REGION 10 ADMINISTRATOR
SEATTLE, WA 98101

Municipality of Skagway Borough
Wastewater Treatment Plant
Application for a Modified NPDES Permit
Under Section 301(h) of the Clean Water Act

Final Decision of the Regional Administrator
Pursuant to 40 CFR Part 125, Subpart G

I have reviewed the attached evaluation analyzing the merits of the Municipality of Skagway Borough's request and application for a variance from secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the Act for the Municipality of Skagway Borough wastewater treatment plant. It is my decision that the Municipality of Skagway Borough be granted a variance pursuant to Section 301(h) of the Act for the Municipality of Skagway Borough wastewater treatment plant in accordance with the terms, conditions, and limitations of the final 301(h)-modified NPDES permit AK0021466.

My decision is based on available information specific to the discharge from the Municipality of Skagway Borough wastewater treatment plant. It is not intended to assess the need for secondary treatment in general, nor does it reflect on the necessity for secondary treatment by other publicly owned treatment works discharging to the marine environment.

Under the procedures of permit regulations at 40 CFR Part 124, public notice and comment regarding the draft version of this decision and accompanying NPDES permit were made available to all interested persons.

This decision shall become effective on January 7, 2025, unless a request for review is filed. If a request for review is filed, this decision is stayed. Requests for review must be filed by January 6, 2025, and must meet the requirements of 40 CFR 124.19. All requests for review should be addressed to the Environmental Appeals Board. Those persons filing a request for review must have filed comments on the tentative decision. Requests for review from other persons must be limited to the extent of the changes made from the tentative decision to the final decision. EPA regulations regarding the effective date for the decision and requests for review procedures are set forth in 40 CFR 125.15, 125.19 and 125.20.

The Notice of Final Decision will also be posted on the EPA Region 10 website.

/signed/ 11-15-2024
Casey Sixkiller
Regional Administrator

Municipality of Skagway Borough

Wastewater Treatment Plant

Application For A Modified NPDES Permit Under

Section 301(h) Of

The Clean Water Act

Decision Document

December 2024

United States Environmental Protection Agency

Region 10

1200 6th Avenue

Seattle, WA 98101

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1) INTRODUCTION

The Municipality of Skagway Borough, Alaska, ("the applicant," "Skagway," or "the permittee") has requested a renewal of its variance (sometimes informally called a "waiver" or "modification") under Section 301(h) of the Clean Water Act (the Act or CWA) from the secondary treatment requirements contained in Section 301(b)(1)(B) of the Act.

The United States Environmental Protection Agency, Region 10 (EPA) approved Skagway's first request for modification of secondary treatment requirements and issued its first CWA Section 301(h)-modified National Pollutant Discharge Elimination System (NPDES) permit on September 6, 1983 [AK0020010]. The most recent NPDES permit was issued on August 6, 2002 (hereafter referred to as the 2002 permit). The 2002 permit became effective on October 1, 2002, and expired on September 7, 2007. A timely and complete NPDES application for permit reissuance was submitted by the permittee on June 20, 2007. Pursuant to 40 CFR Part 122.6, the permit has been administratively continued and remains fully effective and enforceable.

The 301(h) variance is being sought for the Skagway Wastewater Treatment Plant ("WWTP" or "the facility"), a publicly owned treatment works (POTW). The applicant is seeking a 301(h) variance to discharge wastewater receiving less-than-secondary treatment from a single outfall into Taiya Inlet. Secondary treatment is defined in the regulations at 40 CFR Part 133 in terms of effluent quality for total suspended solids (TSS), biochemical oxygen demand (BOD_5), and pH. Pursuant to 40 CFR 133.102, secondary treatment requirements for TSS, BOD_5, and pH are as follows:

TSS: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

BOD_5: (1) The 30-day average concentration shall not exceed 30 mg/l;

(2) The 7-day average concentration shall not exceed 45 mg/l; and

(3) The 30-day average percent removal shall not be less than 85%.

pH: The pH of the effluent shall be maintained within the limits of 6.0 to 9.0 pH standard units.

The permittee has requested a modification for TSS, BOD_5, and pH.

This document presents EPA's findings and conclusions as to whether the applicant's proposed 301(h)-modified discharge (proposed discharge) will comply with the criteria set forth in Section 301(h) of the Act, as implemented by regulations at 40 CFR Part 125, Subpart G, and the Alaska Water Quality Standards (Alaska WQS), as amended.

2) DECISION CRITERIA

Under Section 301(b)(1)(B) of the Act, POTWs in existence on July 1, 1977, are required to meet effluent limits based on secondary treatment as defined by the Administrator of EPA ("the Administrator"). Secondary treatment is defined by the Administrator in terms of three parameters: TSS, BOD_5, and pH. Uniform national effluent limitations for these pollutants were promulgated and included in NPDES permits for POTWs issued under Section 402 of the CWA, POTWs were required to comply with these limitations by July 1, 1977.

Congress subsequently amended the Act, adding Section 301(h) which authorizes the Administrator, with State concurrence, to issue NPDES permits that modify the secondary treatment requirements of the Act with respect to certain discharges. P.L. 95-217, 91 Stat. 1566, as amended by P.L. 97-117, 95 Stat. 1623; and S303 of the Water Quality Act of 1987. Section 301(h) provides that:

> *[T]he Administrator, with the concurrence of the State, may issue a permit under section 402 [of the Act] which modifies the requirements of subsection (b)(1)(B) of this section [the secondary treatment requirements] with respect to the discharge of any pollutant from a publicly owned treatment works into marine waters, if the applicant demonstrates to the satisfaction of the Administrator that:*

(1) there is an applicable water quality standard specific to the pollutant for which the modification is requested, which has been identified under section 304(a)(6) of [the CWA];

(2) the discharge of pollutants in accordance with such modified requirements will not interfere, alone or in combination with pollutants from other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and the protection and propagation of a balanced, indigenous population of shellfish, fish and wildlife, and allows recreational activities, in and on the water;

(3) the applicant has established a system for monitoring the impact of such discharge on a representative sample of aquatic biota, to the extent practicable, and the scope of the monitoring is limited to include only those scientific investigations which are necessary to study the effects of the proposed discharge;

(4) such modified requirements will not result in any additional requirements on any other point or nonpoint source;

(5) all applicable pretreatment requirements for sources introducing waste into such treatment works will be enforced;

(6) in the case of any treatment works serving a population of 50,000 or more, with respect to any toxic pollutant introduced into such works by an industrial discharger for which pollutant there is no applicable pretreatment requirement in

effect, sources introducing waste into such works are in compliance with all applicable pretreatment requirements, the applicant has in effect a pretreatment program which, in combination with the treatment of discharges from such works, removes the same amount of such pollutant as would be removed if such works were to apply secondary treatment to discharges and if such works had no pretreatment program with respect to such pollutant;

(7) to the extent practicable, the applicant has established a schedule of activities designed to eliminate the entrance of toxic pollutants from nonindustrial sources into such treatment works;

(8) there will be no new or substantially increased discharges from the point source of the pollutant into which the modification applies above that volume of discharge specified in the permit; and

(9) the applicant at the time such modification becomes effective will be discharging effluent which has received at least primary or equivalent treatment and which meets the criteria established under [section 304(a)(1) of the CWA] after initial mixing in the waters surrounding or adjacent to the point at which such effluent is discharged.

For the purposes of this subsection the phrase "the discharge of any pollutant into marine waters" refers to a discharge into deep waters of the territorial sea or the waters of the contiguous zone, or into saline estuarine waters where there is strong tidal movement and other hydrological and geological characteristics which the Administrator determines necessary to allow compliance with paragraph (2) of this subsection, and [section 101(a)(2) of the Act]. For the purposes of paragraph (9), "primary or equivalent treatment" means treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biological oxygen demanding material and of the suspended solids in the treatment works influent, and disinfection, where appropriate. A municipality which applies secondary treatment shall be eligible to receive a permit pursuant to this subsection which modifies the requirements of subsection (b)(1)(B) of this section with respect to the discharge of any pollutant from any treatment works owned by such municipality into marine waters. No permit issued under this subsection shall authorize the discharge of sewage sludge into marine waters. In order for a permit to be issued under this subsection for the discharge of a pollutant into marine waters, such marine waters must exhibit characteristics assuring that water providing dilution does not contain significant amounts of previous discharged effluent from such treatment works. No permit issued under this subsection shall authorize the discharge of any pollutant into saline estuarine waters which at the time of application do not support a balanced, indigenous population of shellfish, fish and wildlife, or allow recreation in and on the waters or which exhibit ambient water quality below applicable

> *water quality standards adopted for the protection of public water supplies, shellfish, fish and wildlife or recreational activities or such other standards necessary to assure support and protection of such uses. The prohibition contained in the preceding sentence shall apply without regard to the presence or absence of a causal relationship between such characteristics and the applicant's current or proposed discharge. Notwithstanding any of the other provisions of this subsection, no permit may be issued under this subsection for discharge of a pollutant into the New York Bight Apex consisting of the ocean waters of the Atlantic Ocean westward of 73 degrees 30 minutes west longitude and westward of 40 degrees 10 minutes north latitude.*

On August 9, 1994, EPA promulgated final regulations implementing these statutory criteria at 40 CFR Part 125, Subpart G. The regulations provide that a Section 301(h)-modified NPDES permit may not be issued in violation of 40 CFR 125.59(b) which requires, among other things, compliance with provisions of the Coastal Zone Management Act, as amended, 16 USC 1451 *et seq.*, the Endangered Species Act, as amended, 16 USC 1531 *et seq.*, Title III of the Marine Protection Research and Sanctuaries Act, as amended, 16 USC 1431 *et seq.*, the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC 1801 *et seq.*, and any other applicable provisions of local, state, and federal laws or Executive Orders.

In accordance with 40 CFR 125.59(i), the decision to grant or deny a CWA Section 301(h) waiver shall be made by the Administrator[1] and shall be based on the applicant's demonstration that it has met all the requirements of 40 CFR 125.59 through 125.68, as described in this 301(h) Decision Document (301(h) DD). EPA has reviewed all data submitted by the applicant in the context of applicable statutory and regulatory criteria and has presented its findings and conclusions in this 301(h) DD.

3) SUMMARY OF FINDINGS

Based upon review of the data, references, and empirical evidence furnished by the applicant and other relevant sources, EPA makes the following findings regarding the statutory and regulatory criteria:

1. The applicant's proposed discharge will comply with Alaska WQS for dissolved oxygen, turbidity, and pH. [CWA Section 301(h)(1); 40 CFR 125.61]
2. The applicant has demonstrated it can consistently achieve Alaska WQS and federal CWA Section 304(a)(1) water quality criteria at and beyond the zone of initial dilution (ZID). [CWA Section 301(h)(9); 40 CFR 125.62(a)]
3. The applicant's proposed discharge, alone or in combination with pollutants from other sources, will not adversely impact public water supplies or interfere with the protection

[1] The authority to make decisions on the eligibility of publicly owned treatment works for variances from the secondary treatment requirements of the Clean Water Act pursuant to Section 301(h) of the CWA has been delegated to the Regional Administrators.

and propagation of a balanced, indigenous population (BIP) of shellfish, fish, and wildlife, and will allow for recreational activities in an on the water. [CWA Section 301(h)(2); 40 CFR 125.62(b), (c), (d)]

4. The applicant has a well-established and adequate program to monitor the impact of its proposed discharge on aquatic biota and has demonstrated it has adequate resources to continue the program. These monitoring requirements will remain enforceable terms of the permit. [CWA Section 301(h)(3); 40 CFR 125.63]
5. The applicant's proposed discharge will not result in any additional treatment requirements on any other point or nonpoint sources. [CWA Section 301(h)(4); 40 CFR 125.64]
6. The facility serves a population less than 50,000 people, so does not need to develop an urban area pretreatment program [CWA Section 301(h)(6), 40 CFR 125.65]
7. The applicant will continue to implement its nonindustrial source control program, consisting of public outreach and education designed to minimize the amount of toxic pollutants that enter the treatment system from nonindustrial sources. [CWA Section 301(h)(7); 40 CFR 125.66]
8. There will be no new or substantially increased discharges from the point source of the pollutants to which the 301(h) variance applies above those specified in the permit. [CWA Section 301(h)(8); 40 CFR 125.67]
9. The 301(h) modified permit contains the special conditions required regarding effluent limitations and mass loadings, schedules of compliance, and monitoring and reporting requirements [40 CFR 125.68]
10. The discharge is not expected to conflict with applicable provisions of State, local, or other Federal laws or Executive Orders, including compliance with the Coastal Zone Management Act of 1972, as amended, 16 USC1451 *et seq*.; the Endangered Species Act of 1973, as amended, 16 USC 1531 *et seq*.; Title III of the Marine Protection, Research and Sanctuaries Act, as amended, 16 USC 1431 *et seq*.; and the Magnuson-Stevens Fishery Conservation and Management Act, as amended, 16 USC 1801 *et seq.* [40 CFR 125.59(b)(3)]
11. The applicant has demonstrated the proposed discharge will comply with federal primary treatment requirements. [CWA Section 301(h)(9); 40 CFR 125.60]

4) DECISION

Based on the findings in Section 3, above, EPA has concluded that the applicant's proposed discharge will comply with the requirements of CWA Section 301(h), and 40 CFR Part 125, Subpart G. Accordingly, EPA has decided to grant the applicant a CWA Section 301(h) variance and renew their 301(h)-modified NPDES Permit AK0020010.

5) DESCRIPTION OF TREATMENT SYSTEM

The WWTP serves the community of Skagway, Alaska, with a resident population of approximately 850 people and a seasonal tourism population. In 2019, the City's tourism population from April through October was approximately 980,000. (Skagway Convention and Visitors Bureau, 2019). Skagway WWTP's influent is primarily residential and infiltrated stormwater with a peak effluent flow rate of 0.465 million gallons per day (mgd). The existing WWTP is designed to treat a design flow of 0.63 mgd. However, the actual average daily discharge from August 1996 through April 2001 was approximately 0.325 mgd. In accordance with 40 CFR 125.58(c), the facility is a "small applicant." The existing outfall (001) discharges to Taiya Inlet approximately 1000 feet offshore at a depth of 55 feet below mean lower low water (MLLW). The outfall location is Latitude: 59.448523, Longitude: -135.32658.

Raw sewage enters the WWTP and is pumped over an inclined 0.06-inch mesh screen where solids are automatically removed and bagged for disposal at the municipal landfill. Screened sewage then flows into an aerated grit chamber. Aeration basin wastewater flows to clarifiers where the wastewater is settled and skimmed. The settled material is collected and goes through an aerobic digester, mixed with a polymer where it is dewatered into a sludge cake, and disposed. Clarified water crosses two weirs and discharges to Taiya Inlet through Outfall 001. In addition, between May and September only, the clarified water is periodically chlorinated with calcium hypochlorite tablets then dechlorinated in a contact chamber with calcium thiosulfate to remove bacteria after crossing the two weirs and discharging to Taiya Inlet through Outfall 001. From 2009 to 2010, Skagway upgraded its WWTP adding screens and updating its clarifiers.

See Appendix A for facility figures, area maps, and the treatment process flow diagram.

6) DESCRIPTION OF RECEIVING WATERS

A. General Features

The WWTP discharges into saline estuarine waters in the northern part of Taiya Inlet in Skagway Harbor off the shore of Skagway, Alaska. Taiya Inlet is a deep fjord in the upper Lynn Canal with an average depth of 457 meters.

Surface water densities near the outfall vary due to local freshwater inputs from nearby Taiya and Skagway Rivers. In 2013, the Taiya River discharged an annualized average flow of 1,540 ft^3/s, with the maximum average monthly discharge of 4,268 ft^3/s occurring in June

(USGS 2022). The Skagway River discharged an annualized average flow of 973 ft^3/s (in 1981[1]), with the maximum average monthly discharge of 2,323 ft^3/s occurring in August (USGS 2022).[2]

Taiya Inlet is classified in Alaska WQS as classes IIA(I)(ii)(iii), B(I)(ii), C and D, for use in aquaculture, seafood processing and industrial water supply, water contact and secondary recreation, growth and propagation of fish, shellfish, aquatic life and wildlife, and harvesting for consumption of raw mollusks or other raw aquatic life.

B. Currents and Flushing

According to NOAA, the mean tide range at Skagway, Taiya Inlet (Station ID: 9452400) from 1943 to October 2019 is 14.11 feet, with a diurnal range of 16.73 feet. and a mean tide level of 2.6 feet. above MLLW (NOAA 2022a). The maximum tide level is 10.09 feet above mean higher high water (MHHW) level. The minimum tide level is 6.10 feet above the MLLW level. More detailed information on currents and flushing is available in the current application and the previous fact sheet to the 1996 permit.

Taiya Inlet is a deep fjord with an average depth of 1,500 feet (457 meters). Taiya Inlet supports a classic fjord type of two-layer circulation with a large saline lower layer and a very thin upper brackish layer. A small mass transfer between the lower and upper layer may be expected because the net flow out of a fjord mostly occurs in the upper layers. The circulation of the inlet is dependent on tides and freshwater flow into the inlet. Freshwater from the Taiya and Skagway rivers mixes with the ocean waters to create estuarine conditions in the Taiya Inlet. The Taiya and Skagway rivers have the highest flows into Taiya Inlet in the summer when snowmelt occurs. The permit application indicates that Taiya Inlet is a stratified fjord during summer months and a well-mixed fjord during winter months. There are no obstructions to impede circulation near the outfall.

7) PHYSICAL CHARACTERISTICS OF THE DISCHARGE

Pursuant to 40 CFR 125.62(a)(1), the outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater to meet all applicable WQS at and beyond the boundary of the ZID during periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist.

The facility outfall is a 12-inch steel sewer line that extends 410 feet from shore at approximately 55 feet below MLLW depth. The pipe ends in an eight-port diffuser. The diffuser is 25 feet in length and is a 12-inch diameter high density polyethylene pipe with eight 3-inch

[2] The 2013 and 1981 flows were the highest for the gauges on record for the Taiya and the Skagway Rivers, respectively. The Taiya River flow gauge (USGS 15056210) operated from 1969-1977 and from 2003-present). The Skagway River flow gauge (USGS 15056100) operated from 1963-1986.

diameter holes evenly spaced on opposing sides of the pipe. The diffuser terminates at the 60 feet below MLLW depth.

Zone of Initial Dilution (ZID)

Section 301(h)(9) of the CWA, and 40 CFR 125.62 require 301(h) discharges to meet state WQS and federal CWA Section 304(a) criteria at the boundary of the ZID, which is the region of initial mixing surrounding or adjacent to the end of the outfall pipe or diffuser ports. The ZID may not be larger than allowed by mixing zone restrictions in applicable WQS, as per 40 CFR 125.58(dd). The dilution ratio achieved at the completion of initial mixing at the edge of the ZID is used to determine compliance with these requirements. Dilution is defined as the ratio of the total volume of the sample (ambient water plus effluent) to the volume of effluent in the sample. The ZID is not intended to describe the area bounding the entire mixing process or the total area impacted. Rather, the ZID, or region of *initial mixing,* is the area of rapid, turbulent mixing of the effluent and receiving water and results from the interaction between the buoyancy and momentum of the discharge and the density and momentum of the receiving water. Initial dilution is normally complete within several minutes after discharge. In guidance, EPA has operationally delimited the ZID to include the bottom area within a horizontal distance equal to the water depth from any point on the diffuser and the water column above that area (Amended 301(h) Technical Support Document; 301(h) TSD). Beyond the ZID boundary (i.e., after initial mixing is complete), the effluent is diluted further by passive diffusion processes and far-field ambient receiving water conditions. The ZID is not inclusive of this far-field mixing process.

The 2002 permit used a dilution factor of 72:1 based on the critical summer season and the diffuser design at that time. EPA has refined the dilution achieved at the edge of the ZID using more current information and available effluent and receiving water data.

EPA modeled the discharge to determine the dilution achieved at the edge of the ZID using recent effluent and receiving water data provided by the applicant (2016-2021). In accordance with the 301(h) TSD, EPA used data reflecting critical discharge and receiving water conditions to determine dilution under critical conditions. The dilution modeling report is included in Appendix G.

According to the model, the discharge achieves initial mixing and a dilution of 56:1 about 60 feet from the outfall at a depth of approximately 60 feet within two minutes of discharge under critical discharge and receiving water conditions. EPA used 56:1 dilution as the basis for determining compliance with CWA 301(h)(9) and 40 CFR 125.62. Consistent with the recommendations in the 301(h) TSD for setting spatial boundaries for the ZID, the spatial dimensions of the ZID include the entire water column within 60 feet of any point of the 25-foot diffuser. The ZID is a rectangle of 162 feet (49 m) long (perpendicular to shore) and 138 feet (42 m) wide centered around the diffuser. In its final CWA Section 401 Certificate of Reasonable Assurance (401 certification) the Alaska Department of Environmental Conservation

(ADEC) authorized acute and chronic dilution factors of 19:1 and 32:1, respectively. These dilutions fall within the boundary of the ZID.

8) APPLICATION OF STATUTORY AND REGULATORY CRITERIA

The sections below describe the statutory and regulatory requirements of 301(h) discharges and explains the basis for certain water quality-based effluent limits in the final permit.

A. Compliance with Primary or Equivalent Treatment Requirements [CWA Section 301(h)(9); 40 CFR 125.60]

Under CWA Section 301(h)(9) and 40 CFR 125.60, the applicant must demonstrate it will be discharging effluent that has received at least primary or equivalent treatment at the time the 301(h)-modified permit becomes effective. 40 CFR 125.58(r) defines primary or equivalent treatment as treatment by screening, sedimentation, and skimming adequate to remove at least 30 percent of the biochemical oxygen demanding material and other suspended solids in the treatment works influent, and disinfection, where appropriate. To ensure the effluent has received primary or equivalent treatment, the regulation at 40 CFR 125.60 requires the applicant to perform monitoring of their influent and effluent and assess BOD_5 and TSS removal rates based on a monthly average.

Applicants for 301(h) waivers request concentration and loading (lb/day) limits for BOD_5 and TSS based on what the facility can achieve. Therefore, the technology-based requirements for POTWs with 301(h) waivers are established on a case-by-case basis taking into consideration facility performance and the federal primary treatment standards.

1. Total Suspended Solids

EPA reviewed influent and effluent monitoring data for TSS between 2016 and 2021. A summary table and graphical representation of the data is provided below.

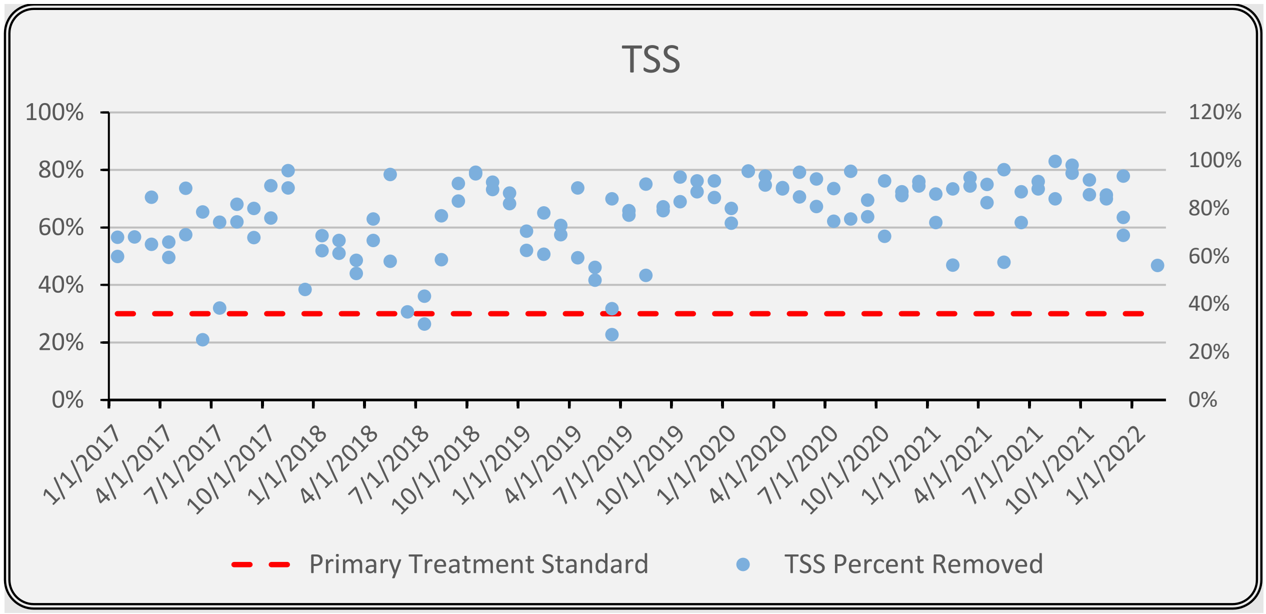

Figure 1. Minimum Monthly TSS Removal (2017-2022)

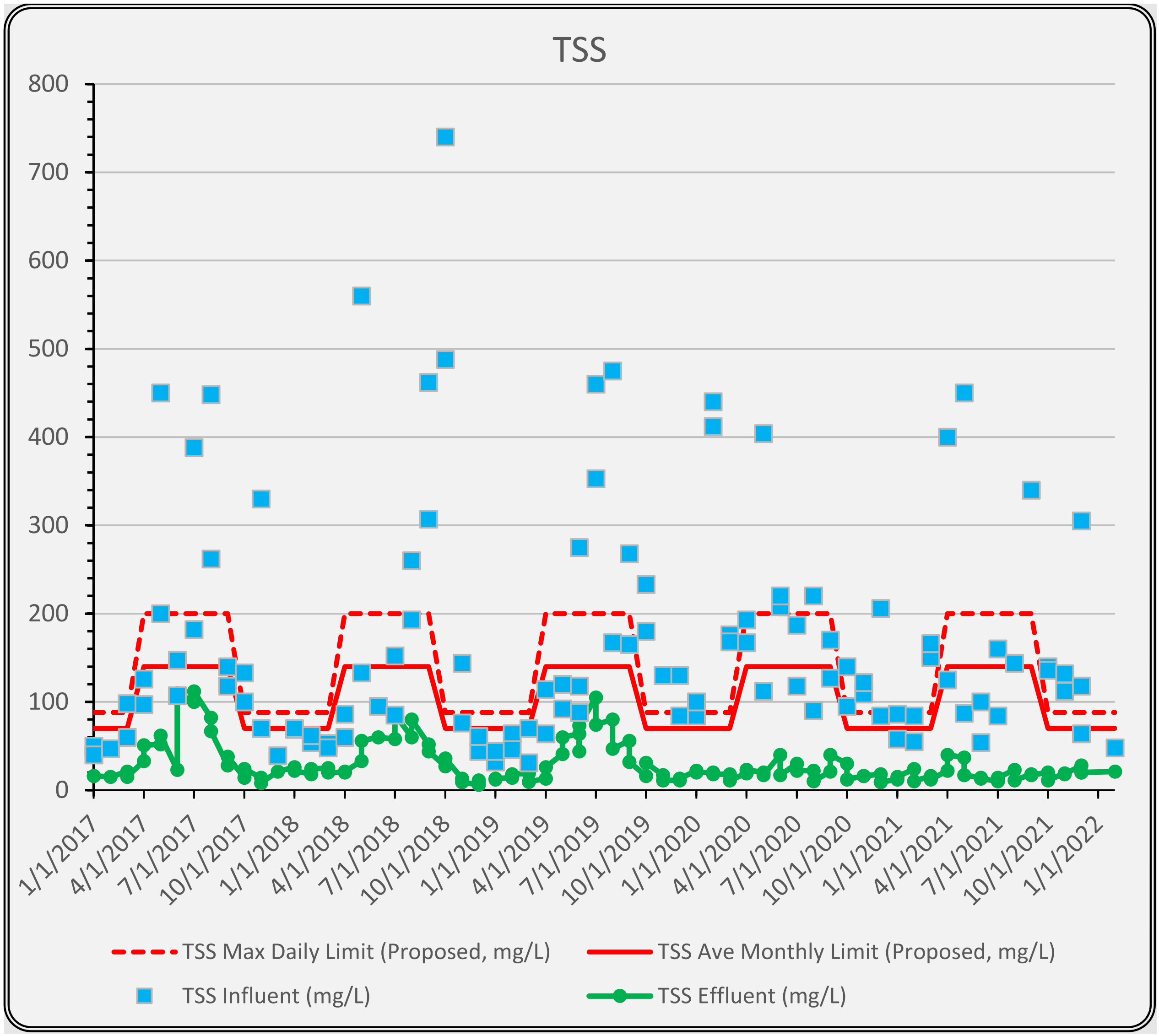

Figure 2. Average Monthly Influent and Effluent TSS Concentrations (mg/L)

The facility achieved the minimum 30% removal requirement for TSS 100% of the time between 2016-2021, with the lowest monthly removal being 33%. Between 2016 and 2021, the facility achieved an average of nearly 76% removal of TSS, with maximum percent removal efficiencies as high as 97%.

Table 1. Influent and Effluent TSS Data (2016-2021)

Statistic	Influent, TSS, mg/L	Effluent, TSS, mg/L (mo avg)	Effluent, TSS, mg/L (daily max)	Percent Removal
PROPOSED LIMIT (10/1-4/30)	---	67	129	≥30%
PROPOSED LIMIT (5/1-9/30)	---	30	45	≥30%
COUNT	57	57	57	--
MEAN	177	32	37	76%
MINIMUM	38	9	11	33%
MAX	614	106	132	97%
STDV	140	23	29	14.34
CV	0.79	0.74	0.79	0.188
5th	47	11	13	47%
95th	584	90	110	95%

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for TSS when the 301(h)-modified permit becomes effective. [CWA section 301(h)(9) and 40 CFR 125.60].

2. Biochemical Oxygen Demand

EPA reviewed influent and effluent data for BOD_5 between 2016 and 2021. A summary table and graphical representation of the data is provided below.

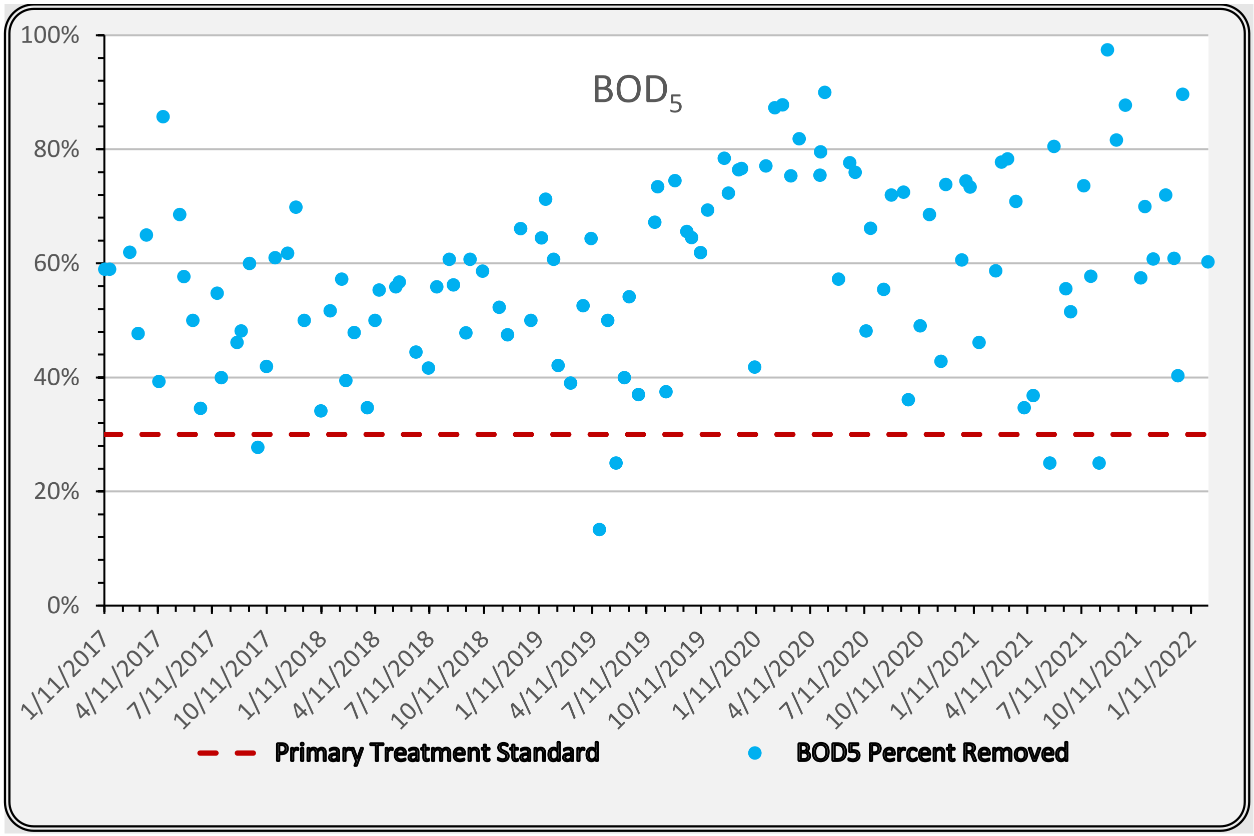

Figure 3. Minimum Monthly BOD5 Removal (2016-2021)

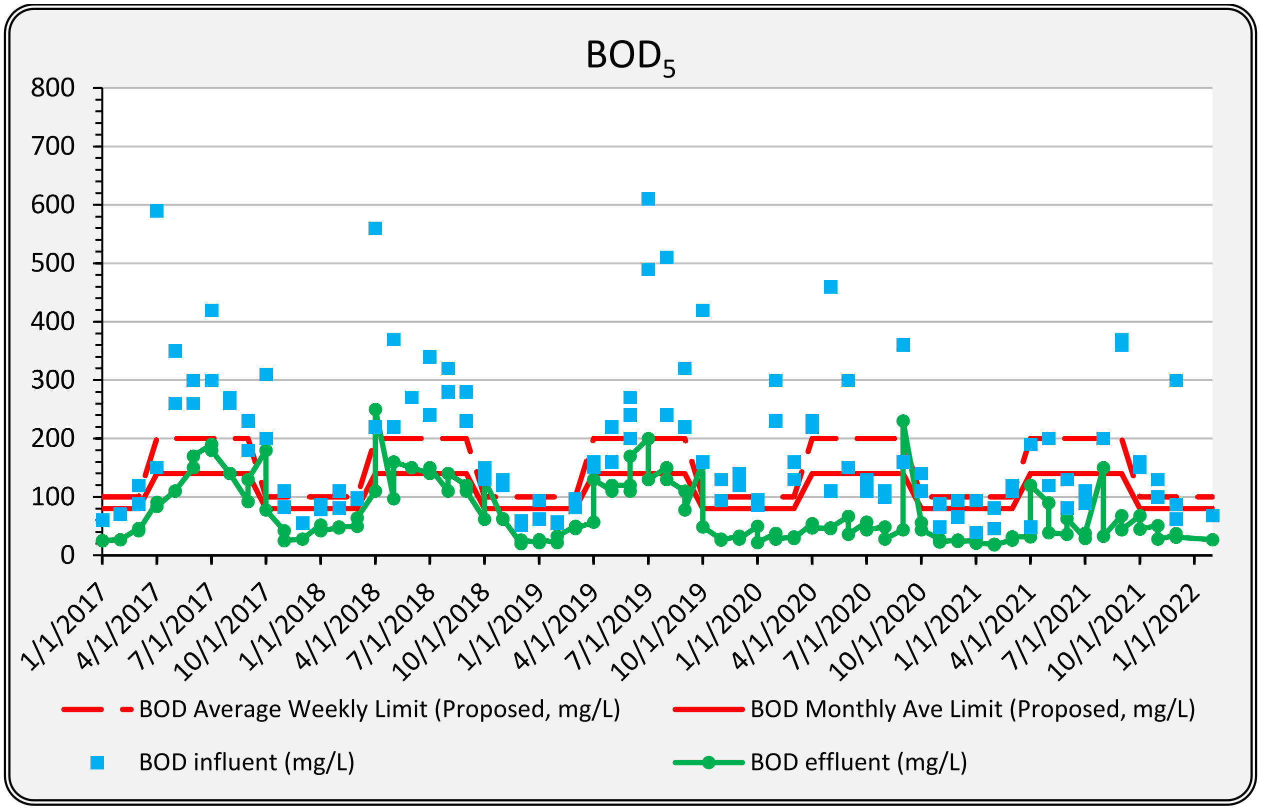

Figure 4. Monthly Influent and Effluent BOD5 Concentrations (2016-2021)

The facility achieved the minimum 30% removal requirement for BOD_5 with the lowest monthly removal being 30% in October 2018. Between 2016 and 2021, the facility achieved an average of 59% removal of BOD_5, with maximum percent removal efficiencies as high as 88%.

Table 2. Influent and Effluent BOD5 Data (2017-2022)

Statistic	Influent, BOD_5, mg/L	Effluent, BOD_5, mg/L (mo avg)	Effluent, BOD_5, mg/L (daily max)	Percent Removal
LIMIT (5/1 – 9/30)	---	140	200	≥30%
LIMIT (10/1-4/30)	---	80	100	≥30%
COUNT	57	57	57	--
MEAN	186	75	75	59%
MIN	56	19	19	13%
MAX	550	193	300	97%
STDV	112	50	66	0.164
CV	0.60	0.67	0.74	0.278
5th	59	23	25	35%
95th	377	181	232	86%

The applicant has demonstrated that it will be discharging effluent that has received at least primary treatment for BOD_5 when the 301(h)-modified permit becomes effective. [CWA section 301(h)(9) and 40 CFR 125.60].

B. Attainment of Water Quality Standards Related to TSS, BOD_5, and pH [CWA 301(h)(1); 40 CFR 125.61]

Under 40 CFR 125.61, which implements CWA section 301(h)(1), there must be WQS applicable to the pollutants for which the modification is requested, and the applicant must demonstrate that the proposed discharge will comply with these standards. The applicant has requested modified secondary treatment requirements for BOD_5, which affects dissolved oxygen (DO), TSS, which affects the color or turbidity in the receiving water, and pH. The State of Alaska has water quality standards for DO, turbidity, and pH.

1. Turbidity and Light Transmittance/Attenuation

Alaska WQS applicable to the estuarine waters of Taiya Inlet provide that turbidity shall not exceed 25 nephelometric turbidity units (NTU), may not interfere with disinfection, may not cause detrimental effect on established levels of water supply treatment, and may not reduce the depth of the compensation point for photosynthetic activity by more than 10%. In addition, turbidity may not reduce the maximum secchi disc depth by more than 10%. Alaska WQS for turbidity can be found in Appendix E.

The applicant collected turbidity data in Taiya Inlet in October 2002, July 2004, and August 2004. The applicant did not collect secchi dish depth data. EPA used the turbidity data to assess whether turbidity standards were met. Sampling was conducted at the surface, mid-depth, and bottom of the receiving water at the following sites:

Site 1: Center of ZID[3]
Site 2: East boundary of ZID
Site 3: 200 meters east of ZID boundary
Site 4: West boundary of ZID
Site 5: 200 meters west of ZID boundary

Sites 3 and 5 are considered reference sites, and sites 2 and 4 are ZID boundary sites. Monitoring results are presented in the tables below.

Table 3. Turbidity Levels (NTU) in Taiya Inlet

	(April – September) 5^{th} – 95^{th} percentile	**(October – March) 5^{th} – 95^{th} percentile**
Turbidity (Site 1, center of the ZID), NTU	0.16 – 25 (11 average)	9.1 – 11 (10.3 average)
Turbidity (Sites 2 and 4, ZID boundaries), NTU	0.2 – 20 (11 average)	10.0 – 13 (7.8 average)
Turbidity (Sites 3 and 5, reference stations), NTU	0.1 – 21 (11 average)	1.8 – 2.5 (2.2 average)
Source: 2002-2006 Taiya Inlet Data, Permit Application		

Average receiving water turbidity values at reference sites 3 and 5 were 11 NTU from April to September (summer) and 2.2 NTU from October to March (winter). Average values within ZID sites 2 and 4 were 11 NTU from April to September (summer) and 7.8 NTU from October to March (winter). The average receiving water turbidity value at the center of the ZID is 11 NTU from April to September (summer) and 10.3 NTU from October to March (winter). The maximum 95^{th} percentile value from April to September was 25 NTU at site 1. The maximum 95^{th} percentile value turbidity levels at the ZID boundary and reference sites are 20 NTU and 21 NTU, respectively.

[3] Note that the ZID is based on the current permit. The ZID in the current and proposed permits are the same distance from the diffuser. The ZID in the current permit applies radially at the center of the diffuser. The ZID in the proposed permit is a rectangular prism applying equal distances along the length of the diffuser. Samples collected within the ZID are expected to best represent impacts to the receiving water from the discharge.

Table 4. ZID Boundary Average Turbidity Monitoring (NTU)

Year	Site	Surface	Mid	Bottom
10/28/02	Site 2	0.70	0.72	0.70
	Site 4	0.60	0.72	0.60
7/19/04	Site 2	20.5	18.8	45.1
	Site 4	22.5	18.8	28.5
8/23/04	Site 2	2.4	0.20	0.4
	Site 4	1.5	0.30	1.4
Max		25.5	21	45.1
Min		0.5	0.5	0.7

Table 5. Reference Site Average Turbidity (NTU) Monitoring

Year	Site	Surface	Mid	Bottom
10/28/02	Site 5	0.65	0.65	1.00
7/19/04	Site 3	23.1	19.1	17.4
	Site 5	20.8	19.0	31.6
8/23/04	Site 3	2.55	0.13	0.20
	Site 5	2.32	1.45	3.30
Max	--	32.9	21.0	31.6
Min	--	0.2	0.50	1.0

EPA evaluated turbidity data collected in Taiya Inlet at the mid-level trapping depth during the two seasons for which the proposed TSS permit limits apply (May through September, and October through April). The permittee indicated in the Subpart G questionnaire that Taiya Inlet has elevated levels of sediment in the summer months due to freshwater and sediment inputs from Skagway River, and that studies in the Skagway River indicate high sediment levels. The 2002-2006 Taiya Inlet Data report reflects the seasonal difference in turbidity levels in Taiya Inlet.

From May to September, the 95th percentile turbidity at Site 1 in Taiya Inlet, closest to the discharge point, is 25 NTU, which meets Alaska's water quality criteria for turbidity of 25 NTU or less. Turbidity levels at the ZID boundary and reference sites are 20 NTU and 21 NTU, respectively. Therefore, the facility's TSS discharge is not expected to violate Alaska's water quality criteria for turbidity from May to September.

From October to April, the 95th percentile turbidity in Taiya Inlet is 11 NTU, which is significantly lower than Alaska's water quality criteria for turbidity. Turbidity levels at the ZID boundary and reference sites are 11 NTU and 2 NTU, respectively. Therefore, the facility's TSS discharge is not expected to violate Alaska's water quality criteria for turbidity from October to April.

The change in suspended solids in the water column is indirectly related to turbidity measurements. To further assess the potential for the discharge to cause or contribute to a violation of Alaska WQS for turbidity and light transmittance, EPA determined the maximum change in suspended solids concentration of TSS in the discharge at the edge of the ZID using formula B-32 from the 301(h) TSD. The results show a 2.4 mg/L increase in suspended solids in the receiving water after initial dilution, or 1.8%.

As discussed in the 301(h) TSD, an increase in TSS of less than 10% after initial dilution is not expected to have a substantial impact on water quality. Based on the above analyses, the proposed discharge is expected to comply with Alaska WQS for turbidity and light transmittance/attenuation. See Appendix E for the full equations.

2. Dissolved Oxygen

The effect of the effluent discharge on DO can occur in the nearshore and far-field as effluent mixes with the receiving water and the oxygen demand of the effluent BOD_5 load is exerted. Pursuant to 40 CFR 125.61(b)(1) and 125.62(a)(1), the applicant must demonstrate that the proposed discharge will comply with water quality criteria for DO and that the outfall and diffuser are located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed criteria at and beyond the ZID. Alaska WQS for DO applicable to the estuarine waters of Taiya Inlet provide that DO may not be less than 5.0 mg/L except where natural conditions cause this value to be depressed, and in no case may DO levels exceed 17 mg/L [18 AAC 70.15(a)(i)]. Alaska WQS for DO are shown in in Appendix D.

In accordance with the procedures outlined in the 301(h) TSD, Section B-11, p.188 and p. 194, EPA conducted a near-field and far-field analysis to estimate the impacts on DO levels in the vicinity of the discharge. Analysis of DO impacts can be found in Appendix E and is summarized below.

DO Concentration at the Edge of the ZID

Monitoring conducted by the permittee in Taiya Inlet from 2002-2005 demonstrates compliance with water quality standards. below shows DO values averaged by depth in Taiya Inlet. EPA evaluated the mid-depth values, since these correspond to DO at the trapping level depth of the discharge. DO concentrations in Taiya Inlet were higher than the 5.0 mg/L in three of four sampling events at all stations. In July 2004, DO values at the center of the ZID were below 5.0 mg/L, but reference DO values were also below 5.0 mg/L, which indicates that DO levels were naturally below DO water quality criteria.

Table 6. Average DO levels by depth (Taiya Inlet 2002-2005 Data)

Sampling Date	**Dissolved Oxygen mg/L**				**Depth**
	10/28/2002	**7/19/2004**	**8/23/2004**	**6/29/2005**	
Station 1 (center of ZID)	11	2.1	9.2	10	surface
	9.3	**1.4**	**8.9**	**7.0**	mid
	9.0	1.2	9.8	13	bottom
Station 2 (eastern ZID boundary)	10	6.4	12	12	surface
	8.1	**3.6**	**10**	**11**	mid
	7.7	3.1	10	11	bottom
Station 3 (200m east of ZID boundary)	no data	2.3	12	13	surface
	no data	**1.6**	**11**	**12**	mid
	no data	1.2	10	12	bottom
Station 4 (western ZID boundary)	12	3.4	9.4	13	surface
	9.5	**2.3**	**9.0**	**12**	mid
	9.3	1.7	9.2	12	bottom
Site 5 (200 m west of ZID boundary)	12	3.3	11	13	surface
	9.7	**2.5**	**10**	**12**	mid
	9.4	2.4	10	12	bottom

EPA also evaluated the near-field DO impacts, using 2002-2005 Taiya Inlet Data (Appendix B) and DMR data from 2016-2021. In accordance with the procedures outlined in the 301(h) TSD Sections B-11 and B-20, EPA conducted a near-field and far-field analysis to estimate the impacts on DO levels in the vicinity of the discharge. EPA used the equation at Figure 5 and the values at Table 7 to calculate near-field impacts from the discharge at the boundary of the ZID for the periods of time that data were collected in Taiya Inlet.

Figure 5. Near-Field Analysis Equation (301(h) TSD, Equation B-5)

$$DO_f = DO_a + \frac{DO_e - IDOD - DO_a}{S_a} \qquad \text{B-5}$$

where:

DO_f	=	Final dissolved oxygen concentration of receiving water at the plume trapping level, mg/L
DO_a	=	Affected ambient dissolved oxygen concentration immediately upcurrent of the diffuser averaged over the tidal period (12.5 hours) and from the diffuser port depth to the trapping level, mg/L
DO_e	=	Dissolved oxygen of effluent, mg/L
IDOD	=	Immediate dissolved oxygen demand, mg/L
S_a	=	Initial dilution (flux-averaged).

Table 7. Near-Field DO inputs and DO depletion results

	10/28/2002	7/19/2004	8/23/2004	6/29/2005	Comments
DO_a (mg/L)	9.3	1.4*	8.9	7.0	Station 1 in Taiya Inlet, 7/19/04, closest to the outfall, trapping mid-depth
DO_e (mg/L)	3.7	4.4	4.4	4.4	Winter season – 10/1 through 3/31- minimum effluent DO for 10/28/02; Summer season – 4/1 through 9/30 - minimum effluent DO for 7/19/04, 8/23/04, and 6/29/05
IDOD (mg/L)	5	5	5	5	Table B-3 in TSD, using travel time 0-100 minutes, and effluent of 200 mg/L
S_a	56	56	56	56	ZID dilution
DO_f (mg/L)	9.1	1.4	8.7	6.9	Calculated
Depleted DO (DO_a - DO_f)	0.19	0.036	0.17	0.14	Calculated
*This ambient DO result is considered an anomalous outlier and is not being used in the RPA. Additional ambient DO monitoring is proposed in the final permit.					

The near-field DO depletion ranges from 0.036 mg/L to 0.19 mg/L. For three of the four instances, the Alaska WQS of no less than 5 mg/L and no greater than 17 mg/L are not violated. In one instance on 7/19/2004, the ambient DO is 1.4 mg/L, and therefore the DO criteria would be violated. However, as explained earlier, EPA believes the low ambient DO to be naturally occurring due to similarly low DO values in the reference areas. Therefore, this instance does not constitute a violation of Alaska WQS.

The permittee evaluated far-field effects of the effluent BOD_5 using the simplified oxygen depletion model from the TSD. The evaluation is provided in permit application section 3.B.2.

The evaluation shows that the DO concentration at the edge of the ZID remains above the water quality criteria, when using an ambient DO concentration of 6.2 mg/L, which was the lowest DO observed at the time of the application.

EPA also evaluated the far-field effect of the effluent BOD_5. Using a simplified method from the 301(h) TSD, EPA calculated the BOD_5 at the edge of the ZID by multiplying the daily maximum limits for BOD_5 by 1.46 to calculate the ultimate carbonaceous BOD (CBOD) and dividing ultimate CBOD by the ZID dilution factor of 56.[4]

Using the BOD_5 maximum daily limit of 200 mg/L from April 1 through September 30, the ultimate CBOD is 292 mg/L. The BOD_5 at the edge of the ZID is 5.2 mg/L in the summer. Similarly, using the BOD_5 maximum daily limit of 100 mg/L from October 1 through March 31, the ultimate CBOD is 146 mg/L. The BOD_5 at the edge of the ZID is 2.6 mg/L in the winter.

Natural background levels of BOD_5 typically range from 2-3 mg/L (Communication Cope to Wu 2022). Therefore, BOD_5 levels at the edge of the ZID of 2.6 mg/L and 5.2 mg/L would be expected to have a negligible far-field effect on DO.

The final permit includes a minimum effluent limit for DO of 6.0 mg/L and a maximum effluent limit of 17 mg/L. The final permit proposes higher frequency of DO monitoring in the summer in Taiya Inlet to better characterize summer DO levels (See Table 3 of the final permit)

Based on the above analyses, the discharge will not cause or contribute to a violation of Alaska WQS for DO. The basis for this conclusion is summarized below:

- DO concentrations at the center of the ZID in Taiya Inlet in June, August and September are within the Alaska DO WQS of not less than 5.0 mg/L and no greater than 17 mg/L.
- DO concentrations in Taiya Inlet at the center of the ZID in July are less than 5.0 mg/L. However, DO concentrations in the reference areas are also less than 5.0 mg/L. EPA has concluded that low DO in Taiya Inlet are a result of naturally low dissolved oxygen. However, the proposed permit requires monitoring in Taiya Inlet, twice every five years in the summer to better assess DO levels in Taiya Inlet.
- Average minimum and maximum DO effluent concentrations are 8.2 mg/L and 11 mg/L, respectively. These are within the Alaska DO WQS of not less than 5.0 mg/L and no greater than 17 mg/L.
- Per the 301(h) TSD, the near-field DO depletion in Taiya Inlet from the discharge is less than or equal, when rounded, to 0.2 mg/L, ranging from 0.036 mg/L to 0.19 mg/L. The far-field impact is expected to be negligible, since estimated BOD_5 concentrations at the edge of the ZID are near natural levels.

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[4] EPA assumes that all BOD_5 is CBOD. This is a conservative assumption since BOD includes oxygen-demanding materials from CBOD and nitrogenous BOD.

Suspended Solids Accumulation

Impacts to DO concentrations resulting from the discharge of wastewater can also be assessed by examining the accumulation of suspended solids. 40 CFR 125.62 states that wastewater and particulates must be adequately dispersed following initial dilution so as not to adversely affect water use areas. The accumulation of suspended solids may lower DO in near-bottom waters and cause changes in the benthic communities. Accumulation of suspended solids in the vicinity of a discharge is influenced by the amount of solids discharged, the settling velocity distribution of the particles in the discharge, the plume height-of-rise, and current velocities. Hence, sedimentation of suspended solids is generally of little concern for small discharges into well-flushed receiving waters.

The questionnaire submitted by the applicant in 2006 states there are no known water quality issues associated with the accumulation of suspended solids from the discharge.

To evaluate the potential impact of solids sedimentation, a simplified approach for small dischargers that are not likely to have sediment accumulation related problems can be found in Figure B-2 of the 301(h) TSD. To use Figure B-2 of the 301(h) TSD to evaluate whether steady state solids accumulation will result in sufficient sediment accumulation to cause a 0.2 mg/L oxygen depression, the TSS mass emissions rate is needed, as well as plume height-of-rise. The mass emission or loading rate was calculated using the TSS concentration limit, facility design flow, and a conversion factor (Loading (lbs/day)) = 45 mg/L X 0.63 mgd X 8.34=225 lbs/day, or 102 kg/day). Plume height-of-rise was calculated to be 36 feet (11 meters) using the approach on page B-5 in the 301(h) TSD, which involves multiplying the water depth at the point of discharge (60 feet at MLLW) by 0.6. When a height-of-rise of 11 meters and a loading rate of 102 kg/day are input in Figure B-2, steady state accumulation is well below the line at which greater than 0.2 mg/L oxygen depression is expected. Per the 301(h) TSD, no further analysis is needed to demonstrate that accumulating solids will not result in unacceptable DO depressions.

Based on the above analyses of DO depletion and suspended solids accumulation, the proposed discharge is expected to comply with Alaska WQS for DO. For the complete equations used in this analysis refer to Appendix E.

In summary, EPA has concluded that the Alaska WQS for DO are not violated based on the following:

- DO concentrations at the center of the ZID in Taiya Inlet in June, August and September are within the Alaska DO WQS of not less than 5.0 mg/L and no greater than 17 mg/L.
- Average minimum and maximum DO effluent concentrations are 8.2 mg/L and 11 mg/L, respectively. These are within the Alaska DO WQS of not less than 5.0 mg/L and no greater than 17 mg/L.

- Per the 301(h) TSD, the near-field impact on DO in Taiya Inlet from the discharge is less than 0.2 mg/L, ranging from 0.036 mg/L to 0.19 mg/L. The far-field impact is expected to be negligible, because estimated BOD_5 concentrations at the edge of the ZID are near natural levels.

3. pH

The applicant requested a CWA Section 301(h) modification for pH to 6.0 to 9.0 s.u. The applicant's request for a 301(h) modification for pH does not apply since the request is the same as the secondary treatment requirements for pH of 6.0 to 9.0 s.u. The proposed discharge must still meet the WQS for pH. Alaska's WQS provide that pH may not be less than 6.5 or greater than 8.5 and may not vary more than 0.2 pH unit outside of the naturally occurring range. The effect of pH on the receiving water following initial dilution was estimated using Table 1. *Estimated pH Values After Initial Dilution* in the 301(h) TSD.

EPA reviewed DMR data for pH between 2016 and 2021. The facility met the pH limits in the 2002 permit 100% of the time. The maximum, minimum, and average pH values observed were 7.1, 6.5, and 7.9 s.u., respectively. This is within the range of 6.5 to 8.5, does not vary more than 0.2 pH units outside the naturally occurring range, and therefore meets Alaska WQS for pH.

Based on the above analysis, the proposed discharge is expected to comply with Alaska WQS for pH.

C. Attainment of Other Water Quality Standards and Impact Of the Discharge On Shellfish, Fish And Wildlife; Public Water Supplies; And Recreation [CWA Section 301(h)(2); 40 CFR 125.62]

CWA Section 301(h)(2) requires that the proposed discharge not interfere, either alone or in combination with other sources, with the attainment or maintenance of that water quality which assures protection of public water supplies and protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife, and allows recreational activities in and on the water. Pursuant to 40 CFR 125.62(a), the applicant's outfall and diffuser must be located and designed to provide adequate initial dilution, dispersion, and transport of wastewater such that the discharge does not exceed, at and beyond the ZID, all applicable EPA-approved state WQS and, where no such standards exist, EPA's CWA Section 304(a)(1) aquatic life criteria for acute and chronic toxicity and human health criteria for carcinogens and noncarcinogens, after initial mixing in the waters surrounding or adjacent to the outfall. In addition, 40 CFR 125.59(b)(1) prohibits issuance of a 301(h)-modified permit that would not assure compliance with all applicable NPDES requirements of 40 CFR Part 122; under these requirements a permit must ensure compliance with all WQS[5].

Attainment of water quality criteria for DO, turbidity, and pH was previously discussed. In accordance with 40 CFR 125.62(a), the applicant must also demonstrate that the proposed discharge will attain other WQS, including those for temperature, toxic pollutants, and bacteria.

EPA used Alaska WQS and the processes described in the 301(h) TSD and the 1991 *Technical Support Document for Water Quality-based Toxics Control* to determine whether the proposed discharge has the reasonable potential to cause or contribute to an excursion above Alaska WQS, to calculate WQBELs, and to assess compliance with CWA Section 301(h)(2) and 40 CFR 125.62.

To determine reasonable potential, EPA compares the maximum projected receiving water concentration at the ZID boundary to the water quality criterion for that pollutant. If the projected receiving water concentration exceeds the criterion, there is reasonable potential for that pollutant to cause or contribute to an excursion above Alaska WQS, and a WQBEL must be included in the permit. If a permittee is unable to meet their WQBEL, it would fail to satisfy CWA Section 301(h)(9) and 40 CFR 125.62 and would be ineligible for a CWA Section 301(h) modification.

Pursuant to 40 CFR 125.62(a)(1)(iv), EPA's evaluation of compliance with WQS must be based upon conditions reflecting periods of maximum stratification and during other periods when discharge characteristics, water quality, biological seasons, or oceanographic conditions indicate more critical situations may exist, commonly referred to as critical conditions.

1. pH

Alaska's WQS provide that pH may not be less than 6.5 or greater than 8.5 and may not vary more than 0.2 pH unit outside of the naturally occurring range.

The effect of pH on the receiving water following initial dilution was estimated using Table 1. *Estimated pH Values After Initial Dilution* in the 301(h) TSD and a reasonable potential spreadsheet.

EPA reviewed DMR data for pH between 2016 and 2021. The facility met the pH limits in the 2002 permit 100% of the time. The maximum and minimum pH values observed were 7.6 to 6.5, respectively. EPA used the chronic dilution factor and measured alkalinity, temperature, and pH data to calculate the minimum and maximum pH at the edge of the ZID and found that pH would be between 7.0 and 8.1 units. This is within the range of 6.5 to 8.5 and meets Alaska WQS for pH.

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[5] ADEC authorized acute and chronic dilution of 19:1 and 32:1, respectively, in its final 401 certification. Since these dilutions fall within the boundary of the ZID, these effluent limits also comply with CWA Section 301(h)(9) and 40 CFR 125.62.

The proposed discharge is expected to comply with Alaska WQS for pH after initial mixing at the edge of the ZID.

2. Ammonia

Marine ammonia criteria are based on a formula, which relies on the pH, temperature, and salinity of the receiving water, because the fraction of ammonia present as the toxic, un-ionized form increases with increasing pH and temperature and decreases with salinity. Therefore, the criteria become more stringent as pH and temperature increase and less stringent as salinity increases. Appendices F and G of the Alaska Water Quality Criteria Manual for Toxic and Other Deleterious Organic and Inorganic Substances include tables to determine acute and chronic criteria based upon these parameters.

EPA used temperature, salinity, and pH values from the receiving water from Table 2-5 of the facility's permit application ("2002-2005 Taiya Inlet Data") to determine ammonia criteria. No ammonia effluent data were collected from 2016 – 2021. Therefore, EPA used data when the permit was last issued in 2002. Based on 4 samples, a 95th percentile effluent concentration of 21.0 mg/L, and CV of 0.6 for the dataset, a reasonable potential calculation showed that the Skagway WWTP discharge would have reasonable potential to cause or contribute to an excursion of the water quality standard for ammonia.

EPA used temperature, salinity and pH values. The facility did not collect any ammonia effluent data during the last permit cycle. Therefore, the only data available to EPA was when the permit was last issued in 2002, over 20 years ago. While this 20-year old data indicates that the discharge might have reasonable potential to cause or contribute to an excursion of the ammonia water quality standard, EPA believes that the limited data set does not reflect the current discharge. Therefore, the final permit does not include a numeric effluent limit for ammonia. Instead, the final permit requires that the permittee monitor ammonia in effluent once per quarter and the receiving water for pH, temperature, and salinity to calculate applicable ammonia criteria and reasonable potential in the next permit cycle.

3. Temperature

Alaska's WQS for temperature provide that the discharge may not cause the temperature of the receiving water to exceed 15°C, and the discharge may not cause the weekly average temperature to increase more than 1°C. The maximum rate of change may not exceed 0.5°C per hour. Normal daily temperature cycles may not be altered in amplitude or frequency.

EPA reviewed surface water and DMR data between 2016 and 2021 to assess whether the modified discharge will comply with Alaska WQS for temperature. The maximum ocean temperature recorded at the trapping depth of the discharge during receiving water monitoring from 2016 to 2021 was 10.7°C, and the maximum recorded effluent temperature between 2016 and 2021 was 19°C. EPA conducted a mass balance analysis using these values and calculated a final receiving water temperature of 10.8°C after initial dilution. Based upon the above analysis the proposed discharge is expected to comply with Alaska WQS for temperature at the edge of the ZID.

4. Toxics

Alaska WQS for toxics for marine uses can be found in 18 AAC 70.020(b)(23) and the *Alaska Water Quality Criteria Manual for Toxics* (ADEC, 2008).

To assess whether the proposed discharge will comply with Alaska WQS for toxics after initial mixing, EPA reviewed DMR data collected between 2016 and 2021 and the results of the priority pollutant scan performed on the effluent.

Several metals were reported above their respective detection limits. Using this data along with DMR data for ammonia, EPA performed reasonable potential analyses using the numeric criteria in the *Alaska Water Quality Criteria Manual* (ADEC 2008) and the processes outlined in the *Technical Support Document for Water Quality-based Toxics Control* (USEPA 1991).

Lead, zinc, chloroform, toluene, phenol, bis (2-ethylhexyl phthalate) do not have reasonable potential to cause or contribute to a violation of Alaska WQS at the edge of the ZID, which is equivalent to the chronic mixing zone.

Chlorine and copper have reasonable potential to cause or contribute to a violation of Alaska WQS at the edge of the ZID. The previous permit had chlorine and copper limits. EPA is proposing more stringent permit limits for both pollutants. The effluent limits developed for chlorine and copper are protective of Alaska WQS, and the proposed discharge is expected to comply with Alaska WQS for toxics after initial mixing at the edge of the ZID.

5. Bacteria

Alaska's WQS for bacteria are found at 18 AAC 17.020(b)(14).

<u>*Fecal Coliform*</u>

Alaska's most restrictive marine criterion for fecal coliform bacteria concentrations is in areas protected for the harvesting and use of raw mollusks and other aquatic life. The WQS specifies that the geometric mean of samples shall not exceed 14 MPN/100 mL, and that not more than 10 percent of the samples shall exceed:

- 43 MPN/100 mL for a five-tube decimal dilution test;
- 49 MPN/100 mL for a three-tube decimal dilution test;
- 28 MPN/100 mL for a twelve-tube single dilution test;
- 31 CFU/100 mL for a membrane filtration test.

This standard must be met at the edge of the ZID.

On July 29, 2002, ADEC provided a final 401 certification that included a mixing zone defined as an arc of a circle with a 1600-meter radius, centered on the outfall going from one shoreline to the other extending on either side of the outfall line and over the diffuser, and extending from the marine bottom to the surface. In the 2002 permit, the number of fecal coliform bacteria in the primary treated effluent was not to exceed a 30-day average of 1.0 million FC per 100 mL and a daily limit of 1.5 million FC per 100 mL of sample. Outside this mixing zone, the fecal coliform concentrations were not to exceed a maximum of 14 FC/100 mL for a monthly average and 43 FC/100 mL for a daily maximum.

Skagway WWTP DMR data from the past 5 years shows FC values ranges from <100—870,000 FC/100mL, with a 95th percentile of 445,000 FC/100mL. Summary statistics of DMR data are provided in Table 8 below.

Table 8. FC DMR Summary Data 2016-2021

	# of samples	Min	Max	95th Percentile	Average
Fecal Coliform (FC/100mL)	**57**	**100**	**870,000**	**445,000**	**62,000**

CWA Section 301(h)(9) requires 301(h) discharges to meet WQS and federal CWA Section 304(a) criteria at the edge of the ZID. The current 1,600 m mixing zone for fecal coliform is inconsistent with the statutory or regulatory definition of a ZID: *the region of <u>initial mixing</u> surrounding or adjacent to the outfall.* ADEC will not reauthorize the 1,600 meter mixing zone for fecal coliform and the point of compliance for all bacteria limits is now the edge of the ZID. Consistent with CWA Section 301(h)(9) and 40 CFR 125.62, EPA used the 14:1 dilution achieved at the chronic mixing zone within the ZID to evaluate reasonable potential and assess compliance with CWA Section 301(h)(9) and 40 CFR 125.62.

Using effluent data from 2016 to 2021 and the same process and equations as those used for toxics, EPA conducted a reasonable potential analysis and determined fecal coliform has the reasonable potential to cause or contribute to a violation of Alaska WQS at the point of discharge.

The Alaska DEC included final fecal coliform limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit and has established interim fecal coliform limits based upon facility performance.

The interim and final effluent limits for fecal coliform will be protective of Alaska WQS after mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

Enterococcus Bacteria

Enterococci bacteria are indicator organisms of harmful pathogens recommended by the EPA to protect primary contact recreation for marine waters. In October 2000, Congress amended the Clean Water Act with the Beaches Environmental Assessment and Coastal Health Act (BEACH Act). The amendment required EPA to develop new or revised CWA criteria for pathogens and pathogen indicators. States and territories with coastal recreation waters were then required to adopt enterococci bacteria criteria into their WQS. EPA approved Alaska's WQS for enterococcus in 2017. The WQS at 18 AAC 70.020(b)(14)(B) for contact recreation specifies that the enterococci bacteria concentration shall not exceed 35 enterococci CFU/100mL, and not more than 10% of the samples may exceed a concentration of 130 enterococci CFU/100mL.

The 2002 permit does not contain an effluent limitation for enterococcus bacteria because there was no applicable enterococcus standard in effect when the permit was issued in August 2002.

40 CFR 122.44(d)(1) requires EPA to account for existing controls on discharges when determining whether a discharge has the reasonable potential to cause or contribute to an excursion of state WQS. The 2002 permit did not require enterococcus monitoring, but the high fecal coliform loads observed are also indicative of high loads of other pathogens commonly found in WWTP effluents, including enterococcus. With the available fecal coliform data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to a violation of Alaska WQS for enterococcus. With the available fecal coliform data and lack of disinfection capacity at the facility, EPA has determined there is reasonable potential for the discharge to cause or contribute to a violation of Alaska WQS for enterococcus.

The Alaska DEC included final enterococcus limitations as a condition of their certification of the permit under CWA Section 401 that come into effect five years after the effective date of the permit. The EPA has incorporated these final limits into the final permit.

The final effluent limits for enterococcus will be protective of Alaska WQS after mixing at the edge of the ZID and will satisfy the requirements of CWA Section 301(h)(9) and 40 CFR 125.63(a).

D. Impact of the Discharge on Public Water Supplies [40 CFR 125.62(b)]

40 CFR 125.62(b) requires that the applicant's proposed discharge must allow for the attainment or maintenance of water quality that assures protection of public water supplies and must not interfere with the use of planned or existing public water supplies. Skagway certified on June 30, 2023 that there are no existing or planned public water supply intakes in the vicinity of the discharge, and EPA concludes that the applicant's proposed discharge will have no effect on the protection of public water supplies and will not interfere with the use of planned or existing public water supplies.

E. Biological Impact of Discharge [40 CFR 125.62(c)]

40 CFR 125.62(c) requires that in addition to complying with applicable WQS, the proposed discharge must allow for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife. A BIP of shellfish, fish, and wildlife must exist immediately beyond the ZID and in all other areas beyond the ZID where marine life is actually or potentially affected by the applicant's discharge. In addition, conditions within or beyond the ZID must not cause or contribute to extreme adverse biological impacts, including, but not limited to, the destruction of distinctive habitats of limited distribution, the presence of disease epicenter, or the simulation of phytoplankton blooms which have adverse effects beyond the ZID, interfere with estuarine migratory pathways within the ZID, or result in the accumulation of toxic pollutants or pesticides at levels which exert adverse effects on the biota within the ZID.

In accordance with the guidance for small dischargers in the 301(h) TSD, EPA has considered the following characteristics of the Skagway discharge as indicators that there is a low potential for impact on the biota in the vicinity of the discharge: the location of the discharge is greater than 10m, the steady-state accumulation of suspended solids is less than 25 g/m^2, there are no distinctive habitats of limited distribution in the vicinity of the discharge, there is a low potential for impact on local fisheries, and less than 0.1% of the flow is from industrial users. Toxic conditions are not expected because the effluent achieves rapid mixing within minutes of discharge, minimizing the potential exposure area. There is no evidence that the ZID is a disease epicenter, interfering with estuarine migratory pathways, or resulting in the accumulation of toxics at levels exerting adverse effects on biota within the ZID.

Further, EPA also considered the results of biological monitoring from the 2002 permit and other available information to evaluate the potential for the discharge to cause or contribute to significant biological impacts. The 2002 permit required the facility to conduct biological monitoring, which consisted of a benthic survey and sediment analysis for total volatile solids (TVS) at the ZID boundary, within the ZID, and at two reference locations. Based on the results of the TVS analysis of sediment presented in Appendix F on Table 10, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID boundary and reference sites. Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the Skagway's WWTP discharge is causing significant changes in the benthic community structure.

Considering the above evidence, EPA has concluded that the discharge allows for the attainment or maintenance of water quality that assures the protection and propagation of a BIP of shellfish, fish, and wildlife.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit. For additional information refer to Part 8.G.3.

F. Impact of Discharge on Recreational Activities [40 CFR 125.62(d)]

Under 40 CFR 125.62(d), the applicant's discharge must allow for the attainment or maintenance of water quality that allows for recreational activities beyond the zone of initial dilution, including, without limitation, swimming, diving, boating, fishing, and picnicking, and sports activities along shorelines and beaches. There must be no Federal, State, or local restrictions on recreational activities within the vicinity of the applicant's outfall unless such restrictions are routinely imposed around sewage outfalls.

In its 2006 Questionnaire, the facility stated that no impacts on recreational activities were expected due to the proposed discharge. Sport fishing, boating, and beach combing activities occur on a small scale but are not common in Taiya Inlet due to the cold water temperatures, prevailing winds, climate, and steep glacial terrain. In its 2006 Questionnaire, the facility indicated that most recreational fishing occurs in Lynn Canal, south of Chilkoot Inlet, and that there are no significant commercial or recreational fisheries in the discharge vicinity. No adverse effects linked to Skagway's discharge have been reported. In 1982, a fish kill of eulachon occurred in the vicinity of the discharge. However, the permit application states that ADEC investigated the event and did not find that Skagway's discharge caused the fish kill.

The 2002 permit required signs to be placed on the shoreline near the 1600 meter mixing zone and the outfall line that state primary treated domestic wastewater is being discharged, mixing zones exist, and certain activities such as the harvesting of shellfish for raw consumption and bathing should not take place within the mixing zone. EPA has retained the requirement to place these signs on the shoreline at the outfall line in the final permit until the final fecal coliform and enterococcus limits are maintained.

The applicant has demonstrated that proposed discharge meets the requirements to allow for the attainment or maintenance of water quality which allows for recreational activities beyond the ZID.

G. Establishment of Monitoring Programs [CWA 301(h)(3), 40 CFR 125.63]

Under 40 CFR 125.63, which implements Section 301(h)(3) of the Act, the applicant must have a monitoring program designed to provide data to evaluate the impact of the proposed discharge on the marine biota, demonstrate compliance with applicable WQS, and measure toxic substances in the discharge. The applicant must demonstrate the capability to implement these programs upon issuance of a 301(h)-modified NPDES permit. In accordance with 40 CFR 125.63(a)(2), the applicant's monitoring programs are subject to revision as may be required by EPA.

1. Influent/Effluent Monitoring Program

40 CFR 125.63(d) requires an effluent monitoring program and the applicant proposes continuation of the current monitoring program. In addition to the 301(h) specific monitoring

requirements, Section 308 of the CWA and federal regulation 40 CFR 122.44(i) require monitoring in permits to determine compliance with effluent limitations. Monitoring may also be required to gather effluent and surface water data to determine if additional effluent limitations are required and/or to monitor effluent impacts on receiving water quality. Throughout the previous permit term (and the administratively continued period), the applicant faithfully submitted effluent monitoring data to the EPA as required by the 2002 permit.

Parameters for which effluent monitoring were required in the 2002 permit include:

- Flow[1]
- BOD_5 [1]
- TSS[1]
- FC
- Ammonia
- pH
- Temperature
- Dissolved oxygen
- Total Residual Chlorine
- Total Copper
- Chronic Whole Effluent Toxicity
- Toxic Pollutants and Pesticides

[1]Influent monitoring also required

Summary statistics of the effluent data submitted by the permittee between 2016 and 2021 is presented in Appendix C.

The final permit retains largely the same effluent and influent monitoring requirements and includes new requirements to monitor the effluent for enterococcus, ammonia, and per- and polyfluoroalkyl substances (PFAS). Consistent with 40 CFR 125.66, the final permit also includes a new requirement for the permittee to perform a whole effluent toxicity analysis of their effluent twice per year annually during the term of the new permit, once during the wet season and once during the dry season.

2. Receiving Water Quality Monitoring Program

40 CFR 125.63(c) requires that the receiving water quality monitoring program must provide data adequate to evaluate compliance with applicable WQS. The applicant proposes continuation of the current receiving water monitoring program. As in the case of effluent monitoring, NPDES permits include receiving water monitoring requirements to allow for compliance assessment, and to determine if additional effluent limitations and/or monitoring requirements are necessary in future permitting actions.

EPA is retaining most of the receiving water monitoring program from the 2002 permit in the final permit. Changes to the receiving water monitoring program include the addition of enterococcus to the suite of parameters analyzed and the movement of the ZID boundary sites from the edge of the 2002 mixing zone at 1,600 meter to the edge of the ZID in the final permit. The ZID dimension calculations are 138 feet in width and 162 feet in length centered around the diffuser. Sampling at the edge of the 1,600 meter mixing zone is no longer required because the 1,600 meter mixing zone is not being reauthorized by ADEC and the point of compliance for all parameters is now the edge of the ZID.

In addition, the EPA has determined that once the facility is able to consistently achieve compliance with the final fecal coliform and enterococcus limits in the permit and has demonstrated ongoing compliance with Alaska WQS at the boundary of the ZID, continued sampling for bacteria in the receiving water is no longer warranted to satisfy the requirements of 40 CFR 125.62(a). By achieving compliance with the final fecal coliform and enterococcus limits the EPA expects that the facility will be able to meet Alaska's WQS for fecal coliform and enterococcus at the edge of the ZID after initial mixing. For additional information refer to the final permit.

3. Biological Monitoring Program

40 CFR 125.63(b) requires a permittee to implement a biological monitoring program that provides data adequate to evaluate the impact of the applicant's discharge on the marine biota. Such a program should, at a minimum, allow for evaluation of any ecosystem impacts; any changes in the amount of organic material in the seafloor sediment; any changes to benthic communities; and the effectiveness/bases for permit conditions.

The Biological Monitoring Program in the 2002 permit consisted of a benthic survey and sediment analysis for TVS at the ZID boundary, within the ZID, and at two reference locations. Based on the results of the TVS analysis of sediment, it does not appear that excess organic sediment is accumulating around the outfall as compared to stations at the ZID Boundary and reference sites. Based on visual observations of the benthic infauna collected in sediment samples, it does not appear that the Skagway WWTP's outfall discharge is causing significant changes in the benthic community structure.

The Biological Monitoring Program from the 2002 permit is being largely retained in the final permit with the exception of the TVS component, which has been removed from the permit.

The 301(h) regulations at 40 CFR 125.63(b)(2) provides that small 301(h) applicants are not subject to sediment analysis requirements if they discharge at depths greater than 10 meters and can demonstrate through a suspended solids deposition analysis that there will be negligible seabed accumulation in the vicinity of the modified discharge. The Skagway WWTP discharges at depths greater than 10 meters (i.e., ~18 meters for Skagway) and the suspended solids deposition analysis provided below demonstrates there will be negligible seabed accumulation in the vicinity of the discharge.

Figure B-2 in Appendix B of the 1994 Amended Section 301(h) Technical Support Document provides a simplified graphical method for small estuarine dischargers to assess the potential for suspended solids deposition around their outfall using the reported daily solids mass emission rate (y-axis in Fig. B-2) and the height-of-rise of the discharge (x-axis in Fig. B-2). For the discharge height-of-rise, also known as the plume trapping depth, the height-of-rise from dilution modeling should be used, or 0.6 times the water depth, whichever is larger. The height-of-rise for the Skagway discharge is approximately 11 meters (~36 feet) and 60% of the discharge depth is the same (0.6 x 18m=~11m), so 11 meters was selected for the x-axis in Figure B-2.

The guidance recommends calculating the suspended solids daily mass emission rate using the average flow rate and an average suspended solids concentration. The reported monthly average flow rate from the Skagway WWTP between 2016 and 2021 was approximately 0.26 million gallons per day and the monthly average TSS concentration was 31.6 mg/L. To determine the daily loading of solids the monthly average concentration of TSS was multiplied by the reported average monthly flow and the loading conversion factor of 8.34 (see Footnote 1 in Table 1 of the final permit for more information on mass loading calculations).

31.6 mg/L X 0.26 million gallons per day X 8.34=68.5 lbs/day.

Using this loading rate along the y-axis and 36 feet (11m) along the x-axis in Figure B-2, the projected steady state sediment accumulation is expected to be well below 25g/m2. The EPA considers this to be a negligible accumulation of sediment. Therefore, the applicant has satisfied the requirement of 40 CFR 125.63(b)(2) and the EPA has removed the requirement to conduct a sediment TVS analysis from the final permit.

In addition, the proposed permit is requiring a larger number of locations to be sampled. See Section IV.B.3 of the Fact Sheet.

H. Effect of Discharge on Other Point and Nonpoint Sources [CWA Section 301(h)(4), 40 CFR 125.64]

Under 40 CFR Part 125.64, which implements Section 301(h)(4) of the Act, the applicant's proposed discharge must not result in the imposition of additional treatment requirements on any other point or nonpoint source. The applicant reports that the proposed discharge would not place any additional treatment requirements on point or nonpoint sources. Pursuant to 40 CFR Part 125.64(b), the applicant is required to submit a determination signed by the State of Alaska indicating whether the applicant’s discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The State determination must include a discussion of the basis for its conclusion.

ADEC provided the determination required under 40 CFR Part 125.64 in their final 401 certification. For additional information refer to Part M – State Determination and Concurrence.

I. Urban Area Pretreatment Program [CWA 301(h)(6), 40 CFR 125.65]

Under 40 CFR Part 125.65, dischargers serving a population greater than 50,000 are required to have a pretreatment program. As previously discussed, the Skagway WWTP serves a population of approximately 850 people, so this provision in not applicable to this analysis. Although the tourism population from April through October in 2019 was approximately 980,000 from cruise ships, Skagway WWTP does not directly serve this population. ADEC regulates cruise ships under a permit, which requires them to treat their wastewater before discharging. The permit for large cruise ships includes numeric limits for fecal coliform, chlorine, pH, BOD, and TSS, which are lower than corresponding limits in the proposed Skagway WWTP permit. The permit for large cruise ships allows them to discharge at multiple locations, so it is unclear if and how much they discharge to Taiya Inlet. More information is available at https://dec.alaska.gov/water/cruise-ships.

J. Industrial and Nonindustrial Sources and Toxics Control [CWA Section 301(h)(7), 40 CFR Part 125.66]

1. Chemical Analysis and Toxic Pollutant Source Identification [40 CFR 125.66(a) and (b)]

Under 40 CFR 125.66(a), applicants are required to perform chemical testing for toxic pollutants and pesticides.

The 2002 permit required an industrial user survey and toxic chemical analyses of the effluent be submitted with the permit reapplication. As previously discussed, the permittee conducted one toxics pollutant scan in 2006, the results of which EPA used in development of the final permit. In its 2006 permit application, the applicant included an unsigned certification that there no known industrial inputs into the treatment system, and the application restates that there are no industrial users and no known sources of industrial toxic pollutants or pesticides that discharge into Skagway WWTP. Absent any industrial users, the likely sources of toxics are unknown. EPA's analysis showed reasonable potential for copper and chlorine to exceed effluent limits. EPA is proposing numeric limits for copper and chlorine that will meet Alaska WQS.

Pursuant to 40 CFR 125.66, the final permit requires an updated toxics and pesticides scan and industrial user survey be provided at the time of permit reapplication. The final permit also requires whole effluent toxicity twice a year throughout the permit term.

2. Industrial Pretreatment Program [40 CFR 125.66(c)]

40 CFR 125.66(c) requires that applicants that have known or suspected industrial sources of toxic pollutants shall have an approved pretreatment program in accordance with the requirements of 40 CFR Part 403 (Pretreatment Regulations). This requirement shall not apply to any applicant which has no known or suspected industrial sources of toxic pollutants or pesticides and so certifies to EPA. Because the facility certified on June 29, 2023 that there are

no known industrial sources of toxic pollutants, under 40 CFR 125.66(c)(2), the facility is not required to have an approved pretreatment program.

Pursuant to 40 CFR 126.66, the final permit requires an updated industrial user survey be submitted at the time of permit reapplication.

3. Nonindustrial Source Control Program [40 CFR 125.66(d)]

40 CFR 125.66(d), which implements Section 301(h)(6) of the Act, requires the applicant to submit a proposed public education program designed to minimize the entrance of non-industrial toxic pollutants and pesticides into its POTW. The applicant must also develop and implement additional nonindustrial source control programs on the earliest possible schedule. The requirement to develop and implement additional nonindustrial source control programs does not apply to a small Section 301(h) applicant that certifies there are no known or suspected water quality, sediment accumulation, or biological problems related to toxic pollutants or pesticides in its discharge.

In the permit application, Skagway indicated that it is an active participant in the Southeast Conference Annual Household Hazardous Waste Collection and Disposal events. The application also included a household hazardous waste mailer sent to Skagway residents and businesses. These meet the requirements of 40 CFR 125.66(d)(1). The Skagway WWTP also indicated that it has implemented a program for restaurants to prevent fats, oil, and grease (FOG), which requires grease traps with annual inspections and maintenance schedules. Skagway has satisfied the requirements for nonindustrial source control.

K. Effluent Volume and Amount of Pollutants Discharged [40 CFR 125.67]

Under 40 CFR 125.67, which implements Section 301(h)(7) of the Act, the applicant's proposed discharge may not result in any new or substantially increased discharges of the pollutant to which the modification applies above the discharge specified in the 301(h)-modified permit. The applicant has applied on the basis of the current discharge and is not being granted any new or substantially increased discharges of TSS, BOD_5, and pH, the parameters for which the facility has requested a waiver.

L. Compliance With Other Applicable Laws [40 CFR 125.59]

Under 40 CFR 125.59(b)(3), a 301(h)-modified permit may not be issued if such issuance would conflict with applicable provisions of state, local, or other federal laws or executive orders. As part of the application renewal, the applicant must demonstrate compliance with all applicable Alaska and federal laws and regulations, and executive orders, including the Coastal Zone Management Act, Marine Protection Research and Sanctuaries Act, the Endangered Species Act, and the Magnuson-Stevens Fishery Conservation and Management Act.

1. Coastal Zone Management Act

Alaska withdrew from the voluntary National Coastal Zone Management Program on July 1, 2011 (NOAA 2019c); therefore, this requirement is not applicable.

2. Marine Protection, Research, and Sanctuaries Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with Title III of the Marine Protection, Research, and Sanctuaries Act (MPRSA), 16 USC 1431 *et seq.*, which authorizes the Secretary of Commerce (i.e., NOAA) to designate and protect areas of the marine environment with special national significance due to their conservation, recreational, ecological, historical, scientific, cultural, archeological, educational or esthetic qualities as national marine sanctuaries. In the U.S., there are 14 national marine sanctuaries and two marine national monuments, none of which are in Alaska (NOAA 2019d).

The final permit is therefore expected to comply with Title III of the MPRSA.

3. Endangered Species Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with the Endangered Species Act (ESA), 16 USC 1531 *et seq.* The ESA requires federal agencies to consult with the National Marine Fisheries Service (NMFS) and/or the U.S. Fish and Wildlife Service (USFWS) (collectively, “the Services”) if any activity proposed to be permitted, funded, or undertaken could beneficially or adversely affect any threatened or endangered species (ESA-listed species) or such species designated critical habitat.

Pursuant to ESA Section 7, on August 30, 2024, the EPA requested concurrence from the NMFS that renewal of the 301(h)-modified NPDES permit to the Skagway WWTP is not likely to adversely affect the following threatened, endangered, or candidate species or their designated critical habitats:

- Western Distinct Population Segment (Western DPS or WDPS) Steller sea lions, and
- Mexico DPS humpback whales
- Sunflower sea star

On October 15, 2024, the NMFS concurred with EPA’s determination that renewal of AK0020010 is not likely to adversely affect any ESA-listed species or designated critical habits under their jurisdiction.

No ESA-listed species or designated critical habitat under the jurisdiction of USFWS were identified.

4. Magnuson-Stevens Fishery Conservation and Management Act

Under 40 CFR 125.59(b)(3), no section 301(h) modified permit shall be issued if such issuance would conflict with the Magnuson-Stevens Fishery Conservation and Management Act

(MSFCMA), 16 USC 1801 *et seq*., which protects against adverse impacts to Essential Fish Habitat (EFH). The MSFCMA requires federal agencies to consult with NMFS when any activity proposed to be permitted, funded, or undertaken by a federal agency may have an adverse effect on designated EFH as defined by the MSFCMA. The EFH regulations define an *adverse effect* as any impact that reduces quality and/or quantity of EFH and may include direct (e.g. contamination or physical disruption), indirect (e.g. loss of prey, reduction in species' fecundity), site-specific, or habitat-wide impacts, including individual, cumulative, or synergistic consequences of actions.

EPA has prepared an EFH Assessment and determined that renewal of AK0020010 will not have an adverse effect on EFH for any managed species.

M. State Determination and Concurrence [40 CFR 125.61(b)(2); 40 CFR 125.64(b)]

Under 40 CFR 125.61(b)(2) the applicant must provide a determination signed by the state or interstate agency(s) authorized to provide certification under 40 CFR 124.53 and 124.54 that the proposed discharge will comply with applicable provisions of state law, including WQS. This determination must include a discussion of the basis for the conclusion reached. Furthermore, pursuant to 40 CFR 124.53 and 124.54, the state must either grant a certification pursuant to Section 401 of the CWA or waive this certification before EPA may issue a 301(h)-modified permit. The applicant did not provide this certification at the time of application.

40 CFR 125.64(b) requires applicants to provide a determination from the state or interstate agency(s) having authority to establish wasteload allocations indicating whether the applicant's discharge will result in an additional treatment pollution control, or other requirement on any other point or nonpoint sources. The state determination shall include a discussion of the basis for its conclusion. The applicant did not submit this determination with their application.

The EPA requested that ADEC provide final 401 certification and the determinations under 40 CFR 125.61(b)(2) and 125.64(b) during the public notice period of the draft permit and tentative 301(h) decision. ADEC provided final 401 certification and the requested determinations on May 14, 2024.

9) REFERENCES

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E-mail from Andy Miles, Skagway WWTP, to Jennifer Wu, EPA Region 10 re: [External Email] Skagway NPDES permit check-ins. January 4, 2022.

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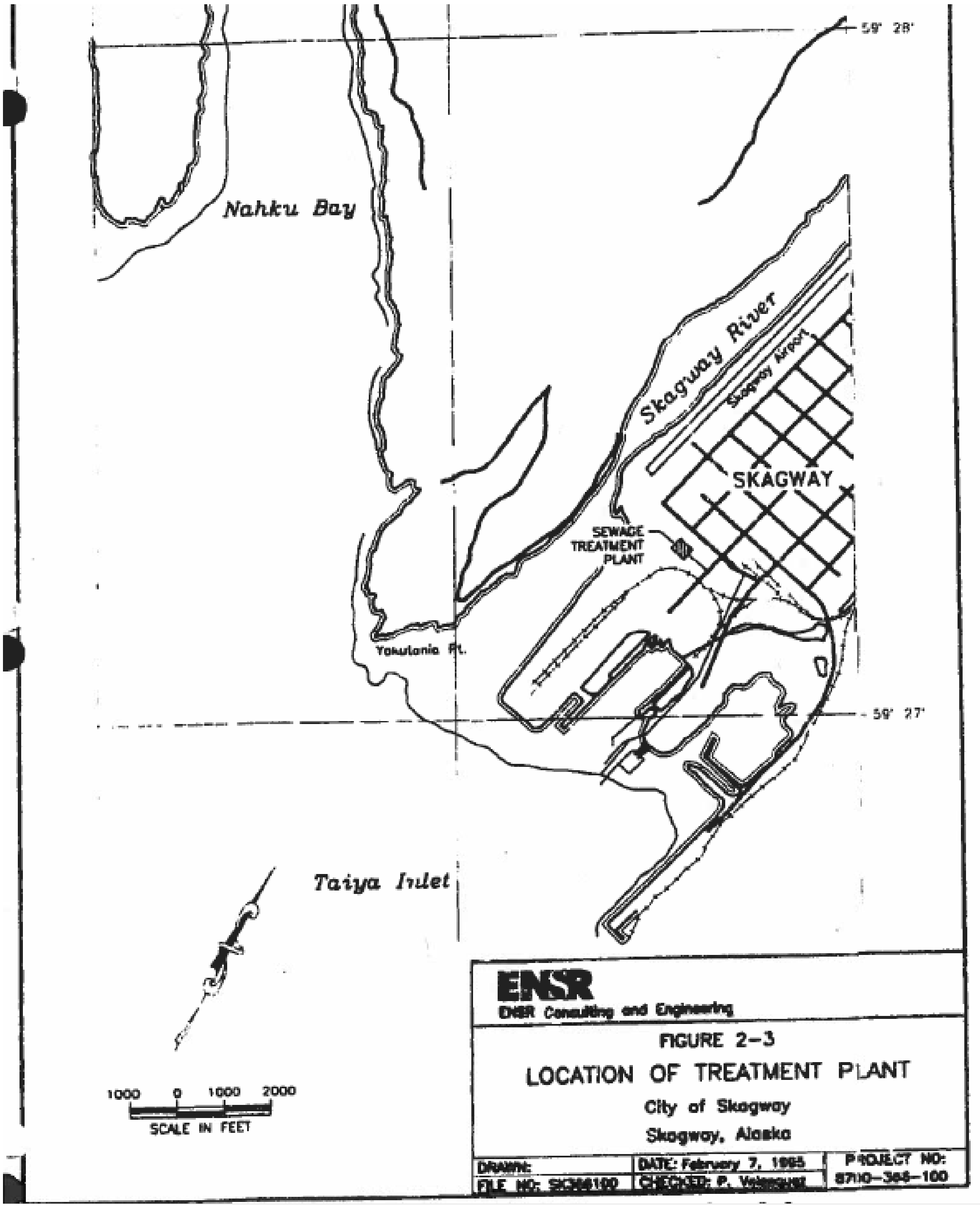
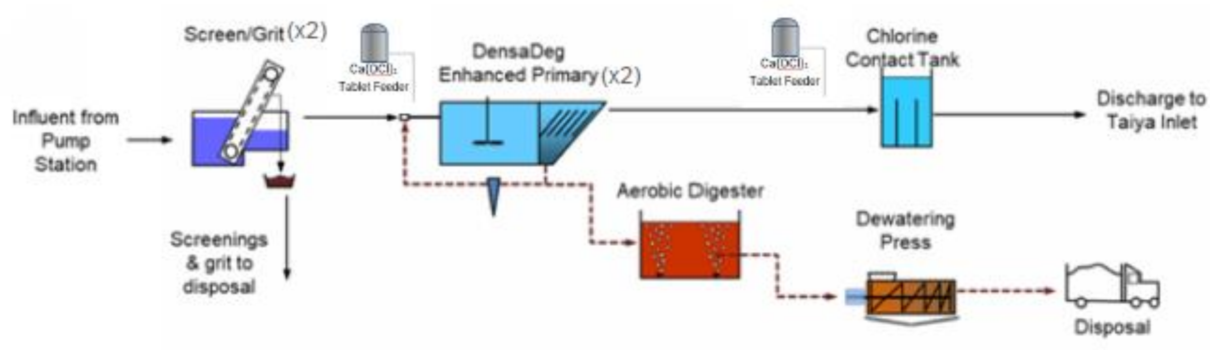
Appendices

A. Facility and Outfall Locations



B. Facility Figures and Process Flow Diagram



C. Summary Statistics of Discharge Monitoring Data (2016-2021)

The water quality data are from discharge monitoring reports (DMRs) from December 2016 to September 2021, data from the Skagway WWTP transmitted February 8, 2022, and the permit application.

Treatment Plant Effluent Data, DMR: BOD

	Raw Sewage Influent	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal
	BOD, 5-day, 20 deg.	**BOD, 5-day, 20 de**	**BOD, 5-day, 20 de**	**BOD, 5-day, 20**	**BOD, 5-day, 20**	**BOD, 5-day, perce**
	Milligrams per Liter	Milligrams per Liter	Milligrams per Liter	Pounds per Day	Pounds per Day	Percent
	MO AVG	DAILY MX	MO AVG	DAILY MX	MO AVG	MN % RMV
LIMIT (5/1-9/30)		**200**	**140**	**1050**	**740**	
LIMIT (10/1-4/30)	**No Limit**	**100**	**80**	**530**	**420**	**30%**
Date	Raw Sewage InfluentB	Effluent GrossBOD,	Effluent GrossBOD	Effluent GrossB	Effluent GrossBC	Percent RemovalBC
12/31/2016	71	32	28	79	69	61
01/31/2017	61	25	25	62	62	59
02/28/2017	89.8	27	27	66	66	81
03/31/2017	104	46	44	95	91	58
04/30/2017	370	91	87.5	155	149	76
05/31/2017	305	110	110	279	279	64
06/30/2017	280	170	160	494	465	43
07/31/2017	360	190	185	526	512	48
08/31/2017	303.33	300	193.33	776	500	38
09/30/2017	205	130	111	358	306	44
10/31/2017	255	180	129	372	267	52
11/30/2017	96.5	42	33.5	78	62	66
12/31/2017	59	37	32.5	77	67	45
01/31/2018	83	52	47	104	94	43
02/28/2018	95.5	49	48	107	105	50
03/31/2018	97	64	57	134	119	41
04/30/2018	390	250	180	541	390	53
05/31/2018	295	160	128.5	400	322	57
06/30/2018	255	150	130	398	345	49
07/31/2018	290	150	145	390	377	49
08/31/2018	300	140	125	375	330	59
09/30/2018	255	120	115	280	247	55
10/31/2018	140	130	96	108	192	30
11/30/2018	125	63	62.5	116	118	50
12/31/2018	56	26	23	43	48	58
01/31/2019	78	27	24.5	72	53	68
02/28/2019	57	33	28	65	55	52
03/31/2019	89.5	50	48	89	93	46
04/30/2019	155	130	93.5	290	197	39
05/31/2019	190	120	115	338	288	38
06/30/2019	235	170	145	489	421	39
07/31/2019	550	200	165	512	432	70
08/31/2019	375	150	140	395	401	57
09/30/2019	270	110	94	272	241	66
10/31/2019	300	160	91	268	174	70
11/30/2019	112	28	27	64	48	76
12/31/2019	130	33	31	76	58	76

Treatment Plant Effluent Data, DMR: BOD (cont.)

	Raw Sewage Influent	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal
	BOD, 5-day, 20 deg.	**BOD, 5-day, 20 de**	**BOD, 5-day, 20 de**	**BOD, 5-day, 20**	**BOD, 5-day, 20 (**	**BOD, 5-day, perce**
	Milligrams per Liter	Milligrams per Liter	Milligrams per Liter	Pounds per Day	Pounds per Day	Percent
	MO AVG	DAILY MX	MO AVG	DAILY MX	MO AVG	MN % RMV
LIMIT (5/1-9/30)		**200**	**140**	**1050**	**740**	
LIMIT (10/1-4/30)	**No Limit**	**100**	**80**	**530**	**420**	**30%**
Date	Raw Sewage InfluentB	Effluent GrossBOD,	Effluent GrossBOD	Effluent GrossB	Effluent GrossBC	Percent RemovalBC
01/31/2020	91	50	36	99	89	63
02/29/2020	265	38	33	89	66	88
03/31/2020	145	32	31	67	56	79
04/30/2020	225	54	51	84	91	78
05/31/2020	285	47	47	88	78	74
06/30/2020	225	67	52	118	97	77
07/31/2020	120	57	51	109	95	57
08/31/2020	105	49	39	103	72	64
09/30/2020	260	230	137	475	218	55
10/31/2020	125	56	50	107	64	59
11/30/2020	69	28	26	67	44	59
12/31/2020	80	26	25	198	78	68
01/31/2021	67	25	23	76	43	60
02/28/2021	64	19	19	66	47	69
03/31/2021	115	32	29	91	56	75
04/30/2021	170	120	78	292	122	
05/31/2021	160	90	65	194	99	
06/30/2021	106	63	50	158	100	
07/31/2021	100	38	33.5	80	65	
08/31/2021						
09/30/2021	365	68	56	118	94	
10/31/2021						
Date						
4/1 - 9/30						
COUNT	29	29	29	29	29	24
MEAN	259	128	106	313	253	56.2
MIN	100	38	33.5	80	65	38
MAX	550	300	193	776	512	78
STDV	102	64.6	47.6	176	145	12.8
CV	0.393	0.503	0.448	0.560	0.575	0.229
5th	105	47.8	42.2	85.6	74.4	38.2
95th	384	242	183	535	486	76.9
99th	505	286	191	710	509	77.8
Date						
10/1 - 3/30						
COUNT	28	28	28	28	28	28
MEAN	111	50.4	41.9	105	85.1	60.8
MIN	56	19	19	43	43	30
MAX	300	180	129	372	267	88
STDV	62.8	40.0	25.5	68.9	51.0	13.6
CV	0.563	0.794	0.609	0.657	0.599	0.223
5th	57.7	25	23	62.7	45.1	41.7
95th	262	150	94.3	244	186	80.3
99th	291	175	120	344	247	86.1

Treatment Plant Effluent Data, DMR: TSS

	Solids, total suspende	Solids, total suspe	Solids, total susp	Solids, total sus	Solids, total sus	Solids, suspended
	Milligrams per Liter	Milligrams per Liter	Milligrams per Lite	Pounds per Day	Pounds per Day	Percent
	MO AVG	DAILY MX	MO AVG	DAILY MX	MO AVG	MN % RMV
LIMIT (5/1-9/30)		**200**	**140**	**1050**	**740**	
LIMIT (10/1-4/30)	**No Limit**	**88**	**70**	**460**	**370**	**30%**
Date	Raw Sewage InfluentSol	Effluent GrossSolids	Effluent GrossSolid	Effluent GrossSo	Effluent GrossSo	Percent RemovalSo
12/31/2016	62	19	17.5	47	43	72
01/31/2017	45	16	16	40	40	64
02/28/2017	47.5	21	18	51	44	82
03/31/2017	79	21	18	44	37	77
04/30/2017	111.5	51	42	87	71	62
05/31/2017	325	62	57	157	144	82
06/30/2017	127	110	66.5	320	193	48
07/31/2017	285	112	106	310	294	56
08/31/2017	298	132	93.67	341	242	61
09/30/2017	129	38	33	105	91	74
10/31/2017	116.5	24	19	50	39	83
11/30/2017	200	14	11	26	20	93
12/31/2017	51.5	21	20.5	43	42	58
01/31/2018	69.5	26	24	67	62	66
02/28/2018	58	24	21	53	46	64
03/31/2018	50.5	25	22.5	52	47	56
04/30/2018	73	21	20.5	45	44	72
05/31/2018	346.5	56	44.5	140	111	76
06/30/2018	185	60	52	159	138	61
07/31/2018	119	86	72	223	187	38
08/31/2018	226.5	80	70	214	185	68
09/30/2018	385	52	48	121	103	87
10/31/2018	614	36	32	102	64	95
11/30/2018	110	13	11.1	24	21	90
12/31/2018	53	11	9	26	19	85
01/31/2019	38	13	12.5	35	27	66
02/28/2019	55	18	16	35	32	70
03/31/2019	50.5	19	28.6	34	55	71
04/30/2019	89	26	19.5	58	41	74
05/31/2019	106	60	50.5	169	126	53
06/30/2019	103	73	68.5	210	199	33
07/31/2019	406.5	105	89.5	269	234	78
08/31/2019	260	80	77	211	221	66
09/30/2019	217	56	44	139	113	80
10/31/2019	250	33	27	48	51	89
11/30/2019	130	17	14	35	25	89
12/31/2019	107	13	12	30	22	89

Treatment Plant Effluent Data: TSS (cont.)

	Raw Sewage Influent	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Percent Removal
	Solids, total suspende	**Solids, total suspe**	**Solids, total susp**	**Solids, total sus**	**Solids, total sus**	**Solids, suspended**
	Milligrams per Liter	Milligrams per Liter	Milligrams per Lite	Pounds per Day	Pounds per Day	Percent
	MO AVG	DAILY MX	MO AVG	DAILY MX	MO AVG	MN % RMV
LIMIT (5/1-9/30)		**200**	**140**	**1050**	**740**	
LIMIT (10/1-4/30)	**No Limit**	**88**	**70**	**460**	**370**	**30%**
Date	Raw Sewage InfluentSol	Effluent GrossSolids	Effluent GrossSoli	Effluent GrossSo	Effluent GrossSo	Percent RemovalSo
01/31/2020	92	22	21	43	52	77
02/29/2020	426	20	19	47	38	96
03/31/2020	172	18	15	38	27	92
04/30/2020	180	23	21	30	38	88
05/31/2020	258	20	19	32	32	90
06/30/2020	214	17	29	71	54	87
07/31/2020	153	30	26	57	48	82
08/31/2020	155	22	16	46	30	86
09/30/2020	149	40	31	83	49	80
10/31/2020	118	30	21	57	27	80
11/30/2020	116	16	16	38	27	86
12/31/2020	145	18	14	137	44	90
01/31/2021	77	15	14	46	26	80
02/28/2021	70	24	17	59	42	72
03/31/2021	158	16	14	45	27	91
04/30/2021	582	40	33	97	52	90
05/31/2021	269	37	27	80	41	77
06/30/2021	77	14	14	35	28	81
07/31/2021	122	14	12	29	23	90
08/31/2021						
09/30/2021	605	18	17.5	31	29	97
10/31/2021						
Date						
4/1 - 9/30						
COUNT	29	29	29	29	29	29
MEAN	226	52.9	44.8	133	109	73
MIN	73	14	12	29	23	33
MAX	605	132	106	341	294	97
STDV	138	33.0	26.2	94.3	79.3	16.1
CV	0.611	0.623	0.585	0.707	0.727	0.220
5th	81.8	15.2	14.8	30.4	28.4	42
95th	512	111	92.0	316	239	90
99th	599	126	103	335	279	95.0
Date						
10/1 - 3/30						
COUNT	28	28	28	28	28	28
MEAN	127	20.1	17.9	48.3	37.4	79.4
MIN	38	11	9	24	19	56
MAX	614	36	32	137	64	96
STDV	125	6.09	5.48	23.1	12.7	11.7
CV	0.983	0.303	0.306	0.478	0.340	0.148
5th	45.9	13	11.0	26	20.4	60.1
95th	364	32.0	28.0	89.7	59.6	94.3
99th	563	35.2	31.1	128	63.5	95.7

Treatment Plant Effluent Data, Measured Facility Data (received from Andy Miles, 2/8/22): BOD and TSS

Date	BOD Influent	BOD Effluent	TSS Influent	TSS Effluent
1/11/2017	61	25	50	16
1/19/2017	61	25	40	16
2/8/2022	68	27	48	21
2/22/2017	71	27	47	15
3/8/2017	88	46	60	21
3/22/2017	120	42	98	15
4/12/2017	150	91	97	33
4/19/2017	590	84	126	51
5/17/2017	350	110	450	52
5/24/2017	260	110	200	62
6/8/2017	300	150	107	23
6/21/2017	260	170	147	110
7/19/2017	420	190	388	100
7/26/2017	300	180	182	112
8/21/2017	260	140	448	82
8/28/2017	270	140	262	67
9/11/2017	230	92	140	28
9/25/2017	180	130	118	38
10/10/2017	310	180	133	14
10/24/2017	200	78	100	24
11/14/2017	110	42	330	14
11/28/2017	83	25	70	8
12/12/2017	56	28	39	21
12/19/2021	62	37	64	20
1/9/2018	79	52	69	26
1/25/2018	87	42	70	22
2/13/2018	110	47	54	18
2/20/2018	81	49	62	24
3/6/2018	96	50	53	25
3/28/2018	98	64	48	20
4/10/2018	220	110	60	20
4/17/2018	560	250	86	21
5/15/2018	220	97	560	33
5/21/2018	370	160	133	56
6/11/2019	240	110	275	44
6/18/2018	270	150	95	60
7/9/2018	240	140	85	58
7/23/2018	340	150	152	86
8/13/2018	280	110	260	60
8/20/2018	320	140	193	80
9/10/2018	230	120	307	52
9/17/2018	280	110	462	44
10/8/2018	150	62	488	27
10/23/2018	130	130	740	36
11/5/2018	130	62	144	13
11/19/2018	120	63	76	9.2
12/11/2018	59	20	44	6
12/19/2018			61	11
12/28/2018	52	26		

Treatment Plant Effluent Data, Measured Facility Data (received from Skagway, 2/8/22): BOD and TSS

Date	BOD Influent	BOD Effluent	TSS Influent	TSS Effluent
1/15/2019	62	22	32	12
1/22/2019	94	27	44	13
2/4/2019	56	22	64	14
2/12/2019	57	33	46	18
3/5/2019	82	50	70	19
3/26/2019	97	46	31	9.6
4/8/2019	160	57	114	13
4/22/2019	150	130	64	26
5/6/2019	220	110	92	41
5/20/2019	160	120	120	60
6/3/2019	200	120	88	64
6/27/2019	270	170	118	73
7/24/2019	610	200	460	105
7/29/2019	490	130	353	74
8/12/2019	240	150	167	80
8/27/2019	510	130	475	47
9/16/2019	320	110	268	56
9/24/2019	220	78	165	32
10/9/2019	420	160	233	16
10/21/2019	160	49	180	31
11/18/2019	130	28	130	17
11/25/2019	94	26	130	11
12/12/2019	140	33	130	11
12/17/2019	120	28	84	13
1/8/2020	86	50	84	22
1/27/2020	96	22	100	20
2/11/2020	300	38	440	20
2/24/2020	230	28	412	18
3/9/2020	130	32	176	18
3/23/2020	160	29	168	11
4/27/2020	220	54	167	19
4/28/2020	230	47	193	23
5/5/2020	460	46	404	20
5/28/2020	110	47	112	17
6/16/2020	300	67	208	40
6/25/2020	150	36	220	17
7/13/2020	110	57	118	30
7/21/2020	130	44	187	22
8/12/2020	110	49	90	22
8/25/2020	100	28	220	10
9/14/2020	160	44	127	21
9/22/2020	360	230	170	40
10/12/2020	110	56	95	30
10/28/2020	140	44	140	12
11/16/2020	49	28	109	16
11/24/2020	88	23	122	16
12/21/2020	66	26	206	18
12/28/2020	94	24	84	9

Treatment Plant Effluent Data, Measured Facility Data (received from City of Skagway, 2/8/22): BOD and TSS (cont.)

Date	BOD Influen	BOD Effluent	TSS Influen	TSS Effluent
1/4/2021	94	25	86	12
1/19/2021	39	21	58	15
2/16/2021	46	19	55	24
2/26/2021	81	18	84	10
3/8/2021	120	26	150	16
3/22/2021	110	32	166	12
4/5/2021	49	32	125	22
4/20/2021	190	120	400	40
5/18/2021	120	90	87	37
5/25/2021	200	39	450	17
6/14/2021	81	36	54	14
6/22/2021	130	63	100	13
7/14/2021	110	29	84	10
7/26/2021	90	38	160	14
8/9/2021	200	150	144	23
8/23/2021	1300	33	2740	11
9/7/2021	370	68	340	18
9/22/2021	360	44	870	17
10/18/2021	160	68	140	20
10/25/2021	150	45	136	11
11/8/2021	130	51	132	19
11/29/2021	100	28	112	18
12/13/2021	87	34	118	28
12/27/2021	300	31	305	20

Date	BOD inf	BOD eff	TSS inf	TSS effluent
4/1 - 9/30				
COUNT	**60**	**60**	**60**	**60**
MEAN	**272**	**104**	**260**	**43**
MIN	**49**	**28**	**54**	**10**
MAX	**1300**	**250**	**2740**	**112**
STDV	**185**	**53**	**361**	**27**
CV	**0.68**	**0.51**	**1.39**	**0.64**
5th	**91**	**32**	**65**	**11**
95th	**589**	**200**	**556**	**105**

Date	BOD inf	BOD eff	TSS inf	TSS effluent
10/1 - 3/30				
COUNT	**60**	**60**	**60**	**60**
MEAN	**116**	**43**	**131**	**17**
MIN	**39**	**18**	**31**	**6**
MAX	**420**	**180**	**740**	**36**
STDV	**71**	**30**	**126**	**6**
CV	**0.61**	**0.70**	**0.96**	**0.35**
5th	**49**	**20**	**39**	**9**
95th	**300**	**127**	**439**	**30**

Year-round				
COUNT	**120**	**120**	**120**	**120**
MEAN	**194**	**73**	**195**	**30**
MIN	**39**	**18**	**31**	**6**
MAX	**1300**	**250**	**2740**	**112**
STDV	**160**	**53**	**277**	**23**
CV	**0.82**	**0.72**	**1.42**	**0.78**
5th	**56**	**22**	**44**	**10**
95th	**489**	**180**	**474**	**82**

Treatment Plant Effluent Data, DMR: Chlorine and Fecal Coliform

	Effluent Gross Chlorine micrograms pe DAILY MX	Effluent Gross Chlorine micrograms pe MO AVG	Effluent Gross Chlorine lbs per day DAILY MX	Effluent Gross Chlorine lbs per day MO AVG	Effluent Gross Coliform, fecal MF, M Number per 100 Millilit DAILY MX	Effluent Gross Coliform, fecal Number per 100 MO GEO
LIMIT (5/1-9/30)						
LIMIT (10/1-4/30)	**240.0**	**120.0**	**1.3**	**0.6**	**1.50E+06**	**1,000,000**
Date					Effluent GrossColiform	Effluent GrossCo
12/31/2016	0.0	0.0	0.000	0	1700	1700
01/31/2017	0.0	0.0	0.000	0	1400	1400
02/28/2017	0.0	0.0	0.000	0	990	990
03/31/2017	0.0	0.0	0.000	0	450	450
04/30/2017	0.0	0.0	0.000	0	1400	1400
05/31/2017	0.0	0.0	0.000	0	53000	53000
06/30/2017	0.0	0.0	0.000	0	410000	410000
07/31/2017	0.0	0.0	0.000	0	50000	50000
08/31/2017	0.0	0.0	0.000	0	400000	400000
09/30/2017	10.0	5.0	0.028	0.0138	450	450
10/31/2017	0.0	0.0	0.000	0	540	540
11/30/2017	0.0	0.0	0.000	0	39000	39000
12/31/2017	0.0	0.0	0.000	0	8500	8500
01/31/2018	0.0	0.0	0.000	0	5000	5000
02/28/2018	0.0	0.0	0.000	0	16000	16000
03/31/2018	0.0	0.0	0.000	0	2000	2000
04/30/2018	30.0	10.0	0.065	0.0217	1400	1400
05/31/2018	0.0	0.0	0.000	0	73000	73000
06/30/2018	10.0	10.0	0.027	0.0266	37000	37000
07/31/2018	0.0	0.0	0.000	0	67000	67000
08/31/2018	10.0	2.5	0.026	0.0066	35000	35000
09/30/2018	20.0	10.0	0.043	0.0215	240000	240000
10/31/2018	0.0	0.0	0.000	0	3000	3000
11/30/2018	0.0	0.0	0.000	0	100	100
12/31/2018	0.0	0.0	0.000	0	630	630
01/31/2019	0.0	0.0	0.000	0	4300	4300
02/28/2019	0.0	0.0	0.000	0	8400	8400
03/31/2019	0.0	0.0	0.000	0	8600	8600
04/30/2019	0.0	0.0	0.000	0	2700	2700
05/31/2019	10.0	2.5	0.026	0.0063	27000	27000
06/30/2019	0.0	0.0	0.000	0	180000	180000
07/31/2019	0.0	0.0	0.000	0	870000	870000
08/31/2019	0.0	0.0	0.000	0	760000	760000
09/30/2019	0.0	0.0	0.000	0	57000	57000
10/31/2019	0.0	0.0	0.000	0	11000	11000
11/30/2019	0.0	0.0	0.000	0	5500	5500
12/31/2019	0.0	0.0	0.000	0	2100	2100
01/31/2020	0.0	0.0	0.000	0	9300	9300
02/29/2020	0.0	0.0	0.000	0	6000	6000
03/31/2020	20.0	5.0	0.036	0.0091	12000	12000
04/30/2020	160.0	53.0	0.283	0.095	3100	3100
05/31/2020	20.0	15.0	0.033	0.025	450	450
06/30/2020	17.0	15.0	0.032	0.028	11000	11000
07/31/2020	0.0	0.0	0.000	0	30000	30000
08/31/2020	0.0	0.0	0.000	0	3700	3700
09/30/2020	0.0	0.0	0.000	0	2300	2300
10/31/2020	0.0	0.0	0.000	0	5500	5500
11/30/2020	0.0	0.0	0.000	0	1300	1300
12/31/2020	0.0	0.0	0.000	0	630	630
01/31/2021	0.0	0.0	0.000	0	630	630
02/28/2021	0.0	0.0	0.000	0	6600	6600
03/31/2021	0.0	0.0	0.000	0	9600	9600
04/30/2021	0.0	0.0	0.000	0	44000	44000
05/31/2021	0.0	0.0	0.000	0	8600	8600
06/30/2021	160.0	5.0	0.401	0.01	1500	1500
07/31/2021	400.0	208.0	0.804	0.4029	100	100
08/31/2021						
09/30/2021	110.0	67.0	0.171	0.1128	900	900
10/31/2021						
Year-round						
COUNT	**57**	**57**	**57**	**57**	**57**	**57**
MEAN	**17**	**7**	**0**	**0**	**62129**	**62129**
MIN	**0**	**0**	**0**	**0**	**100**	**100**
MAX	**400**	**208**	**1**	**0**	**870000**	**870000**
STDV	**61**	**29**	**0**	**0**	**166904**	**166904**
CV	**3.57**	**4.11**	**3.58**	**4.11**	**2.69**	**2.69**
5th	**0**	**0**	**0**	**0**	**415**	**415**
95th	**160**	**54**	**0**	**0**	**445000**	**445000**
99th						**808400**

Treatment Plant Effluent Data, DMR: Copper and Flow

	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross	Effluent Gross
	Copper, total re	**Copper, total**	**Copper, total recov**	**Copper, total recov**	**Flow, in conduit**	**Flow, in cond**
	Micrograms per L	Micrograms pe	Lbs per day	Lbs per day	Million Gallons pe	Million Gallons
	DAILY MX	MO AVG	DAILY MAX	MO AVG	DAILY MX	MO AVG
LIMIT (5/1-9/30)						
LIMIT (10/1-4/30)	**210**	**150**	**1.1**	**0.8**	**0.63**	**0.53**
Date	Effluent GrossCo	Effluent GrossC	Effluent GrossCoppe	Effluent GrossCoppe	Effluent GrossFlov	Effluent GrossF
12/31/2016	50	50	0.1238	0.1238	0.3446	0.2968
01/31/2017	95	95	0.2357	0.2357	0.4296	0.2975
02/28/2017	82	82	0.2011	0.2011	0.49	0.294
03/31/2017	78	78	0.1618	0.1618	0.3036	0.2488
04/30/2017	100	100	0.1702	0.1702	0.2281	0.2041
05/31/2017	24	24	0.0608	0.0608	0.3876	0.3039
06/30/2017	31	31	0.0901	0.0901	0.3967	0.3484
07/31/2017	36	36	0.0997	0.0997	0.3683	0.332
08/31/2017	44	44	0.1138	0.1138	0.3314	0.31
09/30/2017	17	17	0.0469	0.0469	0.3962	0.3305
10/31/2017	9.3	9.3	0.0192	0.0192	0.334	0.2479
11/30/2017	21	21	0.0388	0.0388	0.2472	0.2217
12/31/2017	9.5	9.5	0.0197	0.0197	0.3292	0.2482
01/31/2018	18	18	0.036	0.036	0.311	0.2397
02/28/2018	11	11	0.0241	0.0241	0.3049	0.2624
03/31/2018	16	16	0.0335	0.0335	0.2935	0.2512
04/30/2018	12	12	0.026	0.026	0.3407	0.2596
05/31/2018	15	15	0.0375	0.0375	0.3476	0.3
06/30/2018	19	19	0.0505	0.0505	0.3582	0.3184
07/31/2018	28	28	0.0728	0.0728	0.3366	0.3116
08/31/2018	29	29	0.0767	0.0767	0.4161	0.317
09/30/2018	35	35	0.0751	0.0751	0.2996	0.2572
10/31/2018	12	12	0.0209	0.0209	0.3839	0.2402
11/30/2018	5.8	5.8	0.0107	0.0107	0.2651	0.227
12/31/2018	5.7	5.7	0.0118	0.0118	0.3391	0.248
01/31/2019	7.8	7.8	0.0159	0.0159	0.3197	0.2571
02/28/2019	9	9	0.0177	0.0177	0.36	0.2363
03/31/2019	17	17	0.3281	0.3281	0.4161	0.2314
04/30/2019	11	11	0.0232	0.0232	0.3263	0.2524
05/31/2019	26	26	0.0651	0.0651	0.3494	0.3
06/30/2019	22	22	0.0639	0.0639	0.3693	0.3482
07/31/2019	35	35	0.0916	0.0916	0.3633	0.3138
08/31/2019	36	36	0.1032	0.1032	0.3894	0.3437
09/30/2019	28	28	0.0717	0.0717	0.3826	0.3072
10/31/2019	21	21	0.0401	0.0401	0.3328	0.2287
11/30/2019	13	13	0.023	0.023	0.2738	0.2121
12/31/2019	13	13	0.0243	0.0243	0.2764	0.2241
01/31/2020	17	17	0.0418	0.0418	0.3519	0.295
02/29/2020	13	13	0.0258	0.0258	0.3288	0.2383
03/31/2020	5.6	5.6	0.0102	0.0102	0.2518	0.2176
04/30/2020	6.9	6.9	0.0123	0.0123	0.2585	0.2142
05/31/2020	3.4	3.4	0.0057	0.0057	0.2484	0.1995
06/30/2020	18	18	0.0336	0.0336	0.2621	0.2241
07/31/2020	21	21	0.039	0.039	0.2523	0.2228
08/31/2020	5	5	0.0093	0.0093	0.2523	0.2228
09/30/2020	5.3	5.3	0.0084	0.0084	0.2477	0.1908
10/31/2020	15	15	0.0255	0.0255	0.229	0.1528
11/30/2020	9.6	9.6	0.0164	0.0164	0.2853	0.2047
12/31/2020	6.4	6.4	0.02	0.02	0.9149	0.3745
01/31/2021	8.2	8.2	0.0154	0.0154	0.364	0.2258
02/28/2021	8.4	8.4	0.021	0.021	0.4179	0.2997
03/31/2021	13	13	0.025	0.025	0.3403	0.2306
04/30/2021	16	16	0.0251	0.2917	0.2917	0.188
05/31/2021	14	14	0.0213	0.2582	0.2582	0.1825
06/30/2021	12	12	0.0241	0.3005	0.3005	0.241
07/31/2021	11	11	0.0214	0.3892	0.3892	0.2328
08/31/2021						
09/30/2021	13	13	0.0219	0.2612	0.2612	0.2019
10/31/2021						
Year-round						
COUNT	**57**	**57**	**57**	**57**	**57**	**57**
MEAN	**22**	**22**	**0**	**0.0796**	**0.34**	**0.26**
MIN	**3**	**3**	**0**	**0.0057**	**0.23**	**0.15**
MAX	**100**	**100**	**0**	**0.39**	**0.91**	**0.37**
STDV	**21**	**21**	**0**	**0.093**	**0.10**	**0.05**
CV	**0.96**	**0.96**	**1.11**	**1.168**	**0.287**	**0.191**
5th	**5**	**5**	**0**	**0.0092**	**0.25**	**0.19**
95th	**83**	**83**	**0**	**0.3033**	**0.4356**	**0.3482**

D. Alaska WQS

Alaska WQS for Turbidity for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(24) TURBIDITY, FOR MARINE WATER USES	
(A) Water Supply (i) aquaculture	May not exceed 25 nephelometric turbidity units (NTU).
(A) Water Supply (ii) seafood processing	May not interfere with disinfection.
(A) Water Supply (iii) industrial	May not cause detrimental effects on established levels of water supply treatment.
(B) Water Recreation (i) contact recreation	Same as (24)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (24)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	May not reduce the depth of the compensation pointfor photosynthetic activity by more than 10%. Maynot reduce the maximum secchi disk depth by more than 10%.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (24)(C).

Alaska WQS for Dissolved Gas for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(15) DISSOLVED GAS, FOR MARINE WATER USES	
(B) Water Supply (i) aquaculture	Surface dissolved oxygen (D.O.) concentration in coastal water may not be less than 6.0 mg/l for a depth of one meter except when natural conditions cause this value to be depressed. D.O. may not be reduced below 4 mg/l at any point beneath the surface. D.O. concentrations in estuaries and tidal tributaries may not be less than 5.0 mg/l except where natural conditions cause this value to be depressed. In no case may D.O. levels exceed 17 mg/l. The concentration of total dissolved gas may not exceed 110% of saturation at any point of sample collection.
(A) Water Supply (ii) seafood processing	Not applicable.
(A) Water Supply (iii) industrial	Not applicable.
(C) Water Recreation (i) contact recreation	Same as (15)(A)(i).
(B) Water Recreation (ii) secondary recreation	Same as (15)(A)(i).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (15)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (15)(A)(i).

Alaska WQS for pH for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(18) pH, for marine water uses (variation of pH for waters naturally outside the specified range must be toward the range)	
(A) Water Supply (i) Aquaculture	May not be less than 6.5 or greater than 8.5, and may not vary more than 0.2 pH unit outside of the naturally occurring range.
(A) Water Supply (ii) seafood processing	May not be less than 6.0 or greater than 8.5.
(A) Water Supply (iii) industrial	May not be less than 5.0 or greater than 9.0
(D) Water Recreation (i) contact recreation	May not be less than 6.0 or greater than 8.5. If the natural pH condition is outside this range, substances may not be added that cause any increase in buffering capacity of the water.
(B) Water Recreation (ii) secondary recreation	Same as (18)(A)(iii).
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (18)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (18)(A)(ii).

Alaska WQS for Temperature for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(22) TEMPERATURE, FOR MARINE WATER USES	
(C) Water Supply (i) aquaculture	May not cause the weekly average temperature toincrease more than 1° C. The maximum rate of change may not exceed 0.5° C per hour. Normal daily temperature cycles may not be altered inamplitude or frequency.
(A) Water Supply (ii) seafood processing	May not exceed 15° C.
(A) Water Supply (iii) industrial	May not exceed 25° C.
(E) Water Recreation (i) contact recreation	Not applicable.
(B) Water Recreation (ii) secondary recreation	Not applicable.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Same as (22)(A)(i).
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (22)(A)(i).

Alaska WQS for Toxics for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(23) TOXIC AND OTHER DELETERIOUS ORGANIC AND INORGANIC SUBSTANCES, FOR MARINE WATER USES	
(D) Water Supply (i) aquaculture	Same as (23)(C).
(A) Water Supply (ii) seafood processing	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marinewater shown in the *Alaska Water Quality Criteria Manual* (see note 5). Substances may not be introduced that cause, or can reasonably be expected to cause, either singly or in combination, odor, taste, or other adverse effects on the use.
(A) Water Supply (iii) industrial	Concentrations of substances that pose hazards to worker contact may not be present.
(F) Water Recreation (i) contact recreation	There may be no concentrations of substances in water, that alone or in combination with other substances, make the water unfit or unsafe for theuse.
(B) Water Recreation (ii) secondary recreation	Concentrations of substances that pose hazards to incidental human contact may not be present.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	The concentration of substances in water may not exceed the numeric criteria for aquatic life for marine water and human health for consumption of aquatic organisms only shown in the *Alaska Water Quality Criteria Manual* (see note 5), or any chronic and acute criteria established in this chapter, for a toxic pollutant of concern, to protect sensitive and biologically important life stages of resident species of this state. There may be no concentrations of toxic substances in water or in shoreline or bottom sediments, that, singly or in combination, cause, or reasonably can be expected to cause, adverse effects onaquatic life or produce undesirable or nuisance aquatic life, except as authorized by this chapter. Substances may not be present in concentrations that individually or in combination impart undesirable

	odor or taste to fish or other aquatic organisms, as determined by either bioassay or organoleptic tests.
(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	Same as (23)(C).

Alaska WQS for Bacteria for Marine Uses

Water Quality Standards for Designated Uses	
POLLUTANT & WATER USE	**CRITERIA**
(14) BACTERIA, FOR MARINE WATER USES, (see note 1)	
(E) Water Supply (i) aquaculture	For products normally cooked, the geometric mean ofsamples taken in a 30-day period may not exceed 200fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml. For products not normally cooked, the geometric mean ofsamples taken in a 30-day period may not exceed 20 fecal coliform/100 ml, and not more than 10% of thesamples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (ii) seafood processing	In a 30-day period, the geometric mean of samples may not exceed 20 fecal coliform/100 ml, and not more than 10% of the samples may exceed 40 fecal coliform/100 ml.
(A) Water Supply (iii) industrial	Where worker contact is present, the geometric meanof samples taken in a 30-day period may not exceed 200 fecal coliform/100 ml, and not more than 10% of the samples may exceed 400 fecal coliform/100 ml.
(G) Water Recreation (i) contact recreation	In a 30-day period, the geometric mean of samples may not exceed 35 enterococci CFU/100 ml, and notmore than 10% of the samples may exceed a statistical threshold value (STV) of 130 enterococci CFU/100 ml.
(B) Water Recreation (ii) secondary recreation	In a 30-day period, the geometric mean of samples may not exceed 200 fecal coliform/100ml, and not more than 10% of the samples may exceed 400 fecalcoliform/100ml.
(C) Growth and Propagation of Fish, Shellfish, Other Aquatic Life, and Wildlife	Not applicable.

(D) Harvesting for Consumption of Raw Mollusks or Other Raw Aquatic Life	The geometric mean of samples may not exceed 14 fecal coliform/100 ml; and not more than 10% ofthe samples may exceed; - 43 MPN per 100 ml for a five-tube decimal dilution test; - 49 MPN per 100 ml for a three-tube decimaldilution test; - 28 MPN per 100 ml for a twelve-tube single dilution test; - 31 CFU per 100 ml for a membrane filtration test (see note 14).

E. Equations and Analysis

1. Section 8.B.1: Attainment of TSS Standard

EPA calculated the maximum change in the concentration of TSS at the edge of the ZID using formula B-32 from the 301(h) TSD. The maximum daily TSS limitation of 132 mg/L and the modeled critical initial dilution of 56:1 were used in the equation. The results show a 2.4 mg/L increase in suspended solids in the receiving water after initial dilution, or 1.8%.

Formula B-2

$$SS = SSe/Sa$$

where,

SS = change in suspended solids concentration following initial dilution

SS_e = effluent suspended solids concentration (132 mg/L)

S_a = critical initial dilution (56:1)

132/56 = 2.4 mg/L

2. Section 8.B.2: Attainment of DO Standard

EPA calculated the final concentration of DO at the boundary of the ZID using equation B-5 from the 301(h) TSD. Minimum ambient DO concentrations are all below the minimum effluent concentration of 4.6 mg/L. Therefore, in critical conditions when DO in Taiya Inlet is lowest, the discharge from the facility raises DO in Taiya Inlet. The analysis is presented in the Table below.

Dissolved Oxygen Analysis

Dissolved Oxygen in mg/L	Surface	Mid	Bottom	Notes
Ambient DO concentration (DO_a) = (reference sites)	**2.13**	**1.42**	**1.41**	5th percentile observed at two reference sites on 7/19/04 and 8/23/05
Ambient DO concentration (DO_a) = (ZID boundary sites)	**3.30**	**1.96**	**1.90**	minimum observed at two outfall sites
Effluent DO concentration (DO_e) =	**4.6**	**4.6**	**4.6**	5th Percentile
Immediate DO demand (IDOD) =	**2.0**	**2.0**	**2.0**	Table B-3 301(h) TSD[1]
Initial dilution (S_a) =	**56**	**56**	**56**	Dilution modeling results
Final DO at Reference Sites $DO_f = DO_a - (DO_a + IDOD - DO_e)/S_a$ = (using reference site ambient DO)	**2.14**	**1.44**	**1.43**	Equation B-5 from 301(h) TSD, using reference site ambient DO
Assuming 0 mg/L effluent (worst-case) $DO_f = DO_a - (DO_a + IDOD - DO_e)/S_a$ =	**2.17**	**1.48**	**1.47**	Worst-Case
FINAL DO at ZID Boundary $DO_f = DO_a - (DO_a + IDOD - DO_e)/S_a$ = (using ZID boundary ambient DO)	**3.29**	**1.97**	**1.91**	Equation B-5 from 301(h) TSD, using outfall site ambient DO
Increase at Reference Sites	**0.01 (0.4%)**	**0.02 (1%)**	**0.06 (1.5%)**	
Increase at ZID Boundary Sites	**1.16 (0.7%)**	**0.55 (0.7%)**	**0.5 (0.6%)**	
[1] Primary facility, effluent BOD_5 50-100 mg/L, travel time 0-100 minutes.				

3. Section 8.C.3. Toxics Analysis

The following mass-balance equation was used to determine whether the discharge has reasonable potential to cause or contribute to an excursion above Alaska WQS:

$$Cd = Ce + \frac{Cu\ (Sa-1)}{Sa}$$

Cd = Resultant magnitude or predicted concentration at edge of mixing zone, µg/L

Ce = Maximum projected effluent concentration, µg/L

Cu = Background receiving water concentration, µg/L

Sa = dilution factor

The maximum projected effluent concentration (Ce) in the mass balance equation is represented by the highest reported concentration measured in the effluent multiplied by a reasonable potential multiplier. The reasonable potential multiplier accounts for uncertainty in the data. The multiplier decreases as the number of data points increases and variability of the data decreases. Variability is measured by the coefficient of variation (CV) of the data. When there is not enough data to reliably determine a CV (n<10), the TSD recommends using 0.6 as a default value. A partial listing of reasonable potential multipliers can be found in Table 3-1 of the TSD. The resulting maximum projected effluent concentration is then divided by the minimum critical dilution. This product represents the maximum effluent concentration at the edge of the ZID. The maximum effluent concentration at the edge of the ZID is then added to the background concentration, Cu, which is represented by the 95th percentile value from the background data set (the 5th percentile value is used for DO). The sum Cd represents the projected maximum receiving water concentration at the edge of the ZID. This concentration is compared to the water quality criterion to determine whether a water-quality based effluent limitation is needed. If the receiving water concentration at the edge of the ZID exceeds the water-quality criteria a water-quality based effluent limitation is developed. If a permittee is unable to meet their WQBEL they would fail to satisfy CWA § 301(h)(9) and 40 CFR 125.62 and would be ineligible for a 301(h)-modified permit.

A summary of the reasonable potential analyses is presented in the 2023 Fact Sheet for the Skagway WWTP NPDES permit. The Table footnotes indicate the criterion source used to evaluate reasonable potential (i.e., the criterion in effect for Clean Water Act purposes). Chlorine and copper are the constituents that demonstrated reasonable potential. WQBELs for chlorine and copper have been developed and included in the final permit. The effluent limits developed for chlorine and copper are protective of Alaska WQS, and the proposed discharge is expected to comply with Alaska WQS for toxics after initial mixing, satisfying the requirements of CWA § 301(h)(9) and 40 CFR 125.62. For more information on the process used to develop effluent limits refer to Appendix D of the Fact Sheet.

Table 9. Reasonable potential analysis for pH exceedances at the edge of the ZID

INPUT	Min Limit	Max Limit
1. Dilution Factor at Mixing Zone Boundary	**56.0**	**56.0**
2. Ambient/Upstream/Background Conditions		
Temperature (deg C):	9.40	5.66
pH:	7.60	7.85
Alkalinity (mg $CaCO_3$/L):	25.00	25.00
3. Effluent Characteristics		
Temperature (deg C):	11.00	19.00
pH:	**6.00**	**9.00**
Alkalinity (mg CaCO3/L):	25.00	25.00
4. Applicable Water Quality Standards	**6.50**	**8.50**
OUTPUT		
1. Ionization Constants		
Upstream/Background pKa:	6.47	6.51
Effluent pKa:	6.45	6.39
2. Ionization Fractions		
Upstream/Background Ionization Fraction:	0.93	0.96
Effluent Ionization Fraction:	0.26	1.00
3. Total Inorganic Carbon		
Upstream/Background Total Inorganic Carbon (mg CaCO3/L):	27	26
Effluent Total Inorganic Carbon (mg CaCO3/L):	96	25
4. Conditions at Mixing Zone Boundary		
Temperature (deg C):	9.43	5.90
Alkalinity (mg CaCO3/L):	25.00	25.00
Total Inorganic Carbon (mg CaCO3/L):	28.09	26.12
pKa:	6.47	6.50
RESULTS		
pH at Mixing Zone Boundary:	**7.38**	**7.85**
Reasonable Potential to contribute to excursion above W(	**NO**	**NO**

F. TVS Survey Results

Table 10. Total Volatile Solids Results (2006)

	Date collected	Method	TVS1	TVS2
Reference Station East 1 (200 m east of diffuser)	9/2/2006	SM2540G	5.9	1.8
ZID Boundary East 2 (60 feet east of diffuser)	9/2/2006	SM2540G	1.3	0.77
Outfall Station 3	9/2/2006	SM2540G	2.1	2.2
ZID Boundary West 4 (60 feet west of diffuser)	9/2/2006	SM2540G	7.3	1
Reference Station 5 (200 m west of diffuser)	9/2/2006	SM2540G	2.7	3.2

G. Dilution Modeling Report

FINAL

Mixing Zone Dilution Modeling for Six Alaska POTWs

Prepared for:

United States Environmental Protection Agency
Cincinnati Procurement Operations Division
Cincinnati, Ohio 45268

USEPA OW Contract: 68HERC20D0010; Task Order: 68HERV21F0114

Technical Support for National Pollutant Discharge
Elimination System (NPDES), Clean Water Act Section 301(h),
and Endangered Species Act Section 7 Implementation
in EPA Region 10 NPDES Permits Section

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Date: August 5, 2021

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MIXING ZONE DILUTION MODELING FOR SIX ALASKA POTWS

For each of the six POTWs of interest in southeast Alaska (Haines, Ketchikan, Petersburgh, Sitka, Skagway, and Wrangell) mixing zone dilution models were developed and applied to predict the steady-state dilution of effluent being discharged into the marine coastal receiving waters. Because of the nature of the discharges and receiving waters, initial dilution models within the EPA-approved Visual Plumes software (EPA 2003) were selected for use. From a modeling perspective, each of the receiving water mixing zones share several important characteristics that led to the selection of Visual Plumes, as opposed to the alternative EPA-approved modeling framework, CORMIX:

- Discharge of buoyant effluent into a deep (20-30 meter), stratified marine water body;
- No shoreline boundaries within 100 meters of the outfalls;
- Relatively small discharge flow rates (0.6-7 MGD); and
- No obstructions in the receiving waters to impede circulation near the outfalls, making tidal build-up of pollutants unlikely.

For each site, appropriate models were applied to predict average dilution at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point, as well as the geometry (depth, width, etc.) of the plume itself. Aquatic life-based mixing zone analyses involve the concept of determining reasonable worst-case values for various parameters because the durations established for these water quality criteria vary for both acute and chronic toxicities (Washington DoE, 2018). The term *reasonable worst-case* refers to the value selected for a specific effluent or receiving water parameter. *Critical conditions* refer to a scenario involving reasonable worst-case parameters, which has been set up to run in a mixing zone model. For this work, steady-state mixing zone models were applied using a combination of parameters (e.g., effluent flow, current speed, density profile) to simulate critical conditions. The predictions were based on input data representing critical conditions demonstrated to minimize the dilution of effluent pollutants. It should be understood that each critical condition (by itself) has a low probability of occurrence.

It should also be understood that mixing zone modeling is not an exact science (Reese et al., 2021). With limited data and numerous variables, mixing zone sizes may be considered best estimates to ± 50%. Sensitivity analysis and comparison of alternative models were used to develop confidence in the dilution model predictions. All simulations explicitly included fecal coliform (FC) as a pollutant, which required the models to simulate bacterial decay in the receiving waters. Maximum effluent (end-of-pipe) FC concentrations were estimated for modeling by applying the EPA (1991) reasonable potential procedure to maximum monthly concentrations reported over the past five years in Discharge Monitoring Reports (DMRs) provided by EPA Region 10. The maximum effluent FC concentrations for each discharge are presented in Table 1 along with the dilution factors required to meet the Alaska marine water quality standards for harvesting for consumption of raw mollusks or other raw aquatic life (18 AAC 70 Water Quality Standards, amended as of March 5, 2020):

The geometric mean of samples may not exceed 14 fecal coliform/100 ml, and not more than 10% of the samples may exceed 43 MPN per 100 mL for a five-tube decimal dilution test.

Table 1. Maximum Effluent FC Concentrations Based on EPA (1991) Reasonable Potential Procedure (Maximum Monthly Concentrations Reported in DMRs Over the Past 5 Years)

City	Haines	Kechikan	Petersburg	Sitka	Skagway	Wrangell
Maximum expected effluent FC (daily max, 99%; n/100 mL)	2,100,000	2,900,000	2,000,000	3,700,000	2,600,00	190,000
Dilution factor[1] required to meet 14/100 mL FC criterion	150,000	210,000	140,000	270,000	190,000	14,000
Dilution factor required to meet 43/100 mL FC criterion	50,000	67,000	47,000	87,000	60,000	4,400

Model predictions of the size of the mixing zones required to attain these dilution factors are presented in the summary of this report.

Most mixing zone simulations required the combination of initial dilution and far-field models. Initial dilution models simulate the "initial mixing region" or "hydrodynamic mixing zone" defined to end where the self-induced turbulence of the discharge collapses under the influence of ambient stratification and initial dilution reaches its limiting value (EPA, 1994). At the end of this region/zone the waste field is established and then drifts with the ocean currents and is diffused by oceanic turbulence.

The initial dilution models included UM3, DKHW and NRFIELD, all contained within the Visual Plumes (VP) framework. Although the three initial dilution models run under the same VP interface, they differ in terms of origin and development, underlying assumptions, empirical datasets, solution techniques and coding. UM3 is a three-dimensional Updated Merge (UM) model for simulating single and multiport submerged diffusers. DKHW is an acronym for the Davis, Kannberg and Hirst model, a three-dimensional model for submerged single or multi-port diffusers. DKHW is limited to positively buoyant plumes and considers either single or multiport discharges at an arbitrary horizontal angle into a stratified, flowing current. NRFIELD is based on the Roberts, Snyder and Baumgartner (RSB) model, an empirical model for multiport diffusers (T-risers, each having two ports for a total of 4-ports) in stratified currents. A shortcoming of each of these initial dilution models in VP is their inability to recognize and address lateral boundary constraints, although that is not a major issue for these Alaskan mixing zone sites. Although the original 2001 version of VP is still available from EPA's CEAM site, it is currently unsupported and known to contain a number of errors (Frick et al. 2010; Frick and Roberts, 2019). We instead used the updated VP version 20, maintained and distributed by the California State Water Resources Control Board, Ocean Standards Unit (https://ftp.waterboards.ca.gov).

The Brooks far-field model was used to extend dilution simulations beyond the spatial bounds of initial dilution. Although this model is incorporated in VP, we also used a stand-alone spreadsheet version of the

[1] Dilution Factor, DF = (end of pipe) concentration/mixed concentration.

Brooks model, FARFIELD, that is contained in the Washington Department of Ecology (DoE), *Permit Calculation workbook* (https://ecology.wa.gov/Regulations-Permits/Guidance-technical-assistance/Water-quality-permits-guidance). FARFIELD calculates dilution using the method of Brooks (1960) and is recommended by Frick et al. (2010) in lieu of using far-field predictions within VP, since the latter does not allow for the use of linear diffusivity as recommended in estuaries. FARFIELD was used to double-check the far-field results in VP, and in some instances to replace them.

The initial dilution models relied upon a variety of data to characterize the effluent, discharge outfall and receiving water. These data are summarized in Table 2. The data were gathered from a number of sources including EPA Region 10 and the State of Alaska; from the permittees as documented in permit files, as-built drawings and charts, etc.; tidal current predictions made by the National Oceanic and Atmospheric Administration (NOAA); and other literature sources found by Internet search.

All six of the POTWs discharge effluent using deeply-submerged outfalls with diffusers and multiple ports (Table 2). Haines and Petersburg both use two-diffuser ports, while the others use multiport diffusers with 6 to 16 ports. Modeling initial dilution from the four sites using multiport diffusers required additional considerations, because these diffusers have opposing ports (ports on both sides of the diffuser pipe that discharge effluent into opposite directions), creating co-flowing and counter-flowing plumes. Counter-flowing plumes are discharged opposing the ambient current and will generally rise and bend back into the direction from whence they came, eventually merging with the co-flowing plumes that are discharged on the opposite side of the pipe in the direction of the current. This is called cross-diffuser merging (EPA, 2003). Two alternative modeling approaches were applied to simulate initial mixing from opposing ports in the UM3 and DKHW models (NRFIELD models cross-diffuser merging directly). The first approach ("half spacing") treated the diffuser as if all ports are on one side with half the spacing. In the context of merging plumes, this approach works well when the distances of interest are somewhat beyond the point of merging.

The second approach ("downstream only") involves simulating only downstream ports. This necessitates doubling the flow per port (assuming there is an even number of ports in the diffuser) and increasing the diameter of the ports to maintain approximately the same densimetric Froude number. With this approach only the downstream ports would be used when determining spacing and number of ports. The Washington DoE Permit Writer's Manual, Appendix C (2018) discusses the merits of these approaches. When possible, we applied both approaches to modeling cross-diffuser merging and compared the results.

We assumed that all ports on a multiport diffuser discharged effluent flow equally and at the same depth. The multiport diffuser at Ketchikan was unique because it was the only diffuser that combined ports of different sizes. Five 6-inch opposing ports were spaced along a 12-inch manifold, and a sixth 12-inch port was located at the manifold's end. The CORMIX hydraulic module CorHyd (MixZone, 2020) was used to determine the flow distribution between the 6-inch ports and the 12-inch port. At a nominal flow rate of 5.35 MGD, CorHyd calculated that the 6-inch ports would discharge 52% of the flow, and the remaining 48% would be discharged from the 12-inch port. These same percentages were applied to other flow rates at Ketchikan. Initial model simulations suggested that the plumes emanating from the 12-inch port would not merge with the plume from the other ports, due to the 90° difference in port orientations. Therefore, these plumes were modeled separately.

The diffuser port orifice contraction coefficient is an initial dilution model hydraulic parameter that is specified according to how ports are machined in the diffuser pipe wall (EPA, 2003). For all of the outfalls except Sitka, sharp-edged ports were assumed, and contraction coefficients of 0.61 were specified. For Sitka, the port orifices were bell-shaped, so a contraction coefficient of 1.0 was applied.

Tidal current predictions were used to calculate 10^{th} percentile and average current velocities at each site. The tidal prediction location nearest each discharge site was identified and tidal velocity predictions for 2021 were downloaded from the NOAA Tides & Currents web site (http://tidesandcurrents.noaa.gov). These data were imported into a spreadsheet and the predictions for the month in which the critical ambient conditions fell were selected. For Haines, Ketchikan and Skagway, 6-minute tidal velocity predictions were available. The tenth percentile of the absolute value of these velocities were calculated and used as the critical ambient velocity input for mixing zone dilution modeling. For the other locations, only times and velocities for ebb, slack and flood tides were available. The Excel FORECAST function was then used to interpolate hourly values from the tidal velocity predictions, and the tenth percentile of the absolute value of these interpolated hourly values was calculated and used for modeling[2]. These velocities, ranging from 1.4 to 5.9 cm/s, are presented in Table 2. The compass directions of tidal currents (also presented in Table 2) were based on the tidal current predictions, the orientation of the nearest shoreline (presuming currents to flow parallel to the shoreline), and other information from the permit files. The average hourly ebb and flood tidal velocities were calculated similarly and are also presented in Table 2 and were used in the model sensitivity analysis.

The decay of fecal coliform was included in the initial dilution and far-field models by using the Mancini (1978) bacteria model that incorporates four variables (salinity, temperature, solar insolation, and water column absorption) to determine the rate of first-order decay. Summertime solar insolation in southeast Alaska was based upon the models and measurements of Dissing and Wendler (1998). Summertime solar radiation flux, that takes into account both latitude and fractional cloud cover, averaged 190 Watts/m^2 (16.3 Langleys/hr) in the Alexander Archipelago. The bacterial decay model used ambient water temperature and salinity, and a default light absorption coefficient of 0.16, to calculate decay rates of ~0.0002/d. Decay of fecal coliform was found to be insignificant in comparison to physical dilution at the time and space scales of interest for mixing zone analysis.

[2] Comparison between linear interpolation and cubic spline interpolation of the tidal velocity predictions suggests that linear interpolation may yield average velocities that could be low by a factor of 1.6 to 2.3. The impact of this discrepancy on DF predictions will be demonstrated via sensitivity analysis.

Table 2. Summary of Data Used for Mixing Zone Dilution Modeling

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
Permit	*AK0021385*	*AK0021440*	*AK0021458*	*AK0021474*	*AK0020010*	*AK0021466*
DMR data available	2011-2020	2013-18	2015-2019	2015-20	2007-19	2007-19
DMR data used	2016-2020	2013-2018	2015-2019	2015-2020	2014-2019	2015-2019
Permit Maximum Flow Rate (MGD[3])	2.9	7.2	3.6	5.3	0.63	3.0
monthly[4] average effluent temperature	12.0	14.6[5]	13.2	14.0	14.7	17.3
monthly maximum effluent temperature	15.8	20.5	14.6	15.0	17.3	18.4
Outfall						
distance from shore (m)	549	221	366	114	125	457
depth at LWWD (m)	21.3	29.9	18.3	24.4	18.3	30.5
number of diffuser ports	2 (3rd is capped)	6	2 (3 others capped)	16 bell-shaped	8	16
diffuser length (ft)	30	190	45.9	195	25	240
port diameter (in)	3	5@6", 1@12"	4	4	3	3
Elevation of ports above bottom (in)	8	12	9	18	6	6
Port spacing (ft)	15-30[6]	40 (20' apart on alternating sides of pipe)	10-34[6]	26 (13' apart on alternating sides of pipe)	7	32 (16' apart on alternating sides of pipe)
Port orientation	horizontal	horizontal (opposing/ alternating) + diffuser end	horizontal	horizontal opposing/ alternating	horizontal opposing	horizontal opposing/ alternating

[3] Million gallons per day.
[4] Average effluent temperature for month of limited dilution
[5] Average of maximum monthly effluent temperatures (no monthly averages in DMR)
[6] Port spacing is uncertain given information in permit fact sheet.

City	Haines	Ketchikan	Petersburg	Sitka	Skagway	Wrangell
VP discharge angle[7] (degrees)	90	115 (5x6" ports), 205 (1x12" port)	115	300	350	90
Receiving Water						
Water body	Portage Cove, Chinook Inlet	Tongass Narrows, Charcoal Point	Frederick Sound	Sitka Sound, Middle Channel	Tiaya Inlet	Zimovia Strait
tidal range (ft)	14.2	13	15	7.7	14.1	13
data source/file[8] name for ambient data	NA; used Skagway data	AK0021440_Ketchikan_temp_salinity	Petersburg_Receiving Water Data	Sitka Receiving Water Monitoring	Table 2-5_v2	Wrangell FC and RW Monitoring
Ambient salinity/temp profile limiting dilution	Skagway site 1, June 2005	Ketchikan site 3, July 1997	Petersburg site 1, August 2005	Sitka site C, July 2010	Skagway site 1, June 2005	Wrangell site 4, August 2016
NOAA tides & current predictions	Battery Point, Chinook Inlet (SEA0826)	East of Airport (SEA0711)	Cosmos Point (PCT3811)	Sitka Harbor, Channel off Harbor Island (PCT4166)	Tiaya Inlet (SEA0825)	Wrangell Harbor (PCT3131)
Tidal current 10th percentile (cm/s)	June: 2.1 @ 35', 2.8 @ 133'; 2.3 (interpolated to discharge depth)	July: 5.9 @87'	August: 1.6	July: 1.7	June: 1.4 @37'	August: 4.0
Tidal current average (Ebb/Flood, cm/s)	June: 10.2/10.7 @ 35', 11.3/16.1 @ 133'; 10.5/12.6 (interpolated to discharge depth)	July: 49.2/20.1 @87'	August: 10.4/7.8	July: 10.3/8.0	June: 6.9/12.2 @37'	August: 20.8/23.5
VP current angle[7] (degrees)	90	140	120	225	350	90

[7] Zero degrees is eastward.
[8] Names of electronic files provided by EPA Region 10 on March 31, 2021.

In the following sections, the modeling of effluent dilution in mixing zones at each site is presented and results are displayed in both tables and graphs. Text output from the VP and FARFIELD model simulations at each location are provided in an appendix to this report.

HAINES

The wastewater treated at Haines is discharged 549 m offshore in Portage Cove, Chinook Inlet (Figure 1), from a 2-port diffuser at a depth of 21.3 m (MLLW[9]). The permitted maximum flow rate is 2.9 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The diffuser port spacing at Haines is uncertain (somewhere in the range of 15 to 30 ft.) due to one of three ports being closed. The models predicted lower DFs for the narrowest port spacing (15 ft.), so that spacing was used for all model simulations.

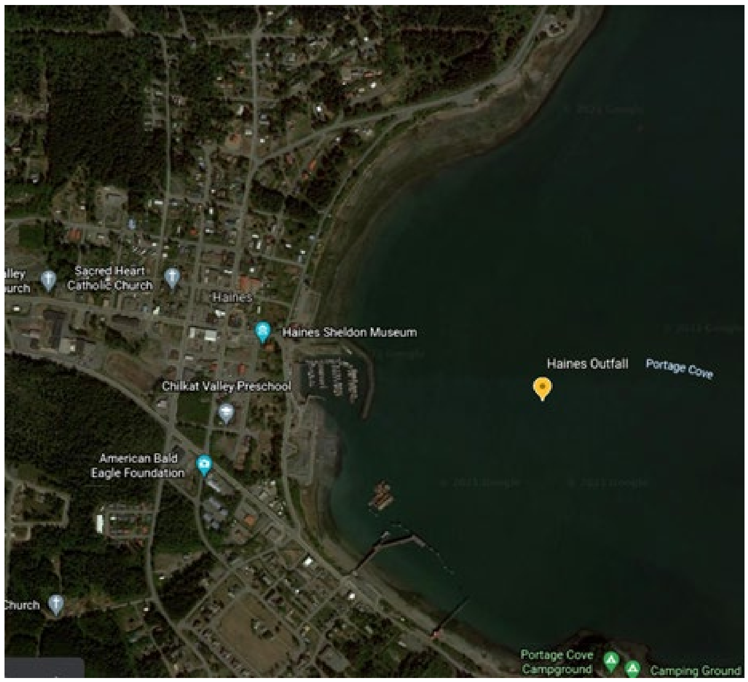

Figure 1. Aerial View of the POTW Outfall Location at Haines

According to the permit fact sheet, the circulation patterns within Portage Cove are not known. The effluent discharged by the Haines WWTP is subject to a net transport of water out of Chinook Inlet due to fresh water supplied by runoff. The period of low net circulation is expected to be December through April, during times of minimum river flow. NOAA 6-minute tidal current predictions from Battery Point, Chinook Inlet (SEA0826) were used to calculate the 10^{th} percentile and average tidal current velocities at 35 and 133 ft. (10.7 and 40.5 m; Table 2), that were then interpolated to the discharge depth of 21.1 m. The resulting 10^{th} percentile current velocity used for modeling was 2.3 cm/s, while the average ebb and flood tidal velocities were 10.5 and 12.6 cm/s.

No specific data were available for vertical profiles of temperature and salinity in Portage Cove or Chinook Inlet. Such data are used to calculate the density profile and define the vertical stratification that limits vertical mixing of the buoyant discharge plume. Instead, we used vertical profiles of temperature and salinity measured in Tiaya Inlet, an adjoining waterway that is also the receiving water body for Skagway's discharge. Vertical profile data were available for five locations that were sampled in October

[9] Mean lower low water.

2002, July and August 2004, and June 2005. Preliminary initial dilution simulations made with UM3 for profiles measured at four of the locations (the fifth was excluded because it was influenced by freshwater input from a tributary near Skagway), determined that the June 2005 vertical profile from site 1 (shown in Figure 2) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Haines.

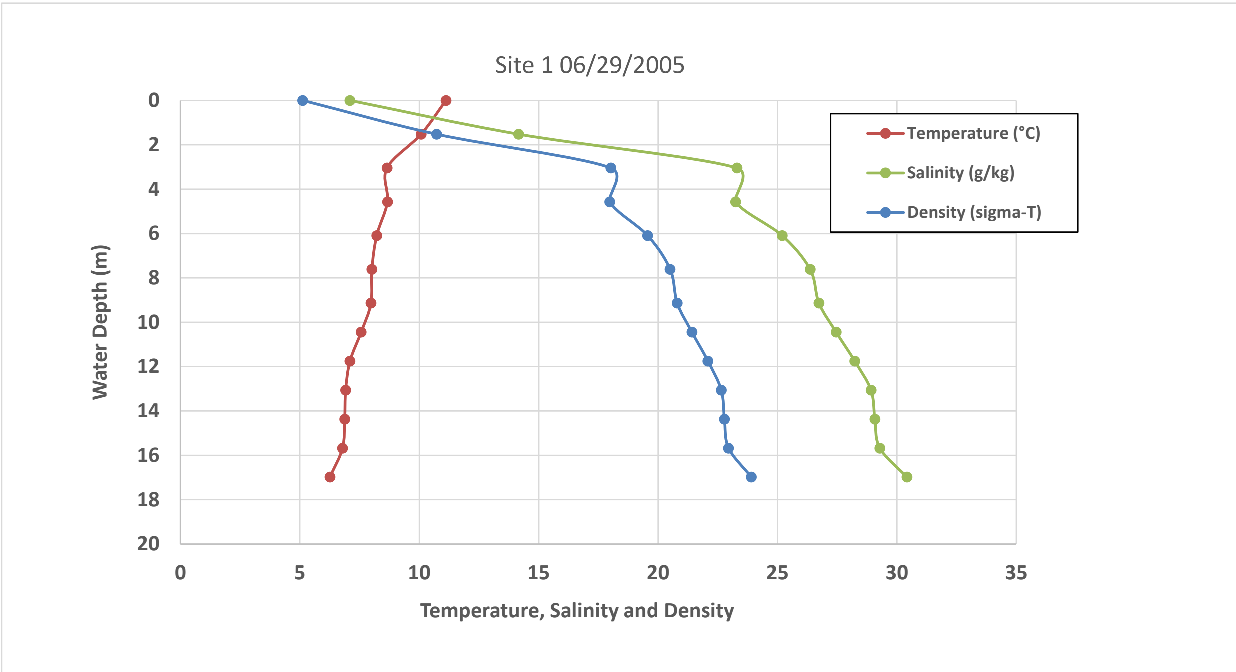

Figure 2. Vertical Ambient Profile of Temperature, Salinity and Density in Haines Mixing Zones Resulting in Least Mixing

Mixing zone dilution modeling results for Haines are summarized in Table 3. The two applicable initial mixing models, UM3 and DKHW, gave nearly identical results for dilution at a distance of 1*depth (Table 3, simulations 10 vs. 11). UM3 was selected for further analysis at Haines. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 100 to 766 (Table 3, simulations 15-18); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 3 (plan view from above of the discharge plume boundary), 4 (profile view from the side of the discharge plume centerline and boundary) and 5 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 3, the plume was trapped at a depth of 20 m by the ambient density stratification, the initial mixing region extended 16 m from the outfall, and the travel time to the mixing zone boundaries ranged from 4 minutes (MZ=1*depth) to 143 minutes (MZ=10*depth). A dilution factor of 99 was predicted for the boundary of the initial mixing region and at the distance to the shore (549 m) the DF was 2770.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[10], current velocity and direction, and discharge flow rate) is demonstrated in simulations 20-28 (Table 3). Of these

[10] The alternative effluent temperature used for sensitivity analysis was the monthly average effluent temperature for the month found to have the most limited dilution.

parameters, DFs were most sensitive to variation in effluent flow rate (Q), with dilution increasing with greater flow. DFs were relatively insensitive to variation in ambient velocity. Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity (see Washington DoE, 2018 for explanation).

Table 3. Haines mixing zone dilution modeling results

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
1. MZ=1*depth	Skagway site 1 Oct. 2002	UM3	21.3	190	117	118	17	>21.3	
2. " "	Skagway site 2 Oct. 2002	UM3	" "	191	118	118	17	>21.3	
3. " "	Skagway site 4 Oct. 2002	UM3	" "	190	117	118	17	>21.3	
4. " "	Skagway site 1 Jul. 2004	UM3	" "	189	117	118	17	>21.3	
5. " "	Skagway site 2 Jul. 2004	UM3/FF	" "	185	110	113	19	20	2
6. " "	Skagway site 4 Jul. 2004	UM3/FF	" "	181	113	116	19	21	0.5
7. " "	Skagway site 1 Aug. 2004	UM3	" "	188	118	118	17	>21.3	
8. " "	Skagway site 2 Aug. 2004	UM3	" "	186	117	117	17	>21.3	
9. " "	Skagway site 4 Aug. 2004	UM3/FF	" "	181	114	117	19	21	0.2
10. " "	Skagway site 1 June 2005	UM3/FF	" "	179	99	104	20	16	5
11. " "	Skagway site 1 June 2005	DKHW/FF	" "	179	99	99	20	16	4
12. " "	Skagway site 2 June 2005	UM3/FF	" "	183	105	109	20	18	2
13. " "	Skagway site 4 June 2005	UM3	" "	185	117	117	17	>21.3	

[11] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Different mixing zone distances:									
14. MZ= initial mixing region	Skagway site 1 June 2005	UM3	16	179	**99**	100	20		1
15. MZ=1*depth	" "	UM3/FF	21.3	179	**100**	100	20	16	4
16. MZ=2*depth	" "	UM3/FF	42.6	179	**136**	137	20	16	19
17. MZ=5*depth	" "	UM3/FF	106.5	179	**330**	331	20	16	65
18. MZ=10*depth	" "	UM3/FF	213	179	**766**	768	20	16	143
19. MZ=distance to nearest shore	" "	UM3/FF	549	179	**2770**	2780	20	16	386
Model sensitivity:									
20. avg. effluent T=11.975° C	Skagway site 1 June 2005	UM3/FF	21.3	181	100	100	20	16	4
21. ½*current v=1.15 cm/s	" "	UM3/FF	" "	178	101	101	20	16	8
22. ¼ *current v=0.575 cm/s		UM3/FF	" "	179	120	120	20	16	16
23. 2*current v=4.6 cm/s	" "	UM3/FF	" "	179	105	105	20	17	2
24. average current v=12.6 cm/s	" "	UM3/FF	" "	179	126	126	20	19	4
25. reverse current direction=270°	" "	UM3/FF	" "	179	92	92	20	15	4
26. average Q=0.27 MGD	" "	UM3/FF	" "	17	63	63	18	5	12
27. Q/2=1.45 MGD	" "	UM3/FF	" "	89	87	87	20	11	7
28. 2*Q=5.8 MGD	" "	UM3	" "	358	111	111	20	21	0.5

Model simulation	Ambient Input	Model(s)	MZ Distance (m)	Froude Number	Dilution Factor	Dilution Factor w/Bacteria Decay	Trapping depth (m)	Length of Initial Mixing Region (m)	Travel Time to MZ Boundary (min)[11]
Far-field model sensitivity to diffusion parameter:									
29. alpha=0.0001	Skagway site 1 June 2005	UM3/FF	213	178	248	249	20	16	143
30. alpha=0.000453	" "	UM3/FF	" "	178	1280	1280	20	16	143
31. Linear eddy diffusivity	" "	UM3/FF	" "	178	486	488	20	16	143

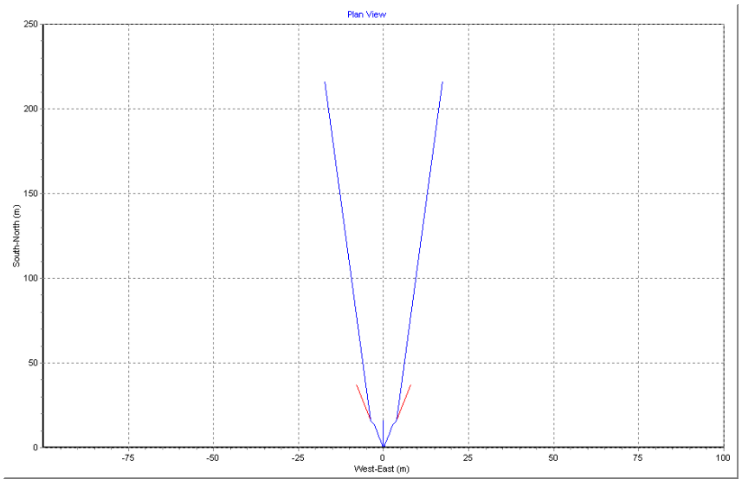

Figure 3. Haines Discharge Plume Boundary Plan View from Above

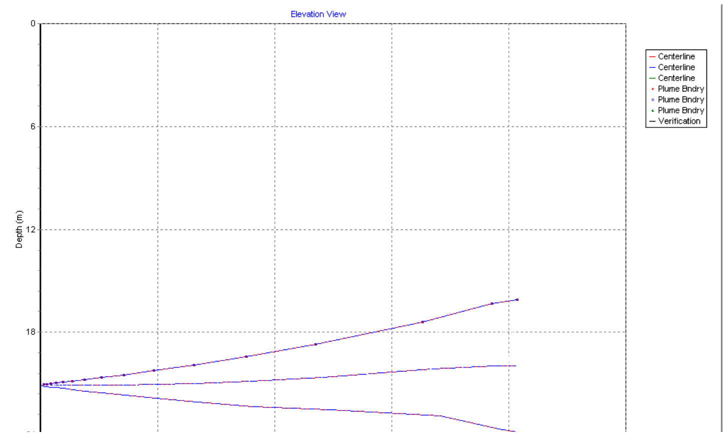

Figure 4. Haines Discharge Plume Centerline and Boundary Profile View from Side

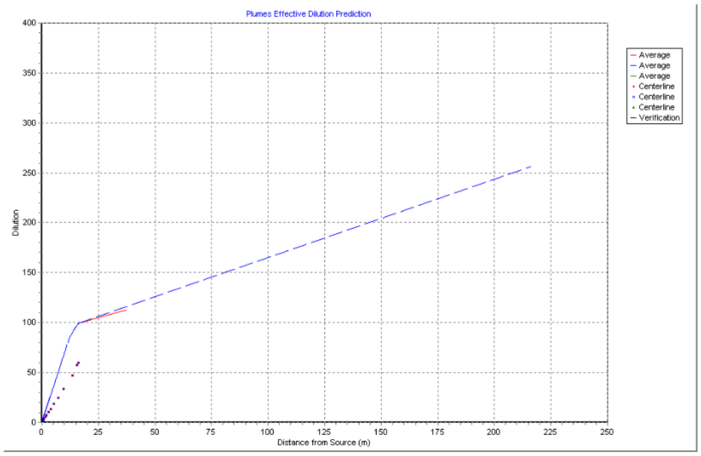

Figure 5. Haines Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

KETCHIKAN

The wastewater treated at Ketchikan is discharged 221 m offshore of Charcoal Point in the Tongass Narrows (Figure 6), at a depth of 29.9 m (MLLW). Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2.

Figure 6. Aerial View of the POTW Outfall Location at Ketchikan

Charcoal Point is at the narrowest width of the Narrows and is approximately 400 m wide and 34 m deep. According to the 2000 Permit application, the Tongass Narrows has a net northwest seaward exchange (away from the City and Pennock Island) with the Gulf of Alaska. Strong currents (that do not vary seasonally) provide vertical mixing in Tongass Narrows, minimizing the vertical density gradient and preventing stratification. Ambient tidal current data were collected with a current meter deployed near shore in December 1988 to verify published Tidal Current Table predictions. The data collected indicate that the flood tide current velocity was 34 cm/s, while the ebb tide currents was 1 cm/s in both directions. NOAA 6-minute tidal current predictions from East of Airport (SEA0711) were used to calculate the 10^{th} percentile and average tidal current velocities at a depth of 87 ft. (26.5 m; Table 2). The 10^{th} percentile current velocity used for modeling was 5.9 cm/s, while the average ebb and flood tidal velocities were 49.2 and 20.1 cm/s.

Preliminary initial dilution simulations made with UM3 for five available ambient profiles, determined that the July 1997 vertical profile from Site 3 (Figure 7) was limiting in terms of minimizing effluent dilution. As noted previously, the diffuser at Ketchikan was a hybrid, consisting of five 6-inch ports on a manifold and a single 12-inch port. These were modeled separately, and initial simulations with both UM3 and DKHW demonstrated that effluent dilution from the single 12-inch port was lower than from the five, 6-inch ports. UM3 gave more conservative dilution predictions (see Table 4, simulations 5 vs. 6), so that initial mixing model was selected for further analysis at Ketchikan.

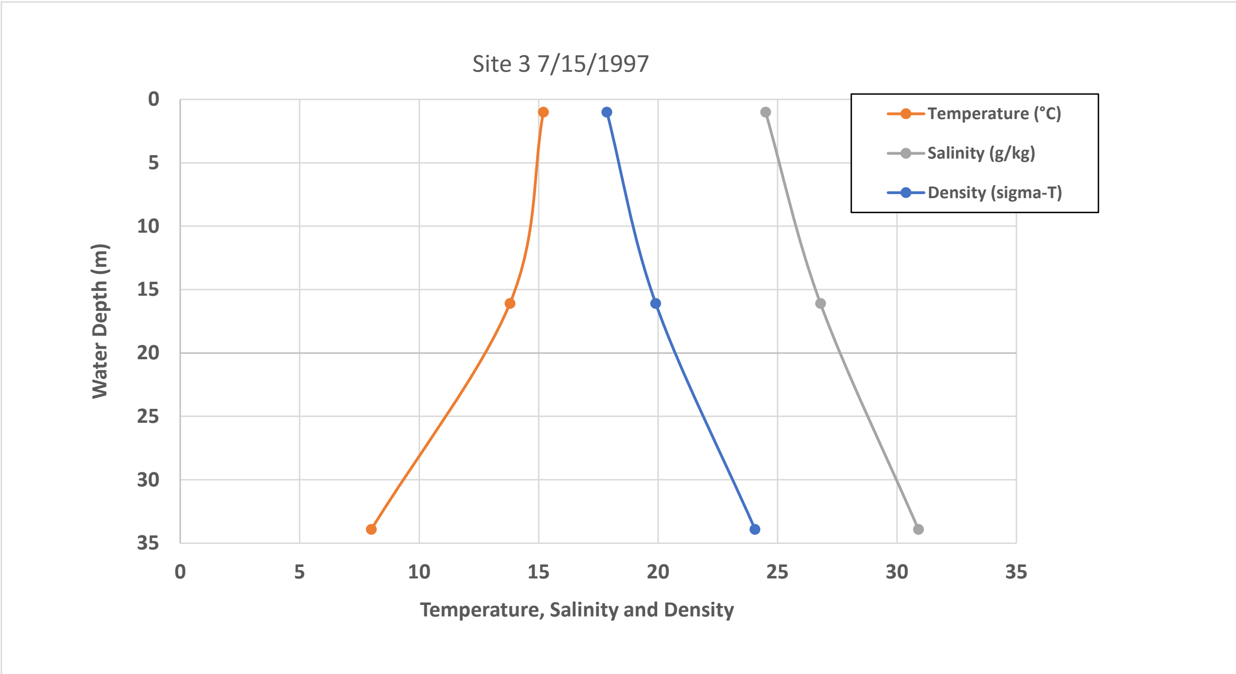

Figure 7. Vertical Ambient Profile of Temperature, Salinity and Density in Ketchikan Mixing Zone Resulting in Least Mixing.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Ketchikan on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 4 (simulations 20 vs. 31 and 32).

Dilution factors at distances of 1*depth to 10*depth range from 52 to 179 (Table 4, simulations 17-20). It should be noted that the 10*depth distance (299 m) is greater than the distance from the diffuser to shore (221 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 8 (plan view from above of the discharge plume boundary), 9 (profile view from the side of the discharge plume centerline and boundary) and 10 (discharge plume average and centerline dilution vs. distance from the outfall). Note that these figures include dilution model predictions for both the single 12-inch port and the five 6-inch ports. As shown in Table 4, the plume was trapped at a depth of 22 m by the ambient density stratification, the initial mixing region extended 13 m from the outfall. The travel time to the mixing zone boundaries ranged from 5 minutes (MZ=1*depth) to 81 minutes (MZ=10*depth). A dilution factor of 51 was predicted for the boundary of the initial mixing region and at the distance to the shore (221 m) the DF was 141.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature[12], current velocity and direction, and discharge flow rate) is demonstrated in simulations 22-30 (Table 4). Of these parameters, DFs were most sensitive to variation in ambient velocity (simulations 23-26).

[12] The alternative effluent temperature used for sensitivity analysis was the average of maximum monthly effluent temperatures (no monthly averages in DMR).

Table 4. Ketchikan Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Ketchikan 2000	UM3/FF	29.9	12" port	14	73	75	19	15	4
2. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	117	123	22	12	5
3. " "	Ketchikan Pier 12/1988	UM3/FF	" "	12" port	14	158	168	7	17	4
4. " "	" "	UM3(half spacing)/FF	" "	5x6" ports	18	305	324	8	18	3
5. " "	Ketchikan site 3 7/1997	UM3/FF	" "	12" port; limiting	14	52	54	22	13	5
6. " "	" "	DKHW/FF	" "	12" port	14	79	79	24	12	5
7. " "	" "	UM3(DS only, 3 ports x7.35")/FF	" "	5x6" ports	17	60	62	23	12	5
8. " "	Ketchikan site 3 9/1997	UM3/FF	" "	12" port	14	99	104	14	15	4
9. " "	Ketchikan site 3 8/1997	UM3/FF	" "	12" port	13	106	112	12	14	4
10. " "	Ketchikan site 3 7/1996	UM3/FF	" "	12" port	13	99	104	14	15	4
11. " "	Ketchikan site 3 8/1996	UM3/FF	" "	12" port	14	79	83	18	15	4

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
12. " "	Ketchikan site 3 9/1996	UM3/FF	" "	12" port	14	101	106	15	16	4
13. " "	Ketchikan site 3 7/1998	UM3/FF	" "	12" port	14	89	93	16	6	4
14. " "	Ketchikan site 3 8/1998	UM3/FF	" "	12" port	13	112	118	13	17	4
15. " "	Ketchikan site 3 9/1998	UM3/FF	" "	12" port	14	92	97	16	16	4
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:										
16. MZ= initial mixing region	Ketchikan 3 7/1997	UM3	13	12" port	14	**51**	52	22		1
17. MZ=1*depth	Ketchikan 3 7/1997	UM3/FF-LED	29.9	" "	14	**52**	52	22	13	5
18. MZ=2*depth	" "	" "	59.8	" "	14	**62**	63	22	13	13
19. MZ=5*depth	" "	" "	149.5	" "	14	**105**	106	22	13	39
20. MZ=10*depth	" "	" "	299[13]	" "	14	**179**	180	22	13	81
21. MZ=distance to nearest shore	" "	" "	221	" "	14	**141**	141	22	13	59
Model sensitivity:										
22. avg. effluent T=14.6° C	Ketchikan 3 7/1997	UM3/FF-LED	29.9	12" port	14	52	52	22	13	5

[13] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Diffuser port(s)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
23. ½*current v=2.95 cm/s	" "	" "	" "	" "	14	54	54	20	13	10
24. ¼ *current v=1.475 cm/s	" "	" "	" "	" "	14	67	67	20	13	19
25. 2*current v=11.8 cm/s	" "	" "	" "	" "	14	88	88	24	14	2
26. average current v=49.2 cm/s	" "	UM3	" "	" "	14	179	180	27	30	1
27. reverse current direction=320°	" "	UM3/FF-LED	" "	" "	14	47	47	22	10	6
28. Q/4=0.864 MGD	" "	" "	" "	" "	4	72	72	22	6	7
29. Q/2=1.728 MGD	" "	" "	" "	" "	7	58	59	22	8	6
30. 2*Q=6.912 MGD	" "	" "	" "	" "	28	56	57	23	20	3
Far-field model sensitivity to diffusion parameter:										
31. alpha=0.0001	Ketchikan 3 7/1997	UM3/FF	299	12" port	14	94	94	22	13	81
32. alpha=0.000453	" "	" "	" "	" "	14	396	398	22	13	81

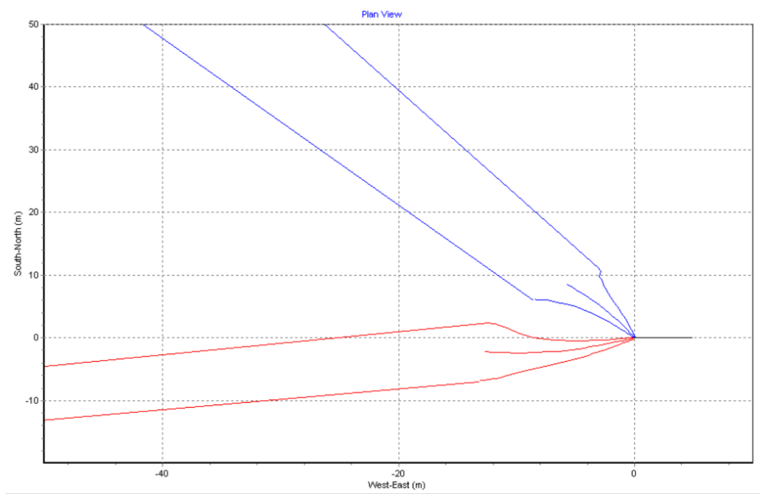

Figure 8. Ketchikan Discharge Plume Boundary Plan View from Above
(plume from 12-inch port is red; plume from five 6-inch ports is blue)

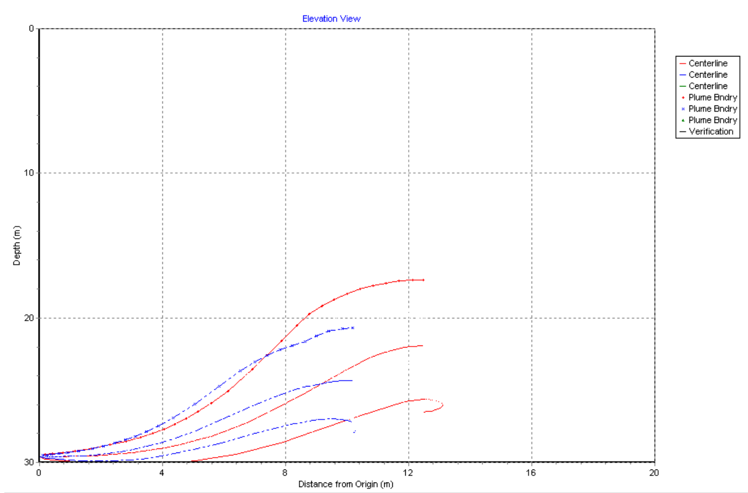

Figure 9. Ketchikan Discharge Plume Centerline and Boundary Profile View from Side

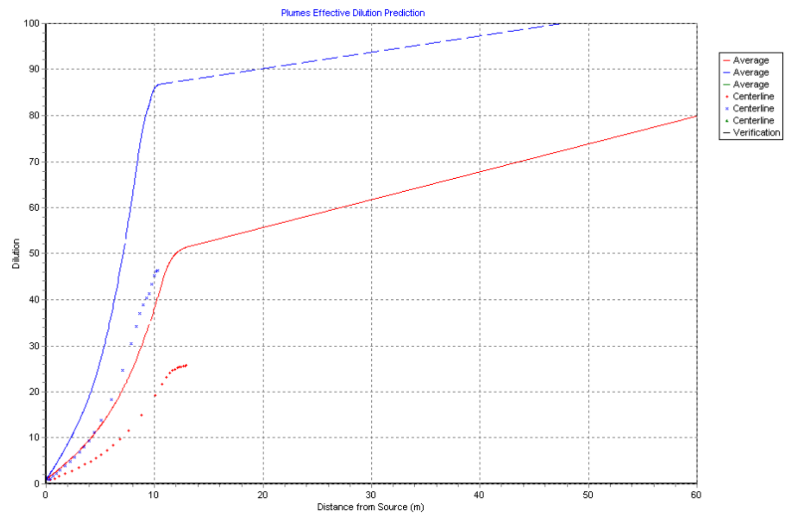

Figure 10. Ketchikan discharge plume average and centerline dilution vs. distance from outfall
Figure is based on graphic output by VP; DFs in far field (beyond 13 m for the 12-inch port) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity.

PETERSBURG

Wastewater treated at Petersburg is discharged 366 m offshore in Frederick Sound (Figure 11), from a two-port diffuser at a depth of 18.3 m (MLLW). The permitted maximum flow is 3.6 MGD. Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. The port spacing at Petersburg is uncertain (somewhere in the range of 10 to 34 ft.) due to only two of five diffuser ports being open. The models predicted lower DFs for the narrowest port spacing (10 ft.), so that spacing was used for all model simulations.

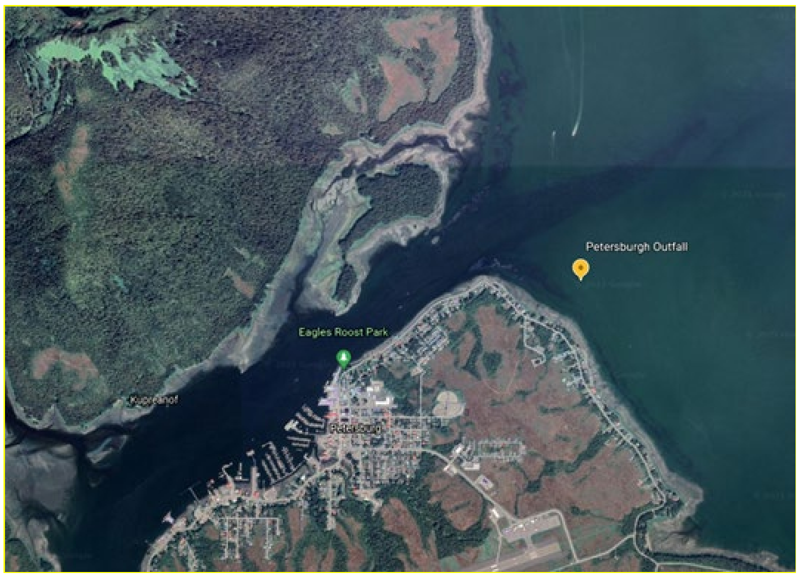

Figure 11. Aerial View of the POTW Outfall Location at Petersburg

Frederick Sound is connected to the Pacific Ocean via Chatham Strait to the northwest and Dry Strait/Sumner Strait to the southeast. According to the 1990 permit questionnaire, surface water densities near the outfall vary due to freshwater inputs from nearby streams. Maximum freshwater input to Frederick Sound occurs in summer (June or July) and minimum freshwater input occurs in March. The freshwater input is due primarily to the combined flows of the Stikine and Iskut Rivers. Currents generally flow northwestward in Frederick Sound with southwestward flows during large tides. NOAA tidal current predictions for nearby Cosmos Point (PCT3811) were used to calculate the 10^{th} percentile current velocity used for modeling, 1.6 cm/s, and the average ebb and flood tidal velocities, 10.4 and 7.8 cm/s. According to the questionnaire, current velocities in the area are reportedly in the range of two to five knots (100 to 260 cm/s), 10 to 100 times larger than the velocities calculated from NOAA tidal current predictions and used for modeling. This discrepancy in the magnitude of ambient velocities could not be resolved given the information available, but may warrant further inquiry.

Preliminary initial dilution simulations made with UM3 for eight available ambient profiles sampled at two ZID boundary monitoring locations in January of 2002 and 2004, and August 2003 and 2005, determined that the August 2005 vertical profile from Site 1 (Figure 12) was limiting in terms of minimizing effluent dilution.

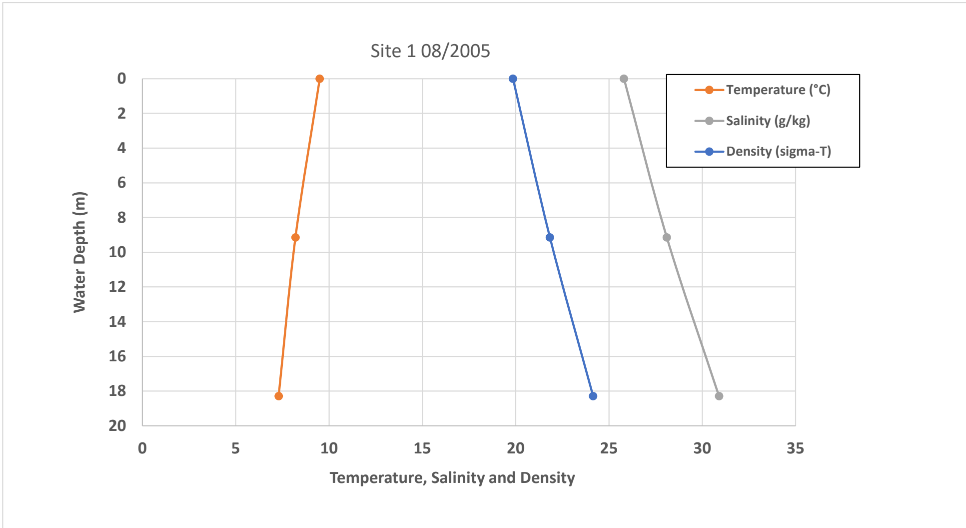

Figure 12. Vertical Ambient Profile of Temperature, Salinity and Density in Petersburg Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Petersburg are summarized in Table 5. The two applicable initial mixing models, UM3 and DKHW, gave very similar results for dilution at a distance of 1*depth (67 vs. 70). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Petersburg. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Dilution factors at distances of 1*depth to 10*depth range from 67 to 647 (Table 5, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 13 (plan view from above of the discharge plume boundary), 14 (profile view from the side of the discharge plume centerline and boundary) and 15 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 5, the plume was trapped at a depth of 14 m by the ambient density stratification, the initial mixing region extended 23 m from the outfall, and the travel time to the mixing zone boundaries ranged from 1 minute (MZ=1*depth) to 167 minutes (MZ=10*depth). A dilution factor of 74 was predicted for the boundary of the initial mixing region and at the distance to the shore (366 m) the DF was 1720.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 5). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 21-24). Sensitivity of the far-field model to bounding values of the diffusion parameter α (alpha) was also found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Table 5. Petersburg Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
1. MZ=1*depth	Petersburg 1 8/2005	UM3	18.3	114	67	67	15	>18.3	
2. " "	" "	DKHW	18.3	114	70	70	14	>18.3	
3. " "	Petersburg 1 8/2003	UM3	18.3	95	72	73	12	>18.3	
4. " "	Petersburg 1 1/2002	UM3	18.3	114	69	69	14	>18.3	
5. " "	Petersburg 2 1/2002	UM3	18.3	113	69	69	14	>18.3	
6. " "	Petersburg 1 1/2004	UM3	18.3	114	69	69	14	>18.3	
7. " "	Petersburg 2 1/2004	UM3	18.3	114	69	69	14	>18.3	
8. " "	Petersburg 2 8/2003	UM3	18.3	94	72	72	12	>18.3	
9. " "	Petersburg 2 8/2005	UM3	18.3	116	68	68	15	>18.3	
Dilution at different distances:									
10. MZ= initial mixing region	Petersburg 1 8/2005	UM3	23	115	**74**	75	14		1
11. MZ=1*depth	" "	UM3	18.3	115	**67**	67	15	>18.3	1
12. MZ=2*depth	" "	UM3/FF	36.6	115	**90**	90	14	23	15
13. MZ=5*depth	" "	UM3/FF	91.5	115	**256**	257	14	23	72
14. MZ=10*depth	" "	UM3/FF	183	115	**647**	650	14	23	167
15. MZ=distance to nearest shore	" "	UM3/FF	366	115	**1720**	1730	14	23	358

[14] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[14]
Model sensitivity:									
16. avg. effluent T=13.2° C	Petersburg 1 8/2005	UM3	18.3	115	67	68	15	>18.3	
17. ½*current v=0.8 cm/s	" "	UM3	18.3	115	66	66	15	>18.3	
18. 2*current v=3.2 cm/s	" "	UM3	18.3	115	70	70	15	>18.3	
19. average current v=10.4 cm/s	" "	UM3	18.3	115	80	81	16	>18.3	
20. reverse current direction=300°	" "	UM3	18.3	115	66	66	15	>18.3	
21. average Q=0.43 MGD	" "	UM3/FF	18.3	14	81	82	12	6	13
22. Q/4=0.9 MGD	" "	UM3/FF	18.3	29	68	69	13	9	9
23. Q/2=1.8 MGD	" "	UM3/FF	18.3	57	65	65	14	15	4
24. 2*Q=7.2 MGD	" "	UM3	18.3	229	65	65	17	>18.3	
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Petersburg 1 8/2005	UM3/FF	183	114	202	203	14	23	167
26. alpha=0.000453	" "	UM3/FF	183	114	1090	1091	14	23	167
27. Linear eddy diffusivity	" "	UM3/FF	183	114	397	399	14	23	167

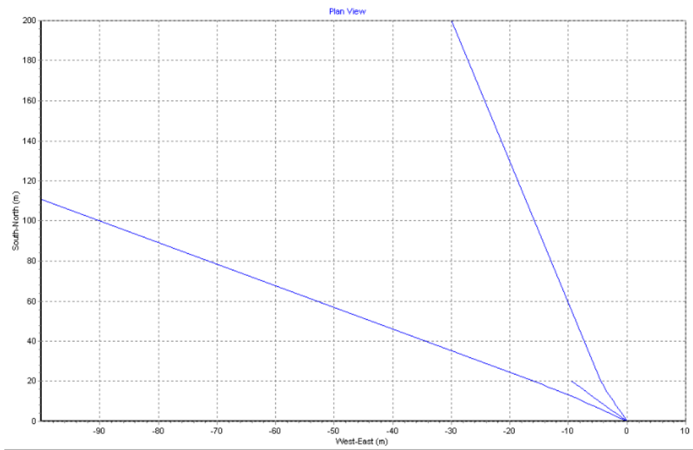

Figure 13. Petersburg Discharge Plume Boundary Plan View from Above

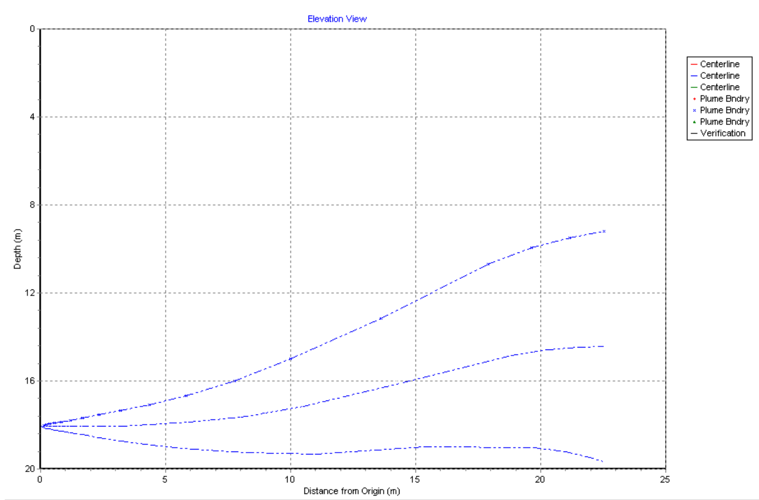

Figure 14. Petersburg Discharge Plume Centerline and Boundary Profile View from Side

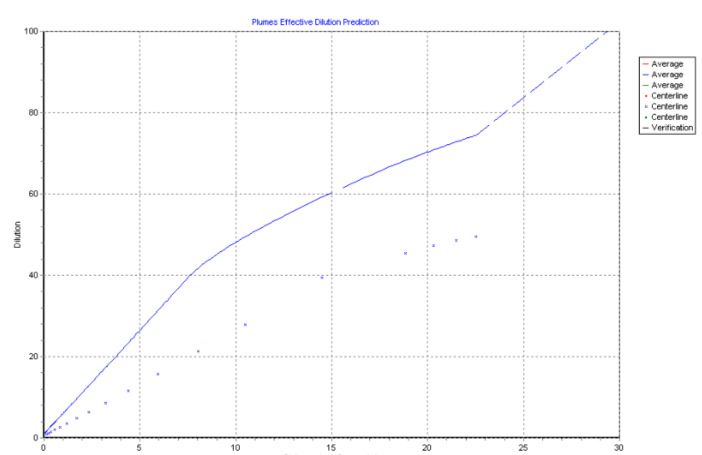

Figure 15. Petersburg Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SITKA

The wastewater treated at Sitka is discharged 114 m offshore in the Middle Channel of Sitka Sound (Figure 16), from a 16-port diffuser at a depth of 24.4 m (MLLW). The permitted maximum flow is 5.3 MGD.

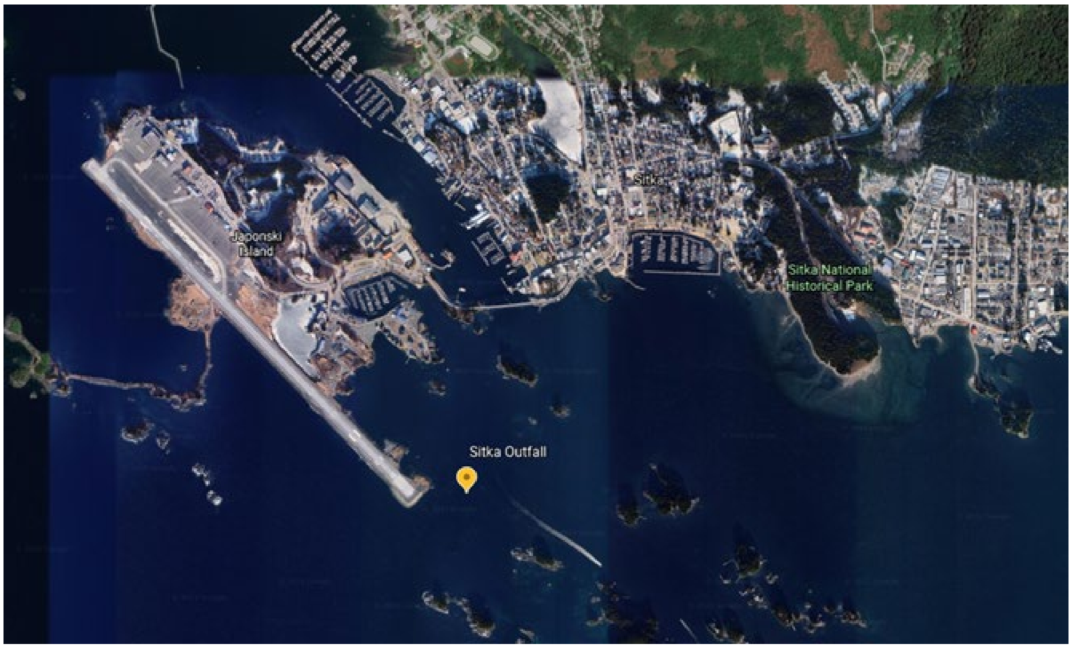

Figure 16. Aerial View of the POTW Outfall Location at Sitka

According to the permit fact sheet, the Middle Channel has relatively weak tidal currents, rotating in a clockwise pattern, which are superimposed on the seaward flow of fresh water in Sitka Sound. The net current is toward the southeast and included an easterly wind-driven component. The direction of transport of effluent from the outfall varies, depending upon the tidal stage and direction of prevailing winds. NOAA tidal current predictions for Sitka Harbor, Channel off Harbor Island (PCT4166) were used to calculate the 10^{th} percentile current velocity used for modeling, 1.7 cm/s, and the average ebb and flood tidal velocities, 10.3 and 8.0 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Detailed vertical ambient profiles were only available for one location (Site C, a reference station west of the outfall) that was in sampled in the months of April and July in 2010 and 2015. Preliminary initial dilution simulations made with UM3 for these four available ambient profiles, determined that the July 2010 vertical profile from Site C (Figure 17) was limiting in terms of minimizing effluent dilution (Table 6, simulations 1, 2, 8 and 9).

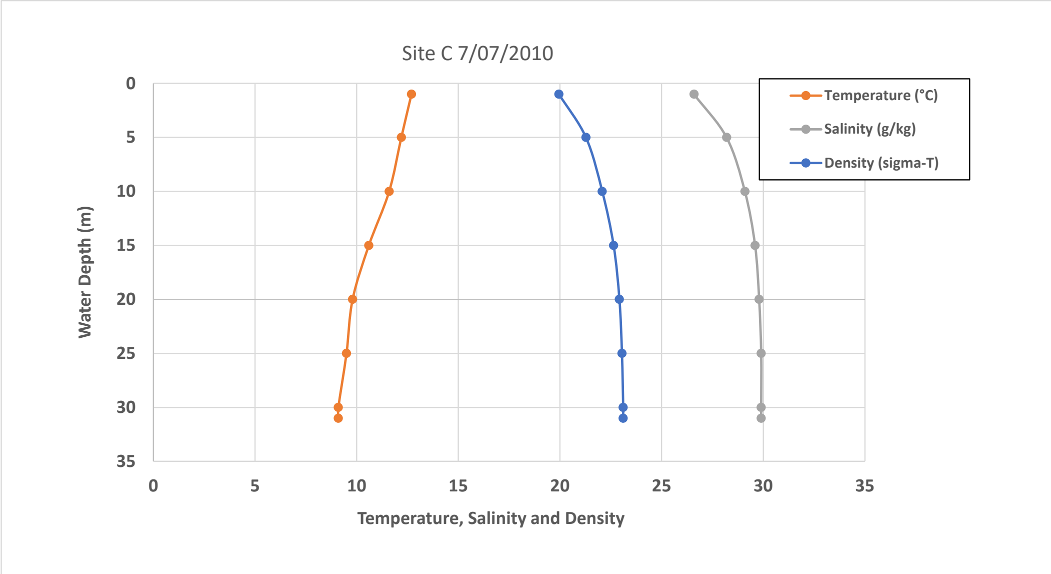

Figure 17. Vertical Ambient Profile of Temperature, Salinity and Density in Sitka Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Sitka are summarized in Table 6. The two initial mixing models, DKHW and UM3, combined with the Brooks far-field model gave similar results for dilution at a distance of 1*depth (sims. 2 and 5); simulation results for the downstream-only cross-diffuser merging approach and the third initial mixing model, NRFIELD, also fell within this range of DFs. DKHW gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Sitka.

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Sitka on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 6 (simulations 14 vs. 25 and 26).

Dilution factors at distances of 1*depth to 10*depth range from 87 to 227 (Table 6, simulations 11-14); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 5*depth and 10*depth distances (122 and 244 m) are greater than the distance from the diffuser to shore (114 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 18 (plan view from above of the discharge plume boundary), 19 (profile view from the side of the discharge plume centerline and boundary) and 20 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 6, the plume was trapped at a depth of 10 m by the ambient density stratification, the initial mixing region extended 6.9 m from the outfall, and the travel time to the mixing zone boundaries ranged from 17 minutes (MZ=1*depth) to 232 minutes (MZ=10*depth). A dilution factor of 86 was predicted for the boundary of the initial mixing region and at the distance to the shore (114 m) the DF was 138.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 6). DFs were moderately sensitive to variation in ambient velocity (DFs increase with velocity, simulations 17-19) and effluent flow rate (DFs decrease with Q, simulations 22-24).

Table 6. Sitka Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
1. MZ=1*depth	Sitka C 7/2015	UM3(half spacing)/FF	24.4	11	131	133	9	7	17
2. " "	Sitka C 7/2010	" "	24.4	12	118	119	12	6	18
3. " "	Sitka C 7/2010	" "	16.0	12	113	114	12	6	10
4. " "	Sitka C 7/2010	NRFIELD	16.0	12	89		10		
5. " "	Sitka C 7/2010	DKHW(half spacing)/FF	24.4	12	87	87	10	7	17
6. " "	" ";	UM3(DS-only, 8 portsx5.3")/FF	24.4	11	109	110	11	7	17
7. " "	" "	DKHW(DS-only, 8 portsx5.3")/FF	24.4	11	90	90	10	8	16
8. " "	Sitka C 4/2010	UM3(half-spacing)/FF	24.4	12	179	181	4	7	17
9. " "	Sitka C 4/2015	" "	24.4	11	172	174	5	7	17
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
10. MZ= initial mixing region	Sitka C 7/2010	DKHW(half-spacing)	6.9	12	**86**	86			1
11. MZ=1*depth	" "	DKHW(half-spacing)/FF-LED	24.4	12	**87**	87	10	7	17
12. MZ=2*depth	" "	" "	48.8	12	**97**	97	10	7	41
13. MZ=5*depth	" "	" "	122[16]	12	**143**	143	10	7	113
14. MZ=10*depth	" "	" "	244[16]	12	**227**	227	10	7	232

[15] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.
[16] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[15]
15. MZ=distance to nearest shore	" "	" "	114	12	**138**	138	10	7	105
Model sensitivity:									
16. avg. effluent T=14° C	Sitka C 7/2010	DKHW(half-spacing)/FF-LED	24.4	12	87	87	10	7	17
17. ½*current v=0.85 cm/s	" "	" "	" "	12	79	79	9	7	35
18. 2*current v=3.4 cm/s	" "	" "	" "	12	119	119	11	9	8
19. average current v=10.3cm/s	" "	" "	" "	12	187	187	15	22	0.5
20. reverse current direction=45°	" "	" "	" "	12	87	87	10	7	17
21. current dir +30°	" "	" "	" "	12	131	131	12	7	17
22. average Q=0.98 MGD	" "	" "	" "	2	208	208	15	4	20
23. Q/2=2.65 MGD	" "	" "	" "	6	121	121	12	5	19
24. 2*Q=10.6 MGD	" "	" "	" "	23	66	66	8	12	12
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Sitka C 7/2010	DKHW(half-spacing)/FF	244	12	126	126	10	7	233
26. alpha=0.000453	" "	" "	" "	12	426	426	10	7	233

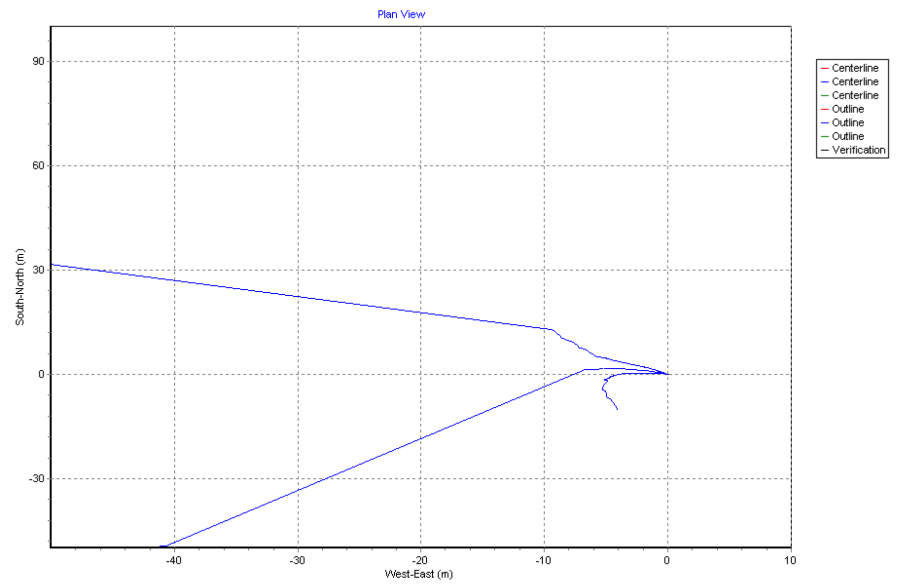

Figure 18. Sitka Discharge Plume Boundary Plan View from Above

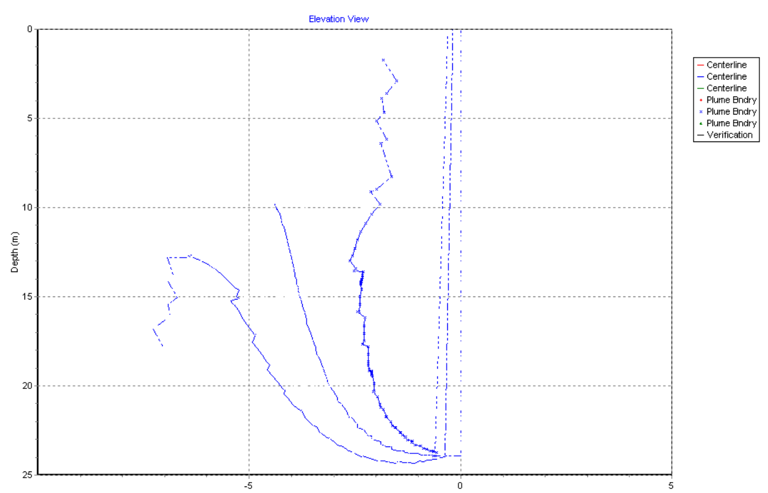

Figure 19. Sitka Discharge Plume Centerline and Boundary Profile View from Side

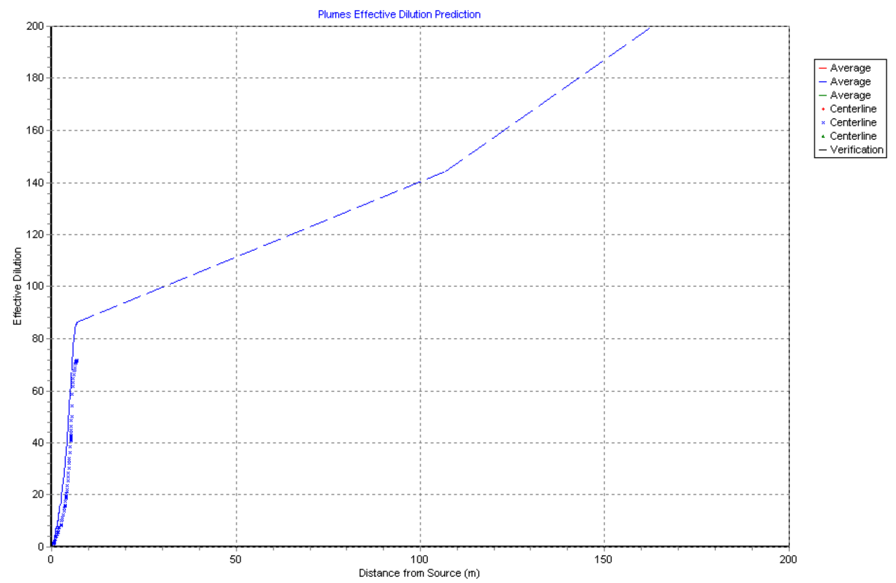

Figure 20. Sitka Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 7 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity).

SKAGWAY

Wastewater treated at Skagway is discharged 125 m offshore in Tiaya Inlet (Figure 21), at a depth of 18.3 m (MLLW), from an 8-port diffuser. The permitted maximum flow rate is 0.63 MGD.

Figure 21. Aerial View of the POTW Outfall Location at Skagway

According to the permit fact sheet, Taiya Inlet is a deep fjord with a 457 m average depth. Taiya Inlet supports a classic fjord-type, two-layer circulation, with a large saline lower layer and a very thin upper brackish layer. The circulation of the inlet is dependent on tides and freshwater flow into the inlet. There are no obstructions to impede circulation near the outfall. Stratification in Taiya Inlet is dependent on freshwater inflows from the Taiya and Skagway Rivers with the highest stratification typically occurs during the high runoff summer period from June through August. As noted in the 2007 permit reapplication, a small cross-current (2 cm/s) was present under stratified condition in a June 1999 temperature/salinity data set.

NOAA 6-minute tidal current predictions from Tiaya Inlet (SEA0825) were used to calculate the 10th percentile and average tidal current velocities (Table 2). The 10th percentile current velocity used for modeling was 1.4 cm/s, while the average ebb and flood tidal velocities were 6.9 and 12.2 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Tiaya Inlet were available for five locations that were sampled in October 2002, July and August 2004 and June 2005. Preliminary initial dilution simulations made with UM3 for all available profiles, determined that the June 2005 vertical profile measured at site 1 (shown in Figure 22) was limiting in terms of minimizing effluent dilution[17]. That profile was used for all subsequent dilution modeling at Skagway.

[17] A different vertical profile measured in June 2005 at site 5 (a site in the cruise ship terminal harbor nearest to freshwater inflow from the Skagway River) actually produced smaller DF predictions. However, the unusually low

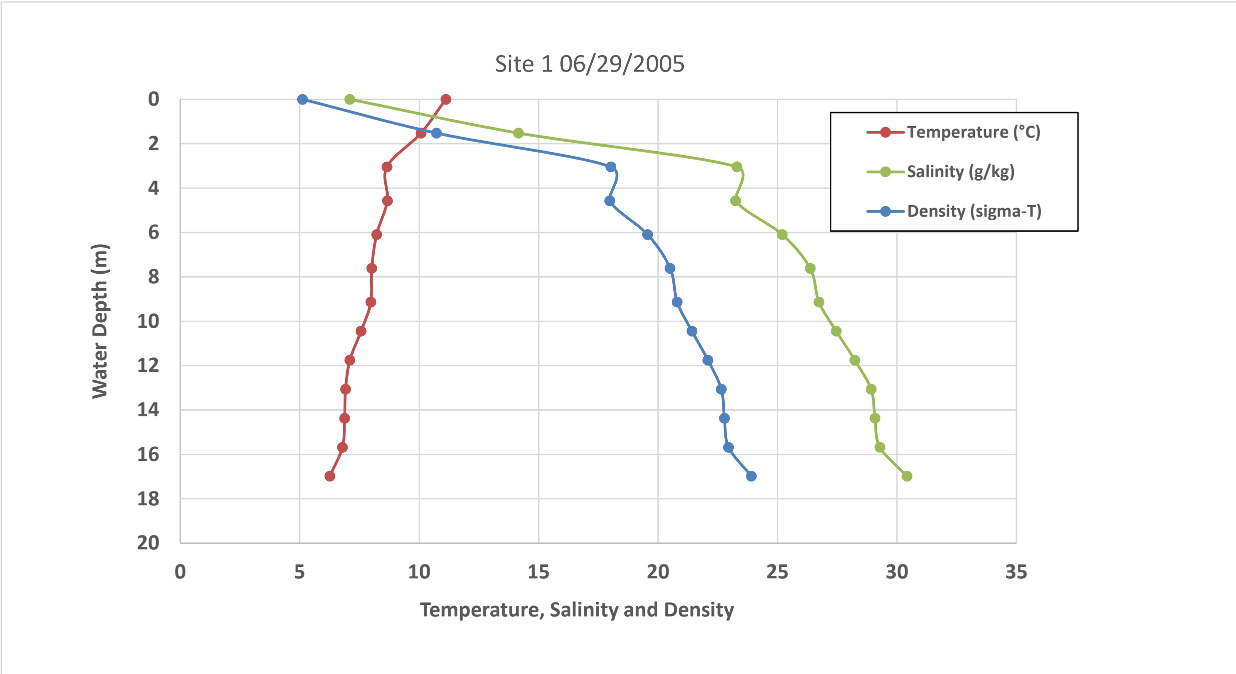

Figure 22. Vertical Ambient Profile of Temperature, Salinity and Density in Skagway Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Skagway are summarized in Table 7. Two of the applicable initial mixing models, UM3 and DKHW, gave similar results for dilution at a distance of 1*depth, for both cross-diffuser merging approaches (simulations 11-13). UM3 gave slightly more conservative dilution predictions, so that initial mixing model was selected for further analysis at Skagway. We also applied the third initial mixing model, NRFIELD, that predicted DFs reasonably comparable to UM3 (simulations 14 vs. 15) at a distance shorter than 1*depth (5.9 m).

The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Because the nearest shoreline was within ten times the plume diameter (calculated as the 10*depth mixing zone distance), it was assumed to impose a boundary constraint on far-field mixing. Following the guidance of Frick et al. (2010), we based far-field predictions at Skagway on the linear eddy diffusivity (LED) parameterization in FARFIELD. Sensitivity of DF predictions to this assumption is shown in Table 7 (simulations 23 vs. 33 and 34).

Dilution factors at distances of 1*depth to 10*depth range from 56 to 330 (Table 7, simulations 20-23); accounting for bacterial decay had a negligible effect on dilution factors. It should be noted that the 10*depth distance (183 m) is greater than the distance from the diffuser to shore (125 m), so it may be appropriate to truncate DF predictions at the distance to shore. Graphical examples of the dilution model predictions are presented in Figures 23 (plan view from above of the discharge plume boundary), 24

salinity of the upper 3-4 m of that profile led to difficulties in modeling dilution over the range of parameters and conditions of interest, so the site 1 June 2005 profile (that was the next most conservative in terms of limiting DFs) was used instead.

(profile view from the side of the discharge plume centerline and boundary) and 25 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 7, the plume was trapped at a depth of 15 m by the ambient density stratification, the initial mixing region extended 3.5 m from the outfall, and the travel time to the mixing zone boundaries ranged from 18 minutes (MZ=1*depth) to 214 minutes (MZ=10*depth). A dilution factor of 42 was predicted for the boundary of the initial mixing region and at the distance to the shore (125 m) the DF was 233.

The sensitivity of the initial mixing model to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 25-32 (Table 7). DFs were moderately sensitive to variation in ambient velocity (minimum DFs at velocities near 2 cm/s, simulations 26-28) and effluent flow rate (DFs decrease with Q, simulations 30-32).

Table 7. Skagway Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
1. MZ=1*depth	Skagway site 1 10/02	UM3 (half spacing) /FF	18.3	10	129	130	9	4	17
2. " "	Skagway site 2 10/02	" "	18.3	10	145	147	7	5	16
3. " "	Skagway site 4 10/02	" "	18.3	10	127	128	9	4	17
4. " "	Skagway site 1 7/2004	" "	18.3	10	94	95	12	4	18
5. " "	Skagway site 2 7/2004	" "	18.3	10	97	97	12	4	17
6. " "	Skagway site 4 7/2004	" "	18.3	10	79	79	13	4	17
7. " "	Skagway site 1 8/2004	" "	18.3	10	130	131	9	4	17
8. " "	Skagway site 2 8/2004	" "	18.3	10	113	114	10	4	17
9. " "	Skagway site 4 8/2004	" "	18.3	10	82	83	13	4	17
10. " "	Skagway site 1 6/2005	" "	18.3	10	59	59	15	3	18
11. " "	" "	UM3(DS-only, 4x3.95")/FF	18.3	10	59	59	14	5	16
12. " "	" "	DKHW(half spacing)/FF	18.3	10	62	63	16	3	18
13. " "	" "	DKHW(DS-only, 4x3.95")/FF	18.3	10	66	66	15	4	17
14. " "	" "	NRFIELD	5.9	10	39		14		
15. " "	" "	UM3(half spacing) /FF	5.9	10	42	42	15	3	3
16. " "	Skagway site 2 6/2005	" "	18.3	10	80	80	13	4	17
17. " "	Skagway site 4 6/2005	" "	18.3	10	100	100	12	4	17
18. " "	Skagway site 5 6/2005	" "	18.3	9	39	39	16	2	19
Linear eddy diffusivity (LED) far-field model and different mixing zone distances:									
19. MZ= initial mixing region	Skagway site 1 6/2005	UM3(half spacing)	3.5	10	**42**	42	15		0.7

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
20. MZ=1*depth	" "	UM3(half spacing) /FF-LED	18.3	10	**56**	56	15	3	18
21. MZ=2*depth	" "	" "	36.6	10	**86**	86	15	3	39
22. MZ=5*depth	" "	" "	91.5	10	**177**	178	15	3	105
23. MZ=10*depth	" "	" "	183[18]	10	**330**	331	15	3	214
24. MZ=distance to nearest shore	" "	" "	125	10	**233**	234	15	3	145
Model sensitivity:									
25. avg. effluent T=14.7° C	Skagway site 1 6/2005	UM3(half spacing) /FF-LED	18.3	10	56	56	15	3	18
26. ½*current v=0.7 cm/s	" "	" "	" "	10	76	76	15	3	36
27. 2*current v=2.8 cm/s	" "	" "	" "	10	52	52	15	4	9
28. average current v=12.2 cm/s	" "	" "	" "	10	101	101	17	6	2
29. reverse current direction=170°	" "	" "	" "	10	56	56	14	5	19
30. average Q=0.27 MGD				4	73	73	15	2	19
31. Q=0.5 MGD	" "	" "	" "	8	60	60	15	3	18

[18] Distance is greater than the distance from the diffuser to shore.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)
32. 2*Q=1.26 MGD	" "	" "	" "	20	49	49	15	5	16
Far-field model sensitivity to diffusion parameter:									
33. alpha=0.0001	Skagway site 1 6/2005	UM3(half spacing) /FF	183	10	173	174	15	3	214
34. alpha=0.000453	" "	" "	183	10	1100	1103	15	3	214

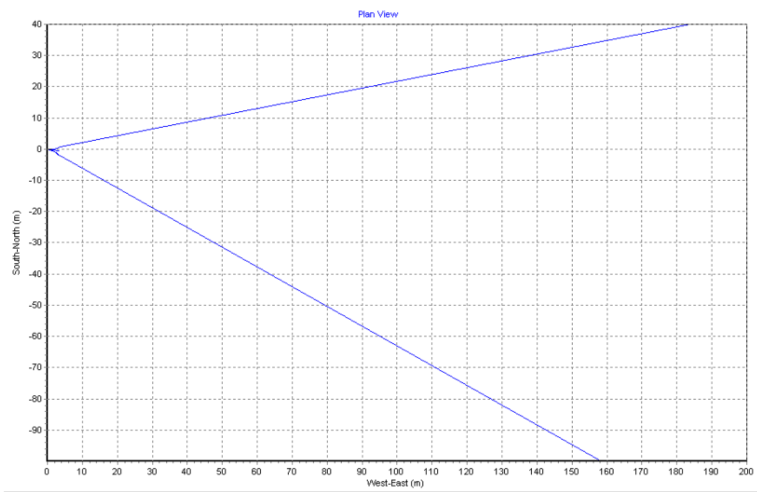

Figure 23. Skagway Discharge Plume Boundary Plan View from Above

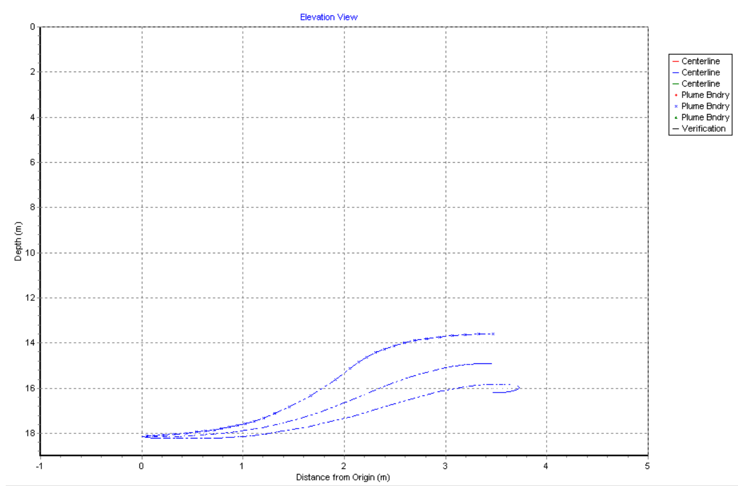

Figure 24. Skagway Discharge Plume Centerline and Boundary Profile View from Side

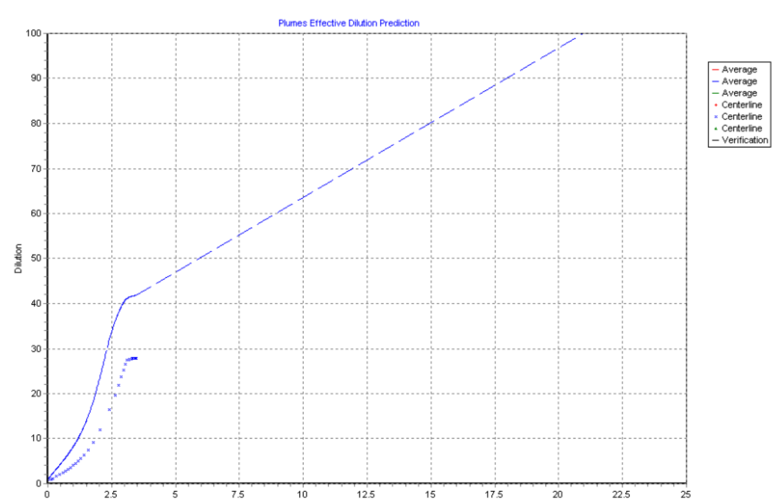

Figure 25. Skagway Discharge Plume Average and Centerline Dilution vs. Distance from Outfall (Figure is based on graphic output by VP; DFs in far field (beyond 3 m) are overestimated because VP assumes 4/3-power law instead of linear eddy diffusivity)

WRANGELL

The wastewater treated at Wrangell is discharged 457 m offshore in the Zimovia Strait (Figure 26), at a depth of 30.5 m (MLLW), from a 16-port diffuser. The permitted maximum flow rate is 3.0 MGD.

Figure 26. Aerial View of the POTW Outfall Location at Wrangell

According to the permit fact sheet, Zimovia Strait has a net northwest seaward exchange with the Gulf of Alaska. The maximum current velocity is around 51.4 cm/sec (1.0 knot) and the water circulation patterns do not vary seasonally. Strong currents provide vertical mixing, minimize the vertical density gradient, and prevent stratification. Also, according to the permit fact sheet, prior dilution modeling in Zimovia Strait used a conservative current speed of 2.35 cm/sec and no stratification. NOAA tidal current predictions for Wrangell Harbor (PCT3131) were used to calculate the 10^{th} percentile current velocity used for modeling, 4.0 cm/s, and the average ebb and flood tidal velocities, 20.8 and 23.5 cm/s.

Other site-specific data for the wastewater discharge, outfall, and ambient receiving water is summarized in Table 2. Vertical profiles of temperature and salinity measured in Zimovia strait at the ZID boundaries were available for two mixing zone locations that were sampled in August of 2015, 2016 and 2017. Preliminary initial dilution simulations made with UM3 for all profiles, determined that the vertical profile measured at station 4 in August of 2016 (shown in Figure 27) was limiting in terms of minimizing effluent dilution. That profile was used for all subsequent dilution modeling at Wrangell.

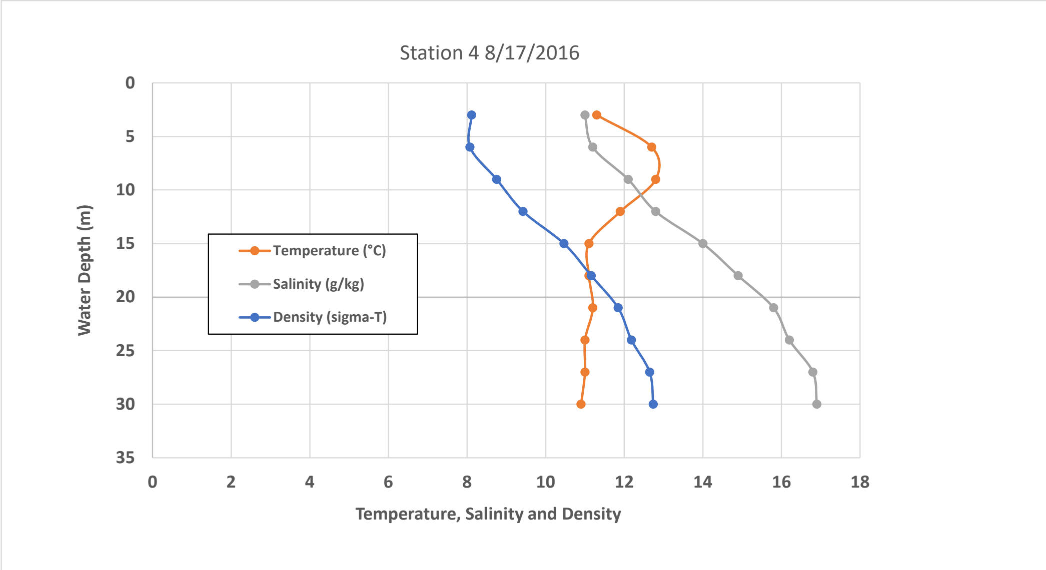

Figure 27. Vertical Ambient Profile of Temperature, Salinity and Density in Wrangell Mixing Zone Resulting in Least Mixing

Mixing zone dilution modeling results for Wrangell are summarized in Table 8. Two of the applicable initial mixing models, UM and DKHW, gave different results for dilution at a distance of 1*depth (30.5 m; simulations 3 vs. 4). The third initial mixing model, NRFIELD, predicted a lower DF at a distance shorter than 1*depth (16.8 m; simulations 5 vs. 6). UM3 gave more conservative DF results (simulation 7) when run using the downstream-only cross-diffuser merging, so we selected this approach for further analysis at Wrangell. The initial mixing model was combined with the Brooks far-field model to extend dilution predictions beyond the initial mixing region. Sensitivity of the far-field model to bounding values of the diffusion parameter α was found to have a significant effect on dilution factors, as was substituting the 4/3-power law with linear eddy diffusivity.

Dilution factors at distances of 1*depth to 10*depth range from 112 to 229 (Table 8, simulations 10-13); accounting for bacterial decay had a negligible effect on dilution factors. Graphical examples of the dilution model predictions are presented in Figures 28 (plan view from above of the discharge plume boundary), 29 (profile view from the side of the discharge plume centerline and boundary) and 30 (discharge plume average and centerline dilution vs. distance from the outfall). As shown in Table 8, the plume was trapped at a depth of 24 m by the ambient density stratification, the initial mixing region extended 12 m from the outfall, and the travel time to the mixing zone boundaries ranged from 8 minutes (MZ=1*depth) to 122 minutes (MZ=10*depth). A dilution factor of 112 was predicted for the boundary of the initial mixing region and at the distance to the shore (457 m) the DF was 323.

The initial mixing model was moderately sensitive to a number of inputs (effluent temperature, current velocity and direction, and discharge flow rate) is demonstrated in simulations 16-24 (Table 8). DFs were sensitive to variation in ambient velocity (dilution increasing with velocity, simulations 17-19) and effluent flow rate (dilution decreases with Q, simulations 21-24).

Table 8. Wrangell Mixing Zone Dilution Modeling Results

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
1. MZ=1*depth	Wrangell station 4 8/2015	UM3(half spacing)/FF	30.5	34	262	274	23	15	7
2. " "	Wrangell station 3 8/2016	" "	" "	33	232	243	23	13	8
3. " "	Wrangell station 4 8/2016	" "	" "	32	153	160	25	10	8
4. " "	" "	DKHW(half spacing)/FF	" "	32	228	228	26	11	8
5. " "	" "	UM3 (half spacing)/FF	16.8	32	153	157	25	10	3
6. " "	" "	NRFIELD	16.8	33	75		25		
7. " "	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	112	117	24	12	8
8. " "	Wrangell station 3 8/2017	UM3(half-spacing)/FF	" "	39	494	516	17	25	2
9. " "	Wrangell station 4 8/2017	" "	" "	40	743	791	6	21	4
Dilution at different distances:									
10. MZ= initial mixing region	Wrangell station 4 8/2016	UM3 (DS-only, 8x3.95")	12	33	**112**	113	24		2
11. MZ=1*depth	" "	UM3(DS-only, 8x3.95")/FF	30.5	33	**112**	113	24	12	8
12. MZ=2*depth	" "	" "	61	33	**115**	115	24	12	20
13. MZ=5*depth	" "	" "	152.5	33	**149**	149	24	12	59
14. MZ=10*depth	" "	" "	305	33	**229**	230	24	12	122

[19] Travel time to MZ boundary was calculated only for distances exceeding length of initial mixing region.

Model simulation	Ambient input	Model(s)	MZ distance (m)	Froude number	Dilution factor	Dilution factor w/ bacteria decay	Trapping depth (m)	Length of initial mixing region (m)	Travel time to MZ boundary (min)[19]
15. MZ=distance to nearest shore	" "	" "	457	33	**323**	325	24	12	185
Model sensitivity:									
16. avg. effluent T=17.3° C	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	30.5	33	112	112	24	12	8
17. ½*current v=2 cm/s	" "	" "	" "	33	86	86	24	11	16
18. 2*current v=8 cm/s	" "	" "	" "	33	198	199	25	15	3
19. ave. current v=23.5 cm/s	" "	UM3 (DS-only, 8x3.95")	" "	33	412	412	27	31	2
20. reverse current direction=270°	" "	UM3(DS-only, 8x3.95")/FF	" "	33	112	113	24	12	8
21. ave. Q=0.36 MGD	" "	" "	" "	3.9	243	244	26	5	11
22. Q/4=0.75 MGD	" "	" "	" "	8.1	161	161	25	6	10
23. Q/2=1.5 MGD	" "	" "	" "	16	125	126	25	8	9
24. 2*Q=6.0 MGD	" "	" "	" "	65	119	120	25	18	5
Far-field model sensitivity to diffusion parameter:									
25. alpha=0.0001	Wrangell station 4 8/2016	UM3(DS-only, 8x3.95")/FF	305	33	130	131	24	12	122
26. alpha=0.000453	" "	" "	" "	33	321	323	24	12	122
27. Linear eddy diffusivity	" "	" "	" "	33	203	204	24	12	122

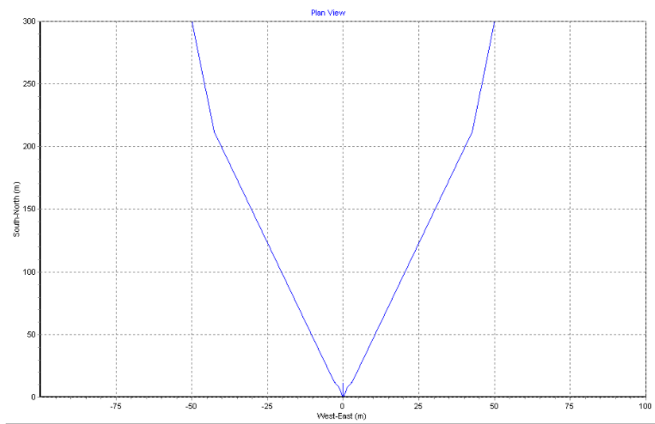

Figure 28. Wrangell Discharge Plume Boundary Plan View from Above

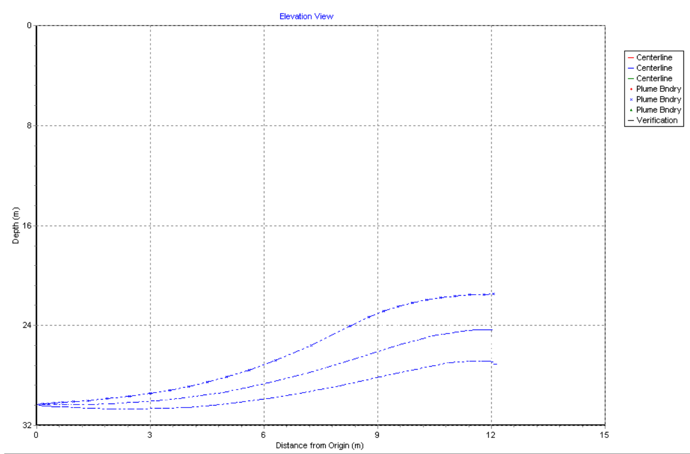

Figure 29. Wrangell Discharge Plume Centerline and Boundary Profile View from Side

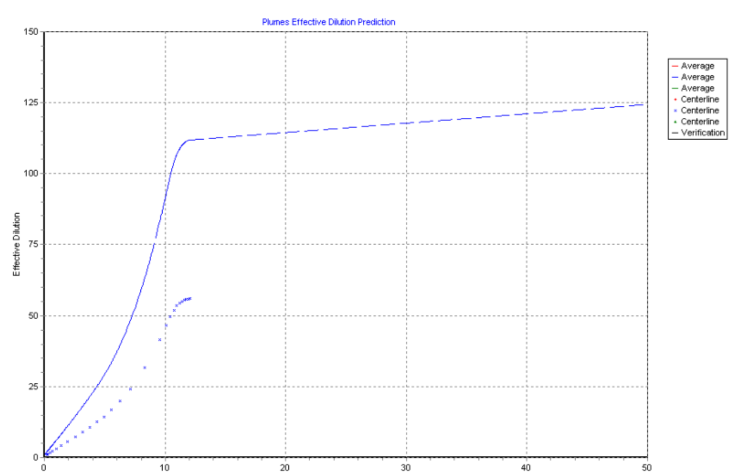

Figure 30. Wrangell Discharge Plume Average and Centerline Dilution vs. Distance from Outfall

SUMMARY

A summary of the average dilution predictions at various distances (corresponding to 1-10 times the depth of discharge) from the discharge point at each Alaskan mixing zone location is presented in Table 9. As indicated in this table, some of the distances exceed the distance from the outfall to the nearest shore. Under some conditions the tidal currents could direct the discharge plume towards the shore and, upon reaching this boundary, further mixing would likely not occur. The distance from the outfall to nearest shore at each location and the predicted DFs and travel times for these distances are presented in Table 10. The dilution predictions are also graphed as a function of distance from the outfall (Figure 31). In this figure, DFs for Ketchikan, Sitka and Skagway have been truncated at the distance to shore.

Table 9. Average Dilution Factor Predictions at Distances from the Discharge Point Corresponding to 1-10 Times the Depth of Discharge

Location	1*depth			2*depth			5*depth			10*depth		
	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)	Distance (m)	DF	Time (min)
Haines	21.3	100	4	43	136	19	107	330	65	213	766	143
Ketchikan	29.9	52	5	60	62	13	150	105	39	299*	179	81
Petersburg	18.3	67	1	37	90	15	92	256	72	183	647	167
Sitka	24.4	87	17	49	97	41	122*	143	113	244*	227	232
Skagway	18.3	56	18	37	86	39	92	177	105	183*	330	214
Wrangell	30.5	112	8	61	115	20	153	149	59	305	229	122

* Distance greater than the distance from the outfall to shore.

Table 10. Average Dilution Factor Predictions at the Distance from the Outfall to Shore

Location	Distance from outfall to shore (m)	DF at distance from outfall to shore	Travel time to shore (min)
Haines	549	2770	386
Ketchikan	221	141	59
Petersburg	366	1720	358
Sitka	114	138	105
Skagway	125	233	145
Wrangell	457	323	185

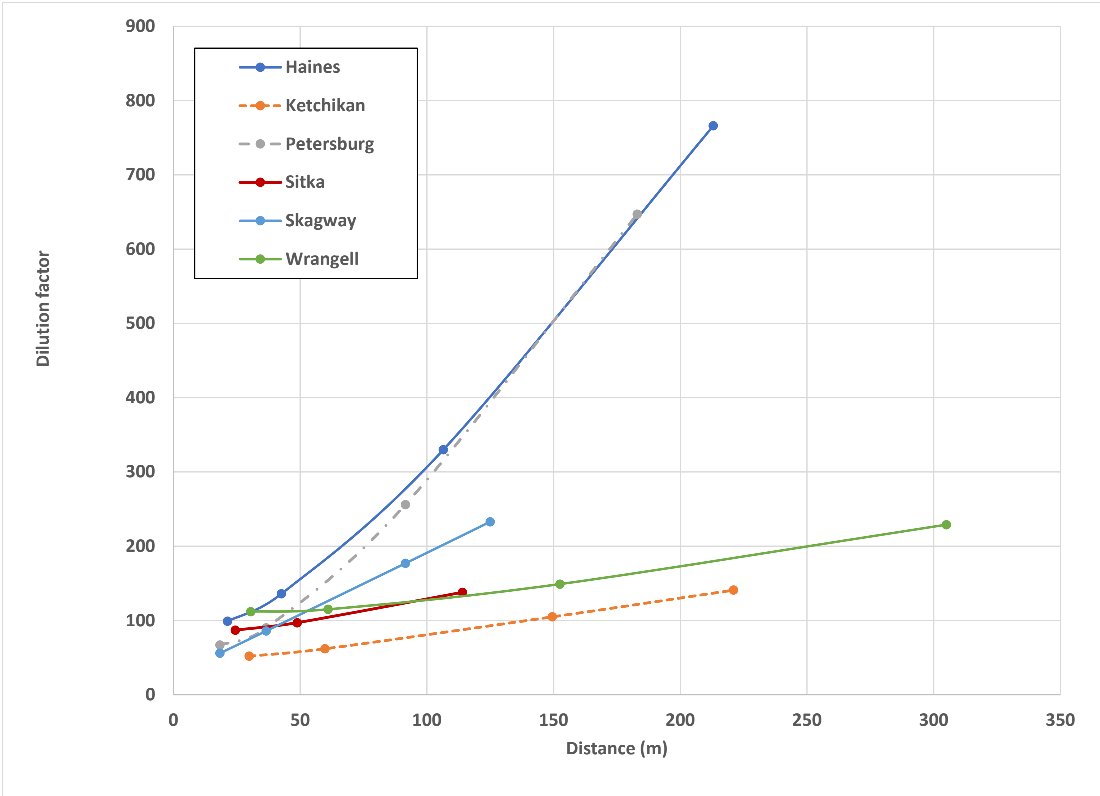

Figure 31. DF Predictions Graphed as a Function of Distance from the Outfall
(predictions are DFs for distances corresponding to 1-10 times the depth of discharge; in the cases of Ketchikan, Sitka and Skagway, DFs have been truncated at the distances to the shore)

A summary of the dilution factors predicted at the initial mixing region boundaries is presented in Table 11. For each location this table includes the distance to this boundary, the predicted DF and the travel times to the boundary. Compared to the depth-based distances in Table 9, the initial mixing region boundary distances are quite short, although the DFs at a distance of 1*depth are comparable (within 25%) of the initial mixing region dilution factors.

Table 11. Dilution Factor Predictions at Distances Equal to Initial Mixing Region Boundaries

Location	Initial Mixing Region Boundary (m)	DF	Travel Time to Boundary (min)
Haines	16	99	1
Ketchikan	13	51	1
Petersburg	23	74	1
Sitka	6.9	86	1
Skagway	3.5	42	0.7
Wrangell	12	112	2

The far-field model was also used to calculate the distances required to attain the FC criteria (i.e., the DFs in Table 1). These distances, presented in Table 11, range from 3.4 to 135 km to attain the 43/100 mL FC criterion and 7.2 to 420 km to attain the 14/100 mL FC criterion. These distances greatly exceed the mixing zone sizes certified by the state in the current wastewater discharge permits for the six POTW facilities.

Table 12. Dilution Factors and Mixing Zone Distances Required to Attain FC Criteria

Location	DF required to attain the 43/100 mL FC criterion	Distance to attain the 43/100 mL FC criterion (km)	DF required to attain the 14/100 mL FC criterion	Distance to attain the 14/100 mL FC criterion (km)
Haines	50,000	4.0	150,000	8.3
Ketchikan	67,000	135	210,000	420
Petersburg	47,000	3.4	140,000	7.2
Sitka	87,000	126	270,000	390
Skagway	60,000	36	190,000	114
Wrangell	4,400	3.9	14,000	8.9

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APPENDIX: VP AND FARFIELD[20] OUTPUT FOR EACH LOCATION

Haines (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Haines" memo4

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:19:37 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: --------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000192	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000194	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000193	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000193	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000193	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000193	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000193	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000193	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000193	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000193	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000192	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000192	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000192	0.023	90.00	0.0003	23.93584

[20] If required.

22.00 0.023 90.00 34.78 4.213 0.0 0.000192 0.023 90.00 0.0003 27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 21.300 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (m)
0 21.10 2.300 2.343 2.130E+6 1.000 0.0 0.0 0.0; 10.68 T-90hr,
100 21.10 2.300 23.86 208749.0 10.20 0.000 1.346 0.6058; 10.68 T-90hr,
160 21.03 2.300 77.28 63725.7 33.42 0.000 4.775 1.9614; bottom hit; 10.65 T-90hr,
200 20.49 2.300 166.7 28847.1 73.76 0.000 10.62 4.2261; 10.42 T-90hr,
204 20.37 2.300 179.9 26645.8 79.84 0.000 11.48 4.5599; trap level; 10.37 T-90hr,
205 20.34 2.300 183.3 26122.1 81.44 0.000 11.71 4.6475; merging; 10.36 T-90hr,
232 19.97 2.300 305.7 21392.8 99.34 0.000 16.27 7.7425; local maximum rise or fall; 10.20 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
21392.8 99.34 12.34 16.27 2.78E-4 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
20539.8 99.48 14.21 21.30 0.061 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
18354.2 113.1 20.80 37.57 0.258 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:19:40 AM. amb fills: 4
/ UM3. 6/23/2021 5:20:06 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.023 90.00 7.100 11.12 0.0 0.000194 0.023 90.00 0.0003 5.180276
1.523 0.023 90.00 14.16 10.08 0.0 0.000198 0.023 90.00 0.0003 10.78304
3.047 0.023 90.00 23.30 8.650 0.0 0.000197 0.023 90.00 0.0003 18.06627
4.570 0.023 90.00 23.25 8.670 0.0 0.000196 0.023 90.00 0.0003 18.02474
6.090 0.023 90.00 25.20 8.220 0.0 0.000196 0.023 90.00 0.0003 19.60292
7.617 0.023 90.00 26.37 8.020 0.0 0.000196 0.023 90.00 0.0003 20.54204
9.140 0.023 90.00 26.74 7.980 0.0 0.000196 0.023 90.00 0.0003 20.83621
10.45 0.023 90.00 27.46 7.570 0.0 0.000196 0.023 90.00 0.0003 21.45192

11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 90.000 0.0 0.0 2.0000 15.000 42.600 200.00 21.100 2.9000 0.0 15.800 2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

```
       Depth  Amb-cur   P-dia  Polutnt  Dilutn  x-posn  y-posn  Iso dia
Step    (m)   (cm/s)    (in) (col/dl)    ()      (m)     (m)      (m)
  0    21.10   2.300   2.343 2.130E+6   1.000    0.0     0.0   0.05935;  10.68 T-90hr,
 100   21.10   2.300   23.86 208749.0   10.20   0.000   1.346   0.6058;  10.68 T-90hr,
 160   21.03   2.300   77.28 63725.7    33.42   0.000   4.775   1.9614; bottom hit;  10.65 T-90hr,
 200   20.49   2.300   166.7 28847.1    73.76   0.000   10.62   4.2261;  10.42 T-90hr,
 204   20.37   2.300   179.9 26645.8    79.84   0.000   11.48   4.5599; trap level;  10.37 T-90hr,
 205   20.34   2.300   183.3 26122.1    81.44   0.000   11.71   4.6475; merging;  10.36 T-90hr,
 232   19.97   2.300   305.7 21392.8    99.34   0.000   16.27   7.7425; local maximum rise or fall;
10.20 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 21392.8   99.34   12.34   16.27 2.78E-4    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 19386.1   118.7   23.00   42.60   0.318    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
 15243.7   136.7   30.62   58.87   0.515    0.0   16.27   2.300   90.00 3.00E-4 6.2421E-5
```

count: 1
;
5:20:07 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	42.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.317995169	26.33	42.6	1.36E+02	1.56E+04	137

/ UM3. 6/23/2021 5:20:24 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	90.000	0.0	0.0	2.0000	15.000	106.50	200.00	21.100	2.9000	0.0	15.800	2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(m)	
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.05935;	10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058;	10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614;	bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261;	10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599;	trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475;	merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425;	local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)

21392.8	99.34	12.34	16.27	2.78E-4	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
16299.5	181.1	56.68	106.5	1.090	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5
10795.8	194.1	66.75	122.8	1.287	0.0	16.27	2.300	90.00	3.00E-4	6.2421E-5

count: 1
;
5:20:24 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	106.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo =	8.5548E-03	m^2/s	
			Beta =	3.6170E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.0897343	90.23	106.5	3.30E+02	6.43E+03	331

/ UM3. 6/23/2021 5:20:41 AM
Case 1; ambient file C:\Plumes20\Haines_Skagway_1_Jun05.006.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth (m)	Amb-cur (m/s)	Amb-dir (deg)	Amb-sal (psu)	Amb-tem (C)	Amb-pol (kg/kg)	Solar rad (s-1)	Far-spd (m/s)	Far-dir (deg)	Disprsn (m0.67/s2)	Density (sigma-T)
0.0	0.023	90.00	7.100	11.12	0.0	0.000194	0.023	90.00	0.0003	5.180276
1.523	0.023	90.00	14.16	10.08	0.0	0.000198	0.023	90.00	0.0003	10.78304
3.047	0.023	90.00	23.30	8.650	0.0	0.000197	0.023	90.00	0.0003	18.06627
4.570	0.023	90.00	23.25	8.670	0.0	0.000196	0.023	90.00	0.0003	18.02474
6.090	0.023	90.00	25.20	8.220	0.0	0.000196	0.023	90.00	0.0003	19.60292
7.617	0.023	90.00	26.37	8.020	0.0	0.000196	0.023	90.00	0.0003	20.54204
9.140	0.023	90.00	26.74	7.980	0.0	0.000196	0.023	90.00	0.0003	20.83621
10.45	0.023	90.00	27.46	7.570	0.0	0.000196	0.023	90.00	0.0003	21.45192
11.75	0.023	90.00	28.24	7.100	0.0	0.000196	0.023	90.00	0.0003	22.12180
13.06	0.023	90.00	28.92	6.920	0.0	0.000195	0.023	90.00	0.0003	22.67724
14.37	0.023	90.00	29.08	6.880	0.0	0.000195	0.023	90.00	0.0003	22.80770
15.68	0.023	90.00	29.29	6.790	0.0	0.000195	0.023	90.00	0.0003	22.98359
16.98	0.023	90.00	30.42	6.260	0.0	0.000195	0.023	90.00	0.0003	23.93584
22.00	0.023	90.00	34.78	4.213	0.0	0.000195	0.023	90.00	0.0003	27.61629

Diffuser table:

P-dia (in)	Ver angl (deg)	H-Angle (deg)	SourceX (m)	SourceY (m)	Ports ()	Spacing (ft)	MZ-dis (m)	Isoplth (concent)	P-depth (m)	Ttl-flo (MGD)	Eff-sal (psu)	Temp (C)	Polutnt (col/dl)
3.0000	0.0	90.000	0.0	0.0	2.0000	15.000	213.00	200.00	21.100	2.9000	0.0	15.800	2.13E+6

Simulation:
Froude No: 178.8; Strat No: 2.20E-3; Spcg No: 76.82; k: 992.9; eff den (sigmaT) -0.960860; eff vel 22.84(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Iso dia (m)	
0	21.10	2.300	2.343	2.130E+6	1.000	0.0	0.0	0.05935;	10.68 T-90hr,
100	21.10	2.300	23.86	208749.0	10.20	0.000	1.346	0.6058;	10.68 T-90hr,
160	21.03	2.300	77.28	63725.7	33.42	0.000	4.775	1.9614;	bottom hit; 10.65 T-90hr,
200	20.49	2.300	166.7	28847.1	73.76	0.000	10.62	4.2261;	10.42 T-90hr,
204	20.37	2.300	179.9	26645.8	79.84	0.000	11.48	4.5599;	trap level; 10.37 T-90hr,
205	20.34	2.300	183.3	26122.1	81.44	0.000	11.71	4.6475;	merging; 10.36 T-90hr,
232	19.97	2.300	305.7	21392.8	99.34	0.000	16.27	7.7425;	local maximum rise or fall; 10.20 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 16.274
Lmz(m): 16.274
forced entrain 1 1.873 1.132 7.764 1.000
Rate sec-1 0.00019515 dy-1 16.8607 kt: 0.000062421 Amb Sal 33.0175
Const Eddy Diffusivity. Farfield dispersion based on wastefield width of 12.34 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
21392.8 99.34 12.34 16.27 2.78E-4 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5

12646.5 246.9 121.4 200.0 2.219 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
8191.65 256.7 134.2 216.3 2.416 0.0 16.27 2.300 90.00 3.00E-4 6.2421E-5
count: 1
;
5:20:41 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	99.34	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	12.34	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	16.27	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	213	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.023	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.14E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 8.5548E-03 m^2/s
Beta = 3.6170E-01 unitless

	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	2.375966184	196.73	213	7.66E+02	2.77E+03	768

Ketchikan (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Ketchikan_1port" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:27:49 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000196	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	29.900	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2374;	13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410;	13.32 T-90hr,

200 27.61 5.900 135.6 1142.4 17.50 -6.017 -2.060 14.40 3.3681; 12.62 T-90hr,
249 24.16 5.900 233.0 562.5 35.49 -9.308 -2.435 34.83 5.6507; trap level; 11.26 T-90hr,
276 22.92 5.900 300.9 445.7 44.77 -10.56 -2.414 45.33 7.2032; begin overlap; 10.77 T-90hr,
300 22.48 5.900 333.7 414.4 48.13 -11.13 -2.377 50.59 7.9496; 10.60 T-90hr,
400 21.94 5.900 383.7 388.9 51.25 -12.54 -2.254 64.07 9.1014; 10.40 T-90hr,
417 21.94 5.900 385.5 387.6 51.42 -12.73 -2.235 65.91 9.1403; local maximum rise or fall; 10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
387.592 51.42 9.799 12.92 2.78E-4 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
372.140 52.31 12.10 29.90 0.0802 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
346.023 56.38 13.95 42.82 0.141 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
count: 1
;
5:27:49 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	29.9	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	6.2830E-03	m^2/s
Beta =	1.3053E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	7.99E-02	16.98	29.90	5.22E+01	3.82E+02	52

/ UM3. 6/23/2021 5:28:05 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.059 140.0 24.50 15.20 0.0 0.000195 0.059 140.0 0.0003 17.89918
1.000 0.059 140.0 24.50 15.20 0.0 0.0002 0.059 140.0 0.0003 17.89918
16.10 0.059 140.0 26.80 13.80 0.0 0.0002 0.059 140.0 0.0003 19.93814
33.90 0.059 140.0 30.90 8.000 0.0 0.000199 0.059 140.0 0.0003 24.08526

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (m)(concent) (m) (MGD) (psu) (C)(col/dl)
12.000 0.0 205.00 0.0 0.0 1.0000 59.800 100.00 29.600 3.4560 0.0 20.500 20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 29.60 5.900 9.372 20000.0 1.000 0.0 0.0 0.0 0.2222; 13.41 T-90hr,
100 29.37 5.900 61.18 2975.1 6.722 -2.606 -1.081 3.096 1.5410; 13.32 T-90hr,
200 27.61 5.900 135.6 1142.4 17.50 -6.017 -2.060 14.40 3.3681; 12.62 T-90hr,
249 24.16 5.900 233.0 562.5 35.49 -9.308 -2.435 34.83 5.6507; trap level; 11.26 T-90hr,
276 22.92 5.900 300.9 445.7 44.77 -10.56 -2.414 45.33 7.2032; begin overlap; 10.77 T-90hr,
300 22.48 5.900 333.7 414.4 48.13 -11.13 -2.377 50.59 7.9496; 10.60 T-90hr,
400 21.94 5.900 383.7 388.9 51.25 -12.54 -2.254 64.07 9.1014; 10.40 T-90hr,
417 21.94 5.900 385.5 387.6 51.42 -12.73 -2.235 65.91 9.1403; local maximum rise or fall; 10.39 T-90hr,
Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
387.592 51.42 9.799 12.92 2.78E-4 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
361.000 64.47 16.52 59.80 0.221 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
273.501 71.65 18.57 72.72 0.282 0.0 16.00 5.900 140.0 3.00E-4 5.9972E-5
count: 1
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	59.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.2830E-03 m^2/s
Beta = 1.3053E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.21E-01	46.88	59.80	6.24E+01	3.19E+02	63

5:28:05 AM. amb fills: 4
/ UM3. 6/23/2021 5:28:34 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	149.50	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222; 13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410; 13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681; 12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507; trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032; begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496; 10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014; 10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403; local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
329.541	122.8	32.26	149.5	0.643	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
149.151	132.4	34.81	162.4	0.704	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 1
;
5:28:34 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	149.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	6.2830E-03	m^2/s
Beta =	1.3053E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.43E-01	136.58	149.50	1.05E+02	1.89E+02	106

/ UM3. 6/23/2021 5:28:46 AM
Case 1; ambient file C:\Plumes20\Ketchikan_3_July1997.004.db; Diffuser table record 3: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.059	140.0	24.50	15.20	0.0	0.000195	0.059	140.0	0.0003	17.89918
1.000	0.059	140.0	24.50	15.20	0.0	0.0002	0.059	140.0	0.0003	17.89918
16.10	0.059	140.0	26.80	13.80	0.0	0.0002	0.059	140.0	0.0003	19.93814
33.90	0.059	140.0	30.90	8.000	0.0	0.000199	0.059	140.0	0.0003	24.08526

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
12.000	0.0	205.00	0.0	0.0	1.0000	299.00	100.00	29.600	3.4560	0.0	20.500	20000.0

Simulation:
Froude No: 14.08; Strat No: 1.68E-3; Spcg No: 9.00E+8; k: 57.66; eff den (sigmaT) -1.837438; eff vel 3.402(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	Dilutn ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	29.60	5.900	9.372	20000.0	1.000	0.0	0.0	0.0	0.2222; 13.41 T-90hr,
100	29.37	5.900	61.18	2975.1	6.722	-2.606	-1.081	3.096	1.5410; 13.32 T-90hr,
200	27.61	5.900	135.6	1142.4	17.50	-6.017	-2.060	14.40	3.3681; 12.62 T-90hr,
249	24.16	5.900	233.0	562.5	35.49	-9.308	-2.435	34.83	5.6507; trap level; 11.26 T-90hr,
276	22.92	5.900	300.9	445.7	44.77	-10.56	-2.414	45.33	7.2032; begin overlap; 10.77 T-90hr,
300	22.48	5.900	333.7	414.4	48.13	-11.13	-2.377	50.59	7.9496; 10.60 T-90hr,
400	21.94	5.900	383.7	388.9	51.25	-12.54	-2.254	64.07	9.1014; 10.40 T-90hr,
417	21.94	5.900	385.5	387.6	51.42	-12.73	-2.235	65.91	9.1403; local maximum rise or fall; 10.39 T-90hr,

Horiz plane projections in effluent direction: radius(m): 2.4839; CL(m): 12.480
Lmz(m): 14.964
forced entrain 1 1.28E+9 7.663 9.791 1.000
Rate sec-1 0.00019971 dy-1 17.2550 kt: 0.000059972 Amb Sal 28.1446
4/3 Power Law. Farfield dispersion based on wastefield width of 9.79 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
387.592	51.42	9.799	12.92	2.78E-4	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
313.051	161.8	42.56	200.0	0.881	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
94.9421	348.2	91.63	400.0	1.823	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5
54.9006	361.8	95.21	412.9	1.884	0.0	16.00	5.900	140.0	3.00E-4	5.9972E-5

count: 2
;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	51.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	9.79	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.92	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	299	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.42E-04	
4. Horizontal current speed (m/sec)	0.059	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	3.88E+02	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	2.00E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	6.2830E-03	m^2/s	
			Beta =	1.3053E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.35E+00	286.08	299.00	1.79E+02	1.11E+02	180

Petersburg (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Petersburg" me

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:40:38 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	18.300	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.0746;	9.342 T-90hr,

100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
221 14.97 1.600 323.8 29956.8 67.21 -7.796 16.57 45.91 8.2053; MZ dis; 8.143 T-90hr,
forced entrain 1 1.914 3.095 8.224 0.970
Rate sec-1 0.00019604 dy-1 16.9376 kt: 0.000077955 Amb Sal 29.8950
Mixing Zone reached in near-field, no far-field calculation attempted
;
5:40:38 AM. amb fills: 4
/ UM3. 6/23/2021 5:40:52 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	36.600	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.07918; 9.342 T-90hr,
100	18.07	1.600	27.00	233103.2	8.665	-0.637	1.364	0.470	0.6855; 9.340 T-90hr,
177	17.70	1.600	121.5	50815.2	39.73	-3.202	6.837	9.667	3.0831; merging; 9.198 T-90hr,
200	16.92	1.600	192.0	38804.9	51.98	-4.867	10.37	20.86	4.8693; 8.895 T-90hr,
212	15.74	1.600	258.0	32719.8	61.58	-6.629	14.10	35.23	6.5408; trap level; 8.436 T-90hr,
269	14.43	1.600	412.1	27015.9	74.42	-9.596	20.37	63.81	10.443; local maximum rise or fall; 7.935 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)

27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
24577.8 89.58 21.72 36.60 0.245 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
13316.6 149.2 37.30 59.12 0.636 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
;
5:40:52 AM. amb fills: 4
/ UM3. 6/23/2021 5:41:05 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ---------------------
----

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.016	120.0	25.80	9.500	0.0	0.000195	0.016	120.0	0.0003	19.89413
9.150	0.016	120.0	28.10	8.200	0.0	0.000196	0.016	120.0	0.0003	21.86897
18.29	0.016	120.0	30.90	7.300	0.0	0.000196	0.016	120.0	0.0003	24.18118
20.00	0.016	120.0	31.42	7.132	0.0	0.000195	0.016	120.0	0.0003	24.61448

Diffuser table:

P-dia	Ver angl	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	115.00	0.0	0.0	2.0000	10.000	91.500	200.00	18.070	3.6000	0.0	14.600	2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.07	1.600	3.124	2.020E+6	1.000	0.0	0.0	0.0	0.07916; 9.342 T-90hr,
100	18.07	1.600	27.00	233103.2	8.665	-0.637	1.364	0.470	0.6855; 9.340 T-90hr,
177	17.70	1.600	121.5	50815.2	39.73	-3.202	6.837	9.667	3.0831; merging; 9.198 T-90hr,
200	16.92	1.600	192.0	38804.9	51.98	-4.867	10.37	20.86	4.8693; 8.895 T-90hr,
212	15.74	1.600	258.0	32719.8	61.58	-6.629	14.10	35.23	6.5408; trap level; 8.436 T-90hr,
269	14.43	1.600	412.1	27015.9	74.42	-9.596	20.37	63.81	10.443; local maximum rise or fall; 7.935 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)
27015.9	74.42	13.51	22.52	2.78E-4	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5
18670.4	255.8	64.12	91.50	1.198	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5
5869.71	340.7	85.44	114.0	1.589	0.0	16.25	1.600	120.0	3.00E-4 8.0118E-5

count: 1
; 5:41:06 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

			Eo =	9.6530E-03	m^2/s	
			Beta =	5.3588E-01	unitless	
	Far-field Travel Time (hours)	**Far-field Travel Distance (m)**	**Total Travel Distance (m)**	**Effluent Dilution**	**Pollutant Concentration**	
Dilution at mixing zone boundary:	1.197569444	68.98	91.5	2.56E+02	7.86E+03	257

/ UM3. 6/23/2021 5:41:17 AM
Case 1; ambient file C:\Plumes20\Petersburg_1_Aug05.002.db; Diffuser table record 1: ----------------------------------

Ambient Table:
Depth Amb-cur Amb-dir Amb-sal Amb-tem Amb-pol Solar rad Far-spd Far-dir Disprsn Density
m m/s deg psu C kg/kg s-1 m/s deg m0.67/s2 sigma-T
0.0 0.016 120.0 25.80 9.500 0.0 0.000195 0.016 120.0 0.0003 19.89413
9.150 0.016 120.0 28.10 8.200 0.0 0.000196 0.016 120.0 0.0003 21.86897
18.29 0.016 120.0 30.90 7.300 0.0 0.000196 0.016 120.0 0.0003 24.18118
20.00 0.016 120.0 31.42 7.132 0.0 0.000195 0.016 120.0 0.0003 24.61448

Diffuser table:
P-diaVer angl H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt
(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
4.0000 0.0 115.00 0.0 0.0 2.0000 10.000 183.00 200.00 18.070 3.6000 0.0 14.600 2.02E+6

Simulation:
Froude No: 114.5; Strat No: 7.46E-4; Spcg No: 38.41; k: 996.7; eff den (sigmaT) -0.776899; eff vel 15.95(m/s);
Depth Amb-cur P-dia Polutnt Dilutn x-posn y-posn Time Iso dia
Step (m) (cm/s) (in) (col/dl) () (m) (m) (s) (m)
0 18.07 1.600 3.124 2.020E+6 1.000 0.0 0.0 0.0 0.07916; 9.342 T-90hr,
100 18.07 1.600 27.00 233103.2 8.665 -0.637 1.364 0.470 0.6855; 9.340 T-90hr,
177 17.70 1.600 121.5 50815.2 39.73 -3.202 6.837 9.667 3.0831; merging; 9.198 T-90hr,
200 16.92 1.600 192.0 38804.9 51.98 -4.867 10.37 20.86 4.8693; 8.895 T-90hr,
212 15.74 1.600 258.0 32719.8 61.58 -6.629 14.10 35.23 6.5408; trap level; 8.436 T-90hr,
269 14.43 1.600 412.1 27015.9 74.42 -9.596 20.37 63.81 10.443; local maximum rise or fall; 7.935 T-90hr,
Horiz plane projections in effluent direction: radius(m): 0.03203; CL(m): 22.520
Lmz(m): 22.552
forced entrain 1 2.252 3.642 10.47 1.000
Rate sec-1 0.00019608 dy-1 16.9412 kt: 0.000080118 Amb Sal 29.7168
4/3 Power Law. Farfield dispersion based on wastefield width of 13.51 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
27015.9 74.42 13.51 22.52 2.78E-4 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
11807.9 646.9 162.2 183.0 2.786 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
2638.61 760.1 190.6 205.5 3.177 0.0 16.25 1.600 120.0 3.00E-4 8.0118E-5
count: 1
;
5:41:17 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	74.42	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	13.51	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	22.52	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.016	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	2.70E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.6530E-03 m^2/s
Beta = 5.3588E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.786111111	160.48	183	6.47E+02	3.11E+03	650

Sitka (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Sitka" memo

Model configuration items checked: Brooks far-field solution; Report effective dilution; ;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 1
Light absorption coefficient 0.16
Farfield increment (m) 100
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	24.400	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:

Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)	
0	23.94	1.700	4.000	3.740E+6	0.0	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc (col/dl)	dilutn	width (m)	distnce (m)	time (hrs)	bckgrnd (col/dl)	decay (ly/hr)	current (cm/s)	cur-dir angle	eddydif (m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
3.53E+6	87.12	100.3	24.40	0.287	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
9.94E+5	89.08	107.1	31.25	0.399	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 1

;

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	24.4	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.87E-01	17.549	24.40	8.70E+01	4.30E+04	87

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	48.800	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165;	merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
43327.2 86.32 83.51 6.851 2.78E-4 0.0 8.000 1.700 225.0 3.00E-4 5.5441E-5

```
 3.26E+6   98.22   125.2   48.80   0.686    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 2.14E+5   102.8   132.5   55.65   0.798    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 1
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	48.8	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.85E-01	41.949	48.80	9.65E+01	3.87E+04	97

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	122.00	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014; 11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016; 11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780; 11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632; 11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372; 11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162; 11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883; 11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405; 11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165; merging; 11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498; 11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298; 10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616; 10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416; 9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811; 9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450; 8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048; 7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008; 6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.76E+6	138.1	183.2	100.0	1.522	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

```
 46877.1   236.4   315.8   200.0   3.156    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
 23592.2   243.8   325.7   206.9   3.268    0.0   8.000   1.700   225.0 3.00E-4 5.5441E-5
count: 2
 ;
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
		Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	122	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.88E+00	115.149	122.00	1.43E+02	2.61E+04	143

/ uDKHLRD; for extra details examine output file \Plumes20\dkhwisp.out
Case 1; ambient file C:\Plumes20\Sitka_C_Jul10.005.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.017	225.0	26.60	12.70	0.0	0.000196	0.017	225.0	0.0003	19.98988
1.000	0.017	225.0	26.60	12.70	0.0	0.000198	0.017	225.0	0.0003	19.98988
5.000	0.017	225.0	28.20	12.20	0.0	0.000198	0.017	225.0	0.0003	21.31369
10.00	0.017	225.0	29.10	11.60	0.0	0.000198	0.017	225.0	0.0003	22.11543
15.00	0.017	225.0	29.60	10.60	0.0	0.000197	0.017	225.0	0.0003	22.67329
20.00	0.017	225.0	29.80	9.800	0.0	0.000197	0.017	225.0	0.0003	22.95817
25.00	0.017	225.0	29.90	9.500	0.0	0.000196	0.017	225.0	0.0003	23.08290
30.00	0.017	225.0	29.90	9.100	0.0	0.000196	0.017	225.0	0.0003	23.14401

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
4.0000	0.0	300.00	0.0	0.0	16.000	13.000	244.00	200.00	23.940	5.3000	0.0	15.000	3.74E+6

Simulation:
Froude No: 11.60; Strat No: 5.45E-4; Spcg No: 39.00; k: 105.3; eff den (sigmaT) -0.836341; eff vel 1.790(m/s);

Step	Depth (m)	Amb-cur (cm/s)	P-dia (in)	Polutnt (col/dl)	net Dil ()	x-posn (m)	y-posn (m)	Time (s)	Iso dia (m)	
0	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1014;	11.44 T-90hr,
1	23.94	1.700	4.000	3.740E+6	1.000	0.0	0.0	0.0	0.1016;	11.44 T-90hr,
2	23.93	1.700	10.94	1.929E+6	1.939	-0.497	0.285	0.320	0.2780;	11.43 T-90hr,
3	23.92	1.700	14.30	1.472E+6	2.540	-0.585	0.334	0.385	0.3632;	11.43 T-90hr,
5	23.90	1.700	21.15	988111.0	3.785	-0.763	0.432	0.566	0.5372;	11.42 T-90hr,
7	23.87	1.700	28.20	733621.0	5.098	-0.940	0.527	0.820	0.7162;	11.41 T-90hr,
9	23.80	1.700	38.91	519516.6	7.199	-1.202	0.662	1.331	0.9883;	11.38 T-90hr,
11	23.64	1.700	52.78	364415.9	10.26	-1.539	0.825	2.240	1.3405;	11.32 T-90hr,
13	23.42	1.700	63.65	283591.1	13.19	-1.848	0.963	3.349	1.6165; merging;	11.24 T-90hr,
17	22.83	1.700	76.78	206140.1	18.14	-2.365	1.164	5.764	1.9498;	11.01 T-90hr,
21	22.14	1.700	87.81	163240.4	22.91	-2.776	1.297	8.271	2.2298;	10.75 T-90hr,
27	21.03	1.700	104.8	125663.6	29.76	-3.270	1.419	12.28	2.6616;	10.33 T-90hr,
55	19.66	1.700	131.6	99789.2	37.48	-3.747	1.497	17.53	3.3416;	9.805 T-90hr,
67	17.85	1.700	164.7	79160.1	47.25	-4.268	1.537	24.48	4.1811;	9.113 T-90hr,
79	15.49	1.700	218.5	62651.8	59.70	-4.873	1.525	33.78	5.5450;	8.222 T-90hr,
133	12.24	1.700	351.2	49337.1	75.81	-5.704	1.423	48.38	8.9048;	7.033 T-90hr,
151	9.808	1.700	947.0	43327.2	86.32	-6.744	1.206	68.20	24.008;	6.180 T-90hr,

4/3 Power Law. Farfield dispersion based on wastefield width of 83.49 m

conc	dilutn	width	distnce	time	bckgrnd	decay	current	cur-dir	eddydif	
(col/dl)		(m)	(m)	(hrs)	(col/dl)	(ly/hr)	(cm/s)	angle	(m0.67/s2)	
43327.2	86.32	83.51	6.851	2.78E-4	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
2.76E+6	138.1	183.2	100.0	1.522	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

46877.1	236.4	315.8	200.0	3.156	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
17411.5	352.0	470.5	300.0	4.790	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5
13591.4	360.5	481.8	306.9	4.902	0.0	8.000	1.700	225.0	3.00E-4	5.5441E-5

count: 3

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	86.32	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	83.49	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	6.851	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	244	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	1.31E-03	
4. Horizontal current speed (m/sec)	0.017	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	4.33E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 1.0947E-01 m^2/s
Beta = 9.2555E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.87E+00	237.149	244.00	2.27E+02	1.65E+04	227

Skagway (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Skagway" memo

Model configuration items checked: Brooks far-field solution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 6/23/2021 5:51:09 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000195	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:
P-dia VertAng H-Angle SourceX SourceY Ports Spacing MZ-dis Isoplth P-depth Ttl-flo Eff-sal Temp Polutnt

(in) (deg) (deg) (m) (m) () (ft) (m)(concent) (m) (MGD) (psu) (C)(col/dl)
3.0000 0.0 350.00 0.0 0.0 8.0000 3.5000 18.300 200.00 18.150 0.6300 0.0 17.300
2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

```
      Depth  Amb-cur   P-dia  Polutnt   Dilutn  x-posn  y-posn    Time   Iso dia
Step    (m)   (cm/s)    (in)  (col/dl)     ()     (m)     (m)      (s)     (m)
   0   18.15   1.400   2.343 2.590E+6   1.000    0.0     0.0      0.0   0.0594;  9.458 T-90hr,
 100   18.07   1.400   12.32 471750.7   5.490   0.639  -0.113   1.673   0.3130;  9.424 T-90hr,
 200   17.61   1.400   21.87 219905.3   11.77   1.318  -0.232   6.056   0.5554;  9.240 T-90hr,
 267   16.05   1.400   42.65  85238.4   30.34   2.296  -0.405   19.44   1.0826; trap level, merging; 8.615 T-90hr,
 300   15.34   1.400   63.27  67833.1   38.10   2.732  -0.482   28.58   1.6057;  8.339 T-90hr,
 318   15.20   1.400   71.39  65187.4   39.64   2.853  -0.503   31.31   1.8117; begin overlap;  8.285 T-90hr,
 400   14.95   1.400   94.95  62151.2   41.55   3.192  -0.563   39.26   2.4091;  8.187 T-90hr,
 480   14.90   1.400   102.6  61721.1   41.83   3.409  -0.601   44.43   2.6036; local maximum rise or fall;  8.170 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 55457.0   59.02   19.36   18.30  0.295     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 38485.5   66.05   21.80   21.76  0.363     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
```

count: 1
;
5:51:09 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT

Linear Eddy Diffusivity
Eo=(alpha)(width)
(Grace/Brooks equation 7-65)

1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	18.3	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.94E-01	14.838	18.30	5.61E+01	4.60E+04	56

/ UM3. 6/23/2021 5:51:23 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	36.600	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620

```
forced entrain      1   14.06   3.247   2.606   1.000
Rate sec-1   0.00019534 dy-1      16.8772  kt:  0.000078146 Amb Sal      29.1654
4/3 Power Law.  Farfield dispersion based on wastefield width of      10.07 m
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 50071.9   100.1   33.29   36.60   0.658     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 23499.3   108.8   36.19   40.06   0.726     0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:23 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	36.6	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	6.58E-01	33.138	36.60	8.58E+01	3.01E+04	86

/ UM3. 6/23/2021 5:51:35 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	91.500	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)            (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 61721.1   41.83   10.08   3.462 2.78E-4    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 36855.9   263.9   87.83   91.50   1.747    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
 9323.75   275.8   91.82   94.96   1.816    0.0   16.30   1.400   350.0 3.00E-4 7.8146E-5
count: 1
 ;
5:51:35 AM. amb fills: 4
```

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	91.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	1.75E+00	88.038	91.50	1.77E+02	1.46E+04	178

/ UM3. 6/23/2021 5:51:47 AM
Case 1; ambient file C:\Plumes20\Skagway_1_Jun05.005.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.014	350.0	7.100	11.12	0.0	0.000194	0.014	350.0	0.0003	5.180276
1.523	0.014	350.0	14.16	10.08	0.0	0.000197	0.014	350.0	0.0003	10.78304
3.047	0.014	350.0	23.30	8.650	0.0	0.000197	0.014	350.0	0.0003	18.06627
4.570	0.014	350.0	23.25	8.670	0.0	0.000196	0.014	350.0	0.0003	18.02474
6.090	0.014	350.0	25.20	8.220	0.0	0.000196	0.014	350.0	0.0003	19.60292
7.617	0.014	350.0	26.37	8.020	0.0	0.000196	0.014	350.0	0.0003	20.54204
9.140	0.014	350.0	26.74	7.980	0.0	0.000196	0.014	350.0	0.0003	20.83621
10.45	0.014	350.0	27.46	7.570	0.0	0.000195	0.014	350.0	0.0003	21.45192
11.75	0.014	350.0	28.24	7.100	0.0	0.000195	0.014	350.0	0.0003	22.12180
13.06	0.014	350.0	28.92	6.920	0.0	0.000195	0.014	350.0	0.0003	22.67724
14.37	0.014	350.0	29.08	6.880	0.0	0.000195	0.014	350.0	0.0003	22.80770
15.68	0.014	350.0	29.29	6.790	0.0	0.000195	0.014	350.0	0.0003	22.98359
16.98	0.014	350.0	30.42	6.260	0.0	0.000195	0.014	350.0	0.0003	23.93584
20.00	0.014	350.0	33.05	5.029	0.0	0.000195	0.014	350.0	0.0003	26.14924

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.0000	0.0	350.00	0.0	0.0	8.0000	3.5000	183.00	200.00	18.150	0.6300	0.0	17.300	2.59E+6

Simulation:
Froude No: 10.06; Strat No: 2.47E-3; Spcg No: 17.93; k: 88.59; eff den (sigmaT) -1.214163; eff vel 1.240(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	Dilutn	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	18.15	1.400	2.343	2.590E+6	1.000	0.0	0.0	0.0	0.05945; 9.458 T-90hr,
100	18.07	1.400	12.32	471750.7	5.490	0.639	-0.113	1.673	0.3130; 9.424 T-90hr,
200	17.61	1.400	21.87	219905.3	11.77	1.318	-0.232	6.056	0.5554; 9.240 T-90hr,
267	16.05	1.400	42.65	85238.4	30.34	2.296	-0.405	19.44	1.0826; trap level, merging; 8.615 T-90hr,
300	15.34	1.400	63.27	67833.1	38.10	2.732	-0.482	28.58	1.6057; 8.339 T-90hr,
318	15.20	1.400	71.39	65187.4	39.64	2.853	-0.503	31.31	1.8117; begin overlap; 8.285 T-90hr,
400	14.95	1.400	94.95	62151.2	41.55	3.192	-0.563	39.26	2.4091; 8.187 T-90hr,
480	14.90	1.400	102.6	61721.1	41.83	3.409	-0.601	44.43	2.6036; local maximum rise or fall; 8.170 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0000; CL(m): 3.4620
Lmz(m): 3.4620
forced entrain 1 14.06 3.247 2.606 1.000
Rate sec-1 0.00019534 dy-1 16.8772 kt: 0.000078146 Amb Sal 29.1654
4/3 Power Law. Farfield dispersion based on wastefield width of 10.07 m

conc dilutn width distnce time bckgrnd decay current cur-dir eddydif
(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
61721.1 41.83 10.08 3.462 2.78E-4 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
22115.3 634.0 211.0 183.0 3.563 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
3965.60 649.9 216.3 186.5 3.631 0.0 16.30 1.400 350.0 3.00E-4 7.8146E-5
count: 1
;
5:51:47 AM. amb fills: 4

Brook's Linear Diffusivity

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the linear diffusivity Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This sheet differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width).

INPUT		
	Linear Eddy Diffusivity Eo=(alpha)(width) (Grace/Brooks equation 7-65)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	41.83	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	10.07	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	3.462	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	183	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width) m^2/sec	6.48E-04	
4. Horizontal current speed (m/sec)	0.014	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	6.17E+04	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.95E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 6.5237E-03 m^2/s
Beta = 5.5529E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	3.56E+00	179.538	183.00	3.30E+02	7.82E+03	331

Wrangell (model output for 1*depth, 2*depth, 5*depth and 10*depth)

Contents of the memo box (may not be current and must be updated manually)
Project "C:\Plumes20\Wrangell" memoQ=

Model configuration items checked: Brooks far-field solution; Report effective dilution;
Channel width (m) 100
Start case for graphs 1
Max detailed graphs 10 (limits plots that can overflow memory)
Elevation Projection Plane (deg) 0
Shore vector (m,deg) not checked
Bacteria model : Mancini (1978) coliform model
PDS sfc. model heat transfer : Medium
Equation of State : S, T
Similarity Profile : Default profile (k=2.0, ...)
Diffuser port contraction coefficient 0.61
Light absorption coefficient 0.16
Farfield increment (m) 200
UM3 aspiration coefficient 0.1
Output file: text output tab
Output each ?? steps 100
Maximum dilution reported 100000
Text output format : Standard
Max vertical reversals : to max rise or fall

/ UM3. 8/3/2021 9:23:16 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ----------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000194	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000194	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000194	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000194	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000194	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000194	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000194	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000194	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000194	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000194	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000194	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)

3.9500 0.0 90.000 0.0 0.0 8.0000 32.000 30.500 200.00 30.350 3.0000 0.0 18.400
1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

```
      Depth  Amb-cur   P-dia  Polutnt  net Dil   x-posn   y-posn    Time   Iso dia
Step   (m)  (cm/s)    (in) (col/dl)     ()       (m)      (m)      (s)     (m)
  0    30.35   4.000   3.085 191000.0   1.000     0.0      0.0      0.0      0.0;  14.06 T-90hr,
 100   30.32   4.000   21.88  25869.1   7.383    0.000    1.223    1.461   0.5546;  14.05 T-90hr,
 200   29.23   4.000   75.55   6306.8   30.29    0.000    5.127    18.85   1.9038;  13.64 T-90hr,
 265   25.85   4.000   147.1   2462.3   77.57    0.000    9.228    57.16   3.6599; trap level;  12.34 T-90hr,
 300   24.85   4.000   191.4   1914.4   99.77    0.000    10.45    72.89   4.7344;  11.95 T-90hr,
 301   24.84   4.000   192.3   1907.0   100.2    0.000    10.47    73.16   4.7551; begin overlap;  11.95 T-90hr,
 400   24.32   4.000   227.5   1702.3   112.2    0.000    11.88    93.03   5.6075;  11.75 T-90hr,
 415   24.32   4.000   228.3   1697.3   112.5    0.000    12.05    95.47   5.6269; local maximum rise or fall;  11.75 T-90hr,
```

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn  width distnce   time bckgrnd   decay current cur-dir eddydif
(col/dl)          (m)     (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4    0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1632.35   112.0   81.17   30.50  0.128     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
 1668.65   112.4   85.91   42.55  0.212     0.0   16.34   4.000   90.00 3.00E-4 5.4521E-5
```

count: 1
;
9:23:18 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	30.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo =	9.3337E-02	m^2/s
Beta =	3.7799E-01	unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.128125	18.45	30.5	1.12E+02	1697	113

/ UM3. 8/3/2021 9:24:14 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	61.000	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603;	14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546;	14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038;	13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599;	trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344;	11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551;	begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075;	11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269;	local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m

```
   conc  dilutn   width distnce    time bckgrnd   decay current cur-dir eddydif
(col/dl)           (m)      (m)    (hrs)(col/dl) (ly/hr)  (cm/s) angle(m0.67/s2)
 1697.28   112.0   74.09   12.05 2.78E-4     0.0    16.34    4.000    90.00 3.00E-4 5.4521E-5
 1565.88   114.7   93.35   61.00   0.340     0.0    16.34    4.000    90.00 3.00E-4 5.4521E-5
 1596.09   117.5   98.31   73.05   0.424     0.0    16.34    4.000    90.00 3.00E-4 5.4521E-5
count: 1
 ;
9:24:14 AM. amb fills: 4
```

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm. The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)		
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	61	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT						
			Eo = 9.3337E-02 m^2/s			
			Beta = 3.7799E-01 unitless			
	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.339930556	48.95	61	1.15E+02	1657	115

/ UM3. 8/3/2021 9:24:33 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	152.50	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia	
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)	
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603;	14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546;	14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038;	13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599;	trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344;	11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551;	begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075;	11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269;	local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1382.28 148.5 133.1 152.5 0.976 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1220.33 154.2 138.7 164.5 1.059 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 1
;
9:24:33 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	152.5	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	0.975347222	140.45	152.5	1.49E+02	1280	149

/ UM3. 8/3/2021 9:24:50 AM
Case 1; ambient file C:\Plumes20\Wrangell_4_Aug16.004.db; Diffuser table record 2: ---------------------------------

Ambient Table:

Depth	Amb-cur	Amb-dir	Amb-sal	Amb-tem	Amb-pol	Solar rad	Far-spd	Far-dir	Disprsn	Density
m	m/s	deg	psu	C	kg/kg	s-1	m/s	deg	m0.67/s2	sigma-T
0.0	0.040	90.00	11.00	11.30	0.0	0.000195	0.040	90.00	0.0003	8.178952
3.000	0.040	90.00	11.00	11.30	0.0	0.000196	0.040	90.00	0.0003	8.178952
6.000	0.040	90.00	11.20	12.70	0.0	0.000196	0.040	90.00	0.0003	8.137535
9.000	0.040	90.00	12.10	12.80	0.0	0.000196	0.040	90.00	0.0003	8.815796
12.00	0.040	90.00	12.80	11.90	0.0	0.000196	0.040	90.00	0.0003	9.487716
15.00	0.040	90.00	14.00	11.10	0.0	0.000196	0.040	90.00	0.0003	10.52628
18.00	0.040	90.00	14.90	11.10	0.0	0.000196	0.040	90.00	0.0003	11.22223
21.00	0.040	90.00	15.80	11.20	0.0	0.000196	0.040	90.00	0.0003	11.90396
24.00	0.040	90.00	16.20	11.00	0.0	0.000196	0.040	90.00	0.0003	12.24129
27.00	0.040	90.00	16.80	11.00	0.0	0.000196	0.040	90.00	0.0003	12.70520
30.00	0.040	90.00	16.90	10.90	0.0	0.000196	0.040	90.00	0.0003	12.79661
31.00	0.040	90.00	16.93	10.87	0.0	0.000196	0.040	90.00	0.0003	12.82707

Diffuser table:

P-dia	VertAng	H-Angle	SourceX	SourceY	Ports	Spacing	MZ-dis	Isoplth	P-depth	Ttl-flo	Eff-sal	Temp	Polutnt
(in)	(deg)	(deg)	(m)	(m)	()	(ft)	(m)	(concent)	(m)	(MGD)	(psu)	(C)	(col/dl)
3.9500	0.0	90.000	0.0	0.0	8.0000	32.000	305.00	200.00	30.350	3.0000	0.0	18.400	1.91E+5

Simulation:
Froude No: 32.56; Strat No: 8.40E-4; Spcg No: 124.5; k: 85.17; eff den (sigmaT) -1.415928; eff vel 3.407(m/s);

Step	Depth	Amb-cur	P-dia	Polutnt	net Dil	x-posn	y-posn	Time	Iso dia
	(m)	(cm/s)	(in)	(col/dl)	()	(m)	(m)	(s)	(m)
0	30.35	4.000	3.085	191000.0	1.000	0.0	0.0	0.0	0.07603; 14.06 T-90hr,
100	30.32	4.000	21.88	25869.1	7.383	0.000	1.223	1.461	0.5546; 14.05 T-90hr,
200	29.23	4.000	75.55	6306.8	30.29	0.000	5.127	18.85	1.9038; 13.64 T-90hr,
265	25.85	4.000	147.1	2462.3	77.57	0.000	9.228	57.16	3.6599; trap level; 12.34 T-90hr,
300	24.85	4.000	191.4	1914.4	99.77	0.000	10.45	72.89	4.7344; 11.95 T-90hr,
301	24.84	4.000	192.3	1907.0	100.2	0.000	10.47	73.16	4.7551; begin overlap; 11.95 T-90hr,
400	24.32	4.000	227.5	1702.3	112.2	0.000	11.88	93.03	5.6075; 11.75 T-90hr,
415	24.32	4.000	228.3	1697.3	112.5	0.000	12.05	95.47	5.6269; local maximum rise or fall; 11.75 T-90hr,

Horiz plane projections in effluent direction: radius(m): 0.0; CL(m): 12.046
Lmz(m): 12.046
forced entrain 1 143.3 6.034 5.800 1.000
Rate sec-1 0.00019572 dy-1 16.9100 kt: 0.000054521 Amb Sal 16.2632
Plumes not merged, Brooks method may be overly conservative.
4/3 Power Law. Farfield dispersion based on wastefield width of 74.08 m
conc dilutn width distnce time bckgrnd decay current cur-dir eddydif

(col/dl) (m) (m) (hrs)(col/dl) (ly/hr) (cm/s) angle(m0.67/s2)
1697.28 112.0 74.09 12.05 2.78E-4 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
1295.62 171.8 155.5 200.0 1.306 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
819.357 286.6 261.7 400.0 2.694 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
642.616 294.2 268.7 412.0 2.778 0.0 16.34 4.000 90.00 3.00E-4 5.4521E-5
count: 2
;
9:24:50 AM. amb fills: 4

Brook's four-third Power Law

FARFIELD.XLS: Far-field dilution of initially diluted effluent plumes using the 4/3 power law Brooks model as presented by Grace (R.A. Grace. Marine outfall systems: planning, design, and construction. Prentice-Hall, Inc.)
This apporach differs from the PLUMES approach by assuming different units for alpha depending on the far-field algorithm.
The initial diffusion coefficient (Eo in m^2/sec) is calculated as Eo = (alpha)(width)$^{4/3}$.

INPUT		
	4/3 Power Law Eo=(alpha)*(width)$^{4/3}$ (Grace/Brooks equation 7-66)	
1. Plume and diffuser characteristics at start of far-field mixing		
Flux-average dilution factor after initial dilution	112	(*e.g.* dilution at end of computations with UDKHDEN)
Estimated initial width (B) of plume after initial dilution (meters)	74.08	(*e.g.* eqn 70 of EPA/600/R-94/086 for diffuser length and plume diameter)
Travel distance of plume after initial dilution (meters)	12.05	(*e.g.* "Y" from UDKHDEN or horizontal distance from PLUMES output)
2. Distance from outfall to mixing zone boundary (meters)	305	(*e.g.* distance to the chronic mixing zone boundary)
3. Diffusion parameter "alpha" per equations 7-62 of Grace, where Eo=(alpha)(width)$^{4/3}$ m^2/sec	0.0003	
4. Horizontal current speed (m/sec)	0.04	(*e.g.* same value specified for UDKHDEN or PLUMES)
5. Pollutant initial concentration and decay (optional)		(these inputs do not affect calculated farfield dilution factors)
Pollutant concentration after initial dilution (any units)	1.70E+03	(*e.g.* effluent volume fraction = 1/initial dilution)
Pollutant first-order decay rate constant (day^{-1})	1.96E-04	(*e.g.* enter 0 for conservative pollutants)

OUTPUT

Eo = 9.3337E-02 m^2/s
Beta = 3.7799E-01 unitless

	Far-field Travel Time (hours)	Far-field Travel Distance (m)	Total Travel Distance (m)	Effluent Dilution	Pollutant Concentration	
Dilution at mixing zone boundary:	2.034375	292.95	305	2.29E+02	829	230