Lower Duwamish Waterway Group

Port of Seattle / City of Seattle / King County / The Boeing Company

QUALITY ASSURANCE PROJECT PLAN: BENTHIC INVERTEBRATE SAMPLING OF THE LOWER DUWAMISH WATERWAY

APPENDICES A- E

FINAL

For submittal to

The US Environmental Protection Agency
Region 10
Seattle, WA

The Washington State Department of Ecology
Northwest Regional Office
Bellevue, WA

July 30, 2004

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APPENDIX A. HEALTH AND SAFETY PLAN

TITLE AND APPROVAL PAGE
LDW BENTHIC INVERTEBRATE
HEALTH AND SAFETY PLAN

By their signature, the undersigned certify that this Health and Safety Plan (HSP) is approved and that it will be used to govern health and safety aspects of fieldwork described in the Quality Assurance Project Plan to which it is attached.

Name Project Manager	Date
Name Corporate Health and Safety Manager	Date
Name Field Coordinator/Health and Safety Officer	Date

Acronyms

ACRONYM	Definition
CPR	cardiopulmonary resuscitation
EPA	US Environmental Protection Agency
FC	field coordinator
HSM	Project Health and Safety Manager
HSO	Field Health and Safety Officer
HSP	health and safety plan
OSHA	Occupational Safety and Health Administration
PCBs	polychlorinated biphenyls
PFD	personal flotation device
PPE	personal protective equipment
TBT	tributyltin

A.1.0 Introduction

This site-specific health and safety plan (HSP) describes safe working practices for conducting field activities at potentially hazardous sites and for handling potentially hazardous materials/waste products. This HSP covers elements as specified in 29CFR1910§120. The procedures and guidelines contained in this plan are based on generally recognized health and safety practices. Any changes or revisions to this plan will be made by a written amendment, which will become a permanent part of this plan. The goal of the HSP is to establish procedures for safe working practices for all field personnel.

This HSP addresses all activities associated with collection and handling of benthic invertebrate and sediment samples in the Lower Duwamish Waterway (LDW). During site work, this HSP will be implemented by the Field Coordinator (FC), who is also the designated site Health and Safety Officer (HSO), in cooperation with the Corporate Health and Safety Manager (HSM) and the Project Manager.

All personnel involved in fieldwork on this project are required to comply with this HSP. The contents of this HSP reflect anticipation of the types of activities to be performed, knowledge of the physical characteristics of the site, and consideration of preliminary chemical data from previous investigations at the site. The HSP may be revised based on new information and/or changed conditions during site activities. Revisions will be documented in the project records.

Observers for the sampling event who are not field personnel will be given a safety briefing by the HSO on physical and chemical hazards. Observers will be advised of chemicals that may be present at the site and where those chemicals may be located. In addition, appropriate attire and any precautions necessary while walking along the shoreline will be discussed.

A.2.0 Site Description and Project Scope

A.2.1 SITE DESCRIPTION

The sampling area is in the LDW (see Figures 3-2, 3-3, and 3-7 in the QAPP). The area is affected by tidal fluctuations. The QAPP to which this HSP is attached provides complete details of the sampling program. The following section summarizes the types of work that will be performed during field activities.

A.2.2 SCOPE OF WORK

Specific tasks to be performed are as follows:

- collection of sediment samples from a boat using a grab sampler and on the shore by hand in intertidal areas
- collection of benthic invertebrate tissue from subtidal and intertidal areas, including clams (intertidal) and gastropods (subtidal)

Additional details on the sampling design and sampling methods are provided in Sections 3.1 and 3.2, respectively.

A.3.0 Health and Safety Personnel

Key health and safety personnel and their responsibilities are described below. These individuals are responsible for the implementation of this HSP.

Project Manager: The PM has overall responsibility for the successful outcome of the project. The PM will ensure that adequate resources and budget are provided for the health and safety staff to carry out their responsibilities during fieldwork. The PM, in consultation with the HSM, makes final decisions concerning implementation of the HSP.

Field Coordinator/Health and Safety Officer: Because of the limited scope and duration of fieldwork, the Field Coordinator (FC) and Health and Safety Officer (HSO) will be the same person. The FC/HSO will direct field sampling activities, coordinate the technical components of the field program with health and safety components, and ensure that work is performed according to the QAPP.

The FC/HSO will implement this HSP at the work location and will be responsible for all health and safety activities and the delegation of duties to a health and safety

technician in the field, if appropriate. The FC/HSO also has stop-work authority, to be used if there is an imminent safety hazard or potentially dangerous situation. The FC/HSO or his designee shall be present during sampling and operations.

Corporate Health and Safety Manager: The HSM has overall responsibility for preparation, approval, and revisions of this HSP. The HSM will not necessarily be present during fieldwork, but will be readily available, if required, for consultation regarding health and safety issues during fieldwork.

Field Crew: All field crew members must be familiar with and comply with the information in this HSP. They also have the responsibility to report any potentially unsafe or hazardous conditions to the FC/HSO immediately.

A.4.0 Hazard Evaluation and Control Measures

This section covers potential physical and chemical hazards that may be associated with the proposed project activities, and presents control measures for addressing these hazards. The activity hazard analysis, Section A.4.3, lists the potential hazards associated with each site activity and the recommended site control to be used to minimize each potential hazard.

Confined space entry will not be necessary for this project. Therefore, hazards associated with this activity are not discussed in this HSP.

A.4.1 PHYSICAL HAZARDS

For this project, it is anticipated that physical hazards will present a greater risk of injury than chemical hazards. Physical hazards are identified and discussed below.

A.4.1.1 Slips, trips, and falls

As with all field work, caution should be exercised to prevent slips on slick surfaces. In particular, sampling from a boat or other floating platform requires careful attention to minimize the risk of falling down or of falling overboard. The same care should be used in rainy conditions or on the shoreline where slick rocks are found. Slips can be minimized by wearing boots with good tread, made of material that does not become overly slippery when wet.

Trips are always a hazard on the uneven deck of a boat, in a cluttered work area, or in the intertidal zone where uneven substrate is common. Personnel will keep work areas as free as possible from items that interfere with walking.

Falls may be avoided by working as far from exposed edges as possible, by erecting railings, and by using fall protection when working on elevated platforms. For this project, no work is anticipated that would present a fall hazard.

A.4.1.2 Sampling equipment deployment

A van Veen grab sampler and benthic sledge will be used to collect invertebrates subtidally. The van Veen will be deployed from the deck of the boat by a hydraulic crane and the benthic sledge will be deployed from the back of the boat. Care will be taken to ensure that the van Veen grab sampler is safely guided from the deck over the railing and into the water. When the benthic sledge is deployed care will be taken to ensure that the line is not tangled with other gear onboard the boat or with body parts. No sampling equipment other than a shovel will be used in the clam study. Before sampling activities begin, there will be a training session for all field personnel for the equipment that will be onboard the sampling vessel.

A.4.1.3 Falling overboard

Some of the sampling activities will be done from a boat. As with any work from a floating platform, there is a chance of falling overboard. Personal flotation devices (PFDs) will be worn while working from the boat.

A.4.1.4 Manual lifting

Equipment and samples must be lifted and carried. Back strain can result if lifting is done improperly. During any manual handling tasks, personnel should lift with the load supported by their legs and not their backs. For heavy loads, an adequate number of people will be used, or if possible, a mechanical lifting/handling device will be used.

A.4.1.5 Heat stress, hypothermia, or frostbite

Sampling operations and conditions that might result in the occurrence of heat stress, hypothermia, or frostbite are not anticipated. The sampling will occur during the time of year when extreme weather conditions are not expected to occur.

A.4.1.6 Weather

In general, field team members will be equipped for the normal range of weather conditions. The FC/HSO will be aware of current weather conditions, and of the potential for those conditions to pose a hazard to the field crew. Some conditions that might force work stoppage are electrical storms, high winds, or high waves resulting from winds. In the event of heavy rain, field team members will not sample near a flowing combined sewer overflow because of potentially high levels of fecal coliform bacteria.

A.4.1.7 Sharp objects

Sampling operations might result in exposure of field personnel to sharp objects on top of or buried within the sediment. If encountered, field personnel should not touch these objects. Also, field personnel should not dig in the sediment by hand.

A.4.2 VESSEL HAZARDS

Because of the high volumes of vessel and barge traffic on the LDW, precautions and safe boating practices will be implemented to ensure that the field boat does not interrupt vessel traffic. Additional potential vessel emergency hazards and responses are listed in Table A-1.

Table A-1 Potential vessel emergency hazards and responses

POTENTIAL EMERGENCY HAZARD	RESPONSE
Fire or explosion	If manageable, attempt to put out a small fire with a fire extinguisher. Otherwise, call the Coast Guard or 911 and evacuate the area (by rescue boat or swimming) and meet at a designated area. The FC/HSO will take roll call to make sure everyone evacuated safely. Emergency meeting places will be determined in the field during the daily safety briefing.
Medical emergency/ personal injury	At least one person with current first aid-CPR training will be aboard the vessel at all times. This person will attempt to assess the nature and severity of the injury, call 911 immediately, and apply CPR if necessary. Stop work and wait for medical personnel to arrive. Fill out a site accident report.
Person overboard	All persons aboard the sampling vessel will wear a personal flotation device at all time. Have one person keep an eye on the person and shout the distance (boat lengths) and direction (o'clock) of the person from the vessel. Stop work and use the vessel to retrieve the person in the water.
Sinking vessel	Call the Coast Guard immediately. If possible, wait for a rescue boat to arrive to evacuate vessel personnel. See fire/explosion section for emergency evacuation procedures. The FC/HSO will take a roll call to make sure everyone is present.
Lack of visibility	If the navigation visibility or personal safety is compromised because of smoke, fog, or other unanticipated hazards, stop work immediately. The vessel operator and FC/HSO will assess the hazard and, if necessary, send out periodic horn blasts to mark vessel location to other vessels potentially in the area, move to a secure location (i.e., berth), and wait for the visibility to clear.
Loss of power	Stop work and call Coast Guard for assistance. Use oars to move vessel towards the shoreline. Vessel personnel should watch for potential collision hazards and notify vessel operator if hazards exist. Secure vessel to a berth, dock, or mooring as soon as possible.
Collision	Stop work and call Coast Guard for assistance. The FC/HSO and vessel operator will assess damage and potential hazards. If necessary, vessel will be evacuated and secured until repairs can be made.

A.4.3 CHEMICAL HAZARDS

Previous investigations have shown that some chemical substances are present at higher-than-background concentrations in the sampling area. For the purposes of discussing potential exposure to substances in sediments, the chemicals of concern are metals, tributyltin (TBT), petroleum hydrocarbons, polycyclic aromatic hydrocarbons, and polychlorinated biphenyls (PCBs).

A.4.3.1 Exposure routes

Potential routes of chemical exposure include inhalation, dermal contact, and ingestion. Exposure will be minimized by using safe work practices and by wearing the appropriate personal protective equipment (PPE). Further discussion of PPE requirements is presented in Section A.7.

Inhalation —Inhalation is not expected to be an important route of exposure.

Dermal exposure — Dermal exposure to hazardous substances associated with sediments, surface water, or equipment decontamination will be controlled by the use of PPE and by adherence to detailed sampling and decontamination procedures.

Ingestion — Ingestion is not considered a major route of exposure for this project. Accidental ingestion of surface water is possible. However, careful handling of equipment and containers aboard the boat should prevent the occurrence of water splashing or spilling during sample collection and handling activities.

A.4.3.2 Description of chemical hazards

Metals and tributyltin — Exposure to metals may occur via ingestion or skin contact. As mentioned above, neither is likely as an exposure route. Metal fumes or metal-contaminated dust will not be encountered during field and sample handling activities. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for passage of any of the metals into the body. Field procedures require immediate washing of sediments from exposed skin.

Petroleum hydrocarbons and PAHs — Exposure to petroleum hydrocarbons and PAHs may occur via ingestion or skin contact. The most important human health exposure pathway for this group of chemicals, inhalation, is not expected to occur at this site. Animal studies have also shown that PAHs can cause harmful effects on the skin, body fluids, and ability to fight disease after both short- and long-term exposure, but these effects have not been seen in people. Some PAHs may reasonably be expected to be carcinogens. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for passage of any of the compounds into the body. Field procedures require immediate washing of sediments from exposed skin.

Polychlorinated biphenyls — Prolonged skin contact with PCBs may cause acne-like symptoms known as chloracne. Irritation to eyes, nose, and throat may also occur. Acute and chronic exposure can damage the liver, and cause symptoms of edema, jaundice, anorexia, nausea, abdominal pains, and fatigue. PCBs are a suspected human carcinogen. Skin absorption may substantially contribute to the uptake of PCBs. Large amounts of sediment would need to be ingested for any detrimental effects to occur. Momentary skin contact allows little, if any, opportunity for passage of any of the compounds into the body. Field procedures require immediate washing of sediments from exposed skin.

A.4.4 ACTIVITY HAZARD ANALYSIS

The activity hazard analysis summarizes the field activities to be performed during the project, outlines the hazards associated with each activity, and presents controls that can reduce or eliminate the risk of the hazard occurring.

Table A-2 presents the activity hazard analysis for the following activities:

- invertebrate sampling from boat
- clam-digging at intertidal areas

Table A-2. Activity hazard analysis

ACTIVITY	HAZARD	CONTROL
Sampling from a boat	Falling overboard	Use care in boarding/departing from vessel. Deploy and recover the van Veen grab sampler from the back deck of the boat and the benthic sledge from the back of the boat.. Wear PFD.
	Skin contact with contaminated sediments or liquids	Wear modified Level D PPE.
	Back strain	Use appropriate lifting technique when deploying and retrieving pots, or seek help.
Clam digging in intertidal areas	Skin contact with contaminated sediments or liquids; contact with sharp objects	Wear modified Level D PPE. Do not dig in sediment with hands. Do not touch sharp objects if found.
	Back strain	Use appropriate lifting technique when digging in sediment with shovel.

A.5.0 Work Zones and Shipboard Access Control

During sampling and sample handling activities, work zones will be established to identify where sample collection and processing are actively occurring. The intent of the zone is to limit the migration of sample material out of the zone and to restrict access to active work areas by defining work zone boundaries.

A.5.1 WORK ZONE

The work zone onshore will encompass the area where sample collection and handling activities are performed. On the beach, the FC/HSO will delineate the work zone as a particular area. Only persons with appropriate training, PPE, and authorization from the FC/HSO will be allowed to enter the work zone while work is in progress.

A.5.2 DECONTAMINATION STATION

A decontamination station will be set up, and personnel will clean soiled boots or PPE prior to leaving the work zone. The station will have the buckets, brushes, soapy water, rinse water, or wipes necessary to clean boots, PPE, or other equipment leaving the work zones. Plastic bags will be provided for expendable and disposable materials. If the location does not allow the establishment of a decontamination station, the FC/HSO will provide alternatives to prevent the spread of contamination.

Decontamination of the boat will also be completed at the end of each work day. Cockpit and crew areas will be rinsed down with LDW water to minimize accumulation of sediment.

A.5.3 ACCESS CONTROL

Security and control of access to the boat will be the responsibility of the FC/HSO and boat captain. Boat access will be granted only to necessary project personnel and authorized visitors. Any security or access control problems will be reported to the client or appropriate authorities.

A.6.0 Safe Work Practices

Following common sense rules will minimize the risk of exposure or accidents at a work site. These general safety rules will be followed on site:

- Do not climb over or under obstacles of questionable stability.
- Do not eat, drink, smoke, or perform other hand-to-mouth transfers in the work zone.
- Work only in well-lighted spaces.
- Never enter a confined space without the proper training, permits, and equipment.
- Make eye contact with equipment operators when moving within the range of their equipment.
- Be aware of the movements of shipboard equipment when not in the operator's range of vision.
- Get immediate first aid for all cuts, scratches, abrasions, or other minor injuries.
- Use the established sampling and decontamination procedures.
- Always use the buddy system.
- Be alert to your own and other workers' physical condition.
- Report all accidents, no matter how minor, to the FC/HSO.
- Do not do anything dangerous or unwise even if ordered by a supervisor.

A.7.0 Personal Protective Equipment and Safety Equipment

Appropriate PPE will be worn as protection against potential hazards. In addition, a PFD will be required when working aboard the boat. Prior to donning PPE, the field crew will inspect their PPE for any defects that might render the equipment ineffective.

Fieldwork will be conducted in Level D or modified Level D PPE, as discussed below in Sections A.7.1 and A.7.2. Situations requiring PPE beyond modified Level D are not anticipated. Should the FC/HSO determine that PPE beyond modified Level D is necessary, the HSM will be notified and an alternative selected.

A.7.1 LEVEL D PERSONAL PROTECTIVE EQUIPMENT

Workers performing general activities in which skin contact with contaminated materials is unlikely will wear Level D PPE. Level D PPE includes the following:

- cotton overalls or lab coats
- chemical-resistant steel-toed boots
- chemical-resistant gloves
- safety glasses

A.7.2 MODIFIED LEVEL D PERSONAL PROTECTIVE EQUIPMENT

Workers performing activities where skin contact with contaminated materials is possible and in which inhalation risks are not expected will be required to wear an impermeable outer suit. The type of outerwear will be chosen according to the types of chemical contaminants that might be encountered. Modified Level D PPE includes the following:

- impermeable outer garb such as rain gear
- chemical-resistant steel-toed boots
- chemical-resistant outer gloves

A.7.3 SAFETY EQUIPMENT

In addition to PPE that will be worn by shipboard personnel, basic emergency and first aid equipment will also be provided. Equipment for the field team will include:

- a copy of this HSP
- first aid kit adequate for the number of personnel
- emergency eyewash

The FC/HSO will ensure that the safety equipment is aboard. Equipment will be checked daily to ensure its readiness for use.

A.8.0 Monitoring Procedures for Site Activities

A monitoring program that addresses the potential site hazards will be maintained. For this project, air, dust, and noise monitoring will not be necessary. No volatile organic compounds have been identified among the expected contaminants, the sampled media will be wet and will not pose a dust hazard, and none of the equipment emits high-amplitude (>85 dBA) sound. For this project, the monitoring program will consist of all workers monitoring themselves and their co-workers for signs that might indicate physical stress or illness.

All personnel will be instructed to look for and inform each other of any deleterious changes in their physical or mental condition during the performance of all field activities. Examples of such changes are as follows:

- headaches
- dizziness
- nausea
- symptoms of heat stress
- blurred vision
- cramps
- irritation of eyes, skin, or respiratory system
- changes in complexion or skin color
- changes in apparent motor coordination
- increased frequency of minor mistakes
- excessive salivation or changes in papillary response
- changes in speech ability or speech pattern
- shivering
- blue lips or fingernails

If any of these conditions develop, work shall be halted immediately and the affected person(s) evaluated. If further assistance is needed, personnel at the local hospital will be notified, and an ambulance will be summoned if the condition is thought to be serious. If the condition is the direct result of sample collection or handling activities, procedures will be modified to address the problem.

A.9.0 Decontamination

Decontamination is necessary to prevent the migration of contaminants from the work zone(s) into the surrounding environment and to minimize the risk of exposure of personnel to contaminated materials that might adhere to PPE. The following sections discuss personnel and equipment decontamination. The following supplies will be available to perform decontamination activities:

- wash buckets
- rinse buckets
- Long-handled scrub brushes
- clean water sprayers
- paper towels

- plastic garbage bags
- Alconox® or similar decontamination solution

A.9.1 MINIMIZATION OF CONTAMINATION

The first step in addressing contamination is to prevent or minimize exposure to existing contaminated materials and the spread of those materials. During field activities, the FC/HSO will enforce the following measures:

Personnel:

- Do not walk through areas of obvious or known contamination.
- Do not handle, touch, or smell contaminated materials directly.
- Make sure PPE has no cuts or tears prior to use.
- Fasten all closures on outer clothing, covering with tape if necessary.
- Protect and cover any skin injuries.
- Stay upwind of airborne dusts and vapors.
- Do not eat, drink, chew tobacco, or smoke in the work zones.

Sampling equipment and boat:

- Place clean equipment on a plastic sheet or aluminum foil to avoid direct contact with contaminated media.
- Keep contaminated equipment and tools separate from clean equipment and tools.
- Clean boots before entering the boat.

A.9.2 PERSONNEL DECONTAMINATION

The FC/HSO will ensure that all site personnel are familiar with personnel decontamination procedures. Personnel will perform decontamination procedures, as appropriate, before eating lunch, taking a break, or before leaving the work location. Following is a description of these procedures.

Decontamination procedure:

1. If outer suit is heavily soiled, rinse it off.
2. Wash and rinse outer gloves and boots with in water.
3. Remove outer gloves; inspect and discard if damaged.
4. Wash hands if taking a break.
5. Don necessary PPE before returning to work.

Dispose of soiled, expendable PPE before leaving for the day.

A.9.3 SAMPLING EQUIPMENT DECONTAMINATION

Before use at each sampling location, the van Veen grab sampler and benthic sledge will be rinsed in river water to dislodge and remove any sediment, washed with detergent, rinsed again with LDW water, and rinsed with deionized water.

A.9.4 VESSEL DECONTAMINATION

Prior to returning to the boat after sampling, personnel will rinse their boots with LDW water to minimize the amount of sediment accumulating in the boat. At the end of each sampling day, the vessel will be rinsed with LDW water to remove sediment from cockpit and crew areas.

A.10.0 Disposal of Contaminated Materials

Contaminated materials that may be generated during field activities include PPE, decontamination fluids, and excess sample material. These contaminated materials will be disposed of as an integral part of the project.

A.10.1 PERSONAL PROTECTIVE EQUIPMENT

Gross surface contamination will be removed from PPE. All disposable sampling materials and PPE, such as disposable coveralls, gloves, and paper towels used in sample processing, will be placed in heavyweight garbage bags. Filled garbage bags will be placed in a normal refuse container for disposal as solid waste.

A.10.2 EXCESS SAMPLE MATERIALS

At each sampling location, excess sediment and benthic invertebrates collected will be returned to the water.

A.11.0 Training Requirements

Individuals performing work at locations where potentially hazardous materials and conditions may be encountered must meet specific training requirements. It is not anticipated that hazardous concentrations of contaminants will be encountered in sampled material, so training will consist of site-specific instruction for all personnel and oversight of inexperienced personnel by an experienced person for one working day. The following sections describe the training requirements for this fieldwork.

A.11.1 PROJECT-SPECIFIC TRAINING

In addition to HAZWOPER training, as described in Section 2.5 of the QAPP, field personnel will undergo training specifically for this project. All personnel must read this HSP and be familiar with its contents before beginning work. They shall acknowledge reading the HSP by signing the field team HSP review form contained in Attachment 1. The form will be kept in the project files.

The boat captain and FC/HSO or a designee will provide project-specific training prior to the first day of fieldwork and whenever new workers arrive. Field personnel will not be allowed to begin work until project-specific training is completed and documented by the FC/HSO. Training will address the HSP and all health and safety issues and procedures pertinent to field operations. Training will include, but not be limited to, the following topics:

- activities with the potential for chemical exposure
- activities that pose physical hazards, and actions to control the hazard
- ship access control and procedure
- use and limitations of PPE
- decontamination procedures
- emergency procedures
- use and hazards of sampling equipment
- location of emergency equipment on the vessel
- vessel safety practices
- vessel evacuation and emergency procedures

A.11.2 DAILY SAFETY BRIEFINGS

The FC/HSO or a designee and the boat captain will present safety briefings before the start of each day's activities. These safety briefings will outline the activities expected for the day, update work practices and hazards, address any specific concerns associated with the work location, and review emergency procedures and routes. The FC/HSO or designee will document safety briefings in the logbook.

A.11.3 FIRST AID AND CPR

At least one member of the field team must have first-aid and cardiopulmonary resuscitation (CPR) training. Documentation of which individuals possess first-aid and CPR training will be kept in the project health and safety files.

A.12.0 Medical Surveillance

A medical surveillance program conforming to the provisions of 29 CFR 1910§120(f) is not necessary for field team members because they do not meet any of the four criteria outlined in the regulations for implementation of a medical surveillance program:

- Employees who are or may be exposed to hazardous substances or health hazards at or above permissible exposure levels for 30 days or more per year (1910.120(f)(2)(I).

- Employees who must wear a respirator for 30 days or more per year (1910.120(f)(2)(ii)).
- Employees who are injured or become ill due to possible overexposures involving hazardous substances or health hazards from an emergency response or hazardous waste operation (1910.120(f)(2)(iii)).
- Employees who are members of HAZMAT teams (1910.120(f)(2)(iv)).

As described in Section A.8, employees will monitor themselves and each other of any deleterious changes in their physical or mental condition during the performance of all field activities.

A.13.0 Reporting and Record Keeping

Each member of the field crew will sign the HSP review form (see Attachment 1). If necessary, accident/incident report forms and OSHA Form 200s will be completed by the FC/HSO.

The FC/HSO or a designee will maintain a health and safety field logbook that records health- and safety-related details of the project. Alternatively, entries may be made in the field logbook, in which case a separate health and safety logbook will not be required. The logbook must be bound and the pages must be numbered consecutively. Entries will be made with indelible blue ink. At a minimum, each day's entries must include the following information:

- project name or location
- names of all personnel onboard
- weather conditions
- type of fieldwork being performed

The person maintaining the entries will initial and date the bottom of each completed page. Blank space at the bottom of an incompletely filled page will be lined out. Each day's entries will begin on the first blank page after the previous workday's entries.

A.14.0 Emergency Response Plan

As a result of the hazards onboard and the conditions under which operations will be conducted, the potential exists for an emergency situation to occur. Emergencies may include personal injury, exposure to hazardous substances, fire, explosion, or release of toxic or non-toxic substances (spills). OSHA regulations require that an emergency response plan be available for use onboard to guide actions in emergency situations.

Onshore organizations will be relied upon to provide response in emergency situations. The local fire department and ambulance service can provide timely response. Field personnel will be responsible for identifying an emergency situation,

providing first aid if applicable, notifying the appropriate personnel or agency, and evacuating any hazardous area. Shipboard personnel will attempt to control only very minor hazards that could present an emergency situation, such as a small fire, and will otherwise rely on outside emergency response resources.

The following sections identify the onboard individual(s) who should be notified in case of emergency, provide a list of emergency telephone numbers, offer guidance for particular types of emergencies, and provide directions and a map for getting from any sampling location to a hospital.

A.14.1 PRE-EMERGENCY PREPARATION

Before the start of field activities, the FC/HSO will ensure that preparation has been made in anticipation of emergencies. Preparatory actions include the following:

- Meeting with the FC/HSO and equipment handlers concerning the emergency procedures in the event that a person is injured.
- A training session given by the FC/HSO informing all field personnel of emergency procedures, locations of emergency equipment and their use, and proper evacuation procedures.
- A training session given by senior staff operating field equipment, to apprise field personnel of operating procedures and specific risks associated with that equipment.
- Ensuring that field personnel are aware of the existence of the emergency response plan in the HSP and ensuring that a copy of the HSP accompanies the field team.

A.14.2 PROJECT EMERGENCY COORDINATOR

The FC/HSO will serve as the Project Emergency Coordinator in the event of an emergency. He will designate his replacement for times when he is not onboard or is not serving as the Project Emergency Coordinator. The designation will be noted in the logbook. The Project Emergency Coordinator will be notified immediately when an emergency is recognized. The Project Emergency Coordinator will be responsible for evaluating the emergency situation, notifying the appropriate emergency response units, coordinating access with those units, and directing interim actions onboard before the arrival of emergency response units. The Project Emergency Coordinator will notify the HSM and the Project Manager as soon as possible after initiating an emergency response action. The Project Manager will have responsibility for notifying the client.

A.14.3 EMERGENCY RESPONSE CONTACTS

All onboard personnel must know whom to notify in the event of an emergency situation, even though the FC/HSO has primary responsibility for notification.

Table A-3 lists the names and phone numbers for emergency response services and individuals.

Table A-3. Emergency response contacts

CONTACT	TELEPHONE NUMBER
Emergency Numbers	
Ambulance	911
Police	911
Fire	911
Harborview Medical Center	(206) 323-3074
Emergency Responders	
U.S. Coast Guard Emergency General information	 (206) 286-5400 (206) 442-5295 UHF Channel 16
National Response Center	(800) 424-8802
EPA	(908) 321-6660
Washington State Department of Ecology – Northwest Region Spill Response (24-hour emergency line)	(206) 649-7000
Emergency Contacts	
Project Manager	
Kathy Godtfredsen	(206) 577-1283
Corporate Health and Safety Manager	
Tad Deshler	(206) 577-1285
Field Coordinator/ Field Health and Safety Officer	Site cellular telephone:
Helle Andersen	(206) 954-1780

A.14.4 RECOGNITION OF EMERGENCY SITUATIONS

Emergency situations will generally be recognizable by observation. An injury or illness will be considered an emergency if it requires treatment by a medical professional and cannot be treated with simple first-aid techniques.

A.14.5 DECONTAMINATION

In the case of evacuation, decontamination procedures will be performed only if doing so does not further jeopardize the welfare of site workers. If an injured individual is also heavily contaminated and must be transported by emergency vehicle, the emergency response team will be told of the type of contamination. To the extent possible, contaminated PPE will be removed, but only if doing so does not exacerbate the injury. Plastic sheeting will be used to reduce the potential for spreading contamination to the inside of the emergency vehicle.

A.14.6 FIRE

Field personnel will attempt to control only small fires, should they occur. If an explosion appears likely, personnel will follow evacuation procedures specified during the training session. If a fire cannot be controlled with a fire extinguisher on board that is part of the required safety equipment, personnel will either withdraw from the vicinity of the fire or evacuate the boat as specified in the training session.

A.14.7 PERSONAL INJURY

In the event of serious personal injury, including unconsciousness, possibility of broken bones, severe bleeding or blood loss, burns, shock, or trauma, the first responder will immediately do the following:

- Administer first aid, if qualified.
- If not qualified, seek out an individual who is qualified to administer first aid, if time and conditions permit.
- Notify the Project Emergency Coordinator of the incident, the name of the individual, the location, and the nature of the injury.

The Project Emergency Coordinator will immediately do the following:

- Notify the boat captain and the appropriate emergency response organization.
- Assist the injured individual.
- Follow the emergency procedures for retrieving or disposing equipment reviewed in the training session and leave the site en route to the predetermined land-based emergency pick-up.
- Designate someone to accompany the injured individual to the hospital.
- If a life-threatening emergency occurs, i.e., injury where death is imminent without immediate treatment, the FC/HSO or boat captain will call 911 and arrange to meet the Medic One unit at the nearest accessible dock. Otherwise, for emergency injuries which are not life-threatening (i.e., broken bones, minor lacerations, etc.) the Project Emergency Coordinator will follow the procedures outlined above and proceed to the Harbor Island Marina or to an alternative location of his choice if that would be more expedient.
- Notify the HSM and the Project Manager.

If the Project Emergency Coordinator determines that emergency response is not necessary, he or she may direct someone to decontaminate and transport the individual by vehicle to the nearest hospital. Directions and a map showing the route to the hospital are in Section A.14.10.

If a worker leaves the boat to seek medical attention, another worker should accompany them to the hospital. When in doubt about the severity of an injury or

exposure, always seek medical attention as a conservative approach, and notify the Project Emergency Coordinator.

The Project Emergency Coordinator will have responsibility for completing all accident/incident field reports, OSHA Form 200s, and other required follow-up forms.

A.14.8 OVERT PERSONAL EXPOSURE OR INJURY

If an overt exposure to toxic materials occurs, the first responder to the victim will initiate actions to address the situation. The following actions should be taken, depending on the type of exposure.

A.14.8.1 Skin contact

- Wash/rinse the affected area thoroughly with copious amounts of soap and water.
- If eye contact has occurred, eyes should be rinsed for at least 15 minutes using the eyewash that is part of the emergency equipment onboard.
- After initial response actions have been taken, seek appropriate medical attention.

A.14.8.2 Inhalation

- Move victim to fresh air.
- Seek appropriate medical attention.

A.14.8.3 Ingestion

- Seek appropriate medical attention.

A.14.8.4 Puncture wound or laceration

- Seek appropriate medical attention.

A.14.9 SPILLS AND SPILL CONTAINMENT

No bulk chemicals or other materials subject to spillage are expected to be used during this project. Accordingly, no spill containment procedure is required for this project.

A.14.10 EMERGENCY ROUTE TO THE HOSPITAL

The name, address, and telephone number of the hospital that will be used to provide medical care is as follows:

Harborview Medical Center
325 - 9th Ave.
Seattle, WA
(206) 323-3074

Directions from the vicinity of LDW to Harborview Medical Center are as follows:

- Dock the vessel at the 1st Ave S boat launch.
- Drive east on S River Street.
- Turn left on Occidental Ave S.
- Turn left on E Marginal Way S.
- Turn right on S Michigan Street.
- Look for entrance ramps to I-5 Northbound.
- Head north on I-5.
- Take the James Street exit.
- Head east on James Street to 9th Avenue.
- Turn right on 9th Avenue.
- Emergency entrance will be two blocks south on the right.

Attachment A1. Field Team Health and Safety Plan Review

I have read a copy of the Health and Safety Plan, which covers field activities that will be conducted to investigate potentially contaminated areas in the LDW. I understand the health and safety requirements of the project, which are detailed in this Health and Safety Plan.

Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date
Signature	Date

APPENDIX B. FIELD COLLECTION FORMS

SURFACE SEDIMENT COLLECTION FORM

Project Name:		Project no.	
Date:		Station:	
Start/Stop time:			X:
Sampling Method:			Y:
Weather:		Sample ID:	
Crew:			

Subsample #:		Sample depth:		Penetration depth		Time:	
Sampling gear:					Acceptable sample (circle)	yes	no

type:	color:	odor:		Comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Subsample #:		Sample depth:		Penetration depth		Time:	
Sampling gear:					Acceptable sample (circle)	yes	no

type:	color:	odor:		Comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

Subsample #:		Sample depth:		Penetration depth		Time:	
Sampling gear:					Acceptable sample (circle)	yes	no

type:	color:	odor:		Comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		

BENTHIC COMMUNITY COLLECTION FORM

Project Name:		Project no.	
Date:		Station:	
Start/Stop time:		X:	
Sampling Method:		Y:	
Weather:		Sample ID	
Crew:			

Subsample #		Bottom depth:	Penetration depth	Time:
Field measured grain size:			Acceptable grab (circle)	yes no
type:	color:	odor:		Sample quality comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	Brown surface	overwhelming		
Description of vertical profile:			Preserved (circle):	yes no

Subsample #		Bottom depth:	Penetration depth	Time:
Field measured grain size:			Acceptable grab (circle)	yes no
type:	color:	odor:		Sample quality comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		
Description of vertical profile:			Preserved (circle):	yes no

Subsample #		Bottom depth:	Penetration depth	Time:
Field measured grain size:			Acceptable grab (circle)	yes no
type:	color:	odor:		Comments:
cobble	drab olive	none	H_2S	
gravel	gray	slight	petroleum	
sand C M F	black	moderate	other:	
silt clay	brown	strong		
organic matter	brown surface	overwhelming		
Description of vertical profile:			Preserved (circle):	yes no

MARKET BASKET INVERTEBRATE COLLECTION FORM

Project Name:		Project no.	
Date:		Station:	
Start/Stop time:		X:	
Sampling Method:		Y:	
Weather:		Sample ID:	

Crew:

Subsample # ____ Sample depth: ____ Penetration depth ____ Time: ____

Sampling gear: Acceptable sample (circle) yes no

type:	color:	odor:	
cobble	drab olive	none	H_2S
gravel	gray	slight	petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	Brown surface	overwhelming	

Description of vertical profile:

Sample quality comments:

Subsample # ____ Sample depth: ____ Penetration depth ____ Time: ____

Sampling gear: Acceptable sample (circle) yes no

type:	color:	odor:	
cobble	drab olive	none	H_2S
gravel	gray	slight	petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Description of vertical profile:

Sample quality comments:

Subsample # ____ Sample depth: ____ Penetration depth ____ Time: ____

Sampling gear: Acceptable sample (circle) yes no

type:	color:	odor:	
cobble	drab olive	none	H_2S
gravel	gray	slight	petroleum
sand C M F	black	moderate	other:
silt clay	brown	strong	
organic matter	brown surface	overwhelming	

Description of vertical profile:

Sample quality comments:

CLAM COLLECTION FORM

Project Name:		Project no.	
Date:		Station:	
Start/Stop time:		X:	
Sampling Method:		Y:	
Weather:		Sample ID:	
Crew:			

Clam species	#	Shell length (cm)		Clam species	#	Shell length (cm)

Comments:

SAMPLE ALTERATION FORM

Project Name and Number: _____

Material to be Sampled: _____

Measurement Parameter: _____

Standard Procedure for Field Collection & Laboratory Analysis (cite reference):

Reason for Change in Field Procedure or Analysis Variation:

Variation from Field or Analytical Procedure:

Special Equipment, Materials or Personnel Required:

Initiator's Name: _____ Date: _____

Project Officer: _____ Date: _____

QA Officer: _____ Date: _____

CORRECTIVE ACTION FORM

Project Name and Number: _____

Sample Dates Involved: _____

Measurement Parameter: _____

Acceptable Data Range: _____

Problem Areas Requiring Corrective Action: _____

Measures Required to Correct Problem: _____

Means of Detecting Problems and Verifying Correction: _____

Initiators Name: _____ Date: _____

Project Officer: _____ Date: _____

QA Officer: _____ Date: _____

APPENDIX C. RISK-BASED ANALYTICAL CONCENTRATION GOALS FOR BENTHIC INVERTEBRATE TISSUE SAMPLES

Acronyms

ACRONYM	Definition
2,3,7,8-TCDD	2,3,7,8-tetrachlorodibenzo-p-dioxin
ACG	analytical concentration goal
BW	body weight
DFC	daily food consumption rate
dw	dry weight
Ecology	Washington State Department of Ecology
EPA	US Environmental Protection Agency
ERA	ecological risk assessment
HHRA	human health risk assessment
LDW	Lower Duwamish Waterway
LOAEL	lowest-observed-adverse-effect level
LOEC	lowest-observed-effect concentration
MDL	method detection limit
NOAEL	no-observed-adverse-effect level
NOEC	no-observed-effect concentration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
QAPP	Quality Assurance Project Plan
RBC	risk-based concentration
SVOC	semivolatile organic compound
TEQ	toxic equivalent
TBT	tributyltin
Windward	Windward Environmental LLC
ww	wet weight

C.1.0 Introduction

This appendix addresses the following question:

> Are standard analytical methods proposed for the chemical analysis of benthic invertebrate tissue sufficiently sensitive to meet the needs of the Phase 2 ecological and human health risk assessments?

To answer this question, standard method detection limits (MDLs) were compared to analytical concentration goals (ACGs) for benthic invertebrate tissue. ACGs are defined for ecological receptors as the concentration of a chemical in tissue of a receptor or in its food associated with no effects,[1] and defined for human health as the concentration of a chemical in food that has been identified as having an acceptable risk level (e.g., excess cancer risk of 10^{-6}). ACGs have not been developed by the US Environmental Protection Agency (EPA) Region 10 for the receptors of interest. Therefore, these concentrations were determined by reviewing the toxicological literature for fish and wildlife, and by reviewing human health guidance documents. Although information from the toxicological literature is used in this document, the objective of this memo is not to establish the toxicity reference values (TRVs) to be used for the Phase 2 risk assessments. The TRVs to be used in those assessments will be determined during Phase 2, in consultation with EPA and Washington State Department of Ecology (Ecology).

To determine ACGs for this quality assurance project plan (QAPP),[2] risk-based concentrations (RBCs) were identified or derived for each receptor species that either: 1) consumes various benthic invertebrates (i.e., fish and spotted sandpiper), 2) consumes clams (i.e., humans and river otter), or 3) will be evaluated for risk based on concentrations of chemicals in its own tissue (i.e., market basket benthic invertebrates from TBT exposures). These RBCs are expressed as concentrations in market basket benthic invertebrate samples[3] or in clams that are food for receptors, or as concentrations in tissue of the receptor at risk. The risk-based ACG for a given tissue is equal to the lowest RBC for that tissue for each chemical. So, for instance, if both humans and river otters consume clams, the risk-based ACG for cadmium in clams is set by the RBC of the receptor most sensitive to cadmium (the lower of the two RBCs).

The remainder of this appendix is organized as follows:

- Section C.2.0 – RBC derivation methods for each receptor

[1] The lowest concentration associated with adverse effects was used if data were not available for a concentration associated with no effects.

[2] ACGs associated with fish and crab tissues will be presented in an appendix to the fish and crab tissue QAPP.

[3] In the market basket approach, all benthic invertebrates (except bivalves and crustaceans greater than 1 cm, see Section 3.1.2 of this QAPP) collected at a targeted sampling location are combined into a single composite sample.

- Section C.3.0 – Comparison of ACGs to MDLs
- Section C.4.0 – Tissue mass required for analysis
- Tables C-1 through C-8 (located at the end of this appendix) summarize RBCs for all receptors for each chemical, list studies selected for each receptor for the calculation of RBCs, compare ACGs and MDLs, and summarize tissue mass requirements to meet standard and modified MDLs.

C.2.0 Risk-based Concentrations

For this QAPP, RBCs are tissue concentrations associated with an acceptable risk level as derived from the toxicity literature or human health guidance documents. In this appendix, RBCs are derived for the following receptors and exposure pathways:

- Benthic invertebrates exposed to tributyltin (TBT) via direct contact with sediment and water and through ingestion of their food (RBC expressed as wet weight (ww) concentration in benthic invertebrate tissue)
- Fish exposed to chemicals via ingestion of their benthic prey as represented by market basket benthic invertebrate tissue samples (RBC expressed as ww concentration in benthic invertebrates)
- Spotted sandpiper exposed to chemicals via ingestion of their benthic prey as represented by market basket benthic invertebrate tissue samples (RBC expressed as ww concentration in benthic invertebrates)
- River otters exposed to chemicals via ingestion of clams (RBC expressed as ww concentration in clams)
- Humans exposed to chemicals via ingestion of clams (RBC expressed as ww concentration in clams)

The following sections describe how RBCs were derived for each receptor. The RBCs for each of the five receptors are summarized in Table C-1. The specific chemicals for which RBCs were derived are discussed in the sections below for each receptor. For some chemicals, no relevant toxicity data were available. For example, no toxicity data were found for fish for alkylated polycyclic aromatic hydrocarbons (PAHs). Therefore, toxicity information for non-alkylated PAHs will be used to set RBCs for total PAHs for the protection of fish.

RBCs were not derived for individual dioxin/furan congeners. Analysis of these congeners in tissue will be conducted if the results of the urban background analysis in sediments indicate that quantitative risk characterization is needed (see Section 3.1.8.1 in the Phase 2 work plan, Windward 2004). If analyzed, the concentrations of individual dioxin/furan congeners would be included in the calculated toxic equivalent (TEQ) for comparison to toxicity data for 2,3,7,8-tetrachlorodibenzo(p)dioxin (2,3,7,8-TCDD).

C.2.1 RBC Derivation for the Protection of Gastropods

In the Phase 2 ecological risk assessment (ERA), TBT is the only chemical that will be analyzed[4] in market basket benthic invertebrate tissue samples for assessing risks to benthic organisms using a critical residue approach. Risks to benthic organisms from other chemicals will be assessed using sediment chemistry data and toxicity tests. Risks to gastropods will be assessed through the direct measurement of imposex in field-collected gastropods. A review of effects data associated with TBT in benthic invertebrate tissues was conducted to determine effects values for this appendix only (i.e., an additional literature search will be conducted for the Phase 2 ERA). Based on that review, the lowest LOEC (lowest-observed-effect concentration; the lowest concentration at which an adverse effect was observed) was 2.4 mg/kg dry weight (dw) associated with reduced growth of the polychaete *Armandia brevis* (Meador and Rice 2001). The highest NOEC (no-observed-effect concentration; the highest concentration at which no adverse effect was observed) found in a laboratory study was 0.85 mg/kg dw (reduced condition index in Pacific oysters, assuming a moisture content of 80% [Davies et al. 1988]). . The LOEC and NOEC are 0.48 and 0.17 mg/kg ww, respectively. The NOEC was selected as the RBC for market basket tissue for TBT (Table C-1).

C.2.2 RBC Derivation for the Protection of Fish

RBCs derived for the protection of fish are expressed as chemical concentrations in the prey of the fish for those chemicals evaluated using a dietary approach in the ERA (i.e., PAHs and metals, except mercury). RBCs are expressed as concentrations in fish prey for these chemicals because they are metabolized or otherwise regulated by fish. RBCs derived in prey tissue for the protection of fish will be considered in the determination of ACGs for the market basket benthic invertebrate tissue samples described in this QAPP.

RBCs for fish represent chemical concentrations in fish prey independent of prey type. English sole consume primarily benthic invertebrates, Pacific staghorn sculpin consume both benthic invertebrates and fish, and juvenile chinook salmon consume both benthic invertebrates and terrestrial insects. Because it is not known what percentages of fish diets are represented by different types of prey, or what the chemical concentrations would be in the different prey items, the RBC for the protection of fish is assumed to be the same whether it is applied to benthic invertebrate tissue or other fish prey types. Thus, a single RBC will be applicable for all fish species regardless of their diet and is relevant in setting the ACG for all tissue types consumed by fish.

RBCs for other chemicals to be evaluated for fish in the Phase 2 ERA, such as PCBs, mercury, DDT, and TBT, will be presented in the fish and crab tissue QAPP, and will

[4] All butyltins will be analyzed, but only TBT data will be used to assess risks.

be determined using a critical tissue residue approach (i.e., RBCs will be expressed as chemical concentrations in fish tissue, not their prey).

To derive RBCs for the protection of fish for this QAPP, toxicity data were reviewed for effects of PAHs and metals (other than mercury) on fish species, and NOECs and LOECs in fish food were identified. Effects endpoints considered were growth, reproduction, and survival.[5]

The NOECs and LOECs derived from the literature are expressed as chemical concentrations in fish food in units of mg/kg ww. Table C-1 summarizes RBCs for fish, based on both NOECs and LOECs, if available. The NOEC-based RBC is the most relevant concentration; LOEC-based RBCs are presented in case the NOEC-based RBC is less than the MDL. Table C-2 presents summary information for the studies selected to derive RBCs in fish prey items. The summary information in Table C-2 includes the endpoint, test species, exposure pathway, and reference for each NOEC and LOEC shown. The following sections describe the literature search process and the derivation of RBCs for the protection of fish.

C.2.2.1 Literature search

Studies relating chemical concentrations in fish food to adverse effects in fish were identified from a search of the following sources:

- ECOTOX (2003)
- scientific literature searched using BIOSIS and Science Direct

Toxicity studies were reviewed for methods, relevance, and interpretation to ensure that NOECs and LOECs were derived appropriately. Toxicity studies were rejected if there was no control group for comparison to treated groups, or if fish were exposed to more than one chemical (except for PAH mixtures). Studies where fish were fed live prey that was exposed to a chemical were preferred over studies where fish were fed a dosed prepared diet, because the natural assimilation of metals or PAHs through live prey is more ecologically relevant and comparable to the exposure of the selected fish receptors in the Lower Duwamish Waterway (LDW). Concentrations of the dosed chemical were measured in both the live prey and the prepared food studies to determine the NOEC and LOEC.

RBCs were derived from the study with the lowest LOEC, and the study with the highest NOEC that was lower than the LOEC of the same endpoint. For some chemicals, either a NOEC or a LOEC for the same endpoint were available, but not both. In addition, for some chemicals, no relevant toxicity data were available and RBCs could not be calculated.

[5] These assessment endpoints will be used in the Phase 2 risk assessments for fish, as discussed in the Phase 2 work plan (Windward 2004).

C.2.2.2 RBC Derivation

RBCs for the protection of fish are equal to LOECs and NOECs derived from the toxicological literature (Table C-1). All RBCs are reported on a wet weight basis in fish food. If only dry weight concentrations were reported in individual literature toxicity studies, these concentrations were converted to a wet weight basis using assumptions regarding moisture content of specific prey for each study, as noted in Table C-2.

C.2.3 RBC Derivation for the Protection of Sandpiper and River Otter

RBCs for the protection of spotted sandpiper and river otter are expressed as chemical concentrations in the tissues of their prey. RBCs were derived for the chemicals of interest presented in Table C-3. This list of chemicals was presented in a draft technical memorandum to EPA and Ecology (Windward 2003a). This memorandum identified specific chemicals for analysis in tissue using a set of decision points based on the following: 1) detection in at least 5% of LDW Phase 1 surface sediment samples, 2) identification as a bioaccumulative chemical by EPA (2000), and 3) detection in tissue collected from the LDW.

RBCs derived for the protection of spotted sandpiper will be considered in the determination of ACGs for the market basket benthic invertebrate tissue samples, and RBCs derived for the protection of river otter will be considered in the determination of ACGs for clams. Other prey items for river otter (e.g., fish) will have RBCs presented in the fish and crab tissue QAPP.

RBCs for wildlife represent chemical concentrations in their prey independent of prey type. Sandpipers consume primarily benthic invertebrates, and otters consume both clams and fish. Because it is not known what percentage of the otter diet is represented by different types of prey, or what the chemical concentrations would be in the different prey items, the RBC for otter is assumed to be the same whether it is applied to clam tissue or other prey tissue types.

Toxicity data identified for bird and mammal species were no-observed-adverse-effect levels (NOAELs), which are the highest doses at which no adverse effects were observed, and lowest-observed-adverse-effect levels (LOAELs), which are the lowest doses at which adverse effects were observed. Effects endpoints included growth, reproduction, and survival.[6]

The NOAELs and LOAELs derived from the literature are expressed as dietary doses in mg/kg body weight (bw)/day. These dietary doses were converted to RBCs in prey tissue in mg/kg ww using the receptor's food ingestion rate and body weight (as described in Section C.2.3.2). Table C-1 summarizes wildlife RBCs, including both NOAELs and LOAELs, if available. The NOAEL-based RBC is the most relevant concentration; LOAEL-based RBCs are presented in case the NOAEL-based RBC is

[6] These assessment endpoints will be used in the Phase 2 risk assessments for wildlife, as discussed in the Phase 2 work plan (Windward 2004).

less than the MDL. Tables C-4 and C-5 present summary information for the studies selected to derive RBCs in bird and mammal prey items. The summary information in Tables C-4 and C-5 includes the endpoint, test species, exposure pathway, and reference for each NOAEL and LOAEL shown. The following sections describe the literature search process and the conversion of dietary doses to dietary RBCs.

C.2.3.1 Literature search

Studies relating dietary concentrations to adverse effects in wildlife were identified from a search of the following electronic databases: ECOTOX, BIOSIS, TOXNET, and IRIS. In addition, reviews of the following summary reports were used to identify original studies for wildlife toxicity data:

- Agency for Toxic Substances and Disease Registry (ATSDR)
- US Fish and Wildlife Service Contaminant Review series (Eisler 2002)
- Oak Ridge National Laboratory database (Sample et al. 1996)

Toxicity studies were reviewed for methods, relevance, and interpretation to ensure that RBCs were derived appropriately. Studies were excluded if there was no control group for comparison to treated groups, or if test species were exposed to more than one chemical. Exceptions were made for certain mixtures of related chemicals such as a mixture of DDT and its metabolites, or a mixture of PCB Aroclors. In addition, the PAH RBC for the protection of sandpiper was derived from an aromatic hydrocarbon chemical mixture including individual PAHs, because no other dietary studies were available. These requirements eliminated most field studies from consideration in the development of RBCs, because field studies generally lack suitable controls, and organisms are typically exposed to a mixture of different types of chemicals in the field.

The LOAEL and NOAEL values for RBC derivation were chosen as follows: 1) the selected LOAEL was the lowest LOAEL from any study using any of the specified endpoints (i.e., growth, reproduction, survival), and 2) the selected NOAEL was the highest NOAEL that was lower than the selected LOAEL, with the same endpoint as the selected LOAEL. Studies were not chosen for RBC derivation if the following concerns warranted the consideration of other studies:

- The exposure duration was not chronic[7] or was not conducted during a sensitive life stage (i.e., reproduction or early growth stages).
- The effect endpoint was egg productivity in a domestic species, such as chickens or Japanese quail. These species are bred to have unnaturally high egg-laying rates, so toxic threshold effects on egg production in these species

[7] Chronic exposure is defined as more than 10 weeks for avian receptors and more than one year for mammals, or exposure during a critical lifestage (i.e. reproduction, gestation, or development) (Sample et al. 1996).

are not comparable to similar effects in non-domestic avian receptors because of differences in reproductive physiology.

- Exposure was through gavage, oral intubation, or injection rather than through the diet. These routes of exposure are not directly related to environmental exposures to the bird or mammal. In addition, studies with drinking water exposures may overestimate dietary risk because gastrointestinal absorption may be higher for chemicals ingested via drinking water than through diet (Sample et al. 1996). However, studies with doses administered via injection, oral intubation, gavage, or drinking water were used for RBC selection if no other studies were available.
- Results were not statistically evaluated to identify significant differences from control values.
- Endpoints were not related to growth, reproduction, or mortality.

For some chemicals, either a NOAEL or a LOAEL of the same endpoint were available but not both. In addition, for some chemicals, no relevant toxicity data were available. Where reviews of appropriate toxicity studies had been previously conducted by Windward for chemicals that are not considered chemicals of interest, RBCs were derived for those chemicals as well. These chemicals include aldrin, beta-BHC, endosulfan, endrin, heptachlor, hexachlorobutadiene, mirex, butyl benzyl phthalate, di-n-butyl phthalate, di-n-octyl phthalate, and 2-methylnapthalene.

C.2.3.2 RBC Derivation

The NOAELs and LOAELs derived from toxicity studies were expressed as daily dietary doses normalized for body weight. To convert these doses to a tissue concentration in ingested food, the following equation was used:

$$C_F = (\text{Dose} \times \text{BW})/\text{DFC}$$

where:

C_F = concentration in food (mg/kg ww)
Dose = NOAEL or LOAEL (mg/kg bw/day)
BW = body weight (kg)
DFC = daily food consumption rate (kg ww/day)

If the NOAEL or LOAEL was based on a reproductive endpoint, the C_F was calculated using the female BW and DFC. If the NOAEL or LOAEL was based on growth or mortality, C_F was calculated using the male and female average for BW and DFC. The following BW and DFC values were used:

- Female spotted sandpiper BW = 0.0471 kg and DFC = 0.037 kg ww/day
- Average spotted sandpiper BW = 0.0425 kg and DFC = 0.034 kg ww/day
- Female river otter BW = 7.9 kg and DFC = 1.32 kg ww/day
- Average river otter BW = 8.55 kg and DFC = 1.41 kg ww/day

Body weights for spotted sandpiper and river otter were obtained from studies by Maxson and Oring (1980) and Melquist and Hornnocker (1983), respectively, both as cited in EPA's Wildlife Exposure Factor's Handbook (EPA 1993). The DFC values for both species were calculated as a function of the metabolic rate and the caloric content of the receptor's prey, described in Section A.5.1.3 of the Phase 1 ecological risk assessment (Windward 2003b). The lowest calculated C_F for each receptor was chosen as the RBC, as summarized in Table C-1. RBCs are presented for both NOAELs and LOAELs, where available.

C.2.4 RBC DERIVATION FOR THE PROTECTION OF HUMANS

RBCs for the protection of humans that might ingest clams are expressed as chemical concentrations in clam tissue. Human health guidance documents were reviewed for RBCs for human health. EPA Region 10 has not developed RBCs in food organisms for the protection of human health. EPA Region 9 has developed RBCs for the protection of human health for exposures to soil and water (EPA 1996), but not for consumption of fish tissue. The Model Toxics Control Act (MTCA, a Washington State statute), which contains human health risk-based cleanup levels for several media, considers uptake into tissue (i.e., fish) from surface water but does not directly provide a human health RBC for tissue. EPA Region 3 (EPA 2001) provides an approach for the development of RBCs for fish tissue which, after modification for site-specific exposure factors, was used to derive RBCs for clam tissue in this appendix.

RBCs can be calculated for chemicals with either carcinogenic or non-carcinogenic endpoints; some chemicals have both types of endpoints. The RBC equations are shown below:

$$\text{RBC(carcinogenic)} = \frac{\text{TR} \times \text{BW} \times \text{AT}_c}{\text{EF} \times \text{ED} \times \text{IR} \times \text{CF} \times \text{CSF}}$$

$$\text{RBC(noncarcinogenic)} = \frac{\text{THQ} \times \text{RfD} \times \text{BW} \times \text{AT}_n}{\text{EF} \times \text{ED} \times \text{IR}}$$

where:

TR = target risk (1×10^{-6})
BW = body weight (79 kg, from Phase 1 HHRA)
AT_c = averaging time, carcinogenic (25,550 days, from Phase 1 HHRA)
EF = exposure frequency (365 days/yr, from Phase 1 HHRA)
ED = exposure duration (55 years, from Phase 1 HHRA)
IR = ingestion rate (see text below)
CF = conversion factor (unitless, factor of 0.001 needed to convert kg to g)
CSF = cancer slope factor (kg-day/mg, chemical-specific)
THQ = target hazard quotient (0.1, EPA 1996)
RfD = reference dose (mg/kg-day, chemical-specific)

AT_n = averaging time, non-carcinogenic (20,075 days, from Phase 1 HHRA)

For the purposes of this appendix, EPA requested that a seafood consumption rate of 98 g/day be used to calculate RBCs for the protection of human consumers. This rate is the 95th percentile rate for the consumption of pelagic fish, benthic fish, and shellfish as estimated in the Tulalip Tribes seafood consumption survey (Toy et al. 1996). The consumption rate for any one of these three food groups is lower than 98 g/day. For example, the clam consumption rate from the same consumption survey was 58 g/day, which is the 95th percentile of the bivalve consumption rate for all Tulalip tribe members, including those that do not consume clams (Toy et al. 1996). To provide a range of RBCs,[8] two consumption rates were used for clams, 58 and 98 g/day, to ensure that ACGs calculated in this appendix are conservative and to reflect the uncertainty in this consumption rate. The Phase 2 human health risk assessment (HHRA) will include a revised shellfish (including clams) consumption rate, but this rate has not been established, pending the release of additional EPA Region 10 guidance for evaluating tribal fish and shellfish consumption. Seafood consumption rates for use in the Phase 2 HHRA will be proposed in a technical memorandum submitted to EPA and Ecology based on the results of the clam, crab, and shrimp surveys.

C.3.0 Comparison of ACGs to MDLs

ACGs were determined for each benthic invertebrate tissue type by selecting the lowest RBC for each chemical from Table C-1. These ACGs for clam, market basket benthic invertebrate, and gastropod tissue samples are compared with MDLs in Table C-6. All ACGs for market basket benthic invertebrate and gastropod tissue samples are higher than the MDLs shown in Table C-6, with the exception of selenium, indicating that all analytical methods cited, except EPA Method 7742 for selenium, are sufficiently sensitive to support the ERA.[9] The MDL for selenium of 1.0 mg/kg ww is the lowest that can be obtained using EPA-approved analytical methods.

For clams, 22 MDLs are higher than the ACGs derived for human health RBCs using either the preliminary clam consumption rate of 58 g/day or the total seafood consumption rate of 98 g/day.[10] An additional six chemicals[11] have ACGs lower than the MDL using a consumption rate of 98 g/day; ACGs for these chemicals are higher than the MDL using a consumption rate of 58 g/day. Therefore, application of the

[8] The human health-based RBC for a given chemical may be derived from either a carcinogenic or non-carcinogenic endpoint. For chemicals with both endpoints, the lower RBC is shown in Table C-1.

[9] Market basket benthic invertebrates and gastropods are not consumed by people, so human health-based RBCs did not affect the ACGs selected for these tissue types.

[10] RBCs derived for the protection of human health were always lower than those derived for ecological receptors, except for selenium.

[11] 2,4-dinitrophenol, aniline, Aroclor 1248, mercury, dieldrin, and heptachlor epoxide

cited analytical methods could result in some uncertainty regarding whether these chemicals represent a significant human health risk if they were undetected using these standard methods. The MDLs in Table C-6 are the lowest that can be obtained using the EPA-approved analytical methods. The chemicals with ACGs lower than these MDLs (with either consumption rate) are seven semivolatile organic compounds (SVOCs), five PCB Aroclors, one PCB congener, four organochlorine pesticides, arsenic (total and inorganic), chromium, selenium, and 2,3,7,8-TCDD (Table C-6).[12] The six additional chemicals with ACGs lower than MDLs (using the 98 g/day consumption rate) are 2,4-dinitrophenol, aniline, Aroclor 1248, mercury, dieldrin, and heptachlor epoxide.

The high values of the ACG range for clams in Table C-6 are based on an assumed clam consumption rate of 58 g/day, although no shellfish or clam consumption rate has been proposed for the Phase 2 HHRA. Clam consumption rates where ACGs and MDLs are equivalent are 34 g/day for Aroclor 1254 and 11 g/day for Aroclor 1260. The equivalent clam consumption rate for the arsenic MDL is less than 1 g/day, which is likely to be lower than the shellfish consumption rate that will be used in the Phase 2 HHRA.

Elevated MDLs relative to ACGs are only problematic when chemicals are not detected. The lab will make additional efforts to achieve ACGs for Aroclors in samples if no Aroclors are detected in a sample. The lab will also make additional efforts to achieve the ACG based on a consumption rate of 58 g/day for PCB congener 126 if it is not detected in a sample. Additional efforts may include additional sample clean-up, extracting more sample, using a lower concentration for the lowest standard in the initial calibration, adjusting the final volume, or adjusting the amount of extract injected into the instrument. For the other chemicals with MDLs above the ACGs, the ramifications for the Phase 2 HHRA will be discussed in the uncertainty assessment.

C.4.0 Tissue Mass Required for Analysis

This section presents the amount of tissue mass required to meet the MDLs presented in Table C-6. This information will be used in the QAPP to set the minimum amount of tissue mass to be targeted in the field.[13]

For clams, a standard mass of 81 g[14] per composite tissue sample will be needed to obtain the low MDLs required to meet the ACGs. For gastropod samples, a minimum

[12] The ultra-low extraction procedure with Method 8270C will be used for clam tissue to meet ACGs for PAHs.

[13] Standard and modified tissue mass requirements do not include the amount needed for laboratory quality control samples, thus additional tissue mass will need to be collected as appropriate (see Section 3.4.2 in the QAPP).

[14] The sample mass of 81 g includes 10 g for SVOCs, 10 g for ultra low extraction for PAHs, 25 g for PCB congeners and dioxins/furans, 20 g for Aroclors, 2 g for metals, 2 g for inorganic arsenic, 2 g for mercury, 10 g for TBT.

sample size of 2 g will provide an MDL of 0.0017 mg/kg ww for TBT, which is lower than the RBC for gastropods (0.12 mg/kg ww).

All of the ACGs for the market basket benthic invertebrate tissue samples are substantially higher than the MDLs, as summarized in Table C-7, with the exception of the selenium ACG. Because collecting sufficient tissue mass in the field may be difficult for the market basket benthic invertebrate tissue samples, the relationship between MDL and tissue mass was further evaluated.

The MDL will increase proportionally as the tissue mass decreases.[15] Specifically, if the required tissue mass is decreased by an order of magnitude, the detection limit will increase by an order of magnitude (Salata 2004b). Thus, for these market basket samples, it is possible to reduce the standard required sample mass from the laboratory's standard amount of 69 g to a minimum amount of 20 g and still meet the ACGs (except for selenium), based on minimum tissue mass requirements, as shown in Table C-8. If TBT analysis is not needed for the market basket benthic invertebrate tissue samples,[16] only 18 g of sample will be required.

[15] Conversely, it may be possible to decrease MDLs by increasing tissue mass, although this would require the laboratory to develop alternative cleanup methods to remove matrix interferences. The MDLs presented in Table C-6 are based on optimal tissue amounts using the laboratory's established standard operating procedures and cleanup methods.

[16] The need for TBT analysis in market basket benthic invertebrate tissue samples will be determined based on results of the gastropod pilot survey.

Table C-1. Receptor-specific RBCs for benthic invertebrates

Analyte	Receptor-specific RBC (mg/kg ww)							
	Human Health[a]	River Otter		Spotted Sandpiper		Fish		Market Basket Benthic Invertebrates
		LOAEL-based	NOAEL-based	LOAEL-based	NOAEL-based	LOEC-based	NOEC-based	
PAHs								
Benzo(a)anthracene	0.0014-0.0023	na	na	na	na	na	na	nd
Benzo(a)pyrene	0.00014-0.00023	60	na	na	na	16	6.6	nd
Benzo(b)fluoranthene	0.0014-0.0023	na	na	na	na	na	na	nd
Benzo(k)fluoranthene	0.014-0.023	na	na	na	na	na	na	nd
Chrysene	0.14-0.23	na	na	na	na	na	na	nd
Dibenzo(a,h)anthracene	0.00014-0.00023	na	na	na	na	na	na	nd
Fluoranthene	3.2-5.5	na	na	na	na	na	na	nd
Indeno(1,2,3-cd)pyrene	0.0014-0.0023	na	na	na	na	na	na	nd
Pyrene	2.5-4.2	na	na	na	na	na	na	nd
Acenaphthene	4.7-8.0	na	na	na	na	na	na	nd
Anthracene	25-42	na	na	na	na	na	na	nd
Fluorene	3.2-5.5	na	na	na	na	na	na	nd
Naphthalene	1.7-2.8	na	na	na	na	na	na	nd
2-Methylnaphthalene	1.7-2.8	695	329	na	na	na	na	nd
Dibenzofuran	0.32-0.55	nd	nd	nd	nd	na	na	nd
Total PAHs	na	na	na	50	na	na	na	nd
Other SVOCs								
1,2,4-Trichlorobenzene	0.83-1.4	nd	nd	nd	nd	nd	nd	nd
1,2-Dichlorobenzene	7.1-12	na	na	na	na	nd	nd	nd
1,3-Dichlorobenzene	2.5-4.2	nd	nd	nd	nd	nd	nd	nd
1,4-Dichlorobenzene	0.042-0.071	653	329	nd	nd	nd	nd	nd
2,4,5-Trichlorophenol	8.3-14	nd	nd	nd	nd	nd	nd	nd
2,4,6-Trichlorophenol	0.094-0.16	nd	nd	nd	nd	nd	nd	nd

Analyte	Receptor-specific RBC (mg/kg ww)							
	Human Health[a]	River Otter		Spotted Sandpiper		Fish		Market Basket Benthic Invertebrates
		LOAEL-based	NOAEL-based	LOAEL-based	NOAEL-based	LOEC-based	NOEC-based	
2,4-Dichlorophenol	0.25-0.42	nd	nd	nd	nd	nd	nd	nd
2,4-Dimethylphenol	1.7-2.8	nd	nd	nd	nd	nd	nd	nd
2,4-Dinitrophenol	0.17-0.28	nd	nd	nd	nd	nd	nd	nd
2,4-Dinitrotoluene	0.17-0.28	nd	nd	nd	nd	nd	nd	nd
2,6-Dinitrotoluene	0.083-0.14	nd	nd	nd	nd	nd	nd	nd
2-Chloronaphthalene	6.5-11	nd	nd	nd	nd	nd	nd	nd
2-Chlorophenol	0.41-0.70	nd	nd	nd	nd	nd	nd	nd
2-Methylphenol	4.1-7.0	na	na	na	na	nd	nd	nd
3,3'-Dichlorobenzidine	0.0023-0.0039	nd	nd	nd	nd	nd	nd	nd
4-Chloroaniline	0.32-0.55	nd	nd	nd	nd	nd	nd	nd
4-Methylphenol	0.41-0.70	nd	nd	nd	nd	nd	nd	nd
4-Nitrophenol	0.65-1.1	nd	nd	nd	nd	nd	nd	nd
Aniline	0.18-0.30	nd	nd	nd	nd	nd	nd	nd
Benzidine	4.7E-6 – 8.0E-6	nd	nd	nd	nd	nd	nd	nd
Benzoic acid	320-550	na	na	na	na	nd	nd	nd
Benzyl alcohol	25-42	na	na	na	na	nd	nd	nd
Bis(2-chloroethyl)ether	0.00094-0.0016	nd	nd	nd	nd	nd	nd	nd
Bis(2-ethylhexyl)phthalate	0.071-0.12	545	419	446	1.8	nd	nd	nd
Bis-chloroisopropyl ether	0.015-0.025	na	na	na	na	nd	nd	nd
Butyl benzyl phthalate	17-28	5,057	5,069	na	na	nd	nd	nd
Carbazole	0.051-0.087	nd	nd	nd	nd	nd	nd	nd
Di-ethyl phthalate	65-110	22,270	11,132	nd	nd	nd	nd	nd
Dimethyl phthalate	830-1400	nd	nd	nd	nd	nd	nd	nd
Di-n-butyl phthalate	8.3-14	479	na	na	na	nd	nd	nd
Di-n-octyl phthalate	1.7-2.8	na	44,886	nd	nd	nd	nd	nd
Hexachlorobutadiene	0.013-0.022	120	12	na	5.9	nd	nd	nd

Analyte	Receptor-specific RBC (mg/kg ww)							
	Human Health[a]	River Otter		Spotted Sandpiper		Fish		Market Basket Benthic Invertebrates
		LOAEL-based	NOAEL-based	LOAEL-based	NOAEL-based	LOEC-based	NOEC-based	
Hexachloroethane	0.071-0.12	nd	nd	nd	nd	nd	nd	nd
Isophorone	1.1-1.9	nd	nd	nd	nd	nd	nd	nd
Nitrobenzene	0.043-0.072	nd	nd	nd	nd	nd	nd	nd
N-Nitrosodimethylamine	2.1E-5 – 3.5E-5	nd	nd	nd	nd	nd	nd	nd
N-Nitrosodi-n-propylamine	0.00015-0.00025	nd	nd	nd	nd	nd	nd	nd
N-Nitrosodiphenylamine	0.21-0.35	nd	nd	nd	nd	nd	nd	nd
Pentachlorophenol	0.0083-0.014	78	24	79	28	nd	nd	nd
Phenol	47-80	na	na	na	na	nd	nd	nd
PCBs								
Aroclor 1016	0.015-0.025	na	na	na	na	nd	nd	nd
Aroclor 1221	0.00051-0.00087	na	na	na	na	nd	nd	nd
Aroclor 1232	0.00051-0.00087	na	na	na	na	nd	nd	nd
Aroclor 1242	0.00051-0.00087	na	na	na	na	nd	nd	nd
Aroclor 1248	0.00051-0.00087	na	na	na	0.52	nd	nd	nd
Aroclor 1254	0.00051-0.00087	0.53	na	1.2	na	nd	nd	nd
Aroclor 1260	0.00051-0.00087	na	na	na	na	nd	nd	nd
PCB-77 [b]	6.8E-5 – 1.2E-4	0.6	0.06	0.026	0.0026	nd	nd	nd
PCB-81 [b]	6.8E-5 – 1.2E-4	0.6	0.06	0.013	0.0013	nd	nd	nd
PCB-105 [b]	6.8E-5 – 1.2E-4	0.6	0.06	13	1.3	nd	nd	nd
PCB-114 [b]	1.4E-5– 2.3E-5	0.12	0.012	13	1.3	nd	nd	nd
PCB-118 [b]	6.8E-5 – 1.2E-4	0.6	0.06	130	13	nd	nd	nd
PCB-123 [b]	6.8E-5 – 1.2E-4	0.6	0.06	130	13	nd	nd	nd
PCB-126 [b]	6.8E-8 – 1.2E-7	0.0006	0.00006	0.013	0.0013	nd	nd	nd
PCB-156 [b]	1.4E-5– 2.3E-5	0.12	0.012	13	1.3	nd	nd	nd
PCB-157 [b]	1.4E-5– 2.3E-5	0.12	0.012	13	1.3	nd	nd	nd
PCB-167 [b]	6.8E-5 – 1.2E-4	6	0.6	130	13	nd	nd	nd

Analyte	Receptor-specific RBC (mg/kg ww)							
	Human Health[a]	River Otter		Spotted Sandpiper		Fish		Market Basket Benthic Invertebrates
		LOAEL-based	NOAEL-based	LOAEL-based	NOAEL-based	LOEC-based	NOEC-based	
PCB-169 [b]	6.8E-5 – 1.2E-4	0.006	0.0006	1.3	0.13	nd	nd	nd
PCB-189 [b]	6.8E-5 – 1.2E-4	0.6	0.06	130	13	nd	nd	nd
Dioxins/furans								
2,3,7,8-TCDD	7.1E-9 – 1.2E-8	6.0×10^{-5}	6.0×10^{-6}	0.0013	0.00013	nd	nd	nd
Metals								
Antimony	0.032-0.055	na	9,082	na	na	na	na	nd
Arsenic	0.00071-0.0012	33	16	49	25	10	7.8	nd
Cadmium	0.083-0.14	79	21	59	25	23	17	nd
Chromium	0.25-0.42	na	8,942	131	9.6	na	na	nd
Cobalt	1.7-2.8	na	na	na	na	na	na	nd
Copper	3.2-5.5	156	108	78	59	na	62	nd
Lead	na	539	66	25	2.5	na	6,336	nd
Molybdenum	0.41-0.70	na	na	45	na	na	na	nd
Nickel	1.7-2.8	531	51	134	96	na	na	nd
Selenium	0.41-0.70	0.73	0.57	1.0	0.53	6.6	3.5	nd
Silver	0.41-0.70	na	na	na	na	na	2,700	nd
Thallium	0.0055-0.0094	nd	nd	nd	nd	na	na	nd
Vanadium	0.55-0.94	na	na	na	na	na	na	nd
Zinc	25-42	2,418	1,209	155	103	1,800	380	nd
Mercury	0.0083-0.014	1.5	0.98	0.11	na	nd	nd	nd
Tri-n-butyltin	0.012-0.020	14	1.4	22	8.7	nd	nd	0.17
Pesticides								
4,4'-DDD	0.0042-0.0071	na	na	1.1	na	nd	nd	nd
4,4'-DDE	0.0030-0.0051	na	na	0.36	0.17	nd	nd	nd
4,4'-DDT	0.0030-0.0051	na	na	1.3	1.1	nd	nd	nd
Total DDT	0.0030-0.0051	7.8	7.2	na	na	nd	nd	nd

Analyte	Receptor-specific RBC (mg/kg ww)							
	Human Health[a]	River Otter		Spotted Sandpiper		Fish		Market Basket Benthic Invertebrates
		LOAEL-based	NOAEL-based	LOAEL-based	NOAEL-based	LOEC-based	NOEC-based	
Aldrin	0.000059-0.00010	25	5.1	0.050	na	nd	nd	nd
alpha-BHC	0.00017-0.00028	na	na	na	na	nd	nd	nd
beta-BHC	0.00059-0.0001	189	35	na	na	nd	nd	nd
Chlordane	0.0029-0.0049	6	1.1	69	1.8	nd	nd	nd
Dieldrin	0.000065-0.00011	5.5	na	0.59	0.30	nd	nd	nd
Endosulfan	0.47-0.80	15	5.1	na	27	nd	nd	nd
Endosulfan sulfate	na	nd	nd	nd	nd	nd	nd	nd
Endrin	0.025-0.042	5.5	na	0.36	0.20	nd	nd	nd
gamma-BHC (Lindane)	0.00077-0.0013	na	37	4.6	2.0	nd	nd	nd
Heptachlor	0.00023-0.00039	11	6	nd	nd	nd	nd	nd
Heptachlor epoxide	0.00011-0.00019	nd	nd	nd	nd	nd	nd	nd
Hexachlorobenzene	0.00065-0.0011	0.8	na	3.9	na	nd	nd	nd
Methoxychlor	0.41-0.70	na	na	na	na	nd	nd	nd
Mirex	0.017-0.028	2.4	1.4	43	23	nd	nd	nd
Toxaphene	0.00094-0.0016	nd	nd	nd	nd	nd	nd	nd

na – toxicity data not available or not applicable based on the selection criteria discussed in Section C.2.0

nd – not determined because risk will be evaluated using another approach (i.e., critical tissue residue approach for fish or direct toxicity testing for benthic invertebrates) or because it was not considered a chemical of interest for river otter and spotted sandpiper, as discussed in Section C.2.3

[a] The RBC for a given chemical may be derived from either carcinogenic or non-carcinogenic endpoints. For chemicals with both endpoints, the lower RBC is shown. The RBCs presented were calculated using two consumption rates: 58 g/day and 98 g/day, as described in Section C.2.4.

[b] Dioxin-like congeners will be evaluated as toxic equivalents (TEQs) in the risk assessments, rather than as individual congeners. However, because TEQs are calculated, rather than measured by the laboratory, RBCs for individual congeners are presented to facilitate comparison with MDLs for those congeners. In reality, risks will be assessed based on sums of these congeners (normalized per their relative toxicity to TCDD), and thus comparison to MDLs on a congener-specific basis is somewhat uncertain.

Table C-2. Studies selected to derive RBCs in prey items of fish

Analyte	NOEC (mg/kg ww)	LOEC (mg/kg ww)	Endpoint	Test Species	Exposure Pathway	Reference
Arsenic	7.76[a]	10.4[a]	growth	rainbow trout	food	Hocket et al. 2003
Cadmium	na	17.26[b]	growth	guppy	food	Hatakeyama and Yasuno 1982
Cadmium	22.8[a]	na	growth	rainbow trout	food	Erickson et al. 2003
Copper	61.6[a]	na	growth	rainbow trout	food	Erickson et al. 2003
Lead	6,336[c]	na	growth	rainbow trout	food	Goettl et al. 1976
Selenium	3.5	6.6	mortality	bluegill juveniles	food	Cleveland et al. 1993
Silver	2,700[c]	na	growth	rainbow trout	food	Galvez and Wood 1999
Zinc	na	1,800[c]	growth	rainbow trout	food	Takeda and Shimma 1977
Zinc	380[a]	na	growth	rainbow trout	food	Mount et al. 1994
Benzo(a)pyrene	6.58[d]	16.24[d]	growth	English sole	food	Rice et al. 2000

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section C.2.2

Note: Conversions to wet weight were based on type of food or prey species used in each study.

[a] Converted to wet weight assuming 20% solids in prey (a typical solids content in aquatic organisms)

[b] Converted to wet weight using measured 13.7% solids in midge prey from a separate study (Hatakeyama and Yasuno 1987)

[c] Converted to wet weight assuming 90% solids in prepared food (Palm et al. 2003)

[d] Converted to wet weight assuming 14% solids in *Armandia brevis* (Windward unpublished data)

Table C-3. Chemicals of interest in tissue based on draft tissue analyte approach memorandum (Windward 2003a)

Metals	PAHs
Antimony	Acenaphthene
Arsenic	Acenaphthylene
Cadmium	Anthracene
Chromium	Benzo(a)anthracene
Cobalt	Benzo(a)pyrene
Copper	Benzo(b)fluoranthene
Lead	Benzo(g,h,i)perylene
Mercury	Benzo(k)fluoranthene
Molybdenum	Chrysene
Nickel	Dibenzo(a,h)anthracene
Selenium	Fluoranthene
Silver	Fluorene
Vanadium	Indeno(1,2,3-cd)pyrene
Zinc	Phenanthrene
Butyltins	Pyrene
Dibutyltin as ion	**PCBs**
Tributyltin as ion	Total PCBs
Pesticides	**SVOCs**
4,4'-DDD	1,2-Dichlorobenzene
4,4'-DDE	1,4-Dichlorobenzene
4,4'-DDT	2-Methylphenol
alpha-BHC	Benzoic acid
alpha-Chlordane	Benzyl alcohol
Chlordane	Bis(2-ethylhexyl)phthalate
Dieldrin	Di-n-butyl phthalate
gamma-BHC	Hexachlorobenzene
gamma-chlordane	Pentachlorophenol
Methoxychlor	Phenol

Table C-4. Studies selected to derive RBCs in prey items of birds

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Exposure Pathway	Reference
2,3,7,8-TCDD	0.0001	0.001	mortality	white leghorn, cockerels	gavage	Schwetz et al. 1973
Aroclor 1254	na	0.94	reproduction	ringed turtledove	food	Peakall et al. 1972
Aroclor 1248	0.41	na	reproduction	screech owl	food	McLane and Hughes 1980
Arsenic	20	39	mortality	mallard	food	USFWS 1964
Cadmium	na	47	growth	mallard	food	DeGiulio and Scanlon 1984
Cadmium	20	na	growth	mallard	food	White and Finley 1978
Chromium	na	105	growth	chicks	food	Chung et al. 1988
Chromium	7.7	na	growth	chicks	food	Romoser et al. 1961
Copper	47	62	growth/ mortality	chicks	food	Mehring et al. 1960
Lead	2	20	reproduction	Japanese quail	food	Edens et al. 1976
Mercury	na	0.091	growth	great egret (1 day old)	food	Spalding et al. 2000
Molybdenum	na	35.3	reproduction	chicken	food	Lepore and Miller 1965
Nickel	77	107	growth/ mortality	mallard	food	Cain and Pafford 1981
Selenium	0.42	0.82	reproduction	mallard	food	Heinz et al. 1989
Zinc	82	123	growth	white rock chicks	food	Roberson and Schaible 1960
Tributyltin	6.8	16.9	reproduction	Japanese quail	food	Schlatterer et al. 1993
PAHs[b]	na	40	growth	mallard	food	Patton and Dieter 1980
Aldrin	na	0.040	mortality	quail	food	DeWitt et al. 1956
Chlordane	na	55	mortality	bobwhite- juvenile	food	Hill et al. 1975
Chlordane	1.4	na	growth/ mortality	bobwhite quail	food	Ludke 1976
DDD	na	0.90	reproduction	mallard	food	Heath et al. 1969
DDE	na	0.28	reproduction	barn owl	food	Mendenhall et al. 1983
DDE	0.13	na	reproduction	American kestrel	food	Lincer 1975
DDT	na	1.0	reproduction	Mallard	food	Kolaja 1977
DDT	0.90	na	reproduction	Mallard	food	Heath et al. 1969

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Exposure Pathway	Reference
Dieldrin	0.24	0.47	mortality	bobwhite quail	food	Fergin and Shafer 1977
Endosulfan	21	na	reproduction	gray partridge	food	Abiola 1992
Endrin	na	0.28	reproduction	screech owl	food	Fleming et al. 1982
Endrin	0.16	na	reproduction	Pheasant	food	DeWitt 1956
Hexachlorobenzene	na	3.1	reproduction	Japanese quail	food	Schwetz et al. 1974
Hexachlorobutadiene	4.7	na	growth/ reproduction	Japanese quail	food	Schwetz et al. 1974
gamma-BHC (Lindane)	1.6	3.6	reproduction	Mallard	gavage	Chakravarty and Lahiri 1986; Chakravarty et al. 1986
Mirex	18	34	reproduction	Chicken	food	Naber and Ware 1965
Pentachlorophenol	22	63	growth	broiler chicks	food	Prescott et al. 1982
Bis(2-ethylhexyl) phthalate	na	350	reproduction	Chicken	food	Ishida et al. 1982
Bis(2-ethylhexyl) phthalate	1.5	na	reproduction	ringed turtledove	food	Peakall 1974

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section C.2.3

[a] Low effects or no effects were observed for all endpoints listed for both the NOAEL and/or LOAEL presented

[b] Food contained a mixture of paraffins and aromatic hydrocarbons, including acenaphthylene, acenaphthene, and phenanthrene

Table C-5. Studies selected to derive RBCs in prey items of mammalian wildlife

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Exposure Pathway	Reference
2,3,7,8-TCDD	0.0000010	0.000010	reproduction	rat	food	Murray et al. 1979
Aroclor 1254	na	0.089	reproduction	mink	food	Brunstrom et al. 2001
Antimony	1,489	na	growth	rat	food	Hext et al. 1999
Arsenic	2.6	5.4	growth	rat	food	Byron et al. 1967
Cadmium	3.5	13	growth	rat	food	Machemer and Lorke 1981
Chromium	1,466	na	mortality	rat	food	Ivankovic and Preussmann 1975
Copper	18	26	reproduction	mink	food	Aulerich et al. 1982
Lead	11	90	reproduction	rat	food	Azar et al. 1973
Mercury	0.16	0.25	growth/ mortality	mink	food	Wobeser et al. 1976
Nickel	8.4	87	growth	rat	food	Ambrose et al. 1976
Selenium	0.094	0.12	growth	rat	food	Halverson et al. 1966
Zinc	202	404	reproduction	rat	food	Schlicker and Cox 1968
Tributyltin	0.23	2.3	growth	rat	food	Wester et al. 1990
Benzo(a)pyrene	na	10	reproduction	mouse	gavage	MacKenzie and Angevine 1981
2-Methylnaphthalene	54	114	growth	mouse	food	Murata et al. 1997
Aldrin	0.83	4.1	mortality	rat	food	Fitzhugh et al. 1964
Chlordane	0.18	0.92	growth	mouse	food	Khasawinah and Grutsch 1989
Total DDT	na	1.3	reproduction	mouse	food	Ware and Good 1967
Total DDT	1.2	na	reproduction	rat	food	Duby et al. 1971
Dieldrin	na	0.92	reproduction	mouse	food	Good and Ware 1969
Endosulfan	0.84	2.5	mortality/ growth	mouse	food	Hack et al. 1995
Endrin	na	0.92	reproduction	mouse	food	Good and Ware 1969
Heptachlor	1.0	1.8	mortality/ growth/ reproduction	mink	food	Crum et al. 1993
Hexachlorobenzene	na	0.13	reproduction	mink/ ferret	food	Bleavins et al. 1984

Analyte	NOAEL (mg/kg bw/day)	LOAEL (mg/kg bw/day)	Endpoint[a]	Test Species	Exposure Pathway	Reference
Hexachlorobutadiene	2.0	20	mortality/ growth/ reproduction	rat	food	Kociba et al. 1977
gamma-BHC (Lindane)	6.1	na	reproduction	rat	food	Palmer et al. 1978
beta-BHC	5.7	31	mortality/ growth	rat	food	Van Velsen et al. 1986
Methoxychlor	na	56	growth/ reproduction	rat	food	You et al. 2002
Mirex	na	0.40	reproduction	rat	food	Chu et al. 1981
Mirex	0.23	na	reproduction	mouse	food	Wolfe et al. 1979
Pentachlorophenol	4.0	13	reproduction	rat	food	Welsh et al. 1987
Butyl benzyl phthalate	na	845	growth/ reproduction	rat	food	Ema et al. 1994
Butyl benzyl phthalate	831	na	growth	rat	food	Agarwal et al. 1985
Bis (2-ethylhexyl) phthalate	na	91	reproduction	mouse	food	Tyl et al. 1988
Bis (2-ethylhexyl) phthalate	70	na	reproduction	mouse	food	Shiota et al. 1980
Diethyl phthalate	1,860	3,721	growth/reproduction	mouse	food	Lamb et al. 1987
Di-n-butyl phthalate	na	80	reproduction	rat	food	Wine et al. 1997
Di-n-octyl phthalate	7,500	na	reproduction	mouse	food	Heindel et al. 1989
1,4-dichlorobenzene	54	107	growth	rat	gavage	Lake et al. 1997

na – NOAEL or LOAEL not available or not applicable based on the selection criteria discussed in Section C.2.3

[a] Low effects or no effects were observed for all endpoints listed for both the NOAEL and/or LOAEL presented

Table C-6. Comparison of MDLs and ACGs

Method and Analyte	MDL[a] (mg/kg ww)		ACGs (mg/kg ww)		Sample type and receptor with ACG lower than MDL
			Clam[b]	Market Basket[c]	
EPA Method 8270C					
PAHs	***Ultra-low extraction***	***Standard low extraction***			
Benzo(a)anthracene	0.000054	0.0055	0.0014-0.0023	na	
Benzo(a)pyrene	0.000076	0.0034	0.00014-0.00023	6.6	
Benzo(b)fluoranthene	0.000045	0.0035	0.0014-0.0023	na	
Benzo(k)fluoranthene	0.000081	0.0034	0.014-0.023	na	
Chrysene	0.000080	0.0028	0.14-0.23	na	
Dibenzo(a,h)anthracene	0.000079	0.006	0.00014-0.00023	na	
Fluoranthene	0.000053	0.0067	3.2-5.5	na	
Indeno(1,2,3-cd)pyrene	0.000073	0.0031	0.0014-0.0023	na	
Pyrene	0.000070	0.0082	2.5-4.2	na	
Acenaphthene	0.000074	0.0045	4.7-8.0	na	
Anthracene	0.000055	0.0047	25-42	na	
Fluorene	0.000054	0.006	3.2-5.5	na	
Naphthalene	0.00026	0.004	1.7-2.8	na	
2-Methylnaphthalene	0.00015	0.004	1.7-2.8	na	
Dibenzofuran	0.000052	0.0053	0.32-0.55	nd[d]	
Total PAHs	0.0013[e]	0.071[e]	na	50	
Other SVOCs					
1,2,4-Trichlorobenzene	0.0048		0.83-1.4	nd	
1,2-Dichlorobenzene	0.005		7.1-12	na[f]	
1,3-Dichlorobenzene	0.005		2.5-4.2	nd	
1,4-Dichlorobenzene	0.0054		0.042-0.071	nd	
2,4,5-Trichlorophenol	0.031		8.3-14	nd	

Method and Analyte	MDL[a] (mg/kg ww)	ACGs (mg/kg ww)		Sample type and receptor with ACG lower than MDL
		Clam[b]	Market Basket[c]	
2,4,6-Trichlorophenol	0.022	0.094-0.16	nd	
2,4-Dichlorophenol	0.020	0.25-0.42	nd	
2,4-Dimethylphenol	0.042	1.7-2.8	nd	
2,4-Dinitrophenol	0.19	0.17-0.28	nd	clam (using total seafood rate only), human health
2,4-Dinitrotoluene	0.018	0.17-0.28	nd	
2,6-Dinitrotoluene	0.0062	0.083-0.14	nd	
2-Chloronaphthalene	0.0059	6.5-11	nd	
2-Chlorophenol	0.033	0.41-0.70	nd	
2-Methylphenol	0.025	4.1-7.0	na[f]	
3,3'-Dichlorobenzidine	1.3	0.0023-0.0039	nd	clam, human health
4-Chloroaniline	0.093	0.32-0.55	nd	
4-Methylphenol	0.028	0.41-0.70	nd	
4-Nitrophenol	0.15	0.65-1.1	nd	
Aniline	0.23	0.18-0.30	nd	clam (using total seafood rate only), human health
Benzidine	5	4.7E-6 – 8.0E-6	nd	clam, human health
Benzoic acid	0.065	320-550	na[f]	
Benzyl alcohol	0.014	25-42	na[f]	
bis(2-chloroethyl)ether	0.0028	0.00094-0.0016	nd	clam, human health
bis(2-ethylhexyl)phthalate	0.14	0.071-0.12	1.8	clam, human health
bis-chloroisopropyl ether	0.011	0.015-0.025	nd	
Butyl benzyl phthalate	0.019	17-28	nd	
Carbazole	0.0051	0.051-0.087	nd	
Di-ethyl phthalate	0.034	65-110	nd	
Dimethyl phthalate	0.0053	830-1400	nd	
Di-n-butyl phthalate	0.0060	8.3-14	na[f]	
Di-n-octyl phthalate	0.0070	1.7-2.8	nd	
Hexachlorobutadiene	0.0052	0.013-0.022	5.9	

Method and Analyte	MDL[a] (mg/kg ww)	ACGs (mg/kg ww)		Sample type and receptor with ACG lower than MDL
		Clam[b]	Market Basket[c]	
Hexachloroethane	0.0050	0.071-0.12	nd	
Isophorone	0.0013	1.1-1.9	nd	
Nitrobenzene	0.0075	0.043-0.072	nd	
N-Nitrosodimethylamine	0.010	2.1E-5 – 3.5E-5	nd	clam, human health
N-Nitrosodi-n-propylamine	0.013	0.00015-0.00025	nd	clam, human health
N-Nitrosodiphenylamine	0.0095	0.21-0.35	nd	
Pentachlorophenol	0.091	0.0083-0.014	28	clam, human health
Phenol	0.054	47-80	na[f]	
EPA Method 8082				
Aroclor 1016	0.0020	0.015-0.025	na[f]	
Aroclor 1221	0.0031	0.00051-0.00087	na[f]	clam, human health
Aroclor 1232	0.0020	0.00051-0.00087	na[f]	clam, human health
Aroclor 1242	0.0035	0.00051-0.00087	na[f]	clam, human health
Aroclor 1248	0.00076	0.00051-0.00087	0.52	clam (using total seafood rate only), human health
Aroclor 1254	0.0015	0.00051-0.00087	1.2	clam, human health
Aroclor 1260	0.0047	0.00051-0.00087	na[f]	clam, human health
EPA Method 1613B and 1668A[g]				
2,3,7,8-TCDD	4.0E-8	7.1E-9 – 1.2E-8	0.00013	clam, human health
PCB-77	3.8E-7	6.8E-5 – 1.2E-4	na	
PCB-81	3.4E-7	6.8E-5 – 1.2E-4	na	
PCB-105	3.6E-7	6.8E-5 – 1.2E-4	na	
PCB-114	3.3E-7	1.4E-5– 2.3E-5	na	
PCB-118	4.0E-7	6.8E-5 – 1.2E-4	na	
PCB-123	6.8E-7	6.8E-5 – 1.2E-4	na	
PCB-126	4.5E-7	6.8E-8 – 1.2E-7	na	clam, human health
PCB-156	4.2E-7	1.4E-5– 2.3E-5	na	
PCB-157	4.2E-7	1.4E-5– 2.3E-5	na	

Method and Analyte	MDL[a] (mg/kg ww)	ACGs (mg/kg ww)		Sample type and receptor with ACG lower than MDL
		Clam[b]	Market Basket[c]	
PCB-167	2.9E-7	6.8E-5 – 1.2E-4	na	
PCB-169	3.7E-7	6.8E-5 – 1.2E-4	na	
PCB-189	3.3E-7	6.8E-5 – 1.2E-4	na	
EPA Method 6020 (except as noted) [h]				
Antimony	0.020	0.032-0.055	na	
Arsenic	0.050	0.00071-0.0012	7.8	clam, human health
Cadmium	0.010	0.083-0.14	17	
Chromium (EPA Method 6010)	0.50	0.25-0.42	9.6	clam, human health
Cobalt	0.0050	1.7-2.8	na	
Copper	0.060	3.2-5.5	59	
Lead	0.0040	na	2.5	
Molybdenum	0.0090	0.41-0.70	45	
Nickel	0.030	1.7-2.8	96	
Selenium (EPA Method 7742)	1.0	0.41 – 0.70	0.53	clam for human health; market basket for sandpiper
Silver	0.0040	0.41-0.70	2700	
Thallium	0.0020	0.0055-0.0094	nd[d]	
Vanadium	0.050	0.55-0.94	na	
Zinc	0.20	25-42	103	
EPA Method 1632				
Inorganic arsenic[i]	0.004	0.00071-0.0012	7.8	clam, human health
EPA Method 7471				
Mercury	0.010	0.0083-0.014	0.11	clam (using total seafood rate only), human health
TBT Method - Krone 1989				
Tri-n-butyltin	0.00033	0.12-0.020	0.17[j]	
EPA Method 8081				
4,4'-DDD	0.00013	0.0042-0.0071	1.1	

Method and Analyte	MDL[a] (mg/kg ww)	ACGs (mg/kg ww)		Sample type and receptor with ACG lower than MDL
		Clam[b]	Market Basket[c]	
4,4'-DDE	0.00012	0.0030-0.0051	0.17	
4,4'-DDT	0.00038	0.0030-0.0051	1.1	
Total DDT	na	0.0030-0.0051	na[f]	
Aldrin	0.0002	0.000059-0.00010	0.050	clam, human health
alpha-BHC	0.00016	0.00017-0.00028	na[f]	
beta-BHC	0.00021	0.00059-0.0001	na[f]	
Chlordane	0.00036	0.0029-0.0049	1.8	
Dieldrin	0.00011	0.000065-0.00011	0.30	clam (using total seafood rate only), human health
Endosulfan	0.00035	0.47-0.80	27	
Endosulfan sulfate	0.00027	na	nd	
Endrin	0.000099	0.025-0.042	0.20	
gamma-BHC (Lindane)	0.00028	0.00077-0.0013	2.0	
Heptachlor	0.00045	0.00023-0.00039	nd	clam, human health
Heptachlor epoxide	0.00015	0.00011-0.00019	nd	clam (using total seafood rate only), human health
Hexachlorobenzene	0.0055	0.00065-0.0011	3.9	clam, human health
Methoxychlor	0.00027	0.41-0.70	na[f]	
Mirex	0.00027	0.017-0.028	23	
Toxaphene	0.0058	0.00094-0.0016	nd	clam, human health

na – not available

nd – not determined

[a] MDLs from Columbia Analytical Services (Salata 2004a)

[b] ACG for clams is the lowest RBC for receptors ingesting clams (humans and river otter)

[c] ACG for market basket benthic invertebrate tissue is the lowest RBC for receptors ingesting benthic invertebrates (spotted sandpiper and fish)

[d] Not determined for spotted sandpiper RBC and not available for fish RBC

[e] This calculated MDL is the sum of the MDLs for individual PAHs

[f] Not available for spotted sandpiper RBC and not determined for fish RBC

[g] Method 1613B for dioxins and furans and Method 1668A for PCB congeners

[h] Chromium and selenium cannot be analyzed by Method 6020 (ICP-MS) due to interferences

[i] Clam tissue will be analyzed for both total and inorganic arsenic

[j] Based on RBC for market basket benthic invertebrates (critical residue)

Table C-7. Minimum market basket benthic invertebrate tissue mass required to meet ACGs

Method and Analyte	ACG	Standard		Modified	
		MDL (mg/kg ww)	Tissue Mass (g)	Modified MDL (mg/kg ww)	Minimum Tissue Mass (g)
EPA Method 8270C					
Benzo(a)pyrene	6.6	0.0034	10	0.017	2
Total PAHs	50	na		na	
Bis(2-ethylhexyl)phthalate	1.8	0.14		0.7	
Hexachlorobutadiene	5.9	0.0052		0.026	
Pentachlorophenol	28	0.091		0.46	
EPA Method 8082					
PCB Aroclors	0.52	0.018	20[a]	0.18	2[a]
EPA Method 1668A and 1613B					
2,3,7,8-TCDD	0.00013	0.00000004	25[b]	0.0000001	10[b]
Individual PCB congeners	na	0.000001		0.000001	
EPA Method 6020 (except as noted)					
Arsenic	7.8	0.05	2	nm	2
Cadmium	17	0.01		nm	
Chromium (EPA Method 6010)	9.6	0.5		nm	
Copper	59	0.06		nm	
Lead	2.5	0.004		nm	
Molybdenum	45	0.009		nm	
Nickel	96	0.03		nm	
Selenium (EPA Method 7740)	0.53	1.0		nm	
Silver	2700	0.004		nm	
Zinc	103	0.2		nm	
TBT Method - Krone 1989					
Tri-n-butyltin	0.17	0.00033	10	0.0017	2

Method and Analyte	ACG	Standard		Modified	
		MDL (mg/kg ww)	Tissue Mass (g)	Modified MDL (mg/kg ww)	Minimum Tissue Mass (g)
EPA Method 7471					
Mercury	0.11	0.01	2	nm	2
EPA Method 8081					
4,4'-DDD	1.1	0.00013		0.0013	
4,4'-DDE	0.17	0.00012		0.0012	
4,4'-DDT	1.1	0.00038		0.0038	
Aldrin	0.05	0.0002		0.002	
Chlordane	1.8	0.00036		0.0036	
Dieldrin	0.30	0.000076	0[c]	0.00076	0[c]
Endosulfan	27	0.00035		0.0035	
Endrin	0.20	0.000099		0.00099	
gamma-BHC (Lindane)	2.0	0.00028		0.0028	
Hexachlorobenzene	3.9	0.0055		0.055	
Mirex	23	0.00027		0.0027	

Note: Standard and modified tissue mass requirements do not include the amount needed for laboratory quality control samples, thus additional tissue mass will need to be collected as appropriate (see Section 3.4.2).

na –not applicable because MDLs are not reported for total PAHs or total DDT, and risk from PCB congeners is based on dioxin toxicity equivalent concentrations.

nm – no modified MDLs because the standard tissue mass is the minimum mass that can be analyzed

[a] A portion of the sample extract will be used for lipid analysis. Therefore, no additional tissue mass is required for lipid determination.

[b] Tissue mass will be archived for samples not initially analyzed for PCB congeners. Also, a portion of the extract from samples analyzed for PCB congeners will be heat-sealed and frozen for potential dioxin/furan analysis.

[c] Same extract will be used for Aroclor and organochlorine pesticide analyses. Therefore, no additional tissue is needed for the organochlorine pesticide analysis.

Table C-8. Comparison of standard and minimum tissue mass requirements for market basket benthic invertebrate samples

ANALYTE	STANDARD MASS (G)	MINIMUM MASS (G)
PCB congeners and dioxins/furans	25	10
PCB Aroclors and organochlorine pesticides	20	2
SVOCs	10	2
Mercury	2	2
Other metals	2	2
TBT	10	2
Total Mass	69	20

C.5.0 References

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APPENDIX D: RISK-BASED ANALYTICAL CONCENTRATION GOALS FOR SEDIMENT SAMPLES COLLECTED AT CLAM SAMPLING LOCATIONS

D.1.0 Introduction

Sediment samples will be collected at each clam sampling location, as described in Section 3.2.6. The sediment chemistry data will be compared to the clam chemistry data collected from the same locations to determine whether a predictive relationship exists for chemicals of concern. One commonly used method for evaluating such a relationship for nonpolar organic chemicals that may bioaccumulate in benthic invertebrates is the biota sediment accumulation factor (BSAF).

BSAFs can be derived using the following equation:

$$BSAF = \frac{C_{WB} \div F_L}{C_{sed} \div F_{oc}} \qquad \textbf{Equation 1}$$

where:

C_{WB} = chemical concentration in whole-body clam tissue (mg/kg ww)
C_{sed} = chemical concentration in sediment (mg/kg dw)
F_L = fraction lipid in clam tissue (kg lipid/kg ww)
F_{oc} = fraction organic carbon in sediment (kg OC/kg dw)

Ideally, BSAFs are based on detected concentrations in both sediment and tissue. Accordingly, this appendix describes analytical concentration goals (ACGs) for sediment based on the analytical concentration goals for clams presented in Appendix C.

D.2.0 ACG Derivation for Sediment

The ACGs for sediment are derived using the BSAF relationship described in Section D.1.0 and the clam ACGs derived in Appendix C.

Equation 1 can be rearranged to solve for C_{sed}, as follows:

$$C_{sed} = \frac{(C_{WB} \div F_L) \times F_{oc}}{BSAF} \qquad \textbf{Equation 2}$$

For this appendix, C_{WB} is set equal to the ACG for clam tissue (Appendix Table C-6). At the request of EPA, ACGs were calculated using two assumed consumption rates, a lower rate of 58 g/day based on clam consumption and a higher rate of 98 g/day based on total seafood consumption. The lipid fraction (F_L) of 0.0095 is based on the analysis of 11 composite tissue samples of Puget Sound clams (Tetra Tech 1994). The organic carbon fraction (F_{oc}) of 0.0165 is the mean organic carbon fraction from

approximately 400 intertidal sediment samples summarized in the Phase 1 RI. BSAFs were from four sources:

- US Army Corps of Engineers Environmental Residue-Effects Database (ERED) - http://www.wes.army.mil/el/ered/
- Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.
- EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: National Sediment Quality Survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.
- Washington State Department of Health. 1995. Tier I report, development of sediment quality criteria for the protection of human health. Washington State Department of Health, Olympia, Washington.

The BSAFs cited in these four sources will not necessarily be used for any other purpose in the Phase 2 RI other than developing ACGs for sediment collected at clam sampling locations in this appendix. BSAFs for bivalve mollusks are most relevant for this appendix. There are several studies summarized in ERED that include BSAFs for bivalve mollusks. To provide a range of ACGs, two BSAFs were calculated, when possible: the median and the 90th percentile. Tracey and Hansen (1996) reported median BSAFs for some pesticides for *Macoma nasuta*, which is a clam species found in the LDW. These median BSAFs were used in this appendix when bivalve BSAFs were not available in ERED. BSAFs from the other two sources listed above are for fish and may not be appropriate for LDW clams because fish may represent a different trophic level than clams and their metabolic processes may differ. Consequently, fish and clams may have different exposures to contaminated sediment and the resulting accumulation rates (i.e., the BSAF) may differ as well. However, fish BSAFs were used in this appendix for 2-methylnaphthalene, dibenzofuran, other SVOCs, and 2,3,7,8-TCDD because bivalve, including *Macoma,* BSAFs for these chemicals were not available in ERED and there is a desire by EPA and Ecology to estimate ACGs for sediment chemicals where possible. The calculated ACG ranges (C_{sed}) for sediment samples collected at clam sampling locations are shown in Table D-1.

Table D-1. Analytical concentration goals for sediment collected at clam sampling locations

CHEMICAL	C_{WB} (mg/kg ww)	F_L	F_{OC}	BSAF	BSAF REFERENCE	C_{SED} (mg/kg dw)	MDL (mg/kg dw)	CHEMICAL WITH ACG<MDL
PAHs								
Benzo(a)anthracene	0.0014-0.0023	0.0095	0.0165	0.15 – 0.47	3	0.0052-0.027	0.00013	
Benzo(a)pyrene	0.00014-0.00023	0.0095	0.0165	0.074 – 0.32	3	0.00076-0.0054	0.00014	
Benzo(b)fluoranthene	0.0014-0.0023	0.0095	0.0165	0.16 – 0.52	3	0.0047-0.025	0.00014	
Benzo(k)fluoranthene	0.014-0.023	0.0095	0.0165	0.16 – 0.52	3	0.047-0.25	0.00015	
Chrysene	0.14-0.23	0.0095	0.0165	0.14 – 0.51	3	0.48-2.9	0.00015	
Dibenzo(a,h)anthracene	0.00014-0.00023	0.0095	0.0165	na	na	na	0.00018	
Fluoranthene	3.2-5.5	0.0095	0.0165	0.094 – 2.6	3	2.1-100	0.00017	
Indeno(1,2,3-cd)pyrene	0.0014-0.0023	0.0095	0.0165	0.025 – 0.83	3	0.0029-0.16	0.00015	
Pyrene	2.5-4.2	0.0095	0.0165	0.11 – 0.49	3	8.9-66	0.00011	
Acenaphthene	4.7-8.0	0.0095	0.0165	0.0085 – 0.015	3	540-1600	0.00021	
Anthracene	25-42	0.0095	0.0165	0.030 – 0.048	3	900-2400	0.00019	
Fluorene	3.2-5.5	0.0095	0.0165	na	na	na	0.00017	
Naphthalene	1.7-2.8	0.0095	0.0165	0.085 – 0.65	3	4.5-57	0.00021	
2-Methylnaphthalene	1.7-2.8	0.0095	0.0165	1.71	1	1.7-2.8	0.00021	
Dibenzofuran	0.32-0.55	0.0095	0.0165	1	1	0.56-0.96	0.0002	
Other SVOCs								
1,2,4-Trichlorobenzene	0.83-1.4	0.0095	0.0165	na	na	na	0.0110	
1,2-Dichlorobenzene	7.1-12	0.0095	0.0165	1	1	12-21	0.0179	
1,3-Dichlorobenzene	2.5-4.2	0.0095	0.0165	na	na	na	0.0183	
1,4-Dichlorobenzene	0.042-0.071	0.0095	0.0165	1	1	0.073-0.12	0.0175	
2,4,5-Trichlorophenol	8.3-14	0.0095	0.0165	0.39	2	37-62	0.0171	
2,4,6-Trichlorophenol	0.094-0.16	0.0095	0.0165	na	na	na	0.0143	
2,4-Dichlorophenol	0.25-0.42	0.0095	0.0165	0.39	2	1.1-1.9	0.0164	
2,4-Dimethylphenol	1.7-2.8	0.0095	0.0165	na	na	na	0.0151	
2,4-Dinitrophenol	0.17-0.28	0.0095	0.0165	na	na	na	0.112	
2,4-Dinitrotoluene	0.17-0.28	0.0095	0.0165	na	na	na	0.0149	
2,6-Dinitrotoluene	0.083-0.14	0.0095	0.0165	na	na	na	0.0156	
2-Chloronaphthalene	6.5-11	0.0095	0.0165	na	na	na	0.0100	
2-Chlorophenol	0.41-0.70	0.0095	0.0165	0.39	2	1.8-3.1	0.0099	

Chemical	C_{WB} (mg/kg ww)	F_L	F_{OC}	BSAF	BSAF Reference	C_{SED} (mg/kg dw)	MDL (mg/kg dw)	Chemical with ACG<MDL
2-Methylphenol	4.1-7.0	0.0095	0.0165	na	na	na	0.0167	
3,3'-Dichlorobenzidine	0.0023-0.0039	0.0095	0.0165	na	na	na	0.027	
4-Chloroaniline	0.32-0.55	0.0095	0.0165	na	na	na	0.0144	
4-Methylphenol	0.41-0.70	0.0095	0.0165	0.39	2	1.8-3.1	0.0168	
4-Nitrophenol	0.65-1.1	0.0095	0.0165	na	na	na	0.146	
Aniline	0.18-0.30	0.0095	0.0165	na	na	na	1.0	
Benzidine	0.59-8E-6	0.0095	0.0165	na	na	na	na	
Benzoic acid	320-550	0.0095	0.0165	na	na	na	0.139	
Benzyl alcohol	25-42	0.0095	0.0165	na	na	na	0.0168	
Bis(2-chloroethyl)ether	0.00094-0.0016	0.0095	0.0165	na	na	na	0.0117	
Bis(2-ethylhexyl)phthalate	0.071-0.12	0.0095	0.0165	1	1	0.12-0.21	0.0186	
Bis-chloroisopropyl ether	0.015-0.025	0.0095	0.0165	na	na	na	0.0141	
Butyl benzyl phthalate	17-28	0.0095	0.0165	1	1	30-49	0.0163	
Carbazole	0.051-0.087	0.0095	0.0165	0.39	2	0.23-0.39	na	
Di-ethyl phthalate	65-110	0.0095	0.0165	na	na	na	0.0141	
Di-methyl phthalate	830-1400	0.0095	0.0165	1	1	1400-2400	0.0164	
Di-n-butyl phthalate	8.3-14	0.0095	0.0165	1	1	14-24	0.0121	
Di-n-octyl phthalate	1.7-2.8	0.0095	0.0165	1	1	3.0-4.9	0.024	
Hexachlorobutadiene	0.013-0.022	0.0095	0.0165	1	1	0.023-0.038	0.0141	
Hexachloroethane	0.071-0.12	0.0095	0.0165	1	1	0.12-0.21	0.0216	
Isophorone	1.1-1.9	0.0095	0.0165	na	na	na	0.014	
Nitrobenzene	0.043-0.072	0.0095	0.0165	na	na	na	0.0261	
N-Nitrosodimethylamine	2.1E-5-3.5E-5	0.0095	0.0165	na	na	na	0.0251	
N-Nitrosodi-n-propylamine	0.00015-0.00025	0.0095	0.0165	na	na	na	0.0191	
N-Nitrosodiphenylamine	0.21-0.35	0.0095	0.0165	na	na	na	0.018	
Pentachlorophenol	0.0083-0.014	0.0095	0.0165	0.68	2	na	0.125	
Phenol	47-80	0.0095	0.0165	0.39	2	210-360	0.0195	
PCBs								
Aroclor 1016	0.015-0.025	0.0095	0.0165	1.15 – 4.26	3	0.0061-0.038	0.0018	
Aroclor 1221	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X
Aroclor 1232	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X
Aroclor 1242	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X
Aroclor 1248	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X

CHEMICAL	C_{WB} (mg/kg ww)	F_L	F_{OC}	BSAF	BSAF REFERENCE	C_{SED} (mg/kg dw)	MDL (mg/kg dw)	CHEMICAL WITH ACG<MDL
Aroclor 1254	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X
Aroclor 1260	0.00051-0.00087	0.0095	0.0165	1.15 – 4.26	3	0.00021-0.0013	0.0018	X
Dioxins/furans								
2,3,7,8-TCDD	7.1 E -9- 1.2 E-8	0.0095	0.0165	0.059	1	3.53E-7-2.09E-6	5.9E-8	
Metals								
Antimony	0.032-0.055	0.0095	0.0165	na	na	na	0.02	
Arsenic	0.00071-0.0012	0.0095	0.0165	0.073-0.2	2	0.006-0.029	0.2	X
Cadmium	0.083-0.14	0.0095	0.0165	6.0-77	2	0.003-0.41	0.03	X
Chromium	0.25-0.42	0.0095	0.0165	0.0031 – 0.0043	3	100-240	0.07	
Cobalt	1.7-2.8	0.0095	0.0165	na	na	na	0.008	
Copper	3.2-5.5	0.0095	0.0165	0.015 – 0.45	3	1.3-8.3	0.08	
Lead	na	0.0095	0.0165	0.19 – 1.3	3	na	0.02	
Molybdenum	0.41-0.70	0.0095	0.0165	na	na	na	0.04	
Nickel	1.7-2.8	0.0095	0.0165	na	na	na	0.07	
Selenium	0.41 – 0.70	0.0095	0.0165	na	na	na	0.2	
Silver	0.41-0.70	0.0095	0.0165	na	na	na	0.02	
Thallium	0.0055-0.0094	0.0095	0.0165	na	na	na	0.006	
Vanadium	0.55-0.94	0.0095	0.0165	na	na	na	0.06	
Zinc	25-42	0.0095	0.0165	0.28 – 2.75	3	16-260	0.2	
Mercury	0.0083-0.014	0.0095	0.0165	0.12 – 0.92	3	0.016-0.20	0.01	
Tri-n-butyltin	0.012-0.020	0.0095	0.0165	0.15 - 75	3	0.00028-0.23	0.00016	
Pesticides								
4,4'-DDD	0.0042-0.0071	0.0095	0.0165	0.62 – 0.88	3	0.0083-0.019	0.000093	
4,4'-DDE	0.0030-0.0051	0.0095	0.0165	1.07 – 2.03	3	0.0026-0.0083	0.000076	
4,4'-DDT	0.0030-0.0051	0.0095	0.0165	2.35 – 5.69	3	0.00092-0.0038	0.00017	
Total DDT	0.0030-0.0051	0.0095	0.0165	2.35 – 5.69	3	0.00092-0.0038	0.00034	
Aldrin	0.000059-0.00010	0.0095	0.0165	1.62	4	6.3 E-05-0.00011	0.00025	X
alpha-BHC	0.00017-0.00028	0.0095	0.0165	na	na	na	0.000083	
beta-BHC	0.00059-0.0001	0.0095	0.0165	1.62	4	0.00063-0.00011	0.00022	
Chlordane	0.0029-0.0049	0.0095	0.0165	2.1 – 2.97	3	0.0017-0.0041	0.000038	
Dieldrin	0.000065-0.00011	0.0095	0.0165	2.13 – 3.43	4	3.3E-05-8.9E-05	0.000082	X
Endosulfan	0.47-0.80	0.0095	0.0165	1.62	4	0.50-0.86	0.00011	
Endosulfan sulfate	na	0.0095	0.0165	na	na	na	0.00021	

CHEMICAL	C_{WB} (mg/kg ww)	F_L	F_{OC}	BSAF	BSAF REFERENCE	C_{SED} (mg/kg dw)	MDL (mg/kg dw)	CHEMICAL WITH ACG<MDL
Endrin	0.025-0.042	0.0095	0.0165	1.62	4	0.027-0.045	0.00024	
gamma-BHC (Lindane)	0.00077-0.0013	0.0095	0.0165	1.62	4	0.00083-0.0014	0.000099	
Heptachlor	0.00023-0.00039	0.0095	0.0165	1.62	4	0.00025-0.00042	0.000097	
Heptachlor epoxide	0.00011-0.00019	0.0095	0.0165	na	na	na	0.00014	
Hexachlorobenzene	0.00065-0.0011	0.0095	0.0165	na	na	na	na	
Methoxychlor	0.41-0.70	0.0095	0.0165	1.62	4	0.44-0.75	0.00019	
Mirex	0.017-0.028	0.0095	0.0165	na	na	na	na	
Toxaphene	0.00094-0.0016	0.0095	0.0165	na	na	na	0.0073	

BSAF references:

1. EPA 1997
2. Washington State Department of Health 1995
3. Environmental Residue-Effects Database – bivalve mollusks only
4. Tracey and Hansen 1996

D.3.0 Comparison of ACGs to MDLs

The sediment ACGs for all chemicals but arsenic, cadmium, six individual PCB Aroclorsand two organochlorine pesticides are higher than the MDLs shown in Table 3-18 of the QAPP, suggesting that standard EPA analytical methods are suitableElevated MDLs relative to ACGs are only problematic when chemicals are not detected. The lab will make additional efforts to achieve ACGs for Aroclors in samples if no Aroclors are detected in a sample. Additional efforts may include additional sample clean-up, extracting more sample, using a lower concentration for the lowest standard in the initial calibration, adjusting the final volume, or adjusting the amount of extract injected into the instrument.

The ACGs for two pesticides, aldrin (0.00011 mg/kg dw) and dieldrin (0.000089 mg/kg dw), are lower than the corresponding MDL values for these compounds. Aldrin and dieldrin have rarely been detected in LDW sediments (i.e., out of 262 samples, aldrin was undetected in 260 and dieldrin was undetected in 237 samples), and have never been detected in LDW tissue samples. However, existing pesticide data in tissue and sediment are limited and may not be representative of Phase 2 results. Arsenic and cadmium were detected in 869 and 715, respectively, of the over 900 samples in which they were analyzed.

D.4.0 References

EPA. 1997. The incidence and severity of sediment contamination in surface waters of the United States. Volume 1: national sediment quality survey. EPA 823-R-97-006. US Environmental Protection Agency, Office of Science and Technology, Washington, DC.

Tetra Tech. 1994. Sediment and shellfish investigation at Defense Fuel Support Point (DFSP), Mukilteo, Washington. Prepared for Groundwater Technology Government Services, Inc., Kent, WA. Tetra Tech, Inc., Redmond, WA.

Tracey GA, Hansen DJ. 1996. Use of biota-sediment accumulation factors to assess similarity of nonionic organic chemical exposure to benthically-coupled organisms of differing trophic mode. Arch Environ Contam Toxicol 30:467-475.

Washington State Department of Health. 1995. Tier I report, development of sediment quality criteria for the protection of human health. Washington State Department of Health, Olympia, WA.

APPENDIX E: DERIVATION OF SALINITY RANGES AND CALCULATION OF AREAL PERCENTAGES FOR EACH RANGE

As discussed in Section 3.1.1 of this QAPP, benthic community sampling locations were assigned based on a matrix of physical variables known to affect benthic community composition and structure: salinity, water depth, sediment chemistry, and sediment grain size. For salinity, three ranges were identified based on the percent of time below 5 parts per thousand (ppt) (i.e., relatively fresh water): 0-30%, 30-70%, and 70-84%. This appendix describes the derivation of these three salinity ranges and the calculation of the area associated with each range.

The most detailed salinity data available for predicting salinity ranges at depth over the length of the Lower Duwamish Waterway (LDW) are from King County's Water Quality Assessment (King County 1999a, b). This assessment used the Environmental Fluid Dynamics Code (EFDC) model to predict water quality through the LDW and in Elliot Bay. The assessment modeled salinity at all depths for one water year (October 1996 through September 1997). The results were analyzed to determine the percent of time salinity was predicted to be below 5 parts per thousand (ppt) (Table 5-31 of Appendix B4; King County 1999b) at twelve stations, including four stations in the LDW near combined sewer overflows (CSOs): Brandon CSO (RM 1.1), West Michigan CSO (RM 2.0), 8th Ave. CSO (RM 2.8), and Norfolk CSO (RM 4.8) (see Table E-1). King County (1999b) used the 5 ppt criteria as a threshold level at which marine benthic invertebrates experience stress.

The LDW is a salt-wedge estuary, meaning that relatively dense salt water from Elliott Bay forms a wedge beneath the less dense fresh water flowing out of the Duwamish River. The salt wedge can be pushed upstream in the LDW during periods of low discharge or during especially high tides. Conversely, the wedge is pushed downstream in the LDW during low tides and periods of high discharge. Therefore, the salinity at a given point in the waterway will vary by depth and over time. Given the large tidal range (MHHW is 11.35 ft relative to a MLLW of 0.0 ft), there is a considerable tidally driven diurnal variation in the salt wedge. Table E-1 shows that at the most downstream stations (RM 1.1), the deep water (>10 ft depth) never drops below 5 ppt, while the surface water is relatively fresh (less than 5 ppt) less than 40% of the time. Water at depths of 10-12 ft at the most upstream station (RM 4.8) is relatively fresh about 50% of the time, while the surface water is relatively fresh more than 80% of the time.

Table E-1. Percent of time predicted salinity is less than 5ppt at four stations in the LDW[a]

	Brandon CSO		W. Michigan CSO		8th Ave CSO		Norfolk CSO	
	RM 1.1		RM 2		RM 2.8		RM 4.8	
Depth Layer[b]	Depth (ft)	% Time <5 ppt	Depth (ft)	% Time <5 ppt	Depth (ft)	% Time <5 ppt	Depth (ft)	% Time <5 ppt
10 (surface layer)	0-4	38.09	0-3	54.94	0-2	68.46	0-2	83.83
9	4-8	2.28	3-6	9.3	2-4	57.85	2-4	78.12
8	8-12	0	6-9	0.36	4-6	32.9	4-6	73.41
7	12-16	0	9-12	0	6-8	15.69	6-8	66.74
6	16-20	0	12-15	0	8-10	6.41	8-10	56.94
5	20-24	0	15-18	0	10-12	2.88	10-12	50.46
4	24-28	0	18-21	0	12-14	1.35	12-14	46.46
3	28-32	0	21-24	0	14-16	0.46	14-16	44.41
2	32-36	0	24-27	0	16-18	0.31	16-18	42.85
1 (bottom layer)	36-40	0	27-30	0	18-20	0.19	18-20	41.19

[a] Salinity values are from modeling results and analysis from King County 1999b.

[b] Depth layers refer to vertical layers assigned to the LDW as part of the King County modeling effort. Each location in the LDW was divided into 10 vertical cells, regardless of the depth. Each cell was of equal height, corresponding to 1/10 the water depth at that location.

To use these data to determine the areas presented in Table 3-5 (in the QAPP), three salinity categories were defined based on the percent of time the water salinity was less than 5 ppt: 0-30% of the time (relatively high salinity), 30-70% of the time (medium salinity), and 70-84% of the time (relatively fresh). No stations in the LDW were predicted to have freshwater 100% of the year; 84% is the highest predicted percentage.

The data in Table E-1 were used as follows. At each of the four stations, the mean water depth was divided by 10 to derive the depth of each layer. These layers were then divided into intertidal (> -5 ft MLLW), shallow subtidal (-5 ft to -15 ft MLLW), and subtidal (< -15 ft MLLW) subcategories. The average of percent time less than 5 ppt was then calculated for each of the three depth categories. To derive a salinity estimate (expressed as percent time less than 5 ppt) for locations between the four stations in Table E-1, simple regression analysis were used. These analyses were used to calculate the relationship between the river mile and salinity for each depth layer. The relationship for three depth intervals is illustrated in Figure E-1. The estimated river mile cut-offs for each salinity category are presented in Table E-2 and illustrated in Figure E-2. Bathymetry data were then used to determine the total area within the LDW represented by each of the depth/river mile pairs in Table E-2. These areas are presented in Table 3-5 in the QAPP.

Table E-2. River mile lengths for each salinity category as a function of sediment elevation relative to MLLW

Elevation (ft , MLLW)	Percent of Time Below 5 ppt		
	0-30%	30-70%	70-84%
	High Salinity	Medium salinity	Low Salinity
Intertidal			
≥ - 5	RM 0-0.7	RM 0.7-3.4	RM 3.4-5.0
Subtidal			
< - 5 to > - 15	RM 0-3.9	RM 3.9-5.0	na
≤ - 15	RM 0-4.2	RM 4.2-5.0	na

References

King County. 1999a. King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay. Vol 1, Appendix B1: Hydrodynamic and fate and transport numerical model. King County Department of Natural Resources, Seattle, WA.

King County. 1999b. King County combined sewer overflow water quality assessment for the Duwamish River and Elliott Bay. Vol 1, Appendix B2, B3, & B4: human health, wildlife, and aquatic life risk assessments. King County Department of Natural Resources, Seattle, WA.

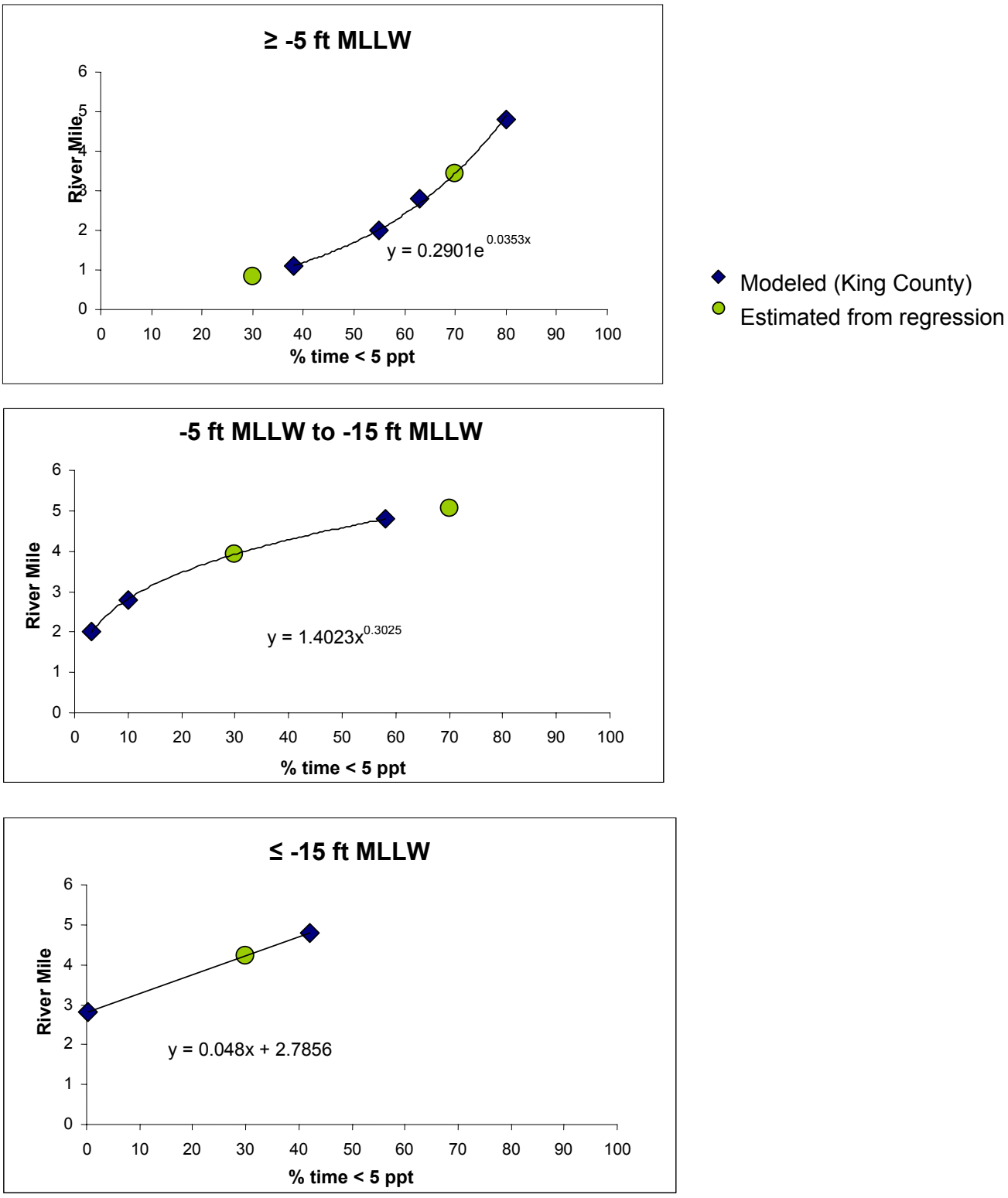

Figure E-1. Regression analyses for each depth layer

Figure E-2. LDW salinity by depth range

(separate file in MS Word version)