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Workshop Summary Report

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Executive summary

The beneficial reuse of dredged sediment is one strategy in a broader portfolio that is being developed for San Francisco Bay to help marshes adapt to rising sea level. Dredged sediment is currently being used in restoration projects around the Bay, but additional sediment is needed to meet the demand. The guidelines for determining if sediment is appropriate for beneficial reuse were developed twenty years ago. As part of assessing the role of dredged sediment in Bay restoration and adaptation strategies, the Regional Monitoring Program for Water Quality (RMP) and stakeholders recognized the need to revisit the beneficial reuse guidelines for dredged sediment. They determined that scientific advances over the last twenty years in sediment chemistry and bioaccumulation testing, risk assessment, and criteria development should be reviewed to determine if the reuse guidelines needed to be revised.

In September 2019, the RMP convened a workshop that included four technical experts to review the beneficial reuse guidelines. The experts were asked to answer three questions: 1) Are the current screening guidelines appropriate for beneficial reuse? 2) Is the current screening process appropriate and adequate? If not, what are your recommendations for improving it? and 3) How should bioaccumulation potential be addressed for the beneficial reuse of sediment? Based on the discussion of these three questions, six recommendations emerged from the workshop.

1. If ambient values are going to continue to be used as guidelines, update them with RMP data from the open Bay and margins areas. Including the margins data is important because it is likely to be more similar than open Bay sediment to wetland sediment quality where dredged sediment could be used. In addition, evaluate ambient values for each subembayment to assess spatial differences in sediment quality throughout the Bay.
2. Use the hazard quotient methodology to assess risk of ecological effects based on the ratio between measured values of contaminants and sediment screening criteria.
3. Use multivariate analyses to determine sediment toxicity screening thresholds based on a combination of contaminants rather than individual contaminants, particularly if sediment chemistry is used as a single line of evidence to determine suitability.
4. Assess current bioassays to determine if they are appropriate for assessing risk to wetland species.
5. Use a tiered framework to assess chemistry, toxicity, and bioaccumulation.
6. Use BRAMS in tandem with the PCB bioaccumulation model that has been developed for San Francisco Bay to determine bioaccumulation levels of concern (based on ambient univariate or multivariate sediment concentration thresholds) and/or sediment screening guidelines (based on tissue concentrations of concern). Assess the uncertainty associated with the model and provide an override of model-derived screening values if direct assessments (i.e., bioaccumulation testing) do not show toxicity.
7. Develop a monitoring strategy to assess the effects of dredged sediment on wetland habitats to inform adaptive management of the screening guidelines and process.

The RMP and San Francisco Regional Water Quality Control Board will review these recommendations and determine the next steps in the review. While the overall goal of this review is to ensure that as much sediment as possible is available for beneficial reuse, the process also needs to be protective of the habitats receiving the sediment, as well as the aquatic species that live in those habitats, some of which are consumed by humans. Carefully considering how risk and uncertainty are accounted for and evaluated will be important components of an updated process.

Introduction

San Francisco Bay is a shallow-water estuary on the west coast of the US. The economy of the region relies heavily on the maritime industry. Because nearly half the Bay is less than three meters deep at low tide, navigation channels, ports, harbors, and marinas need to be dredged on a regular basis to maintain the Bay as a major maritime hub. After dredging occurs, the dredged sediment can either be disposed of at aquatic sites (deep ocean or in the Bay) or at upland sites. Sediment placed at upland sites can be used for beneficial purposes, including restoring marshes, and capping and lining landfills. Recent studies show that shallow water placement of dredged sediment at specific locations in the Bay may also prove to be beneficial for nourishing mudflats adjacent to tidal marsh habitat (Bever et al. 2014). As sea level continues to rise in San Francisco Bay, beneficial reuse is one strategy for helping marshes adapt to rising water levels.

To date, over 25 million cubic yards of dredged sediment have been used to restore over 7,500 acres of wetlands, including Sonoma Baylands, Hamilton Wetlands, Bair Island, Cullinan Ranch, and Montezuma Wetlands (Foley et al. 2019). Although this is a considerable amount of sediment put towards tidal wetland restoration, we know much more will be needed to meet the 100,000-acre regional tidal marsh target set in the 2016 Bayland Goals Update. For example, a recent analysis showed that approximately 150 million cubic yards of sediment would be needed to bring the 40,000 acres of planned or in-progress tidal marsh restoration to current marsh plain elevation (Perry et al. 2015). The Long Term Management Strategy (LTMS) for dredged sediment in San Francisco Bay has a long-term goal of using at least 40% of dredged sediment for beneficial purposes, which will help meet the sediment demand for all the planned marsh restoration. However, reaching that goal will likely require revisiting the screening guidelines used to determine whether dredged sediment can be used for marsh restoration projects.

The current screening guidelines for the beneficial reuse of dredged sediment for San Francisco Bay were released as draft guidance in 2000 (SFBRWQCB 2000). The screening thresholds for metals and organics in dredged sediment that would allow for beneficial reuse were largely based on ambient concentrations in the Bay, as measured by the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP). Under the current screening process (Figure 1), sediment chemistry is analyzed for 19 contaminants or families of contaminants (Table 1), and bioassays are conducted on at least two aquatic species. If any metals or organics exceed the screening guidelines but no toxicity is detected in the bioassays, sediment may be approved for beneficial reuse if it does not present an unacceptable risk to the receiving location. For some beneficial reuse sites, specific sediment acceptance criteria are outlined in individual site permits based on a US Fish and Wildlife Service (USFWS) Biological Opinion. In these cases, the numeric criteria are bright lines that cannot be exceeded regardless of the toxicity results unless USFWS approves exceptions to the criteria.

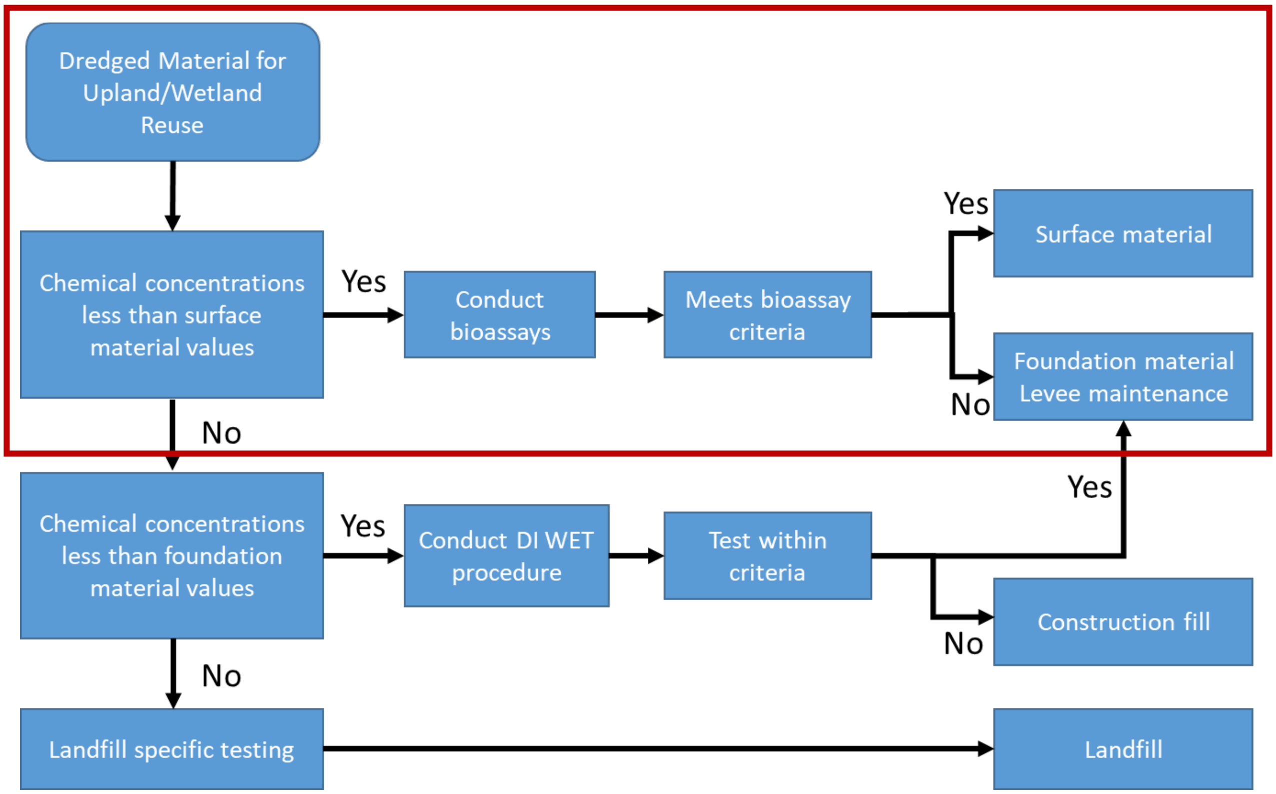

Figure 1. Sediment screening process for beneficial reuse in San Francisco Bay as outlined in the draft guidelines (SFBRWQCB 2000). Some steps of the process tend to be completed in tandem rather than step-wise. For example, dredgers often submit sediment chemistry and bioassay data for review at the same time. The workshop focused on the parts of the process contained within the red box.

In May 2018, the RMP Sediment Workgroup and its stakeholders recognized the need to revisit the beneficial reuse guidelines for dredged sediment. They determined that scientific advances over the last twenty years in sediment chemistry and bioaccumulation testing, risk assessment, and criteria development should be reviewed to determine if the reuse guidelines needed to be revised. In addition, they concluded that the need for sediment to support tidal marshes is so great that review of the decision process followed in the region to determine sediment suitability for beneficial reuse was a high priority.

In September 2019, the RMP convened a workshop to examine the existing sediment screening guidelines in relation to advances in the field and the critical need for sediment for tidal marsh support. The workshop participants included invited technical experts with knowledge of sediment chemistry testing and toxic effects of contaminants on invertebrates, as well as representatives from federal and state regulatory agencies, the port and refinery communities, and the tidal wetland restoration and land management communities. The technical experts included Dr. David Moore, a senior research biologist with the U.S. Army Corps of Engineers (USACE) Engineer Research and Development Center; Dr. Laura

Inouye, a senior toxicologist with the Washington Department of Ecology; Joe Dillon, a water quality specialist from the National Marine Fisheries Service; and Steve Bay, a principal scientist with the Southern California Coastal Water Research Project (SCCWRP). In addition to the experts, four representatives from the Dredged Materials Management Office (DMMO) were on hand to address questions about the current process and screening guidelines. The DMMO representatives included Elizabeth Christian (San Francisco Bay Regional Water Quality Control Board), Brenda Goeden (San Francisco Bay Conservation and Development Commission), Brian Ross (US Environmental Protection Agency, Region IX), and Jessica Vargas (US Army Corps of Engineers).

Dr. Moore specializes in ecotoxicology and leads initiatives on contaminated sediment assessment, as well as management and risk assessment. Dr. Inouye has been involved in developing state management standards for dredged material for Washington State, as well as evaluating dredging projects for the Northwest region. She has also been involved with redeveloping bioaccumulation thresholds based on risk and ecological effects. Mr. Dillon consults on dredging projects with contaminant issues and is a co-author of the contaminant-related sections of the Essential Fish Habitat programmatic consultation for Operations and Maintenance dredging in San Francisco Bay. Mr. Bay leads the toxicology program at SCCWRP where he develops methods to assess the impacts of sediment contamination on humans and aquatic life. He has also been involved in developing sediment quality objectives for the State of California.

The workshop focused on the technical expert panel's answers to three primary questions related to screening guidelines for beneficial reuse of dredged sediment in San Francisco Bay:

(1) Are the current screening guidelines appropriate for beneficial reuse?

(2) Is the current screening process appropriate and adequate? If not, what are your recommendations for improving it?

(3) How should bioaccumulation potential be addressed for the beneficial reuse of sediment?

The purpose of this document is to provide the panel's answers to these questions and recommended next steps for updating the process for developing screening criteria.

Findings and Discussion

Question 1: Are the current screening guidelines appropriate for beneficial reuse?

The 2000 draft sediment screening guidelines (SFBRWQCB 2000) were developed to inform suitability determinations for the beneficial reuse of dredged sediment. These guidelines were designed to provide general guidance for San Francisco Bay, so guidelines may be more stringent depending on site-specific conditions (e.g., presence of endangered species). The screening list includes metals, organochlorine pesticides and PCBs, and polycyclic aromatic hydrocarbons. Screening values are based on a combination of ambient values for either fine grain or coarse grain sediment for San Francisco Bay (SFRWQCB, 1998) and toxicity thresholds (Long et al. 1995) (Table 1).

In reviewing or revising the sediment guidelines, it is important to acknowledge that tradeoffs may exist. Overly protective sediment criteria could reduce the amount of dredged sediment that is available for beneficial reuse, which is a critical component of the Bay's adaptation strategy to sea level rise. However, criteria that are too permissive could result in adverse ecological impacts at restored sites, reducing the effectiveness of restoration.

Determining whether the guidelines are appropriate depends on what the guidelines are meant to inform. If the goal is to allow sediment that is reflective of general conditions within San Francisco Bay to be used for beneficial reuse purposes, then defining screening guidelines by ambient conditions is appropriate. If, however, the goal is to ensure protective ecological thresholds are in place, then a risk-based approach should be developed that accounts for the risk of exposing species to contaminants versus the need to restore and adapt habitats in the face of rising sea level. A combination of these approaches can also be used to address multiple goals.

Assuming the goal is to allow as much sediment as possible for beneficial reuse purposes, ambient conditions are a good starting point for sediment chemistry. The current sediment screening guidelines are based on data from San Francisco Bay prior to 1998 (Gandesbery and Hetzel 1998), as well as on contaminant concentrations predicted to cause biological effects (Long et al. 1995). Using ambient values as screening guidelines allows sediment with contaminant levels similar to those in the Bay to be used for beneficial reuse purposes. While this approach provides a benchmark for average condition, ambient values may not be protective of aquatic life in some cases (Table 1).

Ambient values currently being used to screen sediment for beneficial reuse were developed using data collected prior to 1998. Ambient values for metals and organics could easily be updated using sediment data collected by the RMP between 1998 and 2019. Ambient values were used to develop the sediment screening guidelines based on the assumption that those values would be representative of sediment deposited on wetlands via hydrodynamic processes (e.g., tides or currents). However, the ambient values were calculated from sediment samples mainly collected in the deep channels of the Bay ("open Bay"), which may not be reflective of conditions closer to wetland habitats. In 2015 and 2017, the RMP collected samples from shallow margin areas (i.e., mud flat) in Central and South Bay. Concentrations of metal and organic contaminants in the margin areas were higher than in the deep water areas of the Bay in some cases, particularly where samples were collected near old industrial areas (Yee et al. 2017 and 2019). Margin samples will be collected from North Bay sites in 2020, completing the margins sampling of the Bay. Because margin areas are generally in closer proximity to beneficial reuse project sites, they may be a better indicator of the condition of sediment that is naturally deposited on wetlands than sediment from the open Bay.

Open Bay ambient conditions could be unnecessarily restrictive as screening guidelines if the sediment reaching wetlands naturally via hydrodynamic processes has higher concentrations of metals and organics. In addition, as management actions to improve water quality continue to have their intended effect, some ambient values may be far below toxicity thresholds and may continue to decrease over time (Table 1). Calculating ambient values for the different segments of the Bay (i.e., South Bay, Central Bay, and North Bay) should also be considered, given the differences in surrounding land use and hydrodynamics of the different Bay segments. This is an important factor to consider because much of the dredged sediment currently being used at North Bay restoration areas is coming from dredging projects in Central Bay.

Table 1. Current contaminant screening thresholds. The “current ambient” concentrations were calculated in 1998 using data from the RMP and the Bay Protection and Toxic Cleanup Program. Updated ambient concentrations were calculated using RMP data from 2003-2012. Effects-Risk Low (ERL) and Threshold Effect Level (TEL) thresholds are included for reference. Asterisks denote the value used to set the chemistry guideline for each contaminant. Ambient values being used as a screening threshold that are above the ERL or TEL may not be protective of aquatic life.

Metals (mg/kg)	Current ambient (1998)	Updated ambient (2003-2012)	ERL	TEL
Arsenic	15.3*	13.9	8.2	7.24
Cadmium	0.33*	0.33	1.2	0.68
Chromium	112*	NA	81	52.3
Copper	68.1*	53.9	34	18.7
Lead	43.2*	25.1	46.7	30.2
Mercury	0.43*	0.33	0.15	0.13
Nickel	112*	98.3	20.9	15.9
Selenium	0.64*	0.36	-	-
Silver	0.58*	0.31	1	0.73
Zinc	158*	136	150	124
Pesticides and PCBS (µg/kg)				
PCBs (total)	21.6	18.2	22.7*	21.6
Chlordanes (total)	2.3	0.34	-	2.3*
DDTs (sum)	7.0*	4.7	1.6	3.9
Hexachlorocyclohexane	0.78*	0.05	-	-
Hexachlorobenzene (total)	0.48*	0.20	-	-
Dieldrin	0.72	0.16	-	0.72*
Polycyclic aromatic hydrocarbons (µg/kg)				
PAHs (total)	3390*	4520	4022	1684
Low MW PAHs (sum)	434*	568	552	312
High MW PAHs (sum)	3060*	3640	1700	655

Alternate statistical methods could be used to calculate integrated screening guidelines. The floating percentile methodology has been used as a means to reduce the error inherent in using a single percentile to determine numeric thresholds for all chemicals (RSET 2018). Effects-based screening levels (ERL, TEL) are based on univariate adverse effect threshold approaches, where observed toxicity in a paired sediment-bioassay dataset is assumed to be associated with the chemical being evaluated. In contrast, the floating percentile method is a multivariate approach. This method uses different percentiles for each chemical of interest to improve the false negative and false positive error rates. In short, the optimal percentile is set at a level that provides a low false negative rate (i.e., sediment not identified as toxic when it is). The chemical concentration is then increased until the false positive rate (i.e., sediment identified as toxic when it is not) is as low as possible while the false negative rate remains the same. Setting the optimal percentile allows this method to be protective without being over conservative. It also helps identify which contaminants are more likely to be tied to toxicity. This method was used by Germano and Associates (2004) to evaluate the current sediment screening guidelines and their ability to correctly identify toxic and non-toxic sediment. The multivariate floating percentile approach resulted in a significantly lower rate of false positives (5% vs 16%) than using individual sediment chemistry criteria. Washington State used this method to revise their Sediment Management Standards in 2013 (Department of Ecology 2013) because it was more effective at predicting toxicity than individual contaminant values. Using paired data from sediment chemistry and bioassay tests from dredged sediment tests that are stored in the DMMO database, integrated screening values can be calculated that are specific to San Francisco Bay.

The hazard quotient method can be used to evaluate the risk of ecological impact based on the ratio of measured contaminant concentration to screening values (Li et al. 2019). For dredged sediment, the screening values outlined in the Draft Staff Report (SFBRWQCB 2000) would be used for these calculations. In general, if the hazard quotient is above 1 (indicating measured concentration is above the screening threshold), harmful effects cannot be ruled out but are not guaranteed. Risk can then be further evaluated based on factors such as bioavailability of the contaminant, life stage of organisms exposed to the contaminant, bioaccumulation potential of the contaminant. Comparing multiple screening values (e.g., ambient, ERL, ERM) can also help to assess risk. The hazard quotient methodology is typically used on a contaminant by contaminant basis, but a quotient could be calculated based on the arithmetic mean of all hazard quotient values as long as no individual contaminant exceeds the ERM. The hazard quotient method is less data intensive than the floating percentile methodology and could be used as an interim assessment tool while the floating percentile methodology is being explored.

Multiple lines of evidence could also be used to determine sediment suitability for beneficial reuse. For example, the Sediment Quality Objectives for the State of California were developed using multiple lines of evidence that consider the overall condition of the sediment rather than the concentrations of individual contaminants. This approach uses three lines of evidence—sediment chemistry, sediment toxicity, and benthic community composition—to determine if sediment quality is sufficient to support benthic communities (SWRCB 2018). This approach focuses on in-Bay aquatic species so the approach may need to be modified for beneficial reuse of dredged sediment in wetlands.

There is a high degree of uncertainty associated with numeric criteria for single contaminants. Despite the variability around these numbers, they are often used as definitive limits in decision making contexts, particularly if a Biological Opinion by the US Fish and Wildlife Service is tied to the permit. A site-specific approach to determining suitability and assessing risk could be used to evaluate the uncertainty associated with numeric criteria and the risk potential at a site. These site-level analyses could provide additional information on what levels are appropriate, particularly if they are expected to deviate from ambient conditions. For San Francisco Bay, risk assessments are not conducted at potential restoration sites unless they are also clean-up sites (e.g., old military sites). Current site-specific conditions included in a biological opinion have tended to be transferred across biological opinions, rather than the result of a site-specific analysis that evaluates the conditions and risks at the new sites. These thresholds may need to be reviewed if site conditions are different across projects.

Uncertainty exists in sediment criteria, regardless of how the criteria are derived (i.e., single contaminant or multivariate approach). Monitoring of restored wetlands and adaptive wetland management measures are key components in determining if the criteria are sufficient for meeting the goals of beneficial reuse and habitat restoration. There is currently little ecological monitoring occurring on restored sites to determine if sediment is having adverse effects on wetland species. These monitoring studies would provide confidence that the sediment guidelines are protective enough.

Using updated ambient concentrations from 2015 as a guide (Yee et al. 2015), sediment chemistry concentrations from 1990 to mid-2016 found in the DMMO database were assessed to determine how much sediment would be turned away from beneficial reuse based on sediment chemistry alone. For many of the analytes, ambient concentrations have significantly decreased since 1998 and are now below ERL/TEL values for some analytes (Table 1). It is important to note that the updated ambient values are not currently being used in decision-making. If the current ambient values were used, for metals, between 11 and 47% of sediment (by project not volume) would be turned away due to exceedances (Figure 2). Selenium had the highest number of exceedances, followed closely by cadmium, copper, lead, mercury, and silver. For PCBs and pesticides (Figure 3), 53% of samples tested for chlordanes exceeded ambient concentrations. PCBs (sum of 40) and DDTs (total) exceeded ambient concentrations roughly a quarter of the time, respectively. PAHs (total) exceeded ambient concentrations less than 15% of the time.

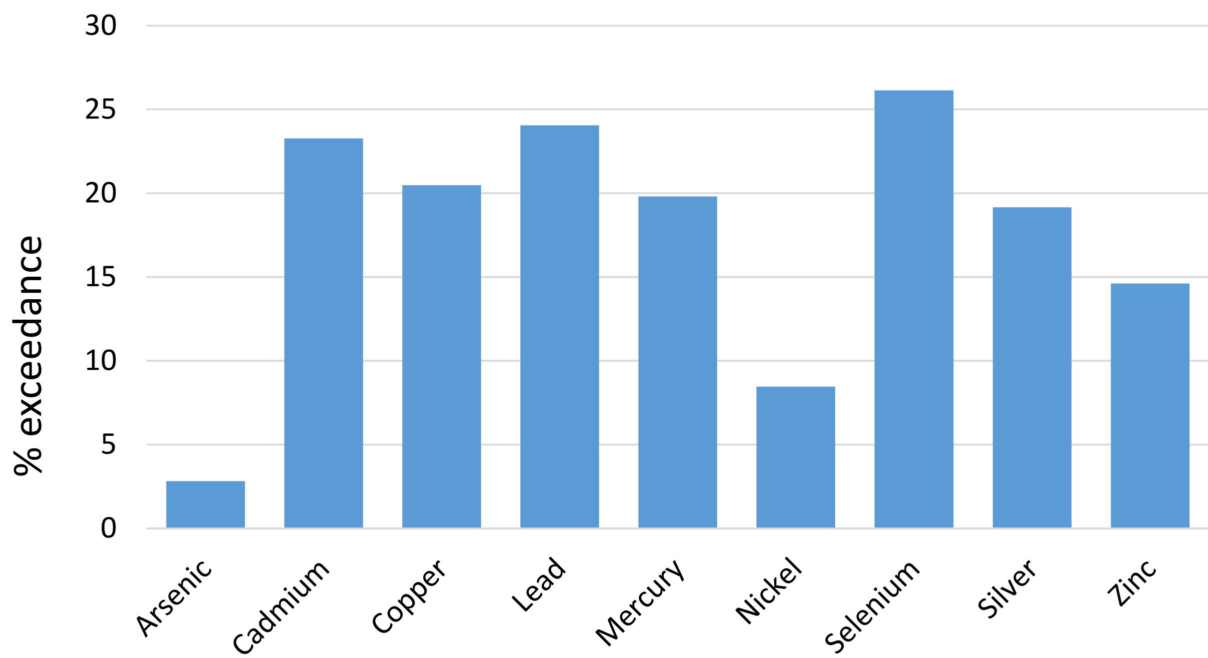

Figure 2. Percent of tests (by project, not volume) exceeding sediment screening guidelines based on 2015 ambient values for San Francisco Bay where ambient values are used as the standard and ERL/TEL where that is the standard (see Table 1 for details). Projects from 2000 through mid-2016 were included in the analysis.

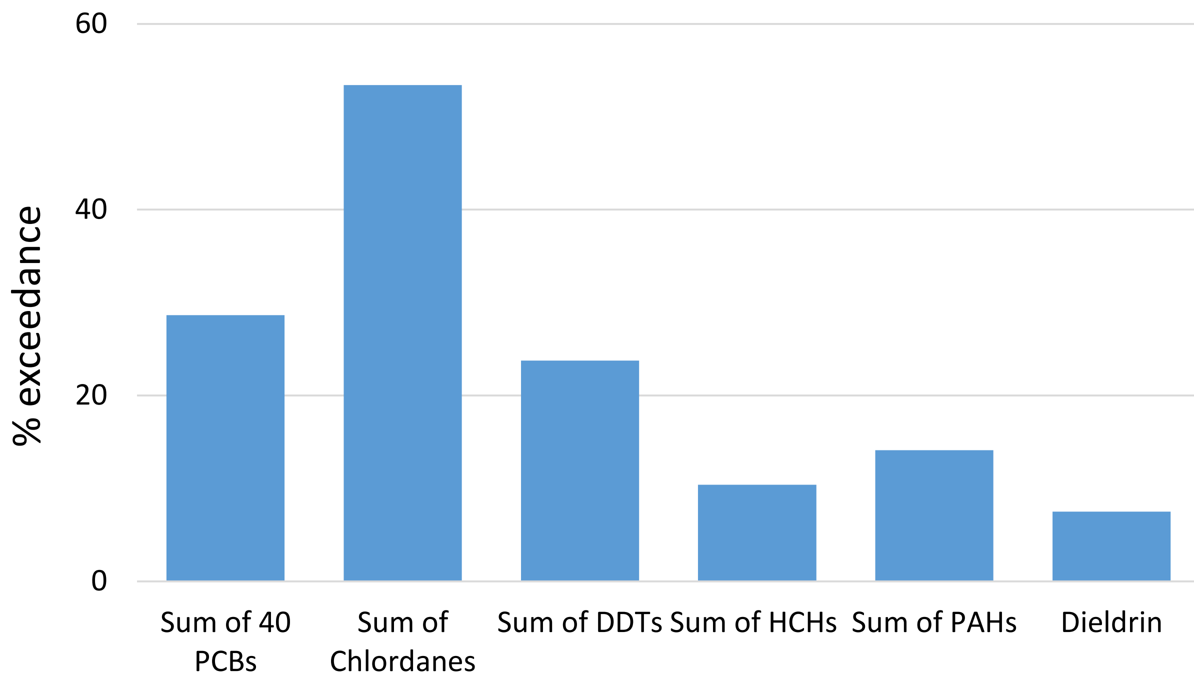

Figure 3. Percent of tests (by project, not volume) exceeding sediment screening guidelines based on 2015 ambient values for San Francisco Bay where ambient values are used as the standard and ERL/TEL where that is the standard (see Table 1 for details). Projects from 2000 through mid-2016 were included in the analysis.

Question 2: Is the current screening process appropriate and adequate? If not, what are your recommendations for improving it?

The current process for evaluating dredged sediment for surface placement at beneficial reuse sites includes two components—sediment chemistry and acute toxicity testing with two benthic species—with the potential for elutriate testing depending on the sediment type and reuse location. In some cases, bioaccumulation testing may be required if the sediment chemistry results have a screening-level exceedance for a bioaccumulative contaminant (e.g., PCBs). Sediment chemistry results are compared to ambient levels for metals and a combination of ambient concentrations and effects thresholds for organic contaminants. To reduce costs for dredgers, the screening process for beneficial reuse has a high degree of overlap with the testing processes for in-Bay and ocean disposal options. Unless there is a Biological Opinion associated with a project receiving dredged sediment, there is no clear process for determining suitability when sediment chemistry and toxicity results disagree. In some cases, there is no toxicity even when contaminant concentrations are very high. Less frequently, there is toxicity when no chemical guidelines have been exceeded. In these cases, the applicant is often asked to do additional testing to evaluate bioaccumulation potential and/or how much of the dredged sediment exceeds chemistry or toxicity thresholds. The final decision regarding placement suitability includes testing results, as well as a review of the contaminants that are in exceedance of the guidelines. If the contaminants are metals, there is more flexibility to allow sediment reuse based on the relatively low risk level metals pose to wetland habitats. In contrast, exceedances of organic contaminants are typically considered higher risk and sediment with exceedances for these analytes are typically not allowed for beneficial reuse.

Given the recommendations for refining the sediment screening guidelines presented above, there was consensus that the tests and process used to determine dredged sediment suitability is appropriate for the region. There was extensive discussion on the merits of prioritizing toxicity bioassays over sediment chemistry (and *vice versa*) and the desire to keep testing cost-effective for dredgers. The current sediment screening process is allowed to be completed as a tiered process (sediment chemistry first, followed by toxicity; Table 1), but most dredgers submit chemistry and toxicity data at the same time due to sediment hold-time limitations. The tiered approach tends to only be used when sediment quality is expected to be low and likely to fail criteria for in-Bay disposal or beneficial reuse based on chemistry alone. In these cases, toxicity testing is done after chemistry analysis, if at all. If streamlining the screening process is important for increasing the amount of sediment used for beneficial reuse, a more well-defined tiered approach could be developed that allows sediment to be approved for beneficial reuse based on a single line of evidence. Using this approach to determine suitability would necessitate an integrated multi-contaminant approach to sediment chemistry and/or toxicity to constrain the uncertainty rather than relying on individual contaminant concentrations.

If sediment chemistry was the first tier of a tiered approach, sediment could be approved for beneficial reuse if no sediment chemistry screening guidelines were exceeded. The justification for using sediment chemistry as a single determinant of suitability is that sediment at or better than ambient condition is assumed to pose acceptable bioaccumulative and benthic impact risks because it is the best possible sediment in the Bay. However, this method is only as good as the screening list and not all toxic contaminants will be measured using this single line of evidence. This approach would require a review of the current sediment screening test list and the addition of emerging contaminants (e.g., pesticides, bisphenols) so it is reflective of current concerns. Many contaminants of emerging concern, however, do not have established toxicity thresholds, so it would be difficult to develop guidelines for those contaminants. Finally, the method detection limits that most commercial laboratories can achieve for some metals and organics are higher than the sediment screening guidelines, which results in a lot of non-detect values, which are of little quantitative use. In some cases, this requires that multiple labs analyze samples, increasing the time and cost of overall testing. Based on these caveats of a single line-of-evidence approach, it was reiterated that developing integrated multi-contaminant thresholds was recommended if suitability decisions would be made on chemistry alone.

If the tiered approach started with bioassays rather than chemistry, acute toxicity tests—a type of bioassay—could be used to provide an indication of short-term sediment toxicity. Currently, two taxa—an amphipod (*Ampelisca abdita, Leptocheirus plumulosus,* or *Eohaustorius estuarius*) and a polychaete (*Neanthes arenaceodentata*) are required in toxicity testing in San Francisco Bay. While other taxa may be used, those listed here are the most common invertebrates used in the region. In general, toxicity is not common in Bay sediment. The species used to evaluate sediment toxicity should be evaluated to determine if they are the most appropriate test organisms for sediment that will be placed in wetland habitats. Starting the tiered process with toxicity testing shifts the focus to potential biological impacts, irrespective of chemical concentration. The effects of chronic exposure are not captured by this approach, nor is the potential for bioaccumulation. Pairing the bioassays with a limited sediment chemistry screen for bioaccumulative contaminants could provide an economically-feasible second line of evidence for determining suitability.

While a tiered system with a single line of evidence may reduce cost to permit applicants, the current process is more robust because it includes a combination of chemistry and toxicity. The experts strongly recommended that multiple lines of evidence be used because of the uncertainty associated with individual test results from either sediment chemistry or toxicity. Recommended modifications to the current process, that reduce uncertainty around the screening guidelines, as suggested during the discussion of Question #1 above, include: (1) updating the sediment screening guidelines to current ambient values (most protective) with an envelope of uncertainty; (2) using a multivariate approach that considers the suite of contaminants together (possibly higher screening values for individual contaminants but fewer false positives); (3) using a hazard quotient approach that compares measured values to a screening benchmark; or (4) update the ambient values and toxicity guidelines and incorporate both into screening. In addition, the experts thought that additional or substitute organisms that are representative of wetland habitats should be considered for toxicity testing.

Question 3: How should bioaccumulation potential be addressed for the beneficial reuse of sediment?

The current screening process for the beneficial reuse of dredged sediment in San Francisco Bay does not include testing for bioaccumulation as a standard test. On a case-by-case basis, bioaccumulation testing (28-day testing) is sometimes requested if there is no acute toxicity and chemistry results are above the current surface sediment screening thresholds for one or more contaminants that are known to bioaccumulate in invertebrate tissue.

The panel recommended that bioaccumulation be added to the current screening process. However, bioaccumulation testing as a first pass was not recommended because of the expense and variability in test results. Instead, they recommended using the chemistry results to apply a bioaccumulation model, such as the Bioaccumulation Risk Assessment Modeling System (BRAMS), developed by the USACE (Baker and Vogell 2012). This approach could be used to determine the likelihood that levels of concern will be exceeded. A bioaccumulation model for PCBs was developed for San Francisco Bay (Gobas and Arnot 2010); this model could be augmented by the BRAMS to more broadly screen sediment for beneficial reuse. Ambient sediment concentrations can be input into BRAMS to calculate the expected tissue concentrations. Those values can then be compared to fish tissue concentrations measured by the RMP. BRAMS could also be used in reverse, starting with concentrations of concern for fish and birds and working backwards to calculate sediment screening guidelines for bioaccumulative contaminants. Site specific guidelines could be incorporated if there are organisms of concern in the area where the sediment is going to be placed. Using the modeling approach as a first cut pass is an inexpensive way to incorporate bioaccumulation into the process. In addition to using ambient chemistry values in the Bay to calculate expected tissue concentrations, current contaminant concentrations in wetlands (tissue and sediment) could provide another measure of bioaccumulation that organisms are currently experiencing.

Using the model to predict tissue concentrations from sediment chemistry assumes that everything measured is available for uptake. It is unlikely that this is the case, so the estimate will be conservative. Passive samplers that measure only the bioavailable fraction of contaminants could be used to assess how total concentrations and bioavailable concentrations compare. The RMP will be using passive samplers in 2020 in Steinberger Slough to measure PCBs in the sediment pore water and at the sediment-water interface. Fish and sediment core samples collected at the same time could provide evidence to reduce the uncertainty around the model calculations for bioaccumulation.

Recommendations and next steps

Based on the discussions during the workshop and the input from the four technical experts, six key recommendations emerged around how sediment screening criteria for beneficial reuse should be determined, what the process should include, and how bioaccumulation testing can be incorporated into the process.

1. If ambient values are going to continue to be used as guidelines, update them with RMP data from the open Bay and margins areas. Including the margins data is important because it is likely to be more similar than open Bay sediment to wetland sediment quality where dredged sediment could be used. In addition, evaluate ambient values for each subembayment to assess spatial differences in sediment quality throughout the Bay.

2. Use the hazard quotient methodology to assess risk of ecological effects based on the ratio between measured values of contaminants and sediment screening criteria.

3. Use multivariate analyses to determine sediment toxicity screening thresholds based on a combination of contaminants rather than individual contaminants, particularly if sediment chemistry is used as a single line of evidence to determine suitability.

4. Assess current bioassays to determine if they are appropriate for assessing risk to wetland species.

5. Use a tiered framework to assess chemistry, toxicity, and bioaccumulation.

6. Use BRAMS in tandem with the PCB bioaccumulation model that has been developed for San Francisco Bay to determine bioaccumulation levels of concern (based on ambient univariate or multivariate sediment concentration thresholds) and/or sediment screening guidelines (based on tissue concentrations of concern). Assess the uncertainty associated with the model and provide an override of model-derived screening values if direct assessments (i.e., bioaccumulation testing) do not show toxicity.

7. Develop a monitoring strategy to assess the effects of dredged sediment on wetland habitats to inform adaptive management of the screening guidelines and process.

These recommendations will be reviewed by the DMMO, LTMS Management Team, and RMP to determine next steps. Additional funding from the RMP may be available in future years to pursue data analyses, updates to the trophic transfer model, and further refinement of toxicity reference values for species in San Francisco Bay.

Conclusions

Technical experts highlighted areas where the current process for screening sediment for beneficial reuse in San Francisco Bay could be improved. Some of the recommendations could be easily implemented (e.g., update values to current ambient levels), while other changes will take more time and consideration of ecological, economic, social, and political goals. As sea level rise increasingly threatens wetland habitats around the Bay, beneficial reuse of dredged sediment is becoming increasingly important. While the overall goal is to ensure that as much sediment as possible is available for beneficial reuse, the process also needs to be protective of the habitats receiving the sediment, as well as the aquatic species that live in those habitats, some of which are consumed by humans. Carefully considering how risk and uncertainty are accounted for and evaluated will be important components of an updated process.

References

Baker, K., and J.T. Vogell II. 2012. Bioaccumulation risk assessment modeling system (BRAMS). U.S. Army Corps of Engineers. U.S. Army Engineer Research and Development Center.

Bever, A.J., M.L. MacWilliams, F. Wu , L. Andes, and C.S. Conner. 2014. Numerical modeling of sediment dispersal following dredge material placements to examine possible augmentation of the sediment supply to marshes and mudflats, San Francisco Bay, USA. PIANC World Congress San Francisco, USA, 2014.

Department of Ecology, State of Washington. 2013. Sediment Management Standards. Chapter 173-204 WAC. Publication Number 13-09-55.

Foley, M.M., B. Christian, B. Goeden, B. Ross, J. Siu, and J. Gravenmier. 2019. Dredging and dredged sediment disposal. In, The Pulse of the Bay: Pollutant Pathways. SFEI Contribution #954. San Francisco Estuary Institute, Richmond, CA.

Gandesbery, T., and F. Hetzel. 1998. Ambient concentrations of toxic chemicals in San Francisco Bay sediments. San Francisco Bay Regional Water Quality Control Board Staff Report, 70 pp.

Germano and Associates. 2004. An evaluation of existing sediment screening guidelines for wetland creatin/beneficial reuse of dredged material in the San Francisco Bay Area along with a proposed approach for alternative guideline development. Report, 82 pp plus appendices.

Gobas, F.A., and J.A. Arnot. 2010. Food web bioaccumulation model for polychlorinated biphenyls in San Francisco Bay, California, USA. *Environ. Toxicol. Chem.* 29(6):1385-95.

Li, X., W. Chi, H. Tian, Y. Zhang, Z. Zhu. 2019. Probabilistic ecological risk assessment of heavy metals in western Laizhou Bay, Shandong Province, China. *PLoS Onte*. 14(3): e0213011.

Long, E.R., D.D. MacDonald, S.L. Smith, and F.D. Calder. 1995. Incidence of adverse biological effects within ranges of chemical concentrations in marine and estuarine sediments. *Environ. Manage.* 19(1):81-97.

Perry, H., A. Lydon, P. Soumoy, and B. Goeden. 2015. San Francisco Bay Sediment: Challenges and Opportunities. Poster presented by BCDC at the 2015 State of the Estuary Conference, Oakland, CA.

RSET. Northwest Regional Sediment Evaluation Team. 2018. Sediment evaluation framework for the Pacific Northwest. RSET Agencies Report, 183 pp plus appendices.

SFBRWQCB. 2000. Beneficial reuse of dredged materials: sediment screening and testing guidelines. San Francisco Bay Regional Water Quality Control Board Draft Staff Report, 35 pp.

SWRCB. 2018. Including substitute environmental documentation for amendments to the Water Quality Control Plan For Enclosed Bays and Estuaries – Part 1 Sediment Quality (Sediment Quality Provisions). State Water Resources Control Board Staff Report, 498 pages.

Yee, D., P. Trowbridge, and J. Sun. 2015. Updated ambient concentrations of toxic chemicals in San Francisco Bay sediments. SFEI Contribution No. 749. San Francisco Estuary Institute, Richmond, CA.

Yee, D., A. Wong, and N. Buzby. 2019. Characterization of sediment contamination in South Bay margin areas. SFEI Contribution No. 962. San Francisco Estuary Institute, Richmond, CA.

Yee, D., A. Wong, I. Shimabuku, and P. Trowbridge. 2017. Characterization of sediment contamination in Central Bay margin areas. SFEI Contribution No. 829. San Francisco Estuary Institute, Richmond, CA.