Appendix D

Decision Criteria

Columbia River Channel Improvement Project
Adaptive Environmental Management Plan

March 2006

D.1 Introduction

Bartell and Nair (2005) presented an Adaptive Environmental Management (AEM) Plan that was developed to support the Columbia River Channel Improvement Project (CRCIP). The proposed AEM Plan includes seven steps for adaptively managing the environmental resources of concern in relation to channel deepening. These steps are briefly described as:

1. Results of the ongoing monitoring programs, ecosystem evaluation actions (EEA), and research are periodically summarized and reported. This reporting might be primarily event-driven, where new observations or data suggest possible violations of existing decision criteria for one or more of the performance measures or risk endpoints.

2. The results of monitoring actions (MA)-1 through MA-6, EEA-1 through EEA-6, and relevant research are collated and analyzed by an informal Technical Support Group.

3. The Technical Support Group would review the monitoring results and advise the Adaptive Management Team (AMT) concerning any performance measures or risk endpoints that exceed the management decision criteria.

4. If none of the decision criteria is exceeded, the AEM Process can continue with the current monitoring programs until the next evaluation (i.e., Step 1).

5. If any decision criteria are exceeded, the AMT can request the United States Army Corps of Engineers (USACOE) to develop a mitigation or management plan. If requested by the AMT, the USACOE will also suggest alternative management actions to address the performance measures or risk endpoints that exceed the decision criteria.

6. Upon evaluating the USACOE mitigation or management plan, the AMT may determine that there is no need to change current CRCIP management practices. Alternatively, the AMT may recommend modifications to current practices. If current practices remain unchanged, the corresponding monitoring and evaluation actions would continue unchanged until the next Technical Group summary and analysis. However, if changes to the current management practices are recommended, the AMT would develop the necessary changes and address potential revisions to monitoring, ecosystem evaluation actions, and decision criteria.

7. Following resolution of the proposed adaptive management actions and possible revisions to monitoring and research recommended by the AMT, the AEM Process continues by cycling back to review and analysis of new data and information by the Technical Support Group.

The steps in the above-described AEM Process are schematically illustrated in the AEM Plan flowchart (Figure 2.3 in AEM Plan).

The implicit hypothesis underlying the AEM Plan is that the channel deepening will not significantly alter the physical or chemical conditions characteristic of the Lower Columbia River (LCR) and estuary. Failure in rejecting this hypothesis further suggests that the corresponding habitat factors that influence the growth, survival, and ocean entry of salmonids will not be significantly altered by the CRCIP. Therefore, the AEM Process will focus initially on specific physical and chemical effects potentially impacted by channel deepening (Bartell and Nair 2005).

Consensus agreement among the AMT identified the following important physical-chemical effects to be addressed by the Channel Improvement AEM Process:

- possible shifts in location or changes in ecological function of the estuarine turbidity maximum;
- deleterious changes in current velocity in shallow water habitats and refugia;
- undesired changes in accretion/erosion rates along the main channels and side-slopes;
- undesired changes in temperature, salinity, and water depth; and
- concerns with predicted dredge volumes as it relates to disposal capacity.

Some of the longer-term benefits that should be achieved as the result of a successful AEM Process for the LCR and estuary include:

- provision of additional shallow water and intertidal marsh habitat;
- increased habitat connectivity and complexity;
- creation of additional rearing habitat for ocean-type salmonids;
- increases in detrital export;
- maintaining native tidal marsh plant communities;
- increased benthic invertebrate productivity;
- sustainability of sturgeon, smelt, and Dungeness crab populations;
- increased access/egress for ocean-type salmonids; and
- improved access for adult salmonids to headwaters for spawning.

The remainder of this Appendix outlines the development of decision criteria that will be used to implement the AEM Process. Following a brief discussion concerning the general nature and desired attributes of such criteria, several methods are presented for deriving their values. These methods are used subsequently to determine initial values of decision criteria. These proposed values can then focus future and continued efforts in arriving at consensus criteria ("trigger values") for the CRCIP Adaptive Management Process.

D.2 Decision Criteria

A scientifically based and informative monitoring program is central to AEM. Importantly, the results of monitoring quantify the response of the performance measures and risk endpoints to channel improvement. Performance measures define those attributes of the ecosystem that provide the manager with information on the response of the ecosystem in relation to the desired conditions (i.e., goals, objectives). Risk assessment endpoints define complementary ecosystem attributes that indicate the likely occurrence of undesired, adverse impacts associated with the project

To be useful as a performance measure or an assessment endpoint, a monitored attribute should serve as an indicator of an integrated ecosystem structure or function. Patterns of spatial-temporal responses of the attribute to management should be consistent with current quantitative ecosystem understanding. The measures should be capable of responding to management actions specific to channel improvements. It should be possible to determine how the attribute might change in response to channel dredging as distinct from other sources of variation. Thus, in developing decision criteria, efforts should be made to

- characterize values of pre-project indicators in relation to historical values and trends;
- analyze values in relation to natural variability in space and time; and
- develop functional relationships between management actions (e.g., dredging) and indicators, including uncertainty.

Importantly, certain values of the performance measures or risk endpoints will be used as criteria for deciding to continue current management actions or to adapt management by undertaking new or different actions. The remainder of this Appendix describes the derivation of selected decision criteria ("trigger values") for the CRCIP AEM Process. Where data are lacking, methods are proposed for development of the corresponding criteria.

2-1 Derivation of Decision Criteria

One of the key activities in implementing the proposed AEM Plan was to explore alternative approaches with the purpose of deriving meaningful and justifiable decision criteria. There are several approaches for deriving values of performance measures or risk endpoints that will serve as decision criteria in the AEM Process. These approaches include: (1) legislative mandates, (2) consensus among stakeholders, (3) pre- and post-project comparisons, (4) empirical derivation, and (5) modeling.

Legislative Mandates

Federal and/or state laws may specify values used as decision criteria for selected water quality parameters. For example, concentrations of nutrients, chemical pollutants, and dissolved oxygen can be specified to meet designated uses in relation to the Clean Water Act. It is assumed that ordinances related to federal, Oregon, and Washington water quality criteria will be complied with during the CRCIP Adaptive Management Process.

Consensus

In the absence of legal requirements, values of decision criteria might be derived as the result of consensus building among project stakeholders. It is desirable that criteria developed through consensus are supported by science. However, the consensus process might well result in compromises among participating stakeholders. Such compromise might produce criteria that reflect socioeconomic and political interests, as well as scientific understanding (e.g., the 10 parts per billion phosphorus criterion for agricultural runoff in South Florida). Depending on the nature and degree of compromise, the consensus process can nevertheless produce useful and defensible decision criteria. This derivation process needs to be carefully documented in order that the resulting criteria are understood within the context of the overall negotiations.

Consensus building among the USACOE, the National Oceanic and Atmospheric Administration Fisheries, the U.S. Fish and Wildlife Service (USFWS), Oregon, Washington and other project principals will likely continue during the CRCIP Adaptive Management Process (Appendix B). Importantly, the proposed AEM Plan (Bartell and Nair 2005) includes provisions for review and evaluation of the decision criteria by the principal participants.

Pre- and Post-Project Comparisons

Comparisons of pre- and post-construction data can be used to evaluate project impacts for certain performance measures, including salinity, current velocity, surface elevations, and fish stranding. The results of the comparisons can “trigger” adaptive management. The pre- and post-construction comparisons require only an adequate characterization of system conditions prior to project implementation and a similar characterization following construction. Perhaps the greatest technical and management challenges to using this approach lies in identifying the appropriate spatial-temporal scales of measurement that define “pre-project” and “post-project” conditions. The identification of appropriate scales may require some consensus building among CRCIP principals. There is current agreement supporting a two-year pre-construction monitoring effort, followed by a post-construction monitoring period of one or more years for several of the performance measures and risk endpoints included in the AEM Process for the CRCIP.

Empirical Derivation

Conceptually, perhaps the most compelling method for determining the decision criteria lies in analysis of historical patterns and trends for the performance measures and risk endpoints. Analyses of existing data can define historical patterns of spatial and/or temporal statistics (e.g., mean, median, variance, maximum, minimum) in selected performance measures. These statistics can be used to estimate decision criteria ("trigger values") for the corresponding performance measures based on historical observations.

More complex methods of statistical time series analyses including, for example, trend analysis (Kukulka and Jay 2003), spectral analyses (e.g., Platt and Denman 1975), and autoregressive integrated moving average models (Shugart 1978) may be necessary to define decision criteria, depending on the quality and quality of available data. Analogous spatial statistics (e.g., two-dimensional spectral analysis, spatial autocorrelation, and kriging) may prove useful in defining the spatial attributes of the decision criteria (Ripley 1981).

Statistical analyses can also be used to evaluate the statistical power (or performance characteristics) of monitoring (e.g., MA-1) in discriminating the potential impacts of channel improvement from historical patterns of variability. Depending on the amount of historical data underlying the decision criteria and the number of samples obtained during monitoring, evaluation of the monitoring data can be undertaken as hypothesis testing. The null hypothesis is that the monitoring data are samples from the same distribution underlying the decision criteria. Clearly, the greater the variability in the data used to develop the decision criteria, the larger the number of monitoring samples that will be required to statistically demonstrate departure from historical conditions as the possible result of channel deepening. Estimates of historical variability can be used to rather straightforwardly determine the number of future samples required for statistical comparisons at a specified level of power (Dixon and Massey 1969).

Modeling

Existing data may prove insufficient for estimating certain performance measures or risk endpoints. Under these circumstances, statistical or process-oriented models might provide recourse for deriving values of decision criteria. Detailed hydrodynamic models (e.g., CORIE estuary circulation model) might be used to determine dredging-induced changes in bathymetry that increase the risks of alterations in the spatial-temporal patterns of salinity, temperature, and water depth.

The initial emphasis of the CRCIP AEM Plan focuses on potential physical-chemical impacts associated with channel improvements in the lower river and estuary. At the same time, however, the ecological importance of significant deviations from historical patterns in the decision criteria resides in the possible implications on the survival, growth, and ocean entry of salmonids. Such implications can be addressed using models of habitat opportunity (e.g., Bottom et al. 2001). It would be possible to use the habitat opportunity models to derive decision criteria for the physical-chemical parameters based on conditions favorable to salmon.

Wherever possible, the uncertainties associated with derivation of criteria using these models should be described and quantified. Bias and imprecision can result from uncertainties associated with model structure, estimates of model parameter values, and specification of initial conditions. Methods of numerical sensitivity and uncertainty analyses can be used to examine the implications of uncertainties in parameter estimation and initial conditions. Comparisons of model predictions with observations can be used to evaluate overall model structure.

2-2 Scale and Decision Criteria

The spatial complexity of the estuary and temporal dynamics of hydrology (tides, river flows, and tributary inputs) and salmonid utilization of the estuary require careful considerations of scale in developing an effective monitoring plan and establishing decision criteria to support adaptive management. Two important aspects of ecological scale are "grain" and "extent" (Gardner and O'Neill 1991, Allen and Starr 1982). Grain refers to the level of resolution (in time or space) of measurement. For example, Landsat imagery has a grain (pixel) size of 30 m x 30 m; AVHRR[1] data have a grain size of 1 km x 1 km (Gardner and O'Neill 1991). Information is gained with increasing grain, given the same extent. Extent defines the sampling universe: spatial size or temporal duration. Increasing extent, while maintaining constant grain, also increases information. Gardner (1998) defines scale as the combination of grain, extent, and number of samples that minimizes the statistical variance (in space and/or time) estimated for the indicator of interest.

Spatial scale has been considered in the monitoring and analysis of the Columbia River estuary (extent). For example, Bottom et al. (2001) divided the estuary into six comparatively distinct regions (grain) defined by topology, bathymetry, and proximity to the river mouth. These six regions are (1) Baker Bay, (2) lower mainstem of the estuary, (3) Youngs Bay, (4) Cathlamet Bay, (5) Grays Bay, and (6) the upper mainstem of the estuary. Figure D.1 illustrates the location of sampling stations that map onto this spatial scheme. (Table D.1 lists the complete names of these sampling locations and monitoring depths.) Several of these stations constitute a major portion of a continuous monitoring program, CORIE (http://www.ccalmr.ogi.edu/CORIE/). Other spatial aggregations within the estuary are, of course, possible. The important point is to recognize the scale-dependence of measurements used to describe the condition of the estuary and its potential response to channel improvement.

Spatial and temporal river-estuarine variations important to scale considerations are readily apparent for the LCR and estuary. Seasonal variations in river discharge and regional meteorology, as well as temporal shifts in timing and magnitude of spring freshets should be examined from the perspective of defining relevant temporal scales in deriving decision criteria. These hydrologic processes in combination with tides and bathymetry largely

[1] Advanced Very High Resolution Radiometer

determine water circulation within and through the estuary. Perhaps overly simplistic, the ever-varying pattern of water circulation defines critical habitat features for juvenile salmon that utilize the estuary. These features can be described as somewhat distinct volumes of water within the estuary that are shallow and warm, deeper and cooler, nearly freshwater or higher in salinity, as well as higher and lower velocity volumes. The spatial-temporal distribution and extent of these water volumes can determine the successful conveyance of salmon to the ocean. This dynamic "landscape" can also define connectivity (contagion) of habitats necessary for salmon growth and survival (e.g., predator avoidance). From a LaGrangian perspective, the challenge in characterizing habitat opportunity and habitat capacity lies in accurately describing the changing shape, location, and extent of these critical volumes, as well as understanding the juxtaposition of these volumes with habitat types (i.e., wetlands marshes, intertidal flats, side channels) necessary for salmon to complete their complex life cycles. The implicit hypothesis is that channel deepening will not significantly alter the current patterns of circulation within the estuary. Examination of this hypothesis through continued monitoring will be influenced by the spatial-temporal scaling of measurements and selected decision criteria.

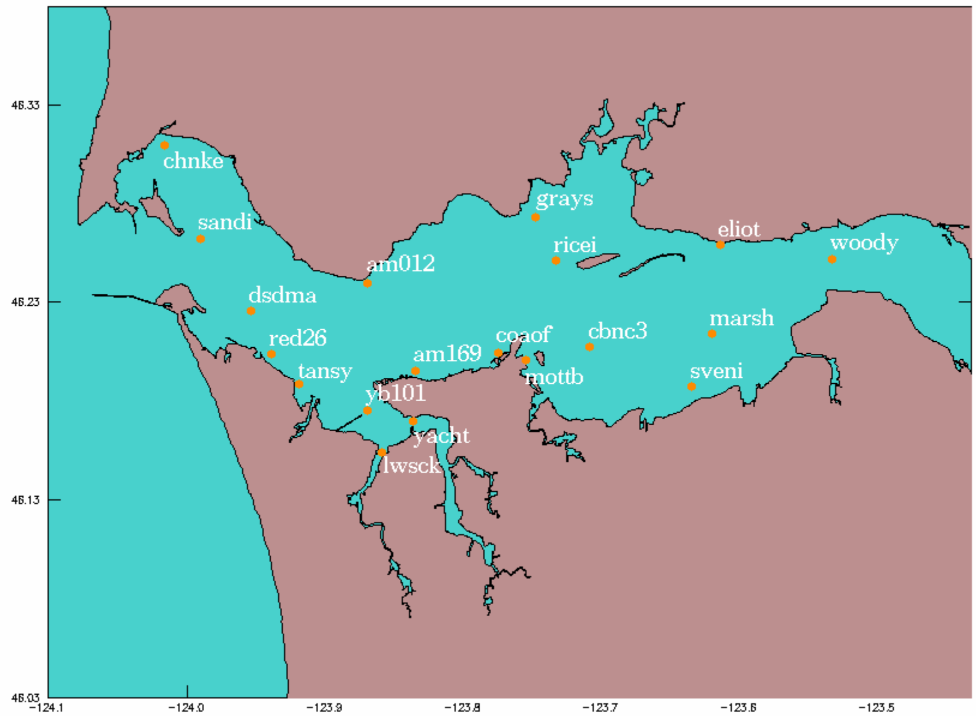

Figure D.1. Map showing locations of CORIE monitoring stations. MA-1 uses red26, grays and cbnc3 locations (http://www.ccalmr.ogi.edu/CORIE/).

Station	Full Station Name	Measurement Depth (m below datum at NGVD29)
chnke	Chinook River - Estuary	2.6
sandi	Lower Sand Island light (USCG day mark green 5)	7.9
dsdma	Desdemona Sands light (USCG day mark)	7.5
red26	Fort Stevens Wharf (USCG day mark)	7.5
tansy	Tansy Point (USCG front range board)	8.4
yb101	New Youngs Bay Bridge (ODOT highway 101)	
lwsck	Lewis and Clark Bridge (ODOT old highway 101)	
yacht	Yacht Club (City of Astoria)	
am169	Astoria Meglar Bridge South Channel (ODOT pier 169)	11.3
am012	Astoria Meglar Bridge North Channel (ODOT pier 12)	
grays	Grays Point (USCG day mark green 13)	1.6
ricei	Rice Island (Division of State Lands)	
eliot	Elliott Point	13.9
woody	Woody Island (USCG Pillar Rock back range board)	2.4
marsh	Marsh Island (USCG day mark green 21)	5.4
sveni	Svenson Island (USCG day mark 12A)	10.8
cbnc3	Cathlamet Bay North Channel (USCG day mark green 3)	6.5
mottb	Mott Basin (Tongue Point Job Corp pier 6)	8.6
coaof	Waste water outfall (City of Astoria)	3.2

These stations can be mapped onto five of the six regions delineated by Bottom et al. (2001) in their assessment of habitat opportunity. Stations chnke and sandi may represent Region 1 (Baker Bay). Region 2 (Lower Columbia mainstem) includes stations: dsdma, red26, tansy, am102, and am169. Stations yb101, lwsck, and yacht appear relevant to Region 3 (Youngs Bay). Region 4 (Cathlamet Bay) includes stations: marsh, sveni, cbnc3, and mottb. Stations grays and ricei can represent Region 5 (Grays Bay). Stations eliot and woody might be included in the mainstem. Region 6 (Upper Columbia mainstem) is not represented.

Table D.1. Names of sampling stations shown in Figure D.1.

Stations closest to the navigation channel include dsdma, red26, tansy, am169, ricei, eliot, woody, and possibly coaof. While decision criteria for physical and chemical parameters monitored through MA-1 have been developed for all stations, only cbnc3, red26, and grays would be the focus during the implementation phase of the AEM Process. Decision criteria for other stations would be used as and when required. For example, if an anomaly were discovered in the post-dredging monitoring data at one of the three stations focus, available data from additional stations would be analyzed to determine whether natural variability or channel deepening was likely the source of the anomaly.

D.3 Criteria for Corps CRCIP Monitoring Actions

3-1 MA-1 Continuous Monitoring Stations

The USACOE maintains three hydraulic monitoring stations on the lower river. Their locations are downstream from Astoria (red26), Grays Bay (grays), and Cathlamet Bay (cbnc3). The measured parameters include salinity, water depth, and water temperature. Physical changes resulting from channel deepening are expected to be minor and occur in proximity to the navigation channel. The proposed monitoring duration includes two years before channel deepening, two years during the construction, and three years following construction.

The MA-1 data have been analyzed to establish pre- and post-project relationships between the channel deepening and values of flow, salinity, water surface elevation, and water temperature. The purpose of MA-1 in the context of the AEM Plan is to verify levels of impact of channel modifications on these physical parameters. Additionally, the results of MA-1 might be used to assess habitat complexity, connectivity, conveyance, and habitat opportunity.

Proposed values of selected physical-chemical decision criteria have been derived through analysis of the CORIE data. Emphasis has been placed on an empirical approach for those performance measures characterized by substantial existing data. CORIE data are publicly available at 1- or 5-minute intervals for years 1996 to the present. Given that the criteria would enter into an annual review and evaluation according to the AEM Plan, it was decided to summarize the available data on a monthly time scale. The data were used to estimate monthly minimum, mean, median, standard deviation, and maximum values for water depth, salinity, and water temperature. Selection of this level of resolution permits examination of possible dredging effects on spatial/temporal patterns of variability in these assessment endpoints. This level of resolution appears further justified by temporal variability in dredging activities. (Note that CORIE data are not available for all months or stations.)

One important consideration in deriving empirical decision criteria is the quality of the data. The detection limits of the CORIE instrumentation contribute in part to the overall data quality. The detection limit of the CORIE instruments used for monitoring salinity is 0.1 practical salinity units (psu), that for monitoring temperature is 0.1˚C, and that for monitoring water depth is 3–10 cm. The temperature and salinity detection limits appear sufficient for purposes of the AEM Plan. That is, it would prove exceptionally challenging to demonstrate differences detected on the order of 0.1 psu or 0.1˚C as unequivocally resulting from channel dredging. The detection limits (sensitivity) of these measures also define the precision for specifying the decision criteria for these parameters. In contrast, the less sensitive 10-cm detection limits for water depth might produce situations where dredging associated changes in water depth (e.g., shallow water habitats) are not reliably measured. At the same time, it is anticipated that changes in depth, apart from the locations of dredging, will not be measurably altered by the Project. So, in practice, the 10-cm detection may prove acceptable for deriving MA-1 decision criteria for water depth.

As the result of previous discussion and analysis of the CORIE data, the AMT has reached consensus on three components of decision criteria for depth, water temperature, and salinity. The AMT will review newly collected monitoring data (MA-1) in relation to (1) a tabular summary of 20- and 80-percentiles of estimated monthly median values; (2) a similar table of 5- and 95-percentile values; and (3) for water temperature, plotted relationships between daily median temperatures for a reference location (woody) and the corresponding values for the three MA-1 stations. The following sections present these decision criteria.

Water Depth

Perhaps the most direct potential impacts of channel deepening are alterations in water depth as the result of dredging throughout the lower river and estuary. Table D.2 summarizes the 20- and 80- percentile values of water elevations referenced to the North Geodetic Vertical Datum of 1929 as determined from analyses of available CORIE data. The corresponding 5- and 95- percentile values are listed in Table D.3. The values indicate the relevance of the various sampling stations in characterizing habitats of different depths throughout the estuary. The depths clearly define the shallower and deeper monitoring stations. The values do not appear particularly sensitive to monthly changes in flows (i.e., river discharge), yet the months of typical low flow (July–September) are evident in corresponding seasonally lower water elevations. The monthly values can be used as decision criteria for selected stations because of the comparative stability of these values. Significant departures from the monthly values following dredging can "trigger" the adaptive components of the AEM Process. Clearly, any deviations from these values would have to be evaluated in relation to patterns of river discharge, as well as local and regional hydrology (e.g., precipitation events, tributary inputs, and watershed alterations). The major challenge resides in determining what defines a significant departure from the recent historical depth values.

Table D.2. Decision criteria for water depth (m) based on 20- and 80-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	0.9	2.3	0.9	2.3	0.8	2.2	0.7	2.0	0.7	2.1	0.7	2.0
sandi	7.1	8.8	7.4	8.7	7.2	8.6	7.0	8.6	7.1	8.5	7.1	8.9
dsdma	6.9	8.6	6.8	8.5	6.3	8.1	6.7	8.3	6.6	8.2	6.6	8.1
red26	6.7	8.3	6.6	8.3	6.8	8.4	6.8	8.3	6.9	8.4	6.8	8.2
tansy	7.9	9.6	7.9	9.6	7.8	9.4	7.7	9.3	7.7	9.3	7.7	9.2
yb101												
lwsck												
yacht												
am169	10.7	12.2	10.5	12.3	10.6	12.2	10.5	12.1				
am012												
grays	1.3	2.8	1.2	2.8	1.1	2.7	1.1	2.6	1.0	2.6	1.0	2.5
ricei												
eliot	13.9	15.5	13.8	15.4	13.8	15.3	13.7	15.2	13.5	15.0	13.4	14.9
woody	2.1	3.6	2.1	3.6	2.0	3.5	2.0	3.4	2.0	3.4	2.0	3.4
marsh	5.2	6.7	5.0	6.5	5.0	6.5	5.0	6.4	5.0	6.5	5.0	6.5
sveni	10.6	12.1	10.5	12.0	10.4	12.0	10.4	12.0	10.4	11.9	10.4	11.9
cbnc3			5.6	6.4	5.7	7.1	5.7	7.2	5.5	6.7	5.5	6.4
mottb	8.2	9.8	8.1	9.6	8.1	9.6	8.1	9.6	7.9	9.4	7.9	9.5
coaof	2.9	4.4	2.7	4.3	2.7	4.3	2.7	4.3	2.7	4.2	2.7	4.2

	July		August		September		October		November		December	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	0.7	2.0	0.7	2.1	0.7	2.1	0.8	2.2	0.7	2.2	0.9	2.3
sandi	7.3	8.7							7.3	8.6	7.1	8.6
dsdma	6.6	8.1	6.6	8.0	6.4	8.0	6.5	7.9	6.7	7.9	6.7	8.3
red26	6.7	8.1	6.7	8.1	6.8	8.1	6.6	8.3	6.6	8.2	6.7	8.2
tansy	7.6	9.2	7.6	9.2	7.6	9.2	7.6	9.3	7.8	9.4	7.8	9.4
yb101												
lwsck												
yacht												
am169					10.3	12.1	10.5	12.1	10.7	12.0	10.4	11.0
am012												
grays	0.9	2.5	0.9	2.5	0.9	2.5	0.9	2.5	1.1	2.7	1.2	2.8
ricei												
eliot	13.2	14.7	13.2	14.7	13.2	14.7	13.4	14.8	13.6	15.1	13.8	15.3
woody	1.9	3.3	1.8	3.3	1.8	3.3	1.8	3.3	2.0	3.5	2.2	3.6
marsh	4.8	6.4	4.8	6.4	4.8	6.3	4.9	6.4	4.9	6.5	5.1	6.6
sveni	10.4	11.9	10.3	11.9	10.3	11.9	10.3	11.9	10.3	11.9	10.6	12.1
cbnc3	5.4	6.3										
mottb	7.8	9.4	7.9	9.4	7.9	9.5	7.8	9.4	8.1	9.7	8.2	9.8
coaof	2.6	4.1	2.5	4.1	2.5	4.1	2.5	4.1	2.6	4.2	2.8	4.4

Table D.3. Decision criteria for water depth (m) based on 5- and 95-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	0.4	2.8	0.5	2.8	0.3	2.6	0.3	2.5	0.2	2.6	0.3	2.5
sandi	6.4	9.3	6.9	9.0	6.6	9.1	6.4	9.0	6.5	9.0	6.3	9.4
dsdma	6.1	9.2	6.1	8.9	5.9	8.6	6.1	8.7	5.9	8.7	6.0	8.6
red26	6.0	8.8	5.9	8.8	6.2	8.9	6.2	8.8	6.3	8.7	6.1	8.6
tansy	7.3	10.1	7.3	10.1	7.2	9.9	7.1	9.7	7.1	9.8	7.0	9.8
yb101												
lwsck												
yacht												
am169	10.2	12.7	10.0	12.8	10.0	12.7	9.9	12.5				
am012												
grays	0.6	3.4	0.5	3.3	0.5	3.2	0.5	3.1	0.4	3.1	0.3	3.1
ricei												
eliot	13.3	16.0	13.3	15.9	13.2	15.8	13.1	15.7	13.0	15.5	12.9	15.4
woody	1.6	4.2	1.6	4.0	1.6	4.0	1.6	3.9	1.6	3.9	1.5	4.0
marsh	4.5	7.2	4.5	7.0	4.5	7.0	4.4	6.9	4.5	7.0	4.4	7.0
sveni	9.9	12.6	9.9	12.5	9.9	12.5	9.9	12.5	9.8	12.4	9.8	12.4
cbnc3			5.3	6.5	5.2	7.8	5.2	7.8	5.1	7.4	5.0	6.8
mottb	7.5	10.3	7.5	10.1	7.5	10.1	7.5	10.1	7.3	9.9	7.3	10.0
coaof	2.2	5.0	2.1	4.9	2.1	4.7	2.1	4.7	2.0	4.7	2.0	4.7

	July		August		September		October		November		December	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	0.2	2.6	0.2	2.6	0.2	2.6	0.3	2.7	0.3	2.7	0.4	2.9
sandi	6.4	9.3							6.6	9.1	6.4	9.1
dsdma	6.1	8.5	6.0	8.5	5.9	8.4	5.9	8.4	6.1	8.4	5.7	9.0
red26	6.1	8.6	6.0	8.6	6.0	8.4	5.9	8.8	5.9	8.7	5.9	8.7
tansy	6.9	9.7	7.0	9.8	7.0	9.7	7.0	9.8	7.2	10.0	7.2	10.0
yb101												
lwsck												
yacht												
am169					9.8	12.6	9.9	12.6	10.1	12.4	10.2	11.2
am012												
grays	0.2	3.0	0.2	3.0	0.3	3.0	0.3	3.0	0.4	3.3	0.5	3.3
ricei												
eliot	12.7	15.2	12.6	15.2	12.7	15.2	12.8	15.3	13.0	15.6	13.2	15.9
woody	1.3	3.9	1.3	3.8	1.3	3.7	1.3	3.8	1.5	4.1	1.6	4.2
marsh	4.2	6.9	4.2	6.9	4.2	6.8	4.3	6.9	4.3	7.0	4.5	7.2
sveni	9.7	12.4	9.7	12.4	9.8	12.4	9.7	12.4	9.7	12.4	9.9	12.6
cbnc3	4.9	6.5										
mottb	7.1	9.9	7.3	9.9	7.3	9.9	7.3	9.8	7.4	10.2	7.5	10.4
coaof	1.9	4.7	1.9	4.6	1.9	4.5	1.9	4.6	2.0	4.7	2.1	4.9

The values in the preceding tables describe variation in the recent historical record of water elevations for each sampling station. Monitoring data associated with dredging activities that lie outside the 20- and 80-percentile values could serve as decision criteria. The corresponding monthly values defined by the mean +/- two standard deviations (i.e., 5- and 95-percentiles) might provide even more compelling decision criteria. Values in Table D.3 reflect a more conservative or risk-averse approach to selecting the decision criteria, given that there is a larger probability that values measured outside these limits are still within the historical variability. This probability decreases, of course, as higher and lower percentile values are used as decision criteria. In other words, using the values in Table D.3 as decision criteria for the CRCIP impacts on water elevation produces a greater likelihood that false positives would result than in using percentiles calculated for two (or more) standard deviations.

Another reason for using the percentile values in the above tables originates from the anticipated statistical power of the monitoring program. The AEM Process will be implemented in the form of statistical hypothesis testing. Therefore, the sample size of the monitoring data and the variability of water depths will determine the performance characteristics in testing the hypothesis that the monitored water depth (per station and month) is statistically the same as the historical depth. Small sample sizes in monitoring compared to the larger historical data record can decrease the probability of rejecting the null hypothesis, especially for significance values associated with higher percentiles of the corresponding distributions.

Temperature

Percentile Values

Table D.4 summarizes the analysis of the CORIE station temperature data and presents the monthly 20- and 80-percentile values proposed as criteria for the AEM Plan. Table D.5 lists the corresponding 5- and 95-percentile values. The results clearly delineate the seasonal pattern of temperature change. The data also indicate the comparatively warmer, shallower stations, as well as the cooler, deeper stations.

The monthly percentile values were used to derive decision criteria for water temperature in the same manner as discussed for water elevation. Again, the main issue is determining the magnitude of deviation from the monthly values that would initiate adaptations to the channel improvement activities.

Table D.4. Decision criteria for water temperature (˚C) based on 20- and 80-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	6.3	8.3	6.5	8.5	8.5	11.7	10.6	13.3	13.1	16.9	16.7	21.0
sandi	5.7	8.8	6.4	9.2	7.3	9.4	9.2	11.0	10.6	12.9	10.5	15.0
dsdma	5.8	8.9	6.2	8.8	7.1	9.3	9.3	11.0	10.6	13.3	11.4	15.4
red26	6.2	9.2	6.4	8.9	7.4	9.7	9.3	11.2	10.6	13.4	10.9	15.6
tansy	5.7	8.6	5.7	8.4	6.9	9.1	8.9	11.0	10.7	13.6	11.6	15.8
yb101												
lwsck												
yacht												
am169	5.7	8.1	5.7	7.9	6.5	8.7	8.9	10.9	11.0	14.0	12.5	16.0
am012												
grays	4.7	6.6	4.7	6.5	6.0	8.4	9.0	11.4	11.6	14.8	15.2	17.6
ricei												
eliot	4.2	6.7	4.9	6.5	5.9	8.2	8.9	11.2	11.7	14.4	15.1	17.5
woody	4.2	6.0	4.3	6.1	5.7	8.1	8.6	11.2	11.5	14.5	14.8	17.5
marsh	5.1	6.9	5.1	6.9	5.7	8.2	9.2	11.6	11.9	14.8	15.8	18.0
sveni	4.5	6.8	5.2	6.8	6.1	8.6	9.3	11.7	12.1	15.0	15.6	17.9
cbnc3	4.1	6.4	4.8	6.5	6.0	8.3	8.9	11.2	12.1	15.0	15.6	17.7
mottb	4.5	7.2	5.4	7.2	6.3	8.8	9.4	11.9	12.1	14.8	15.1	17.5
coaof	4.5	7.4	5.8	7.4	7.0	9.1	9.9	12.1	12.9	15.3	15.5	17.6

	July		August		September		October		November		December	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	18.4	21.7	17.9	20.8	15.1	17.4	11.7	14.3	8.0	10.5	6.8	8.7
sandi	10.6	16.6	11.1	17.3	12.0	16.6	10.2	14.1	9.4	11.3	7.9	10.1
dsdma	11.0	16.7	11.2	17.4	10.9	15.7	10.5	13.4	9.5	11.3	7.6	9.7
red26	10.8	16.9	11.0	17.4	11.0	16.1	11.1	13.9	9.4	11.6	7.6	9.9
tansy	11.2	17.5	11.9	18.3	11.6	16.9	11.1	14.2	9.5	11.6	7.2	9.6
yb101												
lwsck												
yacht												
am169	12.3	17.6	12.7	17.8	12.8	16.8	11.8	14.4	9.0	11.3	6.6	8.8
am012												
grays	18.0	20.6	19.3	21.1	17.3	19.5	12.9	15.9	9.0	11.3	6.2	8.0
ricei												
eliot	18.6	21.3	20.0	21.8	17.8	20.3	13.8	17.4	9.3	11.4	6.3	8.0
woody	18.6	21.0	20.1	21.7	18.1	19.9	13.6	16.8	9.3	11.4	6.2	8.1
marsh	19.0	21.6	20.3	22.0	18.1	20.2	14.0	17.3	9.1	11.0	6.3	7.9
sveni	19.0	21.8	20.3	22.0	18.0	20.2	13.7	17.0	9.1	11.1	6.4	8.0
cbnc3	18.4	21.1	19.5	21.5	17.1	19.5	13.4	16.7	9.0	10.9	6.1	7.8
mottb	15.9	19.5	16.6	20.0	15.0	18.6	12.5	15.5	9.1	10.9	6.5	8.5
coaof	18.2	20.6	18.6	20.9	16.7	18.8	13.3	16.3	9.2	11.0	6.7	8.4

Table D.5. Decision criteria for water temperature (˚C) based on 5- and 95-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	5.1	9.1	5.6	9.6	7.3	13.3	9.7	16.1	12.1	19.0	15.2	23.1
sandi	4.7	9.9	5.4	10.1	6.2	9.8	8.4	11.8	9.2	14.2	9.0	16.0
dsdma	4.7	10.2	5.3	9.7	6.1	9.8	8.4	11.8	9.3	14.6	9.6	16.6
red26	4.9	10.3	5.3	9.9	6.3	10.8	8.4	12.0	9.2	14.5	9.4	16.8
tansy	4.5	9.8	4.6	9.7	6.0	9.9	8.0	11.9	9.5	14.9	9.8	16.9
yb101												
lwsck												
yacht												
am169	4.7	9.1	4.6	8.9	5.5	9.6	8.2	11.8	9.4	14.7	10.7	17.0
am012												
grays	4.0	7.7	4.1	7.3	5.2	9.4	8.0	12.6	10.5	15.9	14.1	18.8
ricei												
eliot	3.0	7.6	4.2	7.3	5.1	8.9	8.1	12.4	10.6	14.8	14.2	18.7
woody	3.4	6.8	3.5	6.9	5.0	9.1	7.6	12.4	10.5	15.6	13.7	18.6
marsh	4.1	7.7	4.3	7.7	5.1	9.2	8.3	12.8	10.9	15.7	15.0	19.1
sveni	3.2	7.7	4.4	7.5	5.2	9.6	8.3	12.9	11.0	15.8	14.7	19.0
cbnc3	3.2	7.3	4.2	7.2	5.1	9.0	8.1	12.6	11.1	16.0	14.9	18.8
mottb	3.2	8.2	4.6	8.1	5.4	9.7	8.4	12.9	11.1	16.3	13.9	18.4
coaof	3.2	8.0	5.2	8.0	6.1	9.8	8.7	13.1	11.7	15.8	14.6	18.6

	July		August		September		October		November		December	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	17.1	23.7	16.6	22.2	14.1	18.8	10.5	15.6	6.5	11.4	6.1	9.5
sandi	9.1	18.2	9.2	18.9	9.5	18.1	8.6	15.5	8.3	12.0	6.7	10.9
dsdma	9.3	18.0	9.5	18.8	9.4	17.0	9.2	14.7	8.5	11.9	6.7	10.6
red26	9.4	18.9	9.3	19.3	9.4	17.7	9.3	15.1	8.3	12.5	6.5	10.8
tansy	9.4	19.3	10.1	19.9	9.8	18.5	9.4	15.8	8.3	12.5	6.0	10.6
yb101												
lwsck												
yacht												
am169	10.7	19.2	10.4	19.5	10.8	18.2	10.5	15.8	7.9	12.3	5.6	9.6
am012												
grays	16.6	21.8	18.3	21.9	16.3	20.5	11.8	17.3	7.4	12.3	5.2	8.8
ricei												
eliot	17.5	22.4	19.0	22.6	16.1	21.4	12.4	18.4	8.1	12.5	5.4	8.7
woody	17.8	22.1	19.3	22.5	17.2	20.9	12.4	18.2	8.0	12.3	5.2	8.8
marsh	18.0	22.7	19.5	22.8	17.2	21.3	12.4	18.4	7.8	12.1	5.5	8.7
sveni	18.0	22.9	19.4	22.7	17.1	21.3	12.3	18.0	7.8	12.3	5.6	8.7
cbnc3	17.4	22.3	18.4	22.3	16.0	20.6	11.9	17.8	7.7	12.0	5.2	8.6
mottb	13.9	20.8	14.5	21.0	13.1	19.9	11.3	16.8	8.0	12.0	5.8	9.4
coaof	17.1	21.5	17.2	21.8	15.5	19.8	12.1	17.3	8.0	12.2	6.1	9.0

Normalized Temperature Plots

Spatial-temporal variations in water temperature within the lower river and estuary reflect complex mixing patterns determined by river flows and tidal circulation. These sources of variation in water temperatures can be evaluated by comparing temperatures at locations not influenced by tidal mixing to temperatures at other stations, including similarly river-dominated stations and those more strongly influenced by tidal mixing. For example, CORIE stations closer to the mouth of the estuary are expected to be less influenced by fresh water or riverine conditions and more by tidal conditions in contrast to the stations located at a greater distance from the river mouth. Median daily temperatures from two CORIE locations strongly influenced by river flows should be strongly correlated. To examine these kinds of relationships, the median daily temperatures from Woody Island, the CORIE station farthest from the mouth of the river, were plotted against corresponding median daily temperatures from the USGS station at Beaver Army Terminal near Quincy, Oregon. Figure D.2 indicates an extremely strong correlation in water temperature between the two stations. Deviations from this relationship that are suggested by future monitoring data a second level of decision criteria for the AEM Plan.

Median daily temperature data from Woody Island were also plotted against corresponding data from other CORIE stations. Figures D.3, D.4, and D.5 present these plots for the CORIE stations at Cathlamet Bay North Channel, Grays Point, and Fort Stevens Wharf. It is evident from these figures that the CORIE station at Stevens Wharf is dominated by tidal influences and the other two stations are more dominated by the river flows. While it is not expected that channel deepening would alter the ocean-dominated pattern at Stephens Wharf, the potential for an alteration of the river-dominated patterns at Grays Point and Cathlamet Bay North Channel cannot be completely ruled out. Therefore, the AMT includes these kinds of analyses as part of the decision criteria. Data obtained during and after channel deepening will be added to these pre-project data plots. This will allow a visual determination of whether the new data are consistent with the pre-project patterns in temperature or if the data indicate a modification of the relative importance of tidal versus river flows for the monitored locations.

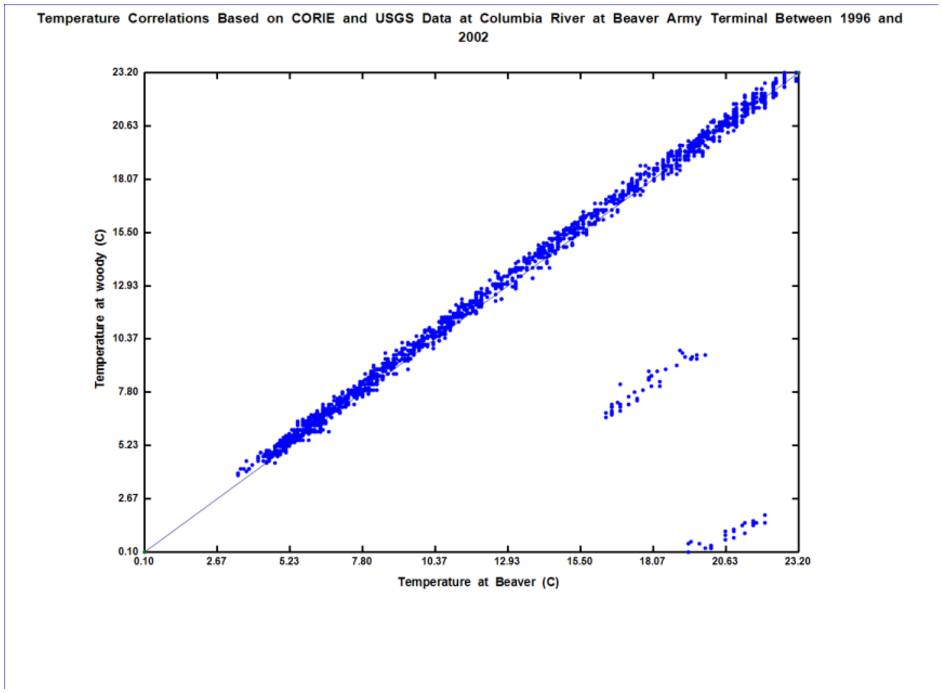

Figure D.2. Median daily temperatures (˚C) from CORIE station at Woody Island and Beaver Army Station at Quincy, Oregon.

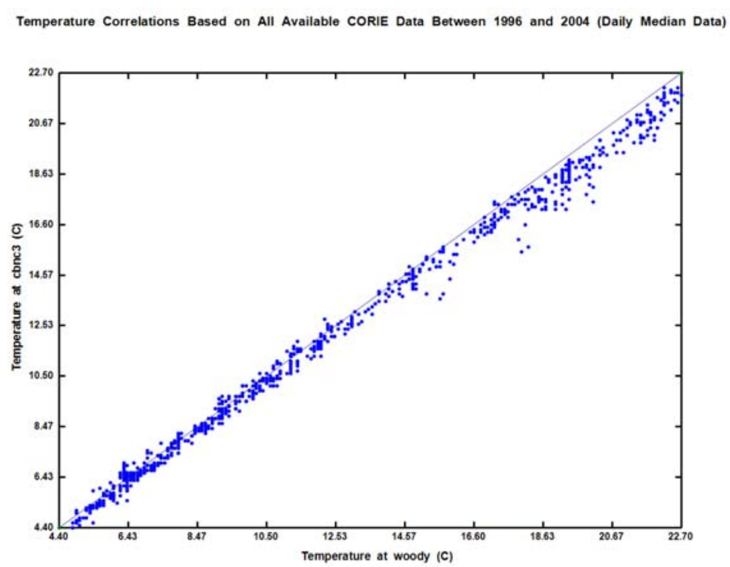

Figure D.3. Median daily temperatures (˚C) from CORIE stations at Woody Island Cathlamet Bay North Channel.

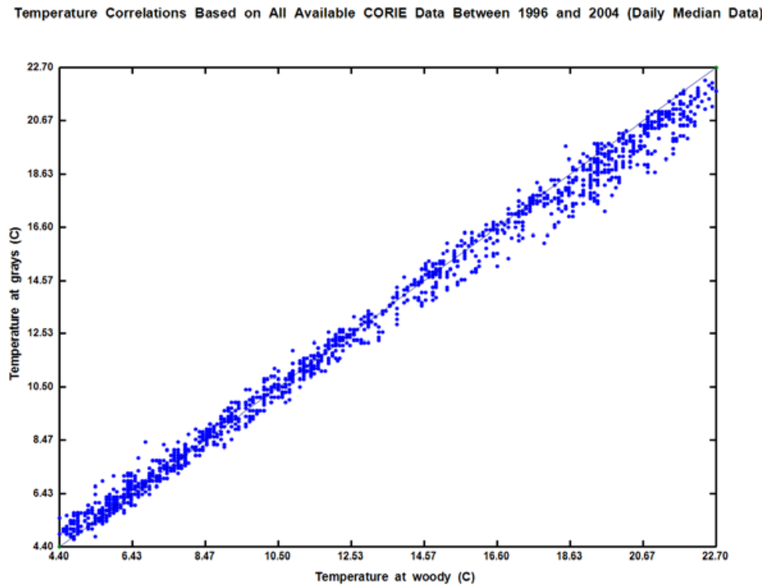

Figure D.4. Median daily temperatures (˚C) from CORIE stations at Woody Island and Grays Point.

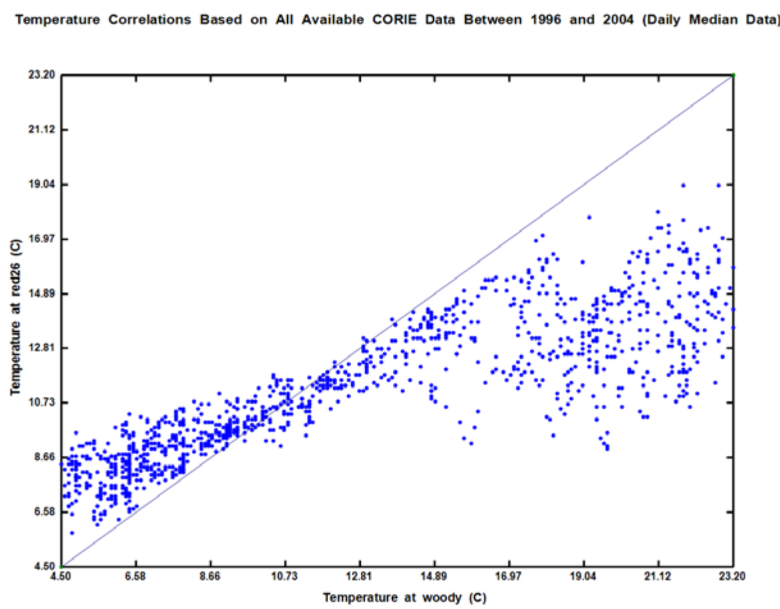

Figure D.5. Median daily temperatures (˚C) from CORIE stations at Woody Island and Stevens Wharf.

Salinity

Tables D.6 and D.7 list the salinity percentile estimates that correspond with the decision criteria developed for depth and temperature. The salinity values in these CORIE summaries are consistent with expectations. The stations nearer the mouth of the river (e.g., sandi, dsdma, red26, and tansy) show elevated salinities compared to stations less influenced by tidal circulation (e.g., grays, eliot, sveni, cbnc3). Salinities are higher in general for July–November period when river flows are lower and tidal influences are stronger. Deviations from these values in association with channel improvements will be used to justify an adaptation of the project in accordance with the proposed AEM Process.

Table D.6. Decision criteria for salinity measured as psu based on 20- and 80-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	2.3	11.0	0.7	8.1	1.0	7.0	1.2	6.3	2.6	7.7	4.3	9.6
sandi			9.8	27.8	7.6	26.4	6.0	27.0	7.0	26.6	7.2	27.2
dsdma	10.1	26.9	6.1	25.0	5.2	24.4	5.0	24.5	4.6	23.2	4.2	24.9
red26	5.3	25.5	5.8	26.1	5.1	24.9	4.5	25.3	4.3	25.0	4.4	26.5
tansy	4.2	23.9	3.7	23.4	3.4	21.5	3.0	23.0	2.7	22.9	1.7	22.9
yb101												
lwsck												
yacht												
am169	0.9	17.9	1.0	19.1	0.5	17.2	0.5	17.8	1.0	17.0	0.3	16.4
am012												
grays	0.3	1.2	0.3	0.8	0.3	0.8	0.3	0.7	0.3	0.7	0.3	0.7
ricei												
eliot	0.3	0.7	0.2	0.7	0.2	0.7	0.3	0.6	0.3	0.6	0.2	0.6
woody									0.0	0.6	0.0	0.6
marsh	0.2	0.6	0.2	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6
sveni	0.0	0.7	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6
cbnc3	0.2	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.2	0.7	0.0	0.7
mottb	0.0	0.8	0.0	1.8	0.0	0.8	0.2	5.7			0.0	0.6
coaof	0.0	2.1	0.2	2.9								

	July		August		September		October		November		December	
Station	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile	20-%ile	80-%ile
chnke	6.9	11.0	6.7	10.9	9.1	14.1	7.8	14.3	5.1	12.6	3.1	15.1
sandi	12.0	29.2	13.4	28.5	14.2	28.9	14.9	29.5	14.3	29.9	15.5	29.9
dsdma	8.1	27.3	9.7	27.8	12.8	27.8	13.2	27.4	11.6	27.3	5.4	24.2
red26	12.8	28.1	10.5	28.0	12.5	27.9	12.8	27.6	11.1	26.7	7.2	26.3
tansy	3.8	25.1	8.7	26.3	10.4	26.0	10.7	26.0	6.8	23.9	5.9	24.6
yb101												
lwsck												
yacht												
am169	7.5	23.0	6.3	23.4	7.6	22.2	8.2	22.3	7.0	22.1	1.7	21.2
am012												
grays	0.3	2.4	0.5	2.4	0.8	4.4	0.7	3.7	0.5	2.7	0.3	0.8
ricei												
eliot	0.7	0.7	1.0	0.7	0.3	1.1	0.3	0.8	0.2	0.7	0.2	0.7
woody	0.0	0.6	0.0	0.6								
marsh	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6	0.0	0.6
sveni	0.0	0.6	0.0	0.7	0.0	0.7	0.0	0.7	0.0	0.7	0.0	0.7
cbnc3	0.2	1.7	0.2	2.5	0.4	3.5	0.2	7.0	0.2	2.2	0.2	0.7
mottb	0.7	12.8	1.0	12.2	3.2	14.8	1.8	15.0	1.5	12.8	0.0	11.2
coaof	1.0	4.7	1.2	6.2	1.2	7.9	0.7	4.5	1.0	5.4	0.5	3.7

Table D.7. Decision criteria for salinity measured as psu based on 5- and 95-percentile values calculated from available CORIE data between 1996 and 2004.

	January		February		March		April		May		June	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	0.8	13.0	0.2	13.0	0.2	8.7	0.2	8.6	0.5	9.5	2.2	13.7
sandi			5.0	29.9	4.1	29.1	3.0	29.3	3.8	29.6	3.8	30.3
dsdma	6.0	28.6	1.0	27.7	2.8	27.5	2.6	27.5	2.0	26.0	1.6	28.2
red26	2.3	28.5	2.4	28.6	2.0	27.8	1.6	27.9	2.0	27.9	1.5	29.3
tansy	1.2	27.3	1.2	26.7	1.2	25.5	1.2	26.6	1.2	26.5	0.7	27.2
yb101												
lwsck												
yacht												
am169	0.2	23.2	0.2	24.5	0.2	23.0	0.2	23.8	0.2	22.9	0.2	23.5
am012												
grays	0.2	3.1	0.2	2.7	0.2	2.0	0.2	1.4	0.0	0.8	0.2	1.3
ricei												
eliot	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3	0.2	0.3
woody									0.0	0.0	0.0	0.2
marsh	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.2
sveni	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
cbnc3	0.2	2.3	0.2	2.1	0.2	3.3	0.2	1.7	0.2	0.9	0.2	1.5
mottb	0.0	8.4	0.0	10.4	0.0	10.0	0.0	10.9			0.0	0.0
coaof	0.0	4.7	0.0	5.9								

	July		August		September		October		November		December	
Station	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile	5-%ile	95-%ile
chnke	5.5	12.5	3.2	13.6	5.3	16.2	2.9	17.0	1.0	16.0	0.9	19.6
sandi	7.9	30.9	10.0	30.2	9.9	30.7	9.9	30.9	10.1	31.1	9.8	30.9
dsdma	4.4	29.8	5.7	30.1	8.6	29.8	9.1	29.1	6.8	29.4	2.1	27.6
red26	6.9	29.9	6.2	30.0	8.1	30.0	8.1	29.4	6.2	29.0	3.1	28.7
tansy	1.6	28.4	3.5	28.9	4.8	28.6	5.0	28.2	3.3	26.9	2.4	27.6
yb101												
lwsck												
yacht												
am169	3.1	26.0	2.2	27.1	3.3	26.6	3.3	26.3	2.5	25.6	0.3	25.0
am012												
grays	0.3	5.5	0.3	4.4	0.5	6.9	0.4	6.2	0.3	4.8	0.3	2.2
ricei												
eliot	0.2	0.9	0.3	6.4	0.3	10.3	0.3	9.5	0.2	1.9	0.2	0.3
woody	0.0	0.0	0.0	0.2								
marsh	0.0	0.3	0.0	0.4	0.0	0.3	0.0	0.3	0.0	0.3	0.0	0.3
sveni	0.0	0.3	0.0	0.3	0.0	1.9	0.0	1.6	0.0	0.2	0.0	0.7
cbnc3	0.2	4.5	0.2	6.3	0.2	9.3	0.2	12.3	0.2	5.3	0.2	2.0
mottb	0.3	18.3	0.3	19.1	0.5	20.5	0.3	19.7	0.3	16.8	0.0	16.7
coaof	0.4	8.7	0.5	10.1	0.5	11.6	0.4	8.2	0.4	8.9	0.2	6.9

Numbers of Samples

The quality and quantity of the available data influence the estimation of the empirically derived decision criteria. The continuous nature of the CORIE monitoring effort provides a large number of measurements for use in estimating the percentile values selected as decision criteria for MA-1. Tables D.8 through D.10 list the number of measurements that were used to estimate the criteria for depth, temperature, and salinity for each month. Values of zero identify gaps in the data record for each station and parameter. Gaps in the data occur for various reasons, including instrument failure and biofouling. To address potential problems associated with data quality in producing biased estimates of the decision criteria, the CORIE measurements undergo a rigorous quality assurance/quality control evaluation before the data are made available for analysis (see http://www.ccalmr.ogi.edu/CORIE). This evaluation includes the analysis of reported measurements to identify likely extreme values (perhaps resulting from biofouling). Potentially erroneous values are removed from the data made publicly available for analysis.

Table D.8. Number of reported CORIE measurements of water depth between 1996 and 2004.

Station ID	January	February	March	April	May	June	July	August	September	October	November	December
chnke	5,031	4,266	5,636	6,721	4,527	3,435	10,616	13,444	12,041	11,521	9,473	4,970
sandi	45,408	9,179	35,686	72,556	13,967	1,484	2,127	0	0	0	10,957	28,269
dsdma	43,843	24,015	8,270	69,497	119,075	78,743	56,950	33,180	44,435	36,421	5,692	8,919
red26	37,913	26,384	79,426	79,227	47,206	50,725	41,155	35,444	5,557	26,566	40,807	41,480
tansy	236,375	250,328	247,127	268,164	239,353	174,112	179,712	202,392	198,763	216,240	168,468	159,412
am169	5,311	9,139	42,616	9,057	0	0	0	0	75,682	47,430	19,304	509
grays	196,048	193,501	187,774	227,489	249,235	214,412	233,710	213,446	228,775	211,757	243,353	211,712
eliot	129,402	119,461	116,713	126,117	132,278	122,439	160,331	200,489	181,331	130,920	151,600	85,468
woody	147,844	207,517	220,658	259,894	245,221	178,994	147,501	161,289	173,584	131,403	171,073	183,942
marsh	69,937	44,272	65,115	69,783	43,914	45,313	44,055	86,005	79,271	97,227	115,789	83,245
sveni	141,945	134,406	141,814	135,738	139,612	129,513	106,169	132,782	134,829	150,661	145,846	132,932
cbnc3	0	2,699	40,407	58,579	37,377	22,346	18,699	0	0	0	0	0
mottb	82,293	77,553	85,587	84,185	152,967	129,149	120,493	110,488	69,041	58,938	61,120	61,792
coaof	76,680	75,796	72,105	74,784	89,714	91,807	61,634	73,660	72,467	101,287	102,860	99,392

Table D.9. Number of reported CORIE measurements of water temperature between 1996 and 2004.

Station ID	January	February	March	April	May	June	July	August	September	October	November	December
chnke	30,850	9,607	7,366	41,357	28,554	40,138	24,336	13,845	38,243	41,906	38,456	40,772
sandi	143,094	167,471	194,201	195,569	151,717	72,490	75,324	75,217	94,735	112,115	121,194	151,337
dsdma	176,664	164,158	138,492	183,785	258,016	270,112	265,112	246,023	224,275	280,923	237,534	235,938
red26	175,009	160,296	246,247	242,222	220,079	237,804	242,924	222,262	216,953	271,253	292,526	293,796
tansy	400,565	380,684	404,549	361,400	376,048	290,844	235,471	276,389	324,588	329,196	325,824	290,164
am169	104,505	129,889	132,741	134,065	132,265	144,944	122,913	127,087	199,994	224,441	172,559	167,943
grays	207,790	200,805	203,803	240,277	249,266	214,713	239,567	225,937	235,905	229,897	250,651	217,338
eliot	131,724	120,019	118,790	126,582	132,743	123,738	169,385	208,701	192,266	202,236	200,437	169,484
woody	207,766	262,510	271,528	325,112	288,761	222,538	186,019	233,532	214,290	158,055	182,633	200,101
marsh	97,946	78,664	86,082	126,795	124,014	92,920	121,850	129,017	138,334	172,007	159,813	152,833
sveni	128,201	121,569	127,846	123,878	129,681	120,229	99,391	122,527	123,245	140,091	137,116	123,653
cbnc3	98,079	124,333	145,653	158,850	142,606	126,965	120,360	121,139	137,902	128,699	138,387	110,222
mottb	126,781	118,388	128,887	157,181	204,382	195,230	181,600	209,033	177,419	177,085	153,543	169,053
coaof	76,680	77,860	77,238	84,684	96,609	114,174	104,035	110,326	75,725	101,287	105,064	105,576

Table D.10. Number of reported CORIE measurements of salinity between 1996 and 2004.

Station ID	January	February	March	April	May	June	July	August	September	October	November	December
chnke	30,865	9,607	7,366	41,357	28,553	39,324	5,944	7,129	38,049	36,989	42,878	40,772
sandi	0	33,087	67,546	74,230	63,377	58,449	69,462	9,749	45,466	75,899	45,655	20,156
dsdma	35,934	40,534	44,634	36,066	69,956	96,964	90,345	35,372	78,660	119,491	33,681	48,100
red26	96,906	122,544	133,201	128,572	86,845	74,685	102,208	102,018	133,045	168,684	169,036	140,429
tansy	131,370	118,754	131,725	79,656	123,382	107,514	47,996	63,196	51,593	85,105	42,651	88,847
am169	54,911	79,524	88,034	120,093	132,265	110,603	67,102	44,494	76,838	136,174	88,672	80,333
grays	138,854	158,007	157,606	154,511	160,760	141,831	161,893	119,465	63,248	30,903	26,688	16,554
eliot	131,724	120,019	118,790	126,582	132,743	123,738	169,385	208,701	192,266	202,236	201,901	169,484
woody	0	0	0	0	513	41,156	30,035	20,852	0	0	0	0
marsh	97,946	78,664	86,082	126,795	124,014	92,919	121,851	129,017	96,539	128,433	117,100	123,540
sveni	87,864	79,959	83,770	83,614	87,618	81,597	84,542	81,940	80,685	70,876	53,109	42,425
cbnc3	98,079	124,333	120,715	116,933	126,903	126,378	112,687	118,330	75,647	43,562	28,770	17,215
mottb	48,895	40,247	59,784	29,439	0	42,884	21,863	39,379	37,179	72,888	43,117	68,297
coaof	33,159	39,395	0	0	0	0	40,029	39,621	41,878	14,631	21,350	23,043

Decision Criteria and the AEM Process for Physical-Chemical Parameters

In the event that monitored daily values of water depth, temperature, or salinity in association with channel dredging are at variance with the decision criteria developed for these parameters, corresponding hypothesis tests for significant differences in the corresponding monthly average values will be performed to determine if the adaptive component of the AEM Plan should be invoked. If there are no significant differences, the monitoring and the AEM Process would continue as prescribed in the AEM Plan.

If there are significant monthly differences, the following analyses, for example, could be undertaken to help understand the differences determined by the MA-1 monitoring:

1. MA-1 data for the variable(s) that exceeded the percentile criteria will be further analyzed for the potentially impacted monitoring station to determine if the differences can be explained by unusual changes in natural (e.g., tides, precipitation) or managed (e.g., Bonneville Dam operations) processes that contribute to the overall variability in the monitored physical-chemical parameters at the station.

2. MA-1 data that exceeded the criteria will be analyzed in relation to corresponding values for one or more nearby monitoring stations (e.g., stations located more seaward and more inland). The analyses will be used to determine if similar trends in the parameter(s) of interest can be established at nearby locations. This evaluation would complement the analyses in Step 1 of the AEM Plan to determine if unusual variability at the MA-1 station might reasonably be reflected in nearby locations as well. If the analyses suggest that nearby stations are responding similarly to changes in natural or managed processes as the MA-1 station, the AEM Process would continue with normal MA-1 monitoring. If, however, natural or managed processes cannot satisfactorily explain observed significant monthly differences at the MA-1 stations and further analyses also indicate similar differences in nearby locations, then, current or future Project activities might be modified in accordance with the AEM Plan.

These and other analyses (e.g., modeling) could be used to examine the likelihood that any measured monthly differences constitute "false positives" in relation to the AEM Plan. If the variances suggested by the decision criteria can be satisfactorily explained in terms of unusual natural variability, such as a shift in climatic conditions, or regulation of flows at Bonneville Dam, the differences would be classified as "false positives" and no further action would be required by the AMT. Under these circumstances, the AEM Plan prescribes a return to the basic MA-1 monitoring. However, if significant differences cannot be explained by naturally varying or managed conditions, the likelihood of impacts due to channel dredging would not be dismissed and further consideration of adapting the dredging (e.g., scheduling) would be undertaken as directed by the AEM Plan.

Higher-Order Decision Criteria

In addition to considering decision criteria developed individually for each of the parameters described previously in this report, it is possible to derive criteria that attempt to quantify possible impacts of channel improvement in a more integrated fashion. Decision criteria developed to detect changes in the functional interrelationships of processes fundamental to the ecological function of the river and estuary represent higher-order criteria.

The seasonal progression of water elevations, temperature, and salinity values are clearly influenced by the regime of river flow through the estuary, tidal forcings, and circulation within the estuary. The net result can be characterized by calculating the correlations of the monthly median values for these physical-chemical factors for each of the sampling locations. The structure (or pattern) of these correlations capture some of the interrelationships among these factors. These patterns of correlations (i.e., depth x temperature, depth x salinity, temperature x salinity) could serve as higher-order decision criteria for the CRCIP AEM Plan. Changes in the nature of these correlations measured in relation to channel improvements might well signal higher-level changes in the way these factors co-vary.

Statistical analyses performed thus far using the pre-project CORIE data suggest that despite this considerable monitoring effort, there are insufficient data to develop useful spatial-temporal correlations among the values reported for the various sampling locations, including the three stations that comprise the MA-1 effort.

3-2 MA-2 Volumes of Dredged Materials

MA-2 will provide annual dredging volumes associated with construction and operation of the 43-foot channel. Volumes will be reported for each dredging bar (~3-mile reaches). Volumes of dredged materials will be compared to projected values (e.g., Table D.11). This management action will continue through the project's duration.

One decision criterion for dredging volume is whether or not actual volumes of dredged materials exceed the volumes proposed in development of the CRCRIP. In addition, the adaptive component of the proposed AEM Plan might be initiated if the volumes of dredged materials exceed the capacity for disposal.

Table D.11. Template for decision criteria based on comparison of projected and measured volumes of dredged materials in cubic yards (cy).

Item No.	Dredging and disposal contract description	Estimated quantity (cy)	Actual dredged quantity (cy)
006	CRM 95 to RM 103+07, Oregon Rehandle, Hayden Island	835,000	
007	CRM 95 to RM 97+00, Oregon Rehandle, Increment for Gateway Disposal (optional)	500,000	
008	CRM 97 to CRM 103+07+50, Oregon Rehandle, Increment for Gateway Disposal (optional)	335,000	
009	OR Slough CRM 0+00 to CRM 1+00, Oregon Rehandle, Hayden Island (optional)	465,000	
010	OR Slough CRM 0+00 to CRM 1+00, Oregon Rehandle, Increment for Gateway Disposal (optional)	465,000	
011	CRM 103+07 to CRM 105+25, Consolidated Material	1,250,000	

Dredging and the disposal of dredged materials will be conducted in accordance with state (i.e., Washington Department of Ecology and Oregon Department of Environmental Quality) concerns regarding undesired modifications of river and estuary bathymetry. Flowlane disposal of dredged materials will be conducted in a manner to minimize potential direct (e.g., burial, behavior) or indirect (e.g., habitat disruption, food resources) impacts on smelt and sturgeon.

Table D.12 lists detailed disposal plans for dredged materials as described in Table S4-1 in the FSEIS. The implementation of each of the disposal plans can be reviewed by the AMT as part of the MA-2 evaluation process. Substantial changes in the execution of these individual disposal plans might justify adaptive management. The degree of acceptable deviations or modifications of the plans outlined in Table D.12 will have to be determined by the AMT.

3-3 MA-3 Channel Bathymetry

Potential variances between projected and actual volumes of dredged materials will be assessed through MA-2 of the CRCIP. MA-3 will evaluate potential impacts of dredging on bathymetry, and accretion/erosion of the side slopes. MA-3 will provide information to assess physical alterations to habitat caused by side-slope adjustments resulting from dredging. Adjustments to side slopes are expected to occur adjacent to the navigation channel both naturally and as a result of deepening.

The MA-3 will examine accretion/erosion and changes in bathymetry of the main channel in relation to the channel deepening. Surveys will be conducted annually for two years prior to construction, two years during construction, and three years after construction. Crossline surveys will be conducted within a December–February time period to coincide with the end of the dredging season. Surveys will be conducted along the navigation channel from Columbia River mile (CRM) 3 to CRM 106. Statistical analyses will produce estimates of mean and median depth at each sampled location across the channel; minimum and maximum values as well as standard deviation and coefficients of variation will also be determined.

The consensus AMT decision criteria for MA-3 are defined as an "envelope" calculated as the minimum surveyed depth +1 standard deviation and the maximum depth +1 standard deviation. The envelope is defined across the channel for each survey with particular emphasis on the northern and southern boundaries of the navigation channel. Changes in bathymetry which exceed the criteria defined by these envelopes will be evaluated by the AMT to determine the need for possible modifications to the Project, as summarized in the AEM Plan.

3-4 MA-4 Habitat Surveys

MA-4 will augment the estuary habitat surveys being conducted by NMFS as part of the Anadromous Fish Evaluation Program (AFEP) (Bottom and Gore 2001). The objective is to determine if changes in habitat result from modifications to the channel. The surveys will assess those habitats currently being studied by NMFS. The survey will also address habitat complexity, connectivity, and conveyance. Habitat-specific food availability will be quantified. The use of peripheral areas by juvenile salmonids will be measured. The survey will be conducted three years after construction.

Table D.12. Proposed Disposal Plan including beneficial use sites, ecosystem restoration and wildlife mitigation (Martin Island Embayment).

Disposal Site*	Disposal History**	Location/Name	Site Acres (rounded)	Site Capacity (cy)	Construction Disposal Volume Rounded (cy)	O&M Use for 20-year Term	43-foot O&M Disposal Volume Rounded (cy)	Total Disposal Volume Rounded (Construction and O&M)[a]	Final Height for Total Volume Placed (feet CRD)
In-water	DMMS	CRM 3-106 - 50'-65' deep, in or adjacent to channel***	NA	NA	2,000,000	20	26,000,000	28,000,000	NA
O-105.0	DMMS	West Hayden Island	102	5,750,000	600,000	20	3,900,000	4,500,000	60
W-101.0	New	Gateway	40	2,300,000	587,000	20	1,600,000	2,300,000	65
W-97.1	DMMS	Fazio Sand & Gravel	27	650,000	112,000	20	1,000,000	1,200,000	Varies due to resale
W-96.9	New	Adjacent to Fazio	17	475,000	0	6-20	As needed	Varies	Varies due to resale
O-91.5	New	Lonestar	45	5,350,000	900,000	20	3,200,000	4,400,000	NA; gravel pit
O-87.8	New	RR Corridor	12	540,000	300,000	20	0	400,000	46
W-86.5	Used	Austin Point	26	1,645,000	136,000	20	1,500,000	1,700,000	Varies due to resale
O-86.2	Used	Sand Island	28	1,250,000	150,000	20	860,000	1,000,000	Shoreline; varies due to erosion
O-82.6	Used	Reichold	49	1,285,000	320,000	20	2,300,000	2,600,000	Varies due to resale
W-82.0	Used	Martin Bar	32	1,500,000	46,000	20	700,000	760,000	51
W-80.0	New Mitigation Site	Martin Is. Mitigation	16	550,000	370,000	Not used	0	460,000	-8
O-77.0	Used	Lower Deer Island	29	1,498,000	440,000	20	700,000	1,200,000	44
O-75.8	DMMS	Sandy Island	30	1,100,000	120,000	20	860,000	1,000,000	42
W-71.9	Used	Northport	27	900,000	189,000	20	1,800,000	1,900,000	Varies due to resale
W-70.1	Used	Cottonwood Is.	62	3,200,000	240,000	20	1,300,000	1,500,000	49
W-68.7	DMMS	Howard Island	200	6,400,000	0	20	600,000	600,000	29
O-67.0	Used	Rainier Beach	52	1,095,000	450,000	20	2,400,000	3,000,000	65
W-67.5	Used	International Paper	29	1,000,000	140,000	20	2,700,000	2,900,000	Varies due to resale
O-64.8	DMMS	Rainier Industrial	53	2,235,000	270,000	20	2,400,000	2,700,000	64
O-63.5	DMMS	Lord Island Upstream	25	1,255,000	0	20	600,000	600,000	63
W-63.5	Used	Reynolds Aluminum	13	500,000	180,000	20	0	200,000	Varies due to resale
W-62.0	New	Mt. Solo	47	2,500,000	300,000	20	2,100,000	2,400,000	49
W-59.7	DMMS	Hump Island	69	1,500,000	400,000	6	900,000	1,500,000	42
O-57.0	DMMS	Crims Island	46	1,600,000	30,000	20	1,100,000	1,200,000	40

Table D.12. Proposed Disposal Plan including beneficial use sites, ecosystem restoration and wildlife mitigation (Martin Island Embayment). (Continued).

Disposal Site*	Disposal History**	Location/Name	Site Acres (rounded)	Site Capacity (cy)	Construction Disposal Volume Rounded (cy)	O&M Use for 20-year Term	43-foot O&M Disposal Volume Rounded (cy)	Total Disposal Volume Rounded (Construction and O&M)a	Final Height for Total Volume Placed (feet CRD)
O-54.0	Used	Port Westward	50	1,875,000	150,000	20	1,500,000	1,700,000	46
W-46.3/ 46.0	DMMS	Brown Island	72	4,700,000	1,200,000	20	3,400,000	4,700,000	66
W-44.0	New	Puget Is. (Vik Prop.)	100	3,500,000	500,000	20	2,700,000	3,300,000	41
O-42.9	DMMS	James River	53	1,280,000	240,000	20	830,000	1,070,000	39
O-38.3	DMMS	Tenasillahe Island	42	2,300,000	0	10	2,300,000	2,300,000	60
O-34.0	DMMS	Welch Island	42	446,000	0	3 (18-20)	400,000	400,000	25
W-33.4	Used	Skamokawa	11	250,000	0	As needed	varies	varies	Shoreline; varies due to erosion and resale
O-27.2	DMMS	Pillar Rock Island	56	2,555,000	0	20	1,000,000	1,000,000	34
	New Restoration	Miller-Pillar Ecosystem Restoration Feature	235	5,500,000	0	15	5,500,000	5,500,000	Surveyed reference (tidal marsh & intertidal flat) elev.
O-23.5	DMMS	Miller Sands	151	NA	0	20	7,000,000	7,000,000	Shoreline; varies due to erosion
W-21.0	DMMS	Rice Island	228	5,500,000	0	20	5,500,000	5,500,000	53
	New Restoration	Lois Island Embayment Ecosystem Restoration Feature	191	6,200,000	4,000,000	20	2,000,000	6,000,000	Surveyed reference (tidal marsh) elev.
Shallow Water Site	Used	Ocean	580	NA	MCR O&M(1)	20	0	0	NA
Deep Water Site	New	Ocean	8,980	225,000,000	0	20	0	0	NA

1. Between 2.0-2.5 mcy per year in Site E and North Jetty Site per year.
2. Construction plus 20 years channel project only; additional material from MCR operations and maintenance (O&M) as needed. 50-year volume 37 mcy.
***** "W" and "O" refer to the Washington or Oregon shoreline. The number refers to the approximate river mile on the navigation channel.
****** DMMS = site is in the No Action Alternative (existing 40-foot channel maintenance) New = site is new for this study Used = site previously used by Corps for disposal
*** Disposal would occur in depths over 65 feet at CRM 5, 29-35, 36.5-37.5, 39-40, 54-56.3, and 72.2 - 73.2 a - Total includes 40-foot O&M volume that is included in material dredged with 43-foot construction material.

Threshold values of change (i.e., decision criteria) will be defined for each habitat type. Measures that exceed any of the decision criteria may result in adaptation to current management actions.

3-5 MA-5 Sediment Contaminants

The MA-5 will include the review of sediment chemistry data to evaluate the potential impacts of channel deepening on the exposure of aquatic organisms to toxic contaminants. The SEDQUAL database will be reviewed annually to determine if there are areas affected by CRCIP that would require additional sampling and analysis. This will ensure that the channel construction does not disturb undetected deposits of fine-grained material, potentially causing redistribution of contaminants that could pose a risk to salmonids and trout. The USACOE, the USFWS, and the NMFS will annually review any new sediment chemistry from the LCR and estuary from sources such as the SEDQUAL database and known permit applicants and determine if there are any changes in the "Management Area Ranking" as defined in the DMEF manual. This management action will occur 2 years before construction, 2 years during the construction period, and annually during maintenance

3-6 MA-6 Fish Stranding

MA-6 addresses the potential impacts of channel improvements on fish stranding by commercial vessels navigating on the LCR and estuary.

Frequency and Probability of Stranding

The proposed decision criteria are based on comparisons of pre- and post-project numbers of stranded fish and associated estimates of the probability of fish stranding. An increase in the probability of fish stranding following channel improvements will initiate the adaptive components of the CRCIP AEM Plan. An important consideration in developing these decision criterion lies in establishing a statistical difference between pre- and post-project fish stranding probability. Table D.13 summarizes the results of intensive field studies aimed at understanding the potential for fish stranding by commercial navigation in the Columbia River and estuary (Pearson et al. 2005). The studies suggest site-specific differences in the frequency of vessel passages that result in fish stranding. On average across all three locations, approximately 26% of the vessel passages were associated with stranding events. This frequency ranged from ~18 to 30% for these three locations. If corresponding post-project stranding frequencies are statistically greater than the values summarized in Table D.13, it would prove reasonable and prudent to follow the adaptive components of the AEM Plan and attempt to determine the likely cause for the measured increase. The feasibility in performing these statistical comparisons will be determined by (1) the quantitative nature of the previous and continuing measures of fish stranding; (2) the statistical design of MA-6 for the collection of appropriate post-construction fish stranding data and (3) the application of a complex, multivariate statistical model. This model forecasts the likelihood of stranding events in relation to local site characteristics, river conditions, fish availability, and commercial vessel characteristics (Pearson et al. 2005).

Table D.13. Summary of stranding events and mean number of fish stranded (Pearson et al., 2005).

Site	Number of events	Percent of total events	Mean number of fish stranded	Percent of total fish stranded
Barlow Point	26	56.5	14.9	53.6
County Line Park	6	13.1	7.3	26.3
Sauvie Island	14	30.4	5.6	20.1

Fish Susceptibility to Stranding

In addition to potentially changing the frequency of fish stranding events, channel modifications in the Columbia River and estuary might alter the susceptibility of different fish species to stranding. Pearson et al. (2005) estimated the relative percentage of 16 species commonly collected in the locations of the stranding studies (Table D.14). (Two unidentified trout and salmonids from Pearson et al. (2005) were not included in Table B.14.) The results of seining indicated that the relative abundance of fish subject to stranding was dominated by three-spine stickleback, peamouth chub, American shad, and age 0+ chinook salmon. The relative abundances of these species among the stranded fish were also calculated. Dividing the relative frequency of stranding by the relative abundance produced a ratio that defines the susceptibility for each of the 16 species (Table D.14). Ratios greater than 1.0 indicate greater susceptibility to stranding. That is, the species is proportionally over-represented among the stranded fish compared to its relative availability. In contrast, susceptibility ratios less than 1.0 indicate some ability of the species to reduce its likelihood of stranding.

Bass (fry) were the most susceptible of the 16 species to stranding by commercial vessel passage. Coho, mountain whitefish, and age 0+ chinook were also susceptible. The remaining species demonstrated some capability to avoid stranding. The susceptibility ratios can also serve as decision criteria for fish stranding in the AEM Plan. Potential modifications in fish habitat and changes in fish behavior associated with channel modifications could increase the local availability or susceptibility of these (or other) species. If post-project susceptibility ratios increase significantly compared to those reported in Table D.14, the AEM Plan should be followed to determine the likely reason for the increases.

Table D.14. Relative susceptibility of different fish species to stranding (Pearson et al. 2005).

Species	Percent stranded	Percent of catch	Susceptibility ratio
0+ Chinook	81.9	49.1	1.7
1+ Chinook	0	0.6	0
Chum	1.5	1.6	0.9
Coho	1.3	0.2	6.5
Mountain whitefish	1.5	0.4	3.8
Threespine stickleback	7.7	21.6	0.4
American shad	0.8	6.4	0.1
Banded killifish	1.3	1.4	0.9
Yellow perch	0.4	2.3	0.2
Bass (fry)	1.0	0.1	10.0
Lepomis sp.	0.2	0	-
Crappie	0.2	0	-
Peamouth chub	1.7	15.1	0.1
Northern pike minnow	0	0.1	0
Sculpin	0	0.3	0
Starry flounder	0.2	0.4	0,5

D.4 Decision Criteria for Other Important Species

The AEM Plan focuses on the potential risks posed by channel improvements to juvenile salmonids. However, other important ecological resources are also of concern in implementing the plan. Accordingly, decision criteria are proposed to assess possible impacts of channel modifications on sturgeon, smelt, and Dungeness crab. The nature of these criteria differs conceptually from those developed in relation to MA-1 through MA-6. The AEM decision criteria for the monitoring actions are dynamic and flexible, and are evaluated within the context of the overall AEM Plan. In contrast, the decision criteria for the following resources are derived mainly as administrative constraints imposed by key stakeholders in the AEM Process. These resource criteria are evaluated as issues of compliance in the AEM Process rather than as flexible or adaptable criteria.

The following sections outline the compliance-based decision criteria developed for sturgeon, smelt, and Dungeness crab. These criteria largely take the form of specific administrative constraints, several of which have been addressed by previous and continuing studies. The results of these studies could be used to determine the importance (i.e., relevance, weight) of decision criteria for these resources in the overall implementation of the CRCIP AEM Plan.

4-1 Sturgeon

Criteria to protect sturgeon as part of the AEM Process address the possible CRCIP impacts on the mortality, movements, feeding behavior, and habitat utilization of these fish in relation to the dredging process and the disposal of dredged materials. Development of such criteria entails the statement of possible impacts of concern, and an associated management response for each impact. The first column in Table D.15 lists the potential impacts on sturgeon that are of concern in the AEM Plan. Column two describes the associated desired management responses to these possible impacts. These actions emphasize the selection of alternative methods for dredging if significant impacts are observed. In addition, the dredging schedule could be modified to minimize impacts on sturgeon.

The third column in Table D.15 briefly describes the results of field monitoring studies of 20+ individual sturgeon (Parsley and Popoff 2004). These investigators collected, electronically tagged, and subsequently monitored the movements of these fish in the Columbia River and estuary. Importantly, the data suggest that individual sturgeon are not impacted by dredging or the disposal of dredged materials. These fish either did not leave areas of active dredging or disposal, or returned shortly after dredging stopped. The study results also indicated that diurnal sturgeon movements, likely associated with feeding, were not affected by dredging.

Table D.15. Decision criteria and observations of sturgeon in relation to dredging monitoring results (Parsley and Popoff 2004).

Potential impacts	Management response	Monitoring results
	Direct mortality	
1.Immediate mortality of significant numbers of fish due to burial	1. Do not dispose in area or use additional sites in future, and/or modify schedule to minimize impact	
2. Delayed mortality of significant numbers of fish due to burial	2. Do not dispose in area or use additional sites in future, and/or modify schedule to minimize impact	
3. Fish survive disposal action	3. No mitigation action	3. Fish not impacted by dredging or disposal
	Disturbance	
1. Significant number of fish leave area permanently	1. Do not dispose in area or use additional sites in future, and/or modify schedule to minimize impact	
2. Significant numbers of fish leave area temporarily	2. Schedule use of site for periods of low abundance	
3. Fish do not leave area	3. No mitigation action	3. Fish did not leave area, or returned shortly
	Feeding – sturgeon feeding in site:	
1. Significant long-term effects	1. Do not dispose in area or use additional sites in future, and/or modify schedule to minimize impact	
2. Minor short-term effects	2. No mitigation action	2. Diurnal movements not affected
3. Sturgeon not feeding in site	3. No mitigation action	3. Fish possibly not feeding
	Loss of habitat	
1. Sturgeon do not use habitat after disposal	1. Do not dispose in area or use additional sites in future, and/or modify schedule to minimize impact	
2. Sturgeon return to area a short time after disposal	2. No mitigation action	2. Fish did not leave area, or returned shortly
3. Fish return to area a long time after disposal	3. No mitigation action	3. Fish possibly not feeding

In addition to the potential impacts outlined in Table D.15, there are concerns that modification of channel slopes and bedform might impact the quality and distribution of preferred sturgeon habitat. Preliminary analysis of the monitoring data suggests that these fish prefer steeply-sloped channels and rough channel bedform. Further analysis continues to examine this initial result. If confirmed, changes in bathymetry caused by disposal actions might require further examination of proposed Project dredging.

The results of the Parsley and Popoff (2004) study raise the question concerning the need for a component of the AEM Process that explores opportunities to remove resources from consideration, if it appears that channel modifications will have negligible or no measured impact. The results summarized in Table D.15 indicate that sturgeon might reasonably be excluded as a risk endpoint in implementation of the AEM Plan. Admittedly, these results are based on the monitoring of a comparatively small number of individual sturgeon. However, the degree of consistency in the general behavioral patterns recorded for these fishes questions the added value of further monitoring.

4-2 Smelt (Eulachon)

Decision criteria to minimize channel improvement impacts on smelt derive from the monitoring of flow lane disposal of dredged materials. The criteria take the form of depth constraints (43 ft.) on flow lane disposal for specified river miles (e.g., between CRM 35 and CRM 75).

Additional criteria derive from the timing of smelt out migration. Particular attention will be paid to in-water disposal, which is not permitted between the 8^{th} and 20^{th} weeks of the year throughout CRM 35 and CRM 75.

The smelt AEM criteria are perhaps best summarized as compliance measures (Table D.16).

Table D.16. Compliance measures offered as decision criteria for smelt in implementation of the CRCIP AEM Plan.
Washington
In-water disposal of dredged material will not occur in areas shallower than 43-feet between CRM 35 and CRM 75 along the Washington shoreline. These areas are defined by depths determined in the pre-construction bank-to-bank bathymetry supplemented by additional channel bathymetry.
Washington, Oregon
In-water disposal will not occur during the period of peak Eulachon out migration (between the 8^{th} and 20^{th} weeks of the year) from the identified spawning areas (CRM 35–CRM 75). If in-water disposal is essential during the period of peak out migration, then the Corps shall further study the potential for Eulachon losses as a result of dredged material disposal impacts. Appropriate mitigation measures shall be developed based on the study outcomes, as determined through an Adaptive Management Process.

4-3 Dungeness Crab

The objectives of the AEM Plan concerning Dungeness crab are to avoid or minimize entrainment mortality and burial by disposal of dredged materials. Several studies (Table D.17) were requested to determine the likely impacts of dredging and disposal of dredged materials on Dungeness crab in the Columbia River estuary (e.g., Pearson et al. 2005).

Table D.17. Requested studies and compliance issues for Dungeness crab.
Washington, Oregon
1. The Corps will conduct additional study of crab entrainment to assess seasonal variations and salinity influence on entrainment rates, and to assess differences among various class sizes (e.g. age O+, 1+, 2+).
2. The Corps shall continue with its efforts to develop a crab distribution and salinity model and shall use the best available model as a management tool for scheduling dredging and disposal in the lower estuary to avoid and minimize entrainment and adverse effects of disposal.
3. The Corps will develop and adhere to a crab mitigation strategy designed to avoid and minimize entrainment and burial of Dungeness crab. The strategy shall specify impact thresholds and compensatory mitigation contingencies for unavoidable impacts to Dungeness crab, and shall be developed through the Adaptive Management Process.
4. Hydraulic dredging at Desdemona Sands and Flavel Bar* shall be conducted during times of least Dungeness crab abundance. To determine times of least abundance, entrainment sampling as described in "Entrainment of Crab in the Columbia River Estuary: June 2002 measurements and status of Summer 2002 measurements" (Pearson, Williams, and Skalski, September 5 2002) shall be conducted at each site each time those locations are dredged using USACE equipment, for a minimum of 5 years or to the extent necessary to gather sufficient data. The resulting crab entrainment data, along with real-time flow and salinity data shall be utilized to develop a model to predict times of least abundance. *Subsequent discussions among the AMT members and crab researchers concluded that dredging will focus on Desdemona. Under this circumstance, Flavel Bar would no longer be a focal point for crab entrainment in the AEM Plan.
5. Flowlane disposal of sediment in areas supporting populations of Dungeness crab shall be limited to times of least crab abundance as determined by the model in condition B.2. The crab unavoidably buried by flowlane disposal shall be calculated. By conducting maintenance dredging during low abundance periods, sufficient avoidance of Dungeness crab shall be accomplished to mitigate those unavoidably lost.
Oregon
The Corps will conduct additional study of crab entrainment to assess seasonal variations and salinity influence on entrainment rates, and to assess differences among various class sizes (e.g. age O+, 1+, 2+).
(vi) The Corps shall continue with its efforts to develop a crab distribution and salinity model and shall use the best available model as a management tool for scheduling dredging and disposal in the lower estuary to avoid and minimize entrainment and adverse effects of disposal.
(vii) The Corps will develop and adhere to a crab mitigation strategy designed to avoid and minimize entrainment of Dungeness crab. The strategy shall specify impact thresholds and compensatory mitigation contingencies for unavoidable impacts to Dungeness crab, and shall be developed through the Adaptive Management Process specified in Condition I (1), above.
(viii) Hydraulic dredging and flow-lane disposal occurring below river mile 17 and in known or suspected areas of overall high crab abundance, shall be conducted during seasons or river conditions of least crab abundance. The seasons or river conditions of least abundance shall be determined through entrainment sampling at dredging sites correlated with real-time flow and salinity data or through application of a salinity-crab model once a final, scientifically rigorous model is available.

Field studies were undertaken from 2002–2004 to estimate the numbers of crabs entrained and killed by the dredging process. These studies also produced a model that predicts the distribution and entrainment of crab as a function of salinity (Pearson et al. 2005).

Entrainment studies were performed at several locations within the estuary, including the mouth of the Columbia River, Desdemona Shoals, Upper Sands, Miller Sands, and Flavel Bar. Estimated crab entrainment rates varied by location, age class, and study year. Entrainment rates decreased progressively upriver from the mouth of the estuary, presumably in relation to the reduced abundance of crabs. Table D.18 summarizes the 2004-entrainment estimates.

Table D.18. Crab entrainment rates (crabs/cy) estimated for 2004 (Pearson et al. 2005).

Location	Age 0+	Age 1+	Age 2+	Age 3+	All
MCR All	0.0572	0.0028	0.0210	0.0128	0.0937
MCR-1	0.0535	0.0023	0.0147	0.0179	0.0883
MCR-2	0.0445	0.0022	0.0341	0.0126	0.0934
MCR-3	0.0760	0.0042	0.0137	0.0067	0.1007
Desdemona	0.0139	0	0.0035	0.0065	0.0239
Flavel Bar	0	0.0031	0.0035	0.0046	0.0112

Estimates of entrainment rates and projected volumes of construction dredging were used to estimate numbers of entrained crabs. These entrainment mortalities were extrapolated to an expected number of lost future adults and losses to the crab fishery (Pearson et al. 2005). Table D.19 presents estimated upper and lower 95% confidence intervals for adult equivalent losses (AEL) for age 2+ and 3+ crab and loss to the fishery. These calculations were made for projected dredging volumes at selected locations. The results summarized in Table D.19 underscore the considerable uncertainty (imprecision) inherent to these estimates. Despite these uncertainties, the kinds of results presented in Table D.19 can be used as AEM decision criteria to assess crab entrainment in relation to channel modifications. Not shown in the above tables are seasonal differences in entrainment estimates. Pearson et al. (2005) present monthly estimates of entrainment rates that indicate reduced rates during the winter months when salinity values (and presumably crab abundance) are reduced in relation to higher river discharge. This seasonality in projected impacts could be used to schedule dredging activities to reduce crab entrainment.

Table D.19. Summary of crab adult equivalent losses and loss to fishery for construction dredging (Pearson et al. 2005).

	AEL Age 2+		AEL Age 3+		Loss to fishery	
Project/location	**Lower 95% CL**	**Upper 95% CL**	**Lower 95% CL**	**Upper 95% CL**	**Lower 95% CL**	**Upper 95% CL**
Dredge to 40’						
Desdemona	36,076	83,560	16,234	37,602	5,683	13,161
Flavel	0	14,874	0	6,694	0	2,343
Upper sands	0	450	0	200	0	70
Tongue Point	0	102	0	46	0	17
Total	**36,076**	**98,968**	**16,234**	**44,542**	**5,683**	**15,591**
Dredge 40’–43’						
Desdemona	28,790	66,686	12,956	30,008	4,535	10,503
Flavel	0	32,080	0	14,436	0	5,053
Upper sands	0	2,498	0	1,124	0	393
Tongue Point	0	1,350	0	608	0	213
Total	**28,790**	**102,614**	**12,956**	**46,176**	**4,535**	**16,162**
Combined Scenarios	**64,866**	**201,600**	**29,190**	**90,718**	**10,218**	**31,752**

The salinity model developed by Pearson et al. (2005) identifies 16 psu as the “bright line” value, below which crab abundance markedly decreases. Characterization of the spatial-temporal distribution of water >16 psu can be used to estimates crab abundance throughout the estuary. The model can be used, at least in a relative sense, to estimate the potential implications of alterations in the circulation patterns and associated salinities attributed to channel modifications. Previous modeling studies (e.g., Baptista et al.2005) indicate that the channel deepening might increase the intrusion of higher salinity water, especially near the channel bottom.

In addition to salinity decision criteria derived from the analysis of existing pre-CRCIP data, additional criteria might be developed through the use of a salinity–crab distribution model. This model would be designed to address potential dredging impacts on patterns of salinity that might impact Dungeness crab. The model would complement management actions aimed at assessing entrainment of crabs during dredging, as well as potential burial of crabs by flowlane disposal of dredged materials. Decision criteria developed to protect Dungeness crab should address possible differences in sensitivities among various age classes of crabs (e.g., 0+, 1+, 2+).

4-4 Sediments

Sediment management has not been formally and separately developed within the AEM Plan. However, the results of AEM monitoring actions (MA-2, MA-3 and MA-4) will provide information that can address the stated concerns regarding the disposal of Project dredged materials and potential risks posed to coastal zone resources. The data produced by these monitoring actions can be evaluated as components of a regional sediment management program. Importantly, differences between pre- and post-construction sediment characterizations within the lower river and estuary can enter into the AEM decision-making process and influence future disposal of Project-related dredged materials.

In parallel to MA-3 and MA-4 decision criteria, the assessment of potential Project impacts on sediment management will be based on comparison of pre- and post-construction sediment disposition. To permit this comparison, the Corps has implemented monitoring actions within the AEM Plan that include the following pre- and post-construction tasks. In addition, the volumes of projected and actual dredged materials that will be determined during MA-2 can enter into the assessment of Project potential impacts on sediments within the lower river and estuary.

Pre-Construction

Prior to Project construction, surveys of riverbed bathymetry and inter-tidal beach/shoreline topography will be completed. The results of MA-3 and MA-4 monitoring actions will contribute information for establishing baseline conditions. The baseline surveys will be comparable in accuracy and data point density to the 1958 and 1982 bathymetric surveys. The bank-to-bank baseline surveys will cover the estuary from CRM3 to CRM 40. Suggested methods for data collection include multi-beam bathymetry measures at high tide and airborne topographic lidar at low tide. The resulting data can be used to generate baseline maps of sediment distributions within the inter-tidal zones.

Post-Construction

Within two years following construction, bank-to-bank bathymetric surveys will be repeated from CRM 3 to CRM 18. The post-construction surveys will be of similar accuracy as the baseline surveys. However, the data density of the post-construction surveys might be reduced to approximately one-half of the baseline effort. In addition, approximately ten bank-to-bank bathymetric survey transects will be conducted at approximately 2-mile intervals from CRM 18 to CRM 40. The cross-sectional and longitudinal coverage of the post-construction data collection should permit analysis of the potential impacts of Project construction on sediment dynamics within the lower river and estuary.

The results of the pre- and post-construction surveys will be summarized and reported to the Adaptive Management Team. The report can include the results of the baseline and post-construction bathymetric surveys, aerial photography, estimated volumes of construction and maintenance dredging in the channel, and available information on river flow and sediment transport during the pre- through post-construction period.

Decisions concerning the management of sediments in relation to channel improvements will be based on comparisons of pre- and post-construction sediment distribution within the lower river and estuary. Bathymetric and estuarine habitat data collected by the Corps as part of Project monitoring actions (MA-3 and MA-4) can be used to assess temporal and spatial bathymetric changes in the estuary with respect to potential impacts on sediment budget and estuarine habitats. Should any unanticipated, negative impacts become evident, the Corps shall use the adaptive management process to determine an appropriate response.

D.5 Decision Criteria Based on Salmon Performance

The discussion has thus far emphasized the identification of physical-chemical decision criteria for a monitoring program that supports the AEM Plan (Bartell and Nair 2005). This emphasis underscores the focus of the AEM Plan on possible direct physical-chemical impacts posed by channel deepening. Again, it is presumed that the CRCIP will pose no additional indirect risks to juvenile salmonids if there are no measurable changes in the physical-chemical parameters directly affected by channel improvement (Bartell and Nair 2005). At the same time, the plan does address the potential need to incorporate decision criteria that focus more directly on juvenile salmonid performance, if variances to the agreed upon physical-chemical criteria are observed during the monitoring. MA-4 is the first step in this analysis. A comparison will be done between the data gathered on juvenile salmon abundance and habitat use by the AFEP study with the year of data to be collected three years after deepening. This is being done to verify that even if the physical parameters do not change significantly that there is no change in the biological factors.

An additional evaluation could also be done of any changes in habitat opportunity by repeating the habitat opportunity evaluation done prior to deepening. Habitat opportunity is defined as the availability (volume) of suitable estuarine habitats for salmon, often determined by physical (spatial) processes. In a sense, the decision criteria derived from a physical-chemical perspective can enter into the analysis of habitat opportunity. For example, Bottom et al. (2001) use a hydrodynamic model to estimate changes in habitat opportunity defined by water velocity and depth for pre-development times (*circia* 1880) compared to more recent conditions. Repeating this analysis could be done to further verify if there had been any changes in habitat associated with the channel deepening.