine whether implemented actions are producing the intended outcomes and whether additional adjustments are needed. In this way, monitoring provides a direct feedback mechanism for evaluating progress, identifying emerging issues, and supporting adaptive decision-making throughout Estuario Plan implementation.

The Monitoring Plan establishes the overall programmatic direction for integrated watershed management by defining the monitoring priorities, objectives, and long-term data needs that support Estuario Plan implementation. In contrast, the Quality Assurance Project Plans (QAPPs) provide detailed measurement protocols, field procedures, quality assurance and quality control (QA/QC) requirements, and data handling methods needed to conduct individual monitoring activities consistently and reliably. Together, the Monitoring Plan and the QAPPs ensure that the monitoring program is both strategically aligned with Estuario's restoration goals and technically sound in its collection and use of data.

This Monitoring Plan strengthens current monitoring efforts and establishes new actions to collect data that supports the implementation of the Estuario Plan.

Adaptive Management

Adaptive management is a core principle of the SJBE monitoring program and Estuario Plan implementation. Through adaptive management, monitoring results are used not only to document environmental conditions, but also to evaluate the effectiveness of restoration, protection, and management actions over time. This approach allows Estuario to make informed adjustments to strategies,

priorities, and monitoring methods as new information becomes available and as ecosystem conditions change. Monitoring is especially important for restoring plant and animal populations because it helps determine whether habitat improvements are supporting populations and improving biodiversity.

The monitoring program supports adaptive management by providing data that can be used to assess whether Estuario Plan actions are producing the intended environmental responses. Progress will be measured by comparing monitoring results over time and determining how the estuarine system responds to restoration actions, management interventions, and natural stressors. When indicators show improvement, decline, or unexpected change, monitoring and implementation efforts will be refined to better address emerging conditions and support restoration goals.

Adaptive management also ensures that the monitoring program remains responsive to evolving ecological, social, and operational needs. As the estuary changes due to restoration activities, climate effects, land use changes, extreme weather, or other stressors, monitoring parameters, station locations, and collection frequencies will be adjusted to improve the ability to detect trends and support decision-making. In this way, the Monitoring Plan serves as a feedback mechanism for the Estuario Plan, helping Estuario track implementation progress and continuously improve management outcomes.

An expansion of the study area would require broadening spatial coverage, including additional stations in tributaries, coastal margins, and additional subwatersheds. With an emphasis on expanding the current study area, changes in current monitoring efforts will need to be assessed for feasibility to develop a watershed-scale water quality monitoring program that is capable of defining current (baseline) conditions and documenting future changes that may occur as a result of one or more large-scale infrastructure projects that are anticipated in coming years.

Monitoring Data Parameters

The water quality monitoring data parameters collected in the field include temperature, dissolved oxygen, pH, transparency, specific conductivity, salinity, and percent oxygen saturation. Further lab testing and analyses are conducted for environmental parameters including turbidity, Secchi depth, oils and fats, nitrate and nitrite (total), total phosphorus, and fecal *Enterococcus* (fecal coliform). Weekly water quality monitoring reports *Enterococcus* levels (Estuario, 2020b). Additionally, environmental indicators are monitored and recorded within the SJBE including benthic macroinvertebrates, seagrass percent area cover, coral reef area cover, fish censuses, and mangrove percent survival rate (Estuario, 2024a).

Monitoring Data Collection

Water quality monitoring is primarily performed by volunteers, also referred to as citizen scientists. There are approximately 400 citizen scientists trained by Estuario. Volunteers must participate in one training session conducted by the field sampling leader and/or the manager before collecting data. The training section consists of learning basic water quality concepts, explanation of the goals and objectives of the monitoring program, field monitoring techniques, and overview of goals and objectives of the monitoring (Estuario, 2025a). The volunteers must attend an additional training session that includes hands-on exercises of water sampling techniques, sample preparations, equipment calibration and deployment, sample incubation (for *Enterococcus* sampling), field data recording, and results reading (Estuario, 2024a). The laboratory manager is responsible for sample preparation, collection, and preservation, as well as maintaining equipment. All data are entered into an Excel spreadsheet and then verified by the QAPP

program manager (Estuario, 2025a). Table 1 summarizes the frequency of trainings, data collection, QA/QC, and reporting (Estuario, 2024a).

Environmental Indicators

Estuario developed Environmental Indicators Monitoring (EIM) based on water quality and environmental indicators. EIM presents trends related to SJBE ecosystems and provides information to better visualize and understand overall progress toward restoration goals. EIM produces valuable data that will help measure and evaluate the effectiveness of action implementation (Estuario, 2024b).

Volunteers who are part of the EIM initiative must participate in two training sessions conducted by the QAPP coordinator/field leader. The training consists of a lecture about environmental indicator's species identification (macroinvertebrates, coral reef species, and fish census), water quality monitoring, seagrass percent area cover, coral reef percent area cover, mangroves planting project site seedling survival rate, mangroves planting project area cover, field note taking, and goals and objectives of the project (Estuario, 2024b). Additionally, proper training is conducted for benthic macroinvertebrates identification including sampling methods, preliminary specimen sorting, specimen handling, stream measurements, equipment usage, and data form completion (Estuario, 2024b). The second training consists of hands-on field exercise techniques, equipment use, and field data recording, which must be conducted no more than two weeks after the first training session.

Table 1. Schedule for the Water Quality Monitoring Program

Task	January	February	March	April	May	June	July	August	September	October	November	December
Volunteer training	-	-	-	-	-	-	X	-	-	-	-	-
Standard operating procedures refresh	X	-	X	-	X	-	X	-	X	-	-	X
Xylem EXO 1 sonde measurements	X	X	X	X	X	X	X	X	X	X	X	X
Water quality parameters collection and analysis	X	X	X	X	X	X	X	X	X	X	X	X
QA/QC audits	-	-	-	-	-	X	-	-	-	-	-	-
Data available to the public	X	X	X	X	X	X	X	X	X	X	X	X

Note: Shaded cells marked with an "X" note which months each activity in the program occurs.

SJBE Illegal Discharges Detection and Elimination (IDDE) Monitoring

The IDDE monitoring serves as a targeted and cost-effective effort to support validation of Estuario Plan actions implemented within the study area related to infrastructure improvements and pollution source corrective actions throughout the watershed.

The new actions included in the Estuario Plan revision focus on improving aging gray infrastructure, correcting illicit discharges, reducing pollutant loads, and improving stormwater and sanitary sewer system performance. The IDDE monitoring validates the effectiveness of these actions through diagnostic monitoring and follow-up assessments conducted before and after corrective actions are implemented.

This monitoring helps Estuario identify persistent contamination sources, support prioritization of specific future corrective measures, and inform adaptive management decisions associated with Estuario Plan implementation. Also, for those circumstances that require validating infrastructure pollution correction

actions implemented under regulatory compliance and Consent Decree frameworks, the IDDE approach brings a solution without requiring large-scale or resource-intensive monitoring systems.

The IDDE protocol was developed by Principal Investigator Dr. Gustavo Martínez and his team from the University of Puerto Rico College of Agricultural Science in collaboration with Estuario (University of Puerto Rico, 2026). The methodology received national recognition through the U.S. Water Prize awarded by the U.S. Water Alliance for advancing collaborative and science-based watershed management solutions.

Beach Monitoring

The Puerto Rico Department of Natural and Environmental Resources (DNER) leads the Beach Monitoring and Public Notification Program, which is implemented to reduce the risk of illness among beachgoers when they are exposed to water contaminated with bacteria (DNER, 2025). DNER monitors for enterococci bacteria to determine if the results are greater than the standard of 70 colonies per 100 milliliters of water that can cause public health concerns. Results are posted on the DNER website (DNER, 2025).

Monitoring Data Collection Frequency

Water quality monitoring data are collected at weekly and monthly frequencies. Samples are collected from multiple monitoring stations across the watershed that are representative of the hydrologic basin and estuarine coast (Estuario 2020).

Weekly Collection

The weekly collection is focused on *Enterococcus* bacteria levels at beaches and lagoons spanning the northeastern coast. The location of each station was based on the proximity to recreational areas, user entry points, and stormwater discharges points. Weekly sampling is performed year-round (Estuario, 2025a). The water samples are collected during the morning hours (8:00 AM to 12:00 PM) on Thursday and then analyzed on the same Thursday with results reported and posted the following Friday. Results for each monitoring station are also used to report compliance as to whether or not the beach or lagoon area is suitable for swimmers (Estuario 2020). Weekly water quality monitoring sampling is conducted at 12 varying stations at beaches and lagoons across the coast of the SJBE watershed (Table 2, Estuario, 2020b). The weekly data are posted to the Estuario website within one week of collection with results on a scorecard as well as a map and table by station.

In addition, the Condado Lagoon Estuarine Reserve (CLER) is sampled two times per year at two monitoring stations (Estuario, 2025a).

Table 2. Weekly Water Sampling Monitoring Stations

Station	Station ID	Latitude	Longitude
Parque Jaime Benítez	CLER 1	18.454931	-66.076625
Playa Baldorioty	CLER 2	18.458592	-66.085893
Playita Condado	CLER 3	18.461138	-66.082425
San Gerónimo	CLER 4	18.459907	-66.082197
Calle Aguadilla	CLER 5	18.457578	-66.076575
Ocean Park	-	18.454617	-66.055368
Pine Groove	-	18.443848	-66.012097
Vacía Talega	-	18.450621	-65.904719

Station	Station ID	Latitude	Longitude
Calle Nairn	-	18.45625	-66.064426
Calle Cervantes	-	18.456862	-66.068982
Calle Serra	-	18.457159	-66.067029
Escambrón	-	18.466885	-66.090948

Monthly Collection

Monthly collection evaluates parameters not assessed in the weekly collections, including temperature, dissolved oxygen, haziness, pH, transparency, specific conductivity, salinity, and percent oxygen saturation (Estuario 2020a). U.S. Environmental Protection Agency [USEPA], 2022). The monthly data are collected within one week each month during the morning hours (8:00 AM to 12:00 PM) (Estuario, 2024a). There are 26 monitoring stations (Table 3), which are partitioned into four groups that are sampled per collection day: Rio Piedras, SJBE, Laguna San José and Torrecillas, and ground stations (Estuario 2020). A duplicate sample for fecal *Enterococcus*, total phosphorus, nitrite and nitrate, and oil and grease are each collected at one sampling station at random for QA/QC compliance (Estuario, 2024a). The monthly data are posted to the Estuario website within three months of collection with results on a map and in a table by station.

Table 3. Monthly Water Sampling Monitoring Stations

Station	Station ID	Group	Latitude	Longitude
Bahía de San Juan 1	BSJ 1	San Juan Bay Stations	18.469567	-66.128554
Bahía de San Juan 2	BSJ 2	San Juan Bay Stations	18.453831	-66.122214
Bahía de San Juan 3	BSJ 3	San Juan Bay Stations	18.437665	-66.101517
Canal La Malaria	CM	Ground Stations	18.435714	-66.134322
Canal San Antonio	CSA	San Juan Bay Stations	18.459911	-66.092909
Canal Suárez 1	CS 1	San José and Torrecilla Lagoon Stations	18.426339	-65.998859
Canal Suárez 2	CS 2	San José and Torrecilla Lagoon Stations	18.432897	-65.98515
Caño Martín Peña	CMP	San Juan Bay Stations	18.432944	-66.060892
Embalse Las Curias*	Las Curias	Piedras River Stations	18.342194	-66.050432
Escambrón Centro Pocita	ECP	Not Applicable	18º 27.915’	-66.05219
Laguna del Condado 1	LC 1	San Juan Bay Stations	18.457225	-66.076954
Laguna del Condado 2	LC 2	San Juan Bay Stations	18.461881	-66.084023
Laguna Los Corozos	LLC	San José and Torrecilla Lagoon Stations	18.441579	-66.038588
Laguna Piñones	LP	Ground Stations	18.442242	-65.956453
Laguna San José 1	LSJ 1	San José and Torrecilla Lagoon Stations	18.428583	-66.035523
Laguna San José 2	LSJ 2	San José and Torrecilla Lagoon Stations	18.424755	-66.020036
Laguna Torrecillas 1	LT 1	San José and Torrecilla Lagoon Stations	18.457653	-65.992482
Laguna Torrecillas 2	LT 2	San José and Torrecilla Lagoon Stations	18.443649	-65.979654
Laguna Torrecillas 3	LT 3	San José and Torrecilla Lagoon Stations	18.436139	-65.969095
Península La Esperanza	PLE	Ground Stations	18.448518	-66.135437
Quebrada Blasina	BC	San José and Torrecilla Lagoon Stations	18.42305	-65.967683
Quebrada Juan Méndez	JM	Ground Stations	18.399418	-66.041855
Quebrada San Antón	QSA	San José and Torrecilla Lagoon Stations	18.417355	-66.012213
Río Piedras 1	RP1	Piedras River Stations	18.40244	-66.0651
Río Piedras 2	RP 2	Piedras River Stations	18.388218	-66.058581
Río Piedras 3	RP 3	Piedras River Stations	18.469567	-66.128554
Río Puerto Nuevo	RPN	San Juan Bay Stations Ground Stations	18.453831	-66.122214

*Additional beach monitoring station chosen due to popularity (Estuario, 2024a).

EIM Collection

Benthic macroinvertebrates are monitored quarterly in the Río Piedras River, which provides an effective representation of the urban rivers in the SJBE watershed. The sampling sites are located adjacent to the aqueduct, selected due to their accessibility, location near the Estuario water quality monitoring stations, and presence of riffles and pools (Estuario, 2024b).

Seagrass cover is monitored quarterly by percentage of area covered, quantified at five quadrats (0, 5, 10, 15, and 20 meters) along two transects parallel to the shore within the Condado Lagoon. Additionally, coral reef monitoring and fishes census is performed every five meters along the transects (Estuario, 2024b).

Mangroves are another environmental indicator involved in the EIM program in restoration-planting project sites. Mangrove seedlings are counted one year after being planted to calculate the survival rate. Total affected area (acres) is also calculated. The areas where mangrove percent survival rate is monitored include the Condado Lagoon, Piñones State Forest, Isla Verde, and other affected areas along the coast (Estuario, 2024). Table 7 shows the schedule of events for the EIM program (Estuario, 2024b).

Real-Time Remote Telemetric (RTRT) Water Quality Monitoring

RTRT monitoring, using sondes, reduces the gap in information and data due to extreme weather and storm events. Response time is improved through a continuous and uninterrupted data logging scheme. The RTRT monitoring system consists of six buoy stations with a series of data loggers attached, collecting continuous water quality data (Estuario, 2025b). This monitoring system provides complimentary data for the monthly water quality monitoring and additional data for total algae. In addition, RTRT monitoring is especially useful for assessing changes in water quality after hurricanes, heavy rainfall, storm surge, and other extreme weather events, when short-term fluctuations in salinity, temperature, dissolved oxygen, turbidity, and other parameters may otherwise be missed by routine sampling. Some recommended protocols include:

- Visual assessment (developing a field sheet to document the condition) and sample collection once it is safe for personnel.
- Identifying new stations if necessary; for example, the existing stations in the QAPP cannot be used due to the impact situation.
- Notifying USEPA of any changes to the approved QAPPs.
- Public notification to the community.
- Leading an Incident Command System (ICS) group among agencies and municipalities (the Estuario IDDE Task Force structure can be used to evaluate monitoring and reporting strategies).

Continuous data from the buoy network supports rapid response efforts and help characterize the estuarine system's reaction to extreme events, improving the ability to evaluate short-term effects and recovery over time. The sampling locations for RTRT monitoring are provided below in Table 4 and Table 5, respectively (Estuario 2021).

Table 4. RTRT Monitoring Buoy Locations

Waterbody	Latitude	Longitude
Condado Lagoon	18.458241	-66.080153
Río Piedras/Puerto Nuevo System	18.424270	-66.080916
Caño Martín Peña	18.43058	-66.049217
San José Lagoon	18.428341	-66.031895

Waterbody	Latitude	Longitude
La Torrecilla Lagoon	18.444104	-65.981107
Juan Méndez Creek	18.425343	-66.040031

Table 5. Proposed Schedule of Events for the RTRT Monitoring Program

Task	January	February	March	April	May	June	July	August	September	October	November	December
Volunteers and citizen scientist training and certification	-	-	-	-	X	-	-	-	-	-	-	-
RTRT buoys assembling and sensors calibration	-	-	-	-	-	X	-	-	-	-	-	-
RTRT buoys deployment	-	-	-	-	-	-	X	-	-	-	-	-
RTRT data telemetric streaming	X	X	X	X	-	-	X	X	X	X	X	X

Note: Shaded cells marked with an "X" note which months each activity in the program occurs.

Long-Term Environmental Indicator Program Monitoring

Estuario also developed a Long-Term Environmental Indicator Program with 25 monitoring stations at locations of high potential for environmental degradation. The monitoring includes sediments and fish-tissue contaminants, both of which are analyzed for parameters such as heavy metals, pesticides, organic contaminants such as polychlorinated biphenyls (PCBs) and semi-volatile organic compounds (SVOCs), and contaminants of emerging concern (CECs) in water (Estuario, 2021). This indicator program was developed from research that was completed in the SJBE in 2011, when sediment and fish and crab tissue samples were collected and analyzed for heavy metals, pesticides, and CECs (Otero & Meléndez, 2011). The Long-Term Environmental Indicator Program is scheduled to be conducted at intervals of every 5 years. Table 6 summarizes the sampling locations and parameters.

Table 6. Sampling Locations for Sediments and Fish and Crab Tissue Contaminants

Station Designation	Coordinates (Latitude, Longitude)	Sediment Samples	Tissue Samples
1SJB	N18.44589, W66.13032	X	X
2SJB	N18.44914, W66.11256	X	-
3SJCA	N18.45762, W66.11152	X	-
16SJB	N18.43692, W66.10102	X	-
15LC	N18.45701, W66.07754	X	-
18LC	N18.45531, W66.07632	X	X
5PC	N18.43851, W66.07987	X	X
4RPN	N18.42865, W66.07702	X	X
6MP	N18.43299, W66.06108	X	X
8SJC	N18.44131, W66.03891	X	X
7MPSJ	N18.42780, W66.03410	X	X
9SJ	N18.42428, W66.02023	X	-
17SJ	N18.41925, W66.01615	X	-
10CS	N18.42680, W65.99709	X	X
11LT	N18.43906, W65.98006	X	X
12BC	N18.45777, W65.99200	X	-
14PN	N18.44280, W65.95259	X	-
13PS	N18.43431, W65.95844	X	-

Table 7. Schedule of Events for Environmental Indicator Monitoring

Task	January	February	March	April	May	June	July	August	September	October	November	December
Volunteers and citizen scientist training and certification		X				X				X		
Macroinvertebrates monitoring	X			X			X			X		
Seagrass monitoring		X			X			X			X	
Fish census and coral reef monitoring		X			X			X			X	
QA/QC audits							X					
Environmental Data Indicator Index calculation, analysis, and reporting			X			X			X			X

Note: Shaded cells marked with an "X" note which months each activity in the program occurs.

Monitoring Data Use and Reporting

Weekly water samples collected on Thursdays are analyzed with the results published on the following Friday. If the sample values exceed the Enterococcus bacteria Beach Action Value (BAV) water quality criteria of 70 colonies in 100 milliliters of water, the public is notified with a flag notification system posted on the Estuario website, which remains posted until the next monitoring event the following week (Estuario, 2025a). Additionally, the results from the weekly samples are posted on Estuario's social media, including X and Facebook (USEPA, 2022). DNER conducts and reports weekly sampling for beach water quality on their Beach Monitoring webpage (2025). At the CLER sites and beaches, signboards provide information about the program and display a colored flag for each station representing the water conditions: green (*Enterococcus* values meet the BAV criteria) or red (*Enterococcus* values do not meet the BAV criteria) (Estuario, 2025a).

Original data sheets are scanned into electronic files and then archived in the Estuario database for a period of five years (Estuario, 2024a). Monthly and weekly water sampling results are published on Estuario's website, with links on the water quality webpage (Estuario, 2020a). A final technical report is compiled using the water quality monitoring data, and includes an executive summary, introduction, methods, assessment reports, tables, graph, discussion of the results, and conclusions (Estuario, 2024a).

Data can be used by regulators, government, industry, and those interested in providing financial support, as well as to help create new strategies to estimate water quality more accurately (Estuario, 2025a). Other data users include DNER, Puerto Rico Aqueduct and Sewer Authority (PRASA), academia and students, stakeholders, U.S. Army Corps of Engineers (USACE), and municipalities (Estuario, 2024a).

In addition, data generated through the IDDE monitoring are used to support the identification, tracking, and validation of pollution source corrective actions and infrastructure improvements throughout the watershed. Results and findings are shared with participating agencies and municipalities through the interagency IDDE Task Force. This task force meets periodically to discuss and implement solutions to eliminate illegal and unauthorized sewage discharges in the SJBE watershed.

Monitoring Data Gaps

The monitoring program currently has several important monitoring data gaps that must be addressed to support effective management and evaluation. To develop an understanding of the water quality for the entire estuary system, two main data gaps must be filled:

1. Understanding the flow of water among the different subbasins and channels.
2. Quantification of the morphology and bathymetry of the system.

Hydrology monitoring paired with water quality is lacking in many subwatersheds. A recommendation is to install continuous stage and flow sensors to calculate loads and enable modeling and predictions for the proposed expanded study area. Implementing an updated and revised Watershed Index QAPP, expanding benthic assessment studies, building centralized data infrastructure and a public dashboard, and adding hydrologic monitoring will substantially reduce monitoring gaps and improve the monitoring program's ability to analysis trends, attribute sources, and inform management.

Data management and public access are additional critical gaps in current watershed monitoring efforts. Monitoring data remain fragmented across partners and formats, so a comprehensive, centralized, and publicly accessible database is needed.

To improve stakeholder communication and usability, a real-time GIS dashboard that pulls partner data into an easy to navigate map interface with click to view station results and plain language summaries is recommended. Estuario is pursuing a technical support consultant to build this tool and will use programmatic funds for database and dashboard development as well as partner capacity building.

Existing Sources of Funding

Estuario's monitoring activities are currently supported by several external grants and programmatic funds. The RTRT Monitoring Program is funded by the Clean Water State Revolving Fund (SRF) grant C-72-250-03 (Estuario, 2025b). In addition, Estuario received support through USEPA grant CE99206929-2, which was active through September 30, 2025. Estuario staff identified additional current and potential funding streams such as ongoing programmatic allocations and additional SRF opportunities. These funding sources have supported core monitoring activities, but additional sustained investment will be needed to expand the program in response to Estuario Plan priorities and emerging monitoring needs. To ensure continuity and expansion of monitoring capacity, it is recommended to proactively secure these funds through near-term actions such as:

- Document and prioritize recurring programmatic needs in Estuario budgets;
- Pursue extensions or follow-on proposals for expiring or past grants;
- Apply for additional state and federal competitive grants; and
- Incorporate monitoring costs into partner agreements and SRF project budgets where appropriate.

Diversifying funding sources and establishing multi-year commitments or memorandums of understanding (MOUs) with partner agencies will reduce the risk of interruptions in monitoring and support planned investments in database development, dashboard tools, benthic and hydrology monitoring, and capacity building. In particular, the Board of Directors has identified CECs as a priority data gap, which requires a targeted funding strategy for expanded sampling, laboratory analysis, QA/QC, and technical support and that aligns programmatic resources, grant opportunities, and partner contributions with long-term monitoring needs.

Additional Funding Required

Additional funding will be required to support CECs monitoring, hydrology and bathymetry studies, data management infrastructure, rapid-response monitoring, and expanded ecological monitoring. These investments will be necessary to strengthen Estuario Plan implementation and address key data gaps identified in this Monitoring Plan and supporting technical recommendations. Without additional funding, the monitoring outlined in this plan cannot be fully implemented.

Timeframe

Short-term Actions (0-2 years)

Key Activities	Performance Measures	Targets	Lead Implementor(s) and Partner(s)	Estimated Costs	Potential Funding Sources
1. Continue monthly water quality sampling and current monitoring efforts while implementing targeted near-term improvements such as consolidating datasets to eliminate gaps and integrating real time reporting and mapping for ease of public access.	Complete standardization of QA/QC and metadata processes.	Expanded benthic and watershed index sampling to fill biological indicator gaps.	Leads: Estuario, DNER Implementing partners: municipalities, academia	$100,000 per year	USEPA, DNER, municipalities
2. Continue Collaborative Water Quality Monitoring efforts and develop an interim monitoring program, if needed, including a QAPP to define roles and responsibilities of the Collaborative Water Quality Monitoring Network, data collection, management, analysis, and interpretation.	Complete project plan and adopt by the Collaborative Water Quality Monitoring Network	Established consistent protocols for field sampling, data management, analysis, and reporting.	Leads: Estuario (Technical Support Consultant contractor) Implementing partners: DNER, municipalities, academia	$185,000 per year	USEPA, DNER, municipalities
3. Host an annual data summit where the annual report is presented and discussed and all researchers and stakeholders working in the SJBE provide updates on ongoing projects.	Hold annual data summit with participation from researchers and stakeholders.	Shared monitoring results, highlighted ongoing projects, and supported coordination among estuary partners.	Leads: Estuario Implementing partners: DNER, municipalities, academia	$50,000 per year	USEPA, DNER, municipalities
4. Continue monitoring of avian populations, including the Christmas bird counts and analysis data for trends.	Collect annual bird count data and complete trend analysis.	Maintained annual participation in Christmas bird counts and used the results to track long-term bird population trends in SJBE.	Leads: Estuario Implementing partners: U.S. Forest Service, Sierra Club, Puerto Rico Conservation Trust, Puerto Rico Ornithological Society, eBirds (Cornell Lab)	$10,000	USEPA, DNER

Key Activities	Performance Measures	Targets	Lead Implementor(s) and Partner(s)	Estimated Costs	Potential Funding Sources
5. Assess water quality sampling locations and identify additional stations if needed.	Review existing sampling locations and identify additional stations as needed.	Evaluated the current monitoring network and adjusted sampling locations to improve spatial coverage and data reliability.	Leads: Estuario, DNER Implementing partners: municipalities, academia	$150,000	USEPA, DNER
6. Develop an annual monitoring report with the data collected throughout the year from the monthly water quality sampling and the EIM.	Circulate the annual monitoring reports widely within the SJBE.	Synthesized annual observations from both atmospheric and maritime events which are reflected in the monitoring efforts.	Leads: Estuario (Technical Support Consultant) Implementing partners: DNER, municipalities, academia	$75,000 per year	USEPA
7. Share information and collaborate to develop the Adaptive Monitoring Plan for the Caño Martín Peña Ecosystem Restoration Project.	Develop the Adaptive Monitoring Plan.	Maintained coordination among partners to develop an effective adaptive monitoring plan for the Caño Martín Peña Ecosystem Restoration Project.	Leads: USACE, DNER, ENLACE Implementing partners: Estuario, academia	$100,000	USEPA, DNER, ENLACE

Medium-Term Actions (2-3 years)

Key Activities	Performance Measures	Targets	Lead Implementor(s) and Partner(s)	Estimated Costs	Potential Funding Sources
1. Develop restoration and/or protection goals for selected living resources, with associated water quality goals.	Identify and track restoration goals for selected resources.	Established resource and water quality goals that support long-term restoration and protection priorities for the SJBE.	Leads: Estuario (Technical Support Consultant contractor) Implementing partners: DNER, municipalities, academia	$200,000	DNER
2. Develop reporting tools for living resource goals and associated water quality targets.	Develop and use reporting tools for living resources and associated water quality targets.	Created reporting tools that clearly communicate progress toward living resource goals and related water quality targets.	Leads: Estuario (Technical Support Consultant contractor) Implementing partners: DNER, Estuario, academia	$100,000	DNER
3. Develop a data management system for all SJBE monitoring activities.	Develop and use a data management system for all SJBE monitoring activities.	Established a centralized data management system that supports consistent storage, access, and use of SJBE monitoring data.	Leads: Estuario (Technical Support Consultant contractor) Implementing partners: DNER, municipalities, academia	$100,000 to develop, $25,000 per year to maintain	USEPA, DNER

Key Activities	Performance Measures	Targets	Lead Implementor(s) and Partner(s)	Estimated Costs	Potential Funding Sources
4. Develop a study for benthic substrate monitoring that identifies sampling and measurement design and addresses how the analysis and monitoring of sediments help with SJBE restoration.	Develop benthic substrate monitoring plan.	Established a study that guides sediment monitoring and analysis to inform estuary restoration priorities.	Leads: Estuario Implementing partners: DNER, academia, National Oceanic and Atmospheric Administration (NOAA)	$150,000	NOAA
5. Record water level stage measurements in key SJBE locations.	Collect regular water level stage measurements at key locations and document results/ analysis.	Maintained regular stage measurements at key SJBE locations to support hydrologic monitoring and estuarine condition assessment.	Leads: DNER, U.S. Geological Survey (USGS) Implementing partners: Academia	To be determined (TBD) based on number of stage monitoring locations	DNER, USEPA
6. Install recording flow meters on waterbodies that discharge freshwater from the watershed to the estuarine system.	Add recording flow meters on priority freshwater discharge locations and document results/ analysis.	Established flow monitoring at key discharge points to improve understanding of freshwater inputs to the estuarine system.	Leads: DNER, USGS Implementing partners: Academia	TBD based on the number of flow meter locations	DNER, USEPA
7. Conduct a bathymetric assessment of the estuary and repeat every five years to evaluate the magnitude of change and decide on future assessment of the bathymetry.	Complete bathymetric assessment on a five-year cycle and document results/ analysis.	Used bathymetric assessments to track change over time and guide future monitoring needs.	Leads: USACE Implementing partners: USGS, NOAA, DNER	$500,000	USACE, NOAA
8. Assess flyovers at five-year intervals to assess the land cover and underwater cover and integrate into a GIS system.	Complete five-year aerial and benthic habitat assessments and integrate into GIS.	Used land cover and benthic habitat assessments to track ecological change over time and support estuary management decisions.	Leads: U.S. Forest Service, USGS Implementing partners: DNER, academia	$350,000	USEPA, DNER, municipalities, USACE
9. Provide comprehensive monitoring of avian populations within the SJBE.	Conduct comprehensive avian population monitoring within the SJBE and document results/ analysis.	Maintained ongoing bird monitoring to track avian population trends and inform estuary management and restoration efforts.	Leads: U.S. Forest Service, USGS Implementing partners: DNER, academia, Audubon Society, local organizations	$150,000 per year	U.S. Forest Service, USGS

Long-Term Actions (3+ years)

Key Activities	Performance Measures	Targets	Lead Implementor(s) and Partner(s)	Estimated Costs	Potential Funding Sources
1. Complete design of long-term monitoring efforts.	Implement long-term monitoring design and document results/analysis.	Finalized a long-term monitoring framework that supports consistent implementation and evaluation of estuary conditions over time.	Leads: Estuario, DNER Implementing partners: municipalities, academia	$150,000	USEPA, DNER, municipalities
2. Repeat quantitative estuary-wide forest inventories every ten years to monitor forest condition and level of services to society.	Complete the quantitative estuary-wide forest inventory and document results/ analysis.	Used decennial forest inventory to assess conditions, track change over time, and evaluate ecosystem services.	Leads: U.S. Forest Service Implementing partners: DNER, municipalities, academia	$100,000	U.S. Forest Service
3. Assess the number of additional remote water quality monitoring platforms required to complement extreme event sampling and evaluate how a rapid-response plan integrates outputs from these platforms to characterize the estuarine system's overall response.	Integrate remote water quality monitoring platforms into a rapid response plan.	Determined the additional monitoring capacity needed to support extreme event response and improve characterization of estuarine conditions during and after major events.	Leads: Estuario, DNER Implementing partners: municipalities, academia	$250,000	USEPA, DNER, municipalities
4. Continue to utilize satellite imagery and GIS to monitor coverage of the SJBE's ecological systems.	Identify gaps in data to better monitor the SJBE's ecological systems.	Used current imagery and GIS resources to monitor current processes within the SJBE's ecological systems.	Leads: Estuario, DNER Implementing partners: municipalities, academia, U.S. Forest Service	$100,000	USEPA, DNER, municipalities, U.S. Forest Service

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