Please note that the Washington State Department of Ecology’s Standard Operating Procedures (SOPs) are adapted from published methods, or developed by in-house technical and administrative experts. Their primary purpose is for internal Ecology use, although sampling and administrative SOPs may have a wider utility. Our SOPs do not supplant official published methods. Distribution of these SOPs does not constitute an endorsement of a particular procedure or method.

Any reference to specific equipment, manufacturer, or supplies is for descriptive purposes only and does not constitute an endorsement of a particular product or service by the author or by the Department of Ecology.

Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.
### SOP Revision History

<table>
<thead>
<tr>
<th>Revision Date</th>
<th>Rev number</th>
<th>Summary of changes</th>
<th>Sections</th>
<th>Reviser(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>12/5/11</td>
<td>1.1</td>
<td>Revisions based on peer review</td>
<td>all</td>
<td>Nuri Mathieu</td>
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</table>
Environmental Assessment Program

Standard Operating Procedure for Measuring Vertically Averaged Salinity in Brackish Waters.

1.0 Purpose and Scope

1.0 This document is the Environmental Assessment Program (EAP) Standard Operating Procedure (SOP) for Measuring Vertically Averaged Salinity in Brackish Waters. This SOP covers the measurement of vertically averaged daily maximum salinity for use in the determination of whether to apply freshwater or marine water quality criteria. WAC 173-201A-260 and the guidance document ‘Determining applicable water quality criteria in brackish waters’ (Mathieu and Brown, 2011) provide guidance on how to use these values for criteria determination.

2.0 Applicability

2.1 This SOP should be followed for salinity measurement, performed by Ecology and other entities, where the intent is to determine the applicable water quality criteria at a given location.

2.2 This SOP may not apply to salinity measurement for use in water quality models or other studies where the stated objective is not to determine the applicable criteria. In these situations the methods for measurement and averaging may be different in order to meet study objectives and should be described in detail in the Quality Assurance (QA) Project Plan.

3.0 Definitions

3.1 Conductivity: A measurement of the conductive material in the liquid sample without regard to temperature. Measures the ability of water to carry an electrical current. It is dependent upon the concentration and type (oxidation state and mobility) of ions in the water and the water temperature. Conductivity does not tell us what specific ions are present in water.

3.2 Estuary: An embayment of the coast in which fresh river water entering at its head mixes with the relatively saline ocean water. When tidal action is the dominant mixing agent it is usually termed a tidal estuary. Also, the lower reaches and mouth of a river emptying directly into the sea where tidal mixing takes place. The latter is sometimes called a river estuary (Hicks, 2000).

3.3 Higher high water (HHW): The highest of the high waters (or single high water) of any specified tidal day due to the declinational effects of the Moon and Sun (Hicks, 2000).
3.4 **Practical Salinity Units:** Used to describe the concentration of dissolved salts in water, based on the UNESCO Practical Salinity Scale of 1978 (PSS78), which defines salinity in terms of a conductivity ratio, so it is dimensionless (Hicks, 2000).

3.5 **Salinity:** Salinity is a measure of the total amount of dissolved salts in water. Salinity has historically been measured in parts per thousand (ppt or °/°°). For example, 35 grams of salt in 1 liter of water has a salinity of 35 ppt. In 1978, the Practical Salinity Scale was developed as an alternate way to express salinity in practical salinity units (PSU).

3.6 **Specific Conductance:** A measure of the ability of water to conduct an electrical current expressed in units of electrical conductance, i.e., Siemens per centimeter at 25 degrees Celsius. Specific conductance can be used for approximating the total dissolved solids content of water (and thus salinity) by testing its capacity to carry an electrical current.

4.0 **Personnel Qualifications/Responsibilities**

4.1 The Field Lead directing sample collection must be knowledgeable concerning all aspects of the project’s QA project plan to ensure that credible and useable data are collected. All field staff should be briefed by the Field Lead on the sampling goals and objectives prior to arriving at the site. For most projects, the Project Manager will also be the Field Lead.

4.2 All field staff must be familiar with the project Safety Plan, if there is one.

4.3 Sampling from an Ecology boat requires one person on board to be a qualified Boat Operator as described in Interim Ecology Policy 11-60. All other persons on board (crew) must be familiar with Chapter 3 of the EA Safety Manual, “Boating.” Responsibilities of the Boat Operator and crew for safety are described in Section 9.0 Safety.

5.0 **Equipment, Reagents, and Supplies**

5.1 General Equipment and Supplies

5.1.1 Field logs (on Rite-in-Rain paper)
5.1.2 Pencils, indelible ink pens
5.1.3 Clipboard with cover
5.1.4 Maps, charts, aerial photographs
5.1.5 GPS unit
5.1.6 Cell phone
5.1.7 Camera
5.1.8 Personal gear, as appropriate for the project (boots, waders, rain gear etc.)

5.2 In situ measurement
5.2.1 Electrical conductivity meter and probe with non-linear function, equipped with a cable longer than the deepest depth expected. Most often equipped on a multi-function instrument with a depth sensor such as a datasonde or a conductivity temperature depth (CTD) instrument.

5.2.2 Handheld rope or cable for lowering smaller instruments (i.e. datasondes).

5.2.3 Electric or manual winch for lowering larger instruments (i.e. CTDs).

5.2.4 Weighted rope with depth markings delineated with 0.1 foot increments (if instrument is not equipped with a depth sensor).

5.3 Grab sample measurement

5.3.1 Thief Sampler: Van Dorn, Kemmerer, or Niskin Bottle.

5.3.2 Adequate rope for thief sampler and maximum depth of site. Rope should be delineated with 0.1 foot increments.

5.3.3 Electrical conductivity meter and probe.

6.0 Summary of Procedure

Measurement, sampling, and calculation methods in this SOP were adapted, in part, from United State Geological Survey (USGS) National Field Manual for the Collection of Water Quality Data (Wilde, 2008).

6.1 Determining sample timing necessary to capture maximum daily salinity

6.1.1 Determine sampling dates based on Ecology’s guidance for how to apply water quality standards criteria (Mathieu and Brown, 2011).

6.1.2 Determine the time of higher high water (HHW) level for a specific sampling date using NOAA’s tide predictions: [http://tidesandcurrents.noaa.gov/tide_pred.html](http://tidesandcurrents.noaa.gov/tide_pred.html)

6.1.3 Select the NOAA tidal station nearest to the measurement transect. Specific knowledge of lag times between NOAA station and measurement transect may be incorporated into sample timing if the information is available.

6.1.4 Plan enough time to set-up sample transect and prepare measurement equipment before measurement is scheduled to begin.

6.1.5 Begin measurement collection approximately 30 minutes prior to the predicted HHW time. Assuming a 1 hour transect measurement time, the measurement collection window will capture the peak salinity and an approximately equal number of measurements before and after. Measurement collection timing will vary based on the number of measurements necessary and level of field staff experience. The measurement window may be adjusted for future dates based on the amount of time needed on previous measurement dates to complete all measurements.

6.1.6 Exact timing based on NOAA’s predicted measurements is not necessary given that the predictions often do not reflect the exact observed water levels. However, field staff should make visual observations about tidal height and velocity at the site and apply the information to both current and future measurements. For example, if the tide is still
rising rapidly, wait to begin measurements until the velocity has slowed to a near stop and collect measurements during slack tide conditions. Record the time of peak tidal height at the transect and note lag time from NOAA predicted time for future reference.

6.2 Determining discrete measurement increments and depths.

6.2.1 Establish a transect across the waterbody at the point of measurement. A transect can be created by 1) setting up a measurement tape or tagline, 2) using a boat and GPS device to ferry across, or 3) using pre-established measurement markings on the bridge, if available.

6.2.2 Divide transect into equal width increments (EWI). Determine EWI by:

6.2.2.1 For waterbodies less than or equal to 5 feet wide, use as many increments as practical, but they must be equally spaced and a minimum of 0.5 feet apart.

6.2.2.2 For waterbodies greater than 5 feet wide a minimum of 5 equal width increments is recommended.

6.2.3 Locate a vertical profile station for salinity at the mid-point of each increment.

6.2.4 Locate the first vertical profile at half the width increment from the edge of water.

EXAMPLE: In a waterbody 20 ft wide that has been divided into 5 increments of 4 ft each, the first measurement vertical would be 2 ft from the water’s edge, and subsequent verticals would be at 6, 10, 14, and 18 ft from the starting point at water’s edge.

6.2.5 Determine the depth at the first vertical profile station by lowering the instrument (with depth sensor) or depth line to the bottom of the channel. As you approach the suspected bottom, slow speed of lowering and take care not to heavily disturb bottom sediments.

6.2.6 Determine the number of measurements and corresponding depths necessary within the vertical profile. The criteria for determining depth and number of measurements is:

6.2.6.1 If the depth is less than 4 feet, collect 1-3 measurements depending on depth and whether or not there is vertical stratification of salinity. Check surface and bottom to determine salinity gradient. One measurement at mid-depth is sufficient if there is no salinity gradient.

6.2.6.2 If the depth is 4 feet or greater:

1) Subtract 1 ft from the total depth and then divide by 5 to determine the vertical measurement increment (VMI). The minimum VMI is 0.5 feet.

2) Collect the first salinity measurement 0.5 feet above the bottom. Allow extra time for meter to stabilize at the bottom measurement depth if the sediment was disturbed when determining the depth.

3) Move vertically up through the water column the distance of the VMI determined in step 1 and collect the next measurement.
4) Collect subsequent measurements by moving up through the water column the distance of the VMI from the previous measurement.

5) The final measurement station will be located 0.5 feet below the water surface.

**EXAMPLE:**

<table>
<thead>
<tr>
<th>Wetted width = 20 ft; EWI = 4 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEW 1 2 3 4 5 REW</td>
</tr>
<tr>
<td>Tape from LEW (ft) =</td>
</tr>
<tr>
<td>0 2 6 10 14 18 20</td>
</tr>
<tr>
<td>Depth (ft) =</td>
</tr>
<tr>
<td>0 2.2 7.5 15 9 3 0</td>
</tr>
<tr>
<td>VMI (ft) =</td>
</tr>
<tr>
<td>n/a n/a 1.3 2.8 1.6 n/a n/a</td>
</tr>
<tr>
<td>Measurements at: (distance from water surface)</td>
</tr>
<tr>
<td>n/a 0.5 0.5 0.5 0.5 0.5 n/a</td>
</tr>
<tr>
<td>1.1 1.8 3.3 2.1 1.5</td>
</tr>
<tr>
<td>1.7 3.1 6.1 3.7 2.5</td>
</tr>
<tr>
<td>4.4 8.9 5.3</td>
</tr>
<tr>
<td>5.7 11.7 6.9</td>
</tr>
<tr>
<td>7 14.5 8.5</td>
</tr>
</tbody>
</table>

**6.3 Measuring salinity in-situ**

6.3.1 Raise or lower measurement instrument to within 0.1 feet of predetermined measurement depth.

6.3.2 Allow salinity (or specific conductance) value to stabilize.

6.3.3 Record the result on the appropriate field form.

6.3.4 Repeat process for all measurement points (determined in Section 6.2)

**6.4 Measuring salinity using a CTD cast**

6.4.1 When using a CTD instrument it may be necessary to perform a ‘cast’ at each vertical profiling station identified in 6.2.1.

6.4.2 In a vertical CTD cast, the instrument logs data values internally at a constant rate as it’s lowered through the water column. This method may be used in lieu of collecting measurements at discrete depths, provided measurements are collected at equal depth increments and the resulting salinity values are vertically averaged.

**6.5 Measuring salinity from grab samples.**

6.5.1 *Note: This method is not recommended as it is more time consuming and labor intensive. However, it may be necessary if the conductivity probe and meter are not suitable for in situ measurements.*

6.5.2 Select appropriate ‘thief sampler’ (Van Dorn, Kemmerer, or Niskin Bottle) to collect a grab sample at a specific depth.
6.5.3 To collect and retrieve sample, lower to appropriate depth and follow either EAP SOP #15: ‘Manually Obtaining Surface Water Samples’ (Ecology, 2006) for a Van Dorn or Kemmerer sampler or EAP SOP #25: ‘Seawater Sampling’ (Ecology, 2010) for Niskin Bottle.

6.5.4 Measure salinity/specific conductance following section 6.3 ‘Sample Measurement Procedure’ of EAP SOP #32: ‘Collection and Analysis of Conductivity Samples’ (Ecology, 2011).

6.6 Calculating Area-Weighted Salinity

6.6.1 To calculate the area-weighted salinity:

6.6.2 Average all salinity measurements taken within the same vertical profile.

EXAMPLE:

<table>
<thead>
<tr>
<th>Wetted width = 20 ft; EWI = 4 ft</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEW</td>
</tr>
<tr>
<td>Tape from LEW (ft) =</td>
</tr>
<tr>
<td>Depth (ft) =</td>
</tr>
<tr>
<td>VMI (ft) =</td>
</tr>
<tr>
<td>Salinity (ppt)</td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td></td>
</tr>
<tr>
<td>Vertical Average Salinity =</td>
</tr>
</tbody>
</table>

6.6.3 Multiply the width of each increment by the depth of the corresponding vertical to calculate the area of each section. Sum all the section areas to obtain the total area.

6.6.4 Multiply the area of each section by the corresponding vertically averaged salinity value. Sum all the products.

6.6.5 Divide the sum of products calculated in 6.6.4 by the total area calculated in 6.6.3 to obtain the area-weighted salinity.

6.6.6 The vertically averaged, area-weighted salinity at HHW for a given day represents the vertically averaged daily maximum salinity referenced in the water quality standards.
### EXAMPLE:

<table>
<thead>
<tr>
<th>Section number</th>
<th>Tape from LEW (ft)</th>
<th>Width of Increment (ft)</th>
<th>Depth of Vertical (ft)</th>
<th>Area of Section (sq ft)</th>
<th>Vertical Average Salinity (ppt)</th>
<th>Product of area and vertical salinity</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEW</td>
<td>0</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>1</td>
<td>2</td>
<td>4</td>
<td>2.2</td>
<td>8.8</td>
<td>2.1</td>
<td>18.5</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>7.5</td>
<td>30</td>
<td>9.8</td>
<td>292.5</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>4</td>
<td>15</td>
<td>60</td>
<td>17.9</td>
<td>1071.0</td>
</tr>
<tr>
<td>4</td>
<td>14</td>
<td>4</td>
<td>9</td>
<td>36</td>
<td>12.6</td>
<td>452.4</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>4</td>
<td>3</td>
<td>12</td>
<td>2.4</td>
<td>28.4</td>
</tr>
<tr>
<td>REW</td>
<td>20</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
<td>n/a</td>
</tr>
<tr>
<td>Sum =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>146.8</td>
<td>Sum = 1862.8</td>
</tr>
<tr>
<td>Area-weighted Salinity =</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>12.7</td>
<td></td>
</tr>
</tbody>
</table>

### 6.7 Converting conductivity/specific conductance to salinity

#### 6.7.1

The preferred method for converting specific conductance measurements to salinity is to collect at least 10 salinity grab samples for comparison at varying conductivities representing the range of observed values. These comparisons can then be used to develop a site specific regression, which can be used to convert the remaining specific conductivity measurements to salinity.

#### 6.7.2

Many instruments can internally convert conductivity/specific conductance to salinity. If only conductivity/specific conductance can be measured by the meter, and there is no site specific regression, salinity can be calculated using the following relationships and the Practical Salinity Scale (APHA, 2005):

\[
S = a_0 + a_1 R_t^{1/2} + a_2 R_t^2 + a_3 R_t^{3/2} + a_4 R_t^2 + a_5 R_t^{5/2} + \Delta S
\]

where

\[
R_t = \frac{C \text{ (sample at } t)}{C \text{ (KCl solution at } t)}
\]

- \(C\) = conductivity
- \(t\) = temperature

\[
\Delta S = \left[ \frac{t - 15}{1 + 0.0162(t - 15)} \right] (b_0 + b_1 R_t^{1/2} + b_2 R_t^2 + b_3 R_t^{3/2} + b_4 R_t^2 + b_5 R_t^{5/2})
\]

- \(a_0 = 0.0080\)
- \(b_0 = 0.0005\)
- \(a_1 = -0.1692\)
- \(b_1 = -0.0056\)
- \(a_2 = 25.3851\)
- \(b_2 = -0.0066\)
- \(a_3 = 14.0941\)
- \(b_3 = -0.0375\)
- \(a_4 = -7.0261\)
- \(b_4 = 0.0636\)
\[ a_5 = 2.7081 \quad b_5 = -0.0144 \]

6.7.3 Additional formulations exist for salinity measurements below 2 ppt (APHA, 2005):

\[
S = S_{\text{PSS}} \left[ \frac{a_0}{1 + 1.5X + X^2} \right] - \left[ \frac{b_0 f(t)}{1 + Y^{1/2} + Y^{3/2}} \right]
\]

Where:

\( S_{\text{PSS}} \) = value determined from Practical Salinity Scale in 6.7.2

\[ a_0 = 0.0080 \]

\[ b_0 = 0.0005 \]

\( X = 40*C*R_t \)

\( Y = 10*C*R_t \)

\( f(t) = (t - 15)/[1 + 0.0162(t - 15)] \)

7.0 Records Management

7.1 Complete the field log for each station sampled. Record the start and end time for transect measurement. Include a description of tidal activity during the measurement including direction, velocity, and peak level.

7.2 Close out the Field Work and Float plans with the designated contact at the end of the sampling work.

7.3 Commonly used forms can be obtained from the EAP Intranet site [http://aww.ecology.ecy.wa.gov/programs/eap/forms/index.html](http://aww.ecology.ecy.wa.gov/programs/eap/forms/index.html)

7.4 The Field Work Plan & Contact Person Form and Float Plan Form can be obtained at EAP’s SharePoint Site [http://ecywblcyadxd0/sites/eap/Field%20Schedules/Forms/AllItems.aspx](http://ecywblcyadxd0/sites/eap/Field%20Schedules/Forms/AllItems.aspx)

8.0 Quality Control and Quality Assurance Section

8.1 The meter and probe should be cleaned, calibrated, and maintained per the manufacturer’s instructions before each run. Reference solutions certified by the National Institute of Standards and Technology (NIST) should be used to calibrate and post-check the meter and probe.

8.2 For grab samples, the grab sampler should be cleaned before and after each run and triple rinsed with ambient water at each site.

8.3 More specific quality control and quality assurance measures should be outlined in the individual project plan.
9.0 Safety

9.1 Never compromise your personal safety or that of a field partner to collect a sample. Always plan ahead to avoid falling and drowning hazards. Always wear appropriate safety gear such as life vests. When working with winches, cables and similar machinery, gloves, hard hats, safety glasses and steel-toed boots are also important safety items.

9.2 Knowledge of the contents of this standard operating procedure is required.

9.3 The following forms must be completed to document field personnel, sampling locations, overnight lodging, itinerary, contact person(s), and emergency contacts:

9.4.1 Float plan
9.4.2 Contact person designation
9.4.3 Field Sampling Notification

10.0 References


