San Diego Sediment Mapping Study

Workplan for Generating Scientifically Defensible Maps of Sediment Condition in the San Diego Region

Prepared by

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and

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Background

Maps are one of the best data summary tools used by managers to convey spatial extent and magnitude of environmental condition to decision makers and the public. Maps are easily displayed, self-explanatory, and give the viewer context over the entire area of interest. In addition, maps of conditions at the same location over time can generate useful assessments of trends in spatial extent (e.g., is a problem growing or shrinking?).

Although maps are useful analytical tools, the ability to create maps with scientific rigor is extremely difficult and rarely accomplished. More often, maps are generated simply using prepackaged software modules with little forethought for assessing spatial variability or describing confidence in the mapping contours. Several techniques are available for creating maps including commonly used algorithms such as linear interpolation or kriging. Linear interpolation simply uses the average between adjacent sites to estimate environmental condition from sampled to unsampled areas. Kriging offers much more sophistication using a cluster of neighboring sites to predict conditions at unsampled locations. Albeit computationally more intensive, kriging offers several advantages, the largest of which lies in its ability to create more precise estimates of condition at greater distances.

The key to effective kriging algorithms lies in the ability of mapmakers to estimate spatial variance. If the variance is large, then samples should be collected at closer distances to increase precision at unsampled locations. In contrast, if the variance is small, then samples can be spaced further apart to achieve the same precision. If the spatial variance is unknown, then the sample locations will likely be placed inefficiently. This may waste resources if samples are spaced too close together, or produce results that suffer from imprecision if samples are spaced too far apart. If the spatial variability for an area is known on the other hand, then optimal sampling distances can be selected based on the level of confidence desired by the end-user.

This workplan describes a sampling program to create maps of environmental condition with known levels of confidence. The program targets sediment quality near the City of San Diego Point Loma Ocean Outfall and the joint City/International Boundary Water Commission (IBWC) South Bay Ocean Outfall. The impetus for this study arises from the need of the City of San Diego, and its regulatory authorities the San Diego Regional Water Quality Control Board (RWQCB) and the United States Environmental Protection Agency (EPA), to have scientifically defensible maps that define sediment conditions in the region. In this case, a dedicated effort will be made to create maps of superior quality for City, IBWC, RWQCB and EPA management, as well as the public.

Specifically, the City is mandated to conduct this "special study" as part of the regulatory requirements governing the discharge of wastewater from the Point Loma Wastewater Treatment Plant (PLWTP) through the Point Loma outfall (NPDES Permit No. CA0107409, Order No. R9-2002-0025, Addendum No. 1). Such special studies, as defined by the *Model Monitoring Program for Large Ocean Discharges in Southern*

California (Schiff et al. 2001) and adopted in Order No. R9-2002-0025 for the PLWTP, are a unique mechanism to focus monitoring efforts on specific questions.

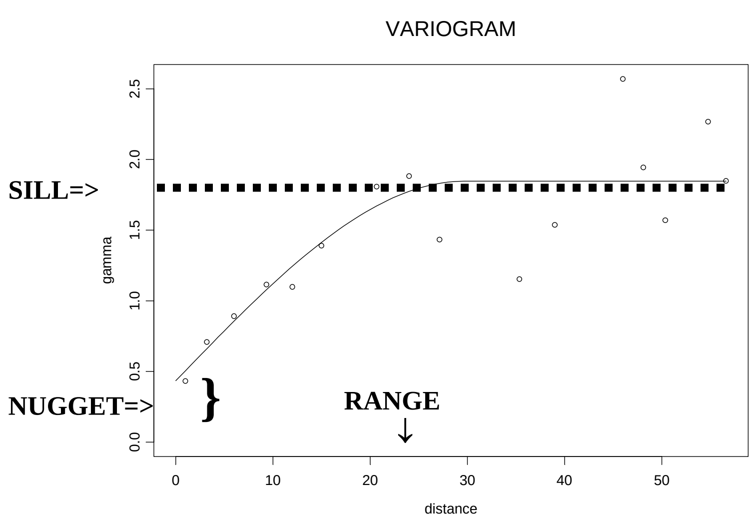
In addition to the above effort, representatives of the City, IBWC, RWQCB and EPA have negotiated a resource exchange agreement that will allow mapping of the South Bay outfall area concurrent with the Point Loma study. This resource exchange will require approval of the Executive Officer of the RWQCB for administrative modifications to the Monitoring and Reporting Programs (MRP) for the discharge of wastewater through the South Bay Ocean Outfall. Two separate NPDES permits govern this discharge, one for the City's South Bay Water Reclamation Plant (NPDES Permit No. CA0109045, Order No. 2000-129) and one for the IBWC's International Wastewater Treatment Plant (NPDES Permit No. CA0108928, Order No. 96-50). Since the receiving waters monitoring requirements for both permits are essentially the same, approval of this resource exchange will apply towards both MRPs.

General Approach

A two-phased approach is proposed to create scientifically defensible maps of the San Diego region. The first phase (Phase 1) will focus on understanding spatial variability in the areas of interest. Once the spatial variability is known, then sampling distances (also known as lag distances) will be optimized for the second phase (Phase 2), where sampling will be conducted to create maps of specific areas and parameters. The focus of this workplan will be on the Phase 1 study. A detailed amendment to the workplan will be added for Phase 2 of the project once Phase 1 is completed.

In order to understand the spatial variability in an area of interest, one needs to plot one-half the variance (gamma) against a series of fixed distances. This type of plot, commonly referred to as a variogram (**Figure 1**), is the key element for determining the optimal lag distances for creating a map using kriging. The variogram has three reference points known as the nugget sill, and range.

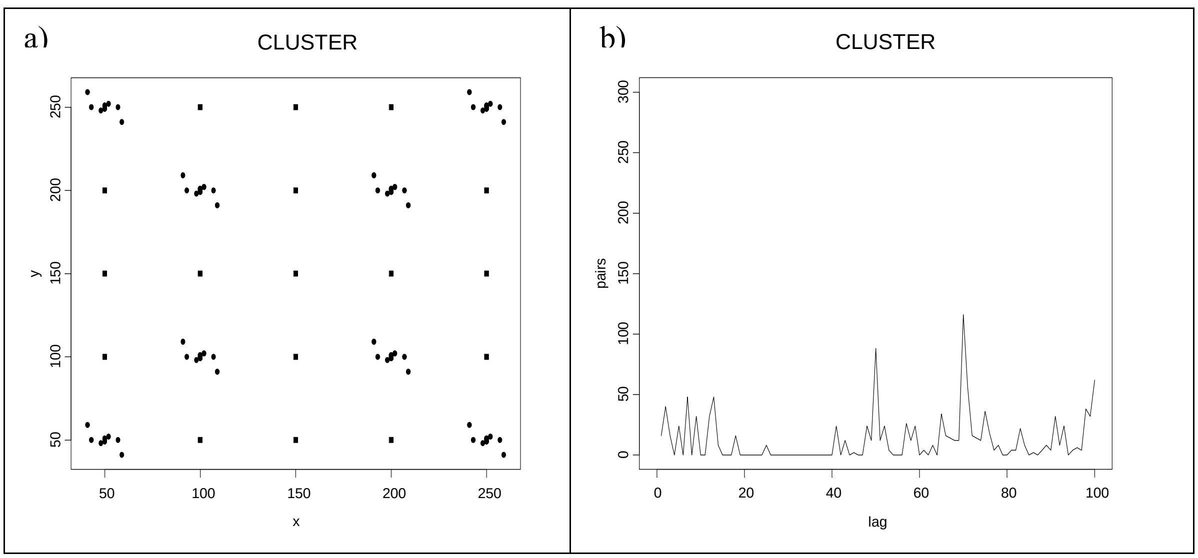
FIGURE 1. Example variogram.



The nugget indicates the variability between samples taken at very close proximities and represents both laboratory measurement error plus small-scale spatial variability. The sill is the variability achieved between samples spaced sufficiently far apart that a spatial relationship no longer exists. In this sense, the sill provides a measure of variability among spatially independent samples. The range is the lag distance at which the sill is achieved and provides the extent of the spatial relationships between sample points.

The primary focus of Phase 1 is to generate sufficient information to create variograms in the areas of interest. This requires sampling a large range of lag distances from the nugget, past the range, to the sill. Ideally, samples will be focused between the nugget and sill in order to best define the shape of the variogram curve. In order to generate these data, several clusters of sites will be sampled at multiple locations throughout the mapping areas. Clusters can be placed on top of existing grid sites to promote efficiency. S-shaped or more complex multi-lag clusters (i.e., overlapping S-clusters) provide tremendous value since they cover a large range of lag distances (e.g., **Figure 2**).

FIGURE 2. Hypothetical S-shaped cluster design (a) and frequency histogram of lag distances generated with this design (b).



Specific Approach

Multi-lag sampling design

We will create variograms for sediment condition in two main areas offshore San Diego: (1) centered around the Point Loma Ocean Outfall; (2) centered around the South Bay Ocean Outfall. Sets of multi-lag clusters will comprise the bulk of the sample sites and will be placed in regions surrounding both outfalls, while additional spatial coverage will be provided by sampling regular NPDES-mandated grid sites in both areas (**Figures 3-5**).

FIGURE 3. Overview of proposed site distribution for San Diego sediment mapping study; blue circles = new mapping sites, black circles = current or old NPDES grid stations, red circles = cluster enhancement areas representing 3-5 sites, 50-m lag distances apart (see Figures 4 and 5 for details).

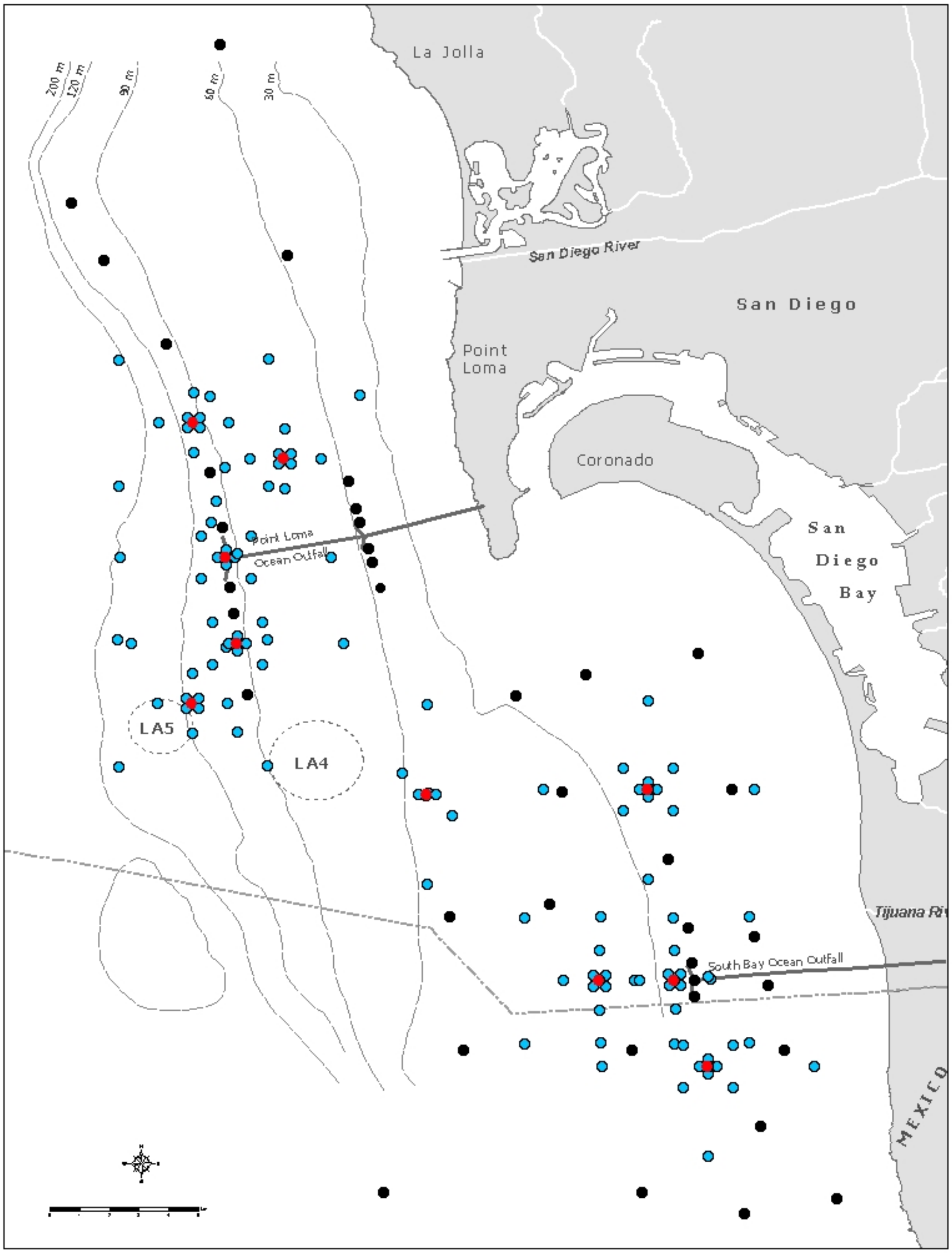


FIGURE 4. Expanded view of proposed site distribution for Point Loma outfall mapping region showing location of multi-lag clusters (five of size n = 17); blue circles = new mapping sites, black circles = current NPDES 98-m grid stations or old NPDES stations along inshore 60-m depth contour, red circles = cluster enhancement areas representing five sites each, 50-m lag distances apart (1 grid or new station in center + 4 new sites).

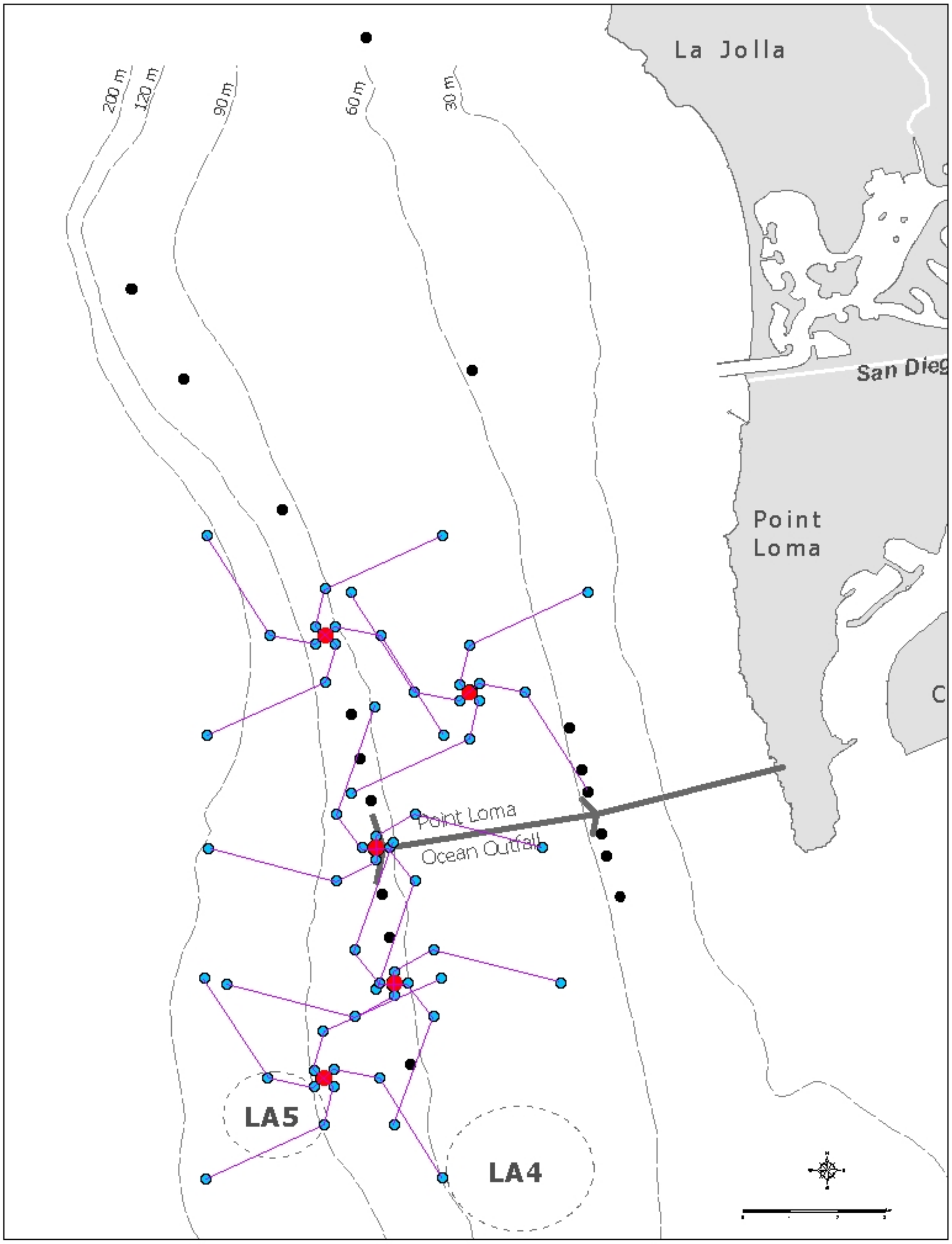
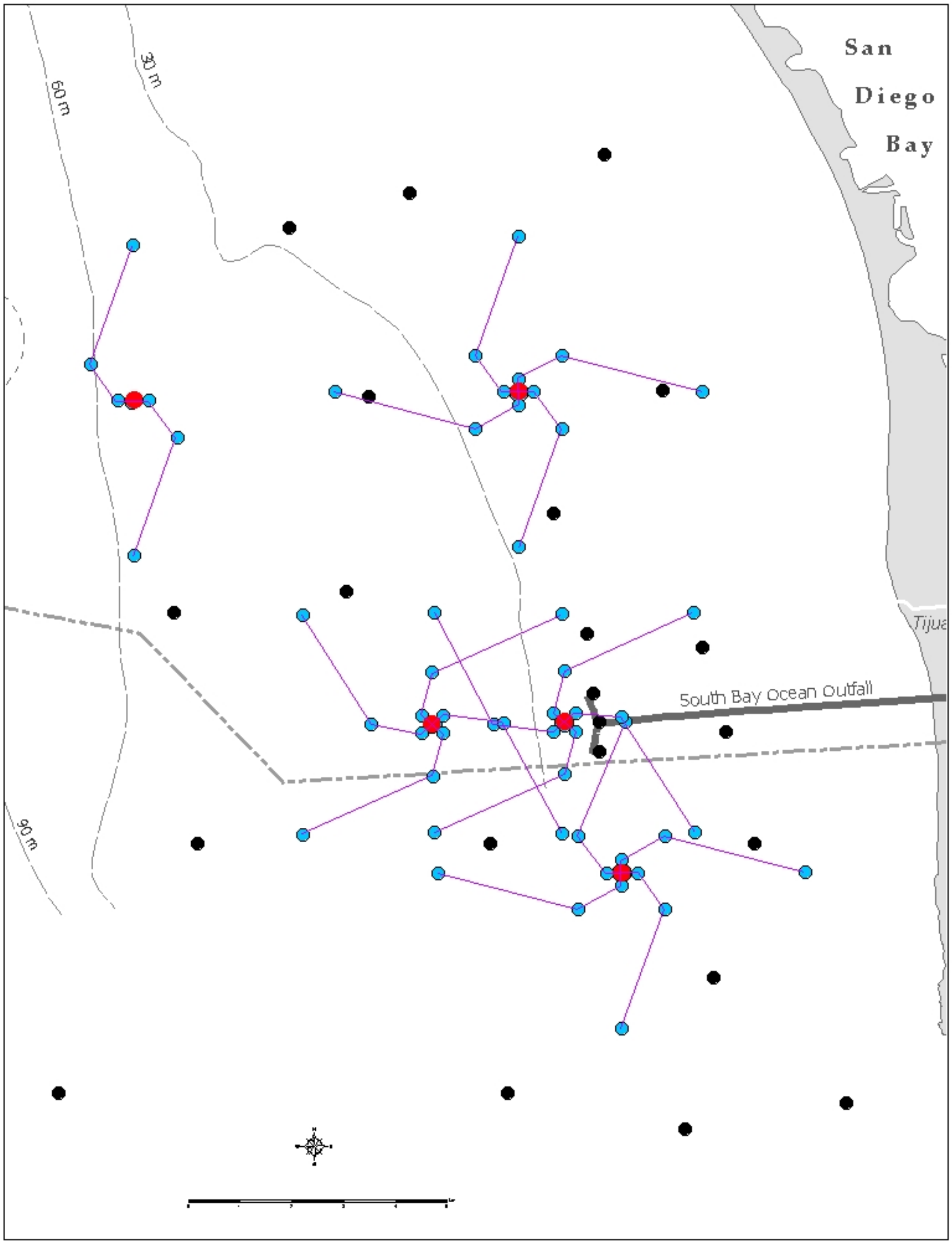


FIGURE 5. Expanded view of proposed site distribution for South Bay outfall mapping region showing location of multi-lag clusters (four of size n = 17, one of size n = 9); blue circles = new mapping sites, black circles = NPDES grid stations, red circles = cluster enhancement areas representing either three sites (1 grid station between 2 new sites) or five sites (1 grid station in center + 4 new sites), 50-m lag distances apart.



The two sampling areas encompass different types of soft bottom habitats that may have different spatial variance structures. Off Point Loma, we will include clusters centered near the existing discharge/diffuser site (depth ~100 m), at locations both north and south of the outfall, in shallower waters between the current and old (~60 m) outfall diffusers, and in an area bordering the LA-5 dredged materials disposal site located down coast and offshore of the outfall. Targeted areas for cluster placement in the South Bay region include near the present outfall diffusers (depth ~30 m), in slightly deeper waters west and north of the discharge site, and at several other locations north and south of the outfall.

Approximately 112 mapping samples will be collected for both sediments and animals (macrofauna) from sites located in the vicinity of the Point Loma Ocean Outfall, and about 107 samples will be collected from sites surrounding the South Bay Ocean Outfall (**Table 1**). Twelve of the sites near the Point Loma Ocean Outfall will be allocated to the primary core stations designated for the existing outfall monitoring grid, while eight sites will correspond to stations sampled previously along the original inshore discharge depth contour. The remaining sites/samples will be allocated among five multi-lag clusters. Twenty-seven of the sites near the South Bay Ocean Outfall will be allocated to the existing monitoring grid. The remaining 80 sites/samples will be allocated to the multi-lag clusters. About 10% of the samples will be designated as field duplicates to help derive the variogram nugget, thus reducing the total number of distinct sites sampled. A summary of the multi-lag cluster designs for both Point Loma and South Bay studies is presented in **Table 2**.

TABLE 1. Proposed sampling effort for Phase 1 of the sediment mapping study for both the Point Loma and South Bay outfall regions.

Sample Type	Number of Samples		
	Regular NPDES grid sites*	New mapping sites†	Total number of samples
Point Loma			
sediment	12	100	112
macrofauna	12 (24)*	100	112 (124)*
South Bay			
sediment	27	80	107
macrofauna	27	80	107

* Regular NPDES sites for Pt Loma = I° core stations currently monitored along the 98-m discharge depth contour; sampling at these 12 sites will include two replicate macrofauna grabs per NPDES permit requirements.

† Included as "new" mapping sites off Pt Loma are the locations of: (a) one II° core station currently monitored along the 116-m depth contour, and (b) eight old inshore stations located along the original 60-m discharge depth contour.

TABLE 2. Detailed sample distribution for Point Loma and South Bay mapping designs.

Site/sample distribution	Distinct # samples
Point Loma	(n = 112)
5 multi-lag clusters of size 17	85
< 5 enhancement areas (n = 5 sites)	
13 NPDES grid sites (98-116 m)	9
< stations E5, E14, E25 = enhancement centers (98 m)	
< station E3 = enhancement center (116 m)	
8 inshore outfall sites (60 m)	7
< station A16 = inshore edge of multi-lag cluster	
11 field duplicates	11
< enhancement centers + 6 sites to be determined	
South Bay	(n = 107)
4 multi-lag clusters of size 17	68
< 4 enhancement areas (n = 5 sites)	
1 multi-lag cluster of size 9	9
< 1 enhancement area (n = 3 sites)	
27 NPDES grid sites	22
< stations I9, I13, I15, I28, I30 = enhancement centers	
8 field duplicates	8
< enhancement centers + 3 sites to be determined	

Sampling and analysis

At each monitoring site, benthic samples will be collected using a 0.1 m^2 chain-rigged VanVeen grab sampler. One sediment grab and one macrofauna grab will typically be collected at each site. However, if designated as a “field duplicate” site, two sediment and two macrofauna grabs will be collected. Differential global positioning (dGPS) will be used for navigation, and the final sampling location will be recorded for each site at the time the grab hits bottom. All samples will be collected and processed according to existing protocols. Sediment samples from the new mapping sites will be processed according to procedures (e.g., holding times, target analyte list) established for the Southern California Bight 2003 Regional Monitoring Project (e.g., Bight’03 Coastal Ecology Committee 2003), while samples from regular grid sites will be processed following the protocols specified in the appropriate NPDES permits (see City of San Diego 2004a, b). All sediment samples will be analyzed for grain size, total organic carbon, total nitrogen, trace metals, chlorinated pesticides, and polychlorinated biphenyl compounds (PCBs). The Bight’03 target list of metals, pesticides and PCBs for analysis of samples from the new mapping sites is specified in **Table 3**. In addition, samples collected for benthic community assessment will be sorted into major taxonomic groups (e.g., polychaetes, crustaceans, mollusks, echinoderms, other phyla combined), identified to the lowest taxon possible, and enumerated. Community assessment for each site will include calculation of total abundance, species richness (number of species), species diversity, dominance, and the benthic response index (BRI).

TABLE 3. Bight'03 target list of trace metals, pesticides and PCBs for sediment analyses (see Bight'03 Coastal Ecology Committee 2003).

Trace Metals	Pesticides	PCBs	
Aluminum	4,4'-DDT	PCB-18	PCB-128
Antimony	2,4'-DDT	PCB-28	PCB-138
Arsenic	4,4'-DDD	PCB-37	PCB-149
Barium	2,4'-DDD	PCB-44	PCB-151
Beryllium	4,4'-DDE	PCB-49	PCB-153
Cadmium	2,4'-DDE	PCB-52	PCB-156
Chromium	α-Chlordane	PCB-66	PCB-157
Copper	γ-Chlordane	PCB-70	PCB-158
Iron		PCB-74	PCB-167
Lead		PCB-77	PCB-168
Mercury		PCB-81	PCB-169
Nickel		PCB-87	PCB-170
Selenium		PCB-99	PCB-177
Silver		PCB-101	PCB-180
Zinc		PCB-105	PCB-183
		PCB-110	PCB-187
		PCB-114	PCB-189
		PCB-118	PCB-194
		PCB-119	PCB-201
		PCB-123	PCB-206
		PCB-126	

Products

The main product from Phase 1 of the mapping study will be a final report. This report will include: 1) a description of sampling success including sampling dates, times and locations; 2) summary tables of sediment condition including results from laboratory analysis; 3) descriptions of benthic community assemblages; and 4) variograms of sediment condition for chemical and biological parameters. Empirical variograms will be generated separately for the Point Loma and South Bay outfall areas, and then compared to determine the differences in spatial variance structures between the regions and/or habitats. Finally, a translation curve will be created using the empirically derived variograms that describe sampling lag distances versus relative confidence in prediction accuracy. This curve will be the focal point for Phase 2 of the mapping study, whereby we set lag distances for creating the final maps of sediment condition in the San Diego region.

Schedule

This project will take at least 54 months to complete (**Figure 6**). The first six months was used for assessing the appropriate sampling design for Phase 1 and drafting the overall workplan included herein. Upon approval of the workplan, approximately 15 months of sampling, and sample processing and analysis will be required for the Phase 1 study. Phase 1 data analysis and reporting will require another estimated six months, but may overlap with Phase 2 planning in order to increase efficiency. Phase 2 sampling and analysis will then require another 15 months, followed by about nine months of data analysis, reporting, and map-making. Project completion for Phase 2 is scheduled for June 2008. Although the Phase 2 study is mandated for the Point Loma region, additional negotiations and resource exchange agreements will be required for a Phase 2 study of the South Bay outfall region.

FIGURE 6. Tentative schedule for Phase 1 and 2 of San Diego mapping study.

Month	03	06	09	12	03	06	09	12	03	06	09	12	03	06	09	12	03	06
Year	04	04	04	04	05	05	05	05	06	06	06	06	07	07	07	07	08	08
Phase 1 Planning	■	■																
Phase 1 Sampling and analysis			■	■	■	■	■											
Phase 1 Data analysis and reporting								■	■									
Phase 2 Planning									■	■								
Phase 2 Sampling and analysis											■	■	■	■	■			
Phase 2 Data analysis and reporting																■	■	■

Literature Cited

Bight'03 Coastal Ecology Committee. (2003). Quality Assurance Manual, Southern California Bight 2003 Regional Marine Monitoring Survey (Bight'03). Prepared for Southern California Coastal Water Research Project. Westminster, CA.

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