***Appendix A: The memoranda prepared by ENTRIX and presented in this appendix are working review drafts which were not edited or finalized by the Trustees.***

**Appendix A-2:**

- **A-2a**, “Models of injury assessment for the estimation of benthic service losses in Castro Cove”

- **A-2b** “Additional models for the estimation of benthic mortality in Castro Cove”

- **A-2c** “Preliminary estimation of discounted service-acre-year (DSAYs) losses in Castro Cove”

- **A-2d** The final curve selected for use in estimating amphipod mortality from TPAH concentration for each polygon in Castro Cove (originally Figure w in “Preliminary estimation of discounted service-acre-year (DSAYs) losses in Castro Cove”)

Original Author(s): ENTRIX

Distributed to the injury subcommittee in the cooperative NRDA process.

**Trustee Comments**: Total polycyclic aromatic hydrocarbon (TPAH) concentrations were used to estimate amphipod mortality and degree of injury, rather than mercury concentrations as is described in these memoranda. This is shown in the memorandum titled “Preliminary estimation of discounted service-acre-year (DSAYs) losses in Castro Cove”. The information contained in the referenced table in this memorandum on calculated DSAY estimates may be found in Appendix I6. TPAH concentrations from 0–1 foot core samples were used where they were available, and surface sample concentrations were used where the core sample data were not available. Additionally, while the “Appendix D” or “Commencement Bay Hylebos Waterway NRDA” method was not utilized, that method was intended to sum the injury from many chemicals present at that site, not utilizing one chemical as an indicator of injury as was done for this case. As a result the “Models of injury assessment for the estimation of benthic service losses in Castro Cove” memorandum shows that method “substantially underestimates amphipod mortality” when compared to the toxicity test results obtained with Castro Cove sediments. The Castro Cove Injury Quantification is presented in Chapter 3.

**E N T R I X**

## MEMORANDUM

# WORKING REVIEW DRAFT

**ENTRIX, Inc.**
2701 1st Avenue
Seattle, WA 98121
206/269-0104

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**Date:** February 23, 2006

**Re:** Models of injury assessment for the estimation of benthic service losses in Castro Cove

**Project No.** **3054545**

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## PURPOSE

The proposed approach to developing an estimate of potential of injury and service loss to Castro Cove is based on the estimation of benthic mortality. This memorandum evaluates different models of benthic mortality against the observed toxicity tests and sediment chemistry samples from Castro Cove. It will be part of the text associated with Section 3.1 of the DARP outline, "Injury Assessment Strategy and Methods."

## INTRODUCTION

Amphipod mortality toxicity results for 26 samples from the Tier II study (Table 1). ranged from 15% to 100% mortality, with an average response of 55% mortality. Mercury concentrations[1] in these samples ranged from 0.11 to 2.1 mg/kg, with an average of 0.69 mg/kg with this range spanning all surface mercury concentrations observed in surface sediments collected from Castro Cove[2].

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[1] Benthic service losses may be estimated using only mercury because its concentrations and effects are representative of other COCs; see memorandum "Chemicals of concern for service loss in Castro Cove."
[2] Estimates of benthic injuries will be based primarily of surface sediment concentrations; see memorandum "Estimation of historical sediment chemical concentrations in Castro Cove."

There is substantial variability in bioassay response at intermediate mercury concentrations. However, these mortality and concentration data are correlated (Pearson's r = 0.65) (Figure 1). Furthermore, at the lowest mercury concentrations, only low mortality values are observed and only high mortality values are observed at the highest mercury concentrations.

The amphipod mortality results were not corrected by subtraction of control mortality, and so the results include mortality that occurs simply because the experiment was conducted with Bay sediment. Accordingly, the Castro Cove toxicity test results are potentially overestimates of the mortality solely due to refinery-related contaminants. However, that potential overestimate is eliminated by subtracting theestimated effects from exposure to the average mercury concentration for regional background[3] from the modeled mortality associated with Castro Cove samples.

This method explicitly allows the unadjusted benthic mortality estimate for a given sample within Castro Cove to take any value from 0% to 100%. For those samples whose mercury concentrations are less than the regional background average, the mortality (injury) will also be less than the injury that based on the regional background average.

## MODELS

Four approaches were considered for the estimation of potential benthic injury and service loss as a function of sediment chemistry:

- EPA/NOAA's logistic regression model (LRM) approach using parameters[4] published in "Predicting Toxicity to Amphipods from Sediment Chemistry" (EPA 2005);
- A LRM with parameters estimated using amphipod mortality and sediment chemistry data collected from Castro Cove;
- A linear regression of amphipod mortality and sediment chemistry data collected from Castro Cove; and
- An approach used by the Trustees for the Commencement Bay Hylebos Waterway NRDA in Puget Sound, Washington (NOAA 2002a).

Each model is described below. In Attachment 1, more details are provided about the LRM and linear regression model.

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[3] See memorandum "Regional background chemical concentrations for Castro Cove."

[4] The LRM has two parameters that are estimated by statistical solution, based on a given set of data. These parameters are analogous to the slope and intercept of a linear regression. These linear regression parameters describe a line, and their estimates for a given set of data define a particular line that fits (*i.e.*, passes through) that set of data. For the LRM, the estimates of the model's parameters result in an equation that estimates the probability of an event (here, a significant toxicity test) based on a given chemical concentration. However, as discussed above, the LRM discusses only the probability of a significant toxicity test, not the magnitude of the toxicity response.

The LRM estimates the probability of a significant toxicity test (P value) for a given concentration of a chemical (or group of chemicals), and by extension, a toxic effect. As the EPA/NOAA (2005) report notes, the P value is correlated with mortality in toxicity tests; *i.e.*, as the estimated probability of a significant toxic effect increases, so does the bioassay mortality. The use of the LRM for injury assessment here rests on this correlation between P value and mortality.

In NOAA/EPA's (2005) report, parameter estimates of the LRM are provided for certain chemicals. These LRM parameter estimates were calculated using a database of over 3,000 tests assembled by EPA/NOAA from sediment toxicity studies across the United States. The LRM was also solved using the toxicity testing data available for Castro Cove to develop site-specific parameter estimates.

As an alternative regression approach, a simple linear regression of the proportion of amphipod mortality on sediment mercury concentration was applied to the Castro Cove toxicity data.

In the settlement for the Hylebos Waterway, the Trustees developed ranges of benthic injuries corresponding to ranges of concentrations for selected chemicals present in the sediments of Commencement Bay (NOAA 2002). These categories of concentration and natural resources injury were applied to Castro Cove data.

**RESULTS**

For each of the modeling approaches, the predicted injury may be compared to the amphipod mortalities observed in the toxicity test results (Figure 2). The NOAA/EPA LRM and site-specific LRM regression estimates are similar throughout much of the range of mercury concentration observed in the samples. The estimates based on the site-specific LRM diverges slightly from the NOAA/EPA LRM, beginning at about 0.5 mg/kg mercury, with the site-specific model estimating slightly lower mortality at higher mercury concentrations.

The linear regression model estimates slightly lower mortalities than either LRM model in the range of 0.5 to 1.5 mg/kg mercury. This difference is never more than about 5% mortality. However, at mercury concentrations above 1.5 mg/kg, the estimates from the two regression approaches differ more. For the highest mercury concentrations observed in a toxicity test sample (about 2 mg/kg), the linear regression estimates 100% mortality (which matches the observed mortality for that sample), while the NOAA/EPA LRM predicts substantially less mortality (about 83%).

The Appendix D method underestimates the observed amphipod mortality throughout the entire range of mortality and mercury concentration. It never predicts more than 20% mortality. This may be due, in part, to the difference in the intent between the Appendix D method and any of these other models. The Appendix D method expresses service loss to the benthic community in the environment, while the regression-based approaches estimate mortality of a single sensitive species in response to a given chemical concentration in a laboratory test.

## CONCLUSION

The LRM and the linear regression both “fit” the observed amphipod mortality results, although in slightly different ways. The linear regression does have the theoretical limitation that for mercury concentrations higher than about 2 mg/kg, the estimated proportion mortality would exceed 1.0 (or 100%). However, for these data from Castro Cove, the linear regression captures the higher mortalities observed better than the LRM, thereby reflecting the actual, higher, mortality of a relevant test species observed in response to mercury in sediment samples collected from Castro Cove. The observed mortality of 100% was associated with the highest mercury concentration observed in surface sediment samples (2.1 mg/kg), and therefore extrapolation beyond the range of 2.1 mg/kg mercury and 100% amphipod mortality will be unnecessary for the majority of samples and locations within Castro Cove[5].

The Appendix D service loss estimate consistently and substantially underestimates amphipod mortality, although it may be more representative of the overall benthic community service losses.

To summarize the advantages and disadvantages of the approaches to estimation of injury:

**LRM**
**Advantages**:
Published approach
**Disadvantages:**
Intended to estimate the probability of a significant toxicity effect

**LINEAR REGRESSION MODEL**
**Advantages:**
Directly estimates relationship between mortality and chemical concentration
Uses site data
Analytically simple and straightforward
**Disadvantages:**
Theoretical limitations

**Appendix D approach of Hylebos DARP**
**Advantages**:
Published injury assessment for another West Coast NRDA site.
**Disadvantages:**
Substantially underestimates observed mortalities in Castro Cove toxicity test data

[5] For 3 sampling locations (DM-18, 23, and 43), mercury concentrations at depth were substantially greater than at surface. For these locations, an interpolation between surface and 1-foot samples is proposed, and for those interpolated mercury concentrations greater than 2 mg/kg, the estimated mortality will simply be bounded at proportion = 1.0, or 100%.

For the estimation of amphipod mortality in Castro Cove, the linear regression has more advantages, and fewer disadvantages, than the other approaches considered.

**REFERENCES**

EPA. 2005. Predicting Toxicity to Amphipods From Sediment Chemistry. EPA/600/R-04/030. March 2005.

NOAA. 2002a. Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Viewed at: http://www.darp.noaa.gov/northwest/cbay/hyle-settlement.html on February 15, 2006.

NOAA. 2002b. Appendix D: Defining Injuries to Natural Resources in Hylebos Waterway *in* Hylebos Waterway Natural Resource Damage Settlement Proposal Report. Viewed at: http://www.darp.noaa.gov/northwest/cbay/hyle-settlement.html on February 15, 2006.

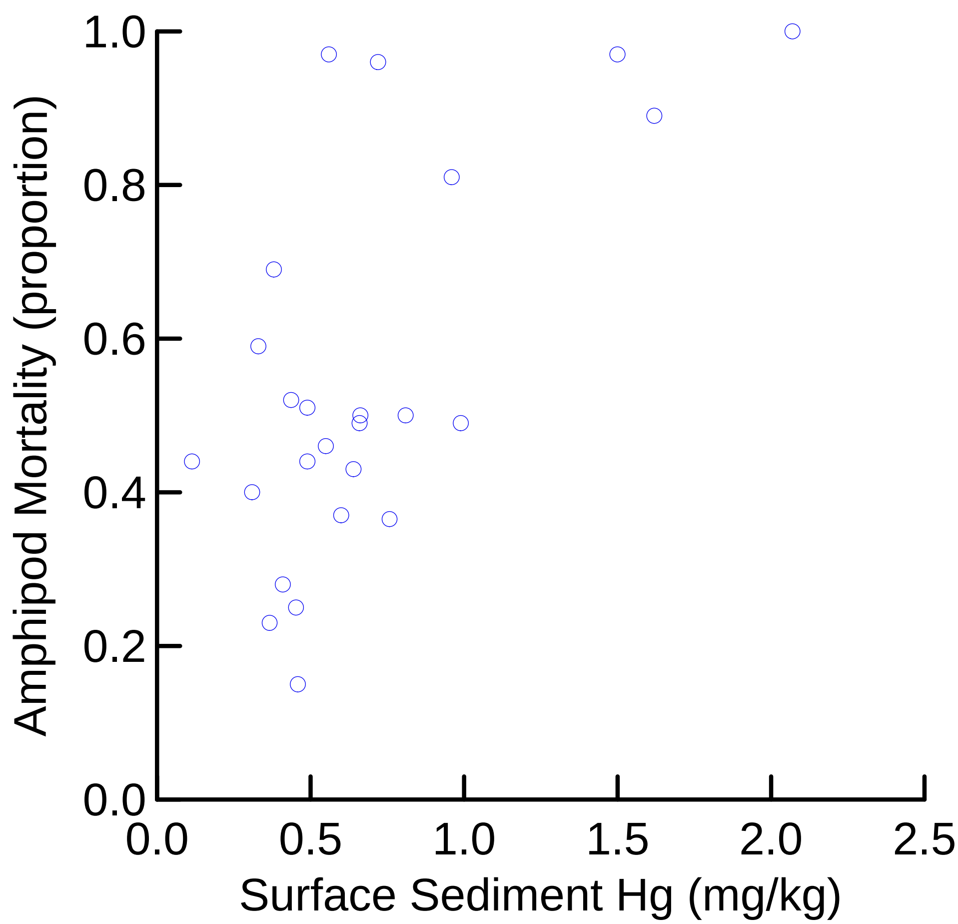


Figure 1. Scatter plot of amphipod mortality against mercury concentration for samples from Castro Cove (Pearson's correlation coefficient r = 0.65).

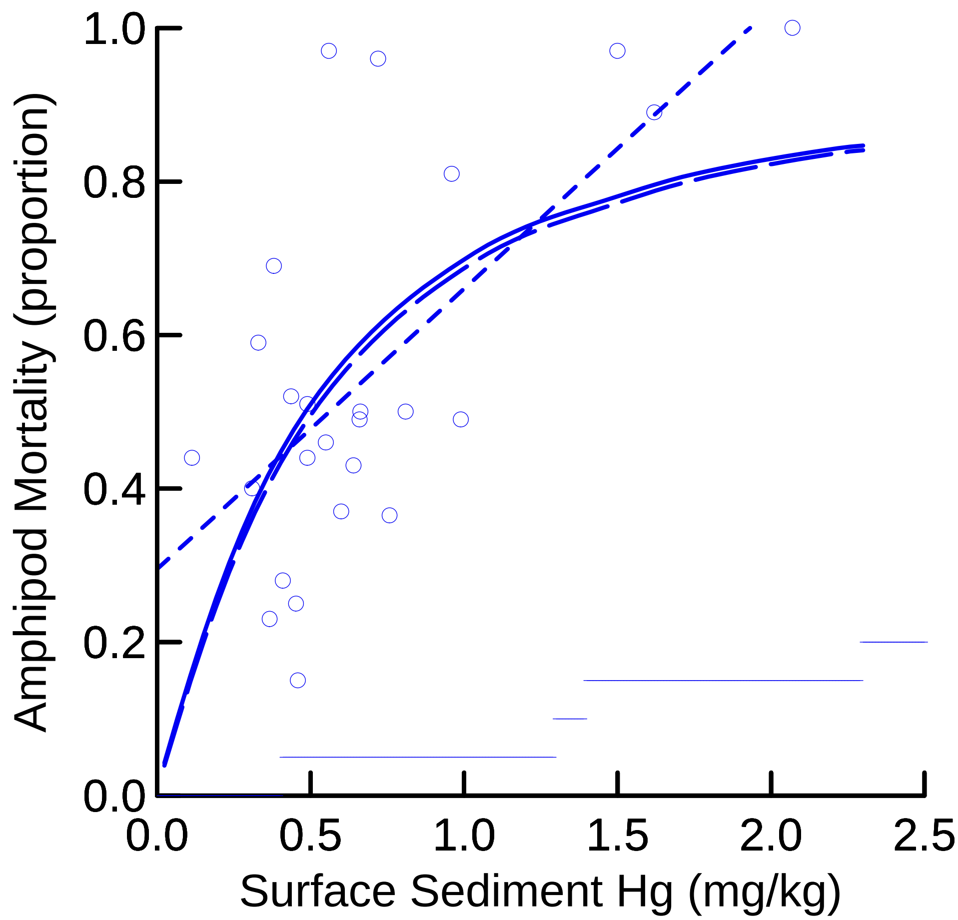


Figure 2. Comparison of injury models. Amphipod mortality and mercury concentrations in samples from Castro Cove (open circles) are compared to EPA/NOAA LRM estimates of P value (solid curved line), site-specific LRM estimates (dashed curved line), linear regression estimates (dashed straight line), and NOAA Hylebos Waterway injury categories (horizontal solid lines).

## ATTACHMENT 1: DISCUSSION OF LOGISTIC REGRESSION AND LINEAR REGRESSION MODELS

**Logistic Regression Model**
The Logistic Regression Model (LRM) is defined as follows:

**P(Y=1|X=x) = exp((a + bx)/(1 + exp((a + bx)),**

Where **P(Y=1|X=x)** is the probability that Y will take the value of 1 when the explanatory (or independent) variable X takes the value **x**. Here, Y = 0 or 1 corresponds to a non-significant or significant amphipod bioassay result, respectively. The variable **x** is the log-transformed chemical concentration. **P(Y=1|X=x)** corresponds to the P values calculated using the equations in March 2005 NOAA/EPA guidance when using the parameter estimates provided in that document (EPA 2005).

For the site-specific development of the LRM, the parameters **a** and **b** are estimated using nonlinear regression software. Amphipod moralities reported in the toxicity tests and their associated sediment sample mercury concentrations were the data used in the analysis.

There is an important distinction between the two LRMs. In the NOAA/EPA approach, the LRM estimates the probability that a certain chemical's concentration would result in a significant statistical test of toxicity, while in the site-specific approach, the LRM estimates the proportion mortality for each sample. This difference arises for two reasons. First, the NOAA document addresses the question: "if a series of toxicity tests were performed for this site, what is the chance they would result in a finding of significant toxicity?" However, the analogous question relevant to the purpose of estimating injury to Castro Cove benthos is: "what mortality (and injury) results from a given concentration of this chemical associated with the site?" Second, the site-specific data were simply too few to allow for an analysis equivalent to the NOAA/EPA approach.

The site-specific LRM estimates were an evaluation of the LRM approach in light of available site-specific data. The NOAA/EPA guidance recommends exactly this:

> "Before applying the models to a particular site, we recommend first evaluating how well the models fit the local situation by collecting a test set of matching sediment chemistry and toxicity test data…. The LRMs should not be considered a complete substitute for direct-effects assessment (*e.g.*, toxicity tests)[6]."

The site-specific data allowed both a validation of the published LRM parameters and development of an alternative LRM.

[6] Section 7.3, p. 60 of EPA (2005).

**Linear Regression Model**
The Linear Regression Model is defined here as follows:

**Mortality = a + bx,**

Where **Mortality** is the proportion of amphipod mortality observed in a particular toxicity test, **x** is the chemical concentration in the associated sediment sample, and **a** and **b** are the intercept and slope parameters, respectively, of the model.

ENTRIX

**MEMORANDUM**

# WORKING REVIEW DRAFT

**ENTRIX, Inc.**
2701 1st Avenue
Seattle, WA 98121
206/269-0104

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**Date:** March 9, 2006

**Re:** Additional models for the estimation of benthic mortality in Castro Cove

**Project No. 3054545**

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## PURPOSE

In our meeting with the Trustees on February 27, 2006, we discussed the choice of model for the estimation of benthic mortality. The Trustees have requested that we also consider the logistic growth model and a quadratic regression for that purpose. This memorandum evaluates those models in comparison to the benthic mortality models previously considered.

## INTRODUCTION

As we noted in our previous memorandum[7], these models were used to estimate amphipod mortality from sediment mercury concentration in samples from the Tier II study. The amphipod mortality results were not corrected by subtraction of control mortality, *i.e.*, the mortality results using the Tier II sediment included mortality that occurred simply because the experiment was conducted with Bay sediment and the animals were in a laboratory setting. As we noted during the meeting, we would, as a result, expect that observed and predicted mortality at very low mercury concentrations would be greater than zero. This component of the mortality is subtracted when the regional background mercury concentration is used to estimate the "but for" incremental amphipod mortality.

[7] See previous memorandum "Models of injury assessment for the estimation of benthic service losses in Castro Cove" dated February 27, 2005.

## MODELS

In the February 27, 2006 memorandum, four approaches were considered for the estimation of potential amphipod mortality as a function of sediment chemistry:

- EPA/NOAA's logistic regression model (LRM) approach using parameters published in "Predicting Toxicity to Amphipods from Sediment Chemistry" (EPA 2005);
- A LRM with parameters estimated using amphipod mortality and sediment chemistry data collected from Castro Cove;
- A linear regression of amphipod mortality and sediment chemistry data collected from Castro Cove; and
- An approach used by the Trustees for the Commencement Bay Hylebos Waterway NRDA in Puget Sound, Washington (NOAA 2002). (This model actually estimates injury and uses mortality as one of the inputs to the injury estimate).

These models are described in detail in the February 27, 2006 memorandum.

Based on discussions in February 27, 2006 meeting, two additional models are considered here: the logistic growth model (LGM) and the quadratic regression model.

### Logistic growth model

The LGM has the form:

$$\mathbf{y = 1/(1 + a*exp(bx))},$$

Where:

**y** is the proportion of amphipod mortality in a given bioassay and
**x** is the concentration of mercury in the same sediment sample used for the bioassay.

The parameters **a** and **b** are estimates for a given data set. With these parameter estimates, the model is fitted to the data. The LRM and LGM are similar in form. Both have an exponential term in the denominator,

$$\mathbf{exp(bx)},$$

And the absolute value of the parameter estimate **b** determines the maximum rate of increase in response with increase in dose. The form of the LRM is intended for modeling a "yes/no" result. In contrast, the LGM is typically used to describe the change in a proportional variable constrained between zero and one. There are several versions of this model within the family of logistic growth models, and there are several different families of sigmoidal growth models. The LGM is derived from a growth equation and is used to estimate dose-response relationships.

### Quadratic regression model

The quadratic regression is simply the linear regression plus an additional squared term allowing the model to be curvilinear:

$$\mathbf{y = a + bx + cx^2,}$$

Where:

**y** is the proportion of amphipod mortality in a given bioassay,
**x** is the concentration of mercury in the same sediment sample used for the bioassay, and
**a**, **b**, and **c** are the parameter estimates of the model.

## RESULTS

For each of the modeling approaches, the predicted amphipod mortality may be compared to the mortality observed in the toxicity test results (Figure 1). The Commencement Bay approach was not included in this figure. The NOAA/EPA LRM and site-specific LRM regression estimates of mortalityare similar throughout much of the range of mercury concentration observed in the samples. The estimates based on the site-specific LRM diverge slightly from the NOAA/EPA LRM, beginning at about 0.5 mg/kg mercury, with the site-specific LRM estimating slightly lower mortality at higher mercury concentrations.

The linear regression model estimates slightly lower mortality than either LRM model in the range of 0.5 to 1.5 mg/kg mercury. This difference is never more than about 5% mortality. However, at mercury concentrations above 1.5 mg/kg, the estimates from the two regression approaches differ more. For the highest mercury concentrations observed in a toxicity test sample (2.07 mg/kg), the linear regression estimates 105% mortality, while the NOAA/EPA LRM predicts substantially less mortality (about 83%).

The LGM yields results similar to those from either the linear regression or the LRM models in the mid-range of mercury concentrations (about 0.75 to 1.5 mg/kg). At lower concentrations, the LGM results are similar to those from the linear regression. At higher concentrations, its results are intermediate between those of the linear regression and the LRM models. In the range of about 1.5 to 2 mg/kg mercury, the LGM predicts higher mortality than either LRM, and its predictions are closer to the observed mortality in those samples whose mercury concentrations fall in this range.

In response to comments from the Trustees, the quadratic regression was applied for models both with and without the intercept. The quadratic regression with an intercept has the form:

$$\textbf{Proportion mortality} = \mathbf{a + b{*}Hg + c{*}Hg^2,}$$

Where **Hg** is mercury concentration and **b** and **c** are parameter estimates that relate mercury concentration to amphipod mortality in the toxicity test results. The parameter estimate **a** is the intercept of the equation and it represents the proportion mortality that would occur if the mercury concentration was equal to zero. For the quadratic regression *with* an intercept, the resulting model is indistinguishable from the linear regression (Figure 1).

For the quadratic regression *without* an intercept, the parameter estimate **a** is "forced" to zero, and then the remaining two parameter estimates are solved from the data. In effect, this approach forces the model solution to estimate proportional mortality to be exactly zero when the mercury concentration is zero. Like the LRM models, the quadratic regression without an intercept underestimates observed amphipod mortality in samples with low mercury concentrations. From about 0.8 to 1.7[8] mg/kg mercury, the quadratic regression model without an intercept predicts higher mortality than any other model discussed here.

The residuals (observed mortality minus predicted mortality) of the site-specific LRM and the LGM were plotted against their predicted mortality values in scatter plots (Figures 2 and 3). The plots are similar, with neither displaying apparent patterns in the residuals except that the highest residuals are associated with some of the intermediate mortality estimates. These are the toxicity test results that were noted in the February 27, 2006 meeting as potential outliers. To assess the effect of outliers, the four data points with the most extreme absolute values for their residuals in the LGM[9] were removed from the data set[10]. The LGM was then fitted to this reduced data set. The model based on the reduced data set predicted lower mortality at lower mercury concentrations, with this difference decreasing with increasing mercury concentrations. This difference is about 5% at lower mercury concentrations, shrinking to a negligible amount as mercury approaches 2 mg/kg.

To illustrate the differences among the models, their responses are compared at three different ranges of mercury concentrations.

**For mercury concentrations near zero mg/kg:** the LGM, linear regression, and quadratic regression with an intercept predict non-zero mortality. This reflects the observed data, which include control mortality. The LRMs and the quadratic regression without an intercept force the mortality to zero.

**In the intermediate range of observed mercury concentrations (around 1 mg/kg):** The quadratic regression model without an intercept generally returns the highest mortality estimate, while the LRM, linear regression, quadratic regression with an intercept, and the LGM all predict similar and lower mortality values.

**At the highest observed mercury concentrations (about 1.5 mg/kg to 2 mg/kg):** the LGM, linear regression, and quadratic regression either with or without an intercept estimate higher mortality than either LRM, thereby better reflecting the observed mortality of amphipods in sediment samples collected from Castro Cove.

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[8] Only one surface sample mercury concentration exceeds this value.
[9] The LGM was selected as a representative example.
[10] These data were associated with DM-23, 35, 46, and 47. The range of their absolute residuals ranged from 0.47 to 0.27. The choice of four data was based on examination of the quantile plot of absolute residuals.

## CONCLUSIONS

The LRMs underestimate observed mortality at both low and high mercury concentrations in the toxicity test. The predicted response mortality using the linear regression model increases proportionally with increasing mercury concentration, continuing to do so even beyond 100% mortality. The quadratic regression model with an intercept is virtually identical to the linear regression. The quadratic regression without an intercept term predicts increasing mortality with increasing mercury concentration up to a point determined by its parameter estimates **b** and **c**; beyond that point, the model predicts decreasing amphipod mortality. At high mercury concentrations, the behavior of any linear or quadratic regression model fails to reflect the assumptions underlying dose-response relationships.

The LGM fits the observed amphipod mortality data across all observed mercury concentrations. The LGM has the further advantage over all other models considered to date for this project in that it is derived from a growth model and is typically used by toxicologists to predict dose-response relationships.

To summarize the advantages and disadvantages of the approaches to estimation of amphipod mortality:

**LRM**
**Advantages**:
Published approach
Can be used in a site-specific model
**Disadvantages:**
Intended to estimate the probability of a significant toxicity effect with increasing concentration, not the magnitude of the effect.

**LINEAR REGRESSION MODEL**
**Advantages:**
Uses site data
Analytically simple and straightforward
**Disadvantages:**
Theoretical limitations – estimated mortality increases proportionally with increasing mercury concentration, even if predicting mortality greater than 100%.

**LOGISTIC GROWTH MODEL**
**Advantages:**
Uses site data
Based on dose-response relationship
Can represent numerous biological response functions from toxicity dose-response to population growth
**Disadvantages:**
No apparent disadvantages

**QUADRATIC REGRESSION MODEL**

**Advantages:**

Uses site data

Analytically simple and straightforward

**Disadvantages:**

Theoretical limitations – estimated mortality increases with increasing mercury concentration up to a limit, and then estimated mortality decreases with increasing mercury concentration.  This situation occurs with the site specific data for Castro Cove.

## REFERENCES


EPA.  2005.  Predicting Toxicity to Amphipods From Sediment Chemistry.  EPA/600/R-04/030.  March 2005.

NOAA.  2002. Hylebos Waterway Natural Resource Damage Settlement Proposal Report.  Viewed at: http://www.darp.noaa.gov/northwest/cbay/hyle-settlement.html on February 15, 2006.

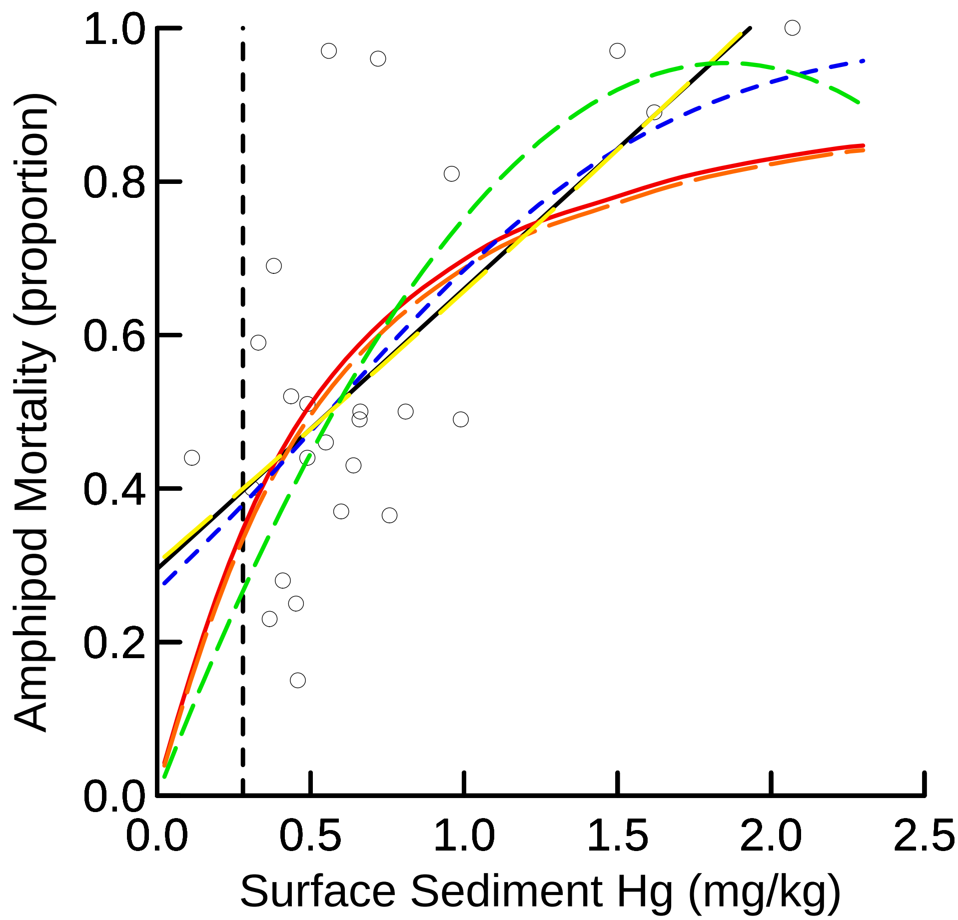


Figure 1. Comparison of mortality estimation models. Amphipod mortality and mercury concentrations in samples from Castro Cove (open circles) are compared to: EPA/NOAA LRM estimates of P value (solid red curved line); site-specific LRM estimates (long-dash orange curved line); logistic growth estimates (short-dash blue line); linear regression (straight black solid line); and quadratic regression with (dashed straight yellow line) and without an intercept term (dashed green curved line).

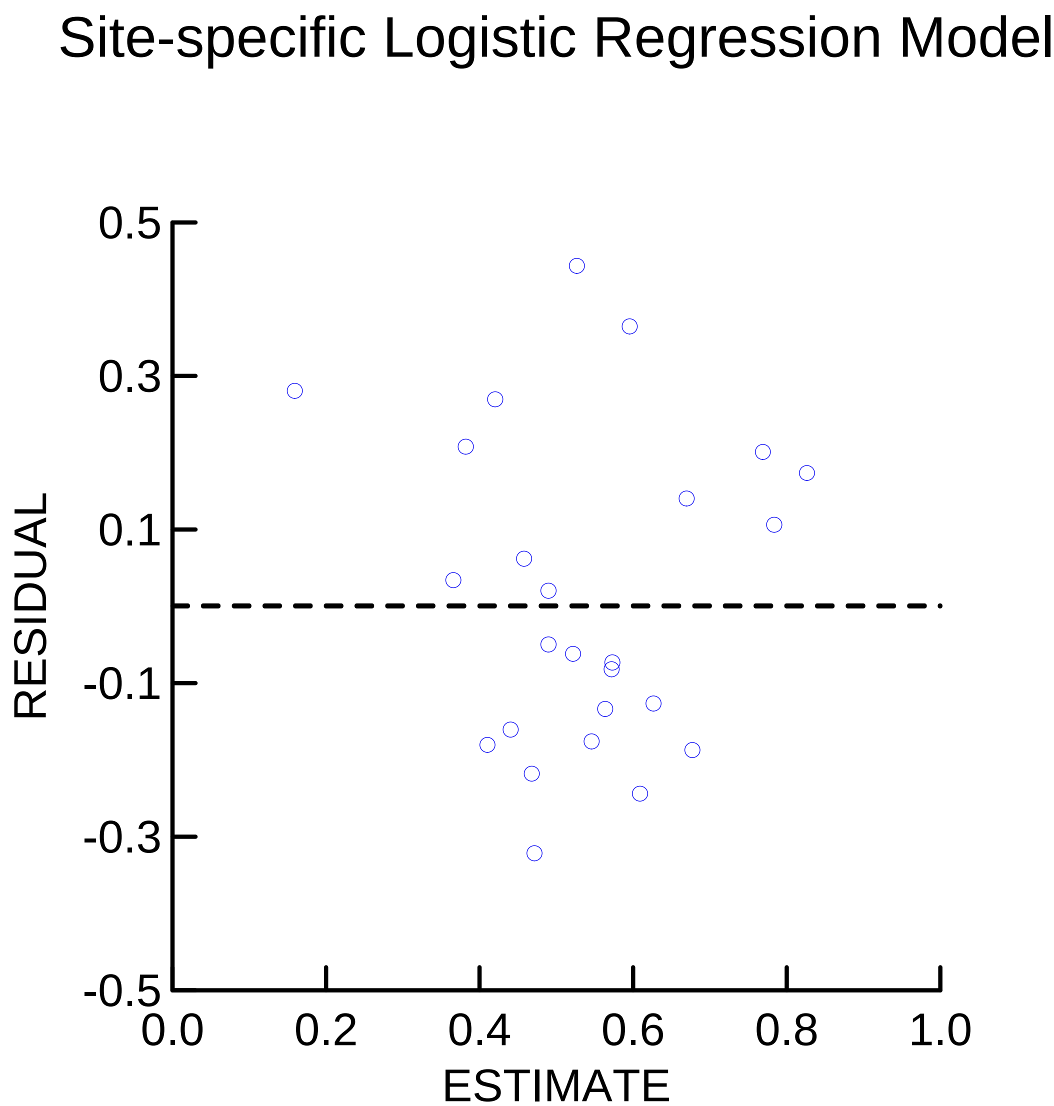


Figure 2.  Residuals plot of site-specific LRM mortality estimates.

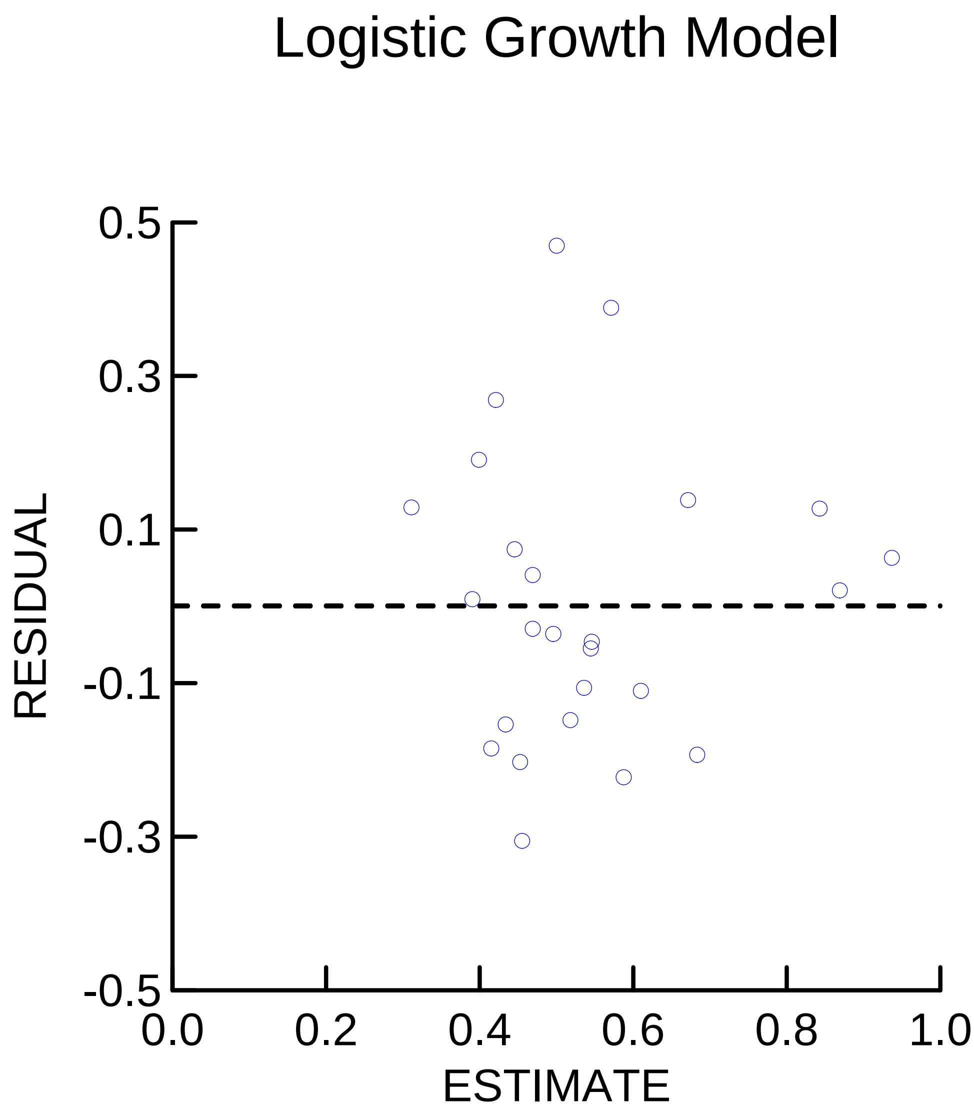


Figure 3.  Residuals plot of LGM mortality estimates.

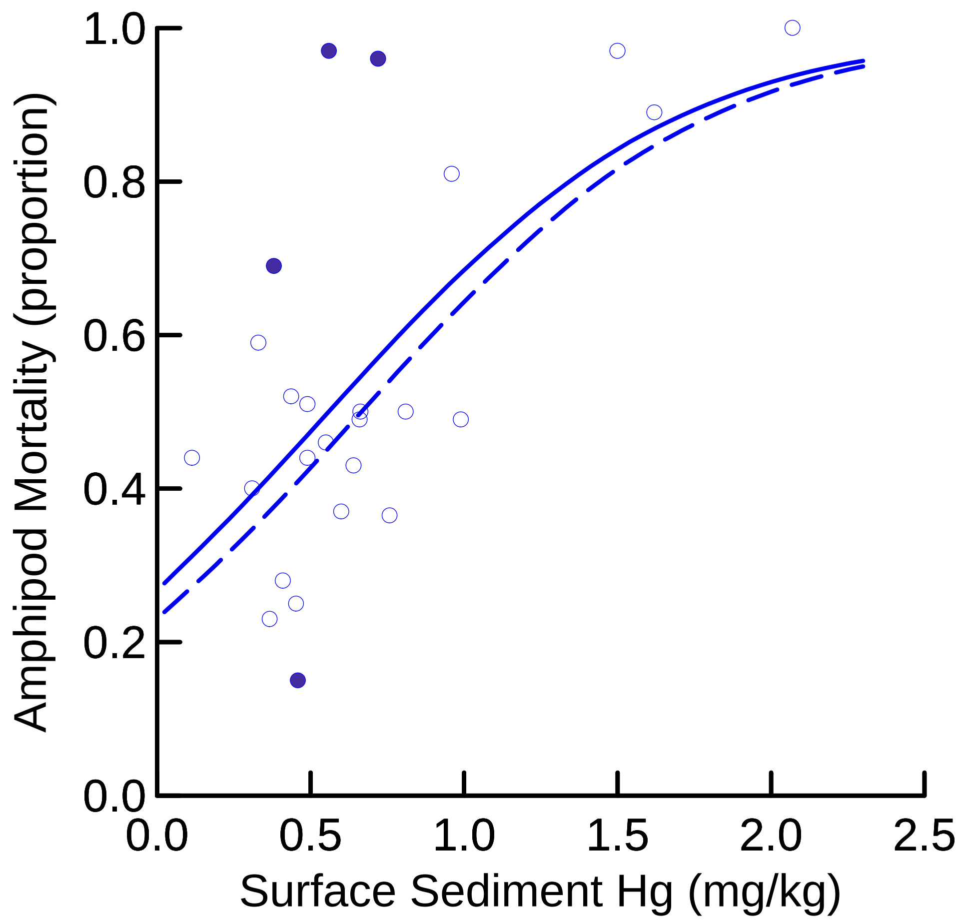


Figure 4. Effect of certain data on LGMs. Amphipod mortality and mercury concentrations in samples from Castro Cove are shown as circles. The LGM based on all toxicity test data (solid curved line) is compared to the LGM based on only selected toxicity test data (dashed curved line), which are shown as open circles. The four data excluded from the second LGM are shown as filled circles; they are discussed in the text.

E N T R I X

## MEMORANDUM

## WORKING REVIEW DRAFT

**ENTRIX, Inc.**
2701 1st Avenue
Seattle, WA 98121
206/269-0104

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**Date:** April 13, 2006

**Re:** Preliminary estimation of discounted service-acre-year (DSAYs) losses in Castro Cove

**Project No. 3054545**

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**PURPOSE**

In a conference call with the Trustees on March 30, 2006, we discussed the estimation of the dose-response relationship of amphipod mortality to sediment chemical concentration using a logistic growth model (LGM). At the Trustees' request, that estimation was based on a data set that excluded the Salt Marsh. In that call, the Trustees requested that we run the DSAYs calculations based on revised LGMs for mercury and total polycyclic aromatic hydrocarbons (TPAHs) and provide those results. This memorandum provides those LGMs and preliminary DSAYs estimates.

The LGMs are used to estimate benthic mortality in response to sediment chemical concentrations. These LGMs were developed based on the bioassay data available for Castro Cove. In the March 30, 2006 call, the Trustees requested that – in addition to the Salt Marsh data – the bioassay data associated with Tubbs Island also be eliminated from the estimation of the LGM. Figures 1 and 2 (attached) are graphs showing the full data set and the resulting LGMs for mercury and TPAHs, respectively. Two LGMs are shown in each figure; they allow a comparison of the models that result from omitting the Salt Marsh data and omitting the Salt Marsh and Tubbs Island data.

In addressing the Trustee request, we have calculated estimates of DSAYs using conservative assumptions for inputs in to the calculation. The attached table describes the assumptions and inputs to the preliminary DSAYs calculations. DSAYs were calculated for mercury and TPAHs, using two different assumptions about baseline services. The table summarizes the inputs and results and assumes that the reader is familiar with the DSAY estimation process. We are prepared to provide to the Trustees the Excel workbooks used to make these calculations.

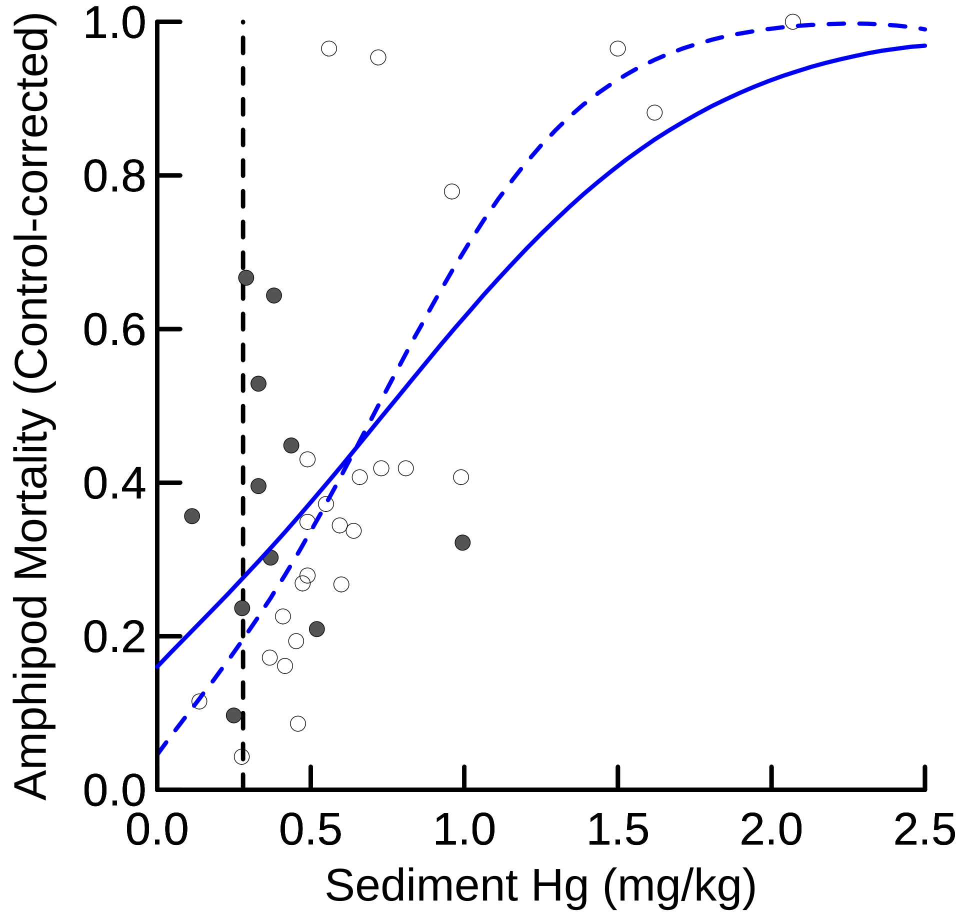


Figure 1. Logistic growth models (LGMs) for toxicity test amphipod mortality responses to mercury concentrations, excluding samples from the Salt Marsh. The solid line represents the LGM derived without samples from the Salt Marsh. The dashed line represents the LGM derived without samples from the Salt Marsh and the Tubbs Island reference station. The filled circles represent samples from salt marsh stations and the Tubbs Island reference station. The vertical dashed line equals the mean mercury concentration in San Francisco Estuarine Institute samples from San Pablo Bay used to represent regional background.

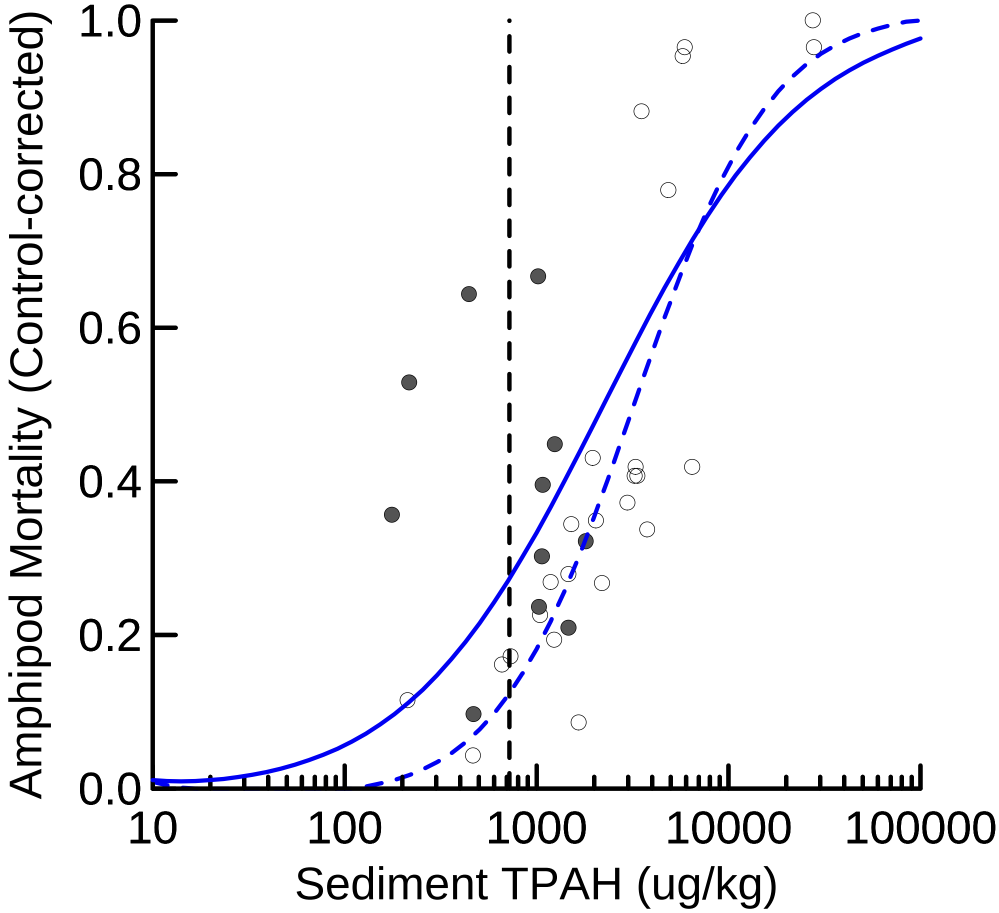


Figure w.  Logistic growth models (LGMs) for toxicity test amphipod mortality responses to TPAH concentrations, excluding samples from the Salt Marsh.  The solid line represents the LGM derived without samples from the Salt Marsh. The dashed line represents the LGM derived without samples from the Salt Marsh and the Tubbs Island reference station.  The filled circles represent samples from salt marsh stations and the Tubbs Island reference station.  The vertical dashed line equals the mean TPAH concentration in San Francisco Estuarine Institute samples from San Pablo Bay used to represent regional background.

Appendix I2d- Final curve selected to represent injury level based upon TPAH concentrations in Castro Cove Sediments. Curve is for estimating amphipod mortality where the equation is $1/1+B_0e^{B_1^{\log[TPAH]}}$, where $B_0$=121,354 and $B_1$=-3.3478.