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Modeling the Removal of Stormwater Pollutants and the Mixing Mechanism of Stormwater Runoff

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ATINER started to publish this conference papers series in 2012. It includes only the papers submitted for publication after they were presented at one of the conferences organized by our Institute every year. The papers published in the series have not been refereed and are published as they were submitted by the author. The series serves two purposes. First, we want to disseminate the information as fast as possible. Second, by doing so, the authors can receive comments useful to revise their papers before they are considered for publication in one of ATINER's books, following our standard procedures of a blind review.

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Abstract

Under the National Pollutant Discharge Elimination System (NPDES) stormwater program, operators of large, medium, and regulated small municipal separate storm sewer systems (MS4s) require authorization to discharge pollutants under an NPDES permit. MS4s can be linear or complex, open, piped, manmade, natural, or a combination of all of the above. Some carry groundwater or piped streams, are tidally influenced, or have some other constant source of non-stormwater discharge. An MS4 is not always just a system of underground pipes-it can include roads with drainage systems, gutters, and ditches. Typically, an outfall from a MS4 discharges into a creek system and ultimately into a larger receiving water body which might or might not be tidally influenced. In order to evaluate the existing and expected water quality of the ultimate receiving water body, mathematical models are used to conduct flushing modeling and water quality modeling of the ambient waters. A hydrodynamic mixing zone model will be used to simulate steady or unsteady discharge from a single open channel outfall or a system of outfalls from municipal separate storm sewer systems (MS4s). This model is applicable for a wide range of hydrologic situations wherein flow and transport are governed by time-dependent forcing functions. Permit requirements will consist of a Water Quality Monitoring Program to be implemented and samples collected according to permitting agencies' procedures for collection, control and preservation.

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INTRODUCTION

The treated effluent from the City of Gainesville, Georgia Linwood Wastewater Treatment Facility is currently discharged through a submerged outfall into Lake Lanier. The effluent is first chlorinated and then dechlorinated before being discharged. The outfall is located just offshore from the City of Gainesville at approximately one mile downstream from the Thompson Bridge. Figure 1 shows the aerial view of the facility. The original outfall is a three-port diffuser. However, according to the report entitled “Development of Linked Watershed and Water Quality Models for Lake Lanier”, two of three ports are silted over (Limno-Tech, Inc.). The remaining functional port is a 24-inch diameter pipe and is located at approximately 120 to130 meters (m) (394 to 427 feet (ft)) from the bank. The effluent is discharged vertically from this port. The water depth at the discharge location is about 30 m (98 ft) and the discharge port is approximately 0.5 m (1.64 ft) above the lake bottom. Future improvement plans call for the Linwood Wastewater Treatment Facility be upgraded in stages and expanded to increase the future ultimate peak day treatment capacity.

Figure1. City of Gainesville, GA Linwood Wastewater Treatment Facility

IMPACT OF STORMWATER DISCHARGE STUDY

The CORMIX 2 model (Gerhard H. Jirka et. al. 1996) is applied to a range of discharge rates to study the impact of stormwater temperature on the ambient water temperature adjacent to the Linwood Wastewater Treatment Facility. This paper documents the results and final recommendation from a CORMIX 2 evaluation of the effect of the higher water temperature of the effluent on the ambient water temperature of the lake.

DESIGN CRITERIA

The Environmental Protection Division (EPD) of the Georgia Department of Natural Resources stipulates that “at a sampling point 3 m (9.8 ft) from the outfall diffuser, the temperature shall not exceed 90 degrees Fahrenheit (F) nor increase the lake ambient temperature more than 5 degrees Fahrenheit." This study was conducted to establish the new outfall discharge location and optimum outfall diffuser configuration to achieve the above stated EPD requirement.

Instead of applying a mixing zone to regulate a point source wastewater discharge to a natural water body, the State of Georgia establishes that any point source effluent parameter must be diluted by a factor of at least two (2.0) at a sampling point 3 m (9.8 ft) from the outfall diffuser. The model will evaluate the dilution level at this location.

Ambient (Lake Lanier) Condition and Modeling Assumption

Ambient conditions were assumed primarily based on the assumptions used in a previous study. The CORMIX 2 model input parameters are listed below.

- The ambient winter water temperature range is between 42.8°F to 46.4°F (6°C to 8°C) and the temperature does not vary over the water depth. An ambient winter water temperature of 42.8°F is used in the model.
- The ambient summer water temperature varies with depth, with a pycnocline at approximately 20 to 60 ft below the water surface. The upper layer temperature varies from 82.4°F to 87.8°F; while the lower layer temperature is about 46.4°F to 50°F**.** An ambient lower layer summer water temperature of 46.4°F is used in the model with a pycnocline height of 30 ft.
- The stormwater discharge temperature is assumed to be 82.4°F.
- The model tested the impact of various discharge rates of 22.6 cubic feet/second (ft^3/s), 33.6 ft^3/s, and 51.7 ft^3/s.
- The ambient current velocity is estimated to be 0.13 ft/s (0.04 m/s).
- The Manning's n for the lake bottom is assumed to be 0.02 (smooth, earth channel, no weeds).
- The wind speed at the water surface is assumed to be 6.6 ft/s (2 m/s) (a breeze condition). CORMIX 2 defines a breeze as a wind speed from 0 ft/s to 9.8 ft/s.

MODEL EVALUATION AND RESULTS

The critical parameter that is evaluated for all the results is the water temperature at a sampling location of 3 m (9.8 ft) from the diffuser port. This study used the CORMIX 2 model to analyze numerous combinations of the following outfall diffuser location and diffuser configuration. Based on the results, the recommended design configuration is detailed in the Table 1 and shown in Figure 2.

- Outfall discharge depth.
- Number of diffuser ports.
- Distance of the diffuser from the shoreline.
- Size of each diffuser port.
- Effluent discharge direction – Against or perpendicular or in the same direction as ambient current direction.
- Orientation of the diffuser to the ambient current direction (Beta angle). Refer to Figure 3.

- Discharge vertical angle (Theta angle). Refer to Figure 3.
- Height of each diffuser port above the lake bottom.

Table 1. Final Design Configuration

(1) Outfall discharge depth	88 ft
(2) Number of diffuser ports	30; spaced evenly at 5 ft apart.
(3a) Distance of the closest diffuser port from the shoreline	500 ft
(3b) Distance of the furthest diffuser port from the shoreline	650 ft
(4) Size of each diffuser port	4-inch diameter
(5) The orientation of the diffuser to the ambient current direction (Beta angle)	90°
(6) Discharge vertical angle (Theta angle)	65°

Figure 2. Diffuser Port Design Configuration

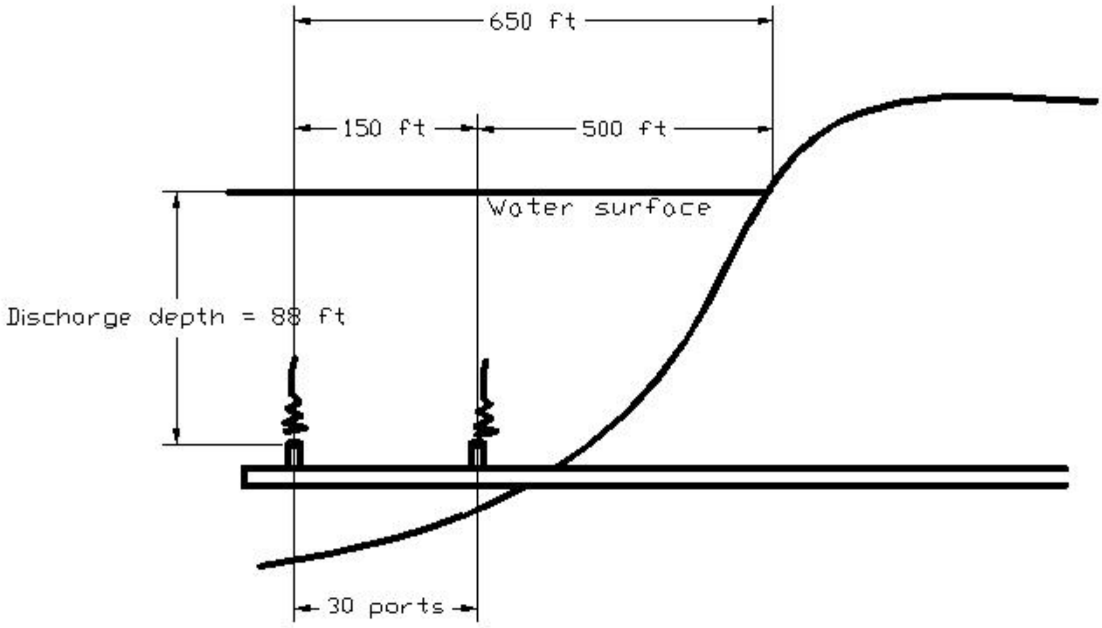
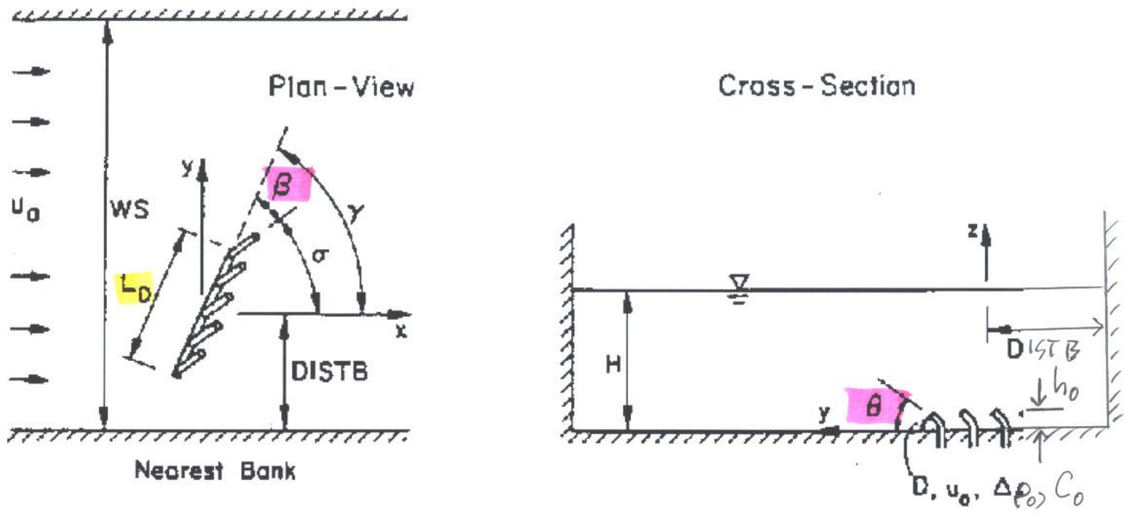


Figure 3. Discharge Vertical Angle (Gerhard H. Jirka et. al. 1996)



a) Definition Diagram CORMIX2

Using the recommended outfall diffuser location and diffuser configuration as given in Table 1, the CORMIX 2 results are shown in Table 2. It tabulates the water temperatures at EPD's regulatory critical location of 3 m (9.8 ft) from the discharge port under the various discharge rate scenarios.

Table 2. Ambient Temperature at 3 meters (9.8 feet) from Each Diffuser Port

		Increase in Ambient Temperature and Actual Temperature			
Discharge	Discharge Depth	Temperature Increase	Actual Temperature	Temperature Increase	Actual Temperature
(ft^3/s)	(Ft)	(°F)	(°F)	(°C)	(°C)
		Winter Ambient Temperature is 42.8°F or 6°C			
22.6	88	1.59	44.39	0.881	6.88
33.6	88	2.07	44.87	1.15	7.15
51.7	88	2.57	45.37	1.43	7.43
		Summer Ambient Temperature is 46.4°F or 8°C			
22.6	88	2.38	48.78	1.32	9.32
33.6	88	2.97	49.37	1.65	9.65
51.7	88	3.55	49.95	1.97	9.97

CONCLUSION

As shown in Table 2, none of the evaluated discharge rates cause any increase in the ambient temperature above EPD's regulatory requirement of no greater than 5°F at a sample location of 3 m (9.8 ft) from the discharge point. This holds true for both the winter period as well as the critical summer period. As such, as long as the diffuser configuration and discharge location as established in Table 1 are implemented, the EPD regulation on temperature increase will be met.

REFERENCES

Gerhard H. Jirka, Robert L. Doneker, and Steven W. Hinton (1996). User's Manual for CORMIX: A Hydrodynamic Mixing Zone Model and Decision Support System for Pollutant Discharges into Surface Waters.

Limno-Tech, Inc. Development of Linked Watershed and Water Quality Models for Lake Lanier.