COASTAL REMOTE SENSING OF THE SAN DIEGO/TIJUANA REGION

WORK PLAN PROPOSAL

Submitted to:
San Diego Regional Water Quality Control Board, City of San Diego Metro Division, County of San Diego Departmental of Environmental Health

By Ocean Imaging Corp.

OBJECTIVES:

1) Establish and document relationships between field-derived water quality variables and remotely sensed characteristics detected in aerial and satellite imagery.

2) Initiate the formation of a remote sensing-based data base which can be utilized to analyze locations, sizes and extent trends of runoff and discharge sources, seasonal effects, long-term changes, etc.

3) Begin analyzing the above database for such variables.

4) Establish a real-time analysis/advisory delivery network between Ocean Imaging and City and state agencies that will provide efficient transfer of remote sensing-derived information which can be used to guide coastal management efforts.

5) Begin operational, real-time runoff/discharge surveillance of the San Diego/Tijuana region.

WORK PLAN AND TIMELINE:

1) Establish and document relationships between field-derived water quality variables and remotely sensed characteristics detected in aerial and satellite imagery: Work toward this objective will commence immediately upon starting the project and will continue throughout the project's duration. The remote sensing data to be used for the correlation analysis will consist of imagery newly acquired during the project, as well as a limited amount of historical satellite data acquired during the past 15 years. The historical data will be chosen based on time coincident availability of field samples.

Both the historical and project-acquired satellite data will be used to establish correlations between radiances in the available image bands (or combinations of bands) and field-sampled variables. The strength of the relationships will be statistically quantified. Of special importance will be the ability to use the remotely sensed patterns to interpolate the field data in space and time, to utilize the imagery for establishing the spatial extents

of each runoff/discharge source, and to develop predictive ability for estimating the chances of beach closures (i.e. excessive bacterial contamination) from the radiance data. These efforts will be based on preliminary work done by Ocean Imaging (OI) for NASA/Orange County in 1995-98 and EPA/City of San Diego in 2000.

As part of the field data vs. remote sensing analysis, if sufficient funds are available (see Budget section below), the field data sets made available to OI will be processed with spatial interpolation algorithms. The interpolated fields will be compared to the effluent plume spread patterns revealed by the collected image data sets. This will reveal any recurring spatial patterns as well as provide data for evaluating the comprehensiveness and efficiency of the present sampling station grid.

Because the band wavelengths of all satellite sensors are fixed, it will not be possible to customize the satellite data for the best radiometric separation between various effluent input sources. It is possible to do this with OI's 4-channel aerial sensor (the DMSC), however, and work will be done during the rest of the 2001-2002 rainy season as well as during the 2002 dry season to establish any unique radiometric characteristics of various effluent sources in the region. Future DMSC overflights will be done with the combination of bands most efficient in aiding separation of discharge plumes from various sources, as well as wave and tidally caused turbidity.

Although work on this objective will continue throughout the year-long project, most effort will be expended in the first half-year. The established relationships will then become the core of the operational monitoring efforts, which will become the prime work focus in the second half of the project.

2) Initiate the formation of a remote sensing-based data base which can be utilized to analyze locations, sizes and extent trends of runoff and discharge sources, seasonal effects, long-term changes, etc.: This objective encompasses two important aspects of the region's wastewater management which are presently not well documented: 1) What/where are the sources of storm and discharge effluent affecting the area's beaches and what is each source's magnitude and spatial extent? 2) What changes in the sources and effluent plume behavior have occurred as the result of urban development, attempts at pollution control, and the addition of the San Antonio de los Buenos Sewage Treatment Facility in Mexico in the 1980s, changes in treatment at the Point Loma Sewage Treatment Facility, and addition of the South Bay Outfall in early 2000. Such information is important for both, evaluating future pollution reduction alternatives as well as assessing the effectiveness of past activities and pollution abatement investments.

In addition to helping answer the above questions, a comprehensive remote sensing data base will allow analysis of multiple environmental and runoff/sewage effluent discharge variables to better understand the links between specific environmental conditions and pollution consequences. For example, the spread patterns of the Tijuana River and the San Antonio de los Buenos sewage plumes can be studied in relation to remotely sensed current patterns. Similarly, the surfacing of the South Bay Outfall plume can be

examined in relation to surface flow and other remotely sensed parameters, leading to better understanding of pollution risk factors under different oceanic conditions, and the relative contributions of each pollution source to the region's beach closures (see next section).

A combination of satellite and aerial data will be contributed to the database:

Advanced Very High Resolution Radiometer (AVHRR) thermal and MODIS optical multispectral imagery: AVHRR has spatial resolution of 1.1km and the MODIS data have resolutions of 250m and 500m. OI collects AVHRR directly from orbiting satellites up to 4 times daily, and has near-real-time access to MODIS data each day. AVHRR image series will be utilized to monitor near-surface flow fields on a full regional basis. MODIS imagery will be used to track the spread patterns of individual runoff and outfall plumes on a regional basis. Both data types will be contributed to the project by OI at no additional per-scene cost.

Thematic Mapper (TM), Indian Remote Sensing Satellite (IRS), Spot and QuickBird multispectral optical imagery: Archived data from these satellites will be used for the historical studies, and new data will be added during the project through pretasking of orbits that correspond to field sampling in the region. These satellites offer spatial resolutions of 3-30m. Their orbit parameters are such that updates are available every 9-14 days. A per-scene fee collected by the satellite operator applies. The cost varies from $350 for historical data to $1000 for new data. None of these data sets can be obtained in near real-time, lessening their value for the later, operational monitoring aspect of the project. The number of images obtained depends on the budget available (see Budget section).

Synthetic Aperture Radar (SAR) satellite imagery: This is the only satellite image type that can image the ocean through clouds and rain. Data will be obtained both for historical and near-real-time analysis. Resolution is 10-50m. A per-scene charge applies, varying from $1500 for historical data to $3000 for near-real-time acquisitions. The number of images obtained depends on the budget available (see Budget section).

DMSC aerial multispectral sensor: This data type will be the most common contributor to the database, aside from AVHRR and MODIS. As described in the preceding section, initial test flights will result in the choice of wavelengths for the DMSC's 4 optical channels to maximize plume detection and source separation capabilities. The sensor can be flown during clear weather or under clouds, if the canopy is higher than approximately 5000 feet. Flights can be pre-scheduled in advance, but on-call response will also be possible during the project, thus making it the most practical (and cost-effective) image acquisition method for any real-time monitoring work. Spatial resolution is user-selectable based on aircraft altitude – most flights will result in 1-2m final data resolution. For the purposes of this project, data acquisition flights will concentrate on the southern part of the San Diego/Tijuana region, from south of San Antonio de los Buenos in Mexico to Pacific Beach. The number of flights is dependent on the budget

available (see Budget section), but will include flights coinciding with regular field sampling as well as on-call imaging after specific events of interest.

3) Begin analyzing the remote sensing database for variables relating runoff/sewage effluent dispersal patterns to environmental conditions. The outcome of work on this objective will be a greatly increased understanding of the behavior of the various pollution effluent sources under different environmental conditions, and hence increased future predictive and avoidance capabilities. The results should also aid in evaluating the potential effectiveness of future pollution abatement projects and potential consequences of nearshore development and other urban activities. When coupled with results from objective #1 (linking remotely sensed signals to bacteriological and other pollution levels), the work will form a basis for remote sensing-based real-time monitoring analysis and advisories, to be initiated in the second half of the project.

Specifically, work will focus on:

1) Quantifying the persistence and "affected shoreline" extents of each identified effluent source under different seasonal and rainfall conditions.
2) Quantifying the plumes' size, concentration and extents under different current flow directions and establishing (using field bacteriological data) minimal condition criteria which lead to beach closures.
3) Evaluating the ability to use remotely sensed data to more effectively estimate existing and near-future beach contamination boundaries – thus minimizing the total shoreline area that needs to be closed.

Intense effort will be expended on the above tasks in the project's first 8 months, providing accuracy for the real-time monitoring/advisory components to be initiated in the project's second half.

4) Establish a real-time analysis/advisory delivery network between Ocean Imaging and City and State agencies that will provide efficient transfer of remote sensing-derived information which can be used to guide coastal management efforts. The second half of this project will increasingly focus attention on bringing the established monitoring techniques and analysis insights into an operational mode that will provide State and local agencies with timely information on nearshore pollution conditions. For that program to succeed, it is important that an efficient information transfer system is established between OI, and the end-user agencies and individuals. During the 5^{th} through 7^{th} months of the project, special effort will be expended on establishing this link. With guidance from the RWQCB, an end-user group will be established and their offices will be provided with simple-to-use GIS software capabilities (e.g. the share-ware Arc Explorer) which will enable importing, viewing and basic analysis of the OI-generated water quality analyses. OI will work closely with the end-user group to fine-tune the analysis products and their formats to best fit the community's needs. OI will also provide basic instruction on the software and remote-sensing data use. The analysis products will be disseminated automatically via the Internet in near real-time. The end-

user group will consist of the County of San Diego DEH, the City of San Diego and the RWQCB.

This task is very important in the overall scope of the project, since it represents the primary catalyst for advancing the utilization of remote sensing science into effective, operational use.

5) Begin operational, real-time runoff/discharge surveillance of the San Diego/Tijuana region. This final objective will be addressed during the last 4-5 months of the project, commencing in October or November 2002. The primary goal is to provide the established end-user group with near-real-time image-based analyses of existing effluent plume sources, their existing and near-term forecasted extents, local beach closure potential, and other oceanic variables. The total coastal area to be monitored is budget dependent (see Budget discussion): the initial target region will be the border-to-Pt. Loma stretch, extending northward into North County if the financial resources are available.

It is anticipated that DMSC-based aerial surveys, and MODIS and AVHRR satellite imagery will be the most frequent data sources, with MODIS and AVHRR available daily and DMSC data being flown once per week (budget permitting). Additional SAR, TM and Quick-Bird satellite data will be acquired/purchased when warranted. Since such data cannot be usually received in real-time, however, their purchase will be made primarily for analysis of unique conditions or events worthy of additional study. All the acquired data will be added to the long-term database, thus enhancing its value for long-term analysis and coastal management.

The operational phase will allow the end-user community itself to evaluate the usefulness of remote sensing for coastal water quality monitoring, and the value of including these techniques in future monitoring programs.

BUDGET:

(Discussion and itemization spreadsheet to be sent separately)