2. ***Application for a Water Quality Certification and Definition of a Mixing Zone for the Arecibo Regional Wastewater Treatment Plant (RWWTP) - May 28, 2020***

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May 29, 2020

Mr. Ángel Meléndez
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Puerto Rico Department of Natural and Environmental Resources
Cruz A. Matos Environmental Agencies Building
Sector El Cinco – Highway 8838
Río Piedras, PR 00926

**Subject: Application for a Water Quality Certificate and Definition of a Mixing Zone for the Arecibo RWWTP (NPDES Permit No. PR0023710)**

Dear Mr. Meléndez,

On behalf of the Puerto Rico Aqueduct and Sewer Authority (PRASA), Jacobs hereby submits the enclosed application for a Water Quality Certificate and Definition of a Mixing Zone for the subject treatment plant.

If questions arise, please contact me at (207) 409-7186, or at Don.Holmes@jacobs.com.

Regards,

Don Holmes
Senior Program Manager

Copies to: Annette Feliberty/DNER, Jaime Géliga/CEPD, Moses Chang/EPA, Irma M. López Santos/PRASA, Juan C. Pérez Bofill/PRASA, Lisby Pagán/PRASA, Víctor Rivera Rivera/PRASA, Luis H. Abreu/Jacobs, Arecibo 301(h) Permit File, Reader File

# Application for a Water Quality Certificate and Definition of a Mixing Zone for the Arecibo RWWTP Outfall System

May 2020

PPS0514200452SJN

Prepared for
**Puerto Rico Aqueduct and Sewer Authority**

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# Executive Summary

This Request for a Water Quality Certificate and Definition of a Mixing Zone (Mixing Zone Application [MZA]) is for discharge from the Puerto Rico Aqueduct and Sewer Authority (PRASA) Arecibo Regional Wastewater Treatment Plant (RWWTP) into Class SB open coastal waters of the Atlantic Ocean. The application has been prepared in accordance with the Puerto Rico Environmental Quality Board (EQB) June 2012 *Interim Mixing Zone and Bioassay Guidelines* and the *Puerto Rico Water Quality Standards Regulation* (PRWQSR) (amended April 2019). The intent of this application is twofold:

1) Demonstrate that an interim mixing zone (IMZ) can be authorized for the Arecibo RWWTP discharge that meets EQB (now the Puerto Rico Department of Natural and Environmental Resources)[1] requirements for projected future flows.
2) Document PRASA's commitment to ongoing effective wastewater treatment and associated coastal water quality compliance.

## Background

PRASA has submitted an application to renew its National Pollutant Discharge Elimination System (NPDES) permit (No. PR0023710) for the Arecibo RWWTP. The renewal application was based on a maximum daily flow of 20 mgd (0.88 $m^3$/s). This MZA uses significant and updated information and reflects future conditions through the expected life of the renewal permit.

## Discharge Characteristics

The Arecibo RWWTP serves the municipality of Arecibo. The effluent is discharged approximately 3,769 feet offshore into the Atlantic Ocean at a depth of 84 to 90 feet. The discharge is through a high-rate diffuser manifold with a 660-foot-long barrel with 56 risers. Each riser has two ports, 180 degrees apart and directed perpendicular to the diffuser barrel, for a total of 112 ports. Currently, 41 of the 112 diffuser ports are open on alternating sides of the diffuser barrel.

This MZA process evaluates the most recent 3 years of data from PRASA discharge monitoring reports and includes data from the 301(h) monitoring studies conducted during the past 5 years. Information and data collected during the mixing zone validation studies (MZVS) conducted in 2007, 2016, and 2019 are also considered. Additionally, the most recent 5 years of whole effluent toxicity testing data are used. The conclusion is that the diffuser clearly provides sufficient initial dilution to comply with PRWQSR toxicity requirements at the edge of the mixing zone (EOMZ).

## Receiving Water Characteristics

The background concentrations of water quality parameters measured during the 2007, 2016, and 2019 MZVSs were used to evaluate assimilative capacity for definition of a mixing zone. The ambient current speed, based on the 301(h) monitoring study and MZVS data, was used to develop the mixing zone geometry in accordance with DNER's required calculation method. The density structure of the water column, measured during the MZVSs, was used to determine the critical initial dilution (CID). The CID was determined to be higher than described in the 2012 MZA.

[1] On August 2, 2018, Law #171 was promulgated and approved by the governor of Puerto Rico to reorganize several agencies. As a result, EQB was eliminated and its responsibilities now fall under DNER.

## Mixing Zone Definition

Predictions using the DNER-approved initial dilution model, UDKHDEN, were used as a screening-level model to evaluate the most critical condition and the DKHW model in the Visual Plumes suite of dilution models was used to determine the CID and associated mixing zone geometry. The modeling results indicate that the existing diffuser with 41 open ports will provide a CID of 376:1, significantly larger than the existing CID of 224:1, at the requested maximum daily flow and will result in a rectangular mixing zone approximately 256 meters long by 110 meters wide.

## Mixing Zone Compliance

The evaluations presented in this MZA indicate that a mixing zone is required for 14 effluent constituents. The dilution achieved in the mixing zone will clearly achieve compliance with all applicable water quality standards for all 14 constituents and for whole effluent toxicity.

A mixing zone validation program is proposed for the Arecibo RWWTP discharge, as required in Rule 1305 of the PRWQSR. The validation study proposed is based on a dye release study and limited laboratory analyses for mixing zone parameters collected at the EOMZ.

This MZA proposes effluent limits based on the evaluations conducted for parameters that cannot meet end-of-pipe receiving water quality criteria and demonstrates compliance with the requirements specified by EQB for the requested flow limit. This MZA is also consistent with PRASA’s latest NPDES permit renewal application.

Authorization of an IMZ based on this MZA will permit the Arecibo RWWTP to continue providing necessary wastewater treatment services to the community in a cost-effective and environmentally sound manner.

# 1. Introduction

This section provides an overview of the Arecibo Regional Wastewater Treatment Plant (RWWTP) ocean outfall and the mixing zone application (MZA) process. It also describes the purpose of the MZA and provides background information on the facility and a summary of the Puerto Rico Department of Natural and Environmental Resources (DNER) requirements concerning applications for mixing zone modifications.

## 1.1 Purpose

This MZA is being submitted by the Puerto Rico Aqueduct and Sewer Authority (PRASA) to DNER to initiate review of mixing zone definitions for PRASA's Arecibo RWWTP. The intent is to obtain a Water Quality Certificate (WQC) and Interim Mixing Zone (IMZ) definition that will be incorporated in a modified National Pollutant Discharge Elimination System (NPDES) permit and associated 301(h) waiver for this facility.

PRASA currently has an approved NPDES permit (PR0023710) and IMZ authorization for its Arecibo RWWTP (refer to Appendix A). The existing discharge permit and IMZ authorization are for a maximum daily flow of 20 million gallons per day (mgd), consistent with the design capacities of the treatment plant

## 1.2 Basis for the Request

PRASA is submitting this MZA to support an application for renewal of NPDES permit number PR0023710. The requested flow is a maximum daily flow of 20 mgd (consistent with the plant design capacity). Before the U.S. Environmental Protection Agency (EPA) renews the NPDES permit, PRASA must obtain a WQC from DNER and approval of an associated IMZ. This MZA presents the information that DNER needs to evaluate and define the proposed IMZ and issue the required WQC. It incorporates data and information collected from the last 3 years of PRASA Discharge Monitoring Reports (DMRs). The data from the 301(h) monitoring studies conducted over the past 5 years and the data from the 2016 and 2019 permit-required Mixing Zone Validation Studies (MZVS)[1,2] are used, as appropriate.

## 1.3 Arecibo Wastewater Treatment Plant Location

The Arecibo RWWTP is located in the municipality of Arecibo on Road 681 km 20 (refer to Figure 1-1). The Arecibo RWWTP is an advanced primary treatment facility with a design average daily flow of 10 mgd and a design maximum daily flow of 20 mgd. Treated chlorinated effluent is discharged through an ocean outfall. The terminus of the outfall is a high-rate, multi-port diffuser located in the Atlantic Ocean approximately 3,769 feet offshore (refer to Figure 1-1). Section 2 provides a more complete description of the facilities.

## 1.4 Summary of Mixing Zone Application Requirements

PRASA understands that the following regulations and guidelines (provided in Appendix A) apply to this MZA:

- Puerto Rico Environmental Quality Board (EQB) *Interim Mixing Zone and Bioassay Guidelines*, Revised June 2012
- The Puerto Rico Water Quality Standards Regulation (PRWQSR), as amended, April 2019

[1] CH2M HILL. 2017. *Arecibo Regional Wastewater Treatment Plant November 2016 Mixing Zone Validation Study*. Prepared for Puerto Rico Aqueduct and Sewer Authority. Submitted to the Puerto Rico Environmental Quality Board. June 7.

[2] CH2M HILL. 2019. *Arecibo Regional Wastewater Treatment Plant April 2019 Mixing Zone Validation Study*. Prepared for Puerto Rico Aqueduct and Sewer Authority. Submitted to the Puerto Rico Environmental Quality Board. July 16.

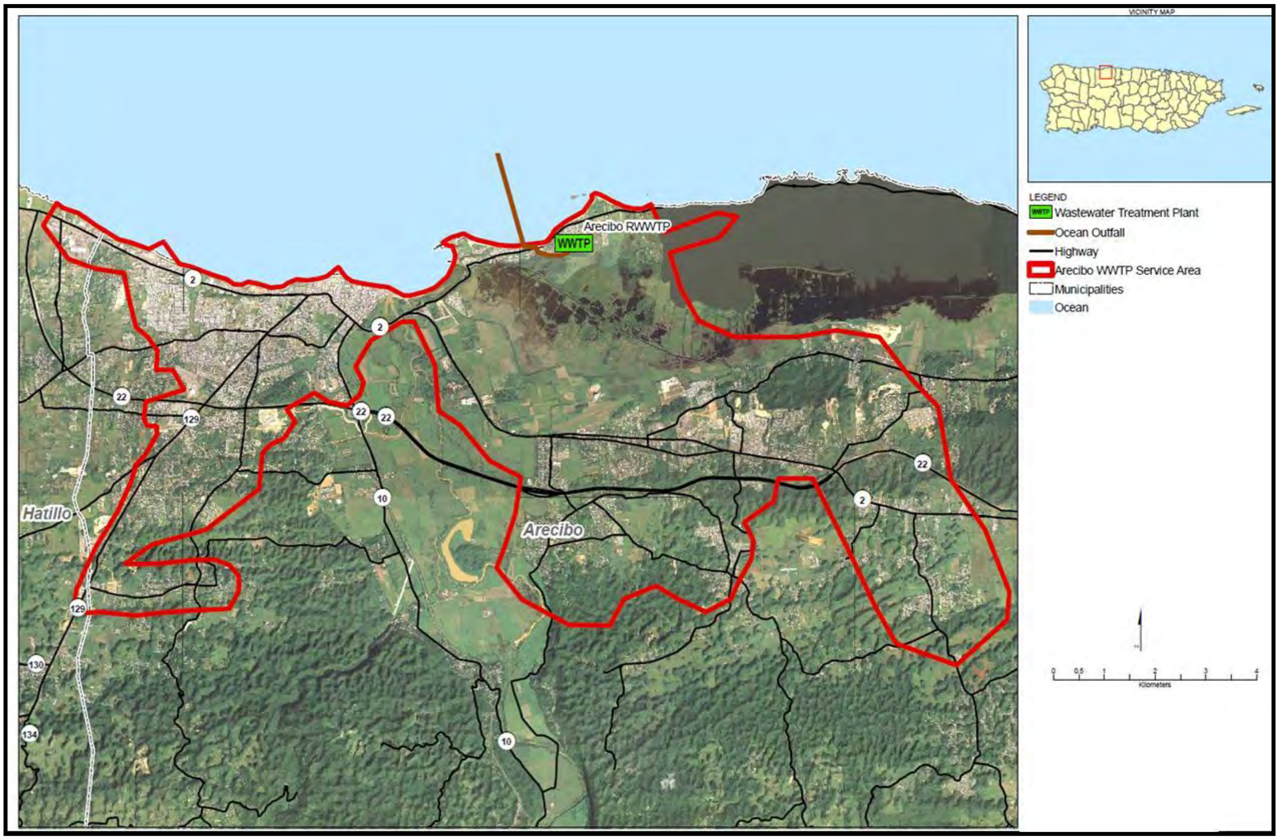


Figure 1-1. Location of Arecibo RWWTP, Ocean Outfall, and Service Area

Prior to submitting the previous MZAs for this facility, PRASA met with EQB representatives, and discussions have continued between the parties. These communications have resulted in agreements concerning applicable regulations and guidelines. The same general guidelines were used to develop this MZA. Appendix A of the 1999 MZA presented the conclusions of these discussions, which are summarized below:

- Dilution water for bioassay testing will be obtained in the vicinity of the bioassay laboratory. For the Arecibo RWWTP, a control test using Puerto Rico receiving waters is not necessary.
- Farfield oxygen demand will be determined using values for the Immediate Dissolved Oxygen Demand (IDOD) from Table VI-7, Typical IDOD Values, contained in EPA's *Revised Section 301(h) Technical Support Document*.
- Critical initial dilution (CID) will be calculated using the EPA DKHW model as provided in the EPA Visual Plumes suite of dilution models.
- In cases where established EPA laboratory procedures will not allow for detection limits low enough to assess compliance with criteria, the laboratory will make a good-faith effort to achieve the necessary detection limits.
- Samples for bioassay testing will be collected after primary treatment but before chlorination.
- The MZA is based on the currently permitted maximum daily flow and reflects the flow in the NPDES renewal application.

## 1.5 Information Included in this Request

This MZA includes all of information required to support an IMZ definition for the Arecibo RWWTP. The following information and data are provided, or referenced, as follows:

- **Section 2** includes facility descriptions and existing permit limitations. An evaluation of any additional parameters to be considered was conducted based on the five most recent priority pollutant scans conducted under the 301(h) monitoring studies.
- **Section 3** includes effluent characterization for those parameters of concern, which include parameters with limitations in the existing permit and any additional parameters identified in the priority pollutant scans performed under the 301(h) monitoring program. Parameters in the existing permit that are no longer regulated under the PRWQSR, or that recent data show have no potential to exceed water quality standards (WQS), are recommended for removal from the renewed permit.
- **Section 4** provides the whole effluent toxicity (WET) testing (bioassay) data from the most recent 5 years, as reported to EPA and DNER.
- **Section 5** summarizes general descriptions of the receiving water conditions. Oceanographic data from the 301(h) monitoring studies and the MZVSs are included and discussed when differences from the data presented in the previous MZA are significant and are, therefore, required to be included in calculations for this MZA. These data are provided in Section 5 and include density structure, dissolved oxygen (DO), pH, and current speed and direction.
- **Section 6** provides a summary and evaluation of receiving water chemistry for those parameters of concern in this MZA; data for all other parameters are provided in the appendices.
- **Section 7** presents the diffuser configuration and determination of the CID. Recent oceanographic data and evaluation of diffuser performance, including the potential for seawater intrusion, are considered in a re-evaluation of critical conditions and the CID.
- **Section 8** presents the mixing zone geometry and evaluation of compliance with PRWQSR criteria at the edge of the mixing zone (EOMZ) for WET. This section also presents the effluent constituents considered in the MZA and identifies those that require effluent limitations and those that require definition of a mixing zone or a compliance plan.
- **Section 9** documents compliance with PRWQSR criteria at the EOMZ for those constituents that require a mixing zone and develops the proposed effluent limitation for each of those parameters. This section also provides a description of the special calculations required to demonstrate compliance for nearfield and farfield DO and additional special calculations, including those for pH, hydrogen sulfide ($H_2S$), and color. These evaluations are made based on the re-evaluated CID.
- **Section 10** discusses regulatory requirements for implementing an IMZ, including applicable environmental permits or documentation and a summary of required monitoring and validation studies. As required by the PRWQSR, this section includes the proposed effluent limitations for water quality certification for those parameters specifically addressed in this MZA.

# 2. Facility Description and Discharge Characterization

The Arecibo RWWTP discharges treated wastewater to the Atlantic Ocean off the north coast of Puerto Rico. This section summarizes the treatment and discharge facilities at this RWWTP and provides NPDES permit monitoring and effluent limitation requirements. Parameters with existing limitations are monitored and concentrations reported in the monthly DMRs. An expanded evaluation, based on the 301(h) monitoring priority pollutant scans for the effluent stream of this facility, is presented in this section. This evaluation is used to determine whether any parameters of concern (POCs), in addition to those with existing permit limitations, should be considered in this MZA.

## 2.1 Treatment Processes and Flows

The Arecibo RWWTP is an advanced primary treatment facility that serves the municipality of Arecibo (refer to Figure 1-1). Treatment processes include screening, grit removal, sedimentation, chlorination, and sludge dewatering. The plant disinfects effluent with chlorine before discharging it into the Atlantic Ocean. Arecibo RWWTP sludge is dewatered and disposed of in an approved landfill. Figures 2-1 and 2-2 illustrate the Arecibo RWWTP layout and process flow diagram, respectively. The Arecibo RWWTP design flow is a maximum daily flow of 20 mgd, which serves as the basis for this MZA.

## 2.2 Discharge Characteristics

The Arecibo RWWTP discharges advanced primary treated wastewater into the Atlantic Ocean into Class SB receiving waters through an outfall/diffuser system that reaches from Jarealito Beach to the diffuser site northeast of Arecibo. The discharge is approximately 3,769 feet offshore at a maximum depth of 89 feet (refer to Figure 1-1). The 48-inch-diameter outfall terminates in a 660-foot-long, multiple-port diffuser manifold. The outfall pipe is buried approximately 6.6 feet below the ocean bottom at a slope of 0.0925 feet per foot. The diffuser has 112 ports (2 per riser), ranging in diameter from 2.5 inches (for 110 ports) to 3.5 inches (for 2 ports) to accommodate maximum daily flows of up to 60 mgd. This MZA is based on the current 42-port configuration. Figure 2-3 illustrates the overall diffuser configuration. Section 7 discusses diffuser design and operational characteristics in more detail.

## 2.3 Summary of Effluent Limitations

Table 2-1 summarizes the effluent limitations in the existing Arecibo RWWTP NPDES permit (included in Appendix A). The following points should be noted with respect to interpreting the table:

- Mixing zone parameters are those that are discharged at end-of-pipe (EOP) concentrations above the PRWQSR criteria and that must meet the PRWQSR criteria at the EOMZ.
- Compliance plan parameters are those that are included in compliance plans and have interim EOP limitations above the PRWQSR criteria.
- EOP parameters are generally technology-based effluent limitations or, as in the case of total Kjeldahl nitrogen (TKN), informational parameters.

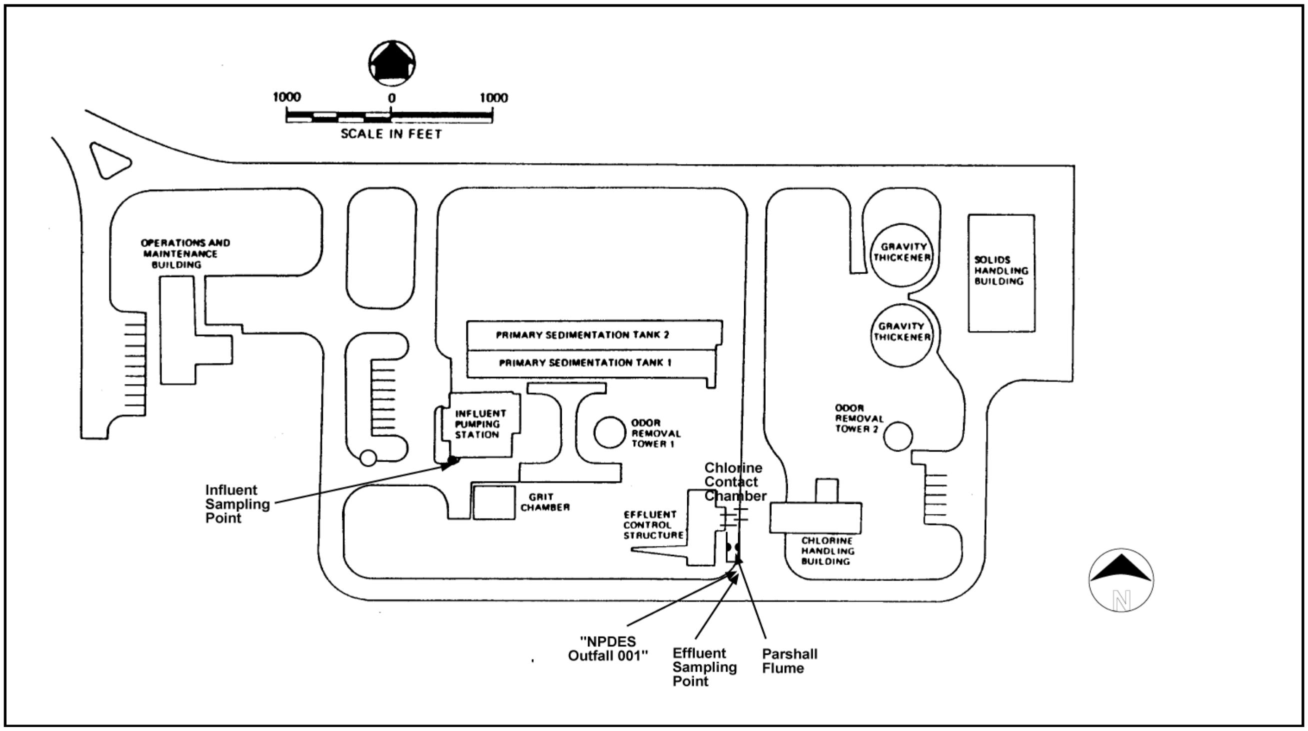


Figure 2-1. Arecibo RWWTP Site Plan

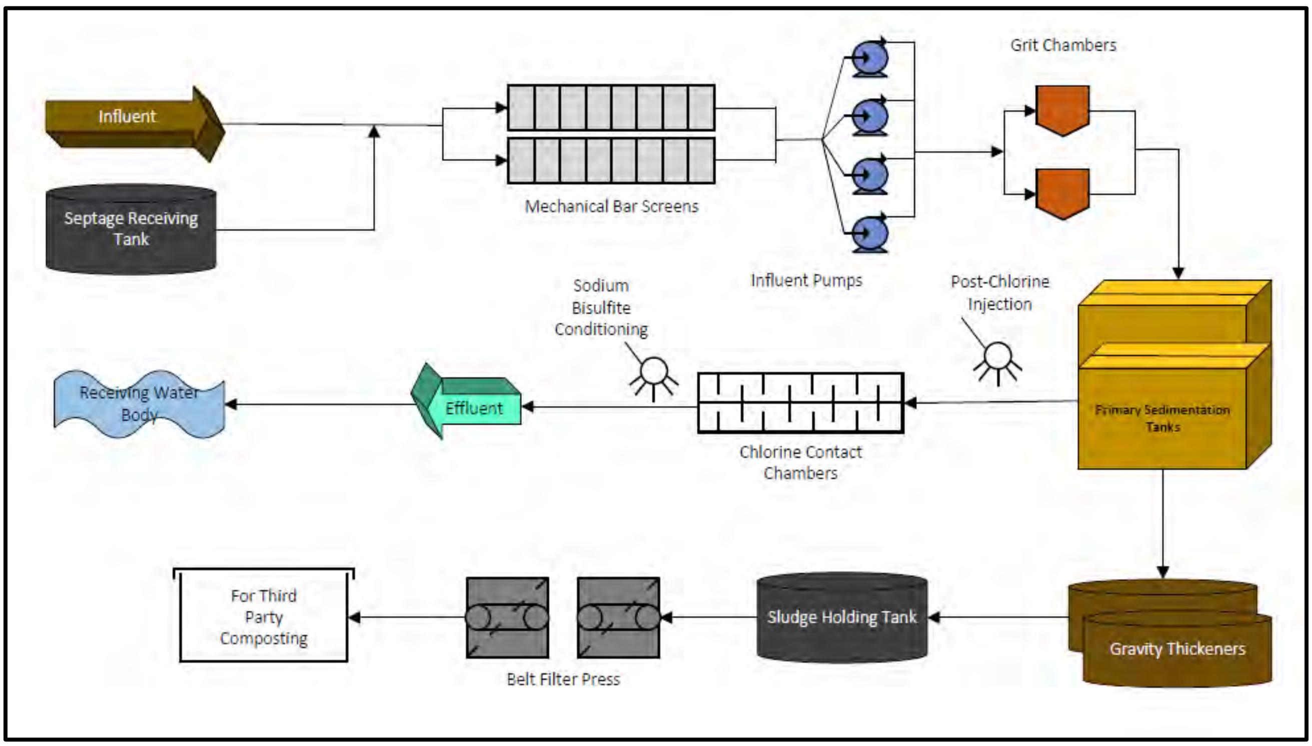


Figure 2-2. Arecibo RWWTP Process Flow Diagram

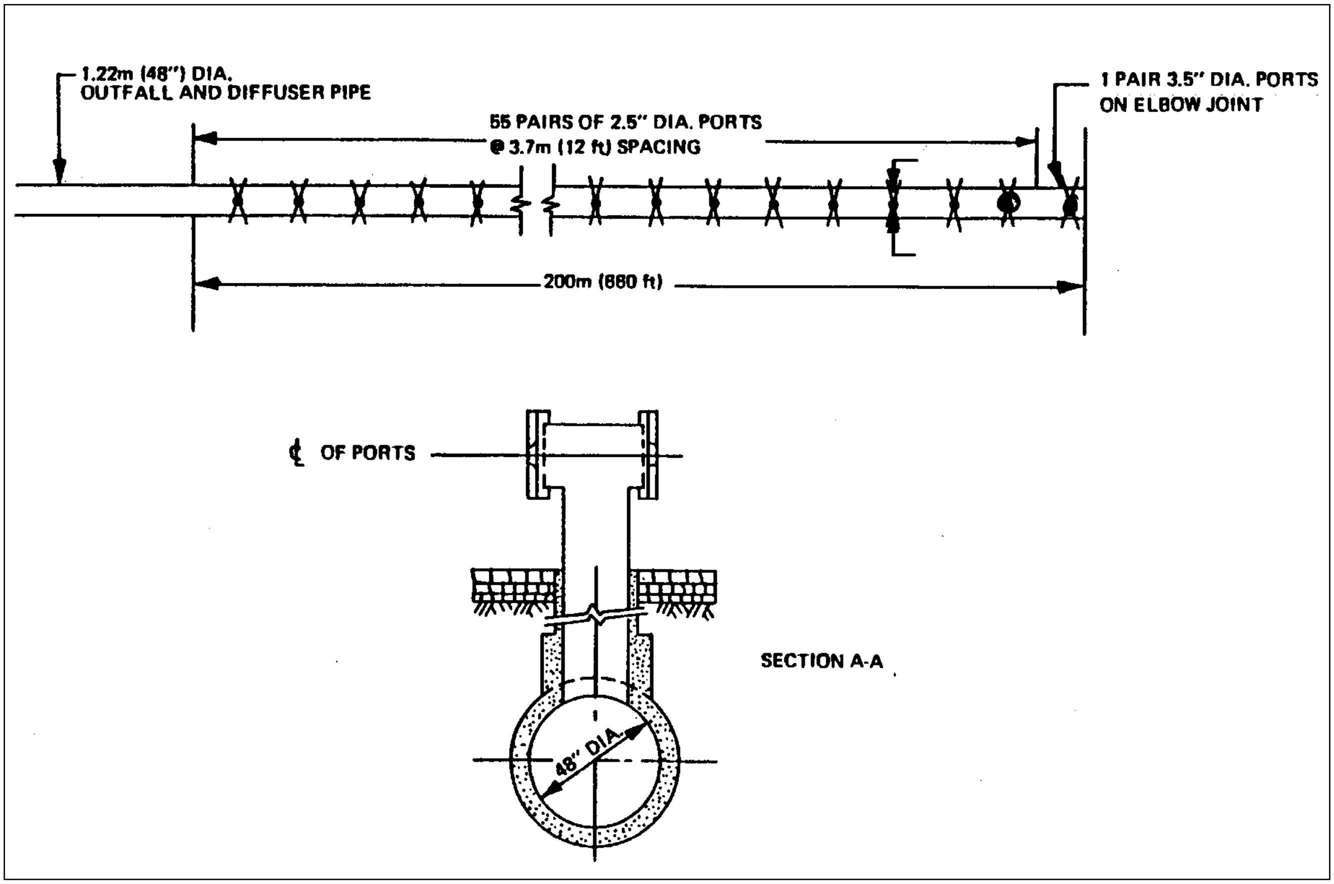


Figure 2-3. Schematic of the Arecibo Diffuser Port Configuration

Table 2-1. Effluent Limitations Listed in 2015 NPDES Permit for the Arecibo RWWTP

| Parameter | Units | Monitoring Frequency | Limitation Type | End of Pipe | Edge of Mixing Zone | Compliance Plan Interim/Final |
|---|---|---|---|---|---|---|
| Flow | mgd | Continuous | Max. Daily | 20.0 | -- | -- |
| $BOD_5$ (Concentration) | mg/L | Twice/week | Avg. Monthly | 120 | -- | -- |
| $BOD_5$ (Mass Loading) | kg/day | Twice/week | Avg. Monthly | 9,805 | -- | -- |
| $BOD_5$ (Percent removal) | % | Twice/week | Avg. Monthly | 30 | -- | -- |
| TSS (Concentration) | mg/L | Twice/week | Avg. Monthly | 110 | -- | -- |
| TSS (Mass Loading) | kg/day | Twice/week | Avg. Monthly | 8,326 | -- | -- |
| TSS (Percent removal) | % | Twice/week | Avg. Monthly | 50 | -- | -- |
| 2,4,6-Trichlorophenol | µg/L | Monthly for first year then | Max. Daily | MO | -- | -- |
| 2,4-Dichlorophenol | | | | | | |

Table 2-1. Effluent Limitations Listed in 2015 NPDES Permit for the Arecibo RWWTP

| Parameter | Units | Monitoring Frequency | Limitation Type | End of Pipe | Edge of Mixing Zone | Compliance Plan Interim/Final |
|---|---|---|---|---|---|---|
| 2-Chlorophenol | | annual thereafter | | | | |
| 2-Methyl-4,6-Dinitrophenol | | | | | | |
| Pentachlorophenol | | | | | | |
| Color | Pt-Co | Monthly | Max. Daily | MO | Narrative | -- |
| Copper (Cu) | µg/L | Monthly | Max. Daily | 55.26 | 3.73 | -- |
| Cyanide, Free (CN) | µg/L | Monthly | Max. Daily | 10.2 | 1.0 | -- |
| Dissolved Oxygen (DO) | mg/L | Daily | Min. Daily | MO | >4.0 | -- |
| Nickel (Ni) | µg/L | Monthly | Max. Daily | 9.48 | 8.28 | -- |
| pH | SU | Daily | Min. Daily | 6.0 | 7.3 | -- |
| | | | Max. Daily | 9.0 | 8.5 | -- |
| Silver (Ag) | µg/L | Monthly | Max. Daily | 6.61 | 2.24 | -- |
| Solids and Other | -- | -- | Avg. Monthly | -- | -- | -- |
| Sulfide (undissociated $H_2S$) | µg/L | Monthly | Max. Daily | 25 | 2 | -- |
| Surfactants (MBAS) | µg/L | Monthly | Max. Daily | 7,969 | 500 | -- |
| Settleable Solids (SS) | ml/L | Daily | Max. Daily | MO | -- | -- |
| Taste and Odor | -- | -- | Avg. Monthly | MO | -- | -- |
| Temperature | °C | Daily | Max. Daily | 32.2 | -- | -- |
| Thallium (Ti) | µg/L | Monthly | Max. Daily | 0.49 | 0.47 | -- |
| TKN | µg/L | Monthly | Max. Daily | MO | -- | -- |
| Turbidity | NTU | Monthly | Max. Daily | 57 | 10 | -- |
| Zinc (Zn) | µg/L | Monthly | Max. Daily | 85.62 | -- | -- |
| **Compliance Plan Parameters** | | | | | | |
| Residual Chlorine | mg/L | Daily | Max. Daily | -- | -- | 0.50/0.011 |
| Enterococci (Geo. Mean) | Col/100 ml | Monthly | Max. Daily | -- | -- | MO/35 |
| Enterococci (Single Sample) | Col/100 ml | Monthly | Max. Daily | -- | -- | MO/Calc |

Table 2-1. Effluent Limitations Listed in 2015 NPDES Permit for the Arecibo RWWTP

| Parameter | Units | Monitoring Frequency | Limitation Type | End of Pipe | Edge of Mixing Zone | Compliance Plan Interim/Final |
|---|---|---|---|---|---|---|
| **Parameters No Longer Regulated Under PRWQSR (2019)** | | | | | | |
| Fecal Coliform (Geo. Mean) | col/100 mL | 200 | Avg. Monthly | 200 | -- | -- |
| Fecal Coliform (Exceedance) | col/100 mL | 400 | Max. Daily | >20% | -- | -- |
| Nitrogen (as NO2+NO3+NH3) | mg/L | Monthly | Max. Daily | 39.753 | 5.00 | -- |

Notes:
°C = degrees Celsius
Avg. = average
$BOD_5$ = 5-day biochemical oxygen demand
col = colonies
Geo. Mean = geometric mean
$H_2S$ = undissociated hydrogen sulfide
kg/day = kilogram(s) per day
Max. = maximum
MBAS = methylene blue active substances
µg/L = microgram(s) per liter
mg/L = milligrams(s) per liter
Min. minimum
ml = milliliter(s) per liter
MO = monitor only
NTU = Nephelometric Turbidity Units
Pt-Co = platinum cobalt
SU = Standard Unit
TSS = total suspended solids

## 2.4 Re-evaluation of Parameters of Concern

All parameters listed in the existing NPDES permit are obvious potential POCs and are included in the analyses presented in this MZA. It is noted that some of these parameters are not regulated under the most recent PRWQSR; therefore, PRASA is requesting that these non-regulated parameters be dropped from the renewed WQC and associated NPDES permit. In addition to the POCs defined by the existing permit, full priority pollutant scans of the effluent were examined to determine whether any additional parameters require limitations and/or mixing zones. These priority pollutant scans were done under the ongoing 301(h) monitoring program for the Arecibo RWWTP. The previous 5 years of 301(h) effluent analyses were used in the evaluation.

The concentrations of each parameter listed in the existing NPDES permit and with a numerical criterion in the PRWQSR were examined to determine if there were detections greater than their PRWQSR criteria or if there were a reasonable potential[3] to exceed the criteria. Appendix B provides the tabulated data and detailed calculations, and Appendix C provides a memorandum discussing the evaluation of the data. A brief discussion of detections of new POCs is provided below and existing POCs are summarized in Section 3.

Total nitrogen (TN) was detected above the PRWQSR in all samples analyzed. The 2019 version of PRWQSR lists TN as $NO_2$+$NO_3$+TKN. Prior versions of the PRWQSR listed nitrogen as total inorganic nitrogen (TIN;

[3] The reasonable potential calculation was performed using the method described in the EPA *Technical Support Document for Water Quality-Based Toxics Control* using a 99-percent confidence level and a 99-percent probability.

$NH_3$+$NO_2$+$NO_3$). The existing permit references TIN. Because TKN includes $NH_3$, total nitrogen as $NO_2$+$NO_3$+TKN is an expected POC and is included in this 2020 MZA.

Three pesticide-related parameters—alpha-BHC, heptachlor, and azinphos-methyl (guthion)—had one detection each above the PRWQSR. All three parameters were determined to be unlikely POCs in the Arecibo RWWTP discharge (refer to Appendix C). None of these parameters was detected in the receiving water; therefore, these parameters are not carried forward as POCs.

# 3. Effluent Characterization

This section discusses water quality criteria based on the PRWQSR, characterizes the constituents present in the Arecibo RWWTP effluent, and compares POCs identified in Section 2 to their respective water quality criteria. This section also discusses constituents determined to require a mixing zone, modifications to an existing mixing zone, or some other action during the NPDES permit and IMZ authorization renewal process.

## 3.1 Water Quality Criteria and Regulations

The existing WQC and mixing zone definition were based on the PRWQSR, as amended in March 2010. As of the date of this MZA, the April 2019 amended PRWQSR are applicable. Criteria for Class SB waters are listed in *Rule 1303, Water Quality Standards and Use Classifications to be Protected in the Waters of Puerto Rico*. These regulations (and those in *Rule 1305, Mixing Zones*) incorporate the EQB[4] *Interim Mixing Zone and Bioassay Guidelines* by reference. It is anticipated that any changes to the NPDES permit will be in conformance with the April 2019 PRWQSR.

The following secondary sources and procedures were used in the interpretation and calculations related to selected parameters in this MZA:

- Calculation of the pH criterion reflects Section 2, Chapter 6(A) of EQB *Interim Mixing Zone and Bioassay Guidelines*.
- Calculation of the DO criterion reflects Section 2, Chapter 6(C) of EQB *Interim Mixing Zone and Bioassay Guidelines*.
- Calculation of the WET criteria reflects Section 2, Chapter 3 of EQB *Interim Mixing Zone and Bioassay Guidelines*.
- EQB regulations have been revised to define total nitrogen as the sum of TKN plus ammonia, pursuant to Rule 1303.2.
- A narrative criterion for oil and grease is given in Rule 1303.1, PRWQSR.
- Narrative criteria for color mandate that color should not vary from the natural condition. Color samples must be analyzed by methods, as indicated in Section 2, Chapter 6(B) of EQB *Interim Mixing Zone and Bioassay Guidelines*.
- The PRWQSR sulfide criterion is given in terms of undissociated hydrogen sulfide ($H_2S$), with calculations based on total sulfide, pH, temperature, and ionic strength (that is, salinity or conductivity).

The procedures for establishing mixing zones for pH, DO, color, $H_2S$, and WET are applied in Sections 8 and 9 of this MZA.

## 3.2 Effluent Characterization and Constituents of Concern

The chemical constituents in the Arecibo RWWTP effluent have been characterized by two discrete sample collection and analysis programs (that is, the DMR program and the 301(h) monitoring program). Full EPA priority pollutant scans conducted under the 301(h) monitoring program were used to determine whether parameters in addition to those with limitations under the existing permits are of concern (see Section 2.4). As mentioned in Section 2, parameters no longer regulated under the PRWQSR are not considered.

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[4] Now DNER: the latest revision was done under EQB.

Because DMR data will be used to evaluate future permit compliance, they are used to define required mixing zones for POCs that are routinely monitored. The DMRs for the most recent 3 years (April 2017 through March 2020; refer to Appendix D) are used for compliance calculations, which is the procedure that is generally used by DNER.

The maximum reported effluent concentrations and the reasonable potential (RP) effluent concentrations, based on a reasonable potential analysis[5] (RPA), were examined. The maximum concentration and RP concentration for each constituent, based on the most recent 3-year dataset, were compared to the water quality criteria (refer to Table 3-1). The results of the comparison produced a list of parameters that could potentially exceed the receiving water criteria at the EOP (refer to Table 3-2). It is recognized, and accounted for in the evaluations, that parameters that exceed WQS at EOP may meet the criteria specified by the PRWQSR within and at the edge of the previously approved IMZ, based on the CID coupled with the background receiving water concentrations.

Flow, 5-day biochemical oxygen demand ($BOD_5$),[6] total suspended solids (TSS), parameters requiring monitoring only (MO), and parameters with narrative standards and limitations are regulated under specific standards and criteria and do not require a mixing zone.

It is noted that there were five specific phenolic compounds listed in the current permit with MO required (refer to Table 2-1). Except for pentachlorophenol, all analyses were reported as not detected, at well below the PRWQSR criteria. In the case of pentachlorophenol, all analyses were reported as not detected at the levels achievable by the laboratory. These parameters are not considered further in this MZA

Table 3-1. Arecibo RWWTP Identified Constituents of Concern

| Parameter | Units | Number of Samples Used[a] | Number of Samples Not Used[b] | PRWQSR | Existing Limitation[c] | Reported Maximum[d] (Minimum) | Reasonable Potential[d] |
|---|---|---|---|---|---|---|---|
| **Existing Mixing Zone Parameters** | | | | | | | |
| Color | Pt-Co | 32 | 0 | Narrative | MO | 45 | 83.19 |
| Copper (Cu) | µg/L | 31 | 1 | 3.73 | 55.62 | 23 | 47.88 |
| Cyanide (CN), Free | µg/L | 30 | 1 | 1 | 10.2 | 3.18 | 6.26 |
| Dissolved Oxygen (DO) | mg/L | 36 | 0 | 5 | MO | 4.0 | 2.46 |
| Nickel (Ni) | µg/L | 30 | 1 | 8.28 | 9.48 | 7 | 9.63 |
| pH | SU | 36 | 0 | 7.3 | 6 | 6.0 | 5.26 |
| pH | SU | 35 | 0 | 8.5 | 9 | 7.58 | 7.78 |
| Silver (Ag) | µg/L | 31 | 0 | 2.24 | 6.61 | 2.7 | 4.74 |
| Sulfide ($H_2S$) | µg/L | 31 | 1 | 2 | 25 | 82.3 | 279.97 |
| Surfactants (MBAS) | µg/L | 32 | 0 | 500 | 7,969 | 4690 | 7,797.27 |
| Thallium (Tl) | µg/L | 22 | 0 | 0.47 | 0.49 | 1 | 1.70 |
| Turbidity | NTU | 32 | 0 | 10 | 57 | 55 | 102.67 |
| **Existing Compliance Plan Parameters** | | | | | | | |
| *Enterococcus* | Number | 35 | 1 | 104 | 104 | 0 | 0.00 |
| *Enterococcus* | col/100 ml | 32 | 0 | 35 | 35 | 2,420 | 10,314.35 |
| Residual Cl | mg/L | 24 | 1 | 0.0075 | 0.5 | 0.47 | 0.62 |
| **Existing End of Pipe Parameters** | | | | | | | |
| $BOD_5$ (percent removal) | % | 34 | 0 | Site Specific | 30 | 38 | 21.65 |

[5] The reasonable potential analysis was performed based on the procedure in the EPA *Technical Support Document for Water Quality-Based Toxics Control* at the 99-percent confidence level and the 99-percent probability level.
[6] The maximum permitted $BOD_5$ is considered in the evaluation of farfield DO demand in Section 5.

Table 3-1. Arecibo RWWTP Identified Constituents of Concern

| Parameter | Units | Number of Samples Used[a] | Number of Samples Not Used[b] | PRWQSR | Existing Limitation[c] | Reported Maximum[d] (Minimum) | Reasonable Potential[d] |
|---|---|---|---|---|---|---|---|
| $BOD_5$ (monthly average) | kg/day | 34 | 0 | Site Specific | 9,085 | 1,545 | 2,207.06 |
| $BOD_5$ (monthly average) | mg/L | 34 | 0 | Site Specific | 120 | 61 | 85.74 |
| $BOD_5$ (weekly average) | kg/day | 14 | 0 | Site Specific | MO | 2,543 | NA |
| $BOD_5$ (weekly average) | mg/L | 14 | 0 | Site Specific | MO | 63 | NA |
| Flow (monthly average) | mgd | 35 | 1 | None | MO | 6.2 | 6.59 |
| Flow (maximum daily) | mgd | 35 | 1 | None | 20 | 18 | 24.90 |
| TKN | µg/L | 32 | 0 | NA | MO | 28,800 | 43,556.23 |
| Temperature | °C | 36 | 0 | 30 | 32.2 | 31.1 | 32.58 |
| TSS (percent removal) | % | 34 | 0 | Site Specific | 50 | 35 | 15.97 |
| TSS (monthly average) | kg/day | 33 | 1 | Site Specific | 8,326 | 1,190 | 1,780.27 |
| TSS (monthly average) | mg/L | 34 | 0 | Site Specific | 110 | 55 | 82.61 |
| TSS (weekly average) | mg/L | 14 | 0 | Site Specific | NA | 63 | NA |
| TSS (weekly average) | kg/day | 14 | 0 | Site Specific | NA | 79 | NA |
| Zinc (Zn) | µg/L | 17 | 0 | 85.62 | 85.62 | 95.7 | 328.59 |
| **Existing Narrative Parameters** | | | | | | | |
| Oil and Grease (O&G) | mg/L | 32 | 0 | Narrative | MO | 16.9 | 35.84 |
| Settleable solids (SS) | ml/L | 32 | 1 | Narrative | MO | 0.5 | 4.88 |
| **Existing Parameters No Longer Regulated** | | | | | | | |
| Nitrogen ($NO2+NO3+NH3$)[e] | µg/L | 32 | 0 | 5,000[f] | 39,752 | 29,020 | 43,416.69 |
| F. Coliforms | col/100 ml | 32 | 0 | NA | 200 | 2,420 | 7,139.98 |
| F. Coliforms | % Exceedance | 32 | 0 | NA | 20 | 100 | 242.63 |

[a] Number of reported values extracted from the PRASA data base, with outliers and inconsistent data removed.
[b] The values reported were higher than three standard deviations from the mean and were removed as outliers.
[c] The permit limitation is the minimum value for BOD and TSS percent removal, minimum pH, and dissolved oxygen.
[d] The reported maximum and reasonable potential values are calculated with outliers and inconsistent data removed.
[e] This form of nitrogen is no longer regulated. However, total nitrogen is now regulated and will require a mixing zone.
[f] Criterion under previous PRWQSR in effect at the time of current permit EDP.

Note:

NA = not applicable

Table 3-2. Arecibo RWWTP Identified Constituents of Concern that May Require a Mixing Zone

| Parameter | Units | Number of Samples Used[a] | Number of Samples Not Used[b] | PRWQSR | Limitation[c] | Reported Maximum[d] (or Minimum) | Reasonable Potential[d] |
|---|---|---|---|---|---|---|---|
| **Existing Mixing Zone Parameters** | | | | | | | |
| Color | Pt-Co | 32 | 0 | Narrative | MO | 45 | 83.19 |
| Copper | µg/L | 31 | 1 | 3.73 | 55.26 | 23 | 47.88 |
| Cyanide, Free | µg/L | 30 | 1 | 1.0 | 10.2 | 3.18 | 6.26 |
| Dissolved Oxygen | mg/L | 36 | 0 | 5.0 | MO | 4.0 | 2.46 |

Table 3-2. Arecibo RWWTP Identified Constituents of Concern that May Require a Mixing Zone

| Parameter | Units | Number of Samples Used[a] | Number of Samples Not Used[b] | PRWQSR | Limitation[c] | Reported Maximum[d] (or Minimum) | Reasonable Potential[d] |
|---|---|---|---|---|---|---|---|
| Nickel | µg/L | 30 | 1 | 8.28 | 9.48 | 7.9 | 9.63 |
| pH (minimum) | SU | 36 | 0 | 7.3 | 6 | 6 | 5.26 |
| pH (maximum) | SU | 35 | 0 | 8.5 | 9 | 7.58 | 7.78 |
| Silver | µg/L | 31 | 0 | 2.24 | 6.61 | 2.7 | 4.74 |
| Sulfide ($H_2S$) | µg/L | 31 | 1 | 2 | 25 | 82.3 | 279.97 |
| Surfactants (MBAS) | µg/L | 32 | 0 | 500 | 7,969 | 4,960 | 7,797 |
| Thallium | µg/L | 22 | 0 | 0.47 | 0.49 | 1 | 1.70 |
| Turbidity | NTU | 32 | 0 | 10 | 57 | 55 | 103 |
| Zinc | µg/L | 17 | 0 | 85.62 | 85.62 | 95.7 | 328.59 |
| **Existing Compliance Plan Parameters** | | | | | | | |
| Residual Chorine | mg/L | 24 | 1 | 0.0075 | 0.5 | 0.47 | 0.62 |
| **Potential POCs not in the Current Permit** | | | | | | | |
| Total Nitrogen[e] | µg/L | -- | -- | 5,000 | -- | -- | -- |

[a] Number of reported values extracted from the PRASA database, with outliers and inconsistent data removed.
[b] The values reported were higher than three standard deviations from the mean and were removed as outliers.
[c] The permit limitation is the minimum value for BOD and TSS percent removal, minimum pH, and DO.
[d] The reported maximum and reasonable potential values are calculated with outliers and inconsistent data removed.
[e] Data are available from 301(h) Monitoring studies. This parameter is discussed in Section 9.

# 4. Whole Effluent Toxicity Testing

The NPDES permit for the Arecibo RWWTP requires chronic WET testing. The establishment of a mixing zone also requires WET testing and demonstration that toxicity is reduced to acceptable levels within the mixing zone and meets prescribed values in terms of toxicity units at the EOMZ. This section presents the results of the WET testing for the past 3 years (March 2017 through February 2020)[7] at the Arecibo RWWTP. The application of those data to determine the toxicity at the EOMZ is provided in Section 8.

The effluent samples were taken at a sampling location downstream from the clarifiers and upstream of the chlorine contact chamber. The results of the tests are provided in Table 4-1. The full laboratory reports are included in Appendix E. It is noted that the current NPDES permit requires only chronic WET testing. Compliance for acute testing was demonstrated in the 2012 MZA.[8]

Table 4-1. Bioassay Test Results for the Arecibo RWWTP Effluent (March 2017–February 2020)

| Test Date[a] | Species[b] | Chronic NOEC Percent Effluent | Chronic $IC_{25}$[c] Percent Effluent |
|---|---|---|---|
| March 2017 | *Mysidopsis bahia* | 11 | 13.2 |
| | *Cyprinodon variegatus* | 11 | 16.8 |
| | *Arbacia punctulata* | 11 | 33.2 |
| June 2017 | *Mysidopsis bahia* | 1.28 | 11.3 |
| | *Cyprinodon variegatus* | 11 | 16.7 |
| | *Arbacia punctulata* | 2.56 | 4.67 |
| August 2017 | *Mysidopsis bahia* | 11 | 16.0 |
| | *Cyprinodon variegatus* | 11 | 19.2 |
| | *Arbacia punctulata*[d] | 2.56 | 7.28 |
| February 2018 | *Mysidopsis bahia*[d,e] | 0.64 | 7.91 |
| | *Cyprinodon variegatus*[e] | 11.0 | >11.0 |
| | *Arbacia punctulata* | 11.0 | 33.0 |
| May 2018 | *Mysidopsis bahia* | 11.0 | 17.5 |
| | *Cyprinodon variegatus* | 11.0 | 19.4 |
| | *Arbacia punctulata* | 11.0 | 32.9 |
| August 2018 | *Mysidopsis bahia*[d] | 11 | 18.6 |
| | *Cyprinodon variegatus* | 11.0 | 28.2 |
| | *Arbacia punctulata* | 11.0 | 33.0 |

[7] The fourth quarter test for 2017 was not done because of hurricane strike in Puerto Rico.
[8] CH2M HILL. 2012. *Revised Application for a Water Quality Certificate and Definition of a Mixing Zone for the Arecibo Regional Wastewater Treatment Plant Outfall System*. Prepared for the Puerto Rico Aqueduct and Sewer Authority. Submitted to the Puerto Rico Environmental Quality Board. August 21.

Table 4-1. Bioassay Test Results for the Arecibo RWWTP Effluent (March 2017–February 2020)

| Test Date[a] | Species[b] | Chronic NOEC Percent Effluent | Chronic $IC_{25}$[c] Percent Effluent |
|---|---|---|---|
| November/December 2019 | *Mysidopsis bahia*[f] | 0.64 | 14.0 |
| | *Cyprinodon variegatus* | 11.0 | 19.7 |
| | *Arbacia punctulata* | 11.0 | 33.9 |
| February 2019 | *Mysidopsis bahia* | 11.0 | 15.4 |
| | *Cyprinodon variegatus* | 11.0 | 19.3 |
| | *Arbacia punctulata* | 11.0 | 4.91 |
| May 2019 | *Mysidopsis bahia* | 11 | 19.4 |
| | *Cyprinodon variegatus*[d,e] | 11 | >11 |
| | *Arbacia punctulata* | 11 | 33.2 |
| August 2019 | *Mysidopsis bahia* | 11 | 14.7 |
| | *Cyprinodon variegatus* | 11 | 22.5 |
| | *Arbacia punctulata* | 1.28 | 32.3 |
| November 2019 | *Mysidopsis bahia* | 11 | 18.1 |
| | *Cyprinodon variegatus* | 11 | 19.4 |
| | *Arbacia punctulata* | 11 | 33.0 |
| February 2020 | *Mysidopsis bahia* | 11 | 14.4 |
| | *Cyprinodon variegatus* | 11 | 19.4 |
| | *Arbacia punctulata* | 11 | 33.9 |

[a] No tests were done in the final quarter of 2017 because of operational disruptions caused by Hurricane Maria.

[b] There is no recognized EPA method for an acute *Arbacia* WET test; therefore, there are no acute toxicity results available for this organism.

[c] $IC_{25}$ is used for the endpoint for determining toxicity for *A. punctulata*.

[d] The test results demonstrate an interrupted dose response. See report for additional discussion.

[e] Test results were affected by low DO levels. See report for details.

[f] Results for a second test. Initial test was considered invalid. See report for details.

Notes:

$IC_{25}$ = Inhibition concentration 25 percent: Statistical calculation of the effluent concentration that causes a 25-percent reduction in growth or reproduction of test organisms.

NOEC = No observed effect concentration; the highest test concentration that causes no observable adverse effects on the test organisms (that is, no statistically significant reduction from the control) using statistical hypothesis testing.

The November/December 2019 test with *M. Bahia* resulted in the most sensitive chronic end point with a value of 0.64-percent effluent. This value is used to assess the criterion continuous concentration (CCC) compliance as presented in Section 8.

# 5. Receiving Water Oceanographic and Hydrographic Conditions

This section discusses the pertinent oceanographic properties of the receiving water in the vicinity of the Arecibo RWWTP high-rate outfall diffuser. The information on density structure, current speed, pH, and DO are necessary to conduct the nearfield diffuser dilution modeling and the farfield DO modeling required by the DNER guide-lines. Information concerning the chemical properties of the receiving water necessary to characterize the ambient water quality available for mixing with the effluent and to define a mixing zone is presented in Section 6.

## 5.1 Density Structure

The determination of CID is required by the PRWQSR to establish an IMZ. For a given diffuser configuration, the CID is based on critical conditions. Critical conditions are defined as those that yield the lowest expected initial dilution for a given diffuser. The critical physical environmental conditions include the critical density profile (the profile resulting in the lowest initial dilution) and the critical (lowest 10 percent) ambient current speed.

The density structure in the vicinity of the Arecibo RWWTP outfall used in this MZA is taken from data acquired at DNER-specified mixing zone background stations, including:

- 8 profiles conducted during the 2016 and 2019 MZVS
- 6 profiles conducted during the MZVS in 2007

The density profile data are provided in Appendix F and illustrated in Figure 5-1. The CID is presented in Section 7. It is noted that during the 301(h) monitoring studies, density profiles were collected and were used in previous MZAs to augment MZVS data. Hydrographic profiles screened in the 2012 MZA included 132 profiles from the 301h monitoring program spanning 1999 to March 2011 and 6 profiles from the 2007 MZVS. The critical density profile for the 2012 MZA was Profile A4 from May 2004. The 2012 MZA critical density profile was included in the current screening along with the MZVS profiles. For the current evaluation, sufficient MZVS data are now available to assess the CID using data from the appropriate DNER-specified background stations, and recent 301(h) monitoring program profiles are not addressed.

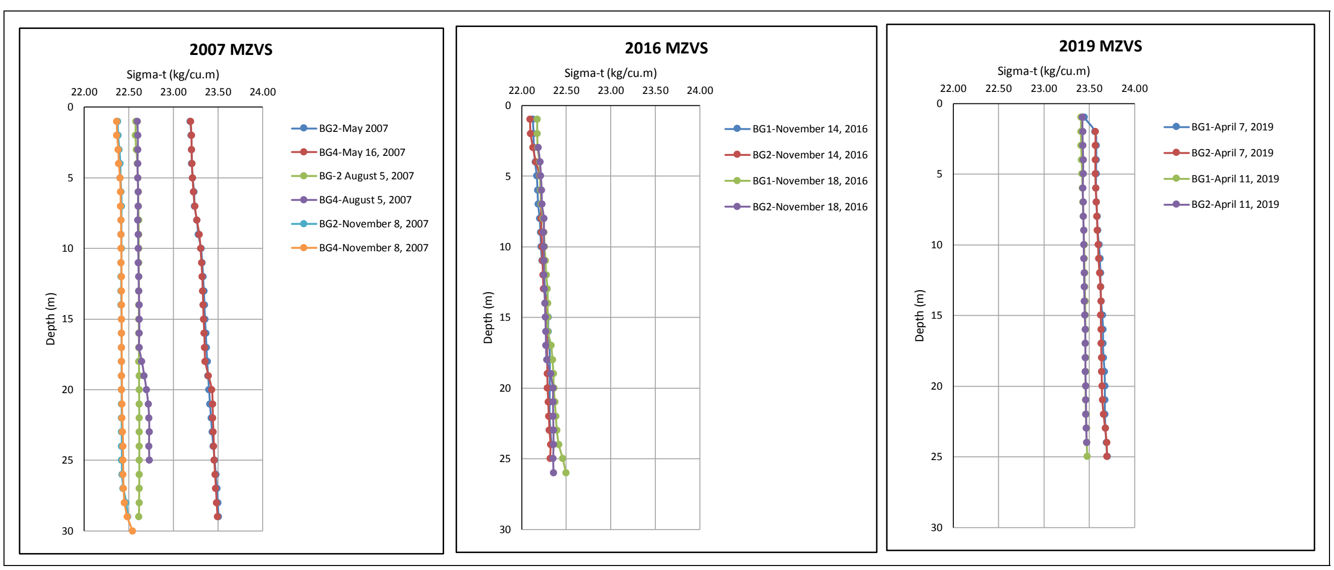


Figure 5-1. MZVS Background Station Density Profiles

## 5.2 Ocean Currents

Wastefield dispersion and transport are affected by the general circulation and overall flushing action in the vicinity of the discharge. Local current speed and direction at the discharge point affect the dilution and trajectory of the discharge plume and also affect the general dispersion and transport. These conditions are described and documented in the following. The critical current conditions are defined based on DNER requirements.

### 5.2.1 Oceanographic Setting and General Circulation

Available data (as presented in the 1985 301(h) Waiver Application and subsequent studies dating from 1971 through the present) indicate that the overall circulation pattern within the coastal area of the Arecibo RWWTP discharge is influenced by mixed semidiurnal tides, diurnal and seasonal wind regimes, and large-scale, wind-driven oceanic circulation patterns, such as the North Equatorial Current. These currents maintain a well-flushed receiving water condition, with little potential for long-term increase in discharged effluent concentration.

The predominant currents near the Arecibo RWWTP diffuser site are tidal, fluctuating from east to west, with a net drift toward the northeast. Tides in the vicinity of the Arecibo RWWTP outfall are semi-diurnal, with an overall mean tide of 0.8 feet  and a maximum spring tide range of 2.0 feet. While near-bottom currents remain predominantly northeasterly, at times, near-surface currents are dominated by diurnal winds, resulting in a net drift that varies between southwesterly and southeasterly. Recent data from the 301(h) monitoring studies and the MZVS confirm this description of oceanographic conditions along the north coast of Puerto Rico.

Current meters are deployed for 2 or 3 days at the time of water quality sampling for the 301(h) and MZVS monitoring events. There have been no observed periods of significant onshore transport observed at the Arecibo RWWTP outfall. The long-term current conditions provide for good flushing in the discharge area and preclude any buildup of effluent in the discharge area.

### 5.2.2 Critical Current Speed

Current speed data obtained between October 1999 and October 2019 were used to characterize the critical current speed for this MZA. This includes data from the 301(h) monitoring events and the 2007 and 2016/2019 MZVSs. The data were collected using acoustic Doppler current profiling (ADCP) instruments and are reported at three depths (10 percent, 50 percent, and 90 percent of total depth) for approximately 2 to 4 days during each monitoring event.

The current records were examined to evaluate the 10th percentile current speed, which is taken as the critical current speed for evaluating initial dilution (see Section 7). The ADCP data were collected as averages every 15 minutes, resulting in a total of 26,755 records in the database. Table 5-1 shows the frequency distribution derived from these data. The distribution is based on percentiles at 5-percent intervals, as well as the 1st and 99th percentile. The current meter data are provided in Appendix G.

The currents vary from nearly zero to more than to 50 centimeters per second (cm/s). The overall 10th percentile current speed in this record is 3.0 cm/s. This is slightly higher than the 10th percentile current used to establish the existing IMZ.

## 5.3 Other Physical Environmental Conditions

Ambient DO concentration and pH data, which are collected as vertical profiles, are also important in evaluating the effects of the effluent discharge and the definition of a mixing zone. Detailed DO and pH data from the

301(h) monitoring program and the MZVSs are provided in Appendix F. Summaries for the 2016/2019 MZVS at the DNER-specified background stations are provided in Tables 5-2 and 5-3.

Table 5-1. Cumulative Frequency Distribution Table of Current Speed (cm/s)

| Percent less than | Near Surface | Mid-depth | Near Bottom | Combined |
|---|---|---|---|---|
| **0** | 0.00 | 0.00 | 0.00 | **0.00** |
| **1** | 1.00 | 0.90 | 0.90 | **1.00** |
| **5** | 2.40 | 1.90 | 2.00 | **2.00** |
| **10** | 3.60 | 2.70 | 3.00 | **3.00** |
| **15** | 4.50 | 3.30 | 3.60 | **3.80** |
| **20** | 5.50 | 4.00 | 4.10 | **4.50** |
| **25** | 6.40 | 5.00 | 5.00 | **5.20** |
| **30** | 7.20 | 5.60 | 5.50 | **6.00** |
| **35** | 8.20 | 6.40 | 6.10 | **6.90** |
| **40** | 9.10 | 7.10 | 6.80 | **7.60** |
| **45** | 10.20 | 8.00 | 7.40 | **8.40** |
| **50** | 11.20 | 9.00 | 8.10 | **9.30** |
| **55** | 12.50 | 10.00 | 9.00 | **10.30** |
| **60** | 13.70 | 11.10 | 9.80 | **11.40** |
| **65** | 15.00 | 12.40 | 10.71 | **12.70** |
| **70** | 16.50 | 13.90 | 11.80 | **14.00** |
| **75** | 18.00 | 15.70 | 13.00 | **15.50** |
| **80** | 20.00 | 17.30 | 14.40 | **17.20** |
| **85** | 22.10 | 19.40 | 16.00 | **19.30** |
| **90** | 25.00 | 22.30 | 18.00 | **22.10** |
| **95** | 29.40 | 26.40 | 22.00 | **26.30** |
| **99** | 38.38 | 35.00 | 29.80 | **35.60** |
| **100** | 51.00 | 54.00 | 50.00 | **54.00** |
| Average | 13.04 | 11.03 | 9.61 | **11.23** |
| Number of readings | 8,919 | 8,918 | 8,918 | 26,755 |

Table 5-2. MZVS Dissolved Oxygen (mg/L) Vertical Profile Summaries

| Station | BG2 [BG1] | BG4 [BG2] | BG2 [BG1] | BG4 [BG2] |
|---|---|---|---|---|
| **Date** | **14-Nov-16** | **14-Nov-16** | **18-Nov-16** | **18-Nov-16** |
| Minimum | 6.31 | 6.30 | 6.16 | 6.13 |
| Average | 6.39 | 6.43 | 6.23 | 6.21 |

Table 5-2. MZVS Dissolved Oxygen (mg/L) Vertical Profile Summaries

| | | | | |
|---|---|---|---|---|
| Maximum | 6.44 | 6.48 | 6.32 | 6.25 |
| St.Dev. | 0.04 | 0.06 | 0.05 | 0.04 |
| **Station** | **BG1** | **BG2** | **BG1** | **BG2** |
| **Date** | **7-Apr-19** | **7-Apr-19** | **11-Apr-19** | **11-Apr-19** |
| Minimum | 6.85 | 6.91 | 6.73 | 6.86 |
| Average | 6.93 | 6.94 | 6.82 | 6.88 |
| Maximum | 6.97 | 6.96 | 6.88 | 6.89 |
| St.Dev. | 0.03 | 0.02 | 0.06 | 0.01 |

Table 5-3. MZVS pH (SU) Vertical Profile Summaries

| Station | BG2 [BG1] | BG4 [BG2] | BG2 [BG1] | BG4 [BG2] |
|---|---|---|---|---|
| **Date** | **14-Nov-16** | **14-Nov-16** | **18-Nov-16** | **18-Nov-16** |
| Minimum | 8.14 | 8.13 | 8.21 | 8.20 |
| Average | 8.14 | 8.14 | 8.21 | 8.21 |
| Maximum | 8.15 | 8.14 | 8.22 | 8.21 |
| St.Dev. | 0.00 | 0.00 | 0.00 | 0.00 |
| **Station** | **BG1** | **BG2** | **BG1** | **BG2** |
| **Date** | **7-Apr-19** | **7-Apr-19** | **11-Apr-19** | **11-Apr-19** |
| Minimum | 8.26 | 8.26 | 8.31 | 8.31 |
| Average | 8.26 | 8.26 | 8.32 | 8.31 |
| Maximum | 8.27 | 8.26 | 8.32 | 8.31 |
| St.Dev. | 0.00 | 0.00 | 0.00 | 0.00 |

# 6. Receiving Water Chemistry

This section provides required information regarding the chemical properties of the receiving water necessary to define a mixing zone for the POCs identified in Sections 2 and 3. Receiving water characteristics are based primarily on data collected during the 2016/2019 MZVS conducted under the existing WQC and NPDES permit These data are the primary source for compliance evaluations in Section 9. The MZVS samples were analyzed only for those parameters with mixing zones in the current permit. The evaluation of total nitrogen (TN) is done using 301(h) monitoring data. Sampling and analyses for metals were performed using clean sampling methods (EPA Method 1669) and clean analytical techniques under a study plan approved by EPA. Only data for POCs defined in Section 2 are presented and discussed in this section.

## 6.1 Receiving Water Sampling

The MZVS data were collected in November 2016 and April 2019. The 301(h) monitoring receiving water data were collected from October 1999 to October 2019 at six stations and at three depths at each station. Figures 6-1 and 6-2 show the station locations for the 301(h) monitoring studies and the MZVS, respectively. Summaries of the receiving water concentrations for POCs considered in this MZA are presented in Sections 6.2 and 6.3 for the MZVS and in Section 6.4 for the 301(h) TN data, respectively. The receiving water monitoring data are presented in Appendix H.

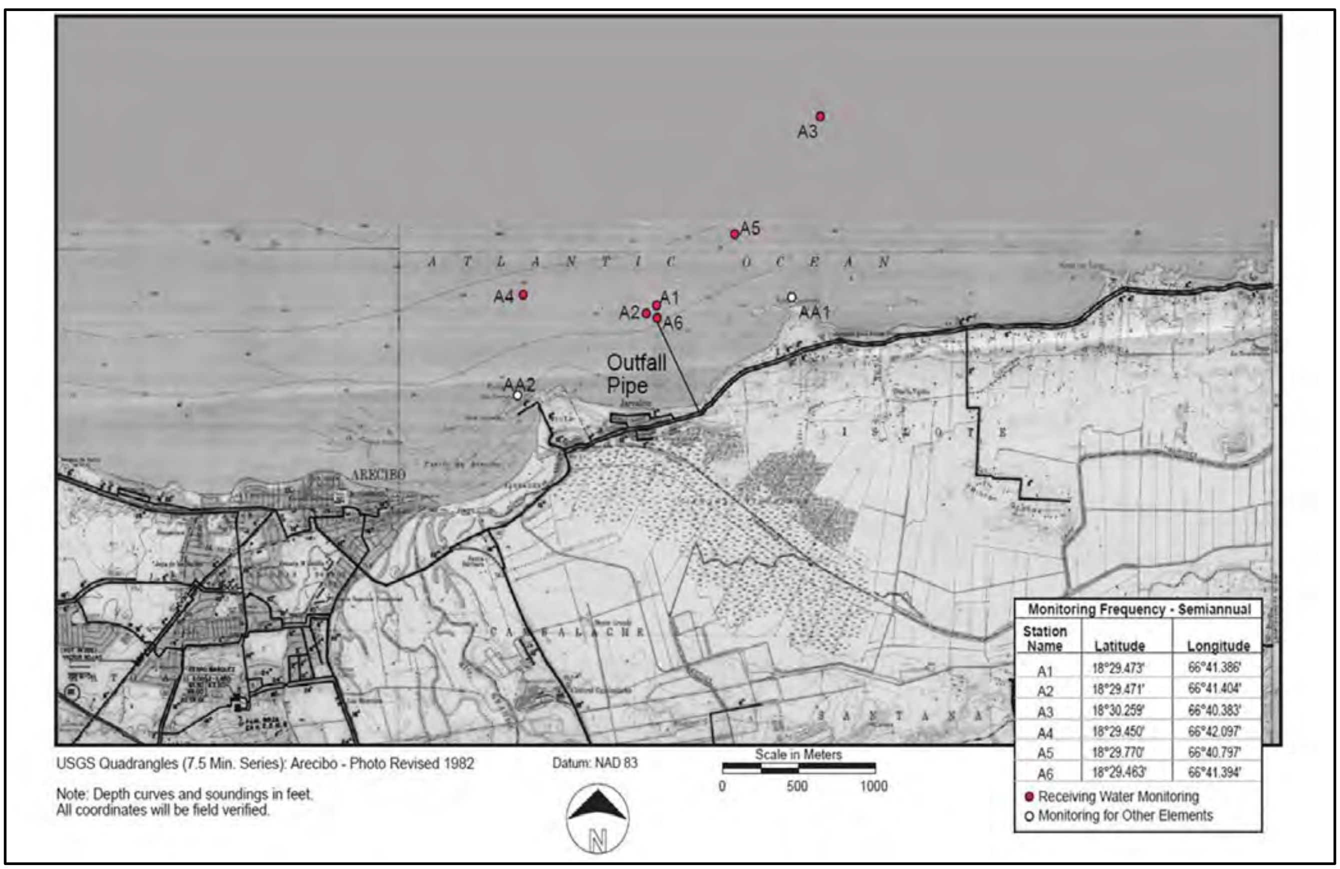


Figure 6-1. Arecibo 301(h) Monitoring Stations and Outfall Location

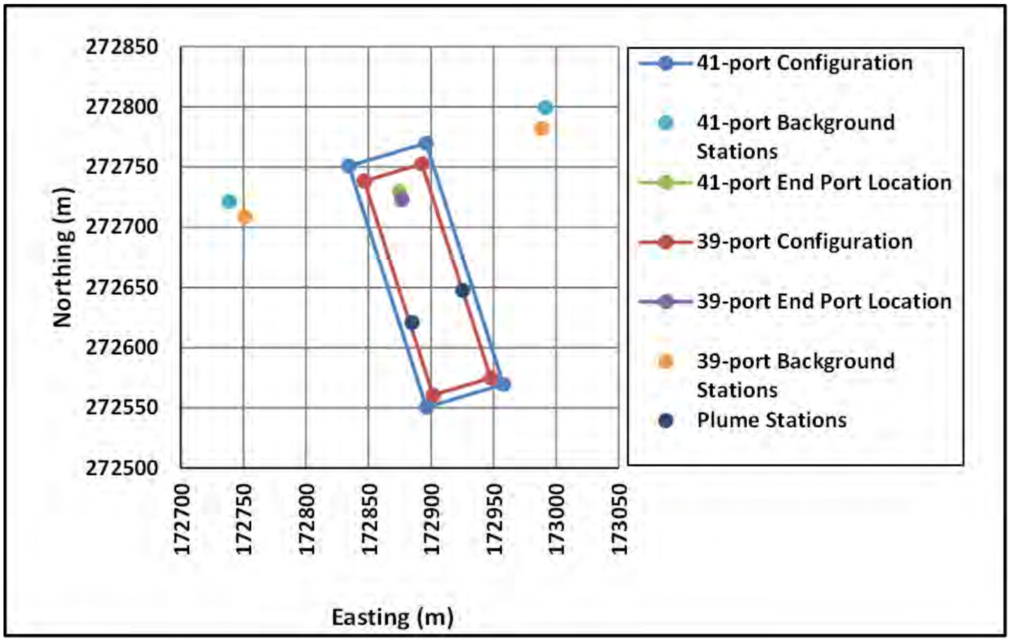


Figure 6-2. Arecibo MZVS Sampling Stations
*(39-port configuration used in 2016; 41-port configuration used in 2019)*

## 6.2 MZVS Receiving Water Concentrations of POCs

Table 6-1 lists the MZVS receiving water data for the background stations. These data, except for TN and total residual chlorine (TRC) (discussed below), are used for compliance calculations in Section 9. The full datasets are provided in Appendix H.

Table 6-1. MZVS Background Station Receiving Water Chemistry Data

| Parameter | Units | Number of Samples | Number of Detected Concentrations | Minimum | Average | Maximum | Standard Deviation | 90th Percentile |
|---|---|---|---|---|---|---|---|---|
| **Metals** | | | | | | | | |
| Copper | µg/L | 24 | 12 | 0.05 | 0.19 | 0.87 | 0.20 | 0.41 |
| Nickel | µg/L | 24 | 17 | 0.15 | 0.21 | 0.36 | 0.06 | 0.29 |
| Silver | µg/L | 24 | 5 | 0.025 | 0.03 | 0.034 | 0.00 | 0.027 |
| Thallium | µg/L | 24 | 1 | 0.002 | 0.01 | 0.025 | 0.01 | 0.025 |
| Zinc | µg/L | 24 | 5 | 0.25 | 1.99 | 12.3 | 2.61 | 3.57 |
| **Conventional Parameters** | | | | | | | | |
| Color | Pt-Co | 24 | 2 | 5 | 5 | 5 | 0.0 | 5 |
| Cyanide, Free | µg/L | 24 | 24 | 0.16 | 0.27 | 0.41 | 0.07 | 0.38 |
| Sulfide, Total | mg/L | 24 | 0 | 0.002 | 0.00 | 0.002 | 0.00 | 0.002 |
| Surfactants | mg/L | 24 | 0 | 0.005 | 0.13 | 0.25 | 0.12 | 0.25 |
| Turbidity | NTU | 24 | 24 | 0.031 | 0.05 | 0.073 | 0.01 | 0.065 |

## 6.3 Residual Chlorine

TRC was measured during both MZVS sampling episodes, and an MZA for residual chlorine was submitted to DNER.[9] The MZA for TRC is included as Appendix I. The results clearly indicated assimilative capacity for residual chlorine at the current effluent limitation of 0.50 mg/L (500 µg/L).

## 6.4 301(h) Nitrogen Data

Total nitrogen has replaced dissolved inorganic nitrogen in the PRWQSR; it was not measured during the MZVS but has been included in the recent 301(h) monitoring studies. Table 6-2 lists the results for the past 5 years of data (March 2015 through March 2019) for all 301(h) stations sampled. The complete 301(h) dataset is included in Appendix H.

Table 6-2. Receiving Water Chemistry 301(h) Monitoring Data Results for TN

| Parameter | Units | Number of Samples | Number of Detected Concentrations | Minimum | Average | Maximum | Standard Deviation | 90th Percentile |
|---|---|---|---|---|---|---|---|---|
| TN | mg/L | 90 | 2 | 0.23 | 0.41 | 2.12 | 0.23 | 0.63 |

[9] CH2M HILL. 2017. *Application for a Water Quality Certification and Definition of a Mixing Zone for Residual Chlorine for the Arecibo Regional Wastewater Treatment Plant Outfall System.* Prepared for Puerto Rico Aqueduct and Sewer Authority. June 30.

# 7. Diffuser Configuration and Dilution

This section provides an overview of the Arecibo RWWTP diffuser design, diffuser hydraulics (specifically, the port flow distribution), and diffuser dilution characteristics. The CID is determined in this section based on the most recent available oceanographic data and is used in Sections 8 and 9 to define the mixing zone boundaries and to evaluate compliance with the PRWQSR. The ambient current and vertical density profiles for critical conditions are described in Section 5.

## 7.1 Diffuser Design and Configuration

Section 2 of this document discusses the location and general characteristics of the outfall. The description below concentrates on the details of the diffuser configuration related to its operation. Figure 7-1 illustrates the diffuser configuration, including port sizes and spacing. The description of the outfall and diffuser follows that given in the previous MZAs and as described in the as-built drawings. As described in Section 2, the existing treatment facility is designed for an average flow of 10 mgd and a maximum daily flow of 20 mgd.

The main outfall is a 48-inch-diameter pipeline that extends 3,769 feet from the shore. The diffuser is a linear, in-line structure with a constant manifold diameter of 48 inches. The outfall and diffuser manifold are buried approximately 6.6 feet under the ocean floor at a slope of approximately 0.0282 meter per meter. The water depth to the ocean floor along the diffuser varies from 82 to 91 feet. The total length of the diffuser is 660 feet.

There are 56 risers from the manifold that are equally spaced at 12 feet, center-to-center. Each riser extends above the ocean floor to a T-section, except for the terminal structure that incorporates two ports and an end gate. Each side of the riser has an orifice port, although not all are open as discussed later. All ports are 2.5 inches in diameter, except that the most seaward riser on the terminal structure has 3.5-inch-diameter ports. The angle of each port is zero degrees from horizontal, as shown in Figure 7-1. The orientation of the diffuser is perpendicular (90 degrees) to the predominant currents.

The diffuser configuration used in this MZA is based on 41 open ports discharging at the seaward end of the diffuser. One port on the end structure of each riser will be open, discharging in opposite directions. A detailed description of the seawater intrusion phenomena in the Arecibo diffuser is provided in Appendix J. The depth of the currently open 2.5-inch-diameter ports ranges from 82 to 87 feet, with an average depth of 84 feet. The port depth for the 3.5-inch-diameter port (Port 2 on Riser 1) is 90 feet.

## 7.2 Diffuser Hydraulic Performance

Hydraulic factors include maintaining a configuration that will operate with the available head for the outfall and diffuser. Detailed hydraulic calculations are provided in Appendix J. In addition, diffuser operation is required to be in conformance with the DNER definition of a high-rate diffuser. This definition requires port velocities of greater than 10 feet per second (ft/sec) or an initial dilution of at least 100:1. The port configuration meets both criteria. A discussion of the hydraulic flow through the diffuser is presented below.

The multi-port diffuser module in a standard hydraulics calculation program (CH2M HILL's HYDRO program) was used to determine the flow through each port for the port configuration used in this MZA. HYDRO results (output files are provided in Appendix K and a summary is shown in Table 7-1) indicate that the differences in distribution of flow between ports of the same size are negligible. Therefore, the flows through the forty 2.5-inch-diameter ports were combined, and separate dilution model runs were made for each port size. This approach has the advantage of accounting for the effects of merging plumes, if applicable, and is consistent with the previous work.

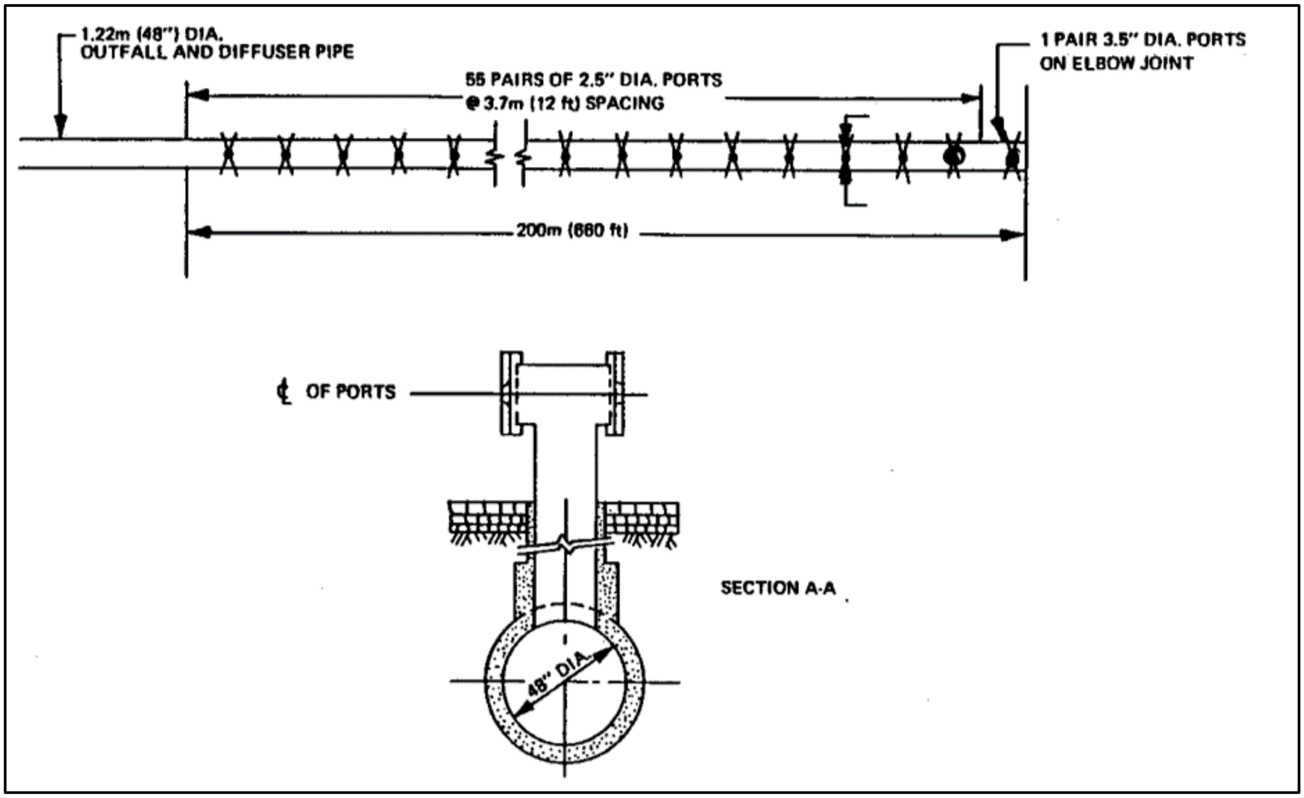


Figure 7-1, Schematic of the Arecibo Diffuser

Table 7-1. Port Flow and Exit Velocity for Maximum Permitted Flow

| Port Size | Number of Open Ports | Range of Port Exit Velocities (ft/sec) | Total Flow Through Port Size Group (mgd) |
|---|---|---|---|
| 3.5-inch | 1 | 21.87 | 0.94 |
| 2.5-inch | 40 | 21.54 to 21.74 | 19.06 |

## 7.3 Dilution Performance and CID

To evaluate the CID and mixing zone dimensions, the DNER-approved dilution model UDKHDEN was used as a screening-level model to determine the critical density profile (the one resulting in the lowest initial dilution) to predict initial dilution for the various simulations. A detailed description of this model is found in the EPA publication EPA/600/3-85-073a,b. The UDKHDEN model input parameters, simulations, and outputs are provided in Table 7-2. For each port size, the trapping level and the dilution when the plume first passes through the calculated trapping level[10] were estimated. The different size ports were modeled independently as separate groups. The way the model handles multiple ports provides for the full effect of merging of adjacent plumes.

[10] The model provides the dilutions for the plume continuously along the plume trajectory. Unless blocked by the water surface, the plume initially rises through the equilibrium or trapping level (where ambient and plume water are of the same density), overshooting the equilibrium level, and then collapsing back to the equilibrium level. The UDKHDEN model tracks the plume to the point of maximum rise and then terminates execution.

Table 7-2. UDKHDEN and HYDRO Model Input Parameters

| Diffuser Parameters | 2.5-inch Ports | 3.5-inch Ports |
|---|---|---|
| Diffuser orientation | Linear and in-line with outfall | |
| Diffuser length, feet | 660 | |
| Diffuser barrel diameter, inches | 48 | |
| Riser diameter, inches | 18 | |
| Number of risers | 40 | 1 |
| Number of ports | 40 | 1 |
| Port diameter, inches | 2.5 | 3.5 |
| Number of open ports | 42 (1 per riser) | 1 |
| Riser spacing, feet | 12 | |
| Vertical discharge angle, degrees | 0 (horizontal) | |
| Horizontal discharge angle, degrees | 90 | |
| **Effluent Parameters** | | |
| Maximum flow, mgd | 20.0 | |
| Effluent temperature, °C | 25 | |
| Effluent salinity, PSU | 0.1 | |
| **Receiving Water Parameters** | | |
| Current speed, 10th-percentile cm/s | 3.0 | |
| Current speed, 99th-percentile cm/s | 35.6 | |
| Water depth, feet | 84 | 90 |
| Critical density profile | November 2016 (Station BG2) | |

Notes:

°C = degrees Celsius

PSU = practical salinity unit

UDKHDEN model output files are provided in Appendix K. The trapping level, if applicable, and initial dilution are given at the end of each model run. The CID was calculated for critical conditions as a flux-averaged value ($CID_A$), accounting for the flow (Q) through the various port sizes. This calculation followed the methods, input data, and procedures required in Section II, Chapter 4 of EQB's April 1988 *Interim Mixing Zone and Bioassay Guidelines*, and is described as follows:

$$CID_A = \frac{\sum (CID_i \; x \, Q_i)}{\sum Q_i}$$

where *i* represents the individual port sizes.

The CID was determined for the 10th-percentile current speed, a maximum daily effluent flow of 20 mgd, and the critical density profile (recorded in November 2016). The diffuser configuration modeled was a 41-port diffuser with a single 3.5-inch-diameter port and 40 of the 2.5-inch-diameter ports open. The open ports discharge in alternate directions (180 degrees) perpendicular to the diffuser barrel. The existing diffuser

Dilution continues during the rise of the plume past the trapping level. However, to be conservative, the dilution as the plume first passes the trapping level is taken as the initial dilution.

configuration and revised ambient conditions presented in this MZA yield a CID of 242:1, slightly higher than the CID of 224:1 currently in use.

The model input (refer to Table 7-2) was as follows:

- The diffuser configuration and orientation were the same as previously used.
- The effluent temperature and salinity were the same as previously used.
- The effluent flow (20 mgd) was the same as previously used.
- The 10th-percentile current speed used was 3.0 cm/s, slightly greater than that previously used (2.8 cm/s).
- The density profile from November 2016 station BG2 was chosen for model input.[11]

Based on the UDKHDEN screening-level modeling, the critical case was modeled using the DKHW model in the EPA Visual Plumes dilution modeling suite. This model predicts a CID of 376:1. The model results for this evaluation are provided in Appendix K.

[11] The density profiles were examined for potential plume interference (as noted by stratified inversion of water density). Plots of the density profiles are provided in Appendix F.

# 8. Mixing Zone Definition

This section integrates the results and information from the previous sections to define the mixing zone geometry (Section 8.1). For DNER to approve a mixing zone for any parameter, the applicant must demonstrate that the parameter will meet the PRWQSR criteria (including compliance with toxicity) at the EOMZ. This requirement is discussed in Section 8.2. Section 8.3 presents a discussion of the effluent POCs and identifies those that require definitions of a mixing zone based on effluent concentrations and WQS presented in Sections 2 and 3. Compliance with PRWQSR criteria for each POC is discussed in Section 9.

## 8.1 Mixing Zone Geometry

The revised CID described in Section 7 is based on redefined and updated critical conditions and the current 41-port diffuser configuration. Using the new and more accurate information results in a revised CID of 376:1 and revised mixing zone geometry. The results and a brief summary of the methodology are summarized below.

The procedures for specifying mixing zone dimensions are provided in detail in Section II, Chapter 4, of the Mixing Zone and Bioassay Guidelines (MZBAG). The dimensions are based on a calculated characteristic mixing zone length, $L_{MZ}$. This length is the horizontal distance from a given port, i, to the edge of the mixing zone. This distance is calculated by the following equation:

$$L_{MZ} = Y_i + \left(\frac{W_i}{2}\right) \times \cos(90 - \theta_i)$$

where:

$Y_i$ = horizontal distance from port "i" to the centerline of the plume where dilution equals the CID ($Y_I = [X^2 + Y^2]^{½}$ in terms of the UDKHDEN output variables)
$W_i$ = width of the plume from port "i" at the point where dilution equals the CID, and
$\theta_i$ = angle of the plume centerline to the horizontal at the point where dilution equals the CID.

The length, $L_{MZ}$, was calculated for the 41-port configuration for the two port sizes at both the 10th percentile and 99th-percentile ambient currents under critical conditions and maximum effluent flow rates. The 99th-percentile current speed (35.6 cm/s) was used rather than the maximum current speed because the maximum current speed value was considered to be an unrealistic outlier (refer to Section 5). Calculation of the $L_{MZ}$ requires the interpolation of the various plume parameters at the point where the dilution equals the CID as described in the MZBAG. Table 8-1 summarizes the calculations described above for each port size and current speed. Model runs containing the plume parameters necessary for the calculation of $L_{MZ}$ and a table providing the lines of model run data used to calculate $L_{MZ}$ results summarized in Table 8-1 are provided in Appendix K.

A modification of the method was needed for the 3.5-inch port at the 10th percentile current speed. The dilution from this single port was substantially lower than the flux-averaged dilution. Internal limits in the VP DKHW model stopped calculations before a dilution of 376:1 was reached. This case was simulated using two 3.5-inch ports, at twice the flow, to account for merging of adjacent plumes. To develop the mixing zone dimensions, the port was simulated as a single port. This method appears to be the most realistic approach, is consistent with the DNER guidelines. Model run output is provided in Appendix K.

DNER procedures require that the largest of the calculated $L_{MZ}$ values for each port group and current speed be used to determine the mixing zone dimensions. This value corresponds to the 3.5-inch-diameter port at 99th percentile ambient current speed. Using the calculated values presented previously (and given in Table 8-1), the mixing zone length parameter is found to be 54.57 meters.

Table 8-1. Calculation of Mixing Zone Length (LMZ)

| Ambient Current | Port Diameter (inches) | Candidate $L_{MZ}$ (meters)[a] |
|---|---|---|
| 10% | 3.5[b] | 24.97 |
| | 2.5 | 34.85 |
| 99% | 3.5 | 54.57 |
| | 2.5 | 35.13 |

[a] Calculation of each candidate $L_{MZ}$ is provided in Appendix K.

[b] Based on the model run with one port, no merging.

For the existing open port configuration, CID, and current speed, the $L_{MZ}$ becomes 54.57 meters. Using this value, the length and width of the mixing zone are calculated using the following formulae:

$$TL = 2xL_{MZ} + DL$$
$$TL = 2x54.57 + 146.40 = 255.54\ meters$$

and

$$WL = 2xL_{MZ} + DW$$
$$WL = 2x54.57 + 1.20 = 110.34 meters$$

where:

- TL = the total length of the mixing zone,
- WL = the total width of the mixing zone,
- $L_{MZ}$ = the mixing zone length as defined previously,
- DL = the diffuser length, and
- DW = the diffuser width.

The diffuser width is generally taken as the barrel diameter, in this case, 4 feet. The diffuser length is the distance between the ports on either end of the discharge (from the centerline of the first active port to the centerline of the last active port). For the 41-port configuration described previously, the diffuser length is 146.4 meters for each leg of the diffuser. Table 8-2 presents the size of the mixing zone based on the recent ambient ocean current and critical density data presented in this document and comparisons to the 2012 MZA.

Table 8-2. Mixing Zone Dimensions

| | 2012 Mixing Zone Application | New Mixing Zone (2020 MZA) |
|---|---|---|
| Mixing Zone Length, LMZ (meters) | 30.01 | 54.57 |
| Total Length (each leg), TL (meters) | 206.4 | 255.5 |
| Total Width, WL (meters) | 61.2 | 110.3 |

The general location of the diffuser and outfall is shown on Figure 1-1. Figure 8-1 shows the proposed mixing zone stations and the DNER-specified background sampling stations 100 meters from the mixing zone boundary. Table 8-3 provides the coordinates of the mixing zone stations and the background stations.

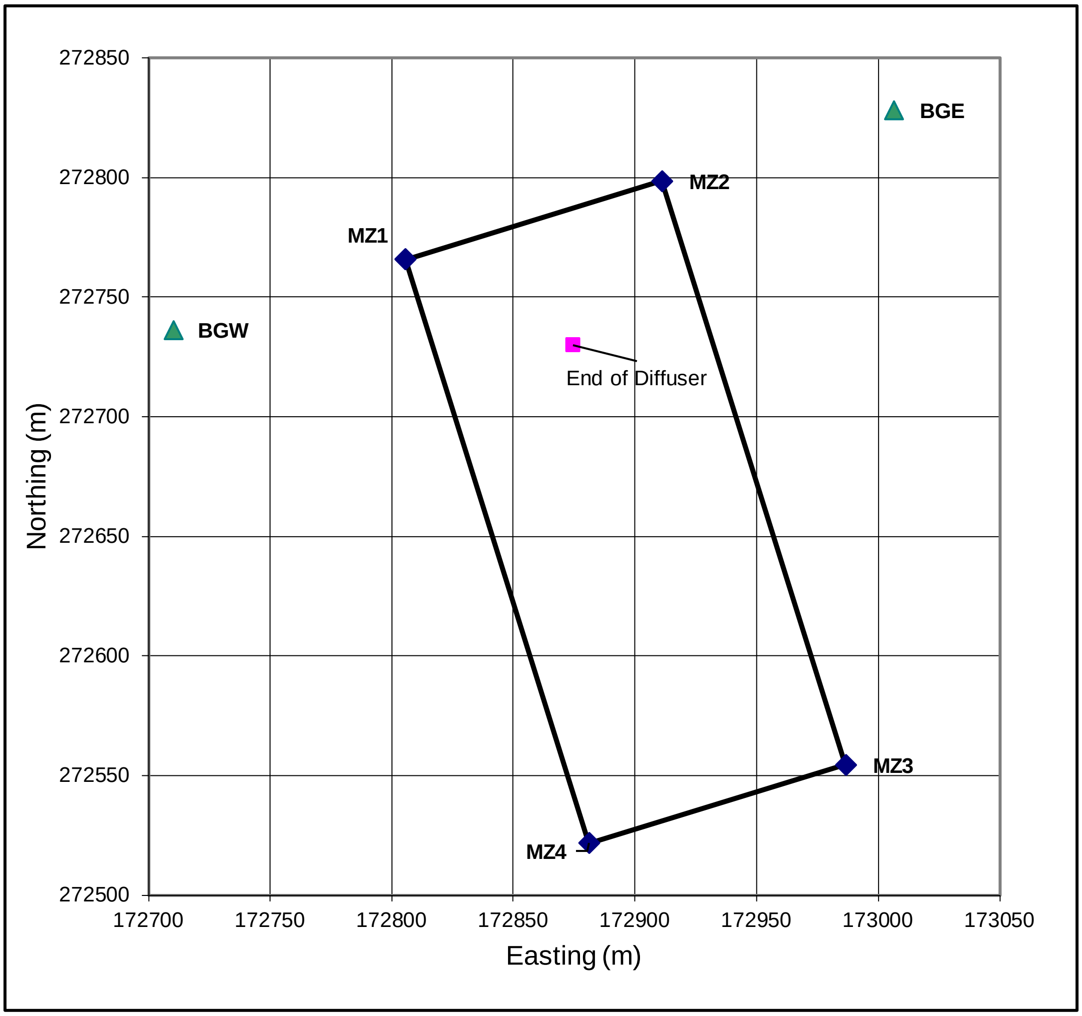


Figure 8-1. Arecibo Mixing Zone (NAD 83)

Table 8-3. Coordinates for the Arecibo Mixing Zone (NAD 83)

| Station | Easting | Northing | Latitude | Longitude |
|---|---|---|---|---|
| MZ1 | 172805.55 | 272765.81 | N18° 29′ 26.125″ | W066° 41' 27.008" |
| MZ2 | 172910.97 | 272798.46 | N18° 29′ 27.192″ | W066° 41' 23.416" |
| MZ3 | 172986.55 | 272554.40 | N18° 29′ 19.257″ | W066° 41' 20.828" |
| MZ4 | 172881.13 | 272521.75 | N18° 29′ 18.191″ | W066° 41' 24.420" |
| BGW | 172710.02 | 272736.23 | N18° 29′ 25.158″ | W066° 41' 30.263" |
| BGE | 173006.50 | 272828.04 | N18° 29′ 28.158″ | W066° 41' 20.161" |

## 8.2 Whole Effluent Toxicity Compliance

As required in the *Interim Mixing Zone and Bioassay Guidelines*, effluent at the EOMZ must meet both criteria maximum concentration (CMC) and criteria chronic concentration (CCC) toxicity levels. Compliance with CMC demonstrates that there will be no acute effects to sensitive species from relatively short-term exposure to effluent. Concentrations in compliance with the CCC demonstrate that there will be no long-term effects to sensitive species. The effluent toxicity testing summarized in Section 4 and the CID presented in Section 7 are used to evaluate these criteria. The evaluation demonstrates that effluent concentrations at the EOMZ are well below concentrations shown to be protective for both acute and chronic exposure.

For acute protection, the CMC must not exceed 0.3 acute toxic unit ($TU_a$) as measured by the most sensitive result from tests conducted on at least three test species.

$$\frac{AcuteToxicity\ of\ Effluent\ (in\ TUa)}{CID} \leq 0.3TUa$$

$$where\ TU_a = \frac{100}{LC_{50} or EC_{50}}$$

There is no requirement in the existing Arecibo NPDES permit to perform acute WET testing. However, as described in the 2012 MZA, the $TU_a$ value at the EOMZ was 0.026 for the most sensitive species and lowest effluent concentration, which does not exceed the applicable criterion. Thus, the requested mixing zone will comply with the whole effluent CMC.

The most sensitive chronic result for bioassay test species was an $IC_{25}$ of 4.67 percent effluent for *Arbacia punctulata* (refer to Table 4-1). The mixing zone guidance establishes the CCC as follows:

For chronic protection, the CCC must not exceed 1.0 chronic toxic unit ($TU_c$), as measured by the most sensitive result from tests conducted on at least three test species.

$$\frac{Chronic\ Toxicity\ of\ Effluent\ (in\ TUc)}{CID} \leq 1.0TUc$$

$$where\ TU_c = \frac{100}{\mathrm{NOEC}}$$

As noted in Section 4, the NOEC (determined by statistical hypotheses testing) is not considered an appropriate measure of toxicity for the *Arbacia* test, and the $IC_{25}$ is used in place of the NOEC. Therefore,

$$TU_c = \frac{100}{\mathrm{IC}_{25}}$$

The number of $TU_c$ calculated based on this series of tests is 21.41. Using the revised CID calculated in Section 7 (equal to 376:1), the $TU_c$ is 0.056 unit, and the requested mixing zone complies with the whole effluent CCC.

## 8.3 Effluent Constituents Considered

The following classes of constituents are considered in the MZA:

- Constituents that are listed in the existing permit, but are no longer regulated by the PRWQSR
- Constituents monitored for informational purposes and/or constituents with narrative water quality criteria
- Technology-based parameters that are not regulated on water-quality-based compliance
- Constituents that can clearly meet PRWQSR criteria at the EOP and do not need to be monitored
- Constituents that are compliance plan parameters in the existing NPDES permit that require a mixing zone to meet PRWQSR, and for which the background concentrations and CID allow for a mixing zone based on compliance at the EOMZ

Constituents that can meet PRWQSR criteria within a mixing zone are discussed in more detail in Section 9. Each parameter for which a mixing zone is requested is considered using the newly calculated CID (376:1) and the appropriate receiving water background concentration to demonstrate that PRWQSR requirements and criteria can be achieved at the EOMZ.

A number of parameters require special consideration in the assessment of compliance with the PRWQSR. These parameters are discussed in more detail in Section 9 and include:

- **pH:** Although pH is a technology-based parameter for effluent limitations, there are specific numerical criteria for marine waters. The evaluation of a mixing zone for pH is done somewhat differently than for other parameters and is considered separately.
- **Sulfide:** Sulfide is considered separately because of the more complex treatment required to account for the kinetics involved in the partitioning between total dissolved sulfide (unregulated) and undissociated sulfide ($H_2S$), which is the regulated substance.
- **DO:** There are specific requirements to show compliance for DO based on levels of ambient DO and effluent concentrations of BOD and TKN that must be met to define mixing zones.
- **Bacteria:** Compliance for bacteria (*Enterococcus*) is discussed in Section 9.
- **Residual chlorine:** This parameter was a compliance plan parameter in the current permit. It is noted that the limitation in the current PRWQSR is lower than the previous limit addressed in the compliance plan..

### 8.3.1 Unregulated Parameters

The following parameters are no longer regulated by the PRWQSR:

- Fecal Coliform is included in the existing permit but is no longer regulated by EPA criteria or by the PRWQSR. ***It is requested that this parameter be removed from the permit to reflect the amended PRWQSR.***
- Nitrogen as TIN (nitrate + nitrate + ammonia) has been replaced with TN (nitrate + nitrate + TKN) in the 2019 PRWQSR. It is requested that this parameter be removed from the permit to reflect the amended PRWQSR and be replaced with TN.

### 8.3.2 Informational and Narrative Parameters

A number of parameters with narrative or MO limitations are listed in the existing NPDES permit for the Arecibo RWWTP (refer to Table 3-2). Some parameters have numerical limitations that are part of the narrative limitation (for example, temperature) or are used to make sure that the narrative limitations are met. In some cases, a mixing zone is defined and the limitation is met at the EOMZ. These parameters include:

- **Solids and other objectionable material**, **settleable solids**, **and taste and odor:** These are parameters with purely narrative criteria; they have no associated numerical criteria and will not require any additional consideration in this document.
- **TKN:** This is an informational parameter that requires monitoring only. TKN affects the DO demand in the receiving water and reflects the nutrient loading to the receiving water. TKN is also a constituent included in TN, which is newly regulated by the PRWQSR.
- **Temperature:** This has a numerical as well as a narrative standard but will not require a mixing zone based on maximum reported effluent temperatures.
- **Oil and Grease:** This is listed with a narrative standard only in the PRWQSR.
- **Whole Effluent Toxicity:** This must meet prescribed numerical criteria at the EOMZ for DNER to approve a mixing zone for any parameter. This requirement is described previously in Section 8.2.
- **Color:** This is a regulated parameter with a narrative standard, but numerical limitations are assigned if the narrative criterion cannot be met at the EOP. This limitation is discussed in Section 9 and proposed limitations are included in Section 10.3.

#### 8.3.3 Technology-based Parameters

There are a number of parameters with technology-based limitations, some of which will require the definition of a mixing zone for compliance with the PRWQSR. The technology-based parameters include the following:

- **$BOD_5$** will be limited in concentration, loading, and removal based on the ability of the advanced primary treatment plant to achieve certain removal efficiencies. This parameter is also evaluated to ascertain the effect on DO in the receiving water.
- **DO** must meet water quality standards at the EOMZ and may require a mixing zone.
- **Flow** is limited based on the design capacity of the WWTP; maximum permitted flows are described in Section 2.
- **pH** is limited to between 6 and 9, but the PRWQSR are more restrictive. Therefore, a mixing zone is required for pH as described in Section 9.4.
- For **residual chlorine**, the current PRWQSR limitation cannot be achieved and still achieve compliance with enterococci. Therefore, a mixing zone will be required.
- **TSS** will be limited in concentration, loading, and removal based on the ability of the advanced primary treatment plant to achieve certain removal efficiencies.

#### 8.3.4 Parameters Requiring Further Action

A number of other parameters, not listed as compliance plan parameters and not discussed previously, will require mixing zones or adjustments to permitted limitations to meet the PRWQSR. These parameters are as follows:

- **Color, pH,** and **DO** are existing mixing zone parameters and will require mixing zones under the renewed permit.
- **Copper** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Cyanide** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Nickel** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **TN** (as $NO_3$+$NO_2$+TKN) is a new parameter and will require a mixing zone under the renewed permit.
- **Residual chlorine** is an existing compliance plan parameter that will require a mixing zone.
- **Silver** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Surfactants** (MBAS) is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Turbidity** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Sulfide (as $H_2S$)** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Thallium** is an existing mixing zone parameter and will require a mixing zone under the renewed permit.
- **Zinc** is an existing EOP parameter and will require a mixing zone under the renewed permit.

In each of these cases, there is assimilative capacity available in the receiving water to provide for a mixing zone.

# 9. Mixing Zone Compliance

This section integrates the results and information from the previous sections of this MZA to evaluate conditions at the EOMZ. The water quality conditions (that is, the concentrations of effluent constituents, including special considerations for DO, pH, color, and $H_2S$) at the EOMZ are evaluated in terms of the CID and compared to quantitative standards and criteria to determine compliance with the PRWQSR. The section concludes with a compliance evaluation of other mixing zone characteristics that are based on narrative standards.

The results presented in this section demonstrate that the Arecibo RWWTP discharge can meet the PRWQSR requirements for the requested mixing zone for most substances based on the proposed approach. A compliance plan may be required for *Enterococcus*.

## 9.1 Compliance for Effluent Constituents

A mixing zone is defined as a volume of water within which WQS may not be achieved, but for which WQS must be met at the boundary of the zone. The required dilution ($D_r$) for a particular constituent is the dilution of the effluent that is necessary to meet the required standard at the boundary of the mixing zone. The $D_r$ for any particular constituent is based on the numerical WQS for the concentration of that constituent, the ambient receiving water concentration, and the effluent concentration. The formula for calculating the $D_r$ to demonstrate that the PRWQSR requirements can be achieved is shown in the following equation:

$$D_r = \frac{(C_e - C_a)}{(C_s - C_a)}$$

where:

$C_a$ = ambient receiving water concentration,
$C_e$ = effluent concentration, and
$C_s$ = numerical water quality standard concentration.

This definition of $D_r$ is found in Section II, Chapter 6, and Appendix A of EQB's June 2012 *Interim Mixing Zone and Bioassay Guidelines*. Meeting the requirements of the PRWQSR is determined by comparing $D_r$ to the CID. If the CID is larger than the $D_r$, then the concentration at the EOMZ will be below the numerical standard, as required.

An alternative, but equivalent, approach to determine whether numerical WQS are met (described in Section II, Chapter 3, of the EQB *Interim Mixing Zone and Bioassay Guidelines*) is to calculate the final concentration of an effluent constituent (C), after CID, at the EOMZ and compare it to the standard. This calculation is shown below:

$$C = C_a + \left[\frac{(C_e - C_a)}{CID}\right]$$

In the evaluations that follow, each parameter is considered in detail and both approaches are used to demonstrate that PRWQSR requirements are achieved at the EOMZ for every parameter for which a mixing zone is requested. Meeting PRWQSR requirements ($D_r \leq$ CID or $C \leq C_s$) at the EOMZ is necessary, except under the following circumstances:

- If the petitioner demonstrates to the satisfaction of DNER through extensive field studies that natural background concentrations of the receiving waters exceed one or more of the water quality standards set forth for the corresponding receiving water classification, DNER may allow the parameters in the discharge to be equal to or less than the natural background values.

- If the standard is below the detection level of the approved analytical method with the lowest detection level, then the applicable limit will be that the substance not be detectable by the required method.

Determination of compliance with the WQS is based on background receiving water concentrations sampled at a point100 meters upstream of the mixing zone boundary, or at a point approved by DNER. The background stations used for this analysis were established and sampled during the 2016/2018 MZVS and are representative of the receiving water available for dilution of the effluent discharge (refer to Table 6-1). Data from the 301(h) monitoring studies are used for additional confirmation when necessary. Station locations are shown in Figures 6-1 and 6-2.

The procedure to determine compliance and define the proposed permit limitation is to use the RP effluent concentration (refer to Section 3) and the 90th percentile background concentration (refer to Section 6) to determine the required dilution and/or the concentration following CID. The PRWQSR defines the background concentration as the *average* of the measurements taken at the background station; the use of the 90th percentile background concentration provides a more conservative approach. This approach is appropriate because validating the mixing zone requires compliance at the EOMZ at least 90 percent of the time. Using the reasonable potential effluent concentration, which is generally greater than the maximum observed concentration, provides an additional safety factor for EOMZ compliance. The exception to this approach is for those parameters with WQS based on human health standards that are calculated from average consumption values over a long period of intake, in which case the ambient receiving water concentration is taken as the average background concentration.

Determination of compliance with the water quality standards, following procedures in the PRWQSR and associated *Mixing Zone and Bioassay Guidelines*, is based on background (BG) receiving water concentrations sampled at three depths, at least twice, and at least 6 hours apart at a point 100 meters up-current of the mixing zone boundary, or at a point approved by DNER. DNER-specified mixing zone background stations were sampled during the MZVS. There are additional data that can also be used to assess compliance; the 301(h) monitoring data and the data from the EOMZ sampled during the MZVS. Some of the 301(h) receiving water stations were closer than 100 meters, and some were more distant. In this MZA, parameters were assessed based on the MZVS-BG station data from 2016/2019 MZVS unless alternate sources of data were required (for example, for the assessment of TN).

The final concentrations and required dilutions for substances detected in the effluent at concentrations above criteria, for substances with laboratory reporting levels above criteria, or substances otherwise required to be considered for effluent limitations, are given in Table 9-1. The calculations were performed using the CID of 376:1. Note that certain parameters (that is, sulfide, color, pH, and DO) are not included in the table because they are special cases, with specific concerns and/or DNER guidelines, and are evaluated independently in Sections 9.2 through 9.6. Note that:

- TN in Table 9-1 is based on receiving water analyses performed during the past five annual 301(h) monitoring studies because it is a new parameter with no DMR or MZVS data available.
- Residual chlorine is discussed separately because a separate MZA was submitted for this parameter. The required dilutions and final concentrations are well below the requirements for compliance.
- Thallium is based on human health criterion, and in Table 9-1, compliance is based on the 90th percentile rather than the average receiving water concentration, so compliance is achieved.

Table 9-1. Calculation of Required Dilution and Concentration after Initial Dilution

| Parameter | Units | PRWQSR ($C_s$) | Reasonable Potential Effluent Concentration ($C_e$) | MZVS-BG Receiving Water Concentration | Dilution Required ($D_r$) | Final Concentration (C) |
|---|---|---|---|---|---|---|
| Copper | µg/L | 3.73 | 47.88 | 0.41 | 14.30 | 0.54 |
| Cyanide (free) | µg/L | 1 | 6.26 | 0.38 | 9.48 | 0.40 |
| Nickel | µg/L | 8.28 | 9.63 | 0.29 | 1.17 | 0.31 |
| Silver | µg/L | 2.24 | 4.74 | 0.027 | 2.13 | 0.04 |
| Surfactants | µg/L | 500 | 7798 | 0.25 | 15.60 | 20.99 |
| Thallium | µg/L | 0.47 | 1.7 | 0.025 | 3.76 | 0.03 |
| Turbidity | NTU | 10 | 102.67 | 0.065 | 10.33 | 0.34 |
| Zinc | µg/L | 85.62 | 328.59 | 3.57 | 3.96 | 4.43 |
| Total Nitrogen | mg/L | 5 | 43.8 | 0.63 | 9.88 | 0.74 |

## 9.2 Compliance for Residual Chlorine

Residual chlorine (TRC) was a new addition to the PRWQSR at the time the current permit was issued. Prior to inclusion of TRC in the PRWQSR,, EPA imposed effluent limitations in the NPDES permits of 0.50 mg/L (500 µg/L) for PRASA discharges. The 2014 update to the PRWQSR included a limitation of 11 µg/L. The 2019 amended PRWQSR now provides for a criterion of 7.5 µg/L. The current NPDES permit includes a compliance plan for TRC and *Enterococcus*. The result of the compliance plan indicates that the *Enterococcus* limitation can be met using the previous limitation for TRC (the interim limitation in the current permit of 500 µg/L). A separate MZA for TRC at this concentration was submitted to DNER under a compliance plan and is included as Appendix I. The TRC MZA requests an effluent limitation of 500 µg/L and clearly demonstrates the available assimilative capacity of the receiving water to accommodate this request.

## 9.3 Compliance for pH

The calculation to determine whether the PRWQSR criteria for pH are satisfied requires a different approach than for other constituents. Because pH represents the negative logarithm of hydrogen ion concentration [H⁺], the pH values must first be converted to actual hydrogen ion concentrations before $D_r$ can be meaningfully defined. The definition of pH is:

$$pH = -\log_{10}[H^+]$$

and the corresponding hydrogen ion concentration is given by

$$[H^+] = 10^{-pH}$$

The required dilution to satisfy the PRWQSR can therefore be calculated as:

$$D_r = \frac{10^{-pH_e} - 10^{-pHa}}{10^{-pH_{L\,or\,H}} - 10^{-pH_a}}$$

where:

$pH_e$ = effluent pH,
$pH_a$ = ambient background pH,
$pH_L$ = applicable lowest PRWQSR pH limitation, and
$pH_H$ = applicable highest PRWQSR pH limitation.

The PRWQSR for pH is a range rather than a limit. Therefore, the dilution required to achieve the standard is based on whether the effluent values are above or below the range. For Class SB waters, the PRWQSR provides for a pH range of 7.3 to 8.5. EPA limits effluent pH values to a range of 6 to 9. To meet the requirements of the PRWQSR, the required dilution must be less than the CID.

The minimum and maximum water background pH, as described in Section 5, for the MZVS background stations were 8.13 and 8.32, respectively. This range is typical for marine waters. The DMR data indicated the effluent pH ranged from 6.0 to 7.53 (minimum and maximum value, respectively).

At the minimum permitted effluent pH of 6.0, the available dilution (the CID) must be sufficient to bring the pH up to the lower criterion of 7.3. Using the 10th percentile ambient value of 8.14 will result in the highest required dilution. For this case, the required dilution is calculated as:

$$D_r = \frac{(10^{-6} - 10^{-8.14})}{(10^{-7.3} - 10^{-8.14})} = 23.2$$

Because the CID is greater than the $D_r$ calculated above, PRWQSR pH standards will be met at the EOMZ for the minimum permitted effluent pH.

At the maximum permitted pH of 9.0, the CID must be sufficient to bring the pH down to the upper criterion of 8.5. Using the 90th percentile ambient value of 8.31 will result in the highest required dilution. For this case, the required dilution is calculated as:

$$D_r = \frac{(10^{-9.0} - 10^{-8.31})}{(10^{-8.5} - 10^{-8.31})} = 2.2$$

which is well below the CID, and the PRWQSR requirements are achieved.

With a CID of 376:1, the Arecibo discharge will meet the water quality standards for pH at the EOMZ for the range of measured effluent and ambient pH values, as well as for the entire range of potential pH values within the EPA effluent limitation.

## 9.4 Compliance for Hydrogen Sulfide

The PRWQSR criterion for sulfide is defined in terms of "undissociated hydrogen sulfide" (that is, un-ionized sulfide, or $H_2S$). Total sulfide is composed of $HS^-$ and $H_2S$. The two forms of sulfide ($HS^-$ and $H_2S$) are in equilibrium. The concentration of $H_2S$ for a given concentration of total sulfide is significantly affected by pH and also varies with temperature and conductivity.

The effluent RP for sulfide based on DMR records (Appendix D) is 279.97 µg/L and is above PRWQSR of 2 µg/L for $H_2S$, indicating that a mixing zone is required. The receiving water level for *total* sulfide at the 90th percentile is 2 µg/L based on the MZVS data (Appendix H). As demonstrated below, there is sufficient assimilative capacity to establish a mixing zone.

The calculation of un-ionized sulfide concentrations when the effluent is diluted with receiving water is more complex than the simple dilution calculations used in Sections 9.1 because the concentration depends on equilibrium with $HS^-$ as a function of pH, temperature, and conductivity. The information required for the calculations described below is from *Standard Methods for the Examination of Water and Wastewater* (17th edition).[12]

Dissolved sulfide ($H_2S$ and $HS^-$) is in equilibrium as:

$$H_2S \leftrightarrow H^+ + HS^-$$

The practical ionization constant in logarithmic form, pK′, is used to calculate the distribution of dissolved sulfide between the two forms. The ionization constant is a function of the temperature and conductivity of the solution.

The effect of ionic strength (conductivity) on pK′ is not large, and generally the effect of this variable can be estimated closely by knowing the nature of the sample (whether it is full-strength seawater, estuarine water, brackish water, or fresh water). The temperature effect is nearly linear and varies inversely for the range of 15 degrees Celsius (°C) to 35°C, which includes temperatures typically found in Puerto Rico coastal waters. A conductivity of 50 millimhos per centimeter (mmhos/cm) is typical of full-strength seawater.

Higher values of pK′ correspond to higher fractions of $H_2S$. Because pK′ is inversely proportional to temperature, the lower end of the receiving water temperature range is the most critical and is used in the following calculations. Based on typical receiving water temperatures in coastal waters of Puerto Rico, the 10th percentile receiving water temperature is approximately 27°C (based of MZVS data provided in Appendix H). For full-strength seawater (conductivity = 50 mmhos/cm), a value of pK′ = 6.85 can be derived from:

$$pK'_{50} = 6.95 - [0.014 \cdot (T - 20°C)]$$

$$pK'_{50} = 6.95 - [0.014 \cdot (27 - 20°C)] = 6.85$$

where:

6.95 = pK′ for full-strength seawater at 20°C
0.014 = change in pK′ per 1°C of temperature
T = ambient temperature in °C

Note that pK′ is relatively insensitive to temperature; a 1°C change in temperature yields only a minor change in pK′.

The dissolved fraction of $H_2S$ can be read from the graph given in *Standard Methods* or directly calculated from:

$$\%H_2S = \frac{10^{pK'-pH}}{1+10^{pK'-pH}} \times 100$$

The percentage of dissolved sulfide present as $H_2S$ is a log-linear function of (pH − pK′). Lower pH values result in higher percentages of $H_2S$. Therefore, to implement a conservative approach, the pH after initial dilution is based on the minimum allowable effluent pH value (6.0) and the minimum percentile ambient pH value (8.13) (refer to Sections 5 and 9.3). Inserting each of these values into the equation, the percent $H_2S$ in the effluent and receiving water are 88.90 percent and 5.01 percent, respectively.

Determination of the $D_r$ and final concentration (C) as described in Section 9.1 is not employed directly on the $H_2S$ concentrations in the effluent and receiving water because of the effects of changing pH and conductivity following initial dilution. First, the pH at the EOMZ is calculated using the DNER-approved method described in

[12] American Public Health Association. *Standard Methods for the Examination of Water and Wastewater, 17th Ed*. Washington, DC, New York: American Public Health Association.

Sections 9.1 and 9.4 (the calculation is based on actual hydrogen ion concentrations) and the percentage of $H_2S$ is determined. Next, *total* sulfide at the EOMZ is calculated, and the percent $H_2S$ is determined from that value.

Using an effluent pH concentration set at the minimum allowable concentration of 6.0 and the receiving water pH set at the 10th percentile concentration of 8.13 yields a pH of 8.00 at the EOMZ.

The lower values of the respective pH ranges are used because the percent of $H_2S$ is larger for lower pH. Using a pK′ of 6.85 and pH of 8.0 indicates 5.01 percent $H_2S$ at the EOMZ. Back-calculating the amount of total sulfide in the effluent from the RP concentration (279.97 µg/L) and percent of $H_2S$ (88.90 percent based on a pH of 6) yields total sulfide concentration of 314.93 µg/L. The total sulfide in the receiving water at the 90th percentile concentration from the 301(h) monitoring program and the MZVS background data are both 2 µg/L. It is noted that sulfide was generally not detected in the receiving water and the value of 2.0 µg/L represents the MDL of non-detected samples.

The final concentration of total sulfide based on the effluent RP and the 90th percentile receiving water concentration yields a final concentration at the EOMZ of

$$C = C_a + \left[\frac{(C_e - C_a)}{CID}\right] \leq 2 + \frac{(279.97 - 2)}{376} = 2.74\ \mu\text{g/l}$$

The final concentration of $H_2S$ based on 5.01 percent of the final sulfide concentrations calculated above is 0.14 µg/L. This is well below the PRWQSR of 2 µg/L; therefore, compliance is demonstrated for $H_2S$.

## 9.5 Compliance for Dissolved Oxygen

The calculation of effluent discharge effects on receiving water DO concentration is based on the procedure presented in Section II, Chapter 6, Part C of the *Interim Mixing Zone and Bioassay Guidelines.* The criterion for DO in Class SB waters requires that the discharge does not cause the receiving water DO to be less than 5 mg/L, except when natural phenomena cause this value to be depressed. The *Interim Mixing Zone and Bioassay Guidelines* provide a sequential process to evaluate DO in the nearfield (following initial dilution) and in the farfield (following subsequent plume diffusion).

The first step in determining whether DO meets PRWQSR criteria is to calculate the DO after initial dilution using the following formula:

$$DO_f = DO_a + \frac{(DO_e - IDOD - DO_a)}{S_a}$$

where:

$DO_f$ = final DO concentration of receiving water at plume trapping level, mg/L,
$DO_a$ = ambient DO concentration averaged from the diffuser port depth to the trapping level, mg/L,
$DO_e$ = DO of effluent, mg/L,
IDOD = immediate dissolved oxygen demand, mg/L, and
$S_a$ = initial dilution (flux-averaged).

The minimum DO value at the MZVS background stations was 6.13 mg/L and was used for $DO_a$. The current permit limitation is MO; therefore, a value of 0.00 mg/L for effluent DO is used in the calculations below. The IDOD value was estimated in accordance with the guidelines in EPA's 1994 *Revised 301(h) Technical Support Document*, Appendix B-II. The IDOD was estimated to be 8 mg/L. Based on the values described above, and using the revised CID of 376:1, the DO immediately after initial dilution is calculated as:

$$DO_f = 6.13 + \left[\frac{(0.00 - 8.0 - 6.13)}{376}\right] = 6.09 mg/L$$

Initial DO demands are negligible and are not very sensitive to either effluent DO or IDOD concentration. Based on these calculations, the DO concentrations in the discharge nearfield will meet the requirements of the PRWQSR.

The method presented in the *Interim Mixing Zone and Bioassay Guidelines* to estimate the impact of the discharge on DO concentrations in the farfield is a stepwise procedure that was applied using a Microsoft Excel spreadsheet application. The method is only incidentally dependent on the initial dilution; therefore, the revised initial dilution will have a negligible effect on the calculated farfield DO demand. The results of the farfield DO demand calculations indicate an insignificant DO demand in the farfield (less than 0.01 mg/L) after initial dilution. The DO criterion required by the PRWQSR will be achieved in both the nearfield and the farfield. The detailed farfield DO calculation is provided in Appendix L.

DO depression in the water column caused by the effluent after initial dilution, with effluent DO assumed to be zero and IDOD assumed to be 5 mg/L (applies only within the plume), yielded a DO demand of less than 0.01 mg/L. Therefore, the DO remains well above the criterion of 5.0 mg/L. PRASA proposes that the limitation in the renewed permit remain as MO for DO, as specified in the existing permit.

## 9.6 Compliance for Color

Based on the DMR data in Section 3, the maximum and reasonable potential color concentrations were 45 and 83 Pt-Co units, respectively. The maximum and 90th percentile color concentrations were both 5 Pt-Co units. The detection limit is 5 Pt-Co.

A color analysis based on serial dilutions was reported in the 1993 mixing zone study for the Arecibo RWWTP wastewater following the procedures specified by EQB in the *Interim Mixing Zone and Bioassay Guidelines*. These data were used in the 1999 MZA. Table 9-2 and Figure 9-1 present the results of the test in tabular and graphical format, respectively. The test was performed for effluent with a color of 75 Pt-Co units. The analysis indicates that the relationship between color and percent effluent is linear, particularly below 30 percent effluent.

Table 9-2. Results of Effluent Color Analysis

| Tube | Percent Effluent | Color Units | pH |
|---|---|---|---|
| 1 | 0 | 3 | 8.29 |
| 2 | 10 | 12 | 8.01 |
| 3 | 20 | 20 | 7.88 |
| 4 | 30 | 30 | 7.71 |
| 5 | 40 | 35 | 7.59 |
| 6 | 50 | 42 | 7.52 |
| 7 | 60 | 50 | 7.48 |
| 8 | 70 | 55 | 7.44 |
| 9 | 80 | 63 | 7.34 |
| 10 | 90 | 70 | 7.31 |
| 11 | 100 | 75 | 7.25 |

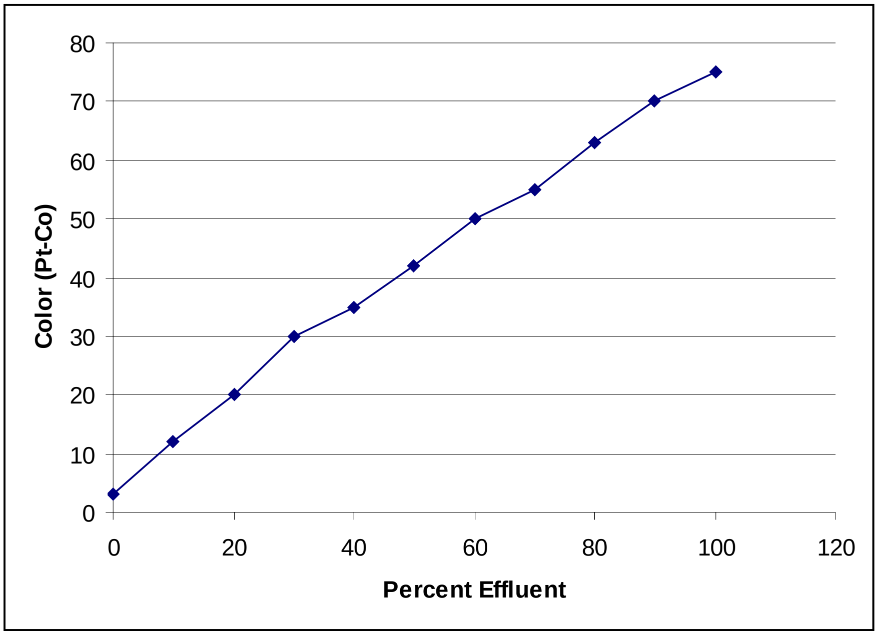


Figure 9-1. Graphical Representation of the Results of Effluent Color Analysis

At the EOMZ, the CID of 376:1 corresponds to approximately 0.2 percent effluent. At this dilution, based on the data in Figure 9-1, the color will be reduced to approximately 3.3 Pt-Co units at the EOMZ. Deducting the background color (0 percent effluent = 3 Pt-Co units), the effluent would raise the diluting water (receiving water) by 0.3 Pt-Co units (maximum daily). This analysis is based on an effluent color of 75 Pt-Co; the result would be less for an effluent with a color of 45 Pt-Co (the maximum color observed in the effluent). The analytical method for color cannot distinguish color differences smaller than 5 Pt-Co units; therefore, the color of the effluent will be indistinguishable from background color at the EOMZ and complies with the narrative criterion of the PRWQSR. Based on the reasonable potential color of the effluent, PRASA concludes that no numeric limits for color are necessary to protect water quality and recommends that the narrative color standard be used in the NPDES permit with an MO limitation.

## 9.7 Compliance with Other Mixing Zone Conditions

- **Compliance with Article 4C, Law 9.** PRASA complied with this requirement prior to the construction of this facility.
- **Discharge System Design.** The outfall and diffuser system configuration is based on best engineering practices, as described in Sections 2.2 and 7. The presentation of this information provides compliance with Section 5.15, Article 5, of the PRWQSR. There is no proposed change from the conditions represented in the 1999 Application, so that compliance will continue.
- **Sedimentation.** The PRWQSR does not provide a numerical limit on the concentration of suspended solids. It does, however, specify that discharges should not cause deposition in, or be deleterious to, existing or designated uses. An analysis of sedimentation of suspended solids is provided in the most recent 301(h) Waiver Applications. The analysis was conducted in accordance with EPA’s 1994 *Revised 301(h) Technical Support Document* methods. The results of this analysis are summarized below.
    - Calculation of suspended solids concentration immediately following initial dilution using the *Revised 301(h) Technical Support Document* method indicates an increase of approximately 0.3 mg/L above ambient conditions.

  - Ambient suspended solids concentration in the vicinity of the discharge site ranged from 0.5 mg/L to 42 mg/L. Under the conservative conditions of the CID, the predicted suspended solids increase at the edge of the zone of initial dilution (ZID) is well within the naturally occurring range measured at the discharge site. Similarly, with this small change in suspended solids concentration, any change in solids deposition resulting from the discharge site would be less than the naturally occurring range of solids deposition.

- **Discharge System Maintenance**. The PRWQSR requires information that demonstrates that the proposed diffuser and outfall maintenance system is adequate and acceptable to DNER. PRASA performs periodic outfall integrity inspections with videotape documentation.
- **Objectionable Substances**. The PRWQSR requires that the mixing zone will be free of debris, scum, floating oils, and any substances that produce objectionable odors. The wastewater treatment unit operations (including pre-treatment screening), the extensive analysis of effluent characteristics, and the high initial dilution obtained all indicate compliance with this condition. The discharge does not contain floating debris, scum, or other floating materials attributable to discharges in amounts sufficient to be unsightly or deleterious to the existing or designated uses of the receiving water body. The outfall location is more than 0.5 miles offshore in an area not frequented by the public. Any odors generated are not discernible more than a short distance from the mixing zone and, therefore, are not objectionable.
- **Oil and Grease**. The PRWQSR requires that the waters of Puerto Rico shall be substantially free from floating non-petroleum oils and greases as well as from petroleum-derived oils and greases. The wastewater treatment process is designed to remove floatable material from the effluent stream, and effluent dilution will be at least 376:1. The concentration of any remaining oil and grease will, therefore, be very low and is expected to be in an emulsified form.
- **Ecological Conditions**. The PRWQSR requires that the discharge shall not cause propagation of organisms that negatively disturb the ecological equilibrium adjacent to the mixing zone. The mixing zone location must allow for the passage of biota at all times, and the mixing zone must not be located in recognized fish spawning or aquatic organism nursery area. As described in Section 8, water quality and toxicity criteria will be met at the EOMZ; thus, there should be no stress on the indigenous populations. The discharge and proposed mixing zone are in the open ocean; therefore, fish passage will not be impeded. The 1985 301(h) Waiver Application demonstrates that these conditions are met, as do the results of the subsequent and ongoing 301(h) monitoring studies conducted since 1999.
- **Adjacent Mixing Zones.** There are no nearby mixing zones.
- **Public Beaches**. Section 5.4(13) of the PRWQSR requires that mixing zones be at least 0.6 miles (1 km) from any public beach. There are no recreational beaches near the Arecibo RWWTP mixing zone. In addition, the discharge is more than 3,700 feet from shore, and thus is more than 1.13 km from any public beach that might be established in the future.
- **Drinking Water Intakes**. No drinking water intake is located within or adjacent to the discharge area.

# 10. Requirements for Implementation

This section presents the regulatory requirements for authorizing a mixing zone. These requirements include applicable environmental permits or documentation, a summary of required monitoring studies, and, as required by the PRWQSR, proposed effluent limitations that are appropriate based on the evaluations presented in this document. Each item is discussed below.

## 10.1 Permitting and Environmental Documentation

The Arecibo RWWTP is an existing facility, currently permitted, with no projected construction activities. Therefore, no additional construction permitting or construction-related environmental documentation is required to support this MZA.

PRASA timely submitted a request for renewal of the existing NPDES permit that included all of the pertinent environmental documentation related to operating the Arecibo RWWTP, including a Coastal Zone Management Act certification request, an Essential Fish Habitat certification request, and a Biological Evaluation that included requests for certification of lack of effects on species listed as Threatened or Endangered by U.S. federal government agencies (that is, the National Oceanographic and Atmospheric Administration's National Marine Fisheries Service and the U.S. Fish and Wildlife Service) or by the DNER. These requests are being updated with additional information from the ongoing 301(h) monitoring studies and will resubmitted as a part of the normal NPDES permit modification processes, once the WQC is issued by DNER.

## 10.2 Mixing Zone Validation

The objective of mixing zone validation is to demonstrate that at least 90 percent of the values obtained by the model for the corresponding points throughout the periphery of the mixing zone are equal or less than the ones obtained through the sampling program. Several types of data will be collected to provide the necessary information to validate the mixing zone model. In general, based on DNER requirements, the program will include:

- Effluent flow and effluent quality data at the Arecibo RWWTP
- Ocean current speed and direction data
- Water column density, DO, and pH profiles collected in the vicinity of the discharge
- Water quality data from mixing zone and background stations to document concentrations of mixing zone POCs

PRASA believes that the most appropriate alternate mixing zone validation approach would, in addition to the items listed above, include the following characteristics:

- Continue to use the well-established performance of initial dilution models (such as UDKHDEN) developed by EPA and approved by EPA and DNER.
- Accept the EPA-approved model predictions and routinely monitor POCs in the effluent.
- Monitor POCs in the receiving water to determine compliance at the EOMZ twice (during two seasons) as required by the PRWQSR.
- Confirm/validate the well-established performance of the EPA initial dilution models by using a one-time dye injection study. One of the receiving water monitoring episodes would be conducted at the same time as the dye study.

This recommended approach is used by Puerto Rico and various U.S. states and territories to maintain documented compliance in the receiving water where mixing zones have been established. The following advantages of a dye study validation have been well-documented:

- The actual location of the plume is identified and the effluent-receiving water mixture within the actual plume is sampled. Using the existing DNER procedure, this real-time plume identification ability does not exist, and a large number of samples are taken under the *assumption* that some of them *may* be located in the effluent plume.
- A definitive description of plume behavior and model verification can be obtained with a single field sampling event. This is much less time-intensive and cost-intensive than the existing DNER requirements (which include as many as 12 field sampling events and the associated analytical chemistry) that fail to produce conclusive results.
- Because the fluorescent dye can be detected accurately at very low concentrations, the validation of the model can be definitively established. As described previously, this cannot be accomplished with the existing PRWQSR-required procedure.

A dye study was conducted at the Arecibo RWWTP in previous MZVSs, with water quality sampling performed in 2016 and 2019. This study clearly validated the mixing zone and mixing zone modeling for this facility.

A Quality Assurance Project Plan and Sampling and Analysis Protocols (QAPP/SAP) will be prepared by PRASA for review and approval by DNER. The QAPP/SAP will contain detailed descriptions of the procedures used for monitoring ocean currents, collecting effluent and receiving water samples, documenting sample chain-of-custody, analyzing the samples for chemical constituents, and applying quality assurance/quality control procedures for sample collection and analysis. Mixing zone validation work will be initiated only after DNER approval of the QAPP/SAP.

## 10.3 Requested Effluent Limitations

The PRWQSR requires applicants for a WQC to request effluent limits. This MZA develops and presents the requested effluent limits for those constituents of concern that were defined in Sections 2 and 3 and discussed in detail in Section 9. The requested limitations for the POCs in this MZA are presented in Table 10-1.

The proposed limitations in Table 10-1 are based on following assumptions:

- DNER will modify, in addition to the effluent limitations, the limitations applied at the EOMZ to reflect the most recent version of the PRWQSR, which has been revised since the existing WQC and NPDES permit were issued.
- DNER will delete any effluent and mixing zone limitations that pertain to parameters no longer regulated by the PRWQSR; in this case, fecal coliform bacteria.
- For existing parameters that have an existing IMZ or EOP limitation and that need to be changed, the proposed limitation is based on the existing limitation, the calculated RP[13] concentration, or the PRWQSR criterion for that parameter, as appropriate.

[13] The reasonable potential value is calculated using the methods provided in EPA/505/2-90-001, and *Technical Support Document for Water Quality-based Toxics Control*, applying a log-normal distribution, 99 percent confidence limits, and 99 percent probability.

Table 10-1. Arecibo RWWTP Proposed Effluent Limitations

| Parameter | Units | Type of Limitation in Existing Permit | Proposed Limitation | Type of Limitation Proposed | Basis for Proposed Limitation |
|---|---|---|---|---|---|
| **Metals** | | | | | |
| Copper | µg/L | IMZ | 47.88 | IMZ | $D_r$ < CID |
| Nickel | µg/L | IMZ | 9.63 | IMZ | $D_r$ < CID |
| Silver | µg/L | IMZ | 4.74 | IMZ | $D_r$ < CID |
| Thallium | µg/L | IMZ | 1.70 | IMZ | $D_r$ < CID |
| Zinc | µg/L | EOP | 328.59 | IMZ | $D_r$ < CID |
| **Conventional Parameters** | | | | | |
| Cyanide (as free cyanide) | µg/L | IMZ | 6.26 | IMZ | $D_r$ < CID |
| Nitrogen ($NO_2$+$NO_3$+TKN)[a] | mg/L | IMZ | 43.800 | IMZ | $D_r$ < CID |
| Sulfide ($H_2S$) | µg/L | IMZ | 280 | IMZ | $D_r$ < CID |
| Surfactants (MBAS) | µg/L | IMZ | 7,797 | IMZ | $D_r$ < CID |
| Turbidity | NTU | IMZ | 103 | IMZ | $D_r$ < CID |
| **Narrative and Informational** | | | | | |
| Color[b] | Pt-Co | IMZ | Narrative | IMZ | Meets criterion |
| Oil and Grease (O&G) (Monthly Average) | mg/L | EOP | Narrative | EOP | Existing Limitation |
| O&G (Daily Maximum) | mg/L | EOP | Narrative | EOP | Existing Limitation |
| TKN | µg/L | INF | MO | -- | Existing Limitation |
| Temperature[c] | °C | EOP | 32.2 | EOP | Existing Limitation |
| **Technology-Based** | | | | | |
| BOD (Monthly Average) | kg/d | EOP | 9,085 | EOP | Existing Limitation |
| BOD (Monthly Average) | mg/L | EOP | 120 | EOP | Existing Limitation |
| BOD | % removal | EOP | 30 | EOP | Existing Limitation |
| TSS (Monthly Average) | kg/d | EOP | 8,326 | EOP | Existing Limitation |
| TSS (Monthly Average) | mg/L | EOP | 110 | EOP | Existing Limitation |
| TSS | % removal | EOP | 50 | EOP | Existing Limitation |
| DO | mg/L | IMZ | MO | IMZ | Existing Limitation |
| *Enterococcus* | col/100 mL | CP | PRWQSR | EOP | New Requirement |

Table 10-1. Arecibo RWWTP Proposed Effluent Limitations

| Parameter | Units | Type of Limitation in Existing Permit | Proposed Limitation | Type of Limitation Proposed | Basis for Proposed Limitation |
|---|---|---|---|---|---|
| Flow (Monthly Average) | mgd | EOP | MO | EOP | Existing Limitation |
| Flow (Daily Maximum) | mgd | EOP | 20 | EOP | Existing Limitation |
| pH (Maximum) | SU | IMZ | 9 | IMZ | Existing Limitation |
| pH (Minimum) | SU | IMZ | 6 | IMZ | Existing Limitation |
| TRC[d] | mg/L | CP | 0.050 | IMZ | $D_r$ < CID |
| **Whole Effluent Toxicity** | | | | | |
| **Chronic Toxicity** | | | | | |
| *Mysidopsis bahia* NOEC | $TU_c$ | IMZ | 376 | IMZ | $D_r$ = CID |
| *Cyprinodon variegatus* NOEC | $TU_c$ | IMZ | 376 | IMZ | $D_r$ = CID |
| *Arbacia punctulata* $IC_{25}$ | $TU_c$ | IMZ | 376 | IMZ | $D_r$ = CID |

[a] There are no effluent data for TN; however, based on data for dissolved organic nitrogen (DIN) reported on the DMRs under the current permit and ancillary data from the 301(h) monitoring, PRASA believes this proposed limitation is adequate. Otherwise, DNER may require a compliance plan.

[b] PRASA requests that color be listed as MO, consistent with the narrative criterion. However, if DNER includes a numerical limitation for color, PRASA requests it be set at 70 Pt-Co, which is the RP value rounded up to the nearest 5 units (5 color units is the resolution of the analytical procedure).

[c] The new PRWQSR criterion is 30°C. The current limitation is 32.2°C, which is the previous PRWQSR criterion. PRASA believes that heat transfer through the pipeline will sufficiently reduce the effluent temperature to meet the criterion at the point of discharge to the receiving water.

[d] TRC will be held for the travel time through the pipeline prior to measurement to correctly reflect the value at the point of discharge to the receiving water

Notes:

CP = compliance plan
$D_r$ = required dilution based on flow-weighted effluent concentration
INF = informational
MO = monitor only
RP = reasonable potential effluent concentration based on 99 percent probability level and 99 percent confidence level