PORTLAND HARBOR RI

APPENDIX G
BASELINE ECOLOGICAL RISK ASSESSMENT

ATTACHMENT 8
EVALUATION OF MODELS USED TO PREDICT TISSUE CONCENTRATIONS

DRAFT

DO NOT QUOTE OR CITE
This document is currently under review by US EPA and its federal, state, and tribal partners, and is subject to change in whole or in part.

August 19, 2009

Prepared for
The Lower Willamette Group

Prepared by
Windward Environmental LLC

TABLE OF CONTENTS

LIST OF TABLES ii

LIST OF FIGURES iii

1.0 MODEL DEVELOPMENT FOR THE BERA 1

2.0 APPLICATION OF MECHANISTIC MODEL AND BIOTA-SEDIMENT ACCUMULATION REGRESSIONS 2

3.0 EVALUATION OF BIOMAGNIFICATION REGRESSIONS 5

3.1 General Approach 5

3.2 BMR Data Preparation 5

3.3 Model Development and Screening 6

3.4 Model Selection 6

4.0 REFERENCES 8

LIST OF TABLES

Table 1. Models Selected to Predict Tissue Concentrations in COPC-Receptor Pairs 2
Table 2. Selected BMRs for Bird Egg COPCs 7

LIST OF FIGURES

Figure 1. Laboratory-Exposed TBT BSAR and Empirical Field-Collected Clam TBT Concentrations 4

1.0 MODEL DEVELOPMENT FOR THE BERA

In the baseline ecological risk assessment (BERA), the relationships between chemical concentrations in different media were used to predict tissue concentrations. The relationship between surface sediment concentrations and biota tissue concentrations were used to predict tissue concentrations based on site-specific biota-sediment accumulation regressions (BSARs) or based on the mechanistic bioaccumulation model. The relationship between fish prey tissue concentrations and piscivorous bird egg tissue concentrations were considered in the development of biomagnification regressions (BMRs).

The mechanistic model, BSARs, and BMRs were used in the BERA as follows:

- The mechanistic model and BSARs were used in the BERA to predict benthic invertebrate and sculpin tissue concentrations from sediment concentrations for COPCs for which a relationship between co-located sediment and tissue concentrations could be established based on data collected for the BERA. The predictive models used in the BERA were selected to provide methodological consistency between BERA tissue-residue predictions and risk-based preliminary remediation goals (PRGs) for the FS. Predicted tissue concentrations were compared to tissue risk thresholds. This evaluation was conducted as an additional line of evidence (LOE) for evaluating risks to benthic invertebrates and sculpin, per EPA (2008) and is presented in Section 6.0 and 7.0 of the BERA. Predicted benthic invertebrate prey tissue concentrations were also used in the evaluation of risks to spotted sandpiper and are presented in Section 8.0 of the BERA.
- BMRs were evaluated in the wildlife section of the BERA to determine if the use of an average ratio of fish and bird egg concentrations (called a biomagnification factor [BMF]) based on Willamette River data reported in Henny (2003; 2008) to predict bird egg tissue concentrations was appropriate. Co-located fish prey tissue concentrations and osprey bird egg tissue concentrations from the Willamette River were evaluated to determine whether a relationship between these media could be characterized. This evaluation was conducted as part of the wildlife risk assessment and is presented in Section 8 of the BERA.

Details on the development of site-specific BSARs and the mechanistic model are presented in the draft bioaccumulation modeling report for the Portland Harbor RI/FS Windward (2009). Section 2.0 of this attachment presents a brief summary of how selected BSARs and the mechanistic model were applied in the BERA. Section 3.0 presents the methods used to develop bird BMRs. Section 4.0 presents the references.

2.0 APPLICATION OF MECHANISTIC MODEL AND BIOTA-SEDIMENT ACCUMULATION REGRESSIONS

BSARs and the mechanistic model were used in the BERA to predict benthic invertebrate and sculpin tissue concentrations from sediment concentrations. Per EPA's Problem Formulation (Attachment 2), the mechanistic model and BSARs were used to predict tissue concentrations from sediment concentration data at sediment sampling locations where tissue residue data were not collected. The predictive models used in the BERA were selected to provide methodological consistency between BERA tissue-residue predictions and risk-based preliminary remediation goals (PRGs) for the FS. The models are presented in the draft bioaccumulation modeling report for the Portland Harbor RI/FS (Windward 2009).

The mechanistic model was available for predicting total PCB, PCB TEQ, pesticide, and dioxin and furan TEQ concentrations. The mechanistic model is appropriate for modeling hydrophobic organic chemicals, so it was not used for modeling other COPCs. For these other chemicals, the development of site specific BSARs was attempted. Site-specific BSARs were selected for benthic invertebrate and sculpin tissue COPCs that met appropriate regression analysis assumptions, had a statistically significant positive slope ($p \leq 0.05$), and had an $r^2 \geq 0.30$. Windward (2009) presents the details of the BSAR analysis and the mechanistic bioaccumulation model.

Table 1 presents the COPCs for benthic invertebrates, sculpin, and spotted sandpiper and the models that were used to predict tissue concentrations.

Table 1. Models Selected to Predict Tissue Concentrations in COPC-Receptor Pairs

COPC	Benthic Invertebrates[a]	Sculpin	Spotted Sandpiper[b]
Metals			
Arsenic	None[c]	NA	NA
Cadmium	None[c]	NA	NA
Copper	None[c]	None[c]	None[c]
Zinc	None[c]	NA	NA
Butyltins			
Tributyltin ion	BSAR[d]	NA	NA
PAHs			
Benzo(a)pyrene	NA	NA	BSAR[e]
Phthalates			
BEHP	NA	None[c]	
Dibutyl phthalate	None[f]	NA	None[f]
PCBs			
Total PCBs	Mechanistic model	Mechanistic model	Mechanistic model

Table 1. Models Selected to Predict Tissue Concentrations in COPC-Receptor Pairs

COPC	Benthic Invertebrates[a]	Sculpin	Spotted Sandpiper[b]
PCB TEQ	NA	NA	Mechanistic model
Dioxins/Furans			
Dioxin/Furan TEQ	NA	NA	Mechanistic model
Total TEQ	NA	NA	Mechanistic model
Pesticides			
Aldrin	NA	NA	Mechanistic model
beta-HCH	NA	Mechanistic model	NA
Sum DDE	NA	NA	Mechanistic model
Total DDx	Mechanistic model	Mechanistic model	Mechanistic model

[a] Benthic invertebrate COPCs were identified for each of the following receptors: clams, crayfish, lab clam, and lab worms.

[b] Predicted COPC concentrations were developed for spotted sandpiper prey (i.e., clams and laboratory-exposed worms).

[c] Site-specific BSARs were not selected for these COPCs because these COPCs is not meet the appropriate BSAR analysis assumptions (Windward 2009), did not have a statistically significant positive slope ($p < 0.05$), and/or had an $r^2 < 0.30$.

[d] TBT BSARs were developed only for laboratory-exposed worms and laboratory-exposed clams; however, only the TBT BSAR for laboratory-exposed worms was used to predict tissue concentrations because the TBT BSAR for laboratory-exposed clams failed at predicting empirical field clam tissue TBT data.

[e] A dibutyl phthalate BSARs was developed only for field clams. None was developed for laboratory-exposed worms because data for this COPC-receptor pair did not meet the appropriate BSAR analysis assumptions (Windward 2009), did not have a statistically significant positive slope ($p < 0.05$), or had an $r^2 < 0.30$.

[f] No appropriate BSAR model could be developed because too few sediment and tissue detected concentration data pairs were available (n=5) to develop a model.

BEHP – bis(2-ethylhexyl) phthalate
BSAR – biota-sediment regression
COPC – chemical of potential concern
DDD – dichlorodiphenyldichloroethane
DDE – dichlorodiphenyldichloroethylene
DDT – dichlorodiphenyltrichloroethane
HCH – hexachlorocyclohexane
NA – not applicable; not a COPC-receptor pair
PCB – polychlorinated biphenyl
Total DDx – sum of all six DDT isomers (2,4′-DDD; 4,4′-DDD; 2,4′-DDE; 4,4′-DDE; 2,4′-DDT; and 4,4′-DDT)

A TBT BSAR was developed for laboratory-exposed clams; however, this BSAR was not used to predict tissue concentrations because it fails at predicting the empirical field clam tissue TBT data. As shown in Figure 1, the BSAR for laboratory-exposed clams in almost all cases overpredicts the empirical tissue concentration. A BSAR that is unable to predict empirical, field-collected data was judged to be an inappropriate model for predicting tissue concentrations elsewhere. Therefore, only the laboratory-exposed worm TBT BSAR was used to predict tissue concentrations and was the only information available for estimating TBT bioaccumulation in benthic infaunal consumers.

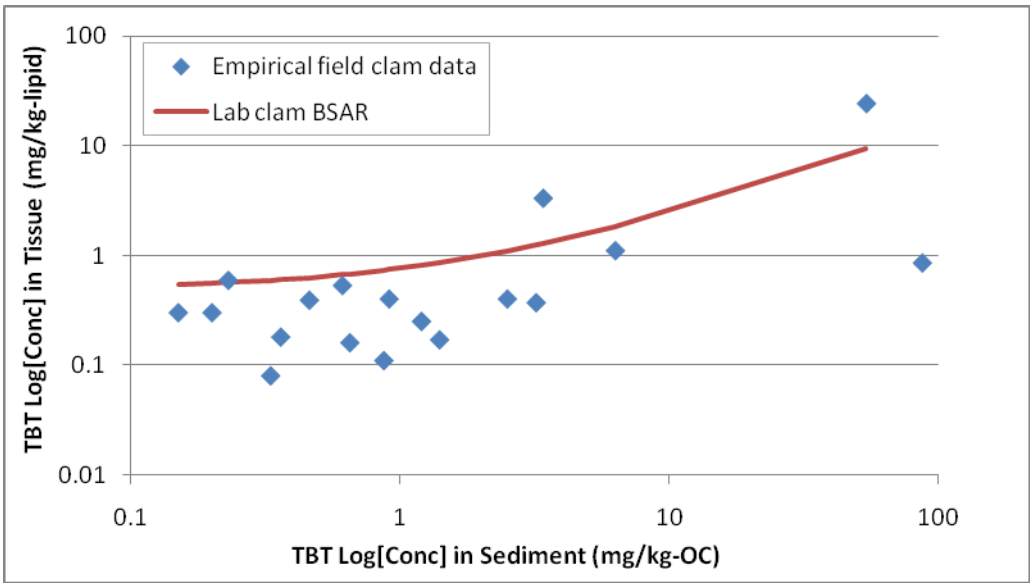

Figure 1. Laboratory-Exposed TBT BSAR and Empirical Field-Collected Clam TBT Concentrations

3.0 EVALUATION OF BIOMAGNIFICATION REGRESSIONS

BMFs are calculated as the ratio of bird egg and fish (maternal prey) concentrations. Per EPA (2008), BMFs were used in the BERA to predict piscivorous bird egg tissue concentrations from fish prey tissue concentrations. Risks to piscivorous birds were evaluated by comparing predicted bird egg concentrations to risk thresholds. The piscivorous bird receptors evaluated in the BERA were osprey and bald eagles.

BMRs (based on linear models) were developed in order to evaluate the implications of using BMFs (based on an average ratio) in the BERA. BMRs based on region- and receptor-specific data were developed in this section for total PCBs, PCB toxic equivalent (TEQ), dioxin TEQ, total TEQ, and sum DDE. BMRs were developed using co-located Willamette River osprey egg concentrations and fish prey concentrations, as reported in Henny et al. (2003).[1] The relationship between these co-located data was evaluated to determine whether a statistical relationship between fish tissue and bird egg tissue concentrations could be established.

The BMR development is presented in this section, and a discussion of whether BMFs are appropriate for predicting bird egg tissue concentrations (based on the evaluation of the Henny et al. (2003) co-located Willamette River osprey egg concentrations and fish prey concentrations) is presented in Section 8.0 of the BERA.

3.1 GENERAL APPROACH

The evaluation of BMRs was conducted using the same two-step process used to develop BSARs as informed by Burkhard (2006). In this process, several possible linear models were screened, and then a best-fit model was selected from those models that passed the screening step. This general process is described in more detail in Section 2.1.

If no model fit the data adequately to allow an estimation of egg concentrations from fish tissue concentrations for a chemical, no BMR was selected.

3.2 BMR DATA PREPARATION

LWG evaluated the data reported by Henny et al. (2003) and developed co-located osprey egg and fish prey data for the developed of BMRs. Co-located egg and fish prey were determined to be samples located roughly within 1 mile of each other. This 1-mile assumption is consistent with the home range assumed for osprey in the wildlife risk assessment (Appendix G). Any co-located data pairs with non-detected egg tissue or fish

[1] Chemical concentration data from individual fish prey composite samples and osprey bird egg samples that were used to derive Willamette-River average osprey BMRs were available from Henny (2003). Individual sample concentrations were not reported in the other study (Buck 2004) from which the mercury BMF used in the BERA was derived.

tissue concentrations were removed from the BMR analysis, so that only pairs of detected egg and detected tissue concentrations were used in the BMR evaluation.

Bird egg concentrations were plotted as the dependent variable on the Y axis, and fish tissue concentrations were plotted as the independent variable on the X axis to display the relationship between concentrations of these chemicals in osprey prey tissue and osprey egg tissue. Likewise, concentrations of chemicals in osprey eggs were used as the dependent variable in linear models and concentrations of chemicals in osprey prey were used as the independent variable.

3.3 MODEL DEVELOPMENT AND SCREENING

In the first step of the BMR evaluation process, several possible linear tissue-sediment models were screened. As with the BSAR process, only linear models were considered in this BSAR development process since data were rarely adequate to consider more complex models. The same process and criteria used to screen the BSAR models were used to screen the BMR models as presented in Section 2.3 and Figure 1.

The following linear regressions were considered in the initial screen for each dataset:

1. Untransformed egg tissue concentrations vs. fish tissue concentrations
2. Untransformed egg tissue concentrations vs. log-transformed fish tissue concentrations
3. Log-transformed egg tissue concentrations vs. log-transformed fish tissue concentrations

Any model that passed the predetermined significance and fit statistics criteria described in Section 2.3 was screened in as a potential BMR.

All BMR calculations, statistical analyses (significance levels, outlier diagnostics, and goodness-of-fit statistics), and graphical summaries were conducted in R. Statistical summaries were downloaded to a Microsoft Excel® workbook, where screening steps were performed through a series of "if-then" statements. Graphical summaries and outlier diagnostic statistics were passed to the second step of the BMR development process, the model selection step.

3.4 MODEL SELECTION

In the second step of the BMR evaluation process, the best-fit model was selected from those models that passed the screening step. Predictions of the models screened in Section 3.3 were overlaid on scatter plots of the empirical data, and the model fitting screening criteria were used to determine if models were potentially valid to represent the relationship between bird egg and dietary tissue concentrations. The same process used to select models for BSARs (Section 2.4) was used to select the models for BMR. If no model fit the data adequately to

allow estimation of egg tissue concentrations from fish tissue concentrations for a particular chemical, no BMR was developed.

Table 2 presents the best fit models chosen from the available models from the BMR screen for bird egg COPCs. A model could only be developed for total TEQ. The lack of a significant relationship for all of the bird egg COPCs with the exception of total TEQs means that if there was a relationship between the prey and egg COPC concentrations reported by Henny et al.(2003), then it was determined to be too weak to discern from the data. The results of this BMR evaluation are further discussed in the wildlife risk assessment of the BERA.

Table 2. Selected BMRs for Bird Egg COPCs

Bird Egg COPC	Selected BMR	Model	r^2
PCBs and Dioxins			
Total PCBs	No model selected[a]	NA	NA
Dioxin TEQ	No model selected[a]	NA	NA
PCB TEQ	No model selected[a]	NA	NA
Total TEQ	$C_{egg} = (C_{fish} \times 4.372) + 3.987$	linear	0.58
Pesticides			
Sum DDE	No model selected[a]	NA	NA

[a] No appropriate BMR model was selected because the linear and log linear models had either an $r^2 < 0.30$ or an insignificant slope.

BMR – biomagnification regression
C_{egg} – egg tissue concentration
C_{fish} – fish tissue concentration
COPC – chemical of potential concern
PCB – polychlorinated biphenyl
TEQ – toxic equivalent

4.0 REFERENCES

Buck J. 2004. Environmental contaminants in aquatic resources from the Columbia River. US Fish and Wildlife Service, Portland, OR.

Burkhard LP. 2006. Estimation of biota sediment accumulation factor (BSAF) from paired observations of chemical concentrations in biota and sediment. EPA/600/R-06/045. Ecological Risk Assessment Support Center, US Environmental Protection Agency, Cincinnati, OH.

EPA. 2008. Problem formulation for the Baseline Ecological Risk Assessment at the Portland Harbor Site. Report and letter dated February 15, 2008 to Lower Willamette Group (from E. Blischke and C. Humphrey to J. McKenna and R. Wyatt). US Environmental Protection Agency Region 10, Oregon Operations Office, Portland, OR.

Henny CJ, Kaiser JL, Grove RA, Bentley VR, Elliott JE. 2003. Biomagnification factors (fish to osprey eggs from Willamette River, Oregon, USA) for PCDDs, PCDFs, PCBs and OC pesticides. Environ Monit Assess 84:275-315.

Henny CJ, Kaiser JL, Grove RA. 2008. PCDDs, PCDFs, PCBs, OC pesticides and mercury in fish and osprey eggs from Willamette River, Oregon (1993, 2001 and 2006) with calculated biomagnification factors. Ecotoxicology DOI 10.1007/s10646-008-0268-z.

Windward. 2009. Portland Harbor RI/FS bioaccumulation modeling report. Draft. WW09-0003. Prepared for Lower Willamette Group. May 29, 2009. Windward Environmental LLC, Seattle, WA.