Planetary Technologies Tufts Cove 2024 OAE Trial

This document provides a high level overview of Planetary Technologies' (Planetary) planned ocean alkalinity enhancement (OAE) activities in the summer and fall of 2024. The purpose of the document is to provide context against which applicants to the *Halifax Ocean Alkalinity Enhancement Joint Learning Opportunity* may plan their research proposals. This does not comprise the full extent of their research, technology or decision-making process and is intentionally simplified for clarity and reference. Also note that this plan is subject to change.

Planetary Alkalinity Trial Overview

Planetary Technologies (Planetary) will be adding an alkaline slurry created by mixing $Mg(OH)_2$ with seawater to a cooling water outfall at the Tufts Cove Generating Station. This is part of a two-year OAE trial that commenced in September, 2023 in collaboration with researchers at Dalhousie University. Details of the trial are described below.

Anticipated Dosing Schedule and Protocol

During the 2023 OAE field trial, Planetary safely dosed alkaline feedstock into the receiving waters of Halifax Harbour at rates ranging from 7 to 21 kg/min. A basal (1x) dosing rate of 7 kg/min was selected based on preliminary modeling work performed by researchers at Dalhousie University that revealed that such a dosing rate would be necessary to measure a detectable pH and total alkalinity (TA) change in the receiving waters of Tufts Cove. In 2024, we will adopt the same initial 1x dose rate, but will select a new, nominal dose rate based on an early-trial experimental phase.

Planetary is proposing to conduct the 2024 alkalinity release trial in two phases (Fig. 1) consisting of (1) an intense, 2-week ramping phase, followed by (2) nominal 5-day/week dosing. The trial will begin in mid-summer (July/August) and will end in winter (late-Nov/early-Dec) 2024.

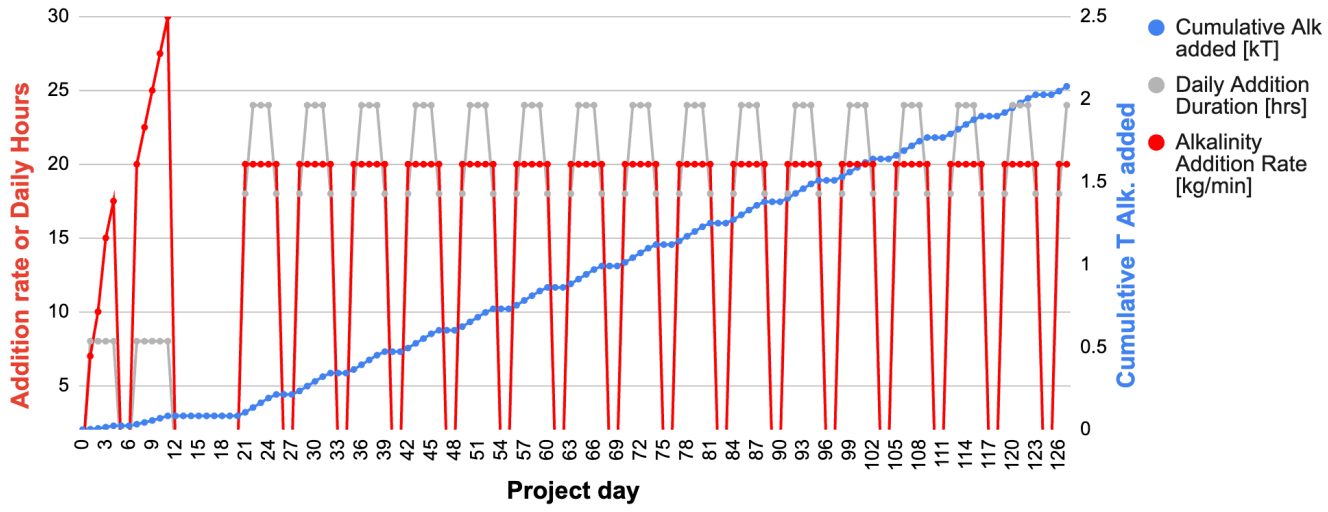

Figure 1 Proposed alkalinity dosing schedule showing a proposed ramping phase (days 1-14), followed by a nominal continuous dosing period. Short breaks represent weekends. Breaks for holidays, maintenance shut-downs, or pauses if a stop-trigger is breached are not currently scheduled.

Ramping Period

The goal of the ramping period will be to ascertain a nominal dosing rate that will not exceed a stop-trigger threshold.

This period will comprise the following:

- Alkaline feedstock delivery rates will be increased incrementally from ~7 kg/min (start of week one) to as high as ~40 kg/min (end of week two, exact max rate TBD)
- Each prescribed dosing rate will be sustained for 12 hours (6AM to 6PM), and the rate will be increased by 2.5-5 kg/min on each subsequent day.
- Planetary will extensively monitor the effluent and ocean receiving waters (see monitoring summary), and will pause dosing operations for at least one week afterwards to analyze the resulting data.

Planetary will immediately reduce dosing rates or pause the ramping phase if a stop-trigger threshold is reached. Stop triggers include exceeding effluent pH > 9 and other metrics to ensure operational performance. In such an event, we will reassess the nominal dose rate based on our most up-to-date learnings.

During the nominal dosing period, we will maintain a constant dosing rate each week until the end of the trial. Notwithstanding holidays, maintenance shut-downs, or pauses dosing will commence at approximately 6am on Monday mornings and will end at 6pm on Friday evenings.

The dosing schedule proposed in Fig.1 will be used to conduct a pre-trial ROMS modeling simulation and include dissolution and sinking parameters chosen based on feedstock testing. This simulation may refine our monitoring plan, by providing insights into optimal sampling locations and timing.

Planned Monitoring Activities

Relevant Protocols and Regulations

Planetary will conduct monitoring activities of the ocean receiving waters in Halifax Harbour and outfall before, during, and after the proposed trial. These activities have been developed in accordance with the standards identified in Section 10 of the Isometric OAE protocol V1.0, and will serve to ensure that dosing activities comply with regulatory thresholds defined in Planetary's Nova Scotia Environment operating permit and with federal regulations defined within the Canadian Council of Ministers of the Environment Water Quality Guidelines.

General Overview

To achieve our monitoring objectives, a range of approaches and platforms will be used to monitor effluent and waters within and outside of the effluent plume (Fig. 2.4.2, Table 2.4.1).

Boat surveys of the Halifax Harbour and Bedford Basin (Fig. 2.4.1) will be conducted at monthly (pre- and post-trial) and bi-weekly (during trial) intervals as described in the *Halifax Ocean Alkalinity Enhancement Joint Learning Opportunity*. These surveys will be supported by continuous observations from a moored sensor package (details below and in table 2.4.1), installed adjacent to the ocean outfall and within the effluent mixing zone (Fig. 2.4.3). The mooring will be deployed from approximately one month prior to the onset of the dosing period, until the end of the dosing period. We will also conduct opportunistic, weekly in/out of plume transects using a remotely

piloted surface vehicle (Blueboat USV) (note, however, that these surveys are aimed towards Research & Development (R&D) and thus not yet part of Planetary's core or routine monitoring activities; data collected from these surveys will be reported, but the frequency and variables reported may be irregular). Biogeochemical properties of the outfall water (effluent), and dosing parameters will be continuously recorded using Planetary's custom-built dosing array (Fig. 2.4.3, top) and sensor packages installed up- and downstream of the dosing location (Fig. 2.4.3, bottom).

The text and tables (2.4.1) below summarize Planetary's monitoring plans. In parallel to these activities, researchers from Dalhousie University will conduct independent research and monitoring activities of Halifax Harbour and Bedford Basin, as described in the main RFP document.

Pre-deployment monitoring

The survey area has been well-baselined through biogeochemical time-series monitoring programs of central Bedford Basin (orange triangle in Fig. 2.4.1) conducted by the Bedford Institute of Oceanography (BIO) (weekly since 1992) and Dalhousie University (since 2008). Carbonate system parameters (pH, total inorganic carbon, total alkalinity (TA)) have been measured at this site since 2016. Additional surveying of the region occurred through a water quality monitoring program that reported on temperature, salinity, dissolved oxygen, water metal content, and total suspended solids (TSS) levels in Halifax Harbour and Bedford Basin between 2004-2010. Historical sediment quality data at six locations in the project region were also collected in a study conducted by Tay et al., 1992.

In preparation for the 2023 OAE field trial, biogeochemical surveys across Halifax Harbour and Bedford Basin began in spring, 2022 (similar to 'Baseline Data Collection' activities' listed in main RFP document).

Boat surveys

Planetary will participate in monthly boat surveys throughout the duration of the 2024 OAE trial and beyond, by obtaining biogeochemical observations at up to four stations throughout the survey area (blue markers in Fig. 2.4.1). One station is located within the outfall plume ("Tufts Cove"), and three are outside. Our routine measurement suite includes the following list.

- Profiles of pH, turbidity, dissolved oxygen, temperature, and salinity obtained at all four locations using a RBR Maestro profiling sensor package. Note that turbidity and O_2 profiles were not collected between January and May 2024 due to servicing on our CTD.
- Discrete surface and bottom water samples for TSS determinations obtained from all four locations. Note that bottom water samples were not collected in January, February, or March 2024.

- Discrete surface water and sediment grab samples for metals content analyses, obtained from two stations (locations TBD based on logistics and pre-trial model simulation). Note that water column metal sampling began in April, 2024.
- Drop camera surveys to assess potential alkalinity accumulation on the seabed and obvious changes in benthic ecology conducted at three to four locations (ocean conditions-permitting)
- Light attenuation estimates using both a photosynthetically active radiation (PAR) sensor and a Secchi disk at all four locations. Note that observations will begin in June, 2024.
- Benthic organism tissue samples, harvested opportunistically from the seabed via a sediment grabber. Note that samples will only be obtained and analyzed if a benthic organism is collected in the sediment grabber.

Note that Planetary's sensor, drop camera and light attenuation data will be processed in-house. TSS analyses will also be performed by Planetary, with periodic verification by a third party laboratory. Metal samples will be collected by Planetary and sent to a third party laboratory for processing and analysis.

As noted above, a pre-trial modeling simulation will be conducted to assess potential biogeochemical impacts of the OAE addition on the receiving waters. Planetary's exact boat survey plans during the trial may change depending on the results of that simulation, in order to focus efforts on the potentially most-impacted regions of Halifax Harbour and Bedford Basin. For example, if the simulation reveals excess accumulation of alkaline material in one location, Planetary will enhance sediment grab efforts in that region.

Sensor packages

Beginning approximately one month prior to the beginning of the 2024 OAE trial, Planetary will begin to monitor the outfall effluent and immediate receiving waters (outfall plume) around Tufts Cove using a suite of sensor packages. These include a shore-tethered mooring, effluent sensor arrays (Figs. 2.4.1, 2.4.3, Table 2.4.2), and opportunistic deployments of a remotely-piloted surface vehicle (BlueBoat; details at the end of this section). The mooring and sensor arrays will be deployed continuously throughout the duration of the trial, with periodic down-time for cleaning and maintenance.

The mooring will continuously (frequency ~30-60 min) measure TA (DOT Alkalinity sensor), pCO_2 (Pro-Oceanus Pro-CV), and pH, turbidity, TSS (derived from turbidity), Chlorophyll *a* (Chl *a*),

temperature, and salinity (all using an In-Situ AquaTroll multiparameter sonde). The data will be logged continuously on the respective sensors, retrieved and analyzed weekly throughout the duration of the alkalinity release. Retrieval of the data from the moored array will involve a short recovery, servicing (cleaning, changing batteries and reagents if necessary), and downloading data and archiving it on Planetary's cloud systems. During the recovery period, we will aim to use the same set of sensors to perform a survey of the Tufts Cove vicinity using a remotely piloted boat (details below). The total mooring down time would likely be ~2-4 hrs, and will occur once per week. The mooring will be installed at a fixed location that is nominally within the outfall plume (Fig. 2.4.3), however, the tidal cycle and prevailing winds at Tufts Cove will result in transient periods where the package is outside of the plume.

In addition, Planetary will install custom-build sensor packages ("SensorBoxes") at locations up and downstream of the alkalinity dosing point (Fig. 2.4.2). The SensorBoxes will continuously monitor (frequency ~5-10 min; TBD based on field testing) the outfall water for pH, turbidity, TSS (derived from turbidity), temperature, and salinity. Planetary will collect discrete carbonate parameter samples from the up- and downstream locations throughout the trial. Discrete bottle samples for TA, DIC, and metal content will be obtained from both measurement locations once per week, during nominal dosing operations. During the intensive ramping period (see Appendix 2, section 2.1), discrete samples will be obtained once daily. Additional samples for pH and TSS determinations will be obtained once per week to calibrate the underway sensors. The carbonate parameters will be measured by researchers from Dalhousie University, and the metals by an independent third party laboratory.

We will also aim to conduct weekly, pre-programmed surface water surveys of the receiving waters around Tufts Cove using a remotely piloted ocean surface vehicle (Blue Robotics BlueBoat). The BlueBoat will be outfitted with a multiparameter sonde capable of pH, turbidity, TSS (derived from turbidity), Chl *a*, temperature, and salinity measurements. Surveys will be designed to cross the outfall plume front (approximate location shown in Figs. 2.4.1 and 2.4.2) on multiple occasions to assess changes in surface water biogeochemistry inside versus outside of the plume. Note that BlueBoat surveys will be conducted opportunistically and as part of Planetary's R&D activities prior to and during the field trial.

References:

Tay K-L, Doe KG, Wade SJ, Vaughan DA, Berrigan RE, Moore MJ. 1992. Sediment bioassessment in Halifax harbour. Environ Toxicol Chem 11: 1567–1581.

Operational measurements and monitoring program

As described above, boat surveys (bi-weekly) and sensor deployments (continuous) will be conducted from approximately one month prior to the beginning of the trial until the end of the deployment (Dec. 2024). These monitoring plans described above will be followed for the duration

of the trial. However, ad-hoc adjustments may be made to address specific observations or results from preliminary modeling work.

All data will be analyzed in-house on a weekly basis in order to assess if any regulatory or environmental thresholds are exceeded in a timely manner. In addition, data from the SensorBoxes will be streamed, in near-real time, to Planetary's cloud-based monitoring and MRV system, and warnings will then be transmitted to operators in the event that a stop-trigger or regulatory threshold is neared or breached.

In addition to the ocean and outfall monitoring described here, Planetary will install an alkalinity dosing platform on the Tufts Cove site (Fig. 2.4.3) that will be used to dose alkalinity into the ocean outfall at a controlled and prescribed rate. The dosing skid consists of a tank, seawater and metering pumps, and a dry alkalinity feeder to simultaneously produce and dose an alkaline slurry. The platform will continuously record the alkalinity dosing rate (e.g., slurry L/min and dry alkalinity equivalent in kg/min) and pH of the dosed slurry at 1-minute intervals. The slurry's physical properties (density, solids content) will be calculated by the system based on feed rates of dry alkalinity and water into the slurry production chamber, and those properties and pH will be verified by collecting daily slurry samples to be analyzed on-site. This approach, and a previous version of this system was tested and validated during the 2023 trial.

Planetary site operators will also collect dry alkalinity sub-samples from the supersac bags of dry alkalinity used to make the on-site slurry. Samples will be drawn regularly from within the supersacs, and subsequently analyzed for metals content. This sampling will be conducted throughout the trial in addition to the pre-trial feedstock characterization.

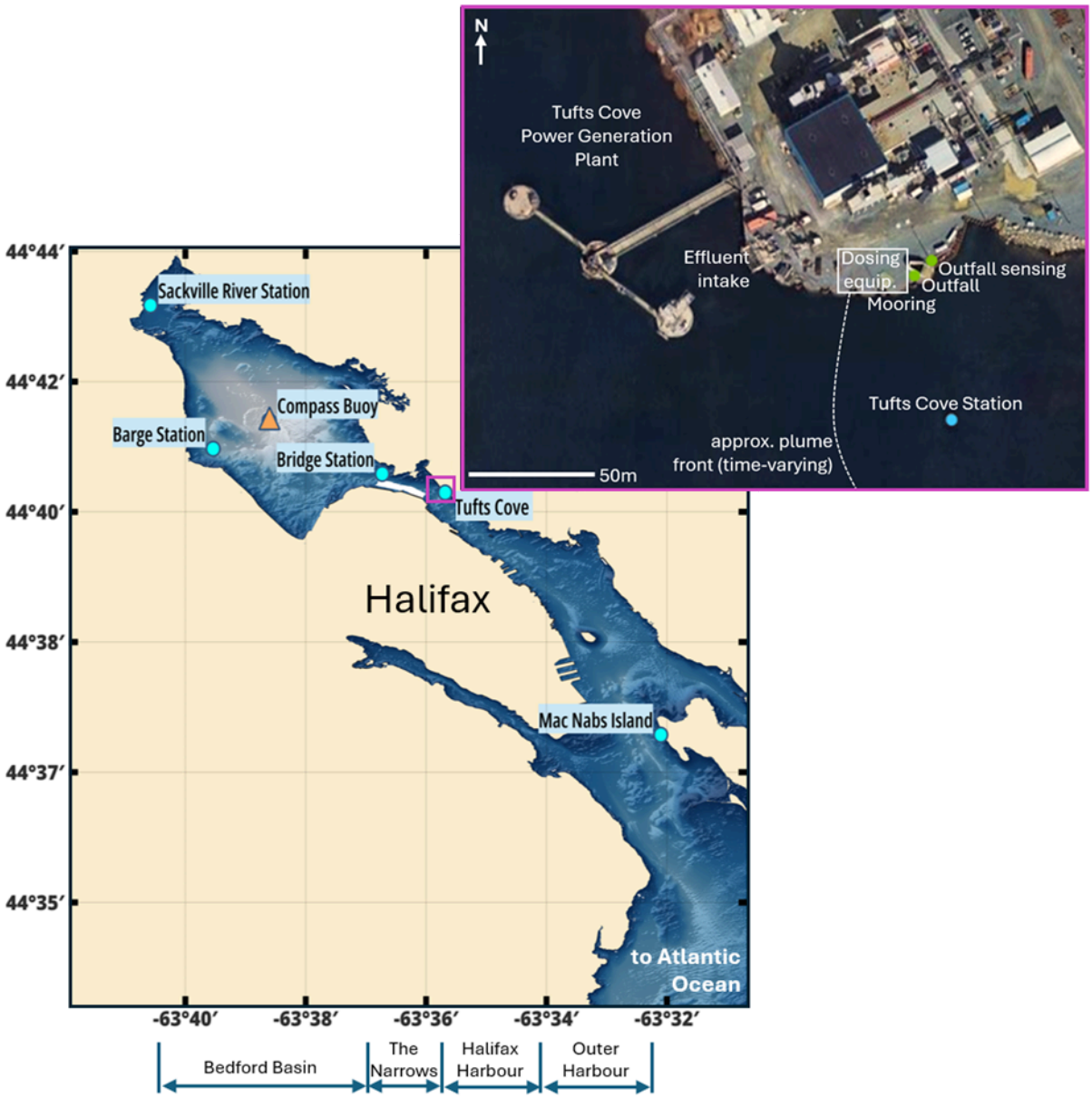

Figure 2.4.1 Map of Bedford Basin and Halifax Harbour. Blue markers represent the regularly sampled ocean monitoring stations. Green markers (right panel) represent the on-shore effluent monitoring stations.

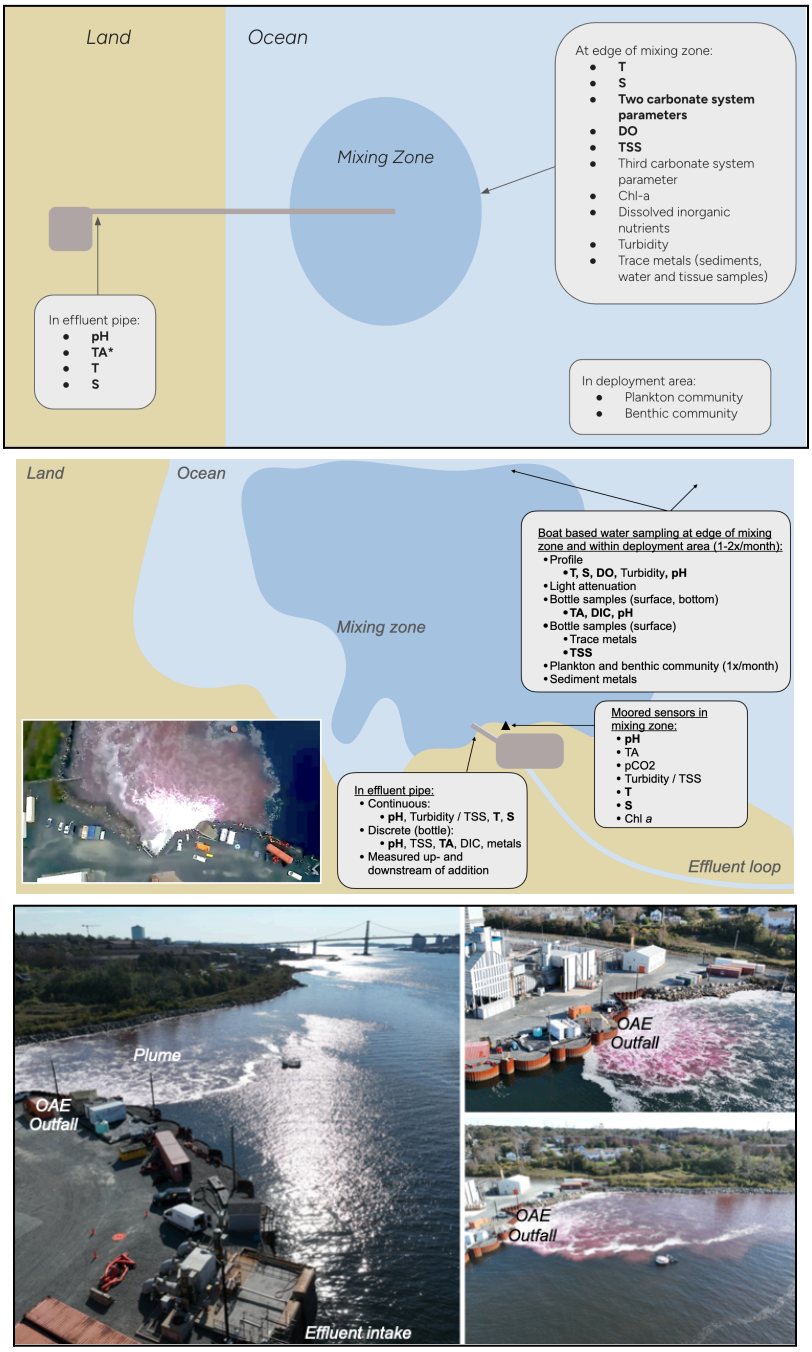

Figure 2.4.2 (TOP) Plan view from Isometric V1.0 OAE protocol Section 10.2 Monitoring Locations. (MIDDLE) Planetary's plan view at Tufts Cove (aerial image inset). Required (bolded) and recommended measurements are listed. (BOTTOM) Zoomed-out images showing the time-varying plume location relative to the OAE discharge.

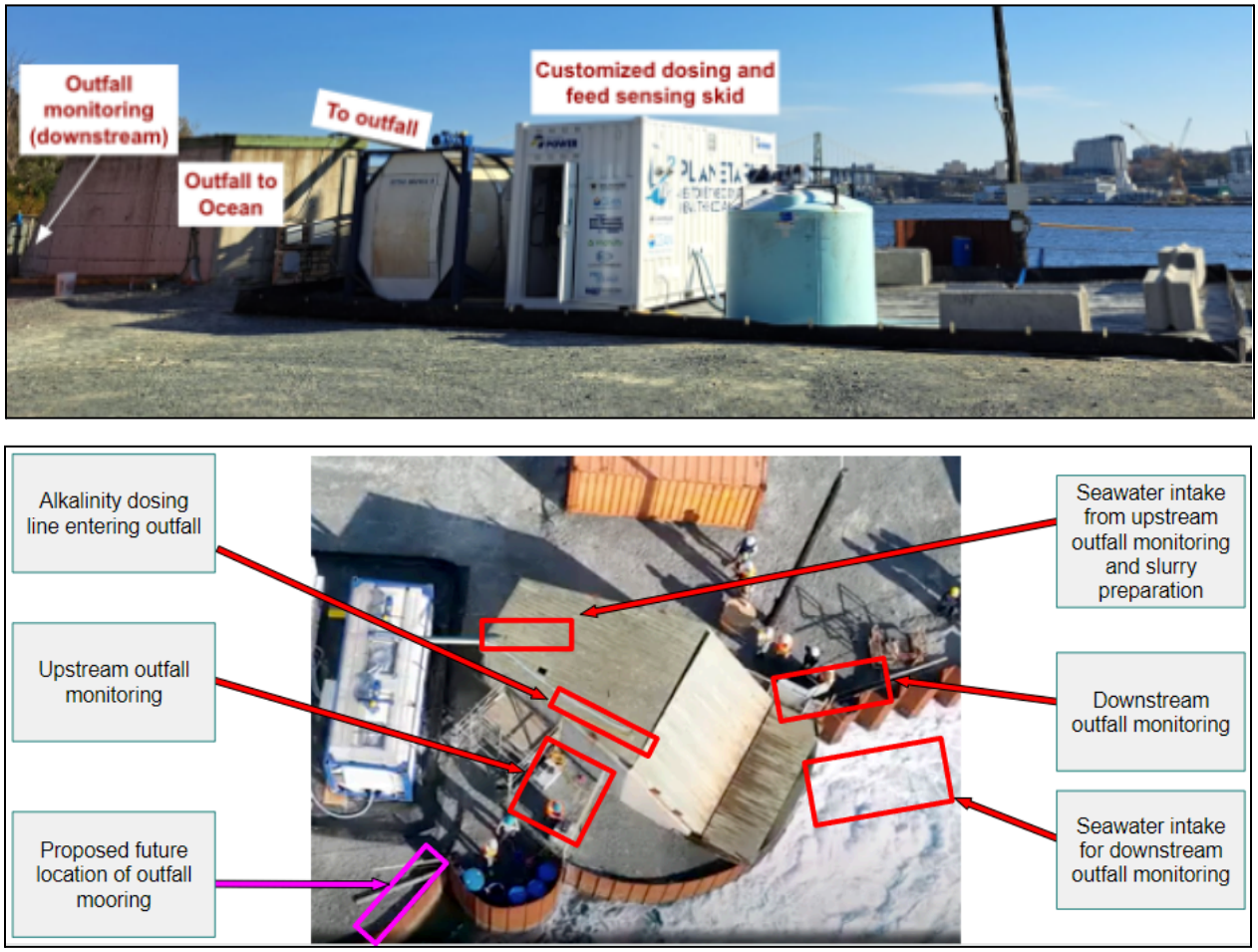

Figure 2.4.3 Planetary's equipment setup at the Tufts Cove power generation plant, showing the locations of the outfall sensing and dosing equipment. NOTE: The water intake location for the downstream outfall monitoring station will be determined pre-trial. In 2023 the intake was located immediately ocean-side of the outfall (<0.5m away from the discharge point) as access to the outfall pipe was not feasible. In 2024, we are exploring accessibility to the outfall pipe and will install requisite sampling infrastructure in May 2024, during a shut-down of the outfall pipe.

Table 2.4.1 Summary of Planetary's ocean, outfall and dosing monitoring plans. Data Package to be Provided by Planetary to relevant JLO participants (Subject to Change as Plans Evolve)

Summary of Planetary's ocean, outfall, and dosing monitoring plans.

Area	Parameter	Requirement & Purpose	Approach	Platform	Location	Timing & Frequency
Ocean receiving waters - mixing zone and deployment area	pH (depth profile)	Regulatory compliance and MRV; Required by IOAE; 7-8.7 or <0.2 change[A]	sensor	(1) Boat survey (2) Mooring (3) BlueBoat[D]	(1) Four stations in BB & HH (2) ~5 m adjacent to outfall, nominally within plume (3) ~250 m radius of OAE outfall	(1) Monthly pre-trial[E]; bi-weekly during trial (2) Continuous during trial (3) Opportunistic weekly
	Turbidity (depth profile)	Regulatory compliance and MRV; Required by IOAE; <8 FNU change[A]	sensor			
	Temperature, Salinity (depth profile)	MRV; Required by IOAE	sensor			
	TSS (surface water)	Regulatory compliance and MRV; Required by IOAE; <25 mg/L change[A]	derived[C]; validated with bottle			
	TA (surface)	MRV; Required by IOAE; <1000 µmol/kg change	sensor	Mooring	~5 m adjacent to outfall, nominally within plume	Continuous during trial
	pCO2 (surface)	MRV; Required by IOAE	sensor			
	Dissolved oxygen (depth profile)	Regulatory compliance and MRV; Required by	sensor	Boat survey	(1) Four stations in BB & HH	Monthly pre-trial[E]; bi-weekly during trial

		IOAE; <10% change beyond expected concentrations[A]				
	Chl *a* (surface)	MRV; Recommended by IOAE	sensor	(1) Mooring (2) BlueBoat[D]	(1) ~5 m adjacent to outfall, nominally within plume (2) ~250 m radius of OAE outfall	(1) Continuous during trial; (2) Opportunistic weekly
	Sediment trace metals and accumulation	Regulatory compliance and MRV; Recommended by IOAE; thresholds vary by element	discrete samples	Boat survey	Two stations in BB & HH	Monthly pre- and during trial[E]
	Water total trace metals content (surface water)	Regulatory compliance and MRV; Recommended by IOAE; thresholds vary by element	discrete samples			Monthly pre- and during trial[E]
	Organism tissue trace metals	MRV; Recommended by IOAE; thresholds vary by element	discrete samples			Opportunistic
	Light attenuation	MRV; Not required by IOAE	PAR meter	Boat survey	Four stations in BB & HH	Monthly pre-trial[E]; bi-weekly during trial
Outfall - effluent	pH	Regulatory compliance; Required by IOAE and NSE;	sensor; validated with bottle	Flow-through sensor package	Up- and downstream outfall	Continuous during trial (5-15-min frequency)

		6.5-9[B]	(weekly)			
	Turbidity	Regulatory compliance;Not required by IOAE	sensor			
	Temperatur e	MRV; Required by IOAE	sensor			
	Salinity	MRV; Required by IOAE	sensor			
	TSS	Regulatory compliance and MRV; Required by NSE; <40 mg/L change[B]	derived[C]; validated with bottle (weekly)			
	TA	MRV; Required by IOAE	bottle	Discrete sample	Up- and downstream outfall	1x weekly during trial
	DIC	MRV; Second carbonate parameter required by IOAE	bottle			
	Trace metals	MRV; Not required by IOAE	bottle			
Outfall - dosing	Alk. dosing rate	MRV and CDR calc.; Required by IOAE	sensor	Dosing platform	Upstream outfall	Continuous during trial (1-min frequency)
	Power consumptio n	CDR calc.; Not required by IOAE	sensor			
	Slurry pH	CDR calc; Not required by IOAE	sensor			

	Slurry physical properties (pH, w/w%, density)	Sensor verification; Not required by IOAE	Bottle	Discrete sample	Upstream outfall	
	Dry feedstock sub-sampling (mass, elemental composition)	MRV; Required by IOAE	Dry sample	Discrete sample	Alkalinity feedstock	
	Flow rate	CDR calc.; Required by IOAE	N/A	Provided by power plant	N/A	Constant, provided by power plant

HH & BB + Halifax Harbour and Bedford Basin
(A) CCME regulations for coastal waters
(B) Defined under Planetary's Nova Scotia Environment (NSE) operating permit
(C) The TSS-vs-turbidity relationship will be derived from water samples collected in spring 2024. The relationship will be validated throughout the trial by collecting weekly TSS bottle samples from the outfall effluent, and bi-weekly samples from the ocean.
(D BlueBoat surveys are R/D activities conducted using a remotely piloted autonomous surface vehicle. These surveys will be completed opportunistically on a targeted weekly basis, but the actual frequency of data collection may be sporadic.
(E) Note that data collected pre-trail spans January-July, 2024. Some variables were not collected during each monthly boat survey in HH & BB due to instrument malfunction, inclement weather or other logistical constraints.

Table 2.4.2 Shore-tethered mooring and BlueBoat sensors and variables.

Sensor	Variables collected
Dartmouth Ocean Technologies TA sensor (mooring only)	Total alkalinity
Pro-Oceanus CO2-Pro Atm.	Seawater and air pCO2
In Situ Aquatroll 600 Multiparameter Sonde	T/S, pH, turbidity, Chl *a*

Table 2.4.3 Stop triggers summary table

Type	Trigger / threshold	Stop action[A]	Resumption requirements
Manual	Personnel **injury**	• Stop dosing immediately	• First aid administered to the injured worker (if necessary), and preventative measures put in place to ensure no repeat injury • Sufficient number of fit operators on-site
	Equipment malfunction resulting in unsafe working conditions (e.g., leaks, sparks), un-monitored dosing or loss of dosing data	• Stop dosing immediately	• Equipment fixed and safety-tested
	Spill occurs	• Stop dosing immediately • Inform environmental regulator.	• Spill cleaned up • Regulator informed of cleanup
	Inclement weather (realized or forecasted)	• Stop dosing immediately	• Inclement weather subsides
Effluent	**pH**: rolling hourly-median value >9 or <6.5	• Stop dosing immediately • Reported to the environmental regulator.	• Reduce dosing rate and monitor closely for further exceedance • Regulator report sent within 48hrs of event
	TSS: rolling hourly-median difference between up- and downstream stations >40 mg/L		
Ocean[B]	**pH**: any measurement outside 7-8.7 range or >2 units above background	• Stop dosing immediately	• Reduce dosing rate and monitor closely via boat survey on the same day • Regulator report sent within 48hrs of event
	TSS: >25 mg/L difference between in- and out-of-plume		

	Dissolved oxygen: A) < 10% below the natural concentration when DO >8mg/L; or B) below natural DO when DO <8mg/L		
	Total metals: in-plume concentration > EQS limit[C] when out-of-plume concentration < EQS limit		
Sed.	**Total metals**: in-plume concentration > EQS limit[C] when out-of-plume concentration < EQS limit	• Stop dosing immediately	• Reduce dosing rate and monitor closely via boat survey on the same day • Regulator report sent within 48hrs of event
Bio./ Eco.	**Abnormal wildlife** activity observed	• Stop dosing immediately	• Reduce dosing rate and monitor closely
	Surfactant build-up in water or shore	• Stop dosing immediately	• Reduce dosing rate and monitor closely

(A) "stopping dosing immediately" is to be done ONLY when it is deemed safe to do so (e.g., if injury has occurred, the injured person must first be secured before taking further action). Stopping dosing must also be communicated clearly to the broader team via Slack.

(B) Ocean thresholds closely follow guidelines imparted by CCME.

(C) EQS limits for metals are defined by CCME and the US-EPA when CCME definitions are not available.