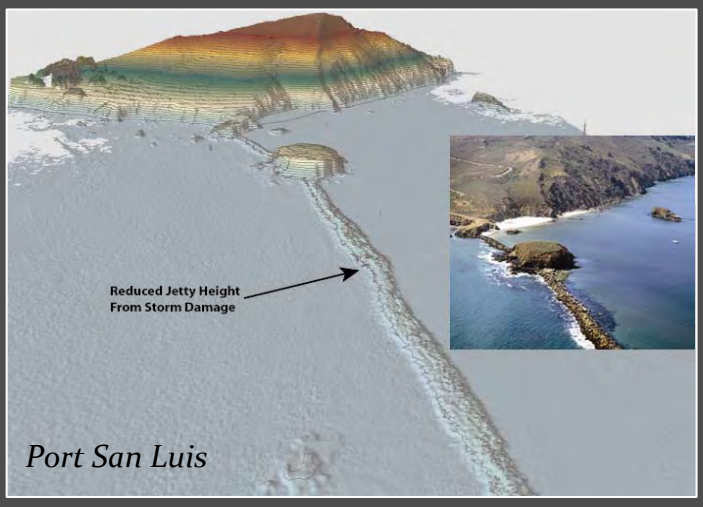
California Coastal LiDAR Project

Toward a modern topography of the coastal zone



February 2010

CALIFORNIA OCEAN PROTECTION COUNCIL

California Coastal LiDAR Project

Toward a modern topography of the coastal zone

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Prepared by
Doug George
California Ocean Protection Council

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Lower left: Monterey Bay National Marine Sanctuary, National Oceanic and Atmospheric Administration
Lower right: Coastal Data Information Program, Scripps Institution of Oceanography

Acknowledgements

A modern topographic survey of the California coastal zone requires cooperation and collaboration across federal, state, regional and local government agencies, academia and industry. The Ocean Protection Council participation in this effort could only be successful because of many partners. We would like to thank our collaborators for their responsiveness, active involvement in planning, and openness in sharing data and time. Although dozens of individuals have made our efforts possible, we would like to specifically highlight Joel Dudas (DWR), Carol Ostergren, Patrick Barnard, and Sam Johnson (USGS), Al Wanger and Greg Benoit (CCC), Tim Doherty and Adam Parris (BCDC), Rebecca Smyth, Kirk Waters, Roger Parsons and Michael Aslaksen (NOAA), Julie Thomas and David Castel (SIO), Ray McDowell and Linda Miller (DFG), Edward Curtis and Kathleen Schaefer (FEMA), Eddie Wiggins, Jennifer Wozencraft, Heather Schlosser, and Anne Sturm (USACE), Michael Byrne and Gary Darling (GIO), Rick Wilson (CGS/DOC), Clif Davenport (DOC), Chris Potter (Natural Resources Agency), Karen Bane (SCC), and Sarah Beesley (Yurok Tribal Fisheries Program). The interest and feedback from the Coastal Sediment Management Workgroup has been indispensable.

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Acronyms

BCDC	San Francisco Bay Conservation and Development Commission
CCC	California Coastal Commission
CCLP	California Coastal LiDAR Project
CDIP	Coastal Data Information Program
CGDME	Collaborative Geospatial Data Management Effort
CGS	California Geological Survey
ConCCo	Contra Costa County
COS	Center for Ocean Solutions
CSMP	California Seafloor Mapping Program
CSMW	Coastal Sediment Management Workgroup
DBW	California Department of Boating and Waterways
DEM	Digital elevation model
DFG	California Department of Fish and Game
DPR	California Department of Parks and Recreation
DWR	California Department of Water Resources
FEMA	Federal Emergency Management Agency
FWS	US Fish and Wildlife Service
GIO	Geographic Information Officer
GIS	Geographic Information System
IWG-OCM	Interagency Working Group for Ocean and Coastal Mapping
JALBTCX	Joint Airborne LiDAR Bathymetry Technical Center of Expertise
LiDAR	Light Detecting And Ranging
NAVOCEANO	Naval Meteorology and Oceanography Command and Naval Oceanographic Office
NCMP	National Coastal Mapping Program
NOAA	National Oceanic and Atmospheric Administration
NPS	National Park Service
OCM	Ocean and Coastal Mapping
OPC	California Ocean Protection Council
OST	California Ocean Science Trust
SANDAG	San Diego Association of Governments
SCBPS	Southern California Beach Processes Study
SCC	California State Coastal Conservancy
SIO	Scripps Institution of Oceanography
SLC	State Lands Commission
SMCMVD	San Mateo County Mosquito and Vector Control District
SWRCB	State Water Resources Control Board
TNC	The Nature Conservancy
USACE	US Army Corps of Engineers
USGS	US Geological Survey

Executive Summary

A Need to Map

A seamless, onshore-offshore high-resolution elevation map of the California coastal zone would benefit resource managers and coastal communities by providing information to assess potential impacts from sea level rise among other uses. Contour intervals of 30 cm (1-foot) up to a topographic elevation of 10 meters (from mean sea-level) represent a desirable resolution over an area that will allow for the development of alternative response strategies to shoreline change and sea level rise. A modern elevation dataset will enable planners, scientists, engineers, and decision-makers to:

- Assess the need for adequate buffer areas around wetlands and estuaries
- Identify and assess areas of potential retreat and relocation for affected development or infrastructure within communities
- Evaluate potential shoreline/bluff erosion and retreat
- Identify potential inundation zones (with flexibility to examine a range of inundation scenarios)
- Conduct risk assessments for impacts from storms and storm surges
- Produce more accurate wave run-up models related to inundation and tsunami planning.

Light Detecting And Ranging (LiDAR) is a remote sensing technology that uses lasers to measure elevation and is a rapid, cost-effective technology to collect high-quality topographic information. A complete baseline LiDAR dataset for the California coast would support the goals of Governor Schwarzenegger's Executive Order S-13-08 of November 2008 that directs all construction projects to consider sea level rise during design, and the Office of Planning and Research to provide land-use guidance related to climate change. This dataset would also be valuable to implementation of the California Climate Adaptation Strategy. The California Coastal LiDAR Project (CCLP) will better provide the data to satisfy these directives than older or lower resolution surveys.

In addition, the results of the CCLP can be integrated with the data from the California Seafloor Mapping Program (CSMP), an OPC-led collaborative project with federal agencies to map the seafloor from shore to three nautical miles offshore (California jurisdictional boundary). The combination of the CCLP and CSMP data will produce the seamless onshore-offshore maps useful to managers and scientists.

2009 LiDAR Activities in California

Development of California LiDAR standards

The California Ocean Protection Council (OPC), with participation from other state and federal agencies, has actively pursued developing a modern elevation dataset of the coastal zone. To define the technical and geographic specifications that would satisfy the largest number of agency and local user needs, the OPC convened a meeting of 40 representatives from 15 state, federal, and academic agencies and groups on December 18, 2008. Subsequent work by the Department of Water Resources (DWR), the

California Coastal Commission (CCC), the San Francisco Bay Conservation and Development Commission (BCDC) and the OPC produced a final set of state agency specifications for coastal collection in spring 2009. These specifications match those used by DWR on the Sacramento-San Joaquin Delta and in the Central Valley. Unfortunately, California's financial crisis prevented the OPC from providing funds to support collection efforts. However, two large-scale programs were developed by federal agencies in the latter half of 2009.

USACE collection along California coastline

The U.S. Army Corps of Engineers (USACE) began a coastal aerial LiDAR collection in October 2009 as part of the National Coastal Mapping Program (NCMP). The mission of this project is to support regional sediment management, construction, operations, and regulatory functions in the coastal zone. Topographic data are collected from the shoreline to 0.5 km onshore at 1 m intervals while bathymetric data are collected from the shoreline to 1 km offshore at 5 m intervals. The technical specifications for the NCMP were developed by a collaboration of the four federal mapping agencies (USACE, U.S. Geological Survey (USGS), National Oceanic and Atmospheric Administration (NOAA), Naval Meteorology and Oceanography Command and Naval Oceanographic Office (NAVOCEANO)) and are different from those assembled by the state agencies. At the time of this publication, shorelines and nearshore bathymetry of the counties of San Diego, Orange, Los Angeles, Ventura, and Santa Barbara were surveyed; portions of San Luis Obispo (62%) and Monterey (43%) counties were also surveyed. Winter weather conditions have delayed further collection efforts until spring 2010 when the remaining coastline (San Luis Obispo to Del Norte counties) will be surveyed. The USACE also funded the Coastal Data Information Program (CDIP)/Southern California Beach Processes Study (SCBPS) for a LiDAR survey from the Mexican Border to Long Beach in March 2009.

Collaborative NOAA/USGS collection in San Francisco Bay Area

A combined effort by NOAA and USGS was developed in the latter half of 2009 to conduct LiDAR surveys of the San Francisco Bay Area extending from the Carquinez Strait to outside of the Golden Gate. With involvement from BCDC primarily, and OPC and DWR, the collection resolution will use the state specifications in the NOAA portion with ongoing efforts for incorporation in the USGS portion. The geographic coverage extends from the bay shoreline to the 5 m topographic contour. The collaborative effort is scheduled to complete by the end of 2010.

Anticipated future LiDAR activities in California

The two federal collection efforts on the coastline and inside San Francisco Bay are expected to be completed by mid-2010. Datasets will become publicly available by the end of 2010. Based on the needs expressed by the state coastal management agencies, the federal collection efforts on the coastline may not be sufficient for local, regional and state agencies' climate change planning. In addition, centralizing known existing datasets in a widely-accessible database will be essential to prioritize future surveys and avoid duplicative collection efforts. The California Geographic Information Officer (GIO) will be a valuable partner in organizing existing and future datasets.

1. Background

1.1 Mapping California's Land-Ocean Interface

Rising sea level will have significant impacts on California's coastline with some estimates up to a 1.4 m sea level rise by 2100.[1] As stated in the California Climate Adaptation Strategy, "Much of the damage from this accelerated sea-level rise will likely be caused by an increase in the frequency and intensity of coastal flooding and erosion associated with extreme weather events and storm surges."[2] While bays and estuaries are expected to experience the most dramatic modifications in the coming century, changes will be seen far inland from the immediate shoreline zone (e.g., the upland migration of vegetation and sensitive habitat zones, or the relocation of coastal population, development and infrastructure).

Light Detecting And Ranging (LiDAR) is a remote sensing technology that uses lasers to measure elevation and is a rapid, cost-effective source of high-quality topographic information. A complete baseline LiDAR dataset for the California coast would benefit resource managers and coastal communities by providing information that can be applied to coastal storm surge hazard modeling and mitigation, tsunami hazard assessment and planning, wetland restoration, floodplain management, storm water management and coastal development planning or response initiatives (Appendix A). This dataset also would support the goals of Governor Schwarzenegger's Executive Order S-13-08 of November 2008 that directs all construction projects to consider sea level rise during design and requires the Office of Planning and Research to provide state land-use guidance related to climate change.

A new high-resolution topographic dataset would allow better planning and response than older or lower resolution surveys. For example, the coastal bluff erosion that occurs in Goleta, Santa Barbara County, or in Pacifica, San Mateo County, is managed mostly during crises. Beach nourishment projects along Orange and San Diego Counties represent tens of millions of dollars in investment, despite extremely dynamic nearshore processes that constantly remove the placed sand. A new elevation dataset would encourage prioritization for proactive mitigation strategies and evaluation of nourishment options.

For California to most effectively monitor, understand, and manage the coastal zone, a baseline LiDAR dataset should be collected to the highest possible standards that will satisfy as many users as possible. The survey should be performed and documented to allow repeatable LiDAR surveys, which will assure that a baseline survey is useful beyond mapping the current coastal land elevations.

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[1] Cayan, Dan, Mary Tyree, Mike Dettinger, Hugo Hidalgo, Tapash Das, Ed Maurer, Peter Bromirski, Nicholas Graham, and Reinhard Flick (2009). Climate Change Scenarios and Sea Level Rise Estimates for the California 2008 Climate Change Scenarios Assessment. PIER Research Report, CEC-500-2009-014, Sacramento, CA: California Energy Commission.

[2] 2009 California Climate Adaption Strategy, Natural Resources Agency, http://www.climatechange.ca.gov/adaptation/index.html.

1.2 Case Studies of LiDAR Projects in California

Local aerial and ground-based LiDAR surveys are common throughout California when an agency, county or research group determine acquisition of elevation data is needed for projects or planning. The following are examples of the type of collection efforts a statewide baseline survey would support and from which lessons could be learned.

1.2.1 Beach Management

The Coastal Data Information Program/Southern California Beach Processes Study (CDIP/SCBPS) at Scripps Institution of Oceanography (SIO) is sponsored by the USACE and the California Department of Boating and Waterways (DBW). The program monitors and models beach erosion, providing the knowledge base for more effective local and regional beach management.

SCBPS collects *in situ* and remote observations of sand level changes on nourished and natural beaches. Airborne topographic LiDAR has been used since May 2002 to survey the beach between the low tide waterline and the back-beach from Point La Jolla to Dana Point (about 79 km), and from the Mexican Border to Long Beach (about 170 km) (Figure 1). The surveys include the approximate times of maximum (early fall) and minimum (early spring) beach width, and are used to estimate alongshore variations in the seasonal cycle of changes in beach width and sand volume, and to identify long-term erosion trends.

Figure 1. Study area with LiDAR coverage of the CDIP/SCBPS, based at Scripps Institution of Oceanography. Courtesy of CDIP/SCBPS.

SCBPS scientists use the data to test and develop models for beach erosion and wave observations. Wave observations from CDIP are combined with a numerical model to estimate the nearshore wave field. These field-validated models allow engineers to predict future beach evolution more confidently. For example, the model could be used to

simulate erosion of a particular beach nourishment project under different scenarios for the intensity and frequency of future storms.

1.2.2 Restoration of the Klamath Estuary

The Yurok Tribal Fisheries Program is developing a prioritized, ecosystem-based restoration plan for the Klamath River estuary. The Klamath River Estuary and its associated marine, tributary, wetland, and slough habitats serve as a nursery and staging area for spring and fall-run chinook salmon, coho salmon (listed as threatened under the Endangered Species Act), steelhead trout, coastal cutthroat trout, sturgeon, eulachon, and lamprey. Anthropogenic activities, including the construction of major dams, during the last 150 years have drastically degraded estuary habitats and resulted in substantial declines to Klamath River fish runs.

Detailed maps and digital elevation models (DEMs) of the Klamath River estuary and its habitats are key to developing restoration strategies. The base map for this project is being generated from LiDAR, aerial imagery, and bathymetric and topographic surveys (Figure 2). Geographic Information System (GIS) map layers depicting land ownership, flood and tsunami inundation zones, and conceptual watershed restoration designs will also be created for the project area.

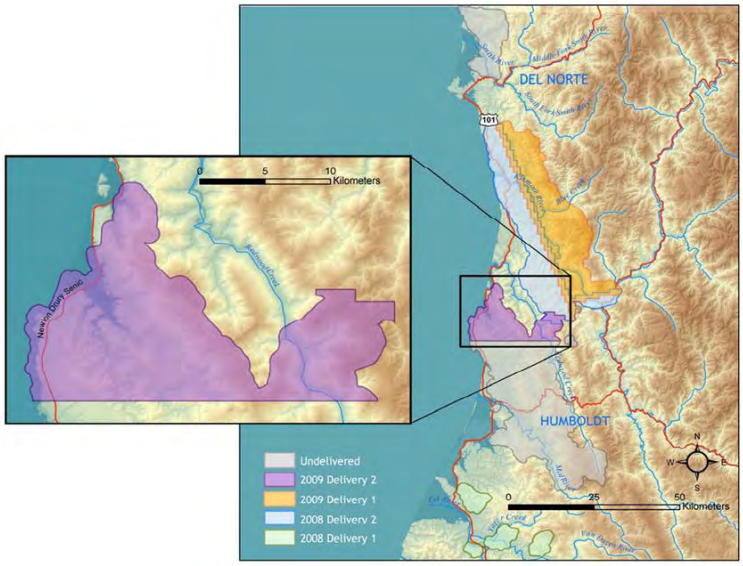


Figure 2. Regions of LiDAR collection in 2008-2009 to support restoration of the Klamath Estuary (light blue area). Additional regions are for resource management by private companies. Courtesy of the Yurok Tribal Fisheries Program.

The Yurok Tribe collaborated with nearby private companies to collect LiDAR in 2008 and 2009. The collection area contains large regions of privately-held lands so public access to this dataset is limited. However, the GIS map layers and DEMs generated for this project will be critical tools for developing the large-scale estuary restoration plan and assessing the effectiveness of future restoration actions and/or changes in river management.

1.2.3 Rapid Post-storm Assessments

A series of storms hit California in January 2010 with large wave events and heavy rainfall. Beaches and cliffs throughout the state were subjected to large-scale erosion, including beaches that have received nourishment. To assess the damage and prioritize emergency responses for infrastructure in southern California, a collaborative effort for

LiDAR collection was organized by SIO. As of this publication, participants included SIO, USACE, DBW, USGS, and San Diego Association of Governments (SANDAG). The collection will be over a similar region as the SCBPS and anticipates occurring within weeks of the storm events to capture the damage before natural processes begin to rebuild beaches.

1.3 The California Coastal LiDAR Project (CCLP)

The OPC organized a multi-agency (state and federal) meeting that included researchers from SIO on December 18, 2008, to assist in planning the California Coastal LiDAR Project (CCLP). The meeting summary, agenda, and attendees can be found in Appendix B. The objectives of the meeting were to

- Gather agency needs for a LiDAR dataset
- Discuss technical and geographic specifications
- Determine how to obtain the most widely accessible and useful dataset
- Begin collaborations with multiple stakeholders.

Collection of agency uses continued through February 2009, which identified many overlapping and complementary needs (Appendix A). The top most commonly requested needs for a modern topographic dataset were related to sea level rise inundation studies, tsunami studies, beach morphology studies (e.g., beach erosion, accretion, dune migration), and detection of invasive species. Other uses included updating coastal flood hazard, infrastructure, and National Wetland Inventory maps, identifying shoreline change, and assisting in setting jurisdictional boundaries.

Despite the collective efforts of many agencies to pursue a multi-purpose modern LiDAR dataset, the economic downturn and California's financial crisis prevented the OPC or any state agency from investing funds in a collaborative collection of coastal LiDAR. As of this publication, no direct State funding for collecting LiDAR data has been identified.

2. California LiDAR Activities in 2009

2.1 California Technical and Geographic Specifications

In April 2009, representatives from the DWR, CCC, BCDC, and OPC produced a set of state standards for the CCLP to satisfy the compiled needs (Appendix C). These specifications match those used by DWR for LiDAR collection in the Sacramento-San Joaquin Delta and in the Central Valley in 2007. The standards were developed in consultation with experts from NOAA, USGS, and SIO. The preferred vertical and horizontal accuracy standards would allow high-detail elevation maps to be produced.

The CCC, BCDC, OPC, the Department of Fish and Game (DFG) and the National Park Service (NPS) constructed a statewide map in ArcGIS identifying areas from the shoreline to the 10 m topographic contour, encapsulating bays, estuaries, and coastal watersheds (Figure 3). The CCLP map encircles areas that may be subject to large potential threats due to inundation from sea level rise and tsunamis.

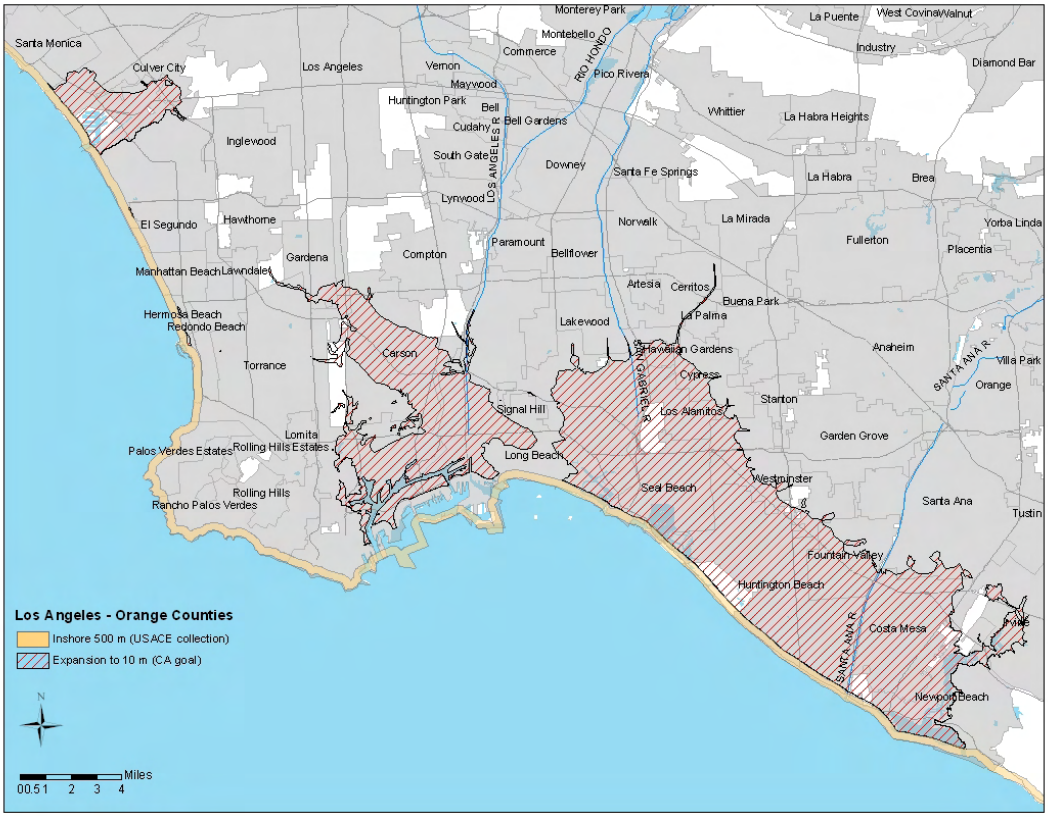


Figure 3. Example of framework map developed by state agencies for the CCLP geographic extent. The red hatched area extends from the shoreline to the 10 m topographic contour. The light brown coastal strip indicates the shoreline to 0.5 km inland region collected by the USACE as part of the NCMP.

2.2 Coastline Collection

The U.S. Army Corps of Engineers (USACE) began a coastal aerial LiDAR collection in October 2009 as part of the National Coastal Mapping Program (NCMP). The NCMP is designed to collect LiDAR of ocean and Great Lakes coastlines and nearshore bathymetry. The NCMP is executed by the Joint Airborne LiDAR Bathymetry Technical Center of Expertise (JALBTCX), a partnership among the USACE, NOAA, and the Naval Meteorology and Oceanography Command and Naval Oceanographic Office (NAVOCEANO). The mission of the NCMP is to support regional sediment management, construction, operations, and regulatory functions in the coastal zone.

The technical specifications for the NCMP to satisfy its mission can be found in Appendix C. These technical specifications were developed from agreements among the four federal mapping agencies (USACE, USGS, NOAA, NAVOCEANO) in January 2009[3]. Geographic coverage of coastal topography in California is from the shoreline to

[3] JALBTCX Workshops: http://www.jalbtcx.org/Standards.aspx

0.5 km onshore at 1 m spacing; bays and estuaries are not included (e.g., inside San Diego or San Francisco Bays) (Figure 3). Bathymetric data have been collected from the shoreline to 1 km offshore or laser extinction (whichever occurs first) at 5 m spacing in some southern California locations.

At the time of this publication, the counties of San Diego, Orange, Los Angeles, Ventura, and Santa Barbara were surveyed; portions of San Luis Obispo (62%) and Monterey (43%) counties were also surveyed (Figure 4). Data for these counties have been quality checked and no reflights are needed. Winter weather conditions have delayed further collection efforts until spring 2010 when the remaining coastline (San Luis Obispo to Del Norte counties) will be surveyed. Data delivery from the California portion of the NCMP is expected by December 2010.

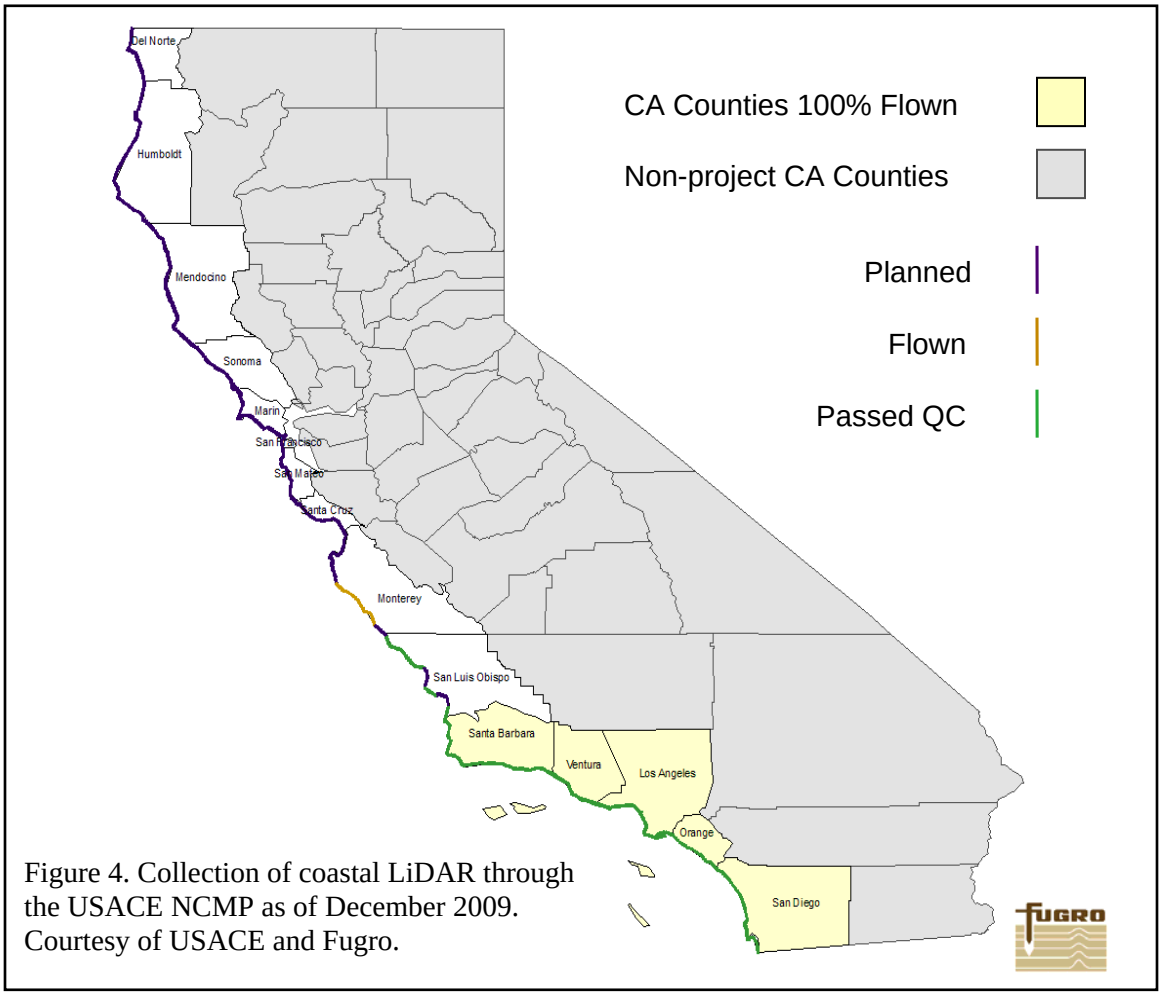


Figure 4. Collection of coastal LiDAR through the USACE NCMP as of December 2009. Courtesy of USACE and Fugro.

2.3 San Francisco Bay Area Collection

A collaborative project between NOAA and the USGS was developed 2009 to conduct LiDAR surveys of the San Francisco Bay Area extending from the Carquinez Strait to outside the Golden Gate. These agencies are interested in acquiring new elevation data to support sea level rise investigations and coastal management decision making. For example, the USGS requires the data for assessing

1) the current shoreline position relative to historical locations,
2) habitat impacts due to modifications of tidal wetlands, salt ponds, tidal marshes,
3) vulnerability of this region to future sea level rise and powerful winter storms.

With collaborative involvement from BCDC, OPC, and DWR, the state specifications (Appendix C) have been adopted for use in the NOAA region; efforts are ongoing to incorporate the same specifications in the USGS region. The geographic coverage extends from the shoreline to the 5 m topographic contour (Figure 5). The collection will occur in two phases with the NOAA portion in early 2010 and the USGS portion in mid-2010. The datasets, which will be publicly available, are expected by December 2010.

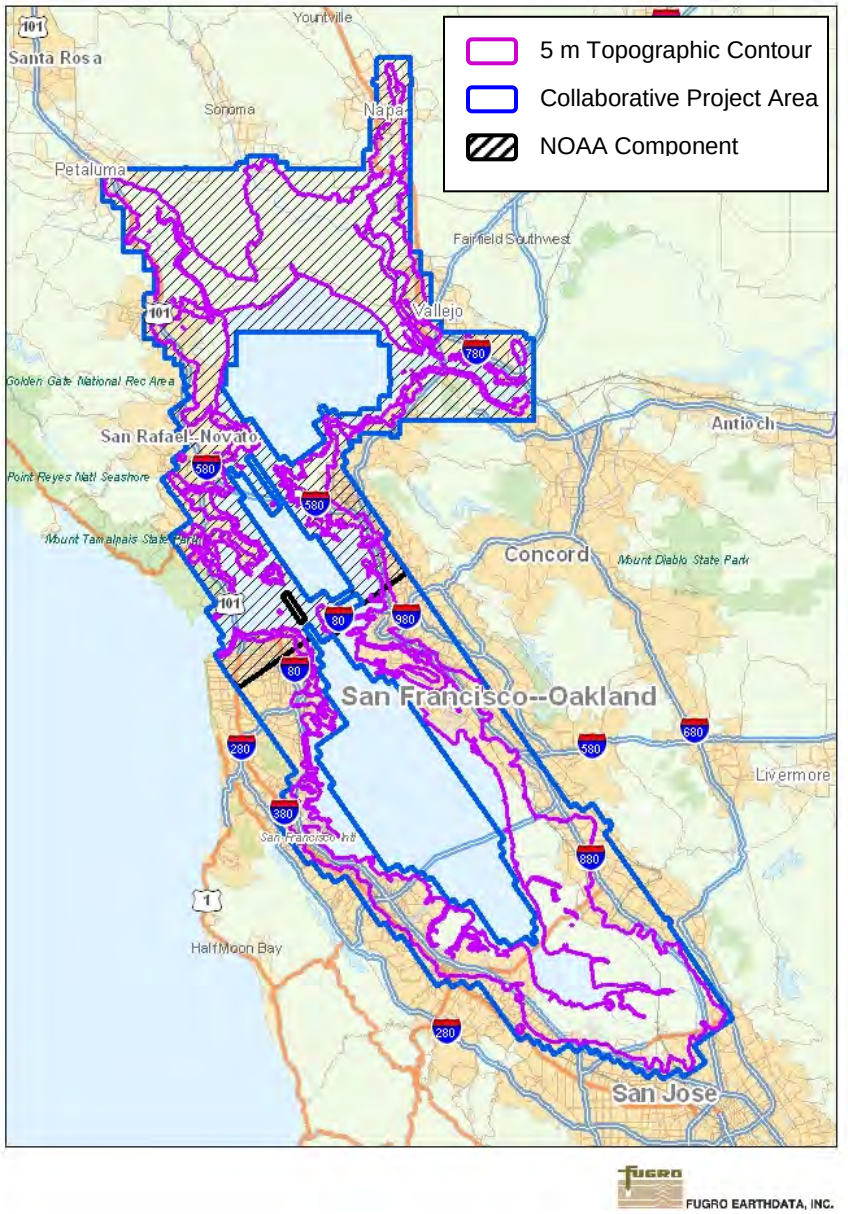


Figure 5. Collection area for collaborative NOAA/USGS LiDAR project. The black hatched area will be collected first by NOAA in early 2010 and the remainder by USGS later in 2010. Courtesy of BCDC.

3. Momentum for the Future

3.1 Conclusions and Collaborations in 2010

The efforts of the USACE, USGS and NOAA will be completed in 2010. Once winter weather clears the coastline, the USACE collection will restart with a scheduled completion of early summer. Delivery of the processed data is anticipated by December 2010. Collection of the San Francisco Bay Area under the joint NOAA/USGS program is scheduled to be completed by mid-year and processing of the data should be completed by December 2010.

California's fiscal crisis is expected to continue to negatively affect the ability of the OPC to invest in a collaborative LiDAR project in the near future. OPC staff considers this project a top priority, however, and will continue to explore funding opportunities to augment the ongoing federal projects. Collaboration has been a successful method in the California Seafloor Mapping Program (CSMP) and the OPC staff is dedicated to using a similar approach for the CCLP. The goal is to identify partners who seek to acquire the best data that serve multiple purposes.

In addition to data acquisition, the OPC plans to investigate how best to address data gaps and data exchange. The lack of a central database of California LiDAR datasets was highlighted by many state and federal agencies as a substantial barrier to project planning and geographic prioritization. One immediate short-term solution could be to use a wiki (a Web-based database for creating, browsing, and searching through information) to consolidate and facilitate information exchange among interested parties. The Geographic Information Officer (GIO) has established a tool through the Office of the State Chief Information Officer (http://www.cio.ca.gov/Government/Governance/gis.html). The OPC also anticipates supporting the GIO in development of the coastal component of its California Business Plan for Improved Elevation Data for Statewide Applications.

3.2 Beyond the California Coastal LiDAR Project

Many groups are acquiring LiDAR datasets as the technology has established itself for cost-efficient topographic and habitat mapping. The increasing number of LiDAR datasets, when combined with other geospatial data, is contributing to an ever-growing volume of data. Management of these datasets, including accessibility and sharing, is an emerging challenge for California and the OPC is addressing this through the Collaborative Geospatial Data Management Effort (CGDME). In 2009, the OPC and NOAA investigated the need for, and barriers to, interagency data sharing and collaboration for effective ocean management. This investigation consisted of interviews with a number of state agencies with coastal and marine jurisdiction, including the State Lands Commission (SLC), CCC, BCDC, DFG, Department of Parks and Recreation (DPR), and State Water Resources Control Board (SWRCB). The interviews revealed that a broad range of stakeholders, such as federal agencies and NGOs, agreed that geospatial data management needed to improve and that a collaborative approach was necessary for comprehensive ocean planning.

The OPC co-organized a workshop in August 2009 with NOAA, the Ocean Science Trust (OST), the Center for Ocean Solutions (COS), and The Nature Conservancy (TNC) for state and federal technical staff and project managers to evaluate capacities and needs related to geospatial data management and tools. The participants considered these ideas in the context of current and emerging ocean uses, such as marine protected areas, aquaculture or renewable energy development. Workshop participants suggested the OPC meet with the GIO to support the creation of a state geospatial information policy. The policy would define California's commitment to geospatial data management and establish a leadership role within each agency to further that policy. Key elements in the policy should be

- Improved communication and coordination for data sharing efforts between agencies with marine and terrestrial jurisdiction and interests, and
- Improved data accessibility for all agencies and an assessment to determine information needs and preferences about how to retrieve and share data as part of a data-sharing framework.

Ideas for tools to support this framework included a Web portal, data clearinghouse, and a search tool able to access various agency databases. The state can build upon existing relationships between academics, NGOs and private organizations to develop data and metadata standards for useful research products and to prioritize research needs to fill data gaps. Additional details can be found in the workshop report, published in October 2009 (Appendix D).

Efforts to organize and coordinate by California agencies complement activities by the federal Interagency Working Group on Ocean and Coastal Mapping (IWG-OCM), which was established in June 2006 with the mission to "…engage the national mapping community, including providers and users, to promote the efficient and effective development and application of ocean and coastal mapping to support informed decision making."[4] The IWG-OCM published a strategic plan in January 2009 with three objectives to build communication, coordination, and collaboration within the national mapping community:

1. Build a national ocean and coastal mapping (OCM) community
   - Focus on increasing awareness, building advocacy, shared priorities and practices, and supporting implementation of integrated ocean and coastal mapping.
2. Provide the tools and expertise to promote an effective national OCM community
   - Focus on providing the national OCM community with critical geospatial data, mapping tools, and expertise to promote the efficient and effective advancement and application of OCM to support informed decision making.
3. Demonstrate and build upon success
   - Focus on developing and promulgating models for effective collaborative development and implementation of mapping programs, and on communicating the value and impact of successful collaborative OCM activities.

[4] National Ocean and Coastal Mapping Strategic Action Plan, Interagency Working Group on Ocean and Coastal Mapping, Joint Subcommittee on Ocean Science and Technology, January 2009.

The strategic plan is guiding the development of many tools, including the Vertical Datum Transformation Tool (VDatum) for transforming elevation data from one vertical datum into another and for blending bathymetric and topographic data sets into the Multipurpose Marine Cadastre (MMC), a multi-year, inter-agency effort to build a GIS-based marine information system for the outer continental shelf and state waters. Additional information can be found at Geospatial One Stop (www.geodata.gov) in the Oceans and Elevation sections.

One project highlighted in the IGW-OCM strategic plan is the CSMP.[5] This OPC-coordinated joint effort with USGS, NOAA, and California State University, Monterey Bay, is acquiring high-resolution bathymetric and habitat maps of the seafloor from the shoreline to three nautical miles offshore (California jurisdictional boundary). The program started in 2005 and data collection is expected to be completed by 2012. The CSMP will provide bathymetric elevation maps to which data from the CCLP could be integrated to produce a seamless onshore-offshore dataset and fulfill the goal of the agencies responsible for managing California's coastal zone.

The motivation to continue developing new applications for LiDAR in coastal research and management was the subject of a timely issue of the Journal of Coastal Research in Fall 2009 (Special Issue 53). The issue explores the role of LiDAR in investigating nearshore submerged and emergent ecosystems, coastal morphodynamics, and hazards due to sea level rise and severe storms in a series of 10 peer-reviewed articles. The goals of the CCLP, in aspiring to satisfy as many research and management needs as possible, align well with perspectives from the scientific community on the use of this mapping technology.

4. Conclusion

For California to be prepared for climate change impacts and better manage the coastal zone, a modern topographic map must be developed. Data from the CCLP coupled with the results from the CSMP can generate a seamless onshore-offshore map to assess sea level rise, tsunami hazards, coastal storm surge hazards, and better plan wetland restoration. Collaboration among state, federal, and local agencies will be essential to successfully acquire the necessary LiDAR data to produce a statewide map that will be useful to as many users. The OPC encourages increased coordination among federal agencies involved in topographic mapping, similar to the successful CSMP. Several state agencies developed technical and geographic specifications in 2009 to meet a broad set of needs. Two federal LiDAR collection efforts in California began in 2009 – the USACE project along the coastline and the NOAA/USGS project in the San Francisco Bay Area. Despite the continuing financial constraints on the State, future work will include improving the sharing and accessibility of existing datasets, ensuring the state agency specifications are employed when possible, and collaborating with the GIO.

[5] CSMP Web sites: USGS - http://walrus.wr.usgs.gov/mapping/csmp/; California State University, Monterey Bay - http://seafloor.csumb.edu/csmp/csmp.html

5. OPC Mapping Program Contacts

The CCLP is one component of the OPC Mapping Program[6]. The two additional components are the California Seafloor Mapping Program (CSMP) and the Collaborative Geospatial Data Management Effort (CGDME). This three-pronged program seeks to modernize and improve accessibility to datasets needed for informed management and research in the California coastal zone.

Topographic Mapping	Seafloor Mapping	Geospatial Data Management
Doug George	Sheila Semans	Christina Cairns
510-286-4179	707-964-0176	510-286-5137
dgeorge@scc.ca.gov	ssemans@scc.ca.gov	ccairns@scc.ca.gov

[6] OPC Mapping Program: http://www.opc.ca.gov/2010/01/mapping-californias-coastal-areas/

Appendix A: Agency Needs for Enhanced LiDAR

State, Federal and Other Agencies' Needs for Enhanced LiDAR Collection in California
Compiled December 2008 – February 2009 by California Ocean Protection Council
Contact: Doug George, dgeorge@scc.ca.gov, 510-286-4179

Identified Need	Agencies/Groups Interested	Rank/Number of Interested Parties
Sea level rise inundation studies	USGS, SCC, SIO/CDIP, CCC, OPC, BCDC, FWS, DFG, CSMW, ConCCo, NOAA	1/11
Tsunami studies	USGS, SIO/CDIP, OPC, FEMA, CGS, ConCCo, DFG	2/7
Shoreline change	BCDC, NOAA, DFG, USGS, SCC, SIO/CDIP	3/6
Beach morphology studies including beach erosion, accretion, dune migration	State Parks, SIO/CDIP, DFG, CSMW, USGS, BCDC	3/6
Detection of invasive species	SIO/CDIP, SCC, SMCMVD, FWS, DFG	4/5
Monitoring of bluff erosion rates and major bluff failure prediction	State Parks, SIO/CDIP, DFG, USGS, BCDC	4/5
Support efforts of the Sediment Management Working Group	SIO/CDIP, CSMW, DFG, SCC, BCDC	4/5
Planning of coastal and beach restoration projects	State Parks, SCC, DFG, SIO/CDIP, BCDC	4/5
Coastal stream and watershed restoration (identification of geological features, mapping of abandoned logging roads, skid trails, and water diversions, baseline habitat mapping and habitat assessments)	State Parks, SCC, FWS, DFG	5/4
Infrastructure mapping (e.g. buildings, trails, roads)	State Parks, CCC, DFG, BCDC	5/4
Managing salt marshes, tidal wetlands	SCC, FWS, BCDC, DFG	5/4
Evaluate areas upland of tidal marshes for retreat	SCC, CCC, DFG, BCDC	5/4
Coastal fault geomorphic mapping	State Parks, DFG, USGS, CGS	5/4
Jurisdictional considerations	DFG, SLC, CCC, SCC	5/4

Public access projects near shorelines (Coastal Trail, Bay Trail and access points for Water Trail) – data for planning purposes	SCC, CCC, DFG, BCDC	5/4
Contribute to a state-wide database of shoreline elevation data	SIO/CDIP, CGS, DFG, BCDC	5/4
Mapping of shallow subtidal areas, planning for native oyster monitoring and restoration, planning for native eelgrass bed, planning for enhancements to subtidal sloughs and channels	SF Bay Subtidal Goals Project, DFG, SCC, BCDC	5/4
Land acquisition	DFG, SLC, SCC	6/3
Assist with establishing contours such as MHHW	SIO/CDIP, SLC, DFG	6/3
Change in mudflats	USGS, DFG, BCDC	6/3
Monitoring of lagoon and wetland closures	SIO/CDIP, DFG	7/2
Updating the coastal flood hazard on CA FIRMs	FEMA, SIO/CDIP	7/2
Fluvial migration	State Parks, DFG	7/2
Coastal terrace elevations	State Parks, DFG	7/2
Monitoring subsidence	DFG, ConCCo	7/2
Improve the determination of setbacks and buffers for new development	CCC, DFG	7/2
Revising National Wetland Inventory maps	FWS, DFG	7/2
Coastal forest stand dynamics to be used for forest restoration	State Parks, DFG	7/2
Fish passage improvement projects	DFG, SCC	7/2
Evaluating the potential for mosquito production, finding hidden sources of standing water (under buildings), potential changes in storm drain water retention (also a mosquito source)	SMCMVD	8/1

Appendix B: OPC LiDAR Project Planning Meeting

OPC LiDAR Project Planning Meeting Agenda

Thursday, December 18, 2008
10 am – 12 pm
11th Floor Conference Room
California Coastal Conservancy
1330 Broadway
Oakland, CA
Conference call-in: 888-232-0371 Participant code: 86119

1. Welcome and introductions
   Doug George, OPC Project Manager

2. Project overview and Governor of California's Executive Order #S-13-08

3. Topics for discussion

   a. Desired products to maximize usefulness
      i. Sea level rise inundation modeling
      ii. Integration with CA Seafloor Mapping Program: onshore-offshore topography
      iii. Identified agency uses of LiDAR (compiled agency list will be developed prior to the meeting
      iv. Formats (e.g. DEMs, etc)

   b. Spatial extent of data collection
      i. Inland extent of data collection-10 m topographic contour?
      ii. SF Bay challenges
      iii. Priority areas outside geographic scope (e.g. are there areas of special significance that we should consider when planning data collection)
      iv. Resolution

c. Hyper-spectral/multi-spectral imagery acquisition/other sensors
    i. Basemap of coastline for feature extraction, collected concurrently as LiDAR
    ii. Should we include this in the program – cost-benefit?

d. Breakline creation for levees and hydrodynamics
    i. Cost-benefit?

e. QC/QA
    i. Independent QA/QC
    ii. Cost-benefit?

f. Possible partnerships

g. Timeline
    i. OPC authorization
    ii. Competitive RFP process
    iii. Contracting (possibly multiple firms)
    iv. Data collection

4. Conclusion

Please contact Doug George (dgeorge@scc.ca.gov, 510-286-4179) with any questions.

OPC LiDAR Project Planning Meeting Summary

December 18, 2008
Oakland and conference call

Attendance: See below

Summary
State and federal agencies and one university group met to discuss the development of a statewide LiDAR collection project. The project goal is to generate a single topographic dataset that will satisfy the greatest number of agency and local user needs. Specifications were discussed to guide the writing of a Request for Proposals from the OPC.

Project overview:
Approximately one year ago, OPC began considering the assembly of a statewide topographic dataset to aid in inundation modeling along the California coast. Conversations and meetings since then identified broader interest in such a dataset. LiDAR was determined to be the most effective technology to use. Today's meeting gathers together many state and federal agencies to help OPC staff develop specifications for a collection and processing effort from the Oregon border to Mexico with the spatial extent still undetermined.

Governor of California's Executive Order #S-13-08:
The Climate Change Executive Order (Ex. O.) of November 2008 provided additional motivation to generate this dataset. The Ex. O. directs all construction projects to consider sea level rise during design and the Office of Planning and Research to provide state land-use guidance related to climate change. A contemporary high-resolution topographic dataset would allow better planning and design to satisfy the directives than older, lower resolution surveys.

Discussion on existing data sets:
Topographic data for the SF Bay Area was used as an example of what exists. The dataset was assembled by Noah Knowles (USGS) and combines photogrammetry, LiDAR and IfSAR surveys. Joel Dudas (DWR) described the 2007 LiDAR collection of the Sacramento-San Joaquin Delta region, including that 10% of the area was reflown to correct for areas that were not adequately sampled. David Castel (SIO) emphasized that benchmarks and accuracy are critical to a good dataset and calibrating to known benchmarks must be included as a basic procedure.

Discussion Point 1: Desired products to maximize usefulness
Agency needs that were submitted before the meeting were presented (see attached pdf of presentation). The formats were discussed and several comments were made with regard to the cost of production of all three types (ASCII, ESRI and native LES) which would be a small fraction of the overall project cost. Including contours and breaklines in the data products were described as being costly and dependent on what is needed for a particular project. Adam Parris (BCDC) commented that for the purposes of this large project, the

focus should be on gathering data sufficient for regional analyses and augmentation could be done by a local project if needed.

Discussion Point 2: Spatial extent of data collection
At the request of the OPC, Adam Parris produced comparison maps for the SF Bay Area with the 10 m topographic contour and the 500 m inland from shore contour highlighted and the estimated inundation caused by a 1.4 m sea level rise. Large portions of the North Bay, Suisan Marsh and South Bay appear to be inundated much farther inland than 500 m, leading to the general agreement that data needs to be collected to the 10 m topographic contour. Ray McDowell (DFG) speaking on behalf of Chris Wills (CA Geological Survey) commented that tsunami runup north of Mendocino could reach above 10 m and suggested collecting to 20 m. It was mentioned that identifying statewide gaps in data could help strategize where new collection was necessary. The OPC informed attendees that an analysis by an independent contractor (Pacific Institute) found that no general dataset for the state could be assembled from existing data. However, some data has been collected since that analysis (e.g., FEMA collected data in the North Bay region of SF Bay to the 15' contour). Reoccupying the benchmarks that NGS maintains was also raised as a necessary component of any collection effort.
General conclusions for this discussion point:

1. 10 m contour should be sufficient to satisfy as many parties as possible
2. 10-20 cm vertical resolution is most probable but 0-5 cm would be beneficial
3. collection should occur during low tide and at the seasonally maximum beach width
4. the specs for the statewide effort should match the Delta dataset
5. airborne LiDAR won't be sufficient to resolve the coastal cliffs, waterborne would be best.

Discussion Point 3: Imagery and other sensor data acquisition
Photogrammetry collection was agreed upon as a necessary component.

Discussion Point 4: Breakline creation
Creating breaklines was described as being expensive and dependent on project needs. However, including them on the wish list was encouraged to see what specific proposals estimate.

Discussion Point 5: QA/QC
Independent QA/QC was agreed upon as a necessary component and Mike Aslaksen (NOAA) volunteered to assist with this task.

Discussion Point 6: Partnerships
FEMA representatives Kathy Schaefer and Ed Curtis suggested that FEMA has funds that could be applied toward this project.

Discussion Point 7: Timeline
Doug George went through the timeline envisioned by the OPC to begin collecting these data in fall 2009. Jennifer Wozencraft (USACE) mentioned a workshop the Army Corps

is hosting January 14-15 to standardize the LiDAR specifications used by USACE, NOAA, USGS and NAVOCEANO. The outcome of the workshop will help guide the OPC RFP development.

Conclusion:
OPC staff will wait for the results of the January workshop. In the meantime, OPC staff will continue to examine the specifications available from FEMA and NOAA. The timeline should be able to handle a delay while waiting for the results.

OPC LiDAR Project Planning Meeting Attendees

Agency	Representative	Phone	Email
BCDC	Adam Parris	415-352-3647	adamp@bcdc.ca.gov
CA Resources	Brian Baird	916-657-0198	brian.baird@resources.ca.gov
CA Resources	Don Crocker	916-651-7586	donald.crocker@resources.ca.gov
CA Resources	Drew Bohan	916-651-8738	drew.bohan@resources.ca.gov
CCC	Al Wanger	415-904-5265	awanger@coastal.ca.gov
CCC	Lesley Ewing	415-904-5200	lewing@coastal.ca.gov
DFG	Ray McDowell	916-324-8848	rmcdowell@dfg.ca.gov
DFG	Paulo Serpa	831-649-7143	pserpa@dfg.ca.gov
DWR	Joel Dudas	916-651-7002	jdudas@water.ca.gov
FEMA	Kathy Schaefer	510-627-7129	kathleen.schaefer@dhs.gov
FEMA	Edward Curtis	510-627-7207	edward.curtis@dhs.gov
NOAA	Kirk Waters	843-740-1227	kirk.waters@noaa.gov
NOAA	Becky Smyth	510-251-8324	Rebecca.smyth@noaa.gov
NOAA	Roger Parsons	301-713-2776	Roger.L.Parsons@noaa.gov
NOAA	Mike Aslaksen	301-713-2663 x160	Mike.Aslaksen@noaa.gov
NOAA	Megan Wood	510-251-1057	megan.wood@noaa.gov
OPC	Sheila Semans	707-964-0176	ssemans@scc.ca.gov
OPC	Doug George	510-286-4179	dgeorge@scc.ca.gov
OPC	Chris Blackburn	510-286-3709	cblackburn@scc.ca.gov
OST	Amber Mace	510-251-8323	amber.mace@calost.org
OST	Diana Pietri	510-251-8285	diana.pietri@calost.org
OST	Sarah Henkel	510-251-8284	sarah.henkel@calost.org
SCC	Neal Fishman	510-286-4175	nfishman@scc.ca.gov
SCC	Steve Ritchie	510-286-3799	sritchie@scc.ca.gov
SCC	Moira McEnespy	510-286-4165	mmcenespy@scc.ca.gov
SCC	Marilyn Latta	510-286-4157	mlatta@scc.ca.gov
SIO	Julie Thomas	858-534-3034	jot@splash.ucsd.edu
SIO	David Castel	858-349-9578	dc@cdip.ucsd.edu
SIO	Randy Bucciarelli	858-822-0643	randy@webfoot.ucsd.edu
SLC	Mike Bell	916-574-2440	bellm@slc.ca.gov
SLC	Gail Newton	916-574-1880	NewtonG@slc.ca.gov
SLC	Lance Kiley		KileyL@slc.ca.gov
SLC	Eric Gillies		gilliee@slc.ca.gov
SPR	Paul Veisze	916-651-2094	pveisze@parks.ca.gov
USACE	Jennifer Wozencraft	228-252-1101	Jennifer.M.Wozencraft@usace.army.mil
USGS	Sam Johnson	831-427-4746	sjohnson@usgs.gov
USGS	Bruce Richmond	831-427-4731	brichmond@usgs.gov

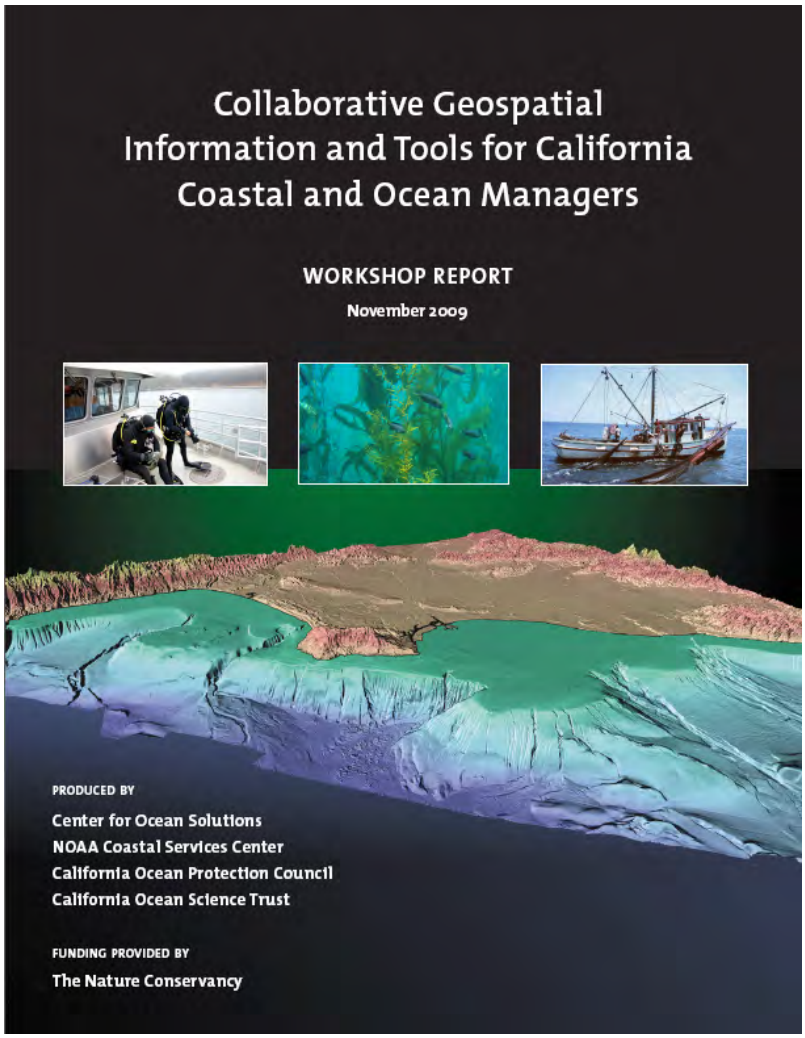
Appendix C: Technical Specifications for Coastal LiDAR

Technical specifications for California coastal LiDAR surveys were developed by the Department of Water Resources (DWR), the California Coastal Commission (CCC), the San Francisco Bay Conservation and Development Commission (BCDC) and the OPC in consultation with experts from NOAA, USGS, and Scripps Institution of Oceanography in spring 2009. Federal specifications for coastal LiDAR surveys were developed at a January 2009 workshop attended by NOAA, USGS, USACE, and NAVOCEANO.

Specification	State Standard	Federal Standard
Vertical Accuracy (95% confidence)	18.2 cm	30 cm
Vertical RMSE	9.25 cm	15 cm
Horizontal Accuracy (95% Confidence)	30 cm	1 m
Horizontal RMSE	12.26 cm	50 cm
Spot Spacing	</=1 m	1 m nominal
Percent Coverage	200	Not specified
Percent Overlap	>20%	Not specified
Effective Footprint	10 cm	Not specified
Tide Coordination	Low Tide	Low Tide +/- 1 hour
Scan Angle	Max +/- 12 deg off nadir	Not specified
Return Logic	At least first and last returns plus intensity	First and last returns
Classification	1,2,9	1,2
Breaklines	Yes	No
Contours	10 foot	No
Horizontal Coordinate System	UTM Zone 10N, NAD83	Geographic NAD83/2007
Vertical Coordinate System	NAVD88	NAVD88 meters
Geographic Extent	Shoreline to 10 m topographic contour	Shoreline to 500 m inland (NCMP only)*

*- This geographic extent is for the National Coastal Mapping Program (NCMP) only, not all federal mapping programs.

Appendix D: Geospatial Data Management Workshop



For the full report, please visit:
http://www.centerforoceansolutions.org/Spatial-Data-and-Tools/Workshop-2009/main.html