Appendix A
Overview of MLOE Approach
June 12, 2006

The sediment quality of marine shallow water and embayment areas of California is determined through a multiple lines of evidence (MLOE) approach, which includes sediment chemistry, toxicity and benthic invertebrate community measurements (Figure 1). The LOE are first integrated into intermediate classifications, combining the benthos and toxicity LOE to assess severity of biological effects, and then combining the chemistry and toxicity LOE to assess whether there exists a likely potential that these effects are chemically-mediated. These intermediate classifications are then integrated to derive an assessment about the likelihood of chemically-mediated biological effects at the site.

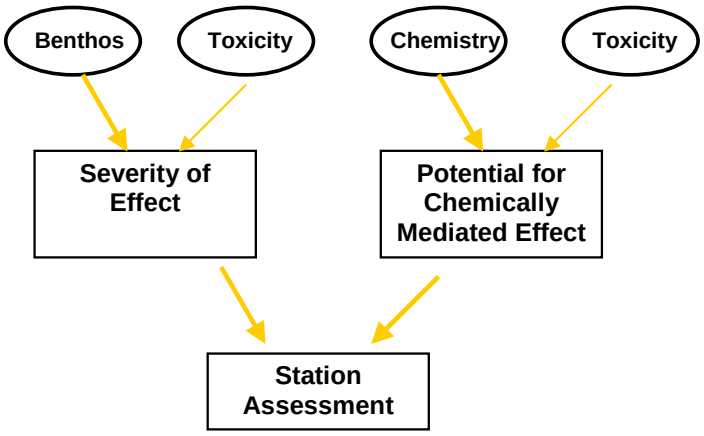

Figure 1. Schematic of multiple lines of evidence (MLOE) framework.

This document provides a summary of the MLOE process and is organized into three sections. The first section describes each of the LOE categories. The second section describes the process for determining the intermediate classifications of effect and chemical exposure. The final section describes the process for combining the intermediate classifications to produce the station assessment.

Lines of Evidence

Three lines of evidence are measured for each station that is evaluated: sediment chemistry, sediment toxicity, and benthic macrofauna community composition (benthos). Details of the specific measurement types used for each LOE (indicators) are provided in the corresponding indicator development reports. A summary of each LOE is provided below.

Chemistry. A combination of two sediment chemistry guidelines is used to determine the magnitude of chemical exposure at each site. One guideline is based on the relationship between sediment chemistry and toxicity in laboratory tests. The other is based on the relationship between sediment chemistry and benthic condition. Guideline-specific thresholds are applied to each guideline to classify the result into one of four exposure categories. The resulting exposure categories are then combined to provide an overall chemistry LOE category. The four chemistry categories are:

- **Minimal exposure:** Sediment-associated contamination may be present, but exposure is unlikely to result in effects.
- **Low exposure:** Small increase in contaminant exposure that may be associated with increased effects, but magnitude or frequency of occurrence of biological impacts is low.
- **Moderate exposure:** Clear evidence of sediment contaminant exposure at concentrations that are likely to result in biological effects.
- **High exposure:** Contaminant exposure is highly likely to result in substantial biological effects.

Toxicity. A combination of two or more sediment toxicity tests is used to determine the magnitude of toxicity at each site. The tests include both lethal (e.g., short-term amphipod survival) and sublethal (e.g., growth and development) methods. Species-specific thresholds are applied to each test to classify the result into one of four toxicity categories. The resulting toxicity categories are then combined to provide an overall toxicity LOE category. The four toxicity categories are:

- **Nontoxic:** Response not substantially different from that in uncontaminated control sediments.
- **Low toxicity**: A low magnitude response that differs from control survival, but by less than the variability typical for that test.
- **Moderate toxicity**: High confidence that a statistically significant toxic effect is present.
- **High toxicity**: High confidence that a toxic effect is present and the magnitude of response includes the strongest effects observed for the test.

Benthos. A combination of four benthic community composition indices is used to determine the magnitude of disturbance to the benthos at each site. The indices include approaches based on community metrics and abundance of individual species. Thresholds specific to regional assemblages are applied to the results in order to classify each index result into one of four disturbance categories. The resulting disturbance categories are then combined to provide an overall benthos LOE category. The four benthos categories are:

- **Reference:** A community composition equivalent to a "least affected" or "unaffected" site.
- **Low disturbance:** A community that shows some indication of stress, but could be within measurement error of unaffected condition.
- **Moderate disturbance:** Confident that the community shows evidence of physical, chemical, natural, or anthropogenic stress.
- **High disturbance:** Changes in the benthos are substantial enough to limit community function.

Intermediate Classifications

The LOE are combined into intermediate classifications to provide corroborating evidence of biological or chemical impacts at a site. For evidence of biological effects, the benthos and toxicity LOE are integrated into "Severity of Effect" categories (Table 1). Benthos is given greater weight for determining the classification, as benthos are the resource to be protected. The classification reflects disturbance to the community and is not intended to differentiate whether effects that are due to chemical contaminants, physical disturbance of the habitat or organic enrichment.

The sediment chemistry and toxicity LOE are used to assess the "Potential that Effects are Chemically Mediated" (Table 2). Chemistry is given slightly greater weight in determining this classification, though toxicity must be considered because it provides the mechanism for assessing whether contaminants are potentially bioavailable and whether unmeasured chemicals are present at levels of potential biological concern,

Table 1. Severity of effect classifications, derived from benthos and toxicity LOE. Categories outlined with bold borders indicate a change from previous framework.

		Toxicity			
		Nontoxic	Low toxicity	Moderate toxicity	High toxicity
Benthos	Reference	1 Unaffected	2 Unaffected	3 Unaffected	4 Low effect*
	Low disturbance	5 Unaffected	6 Low effect	7 Low effect	8 Low effect
	Moderate disturbance	9 Moderate effect	10 Moderate effect	11 Moderate effect	12 Moderate effect
	High disturbance	13 Moderate effect*	14 High Effect	15 High Effect	16 High Effect

* Extreme disagreement between LOE is present that may indicate atypical conditions or suspect data. Review of additional information about the site before making an assessment is recommended.

Table 2. Potential that effects are chemically mediated categories, derived from chemistry and toxicity LOE. Categories outlined with bold borders indicate a change from previous framework.

		Toxicity			
		Nontoxic	Low toxicity	Moderate toxicity	High toxicity
Chemistry	Minimal exposure	17 Minimal potential	18 Minimal potential	19 Low potential	20 Moderate potential*
	Low exposure	21 Minimal potential	22 Low potential	23 Moderate potential	24 Moderate potential
	Moderate exposure	25 Low potential	26 Moderate potential	27 Moderate potential	28 Moderate potential
	High exposure	29 Moderate potential*	30 Moderate potential	31 High potential	32 High potential

* Extreme disagreement between LOE is present that may indicate atypical conditions or suspect data. Review of additional information about the site before making an assessment is recommended.

Sample Assessment

The final data integration step combines the intermediate classifications for severity of effect and potential for chemically-mediated effect to classify a site into one of six categories of impact:

- **Unimpacted.** Confident that any sediment contamination present at the site is not causing significant adverse direct impacts to aquatic life. The sediment conditions support a benthic community composition that is similar to that attained in reference areas representing the best available conditions in the region. High agreement among the LOE is present.
- **Likely unimpacted**. Sediment contamination present at the site is not expected to cause significant adverse direct impacts to aquatic life. Some disagreement among the LOE is present, which indicates uncertainty in the classification.
- **Possibly impacted.** Sediment contamination present at the site may be causing significant adverse direct impacts to aquatic life, but these impacts may be moderate or variable in nature. The LOE may agree in indicating a minor level of effect, or there may be substantial disagreement among the LOE.
- **Likely impacted.** Confidence that sediment contamination present at the site is causing significant adverse direct impacts to aquatic life. There may be disagreement among the LOE, but the evidence for a contaminant-related impact is persuasive.
- **Clearly impacted.** Confidence that sediment contamination present at the site is causing severe adverse direct impacts to aquatic life.
- **Inconclusive.** Unable to classify the site. Extreme disagreement among the LOE indicate that either the data are suspect or that additional information is needed before a classification can be made. This designation is applied when high toxicity is present without corroborating evidence of chemical exposure and benthic disturbance.

The decision matrix for determining the station assessment category is shown in Table 3. Two key principles provide the foundation for this matrix. First, there must be some evidence of biological effect (severity of effect = low, moderate, or high) in order to classify a station as impacted. Second, there must be some evidence of elevated chemical exposure (e.g., low, moderate, or high potential for effects) in order to classify a station as impacted. A summary of the station category resulting for all 64 combinations of the three LOE is shown in Table 4.

Table 3. Multiple lines of evidence station classifications.

		Severity of Effect			
		Unaffected	Low effect	Moderate effect	High effect
Potential that effects are chemically-mediated	Minimal potential	33 Unimpacted	34 Likely unimpacted	35 Likely unimpacted	36 Likely unimpacted
	Low potential	37 Unimpacted	38 Likely unimpacted	39 Possibly impacted	40 Possibly impacted
	Moderate potential	41 Likely unimpacted	42 Possibly impacted or Inconclusive[1]	43 Likely impacted	44 Likely impacted
	High potential	45 Likely unimpacted	46 Likely impacted	47 Clearly impacted	48 Clearly impacted

[1] Inconclusive category applies only when chemistry = minimal exposure, benthos = reference, and toxicity= high. Other LOE combinations represented by this cell are classified as possibly impacted.

Table 4. All possible LOE combinations, and the resulting sample assessment categories.

Chemistry exposure	Benthic disturbance	Toxicity	Sample Assessment
Minimal	Reference	Nontoxic	Unimpacted
Minimal	Reference	Low	Unimpacted
Minimal	Reference	Moderate	Unimpacted
Minimal	Reference	High	Inconclusive
Minimal	Low	Nontoxic	Unimpacted
Minimal	Low	Low	Likely unimpacted
Minimal	Low	Moderate	Likely unimpacted
Minimal	Low	High	Possibly impacted
Minimal	Moderate	Nontoxic	Likely unimpacted
Minimal	Moderate	Low	Likely unimpacted
Minimal	Moderate	Moderate	Possibly impacted
Minimal	Moderate	High	Likely impacted
Minimal	High	Nontoxic	Likely unimpacted
Minimal	High	Low	Likely unimpacted
Minimal	High	Moderate	Possibly impacted
Minimal	High	High	Likely impacted
Low	Reference	Nontoxic	Unimpacted
Low	Reference	Low	Unimpacted
Low	Reference	Moderate	Likely unimpacted
Low	Reference	High	Possibly impacted
Low	Low	Nontoxic	Unimpacted
Low	Low	Low	Likely unimpacted
Low	Low	Moderate	Possibly impacted
Low	Low	High	Possibly impacted
Low	Moderate	Nontoxic	Likely unimpacted
Low	Moderate	Low	Possibly impacted
Low	Moderate	Moderate	Likely impacted
Low	Moderate	High	Likely impacted
Low	High	Nontoxic	Likely unimpacted
Low	High	Low	Possibly impacted
Low	High	Moderate	Likely impacted
Low	High	High	Likely impacted
Moderate	Reference	Nontoxic	Unimpacted
Moderate	Reference	Low	Likely unimpacted
Moderate	Reference	Moderate	Likely unimpacted
Moderate	Reference	High	Possibly impacted
Moderate	Low	Nontoxic	Unimpacted
Moderate	Low	Low	Possibly impacted
Moderate	Low	Moderate	Possibly impacted
Moderate	Low	High	Possibly impacted
Moderate	Moderate	Nontoxic	Possibly impacted
Moderate	Moderate	Low	Likely impacted
Moderate	Moderate	Moderate	Likely impacted
Moderate	Moderate	High	Likely impacted
Moderate	High	Nontoxic	Possibly impacted
Moderate	High	Low	Likely impacted
Moderate	High	Moderate	Likely impacted
Moderate	High	High	Likely impacted

Chemistry exposure	Benthic disturbance	Toxicity	Sample Assessment
High	Reference	Nontoxic	Likely unimpacted
High	Reference	Low	Likely unimpacted
High	Reference	Moderate	Likely unimpacted
High	Reference	High	Likely impacted
High	Low	Nontoxic	Likely unimpacted
High	Low	Low	Possibly impacted
High	Low	Moderate	Likely impacted
High	Low	High	Likely impacted
High	Moderate	Nontoxic	Likely impacted
High	Moderate	Low	Likely impacted
High	Moderate	Moderate	Clearly impacted
High	Moderate	High	Clearly impacted
High	High	Nontoxic	Likely impacted
High	High	Low	Likely impacted
High	High	Moderate	Clearly impacted
High	High	High	Clearly impacted