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ANCHOR QEA

# Memorandum

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To: Hunter Young, Environmental Protection Agency Region 10 – Oregon Operations Office

From: Elizabeth Greene and Sydney Gonsalves, Anchor QEA, LLC

cc: Bob Wyatt, NW Natural

**Re: ISS Remedial Technology Information for Portland Harbor Superfund Site Programmatic Biological Assessment**

## In Situ Solidification and Stabilization

This memorandum provides the following information related to the in-water application of in situ solidification and stabilization (ISS) remedial technology:

- Overview of ISS Technology
- Construction Methods and Sequencing
- Impact Avoidance, Minimization, and Conservation Measures
- Potential Consequences to Salmonid Species in the Lower Willamette River
- Potential Consequences to Salmonid Designated Critical Habitat in the Lower Willamette River
- Potential Consequences to Essential Fish Habitat (EFH) in the Lower Willamette River

The intent is for this information to support the inclusion of ISS as a remedial technology in the *Programmatic Biological Assessment Portland Harbor Superfund Site* (PHSS Programmatic BA; EPA 2021) and Biological Opinion.

### Overview of ISS Technology

ISS techniques, like other in situ treatments, reduce the hazard potential of material while leaving the contaminated sediment in place. Solidification and stabilization involves mixing contaminated material with a binding agent, such as cement, asphalt, fly ash, or clay, that makes loose materials stick together (EPA 2020). The cement grout mixture then cures to solidify and form a stabilized material. The treated material has been shown to immobilize the contaminants, significantly decrease the hydraulic conductivity, and significantly decrease the contaminant leaching potential of the sediments (Jansen et al. 2016). Solidification and stabilization involves mixing contaminated sediment with binding agents that cause a chemical reaction with contaminants to make them less mobile in the environment (EPA 2020).

ISS has been shown to be an effective remedial technology for sites that would otherwise require deep dredging, large-volume projects on urban waterways where staging and amending areas are limited, sites with nonaqueous phase liquid (NAPL) impacts that cannot be controlled during dredging, and sites where eventual NAPL breakthrough is anticipated if reactive caps are used (Jansen et al. 2016). To date, ISS has been effectively used at multiple contaminated sediment sites, as shown in Table 1. It was also specifically evaluated in the U.S. Environmental Protection Agency (EPA) Portland Harbor Feasibility Study and retained as a remedial technology, and it was subsequently retained as a representative treatment option in the *Record of Decision – Portland Harbor Superfund Site, Portland, Oregon* (EPA 2017a). There are multiple additional benefits associated with ISS when compared to dredging and capping, including the following:

- ISS at Gasco will solidify and stabilize[1] the contaminated sediment in place, which reduces or eliminates the potential for short- and long-term chemical releases from the treated materials into the overlying surface water and overlying cover materials.
- ISS allows flexible control of post-construction elevations to maintain current bathymetry, minimize habitat conversions, and allow for habitat enhancements.
- ISS increases treatment implementability and effectiveness for contamination that is underneath and around pilings, docks, berthing or mooring dolphins, and other structures servicing active wharfs or shore-based facilities that remain intact (EPA 2017a).
- ISS minimizes the potential for water quality impacts during construction and in the long term.
- ISS reduces dredging, transportation, and disposal of contaminated sediments, which results in fewer truck/rail trips and diesel emissions and potential for spills during transport, reduced upland landfill disposal space, and the production of significantly less odors because the sediment is not exposed to open air (Jansen et al. 2016).
- ISS eliminates contaminant migration toward surficial sediments via ebullition.
- In groundwater discharge areas, ISS eliminates the need to manage groundwater flux through the contaminated material, which may reduce upland source control requirements for uncontaminated groundwater migration to the river. At the Gasco Sediments Site, ISS will reduce risks to effectiveness of the in-water remedy due to hydraulic control and containment equipment breakdown or extended power outage as well as reducing overall long-term energy usage.
- ISS allows for treatment to much deeper depths than dredging, which facilitates in situ treatment of the full vertical extents of contamination at sites with significant deep contamination.
- ISS increases seismic stability of the constructed remedy.

[1] ISS at other Portland Harbor project areas may include solidification and/or stabilization.

**Table 1**
**Projects with Successful Implementation of In-Water ISS**

| Project Name | Location | Year | Amount of Treated Sediment | NAPL Present | Report or Publication |
|---|---|---|---|---|---|
| Gowanus Canal Superfund Site | New York, New York | Ongoing | 15,600 tons | Yes | EPA 2011; Grubb et al. 2020; Olean et al. 2016 |
| Slurry Pond Sediment Project* | Montgomery, Alabama | 2021 | 550,000 cubic yards | No | -- |
| Koppers Co. Ashley River Superfund Site*, Pilot Study | Charleston, South Carolina | 2003 | 2,450 cubic yards | Yes | Wood 2021 |
| Island End River* | Everett, Massachusetts | 2007 | 100,000 cubic yards | Yes | -- |
| New Bedford Harbor Superfund Site* | New Bedford, Massachusetts | 2011 | 7,000 cubic yards | No | SES 2021 |
| Sydney Tar Ponds | Sydney, Nova Scotia | 2008–2010 | 700,000 cubic meters | No | PWGSC 2014 |
| Connecticut River MGP Pilot Study | Springfield, Massachusetts | 2013 | 74 cubic yards | Yes | EPRI 2014; Jansen et al. 2016 |
| Darling International Site Pilot Study | Newark, New Jersey | 2005 | 300 cubic yards | No | -- |
| Fox River Pilot Study | Menasha, Wisconsin | Late 1990s | 500 tons | No | -- |
| Crotty Street Channel Pilot Study | Bay City, Michigan | 1999 | 2.3 acres | No | -- |
| LaSalle Canal MGP Site | LaSalle, Illinois | 2018 | 70,000 cubic yards | No | Lowry et al. 2019 |
| Kendall Bay | Sydney, Australia | 2021 | 7,000 cubic yards | No | Meric 2022 |
| Jones Street Remediation | Manistee, Michigan | 2018 | 7,500 cubic yards | Yes | Consumers Energy 2019 |
| Former Coastal Oil of New England Terminal, Berth 10 | Boston, Massachusetts | 2018 | 15,650 cubic yards | Potentially present | GEI 2021 |

Notes:
Superfund site projects are EPA-led. An asterisk (*) indicates projects where Sevenson Environmental Services, Inc., a member of the NW Natural design team, was the contractor who performed the sediment cleanup construction at the site.
MGP: manufactured gas plant

## Construction Methods and Sequencing

In-water ISS is expected to be constructed using a hydraulic drill rig equipped with an auger on a barge. Support equipment includes a grout plant, a long-stick excavator with GPS, and a haul barge for transporting dredged swell materials, all contained on barges.

ISS grout injection and mixing occurs within columns. Columns are constructed by drilling into the sediment using an auger with a diameter of between 3 and 12 feet attached to hollow kelly bars (Geo-Solutions 2014). Columns overlap with each other to assure treatment of all impacted sediment. The required number of columns are advanced to depths below the sediment surface down to the deepest depth of Remedial Action Level exceedance. The ISS grout mixture is expected to consist of Portland cement and cementitious amendments.[2] The exact grout mixture is determined based on performance of a site-specific laboratory bench-scale treatability study prior to construction. Injection of the grout mixture within each column occurs by pumping the mixture through the kelly bar and out ports in the drilling auger (Geo-Solutions 2014). The grout acts as both the drilling lubricant and the final binding agent (Geo-Solutions 2014). Grout is injected throughout the entire column and mixed at a constant rate over two to five auger passes (EPRI 2014). Injection starts at the target column start elevation and stops at the target depth below the sediment surface (EPRI 2014). No sediment is removed from the column during grout injection. The volume of grout injected depends on the column volume, sediment bulk density, grout mass and density, and design material characteristics for the final sediment/grout mixture (EPRI 2014). After injection occurs, the auger mixes the grout and sediment until the mixture meets homogenization and field sampling objectives. (EPRI 2014). While the mixing occurs, the auger remains in the column and moves up and down through the column as needed to complete the mixing. Field sampling objectives are based on the site-specific laboratory bench-scale treatability study. When mixing is complete, the auger is extracted and moved to the next column location.

Swell is the expansion of the grout material and sediment mixture that causes a mound to occur at the sediment surface. After the columns are injected over a certain area, dredging would occur, as needed, to remove the swell to achieve the target elevations identified in the remedial design. The dredged swell material would be transported, offloaded, and disposed of at a permitted landfill using the same waste characterization procedures and disposal requirements as dredged material.

## Impact Avoidance, Minimization, and Conservation Measures

In-water ISS results in disturbance to the riverbed and riverbank habitat and can cause resuspension and dispersion of sediment and contaminants. Binding agents, such as cement, have high pH and can raise the pH of surrounding surface water. Physical, mechanical, and operational controls and best management practices (BMPs) can be employed to avoid and minimize these impacts.

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[2] Blast furnace slag silicate is expected to be used at the Gasco Sediments Site.

Physical barriers that could be employed during ISS are the same as those typically used during dredging, including silt curtains and mobile moon pool containment systems. These types of physical barriers are described in more detail in Section 2.5.2.1.1 of the PHSS Programmatic BA (EPA 2021). A pilot study performed by Jansen et al. (2016) at an EPA site on the Connecticut River showed that if an adequate dual turbidity curtain control system is employed, rigid controls like steel sheet piling are not needed. A silt curtain and moon pool containment system was successfully used in the Lower Willamette River for a large-scale dredging operation at the former Portland Gas Manufacturing Site (Anchor QEA 2021). While steel sheet piling may provide more reliable containment of suspended sediment, it can have negative effects such as disturbing NAPL, resuspending sediment, and increasing the potential for scour around the outside of the containment.

Mechanical and operational control techniques are available for the auger mixing tool and cement grout batch mixing plant. Parameters such as auger diameter, auger rotation speed, penetration depth, grout flow, and number of mixing passes can be adjusted as needed to account for variable site conditions and to minimize any identified water quality issues. For example, varying the entrance and exit speeds of the auger at the sediment-water interface can be done to reduce turbidity.

Impact avoidance and minimization measures for ISS are consistent with those described in the PHSS Programmatic BA (EPA 2021), including the following:

- General in-water construction activity impact avoidance and minimization described in Section 2.5.1, including the following:
  - Water quality monitoring, as applicable to ISS activities (Section 2.5.1.1)
- Spill response, as applicable to ISS activities (Section 2.5.1.3)
- General BMPs for all types of dredging, as applicable to ISS activities (Section 2.5.2)
- BMPs for placement of materials for capping, in situ treatment, enhanced natural recovery (ENR), and residual management (Section 2.5.3), as applicable to ISS activities

Additional measures specific to ISS activities include the following:

- Mechanical and operational measures, including the following (Jansen et al. 2016):
  - Control turbidity, sheen, and pH with use of a turbidity curtain system.
  - Reduce turbidity and disruption of the upper sediment surface by using auger weight or low rotational speeds to advance through the first 2 to 3 feet of sediment.
  - Evaluate operations during relatively high-water velocity conditions relative to the silt current containment design.
- Examples of possible operational responses that could be implemented if water quality criteria are exceeded on specific ISS projects include the following (Jansen et al. 2016):
  - Follow quality assurance procedures to confirm the following:
    - Grout mixture meets design specifications.

    - Volume of grout injected into each column meets design values.
    - Auger rotation speed, grout injection flow rate, rotary head pressure, depth, column overlap, vertical alignment, and time to perform the column are within project targets.
  - Adjust operation parameters (e.g., reduce the auger rotation speed or reduce penetration and withdrawal speed) to reduce water quality exceedances.
  - Adjust the volume of cement grout injected into each column.
  - Reduce the water-to-grout ratio to reduce swell.
- Require a debris sweep prior to beginning work in known debris areas (debris caught in ISS equipment can cause additional resuspension and release of contaminated sediments).
- Ensure that the cement grout mixture achieves the following (Jansen et al. 2016):
  - Properly selected for site conditions based on site-specific bench-scale and field pilot testing
  - Properly selected to meet testing requirements for unconfined compressive strength, hydraulic conductivity, and leaching
- Perform water quality monitoring in accordance with a site-specific plan.

## Potential Consequences to Salmonid Species in the Lower Willamette River

Several federally listed species occur within the action area, as described in Section 2.2 of the PHSS Programmatic BA (EPA 2021). Both adult and juvenile Chinook salmon (*Oncorhynchus tshawytscha*), coho salmon (*O. kisutch*), and steelhead (*O. mykiss*) are likely to be present in the Lower Willamette River action area where ISS remediation activities would occur. Bull trout (*Salvelinus confluentus*) could be present in the Lower Willamette River action area but are unlikely to be present. The following evolutionarily significant units (ESUs)/distinct population segment (DPSs) are likely to be present:

- Chinook salmon Upper Willamette River ESU
- Chinook salmon Lower Columbia River ESU
- Coho salmon Lower Columbia River ESU
- Steelhead Upper Willamette River DPS
- Steelhead Lower Columbia River DPS

As described in Section 5.1 of the PHSS Programmatic BA (EPA 2021), the summertime in-water work window avoids both peak smolt outmigration and peak adult migration for both Chinook salmon and steelhead. During the proposed in-water work window for ISS activities, it is likely that juveniles will be rearing in small numbers in the Lower Willamette River action area. Upstream migrating Chinook salmon adults are likely to be present in July, and upstream migrating coho salmon are likely to be present in October but are not expected to spend more than 2 days in the Lower Willamette River (EPA 2021).

Table 2 provides a summary of potential consequences to listed salmonid species.

## Water Quality

### *Contaminants*

Fish have the potential to be exposed to contaminants from resuspended sediment during ISS operations. However, exposure to contaminants is less likely to occur during ISS than during dredging. Because the only sediment being removed is treated swell materials (if required to achieve the remedial design post-construction elevations), less contaminated sediment is resuspended in the water column. However, temporary increases in dissolved and particulate phase concentrations of some chemicals in the vicinity of auger mixing activities at the sediment surface could occur, resulting from resuspension of contaminated surface sediments by the auger, desorption of the contaminants from sediment particles to the water column, or release of contaminated porewater into surface water. The potential for increased contaminant concentration in the water column is low because injection and mixing occurs in the lowest sections of the ISS column below the sediment surface, where the material will be contained by the surrounding sediment. Implementation of impact avoidance, minimization, and conservation measures; ISS operations monitoring; and compliance with project-specific consultation requirements will occur as described in Section 5.1.1.1 of the PHSS Programmatic BA (EPA 2021). Effects to salmonids from exposure to contaminants during ISS operations would be as described in the same section of the PHSS Programmatic BA. However, the likelihood of exposure to contaminants during ISS is much lower than with dredging and is limited to near the sediment surface.

### *Turbidity*

Fish have the potential to be exposed to turbidity during ISS operations. Exposure to turbidity is less likely to occur during ISS than during dredging. Since the only sediment being removed is treated swell materials (if required to achieve the remedial design post-construction elevations), less sediment is likely to be resuspended in the water column. However, some increases in turbidity above background river conditions near the sediment surface could occur when the auger begins drilling into the sediment surface. The potential for increased turbidity is low because injection and mixing occurs in the lowest sections of the ISS column below the sediment surface, where the material will be contained by the surrounding sediment. Implementation of avoidance, minimization, and conservation measures, including working within a silt curtain containment system (e.g., moon pool or similar system), ISS operations monitoring, and compliance with project-specific consultation requirements will occur as described in Section 5.1.1.2 of the PHSS Programmatic BA (EPA 2021). The ISS grout mixture is designed for site-specific submerged sediments during bench-scale testing to optimize the ratio of grout to sediment and the consistency of the grout-sediment mixture (Anchor QEA 2023). This will limit the potential of the mixture to flow into the adjacent water column, ensure that no free grout remains in the blend following mixing, and reduce the generation of turbidity during mixing at each auger location. Potential consequences to salmonids from increased turbidity caused by ISS operations would be as described in the same section of the PHSS Programmatic BA and include direct mortality, gill tissue damage, physiological stress, and behavioral effects. The likelihood of exposure to turbidity during ISS is much lower than with dredging and is limited to near the sediment surface.

During an ISS pilot study in the Connecticut River in Massachusetts near the Springfield Manufactured Gas Plant (MGP; Jansen et al. 2016), monitoring occurred every 2 hours during construction at a reference location 50 feet upstream from the outer turbidity curtain and 15 feet downstream from the outer turbidity curtain. The only time turbidity was detected outside the outer turbidity curtain was during the initial pilot study operations when the auger was entering and exiting the sediment. Based on turbidity monitoring results, operational changes were made, including reduction of the auger entrance and exit speeds, reduction of grout injection pressure, and penetration (no rotation) of the augers with no grout injection during advancement through the top 12 to 16 inches of sediment. These operational changes reduced the observed turbidity as the auger was entering and exiting the sediment, and the measured turbidity did not exceed the project's water quality criteria. Turbidity was not observed when ISS passes were being performed in the target sediment mixing zones and did not exceed criteria at the point of compliance 15 feet downstream from the outer turbidity curtain (Jansen et al. 2016).

### *pH*

During ISS, placement of cement grout material into the columns has the potential to increase pH in water at the sediment surface where the grout material is exposed to the surrounding water column. Water pH would also increase if any of the grout material leaks or is spilled into the water column. This is because commonly used ingredients in the grout mixture, such as Portland cement, have inherently high alkalinity. The potential for elevated pH is highest during injection and mixing of the grout close to the sediment surface during construction. The potential is lowest when injection and mixing occurs in the lowest sections of the ISS column below the surface because the material will be contained by the surrounding sediment. Elevated pH levels are caused when uncured Portland cement, which is highly alkaline, dissolves in water (WDFW 2009). During bench-scale testing, the grout-sediment mixture will be evaluated for its ability to achieve flow and consistency characteristics that limit the potential for leaking into the adjacent water column (Anchor QEA 2023). Bench-scale testing will also optimize grout dosage so that no free grout remains in the blend following mixing (Anchor QEA 2023). This means that if elevated pH occurs, it would be expected to remain localized to the remedial work area. Once mixed, the grout-sediment mixture cures over a 28-day period, and as it cures, there is a greatly reduced likelihood of elevated pH levels in the water column. Therefore, the highest potential for elevated pH in the water column is during construction while the grout material is being injected and mixed into the ISS columns, particularly near the surface sediments.

Impact avoidance, minimization, and conservation measures described in this document and in the PHSS Programmatic BA (EPA 2021) will be employed during ISS to minimize the potential for increased pH levels. Water pH levels will be monitored at the compliance boundary, and activities will be suspended and corrective actions implemented if pH levels increase above applicable water quality standards. Injection and mixing operations will be managed carefully to minimize pH effects according to the applicable requirements for the proposed action, including any additional conditions imposed as a result of the PHSS Programmatic BA consultation or additional site-specific consultations with the National Marine Fisheries Service (NMFS) and compliance with Clean Water Act Section 401 requirements.

An increase in pH could impact listed salmonid species if the increase occurred outside of silt curtain containment system (e.g., moon pool or similar system). Fish species tend to have very narrow ranges of pH tolerance, and levels outside this range will impact their health. The optimal range for most freshwater aquatic organisms, including fish, is between 6.5 and 8 (EPA 2017b). EPA water quality criteria for pH in freshwater allow for a range of 6.5 to 9 (EPA 2017b); however, Oregon state water quality standards for the Willamette River require pH values between 6.5 and 8.5 (OARD 2023). Temporary or long-term pH outside this range can result in decreased reproduction, decreased growth, disease, or death for aquatic species (EPA 2017b).

Increased pH resulting from concrete is thought to have the greatest effects during construction of large projects in areas with poor water circulation (WDFW 2009). Spilled concrete can cause very alkaline water that can result in the direct killing of fish that often have a narrow range of pH tolerance (WDFW 2009). In rainbow trout (*O. mykiss*), severe physiological effects, including increased cortisol and glucose levels, occurred at a pH above 8.4, and mortality occurred at a pH of 9.3 (WDFW 2009). Even for fish species that are less sensitive, prolonged exposure to pH between 9.5 and 10 can damage outer surfaces such as gills, eyes, and skin (EPA 2017b). Over the long term, high pH can damage the olfactory system, making it difficult for fish to find food or mates, avoid toxic chemicals, or detect alarm signals from other fish (EPA 2017b).

Contributing, modifying, and related factors that may increase stress on aquatic organisms when pH is high include ammonia concentration, ionic strength, and dissolved oxygen (DO; EPA 2017b). For example, when both ammonia concentration and pH are high, fish are more susceptible to ammonia toxicity (WDFW 2009). Ammonia toxicity can occur over hours to days, depending on pH and ammonia concentration (EPA 2017b). Ammonia and DO are also interrelated because oxygen is consumed during the nitrification process (e.g., oxidizing of ammonia), whereas ionic strength is controlled to a large extent by pH (EPA 2017b). This means that increased pH can have a variety of interrelated effects on fish and other aquatic organisms.

Although elevated pH levels could impact listed fish species, the BMPs and impact minimization measures described in the Impact Avoidance, Minimization, and Conservation Measures section of this document will be implemented. The pilot study in Springfield, Massachusetts, described by EPRI (2014) employed similar measures and found that pH levels varied between 6.3 and 7.9 and were not higher at the bottom of the water column. In that study, the monitoring location was located 15 feet outside the environmental controls, and measurements were taken at least every 2 hours.

## Benthic Community Disturbance

ISS will disturb, injure, or kill existing benthic organisms and disturb benthic habitat. However, the existing benthic habitat is highly degraded and unsuitable for a healthy benthic community. The benthic habitat will be altered in areas where the grout mixture is injected and mixed to stabilize and solidify the contaminants. This alteration would impact foraging habitat for listed salmonid species because the benthic community would be displaced. However, this is only one source of prey for salmonid species because they also eat prey species found in the water column. This consequence would only be short-term because it is expected that the surrounding sediment that is migrating through the river would deposit on the ISS surface, allowing for recolonization of the sediment within 1 year post-construction. Placement of a habitat layer over the top of the ISS surface during construction would accelerate the recolonization process. As described in Section 5.1.5 of the PHSS Programmatic BA (EPA 2021), recovery for the benthic community is expected to occur within months. According to the NMFS Lower Columbia River Channel Improvement Biological Opinion, "these changes in prey availability are unlikely to be of a magnitude or extent that would appreciably diminish forage resources in the action area" (NMFS 2005). Additionally, ISS followed by placement of sand or a habitat mix layer is expected to improve benthic habitat immediately and species diversity over time (EPA 2021).

Post-construction monitoring of the benthic community occurred as part of the pilot study in Springfield, Massachusetts. Monitoring results indicated that recruitment and re-establishment of benthic invertebrates in surface sediments occurred within 8 months of ISS construction without placement of a habitat layer on top of the ISS surface. Approximately 3 inches of material had accumulated over the ISS surface within the 8-month time period. In addition, monitoring indicated that the surface sediments in the pilot study area contained a benthic community similar to that of an area upstream of the pilot study area (Jansen et. al. 2016). Similarly, at an ISS treatment site in Twin Rivers, Wisconsin, post-construction monitoring found that benthic community family-level composition was indicative of recovery following disturbance and that biotic index scores were similar between the ISS treatment site and reference areas (Tazelaar et al. 2019).

## Potential Consequences to Salmonid Designated Critical Habitat in the Lower Willamette River

This section describes the consequences from ISS to the components of salmonids' designated habitat, including freshwater rearing and migration physical and biological features (PBFs), and describes appropriate compensatory mitigation.

- **Freshwater Rearing PBFs:**
  - Water Quality: There is potential for adverse consequences to water quality, including elevated pH related to ISS activities that mix cement grout with sediment and elevated turbidity when the auger enters, exits, and mixes the sediment surface. The area of exposure would be minimized through construction methods that limit the injection of the grout mixture to within drilled columns that extend below the sediment surface and the implementation of impact avoidance and minimization measures, which would be monitored during construction.
  - Effects to other PBFs would be as described in Section 5.2.1 of the PHSS Programmatic BA (EPA 2021).
- **Freshwater Migration PBFs:**
  - Water Quality: Consequences would be the same as for freshwater rearing PBF.
  - Effects to other PBFs would be as described in Section 5.2.1 of the PHSS Programmatic BA (EPA 2021).
- **Compensatory Mitigation:** The need for compensatory mitigation related to ISS remedial activities would be consistent with Section 5.2.3 of the PHSS Programmatic BA (EPA 2021).

## Potential Consequences to Essential Fish Habitat in the Lower Willamette River

As described in Section 6 of the PHSS Programmatic BA (EPA 2021), Chinook salmon and coho salmon have designated EFH within the proposed action area.

Freshwater EFH for Chinook salmon and coho salmon consists of four major components (PFMC 1999):

- Spawning and incubation (not applicable to the proposed action area)
- Juvenile rearing
- Juvenile migration corridor
- Adult migration corridor and adult holding habitat (Chinook salmon only)

Water quality, including pH, is an important feature of EFH for the four components listed above. There are potential adverse effects to water quality from ISS in the short term during construction. The impact mechanisms are identified in Table 2 and summarized below. Impacts would be avoided and minimized to the extent possible with the implementation of the avoidance and minimization measures and BMPs described previously in this document.

- Water Quality: Potential adverse effects could include increased pH in the water column during grout-sediment mixing and to a lesser extent during curing. Other impacts to water quality from turbidity and resuspension of contaminated sediments during ISS construction activities would be as described in Section 6.2 of the PHSS Programmatic BA (EPA 2021).
- Potential adverse effects to natural cover, sediment and forage, shoreline armoring and slope, and habitat access and refugia from ISS activities would be as described in Section 6.2 of PHSS Programmatic BA (EPA 2021).

**Table 2**
**Summary of Effects of ISS**

| Action Component | Where | Exposure | | | | | | Avoidance and Minimization Measures | Anticipated Effects of the Action |
|---|---|---|---|---|---|---|---|---|---|
| | | Stressor | When | Duration | Frequency | Life History Form | Potential Response to Stressor | | |
| In Situ Solidification and Stabilization | LWR channel and riverbank | 1. Potential disturbance from increased surface water pH<br>2. Potential disturbance from increased turbidity and decreased DO<br>3. Potential toxicity from COCs in sediment, surface water, and suspended sediment<br>4. Potential toxicity from accidental leaks or spills from vehicles and equipment<br>5. Underwater noise and disturbance from vehicles and equipment<br>6. Potential loss of benthic habitat and benthos species | Stressors 1–6: Intermittently in the project area for the duration of construction occurring during the in-water work window (7/1 to 10/31 and 12/1 to 1/31). | Stressors 1–6: Temporary; during and immediately after implementation; construction would occur in the Project Area during in-water work windows and may span multiple years.<br>Stressor 6: Temporary; months to years until benthic communities recolonize and restabilize. Placement of habitat material on top of the ISS surface could accelerate recolonization. | Stressor 1-6: One or more in-water work windows over the construction duration for the Project Area. | Stressors 1–6: Adult migration LCR Chinook salmon, coho salmon, and steelhead will likely be present but in lower numbers compared to other times of the year.<br>Stressors 1–6: UWR Chinook salmon and steelhead adults would not likely be present.<br>Stressors 1–6: Juvenile outmigration increases in November and peaks in April. Juvenile salmonids will likely be present but not at their highest numbers. | Stressor 1: Sublethal effects from physiological change; irritation to eyes, skin, and gills; damage to olfactory system.<br>Stressor 2: Sublethal effects from abrading or clogging of membranes; skin irritation and abrasions. Increased predation after fleeing sediment plume.<br>Stressors 1,2, and 6: Reduced growth from inability to detect prey and reduction in prey.<br>Stressors 3 and 4: Mortality or reproductive effects due to toxicity or bioaccumulation of COCs; reduction in growth due to reduction in prey base.<br>Stressor 5: Startling behavior. Potential long-term physiological effects. Decreased foraging due to loss or disturbance of prey. Increased predation of juveniles from altered behavior.<br>Stressor 6: Localized modification of degraded benthic habitat, which may cause a temporary reduction in prey availability. | Stressors 1–5: Conduct all in-water work within the approved in-water work windows for salmonids.<br>Stressors 1–6: Confine ISS construction activities to the minimum area and duration necessary. Implement general and action-specific avoidance, minimization, and conservation measures.<br>Stressors 1–5: Employ physical barriers (turbidity curtain or moon pool containment), mechanical controls, and operational controls (reduce auger speed and optimize cement mixture) to minimize sediment disturbance and grout mixture interaction with the water column.<br>Stressors 2–4: Establish and adhere to emergency spill response measures.<br>Stressors 1 and 2: Perform water quality monitoring of physical parameters (turbidity, DO, and pH) in accordance with project standard criteria during in-water work. Additional project-specific criteria may be developed based on existing water quality conditions.<br>Stressor 3: Perform water quality monitoring of project-specific COCs in accordance with project standard criteria for in-water work.<br>Stressor 6: Following ISS activities in shallow areas, elevations will be returned to existing grade and habitat material would be placed to maximize post-construction habitat consistent with the design. | Measures will be implemented to avoid and minimize effects to listed species to the extent possible. However, take may still occur. Anticipated effects are expected to be less severe than those resulting from dredging activities, except for the potential for localized increases in surface water pH.<br>Stressors 1 and 3: Direct salmonid mortality from acute exposure to elevated pH levels and COC concentrations is possible but unlikely to occur because the effect would be localized and primarily occur during injection and mixing of the grout close to the sediment surface and within the containment system. Juveniles would be more susceptible than adults. Sublethal effects could also occur if pH and COC concentrations are elevated during ISS.<br>Stressor 2: Direct salmonid mortality is considered unlikely at expected levels of turbidity/TSS. Sublethal physical, behavior, or physiological effects could occur in the turbidity/TSS plume.<br>Stressor 4: Potential for consequences from construction equipment leaks and spills is considered low based on implementation of avoidance, minimization, and conservation measures.<br>Stressor 5: Potential for consequences from elevated underwater noise is considered low based on work timing and limited spatial extent of activities.<br>Stressor 6: Short-term loss of currently degraded benthic foraging areas while the benthic community re-establishes. |

Notes:
COC: contaminant of concern
LCR: Lower Columbia River
LWR: Lower Willamette River
UWR: Upper Willamette River
TSS: total suspended solids

# References

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