Sinclair Inlet Dye Study:

Sampling Plan for Puget Sound Naval Shipyard & Intermediate Maintenance Facility Dry Dock and Storm Water Outfalls

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INTRODUCTION

This document describes plans for performing a dye release study at Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS & IMF) to determine the amount of dilution that occurs in the adjacent waters of Sinclair Inlet when 1) drainage from dry docks (ground water and floor run-off) is discharged from PSNS & IMF Dry Docks and when 2) storm water is discharged from PSNS & IMF storm water outfalls during storm events. The sampling plan is designed to obtain data that can be used to evaluate mixing dynamics and support the development of mixing models for these two types of discharges in Sinclair Inlet (Figure 1).

Dye studies are an effective means of measuring the dilution and mixing of effluents in receiving waters (U.S. EPA 1991). Mixing is very complex in marine and estuarine systems and dye studies are the recommended approach for determining discharge impact zones (U.S. EPA 1991). Dye studies can provide information on the areal extent of mixing, identify the boundary where the effluent is completely mixed with ambient water, and validate computer models of mixing. Data from dye studies can also be used to calculate concentration isopleths for the outfalls under the discharge conditions measured during the study (U.S. EPA 1991).

BACKGROUND

Sinclair and Dyes Inlets, Washington were listed on the 1998 303(d) list of impaired waters because of fecal coliform (FC) contamination in the marine waters and metals and organic contaminants in bottom sediments and fish tissues (WDOE 1998). The Puget Sound Naval Shipyard & Intermediate Maintenance Facility, Department of Ecology, U.S. Environmental Protection Agency and local stakeholders are working together on Project ENVVEST (an acronym for ENVironmental InVESTment) to address contamination issues and develop water cleanup plans for the watershed (Navy, EPA, and Ecology 2000, ENVVEST 2002). Significant progress has been made on the FC Total Maximum Daily Load (TMDL) study for Sinclair and Dyes Inlets (Ecology 2004), which has benefited from the collaboration and cooperation of many stakeholders within the watershed. Currently, the FC model verification sampling for the TMDL study is being planned (Johnston et al. 2004) and storm water flow monitoring is being initiated for representative storm water outfalls within the study area (TEC 2003a, b).

Considerable progress has been made on modeling the watershed and receiving waters within the Inlet (Johnston et al. 2003). The modeling studies have directly contributed to the recent reclassification of Northern Dyes Inlet (about 1500 acres) from “prohibited” to “conditionally approved” for shellfishing by the Washington State Department of Health (Dunagan 2003, WDOH 2003a, b, c). Further progress has also been achieved for storm event sampling of streams (TEC 2003c), watershed monitoring, assessing the mass balance of contamination in the Inlets (Crecelius et al. 2003), and conducting a sediment metals verification study (Diefenderfer et al. 2003, Kohn et al. 2003). Additional studies are being conducted to evaluate contamination accumulation in the food chain of Sinclair and Dyes Inlets by analyzing species of fish and invertebrates from Sinclair Inlet and reference areas in the Puget Sound for metals, polychlorinated biphenyls, and some pesticides (ENVVEST 2003).

Figure 1. The location of PSNS & IMF in Sinclair and Dyes Inlets, WA. (Photo from WDFW).

The Clean Water Act and Washington State regulations (Ch. 173–201A WAC, WAC 2003) allow for the use of a mixing zone when all known, available, and reasonable methods of prevention, control, and treatment (AKART) have been implemented to reduce the amount of contaminants in the discharge. When mixing zones are used in a permit, the discharge must comply with water quality criteria at the edge of the mixing zone rather than at the end-of-pipe. Guidance documents available from the Washington State Department of Ecology (Ecology) recommend the use of direct measurements and numerical models in developing mixing zones (WDOE 2004, 2002). While direct measures of dilution in the receiving environment can provide excellent results under a small set of conditions, numerical models can be used to provide estimates of effluent mixing over any likely discharge scenario (U.S. EPA 1991). However, any numerical model used for developing a mixing zone requires a validation data set that can be reasonably reproduced by the model. This is particularly true when the actual physical conditions of discharge must be approximated within the model inputs (e.g. numerous physical barriers to the discharge such as pier pilings, ships, etc.).

Dry dock and storm water discharges from the Shipyard to Sinclair Inlet require NPDES permits issued by the U.S. Environmental Protection Agency (U.S. EPA). The current dry dock permit has an average monthly total recoverable copper concentration limit of 19 ppb while the storm water permit has a total recoverable copper of 33 ppb (U.S. EPA 1994). In addition, the permit also contains loading limits expressed in pounds per day. Although acute and chronic water quality criteria are not exceeded in Sinclair Inlet (Katz et al., 2004), the potential for adding to elevated copper levels in sediments adjacent to the Shipyard is still a concern. Given that AKART is currently being implemented by PSNS & IMF for discharges from the Shipyard, this investigation will provide direct measurements of dilution and mixing under specific conditions that can be used to develop more detailed mixing zone models (U.S. EPA 1991, Matlock 2003, PSU 2004).

STUDY GOALS

The goals of this study are to measure the amount and spatial extent of dilution into adjacent Sinclair Inlet waters that occurs during 1) normal dry dock discharge and 2) storm water discharge during a storm event. Fluorescent dye added to these discharges will be measured in the receiving environment over varying space and time scales. The measurements will be used to evaluate dilution and mixing in waters adjacent to the Shipyard and will be available for numerical model validation. The study will be a preliminary step in evaluating mixing dynamics near the Shipyard that may be applicable to future permits for dry dock and storm water discharges.

STUDY SITE

Dry Docks

The six dry docks at PSNS need to be continuously pumped dry because of groundwater infiltration. There are three main discharge outfalls that are used for discharging this groundwater. Pump well 6 is used to pump groundwater from Dry Dock 6 at a nominal rate of 5 MGD through Outfall 19 (labeled A in Figure 2). Outfall 19 is a 36 inch square pipe located underneath Pier 9 at a depth of a ~ 5 ft below mean lower low water (MLLW). The outfall pipe points at about a 45-degree angle several feet inboard of the pier head. A clear surface "boil" forms under the pier during discharge. A large barge is more or less permanently berthed on the pier head directly in front of the discharge. Discharge parameters for Pump well 6 are shown in Table 1.

Pump well 4 or 5 is used to pump groundwater from dry docks at a nominal discharge rate of 3 MGD through. Pump well 4 discharges through Outfall 18 (labeled B in Figure 1) while pump well 5 discharges through Outfall 18A shown by the black circle in Figure 1. Discharges are switched between the two pump wells as needed by dry dock operations. The outfall pipes are both 24 inches in diameter and are located approximately 7 feet below MLLW. Outfall 18 A discharges to the east under Pier 3. Outfall 18 discharges to the south along side Dry Dock 4. The end of the pipe for Outfall 18A is located more than 30 feet back under the piers. The discharge pipe at Outfall 18 is terminated at the quay wall with a 24 inch Red Valve Tideflex© checkvalve. A clear surface "boil" forms at the surface about 30' out from the head of Dry Dock 4 when Pump well 4 is engaged. Discharge parameters for Pump wells 4 and 5 are shown in Table 1.

Storm Water Outfalls

Two storm drain systems identified for sampling are Outfall 126 along Pier 8 on the eastern edge of the base and Outfall 15 on the western end of the base (Figure 2). These represent fairly different discharge regimes. OF 126 drains roughly 20 acres within the industrial area of the Shipyard as well as storm water from the City of Bremerton through a 24” diameter outfall pipe. During combined sewer and storm water overflow events (CSO) it is possible that sanitary sewer overflow will discharge from OF 126. Also a 24” diameter pipe, OF 15 drains roughly 100 acres of the Naval Base located outside the Controlled Industrial Area (CIA) as well as an unknown amount of run-on flow from the City of Bremerton. OF 126 discharges into a relatively open area of the base while OF 15 discharges into a narrow region between two carrier piers (Figure 2). OF 126 discharges on the beach under Pier 8 during low tide.

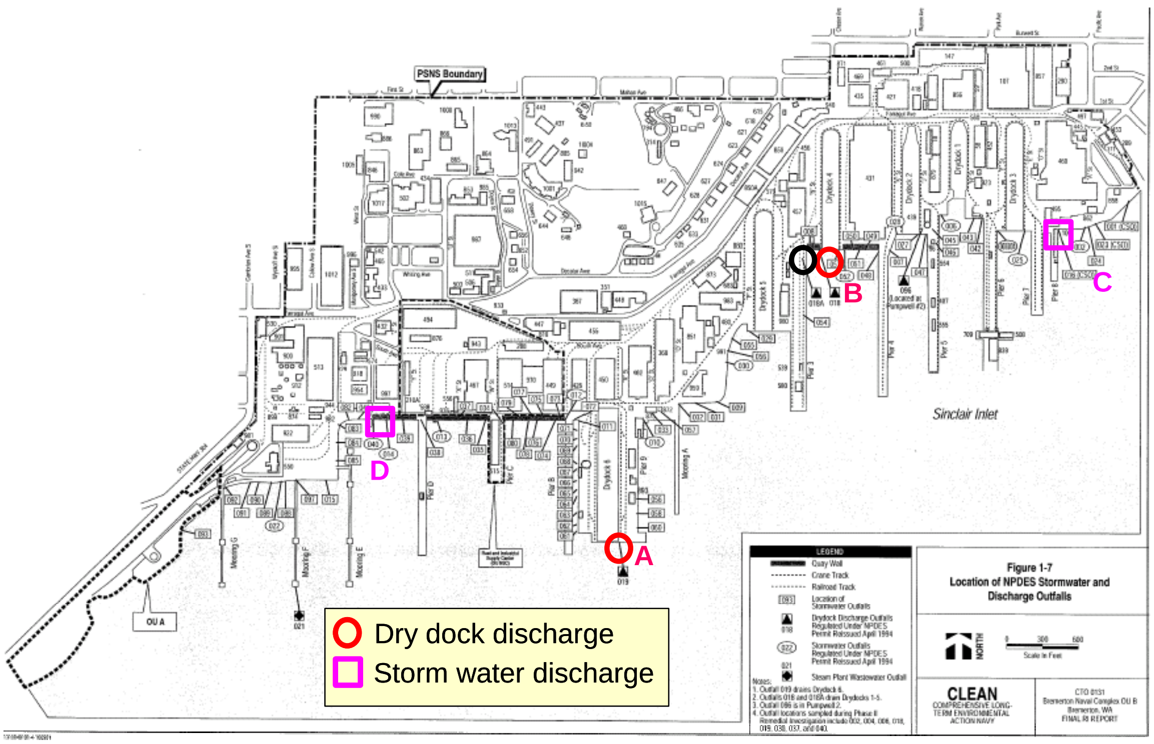

Figure 2. PSNS study site showing three dry dock and two storm water discharge locations.

Table 1. Discharge parameters for pump wells 4 & 5, and 6.

Pump Well	4 & 5	6
Daily flow (MGD)	3.0	5.0
Instantaneous Pump Flow Rate (gpm)	7,200	15,300
Pump Cycle Time (min)	190	30
Pump Run Time (min)	60	7
Approximate Run Time (%)	30	24
Discharge Pipe Diameter (inches)	24	36*
Discharge Depth (ft MLLW)	-7.4	-5.1
Target dye conc at discharge point (ppb)	100	100
Dye (0.4%) addition rate to achieve concentration (gpm)	0.18	0.38

* Discharge pipe is square

METHODS

Dye Release

Concentrated fluorescein dye is a liquid that is 40% dye by weight. A primary 0.4% dye solution will be made by diluting with dry dock groundwater collected from the pumping system. This primary solution will be used for all subsequent releases and calibrations. The dye will be released at a nominal maximum concentration of 100 ppb, thus providing the ability to detect a 1000-fold dilution using a fluorometer (excitation/emission wavelengths of ~490/525 nm) having a 0.1 ppb detection limit. This nominal concentration will be altered in the field if necessary to maintain the capability of observing dilution factors of between ~100 and 1000.

Dry Docks

The primary fluorescein dye solution will be released into the dry dock effluent at constant rate to ensure a consistent dye concentration in the discharge. A peristaltic pump will be switched on automatically when the pump engages using a contact closure as the trigger. The dye pumping rate needed to meet this condition (0.18 to 0.38 gpm) is shown in Table 1. The dry dock discharge will be assumed to have a fully mixed constant concentration of 100 ppb. The pump on/off times will be recorded by a small data logger attached to the pumping system.

Two dye release strategies will be tested on the drydock discharge. The first scenario will be to release dye at the start of a falling (or rising) tide and continue to pump through the entire ebb (flood) tide condition, and monitor into the next flood (ebb) tide condition or until the dye is fully dispersed below detection. Measurements made under this release strategy will show whether or not dye (drydock water and its potential contaminants) builds up over time or if tidal mixing is effective at diluting the discharge to ambient conditions and what that timeframe may be. The second strategy will be to release the dye during one pump cycle and monitor the dye plume until it mixes to below background to determine how fast and where dilution occurs This cycle will be repeated to determine an average condition.

Storm water outfalls.

The primary fluorescein dye solution will be released into storm drains by manually dumping a fixed volume and concentration of dye once rain has fallen and there is a positive flow to the Inlet. This method of dye injection best approximates a first-flush discharge. The exact volume of dye released will be determined once flow measurement data for the two conveyance systems become available (currently underway). However, the target maximum dye concentration at the point of discharge will be 100 ppb. The time of the release will be recorded by the person manually dumping the dye. Dye will be monitored at a point downstream in the conveyance system using a bench top fluorescein dye fluorometer collecting data a 1-Hz data rate. These measurements will allow the discharge concentration to be measured as a function of time through the storm event.

The amount of runoff associated with first-flush can be estimated using the drainage area for each outfall, assuming a100% impermeable surface, and assuming that runoff from the first 0.1” of rainfall represents a first-flush flow condition. Using this estimate, the amount of dye release needed is 1.4 gal for outfall 126 and 6.8 gal for outfall 15 as shown in Table 2. These amounts will be manually dumped into the conveyance system once flow is established in the outfall.

Table 2. Potential discharge parameters for storm water outfalls 126 and 15.

Outfall	126	15
Total Area (acres)	20	100
Runoff (gal) for 0.1" rainfall	54279	271393
Target dye conc at discharge point (ppb)	100	100
Dye (0.4%) addition to achieve concentration (gal)	1.4	6.8

Receiving Water Monitoring

The dye study will utilize the Marine Environmental Survey Capability's (MESC, SSC-SD 2003) mini-MESC system to map out freshwater, particle, and dye plumes generated from storm water and/or drydock discharges during storm events and normal operations. Similar to the dye-release study conducted in the Port Washington Narrows (ENVVEST 2002b), the receiving water monitoring will focus on collecting salinity, temperature, light transmission, and dye fluorescence data offshore of selected outfalls during the dye release. The mini-MESC equipment will be deployed on a Shipyard vessel to map out fluorescien dye, freshwater, and particles generated from dry dock and storm water discharges. The mini-MESC system is a towable real-time multi-sensor and data acquisition system. For purposes of this study, the system will be composed of an in situ fluorescein dye fluorometer, a conductivity, temperature, and depth (CTD) unit, a light transmissometer, a GPS navigation system, and a data acquisition computer. The system will be used to collect and collate sample depth, salinity, temperature, light transmission, fluorescein dye fluorescence data, and position location at a 2-Hz data rate. The data will be displayed and mapped in real time to monitor the levels of each of the parameters as a function of location.

Prior to the dye release, MESC will be used to map out the region immediately adjacent to the point of discharge to assess background conditions. Mapping will be performed by traversing the region (inside all physical barriers) in a zigzag pattern that has ever-increasing spacing between transit lines as shown in Figure 3. The MESC sensors will be towed near the surface (1 to 2 m depth) at 1 to 3 kts. Vertical profiles will occasionally be performed to assess variations with depth. Once dye has been released, MESC will repeat the mapping transect zigzagging through the center of the plume determined either visually or with sensors out to the point where dye concentrations fall below detection (~0.1 ppb) or where there are obstructions such as piers or security barriers. Vertical profiles will occasionally be performed to assess the depth of the plume and the tow depth altered if necessary to map the maximum concentrations of dye. The tracking pattern will be repeated as a function of time to capture mixing occurring through the tide cycle and in the case of dry-dock discharges, through multiple pump cycles.

A second fluorescein fluorometer may also be used to collect dye data from the region of maximum dye concentrations to determine the minimum dilution of dry dock discharges. (this fluorometer will be used in the storm water outfalls to determine the initial dye concentrations prior to discharge). Water will be pumped from the "boil" region of the discharge to the fluorometer using a high speed impeller pump and the data collected independently at a 1-Hz sample rate.

Dye Calibrations

Both fluorometers used in the study will be calibrated by measuring serial dilutions of the initial primary 0.4% dye solution. The serial dilutions will be made using seawater as the dilutent. The range of concentrations used in the calibration will be between 0.01 and 200 ppb. A regression of the fluorometer voltage as a function of concentration will be used for determining dye concentrations of data collected. Calibrations will be performed each day.

Current Measurements

An acoustic Doppler current profiler (ADCP) will be deployed for about a month, between Piers 3 and 4 (worst case for flushing) offshore of the discharges from pump well 4 and 5 (near location “B” in Figure 2). The location of the ADCP will be chosen to avoid Shipyard traffic and ship moorings within the pier area. The ADCP will be deployed prior to the dye release, and be retrieved approximately four weeks later following completion of the spring-neap tidal cycle. The current meter will provide a record of flow conditions within an area of restricted flow near the Shipyard over a complete tidal cycle.

Dilution Calculations

Spatial maps of the dye plumes as a function of time through the tide will be generated for each release experiment. The maps will be generated using both dye concentrations and dilution values to show the amount of mixing occurring as a function of both space and time. Dilution at any point in space or time will be calculated by dividing the initial concentration in the discharge by the measured concentration in the receiving environment. For the dry docks, the initial concentration will be fixed at a nominal 100 ppb based on the assumption of complete mixing of the dye within the effluent between the entry point and the outfall exit point. An *in situ* measurement of 2 ppb would therefore calculate out as a dilution of 50. While the amount of dye released into the storm drain can be compared to the amount observed in the receiving environment, the time varying dilution occurring in the pipe can also be used for comparison to calculate dilution.

Schedule

The dye study will be scheduled for the later part of April 2004. The actual sampling dates will be dependent on logistical considerations within the Shipyard (vessel availability, dry dock operations, docking and undocking operations, etc.) and weather conditions. The optimal sampling period is April 18 – April 26, 2004, when strong tides occur mostly during daylight hours (see Bremerton Tide Chart for April 2004).

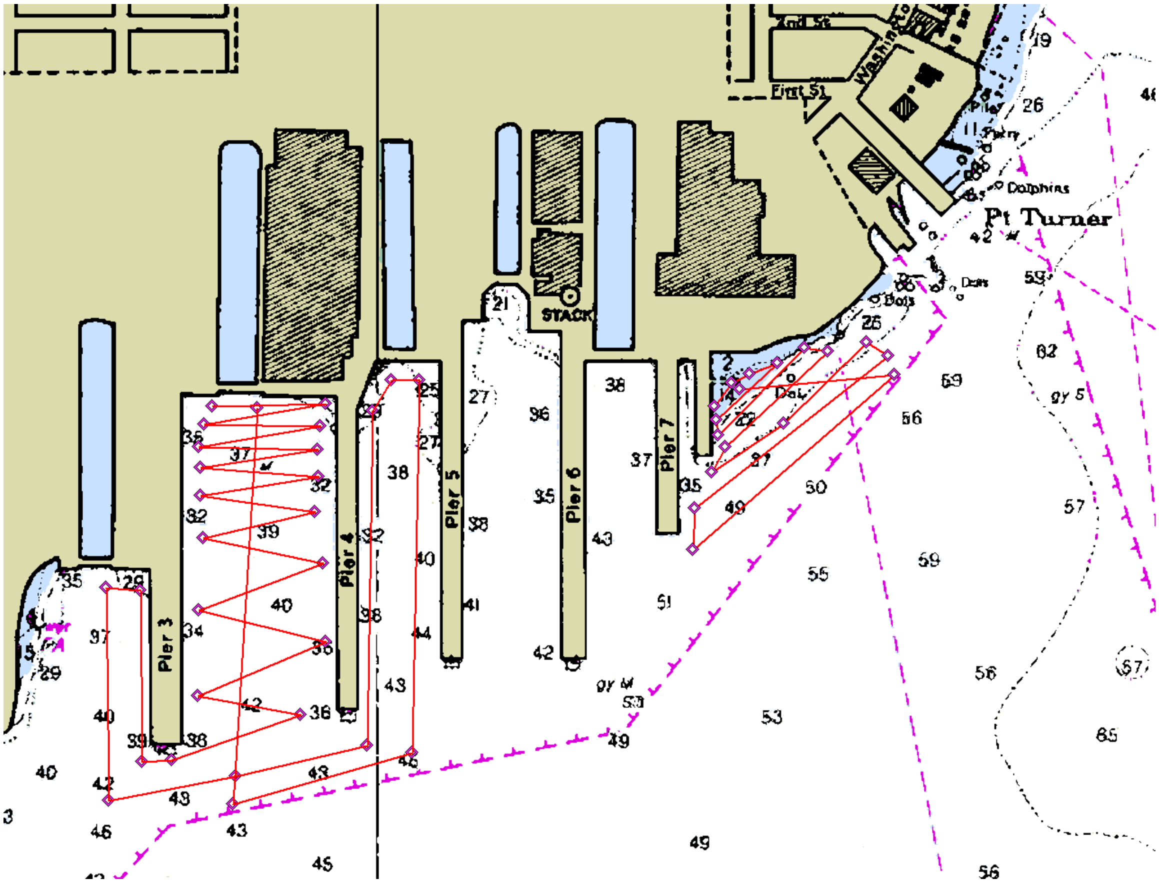

Figure 3. Example transects used to map out spatial extent of dye release from Pump Well 4/5 and OF126.

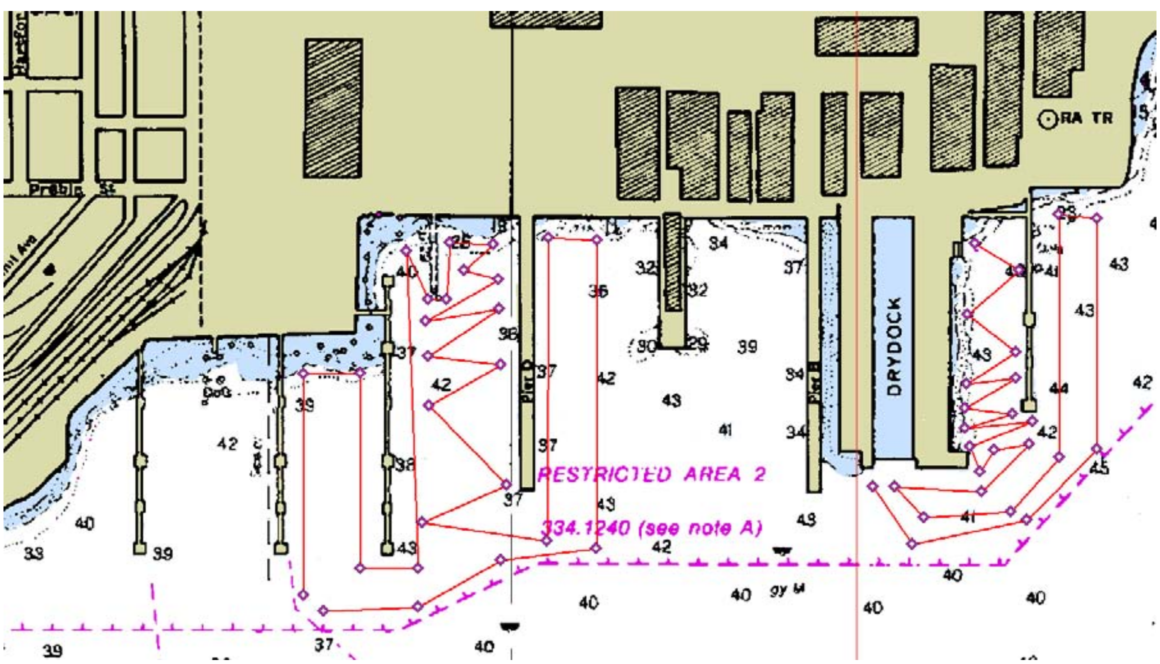

Figure 4. Example transects used to map out spatial extent of dye release from Pump Well 6 and OF15.

Summary

A dye study will be conducted to measure the amount and spatial extent of dilution into adjacent Sinclair Inlet waters that occurs during 1) normal dry dock discharge and 2) storm water discharge during a storm event. The measurements will be used to evaluate dilution and mixing adjacent to the Shipyard and will also be available for numerical model validation. The study will be a preliminary step in evaluating mixing dynamics near the Shipyard that may be applicable to future permits for dry dock and storm water discharges.

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