SAN FRANCISCO BAY EELGRASS INVENTORY

October - November 2009



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Eelgrass mapping is based on acoustic and aerial surveys of October – November 2009. Eelgrass distribution along the shoreline, and within various portions of the bay was refined using site specific survey data and diver ground truthing.

Eelgrass bed density classification is most accurate near the central portion of the range and is less accurate near the extremes of any of the defined density ranges where interpretive error may occur. Eelgrass data reflects a particular period in time and are anticipated to be a seasonally and stochastically dynamic

Note: Charts are for planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.

San Francisco – Oakland Bay Bridge
East Span Seismic Safety Project

San Francisco Bay Eelgrass Inventory
October – November 2009



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The Baywide Eelgrass Inventory and Habitat Management Research Program is being undertaken as a joint effort of the California Department of Transportation (Caltrans) and National Marine Fisheries Service (NOAA-Fisheries). The project is fully funded by Caltrans as one element of the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project environmental mitigation. The purpose of this Program is to support the advancement of eelgrass management science and policy within San Francisco Bay by providing essential information on the distribution, abundance, characteristics, and environmental controls of eelgrass within the Bay.

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SAN FRANCISCO BAY EELGRASS INVENTORY
October-November 2009
San Francisco Bay, California

December 2009

BACKGROUND

Eelgrass (*Zostera marina* L.) is a native plant indigenous to the soft-bottom bays and estuaries of the Northern Hemisphere. It occurs along the Pacific coast of North America from the Bering Straits down to lower Baja California (Figure 1). Although it is naturally restricted to a very limited amount of suitable habitat, it is the most widely distributed marine angiosperm in the Northern Hemisphere (den Hartog 1970). Because of the presence of eelgrass within protected shallow coastal waters, it has historically suffered considerable losses to degradation of water quality, dredging and filling, shading by over water structures, and changes in circulation patterns. Eelgrass abundance has declined worldwide due to increased anthropogenic effects (Short and Wyllie-Echeverria 1996).

Eelgrass is considered to be a habitat forming species that creates unique biological and physical environments when it occurs in the forms of submerged or intertidal aquatic beds or larger meadows. As submerged aquatic beds, eelgrass is given special status under the Clean Water Act, 1972 (as amended), Section 404(b)(1), "Guidelines for Specification of Disposal Sites for Dredged or Fill Material," Subpart E, "Potential Impacts on Special Aquatic Sites." It is also considered an important element of Essential Fish Habitat regulated under the Magnuson-Stevens Fishery Conservation and Management Act.

Historically, very little has been known about the distribution or characteristics of eelgrass beds within San Francisco Bay; and within the past two decades, the need to establish a baseline of eelgrass (*Zostera marina*) coverage in San Francisco Bay has become apparent. While management and restoration of Bay Area marshlands has been a conservation priority, important subtidal habitats such as eelgrass have historically not received the same degree of attention. This has changed in recent years with a focused effort now being put into the San Francisco Bay Subtidal Habitat Goals Project, following the course of the earlier San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project 1999). The Subtidal Habitat Goals Project is a collaborative effort to establish a comprehensive and long-term management vision for research, restoration, and management of the subtidal habitats of San Francisco Bay. The project is an interagency partnership between the San Francisco Bay Conservation and Development Commission (BCDC), the California Coastal Conservancy, National Marine Fisheries (NOAA), and the San Francisco Estuary Partnership. Based on present efforts to improve upon conservation, restoration, and enhancement of subtidal resources, there is an increased need for information regarding the status, distribution, and importance of eelgrass habitat within the San Francisco Bay ecosystem and within a larger coast-wide context.



Figure 1. Eelgrass Growing Near the Shore at Keil Cove, Marin County

Construction activities for the San Francisco-Oakland Bay Bridge East Span Seismic Safety Project (SFOBB Project) will impact eelgrass habitats as a result of both permanent bridge footprint and shading effects and temporary construction activities. As an element of the environmental mitigation required to compensate for impacts to eelgrass habitat from the East Span Project, the California Department of Transportation (Caltrans) committed to funding a $1 million Baywide Eelgrass Inventory and Resource Management Research Program (Research Program) to be co-managed by NOAA Fisheries.

Under the Research Program, several actions have been undertaken to improve understanding of eelgrass resources within San Francisco Bay for management purposes. These include completion of a comprehensive 2003 baywide eelgrass survey (Merkel & Associates 2004), physical and ecological characterization of eelgrass habitat in San Francisco Bay (Merkel & Associates 2005), genetic characterization of eelgrass beds based on microsatellite analyses (Talbot, et al. 2004), and development of a predictive model for eelgrass distribution within San Francisco Bay (Merkel & Associates 2005). The Research Program also funded the development and testing of a regional eelgrass monitoring strategy for San Francisco Bay (Merkel & Associates 2009a).

A large-scale survey of the known and potential occurrence of eelgrass throughout San Francisco Bay was completed over 20 years ago (Wyllie-Echeverria and Rutten 1989); and due to the advances in survey technology over the two decades, more accurate mapping is now possible. The 2003 eelgrass survey revealed considerably more extensive eelgrass habitat with a greater geographic distribution than was previously mapped in San Francisco Bay. Even with eelgrass extending over greater than 800 percent more bay bottom than was known from the 1989 survey, the predictive eelgrass model prepared for San Francisco Bay (Merkel & Associates 2004) suggested that even greater potential for eelgrass might exist. Further, testing results for the regional monitoring program, as well as localized monitoring efforts (Merkel & Associates 2008a), revealed

considerable variability in eelgrass beds through time. Recognizing the dynamic nature of the eelgrass distribution patterns, the extensive model prediction for suitable eelgrass habitat, and a number of recent detections of eelgrass at widespread locations where it has previously not been known to occur, NOAA Fisheries determined that an additional comprehensive Baywide survey for eelgrass should be undertaken in 2009, prior to the predicted El Niño winter. Post 2009 surveys are being conducted by Merkel & Associates under separate funding by NOAA Fisheries.

This survey effort was undertaken in October 2009 and is being reported on in this document. The format of the document, including much of the background and discussion as well as the Eelgrass Atlas map sheets (Appendix A), follows and builds upon the 2003 eelgrass survey report (Merkel & Associates 2004). By adopting this format it is anticipated that greater utility may be garnered from the presentation of the current survey results.

EELGRASS INVENTORY HISTORY

In the late 1920s, eelgrass was reported as "an abundant species along the shores of San Francisco Bay" (Setchell 1929). In 1987, about 60 years later, a survey of San Francisco Bay revealed only 128 hectares (316 acres) (0.1 percent total bay bottom coverage) of eelgrass throughout San Francisco Bay, with much of the existing habitat exhibiting conditions of environmental stress (Wyllie-Echeverria and Rutten 1989, Wyllie-Echeverria 1990). A decade later, surveys of the San Pablo Peninsula, documented over 162 hectares (400 acres) of eelgrass (SAIC and Merkel & Associates 1997a, 1997b). The acoustic survey results from the 1997 survey, suggested either extremely dynamic conditions within the existing beds, an underestimation of eelgrass during the 1987 studies, or a combination of both factors (Thomson et al. 1997).

As documented in the San Francisco Bay Area Wetlands Ecosystem Goals Project (1999), approximately 8,100 hectares (20,000 acres) of deep and shallow bay habitats have been lost since the 1800s as a result of bay fill and sediment deposition. Considering that almost all of the habitat losses have resulted along the shallow Bay margins, it is unlikely that eelgrass escaped impact from these historic losses. However, as a point of fact, the historic status of eelgrass in San Francisco Bay is not well known and it cannot be fully determined whether eelgrass habitat has been substantively reduced from prior levels. Because Setchell's early work did not include comprehensive maps and most of the sites referenced in 1929 remain today, it is not possible to fully determine if significant declines in eelgrass within San Francisco Bay have occurred between 1929 and present. While, there is some reason to believe significant declines have occurred, even today there are many places on San Francisco Bay where eelgrass can be described as "an abundant species along the shores".

In 2003, a comprehensive eelgrass survey was undertaken using a combination of sidescan sonar and helicopter aerial investigations performed at low tide. The principal purpose of the aerial survey component was to rule out the presence of eelgrass within large areas of San Francisco Bay considered to be potentially suitable to support eelgrass based on the application of a pre-screening model. As a result, in 2003 eelgrass was mapped using sidescan sonar and diver, as well as low tide visual inspection ground truthing (Merkel & Associates 2004).

Notwithstanding the difficulty in assessing historic trends for a system as large as San Francisco Bay, eelgrass is highly limited at this location compared to other west coast bays and estuaries. In addition to a general paucity of eelgrass, the beds that do exist in San Francisco Bay are extremely dynamic. In repeated surveys of eelgrass beds at Pt. Molate, the Richmond Harbor training wall, and the Emeryville Flats, eelgrass density and abundance was noted to fluctuate significantly from year to year (Merkel 1997, Merkel & Associates 2008a). This annual variability in eelgrass appears to relate to fluctuations in the turbidity or even average climatic conditions within marginally suited environments. Initial regional monitoring testing efforts also have demonstrated considerable seasonal variability in eelgrass coverage in San Francisco Bay (Merkel & Associates 2009a).

SURVEY AND ANALYSIS METHODS

FIELD SURVEYS

Eelgrass surveys were conducted in October 2009 using both acoustic and aerial survey methods. In order to manage eelgrass survey areas, San Francisco Bay was divided into one-square kilometer (247-acre) cells oriented in a Universal Transverse Mercator (UTM) coordinate grid. The study area for the program encompassed San Francisco Bay, omitting the waters of Suisun Bay. Surveys extended through waters bounded by the Carquinez Bridge in the North Bay, Dumbarton Bridge in the South Bay, and the Golden Gate Bridge. It should be noted that a limited amount of survey was performed upstream of the Carquinez Bridge along the northern shore of the Carquinez Straits. This work was to confirm the presence of eelgrass at the Glen Cove Marina and at Glen Cove Waterfront Park in Vallejo. During the 2003 surveys, widgeongrass (*Ruppia maritima*) was the only seagrass found east of the Carquinez Bridge. Given the confirmed presence of eelgrass above the Carquinez Bridge in 2009, it is likely that at least some additional eelgrass occurs upstream of the bridge at other locations that were not reviewed.

Aerial Surveys

Aerial eelgrass surveys were conducted on October 16-17, 2009. Aerial surveys were performed from a helicopter during daylight low tides. During the surveys, beds were located and photographed at both vertical and oblique angles. In addition, vertical digital video was collected. Helicopter overflights were flown at a mid elevation between 900 and 1280 meters (3,000-4,200 feet) and at a low elevation 60 to 150 meters (500 and 200 feet). Where necessary to confirm identification, the helicopter was lowered to as little as 6 meters (20 feet) off the water surface such that clear visual inspection of plant material or other objects was possible. Low altitude inspections and on-the-

water groundtruthing were critical to avoiding the erroneous mapping of large beds of the red alga, *Gracilariopsis adersonii*, as eelgrass. Several large beds of this species were noted, particularly at Hunters Point, Pt. Pinole, and shoreward of the Emeryville Marina.

A differential GPS (dGPS) was used to collect additional coordinates for on water features that are not present or visible on orthorectified aerial imagery for San Francisco Bay. These additional points on channel markers, moorings, anchored barge corners, and sunken vessels provided additional control points for registration of imagery collected during the survey flights.

Aerial survey video and vertical photographs were rectified using orthorectified shoreline imagery and on-water registration points collected during the flights. Differing from the 2003 survey, the registered high-resolution low altitude photographs were used for eelgrass mapping during the present survey. The photographs allowed for detailed mapping of many of the shallow edges of eelgrass beds and also allowed mapping of eelgrass within highly constrained areas such as within the interior of dilapidated wharf structures. Photographs were not used for mapping when the resolution or image quality was such that it was not possible to assign density classes to mapped eelgrass. At that point, sidescan sonar was employed as the primary mapping tool and the first sonar trackline was established along the boundary of eelgrass that could be mapped from photographic data.

The use of aerial imagery for mapping in the 2009 survey was of substantial benefit in two ways. First, it significantly reduced the amount of on-water survey, thus resulting in significant cost savings over a full sonagraphic survey. Second, it effectively allowed mapping of much of the shallowest portion of existing eelgrass beds thus lengthening the effective sonar survey window by reducing tidal constraints. This gain in efficiency, however, was accompanied by a reduction in the spatial accuracy of mapping in shallow environments. Only about 20 percent of the photographs and 2 percent of the video shot was used to develop registered images for mapping. This limitation was driven by video image quality and the need for true vertical photos with available registration points. In some instances, photo-registration error was as much as ±12 meters (±40 feet) horizontal compared to an estimated ±3 meters (±10 feet) error range for sonagraphic survey data.

Acoustic Surveys

Merkel & Associates (M&A) conducted day and night acoustic eelgrass surveys between October 17 and November 4, 2009. The timing of survey work was dependent on factors such as tides, depth of the survey areas, and weather. Survey work completed in the shallowest waters was conducted at high tides in order to avoid submerged obstructions and maximize survey swath coverage. Windy conditions on San Francisco Bay frequently prevented work from being conducted in the late afternoon and evening, and sidescan operators often found that the calmest waters with the highest tides occurred in the middle of the night. As such, considerable work was conducted during night surveys and during the morning periods.

Acoustic survey techniques utilized sidescan sonar combined with diver groundtruthing to search for and document eelgrass beds. Acoustic surveys were conducted aboard the 7.3-meter (24-foot) R/V Merkel. The survey employed an integrated differential GPS navigation and digital sidescan system. Sidescan data were collected using a Marine Sonic sidescan sonar operating at 600 kHz. The sidescan towfish was positioned approximately 0.5 to 2.0 meters (1.6 to 6.6 feet) below the water surface, depending on the amount of water between the surface and the Bay bottom. To obtain good coverage and resolution, the sidescan was configured to provide a display range of 20 meters (66 feet) per channel (port and starboard). Transects were generally spaced 38 meters (125 feet) apart, which allowed for a trackline overlap of one meter (3.3 feet) between parallel tracklines. The first trackline was generally aligned along the boundary of eelgrass that could be accurately interpreted from aerial imagery. In this manner, there was an approximately 20 meter (66 feet) of overlap between aerial interpreted and sidescan interpreted eelgrass beds. The overlap area allowed for an assessment of boundary mapping and bottom coverage classification differences between the two mapping methodologies employed in the investigations.

The dGPS receiver (Leica MX400) utilized the U.S. Coast Guard FM correction beacon, and collected navigation and positioning data for the surveys. Navigational fixes were collected every second during data collection. Vessel position was maintained along predetermined transect lines using an on-board, real-time GPS display and navigation software that provided cross-track error and position status with each position update. The horizontal system resolution was approximately ±3 meters (±10 feet) as a combined error of the navigation system and side-scan equipment. All data were collected in decimal degrees latitude and longitude and subsequently converted and plotted on a coordinate grid using UTM Zone 10N North American Datum of 1983 in meters (NAD 83).

Ground-Truthing

Acoustic records of eelgrass beds were ground-truthed by SCUBA divers who confirmed the presence of eelgrass in mapped beds. Diver ground-truthing was conducted at Bayfarm Island, Emeryville Flats, Crown Beach, Oakland Middle Harbor, Clipper Cove, Richmond Training Wall, Pt. Molate, Pt. San Pablo, Pt. San Quentin, Angel Island, Keil Cove, Richardson Bay, and Coyote Point. Diver and cast-rake ground-truthing was conducted from the 7.3-meter (24-foot) R/V Merkel.

DATA INTERPRETATION AND EELGRASS MAPPING

Digital maps of the distribution of eelgrass throughout San Francisco Bay were created from the 2009 survey data. Following completion of the surveys, sonar traces were downloaded and processed into mosaic images in a GeoTiff format using Chesapeake Technologies, Inc. Sonar Wiz.

Eelgrass was mapped by manually digitizing from registered sidescan mosaics and aerial photographs using ESRI ArcGIS software. Mapping techniques and areal coverage determination made use of a mix of analytical techniques developed and

employed in prior large-scale eelgrass surveys (SAIC and Merkel & Associates 1997a and b, Merkel 1988, 1992, 2003a, U.S. Navy SWDIV 1994, 2000). Eelgrass beds in San Francisco Bay generally consist of clustered patches of eelgrass as opposed to continuous carpets, such as those observed in most other systems (Keith Merkel personal observation). For the purpose of this survey, a given eelgrass bed included many clustered eelgrass patches, and the edges were determined by locating the greatest extent of the eelgrass patches within the survey area. Within the boundaries of the bed, eelgrass was subdivided into four bottom cover categories defined by the percentage of total bottom coverage within the mapped bed. The cover classes used were 1-5 percent, 5-20 percent, 20-40 percent, and greater than 40 percent cover (Figure 2). Digitizing of eelgrass was typically performed at a standard view scale of 1:600 in order to minimize variance in map detail and interpretation of bed cover class and aggregation of eelgrass in cover classification polygons.

Where individual plants were too far apart to be aggregated into beds, they were considered to define the boundaries of discrete beds. These patches, like many of the patches that occurred within the beds, were typically comprised of single plants with only a few turions and were thus mapped at the highest bottom coverage class of >40 percent.

In addition to creating a 2009 eelgrass coverage theme, a composite theme of maximum documented eelgrass extents was created from all known spatially documented sources including the present survey, the 2003 baywide survey (Merkel & Associates 2004), and such sources as Wyllie-Echeverria and Rutten (1989), SAIC & Merkel (1997a and b), Merkel & Associates (1997, 1999, 2001, 2003b, 2008, 2009, unpublished data), and Kitting (1993, 1998). In order to present these results on a scale that would be useful to resource managers, the 2009 Eelgrass Atlas was created. Each page of this atlas presents a 25-square kilometer (9.7-square mile) section of San Francisco Bay at a scale of 1:36,000. Bathymetry is presented in feet below mean lower low water (MLLW).

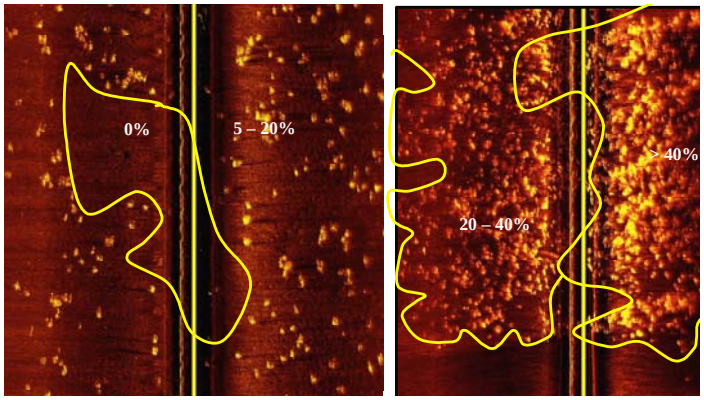


Figure 2. Examples of Mapped Eelgrass Coverage Classes

SURVEY RESULTS

General Eelgrass Distribution

The 2009 Baywide Eelgrass Inventory mapped 1,500 hectares (3,707 acres) of eelgrass within San Francisco Bay during October and early November 2009 (Figures 3-4, and Appendix A). In order to compare survey results between the present 2009 survey and the 2003 survey, it is helpful to compare eelgrass coverage within the same spatial subunits. To accomplish this, the eelgrass bed segments from the regional monitoring program (Merkel & Associates 2009a) have been adopted (Figures 3 and 4). Forty-one eelgrass bed segments exist in the present regional monitoring program, although there is potential for future addition of monitoring segments with regional expansion of eelgrass. The eelgrass not within mapping segments is scattered widely throughout San Francisco Bay. The 2003 and 2009 distribution by eelgrass bed segment is indicated in Table 1.

The overall coverage of eelgrass observed during the current survey was 28.7 percent greater than the eelgrass extent mapped during the previous 2003 baywide eelgrass survey (Merkel & Associates 2004) and was nearly 1200 pecent greater than that mapped in the 1987 surveys (Wyllie-Echeverria and Rutten 1989). The major differences observed between the present 2009 survey and the prior 2003 survey are a considerable expansion of eelgrass northward along the southern shoreline of San Pablo Bay and into the Carquinez Straits. In addition, there has been an increase in eelgrass along both the shoreward (shallower) and bayward (deeper) edges of existing large beds, particularly in the largest beds of San Pablo-Pt. Pinole and Richardson Bay. Very little difference in eelgrass distribution patterns in the southern portion of San Francisco Bay have been noted between the 2003 and present 2009 surveys.

Regional Eelgrass Conditions

The majority of the eelgrass in San Francisco Bay was located within two very large eelgrass beds. By far the largest eelgrass bed in San Francisco Bay is the Pt. San Pablo bed, which is located between Pt. Pinole and Pt. San Pablo in San Pablo Bay (Figure 3, Atlas Pages 20, 21, 33, and 34). This bed was approximately 816.2 hectares (2,016.8 acres) during 2009, and comprised over 54 percent of the total eelgrass coverage in San Francisco Bay. The Pt. San Pablo eelgrass bed occurs on a shallow depositional shoal (approximately –1.5 to –0.5 meters [-4.9 to -1.6 feet] MLLW). This eelgrass bed has consistently been the largest in San Francisco Bay, comprising 53 percent of the eelgrass mapped in 2003 (Merkel & Associates 2004) and 39 percent of all of the eelgrass mapped during the 1987 survey (Wyllie-Echeverria and Rutten 1989).

The second largest eelgrass bed in San Francisco Bay is found in Richardson Bay, near Sausalito in Marin County (Figure 3 and Atlas Pages 6 and 14). This bed was approximately 273.1 hectares (674.7 acres) during the 2009 survey, comprising 18 percent of all eelgrass. This compares to 17 percent of all eelgrass in 2003. Eelgrass in Richardson Bay generally occurred between –3.0 and –0.3 meters (9.8 and -1.0 feet) MLLW during the current survey. The eelgrass in Richardson Bay extended over considerably more of the shallow flats than was found to be the case in 2003.

Table 1. Location and Area (Hectares) of Eelgrass in San Francisco Bay During the 2003 (Merkel & Associates 2004) and Current 2009 Surveys

Eelgrass Segment Number	Bay Region	2003 (ha.)	2009 (ha.)
1	Pt. San Pablo/Pt. Pinole (East)	139.83	208.06
2	Pt. San Pablo/Pt. Pinole (Central-East)	169.83	248.68
3	Pt. San Pablo/Pt. Pinole (Central-West)	128.26	225.91
4	Pt. San Pablo/Pt. Pinole (West)	124.28	133.53
5	Navy Supply Depot Pt. San Pablo	14.69	21.26
6	Navy Supply Depot Pt. San Pablo	13.81	13.00
7	Point Molate Beach	7.25	9.43
8	Point Molate Beach	5.68	11.90
9	Kellers Beach North	11.74	28.17
10	Kellers Beach South	15.71	21.83
11	Kellers Beach South	9.82	13.07
12	Inside Richmond Tr. Jetty	3.85	4.17
13	Inside Richmond Tr. Jetty	4.14	4.20
14	Outside Richmond Tr. Jetty	27.59	35.13
15	Albany Beach	0.28	1.48
16	Golden Gate Fields	0.15	0.49
17	Golden Gate Fields	0.09	0.01
18	Brickyard Cove	2.42	4.05
19	Berkeley Shoreline	1.67	1.78
20	Berkeley Shoreline	3.08	4.72
21	Berkeley Shoal	4.73	4.24
22	Berkeley Shoal	6.89	7.51
23	Emeryville Shoal	3.78	3.92
24	Emeryville Shoal	6.80	8.02
25	Clipper Cove/Treasure Island	2.51	2.19
26	Crown Beach	16.36	5.14
27	Crown Beach	13.04	11.36
28	Crown Beach	10.78	18.31
29	Crown Beach	31.60	35.63
30	Crown Beach	29.95	18.22
31	Bayfarm Island	13.05	11.37
32	Bayfarm Island	28.33	24.44
33	Paradise Cove, North	4.12	2.99
34	Paradise Cove, South	2.25	4.53
35	Keil Cove	2.14	1.94
36	Keil Cove	3.06	3.16
37	Keil Cove	14.13	14.07
38	Richardson Bay	21.58	88.70
39	Richardson Bay	45.50	48.25
40	Richardson Bay	66.54	72.36
41	Richardson Bay Entrance	48.19	63.74
NA	Pt Pinole/Carquinez Bridge	<0.01	54.96
NA	Pt San Quentin/Marin Rod & Gun Club	0.88	0.36
NA	Oakland Middle Harbor	0.53	0.01
NA	Oakland Inner Harbor	0.03	0.15
NA	Alameda Western Shoreline	<0.01	1.45
NA	San Mateo to South San Francisco	1.16	0.01
NA	San Mateo Bridge to Dumbarton Bridge	0.13	0.02
NA	Other Eelgrass Beds	1.33	2.10
BAYWIDE EELGRASS AREA TOTAL		**1,061.34**	**1,500.00**

Eelgrass is most continuous in its distribution along the eastern shoreline of the north and central portions of San Francisco Bay. Broken only by headlands and dredged channels, eelgrass extends in a nearly continuous ribbon along 25 kilometers (15.5 miles) of shoreline from east of Pt. Pinole to the outside of Richmond Training Jetty of Outer Richmond Harbor (Figure 3). The well-defined westerly facing shallow coves along the San Pablo Peninsula support extensive eelgrass beds that contribute significantly to the overall eelgrass habitat total and are generally some of the more stable eelgrass beds in San Francisco Bay. These beds are found along Kellers Beach on the Miller/Knox Regional Shoreline and in the exposed coves between Castro Point, Pt. Molate, Pt. Orient, and Pt. San Pablo.

In 2003, only a few solitary plants were recorded to the east of Pt. Pinole near Wilson Point, and Suisun Bay was found to support extensive beds of Widgeongrass (*Ruppia maritima*) but no eelgrass. During the 2009 surveys, eelgrass was found to be extensive, but sparsely distributed along the southeastern shoreline of San Pablo Bay extending all the way up to the survey limits at the Carquinez Bridge and along the northeastern shoreline from the Carquinez Bridge through the California Maritime Academy and Morrow Cove up to the breakwater at the mouth of the Napa River. Eelgrass east of Pt. Pinole totaled less than 0.01 hectare (>0.01 acre) in 2003 but exhibited an incredible coverage of 55.0 hectares (135.8 acres) in 2009, although the coverage was generally at low cover density (Figure 3, Table 1).

While surveys did not continue upstream of the Carquinez Bridge, eelgrass was documented to extend at least as far east as the Glen Cove Marina and Glen Cove Waterfront Park. It is suspected that additional eelgrass may have been found even further east had subsequent exploration been undertaken.

While considerable expansion of eelgrass was noted in the northern portions of San Francisco Bay between 2003 and 2009, this same change was not seen in the southern portions of San Francisco Bay. Much of the eelgrass within the southern portions of San Francisco Bay remained comparable to that observed in 2003 or even showed declines from the 2003 conditions (Table 1). Eelgrass remained generally distributed over the same areas as observed during the 2003 survey.

DISCUSSION

EELGRASS DYNAMICS AND POTENTIAL HABITAT

Eelgrass coverage within San Francisco Bay is in a constant state of flux. While there appears to have been a considerable expansion of eelgrass between the 2003 and 2009 baywide surveys, the fact is that there was at least one period of significant decline in eelgrass that occurred during the intervening period. This decline occurred during the winter of 2005-2006, when significant sediment loading into San Francisco Bay occurred and many eelgrass beds were buried in fine sediment up to several centimeters thick (Merkel & Associates 2008b and 2009a, K. Boyer personal communication, and K. Merkel personal observation). Further,

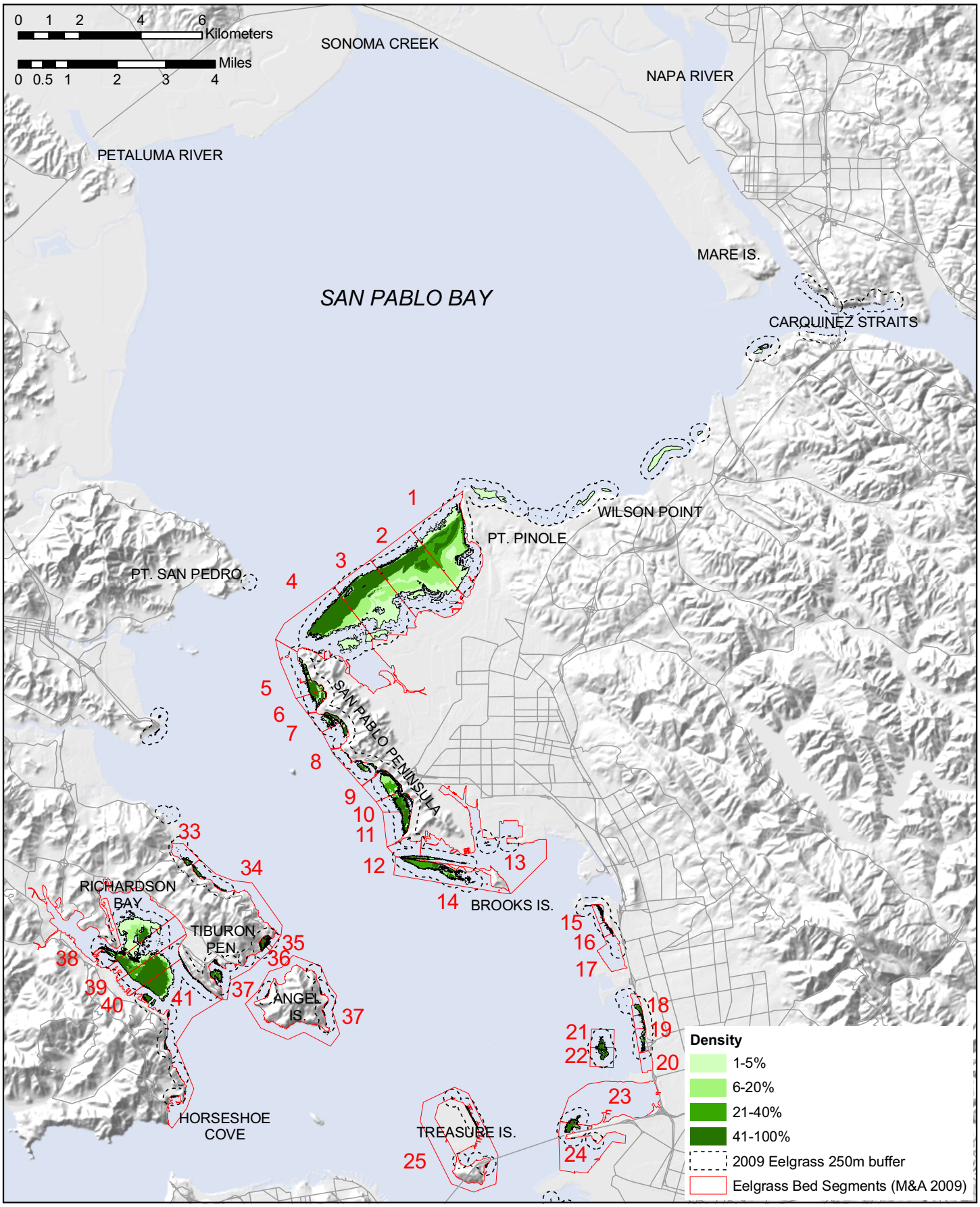


Figure 3. 2009 San Francisco Bay Eelgrass Distribution (North Bay and Central Bay Regions).

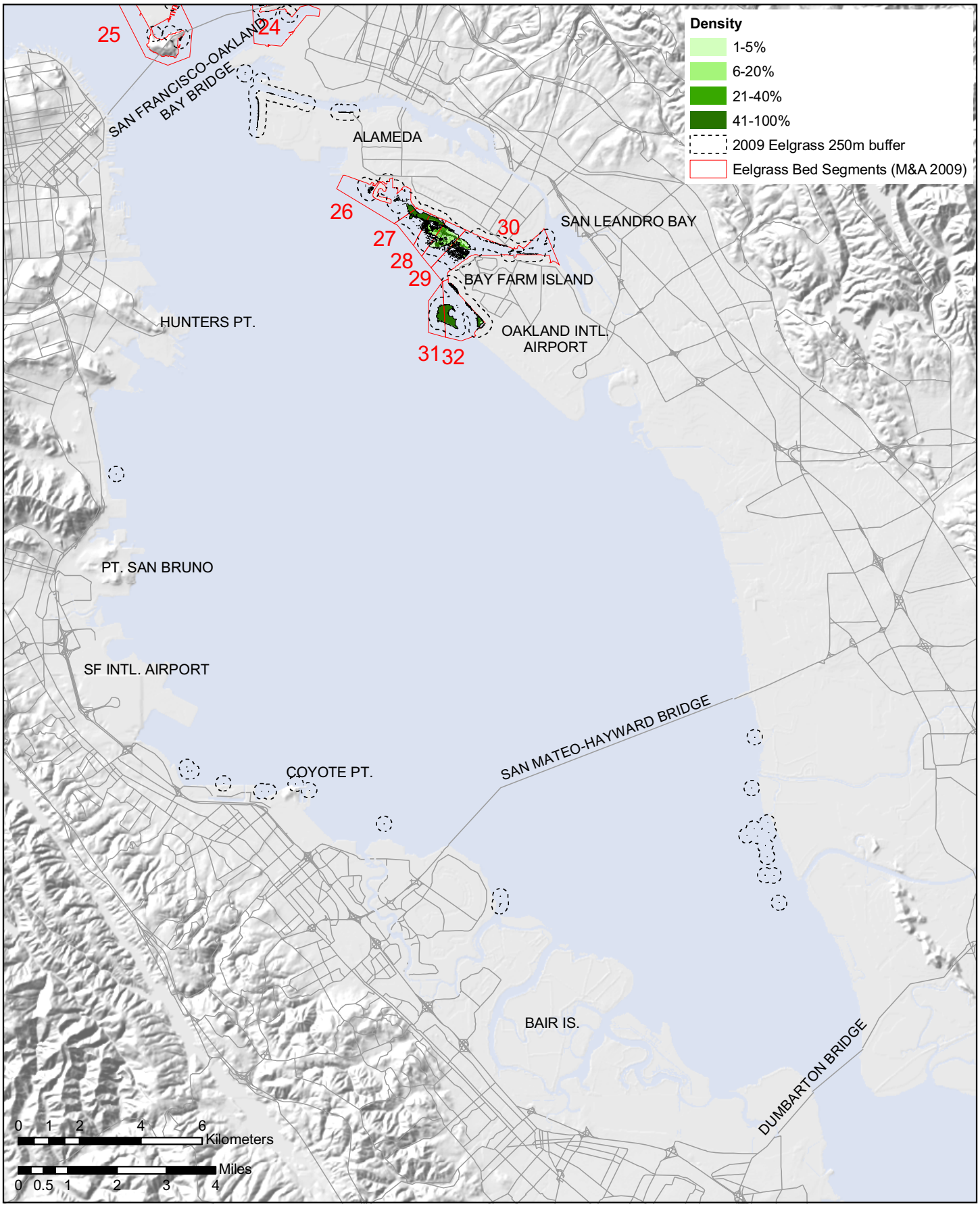


Figure 4. 2009 San Francisco Bay Eelgrass Distribution (South Bay Region).

high variability from year to year has also been observed in the long-term monitoring program for eelgrass at the Emeryville Shoals and Clipper Cove near the SFOBB Project (Merkel & Associates 2008a).

As a result of the high variability in eelgrass coverage within San Francisco Bay, understanding the potential for eelgrass to occur on an intermittent basis is as valuable as understanding where it occurs during any given year. To foster a development of this understanding, two actions have been taken. These include documenting the maximum extent of eelgrass known to occur with each consecutive survey, and revisiting and revising the baywide predictive model of potentially suitable habitat to support eelgrass.

Maximum Eelgrass Extent

In addition to the 2009 eelgrass distribution map, a separate map layer has been prepared of the maximum documented extent of eelgrass (2009 Eelgrass Atlas map sheets, Appendix A). This has been done in anticipation of future updates as additional survey data becomes available in future years. This effort was initiated with the 2003 baywide eelgrass survey; and over time, it will provide a record of recent maximum distribution patterns for eelgrass within San Francisco Bay. The maximum documented eelgrass extent is a combination of all known eelgrass surveys in San Francisco Bay where credible and accurate spatial data exist. Following completion of the 2009 baywide survey, the maximum historical extent of eelgrass was documented to be 1,704 hectares (4,210 acres).

Eelgrass Predictive Model

The San Francisco Bay Ecological Limits, Viability, and Sustainability (ELVS) predictive model for eelgrass (Merkel & Associates 2005) was reviewed in consideration of the present 2009 survey results and the maximum known eelgrass distribution. The model was refined with revised elevation thresholds and plotted as an underlying layer in the 2009 Eelgrass Atlas map sheets, Appendix A). The 2009 revisions to the model are a simplistic bathymetric range restriction modification of the 2005 ELVS model that did not rely directly on bathymetry as a suitability indicator, but rather employed the light regime developed given a multitude of physical parameters, including bathymetry (Merkel & Associates 2005). While the 2009 modifications to the ELVS model enhance the model's predictive ratio (percent eelgrass predicted/percent captured), the inclusion of an absolute limit to the bathymetric range (-2.00 meters to +0.25 meters MLLW), precludes the model capture of deeper, or shallower, environments that support eelgrass for reasons of unique physical environments or during periods of improved water clarity. It further puts considerably more emphasis on bathymetric range than would be justified by the generally limited quality of the regional bathymetric data used in the ELVS model. For this reason, it is essential to consider the true site conditions when evaluating potential eelgrass suitability and to utilize the regional mapping and modeling only as a guidance tool.

The final 2005 eelgrass predictive model predicted 9,486 hectares (23,440 acres) of eelgrass and accurately captured 95.1 percent of the 1,061 hectares (2,622 acres) of eelgrass detected during the 2003 baywide survey (Merkel & Associates 2005). The large ratio of predicted area to eelgrass area is necessary to ensure that significant eelgrass beds are not excluded from the predicted presence of eelgrass. This model also accurately predicts 91.6 percent of the eelgrass detected during the present 2009 baywide survey and 91.2 percent of the maximum known extent of eelgrass mapped within San Francisco Bay. The substantial difference between the model capture for 2003 and the 2009 maximum extent layers is related to the substantial expansion of eelgrass eastward from Pt. Pinole. This area was omitted from the model due principally to a long-term average salinity that exists as a threshold factor resulting in clipping the model at an average surface salinity above 20 parts per thousand (ppt). However, it is likely that the multiple year drought conditions within the San Joaquin Delta have both resulted in an overall increase in salinity further east in San Francisco Bay and have similarly resulted in a reduction of sediment loading into San Pablo Bay (a covariant with reduced salinity). In order to improve model predictive capacity in light of the dynamic nature of the Delta inputs, the model itself would need to be modified to include dynamic fluvial inputs.

With the bathymetric range clips included in the 2009 model modification, the model captures 93.7 percent of the 2003 eelgrass, 90.4 percent of the 2009 eelgrass, and 89.4 percent of the maximum known extent of eelgrass in San Francisco Bay. This lowers the eelgrass capture by 1.2 to 2.0 percent for the various surveys, but results in a significant reduction in the over prediction of eelgrass by reducing the area predicted to be suitable to support eelgrass by 26 percent from 9,530 hectares (23,550 acres) to 7,035 hectares (17,380 acres).

The combined results of the expansion of the known maximum extent of eelgrass and modifications of the ELVS eelgrass predictive model have been an improved predictive capacity for eelgrass in San Francisco Bay. The expanded condition of eelgrass demonstrated that many areas predicted as suitable to support eelgrass, but not occupied in 2003 or prior known survey periods, can support eelgrass. By modifying the present model as is illustrated in the 2009 Eelgrass Atlas (Appendix A), the predicted eelgrass is reduced to 5.9 times the bay area that has been demonstrated to support eelgrass within the recent past. Given that the model is driven by static environmental assumptions within an area that is known to be highly dynamic, this degree of predictive power is considered to be high.

BATHYMETRIC DISTRIBUTION OF EELGRASS

As reported in the 2003 survey report, bathymetry for San Francisco Bay was derived from numerous survey sources that date over extended periods. In most instances, the bathymetry was collected on larger survey vessels that avoided the extreme shallows of San Francisco Bay margins. As a result, bathymetric survey data were sparse in areas that generally support eelgrass beds. To improve upon this condition, bathymetric data were supplemented during the 2003 survey and data were interpolated to shore by using marsh vegetation and intertidal zonation features. While these data may be improved

upon, they are adequate for regional scale analyses. More site specific investigations should rely on refined bathymetric and eelgrass survey data for any interpretive modeling and analyses. Using the existing bathymetric data, it has been possible to determine the elevation range distribution of eelgrass within San Francisco Bay for the 2003, 2005, and maximum extent survey layers (Figure 5). The depth distribution of eelgrass is extremely narrow and is indicative of the turbid nature of San Francisco Bay.

It is notable that the eelgrass represented as existing at elevations higher than +0.25 meters in Figure 5 is almost invariably found within the upper end of well defined coves where shallower bathymetry is an artifact of interpolation methods used to bring existing bathymetric survey data to the shoreline edge. As a point in fact, it is unlikely that much, if any eelgrass with San Francisco Bay extends beyond +0.25 to +0.35 meters MLLW.

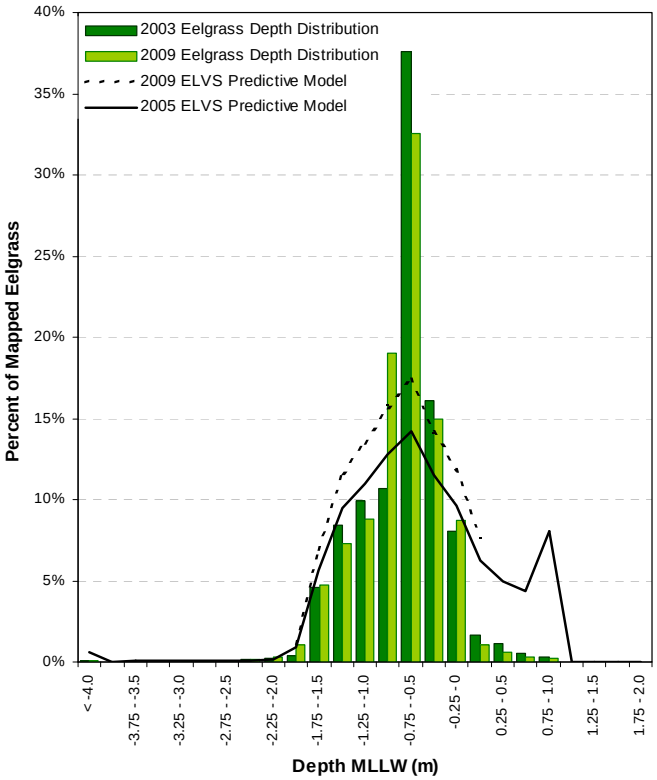


Figure 5. Eelgrass Depth Distribution Relative to Predictive Model Depth Distribution Ranges

EELGRASS EXPANSION CAPACITY

Eelgrass habitat in San Francisco Bay fluctuates considerably over time and is known to have existed over 1,704 hectares (4,210 acres) of bay bottom at some point in the past two decades for which spatial survey data exists. This maximum known extent of eelgrass translates to approximately 1.7 percent of the bay area, which is an order of magnitude less than other large California estuarine systems (Table 2). However, due to the large size of San Francisco Bay, even the small percentage of bottom cover amounts to substantial eelgrass resources on a statewide basis.

Table 2. Comparison of Eelgrass Coverage in California Bays and Estuarine systems

System	Eelgrass (acres)	% Coverage
Mission Bay[1]	528	54%
San Diego Bay[2]	840	19%
Humboldt Bay[3]	1,951	10%
Tomales Bay[4]	391	13%
San Francisco Bay[5]	4,210	1.7%

[1]Merkel & Associates 2008c
[2]Merkel & Associates 2009b
[3]McBride et al., unpublished data
[4]Wyllie-Echeverria and Rutten 1989
[5]Maximun known extent 1989-2009

The most likely explanation for restricted eelgrass coverage in San Francisco Bay is the low light levels available to eelgrass in the North and South Bay regions. More than 4.5 million cubic meters (6 million cubic yards) of sediment enter the Estuary per average year from approximately 20 major freshwater streams and rivers (Goals Project 1999). In addition to the sources of sedimentation from freshwater flows, there is additional suspended sediment resulting from tidal currents and wind-driven waves. The Central Bay region has the clearest water, followed by the South Bay and North Bay, and lastly Suisun Bay. The Suisun and North Bay regions are by far the most turbid of any area in the Estuary due to freshwater input from the Delta and high resident suspended sediment loads.

While there still has not yet been a significant amount of rigorous monitoring of eelgrass in San Francisco Bay, at least some of the high variability appears to be related to large-scale episodic events that influence the distribution of freshwater and sediments in San Francisco Bay (Merkel 2000 and additional unpublished data). Presently, it is hypothesized that episodic high flow fluvial events result in substantial increases in sediment loading to San Francisco Bay. This sediment becomes an additive source of resident suspended sediment that is slowly purged from San Francisco Bay by tidal exchange. During several years following heavy sediment loading, eelgrass is extirpated from areas of high sediment suspension and low sediment export. Eelgrass also likely declines along the deeper fringes of beds that survive increased turbidity, typically those further removed from direct loading or export circulation patterns. Over longer periods of benign fluvial events, such as during the present drought conditions, sediment loading is reduced, thus allowing for a recovering trend in water clarity and improvement of conditions suitable to support eelgrass. At these times, eelgrass is capable of colonizing areas of past extirpations and suitable environments. However, given the large spatial scale of San Francisco Bay, the bathymetric and hydrodynamic environments, and the limited supply of eelgrass, even areas suitable to support eelgrass may go uncolonized for many years due to seed dispersal limitations.

If episodic events control eelgrass extirpation and chance recruitment events control colonization, it would suggest that considerably more suitable habitat might exist at some periods of time, than is occupied by eelgrass. It would also suggest that

maintaining a geographically well-distributed presence of fairly persistent eelgrass beds may be critical in the system to serve as source populations from which material may be derived for recolonization following extirpation events. It would also suggest that considerable opportunity might exist for establishing eelgrass beds in areas around San Francisco Bay, but that these beds may be subject to extirpation events through time.

CONCLUSIONS

The 2009 baywide eelgrass inventory reveals a considerable expansion of eelgrass beyond that observed during the 2003 baywide survey. This inventory is believed to reflect a relatively expansive distribution of eelgrass in San Francisco Bay and has likely been manifested as a result of prolonged reduction in significant sediment and freshwater inputs from the San Joaquin Delta during the prolonged three-year drought that has extended since the 2006-2007 water year, following a significantly wetter than normal 2005-2006 water year. This 2009 Eelgrass Atlas provides a snapshot of the distribution of eelgrass during a single year; and along with the maximum documented eelgrass extent, this survey alludes to the tremendously dynamic nature of eelgrass beds in San Francisco Bay. As a resource management tool, the current survey provides a second comprehensive mapping of eelgrass habitat resources in San Francisco Bay and underpins a regional eelgrass monitoring strategy based on subsampling and extrapolation that has been developed and tested (Merkel & Associates 2009a) and which will be initiated by NOAA Fisheries in 2010.

If the 2009-2010 water year does develop to the predicted high rainfall and runoff conditions anticipated under an El Niño year, it can be expected that eelgrass will decline from its current levels. The decline will likely be most pronounced in the North Bay, where expansions from prior survey years have been greatest.

Notwithstanding, the value of the eelgrass atlas is as a planning and large-scale resource management tool, and it is not intended to replace site specific and up-to-date surveys and analyses where potential impacts to eelgrass habitat are contemplated. Resource managers are cautioned regarding the inapplicability of the present data for completing impact assessments or site-specific evaluations. While these data provide a useful tool for planning and evaluating management needs, they are not adequate to meet the needs of specific project assessments.

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APPENDIX A. SAN FRANCISCO BAY EELGRASS ATLAS OCTOBER – NOVEMBER 2009 ATLAS MAP INDEX AND MAP SHEETS

SAN FRANCISCO BAY EELGRASS ATLAS

October - November 2009



Submitted to:

Caltrans
111 Grand Avenue
Oakland, CA 94623-0660

and

National Marine Fisheries Service
777 Sonoma Avenue, Suite 325
Santa Rosa, CA 95404-6515

Submitted by:

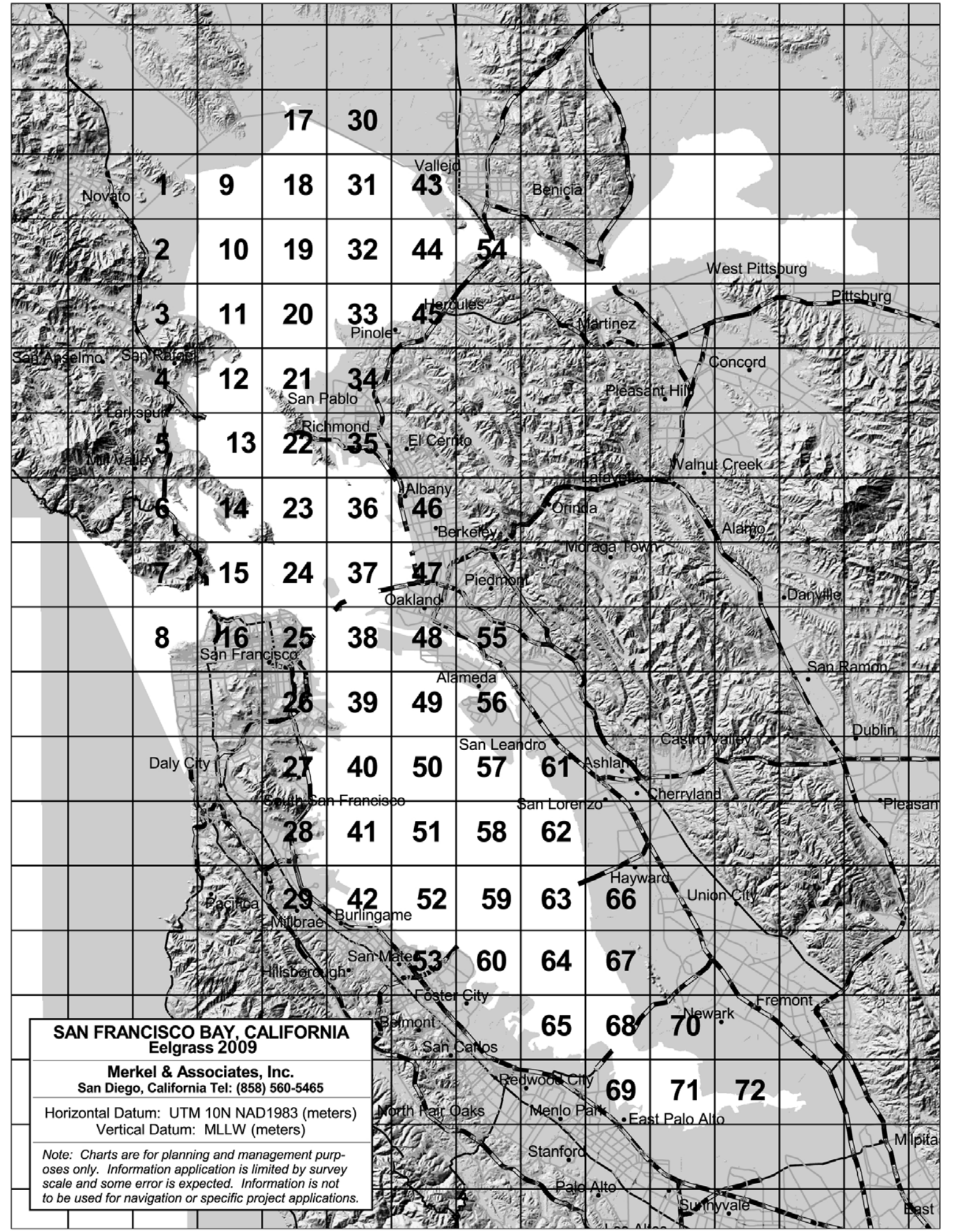
Merkel & Associates, Inc.
5434 Ruffin Road
San Diego, CA 92123
ph. (858) 560-5465
fx. (858) 560-7779

December 2009

Eelgrass mapping is based on acoustic and aerial surveys of October – November 2009. Eelgrass distribution along the shoreline, and within various portions of the bay was refined using site specific survey data and diver ground truthing.

Eelgrass bed density classification is most accurate near the central portion of the range and is less accurate near the extremes of any of the defined density ranges where interpretive error may occur. Eelgrass data reflects a particular period in time and are anticipated to be a seasonally and stochastically dynamic

Note: Charts are for planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.

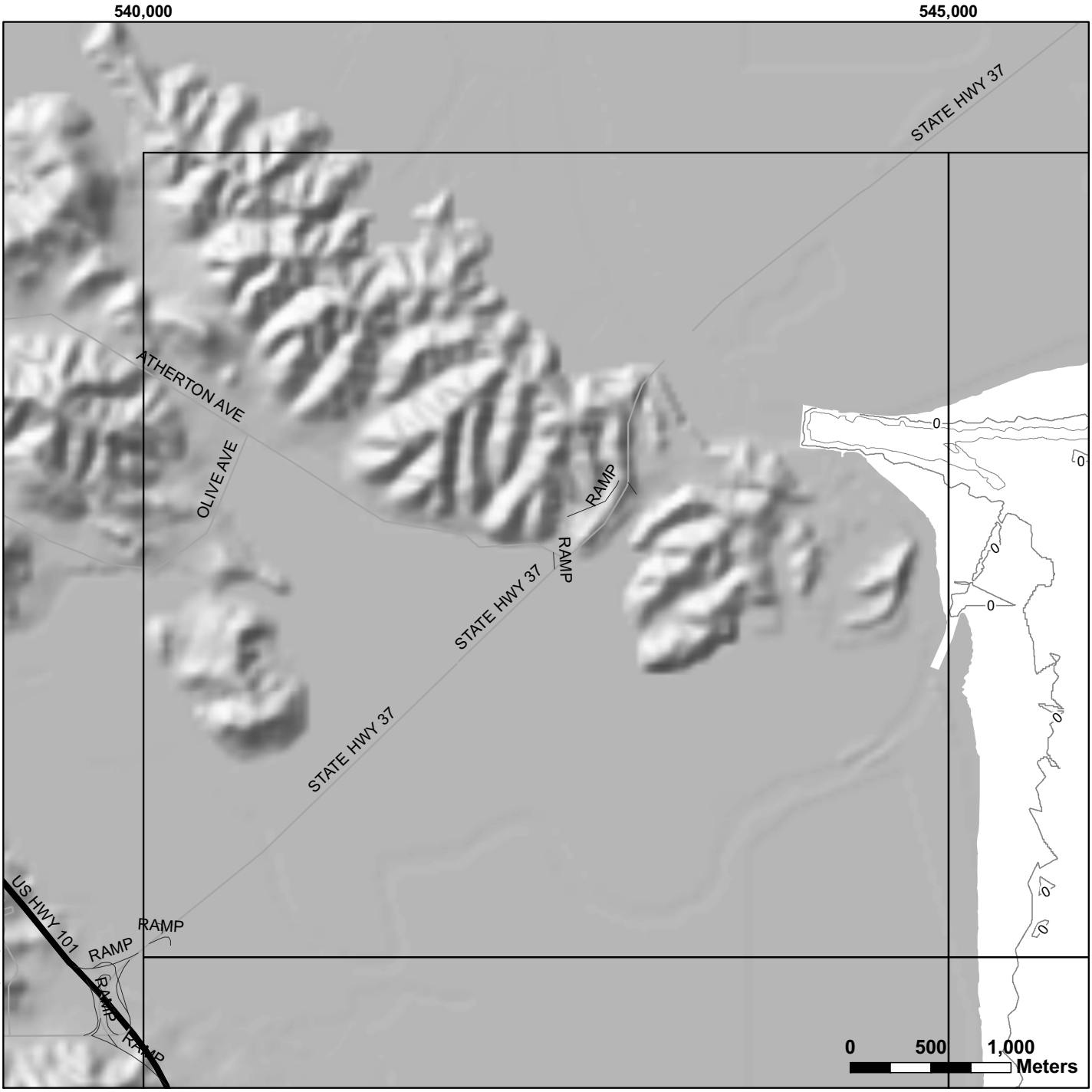


SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

Merkel & Associates, Inc.
San Diego, California Tel: (858) 560-5465

Horizontal Datum: UTM 10N NAD1983 (meters)
Vertical Datum: MLLW (meters)

Note: Charts are for planning and management purposes only. Information application is limited by survey scale and some error is expected. Information is not to be used for navigation or specific project applications.



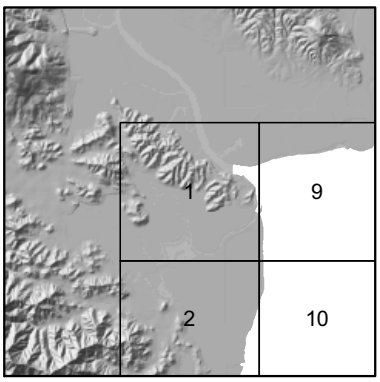
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San Diego, CA - Tel: (858) 560-5465

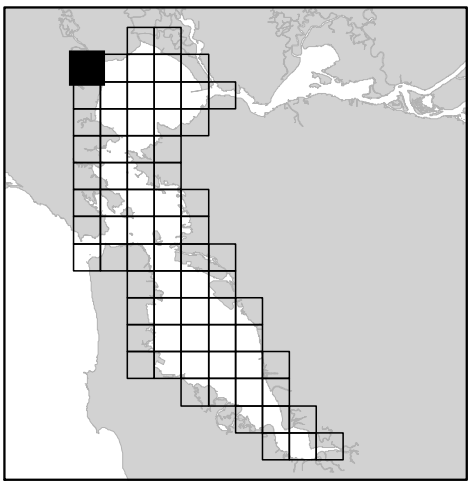
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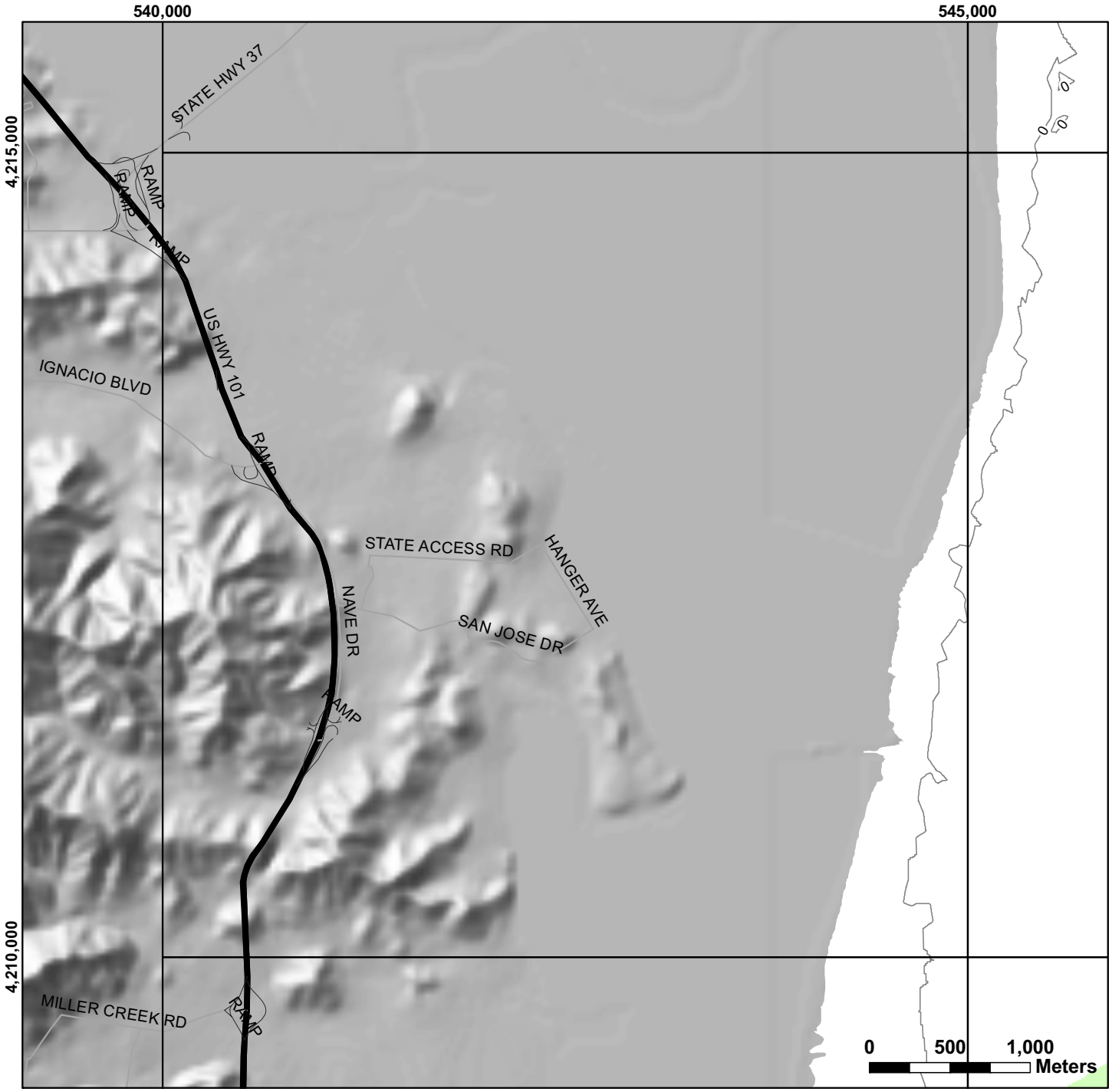
SHEET LOCATOR



Eelgrass Coverage

- 1-5%
- 6-20%
- 21-40%
- 41-100%

- Max Documented Eelgrass Extent
- 2009 Eelgrass 250m buffer
- ELVS Predictive Model 2009



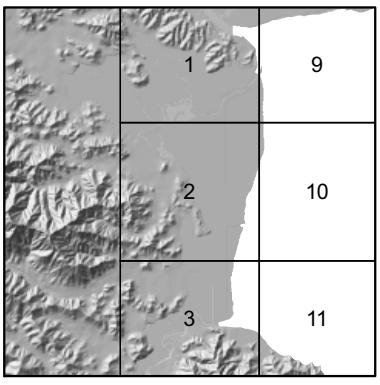
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

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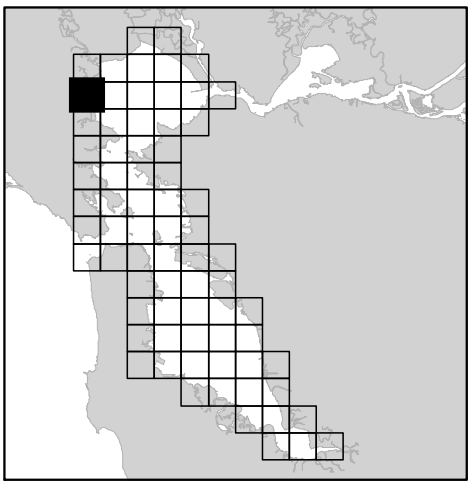
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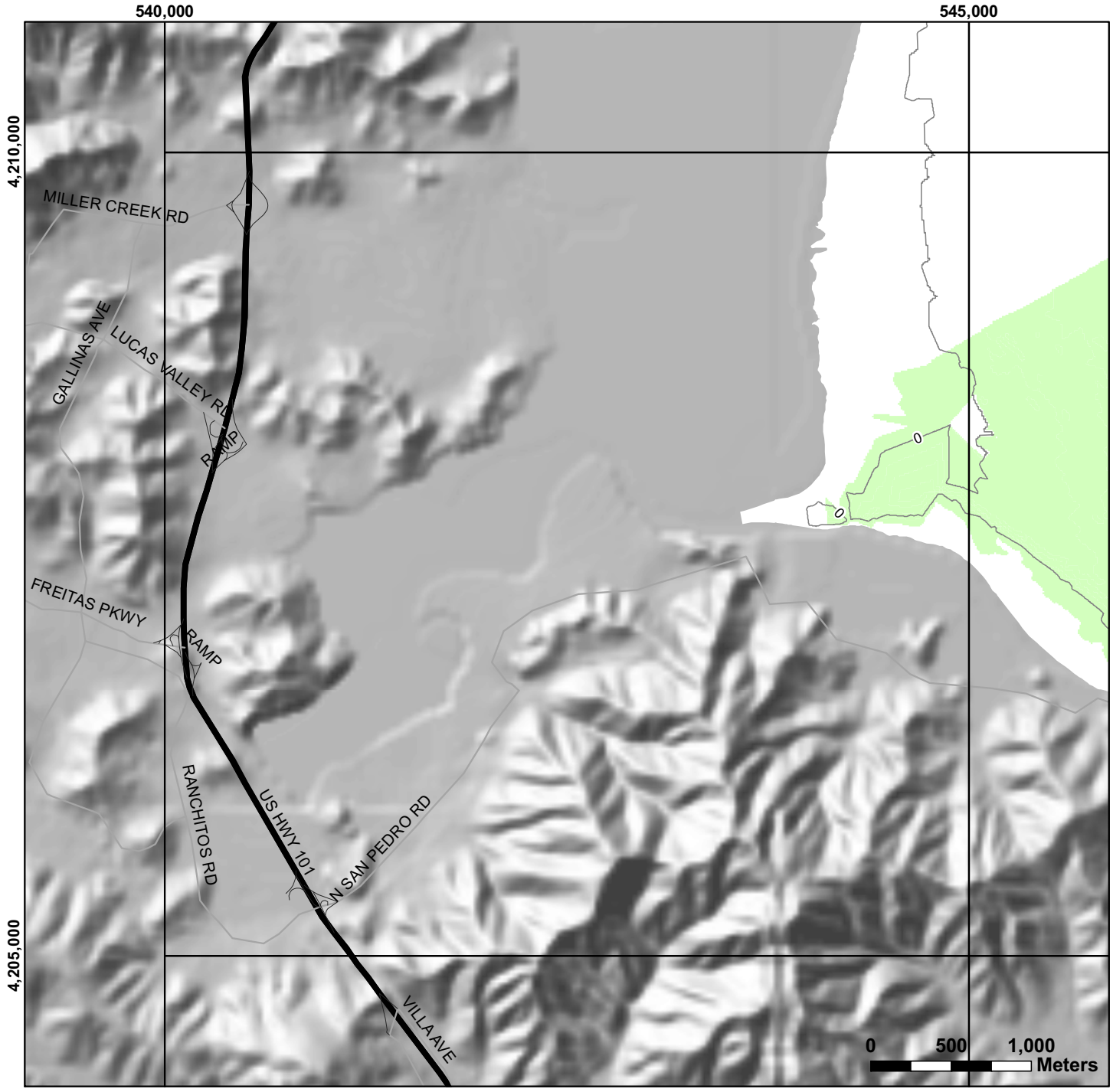




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- 41-100%

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SAN FRANCISCO BAY, CALIFORNIA
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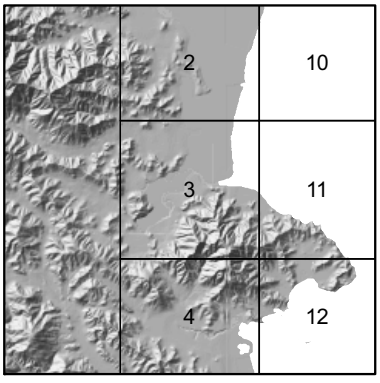
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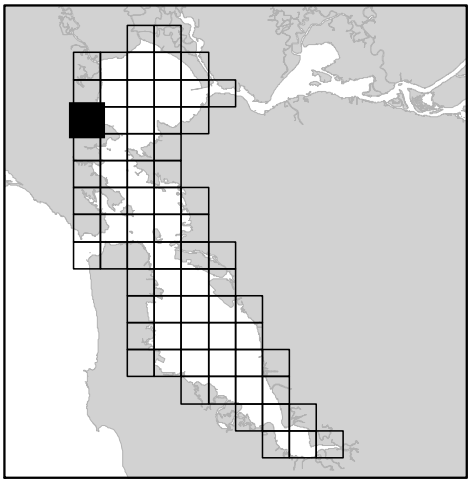
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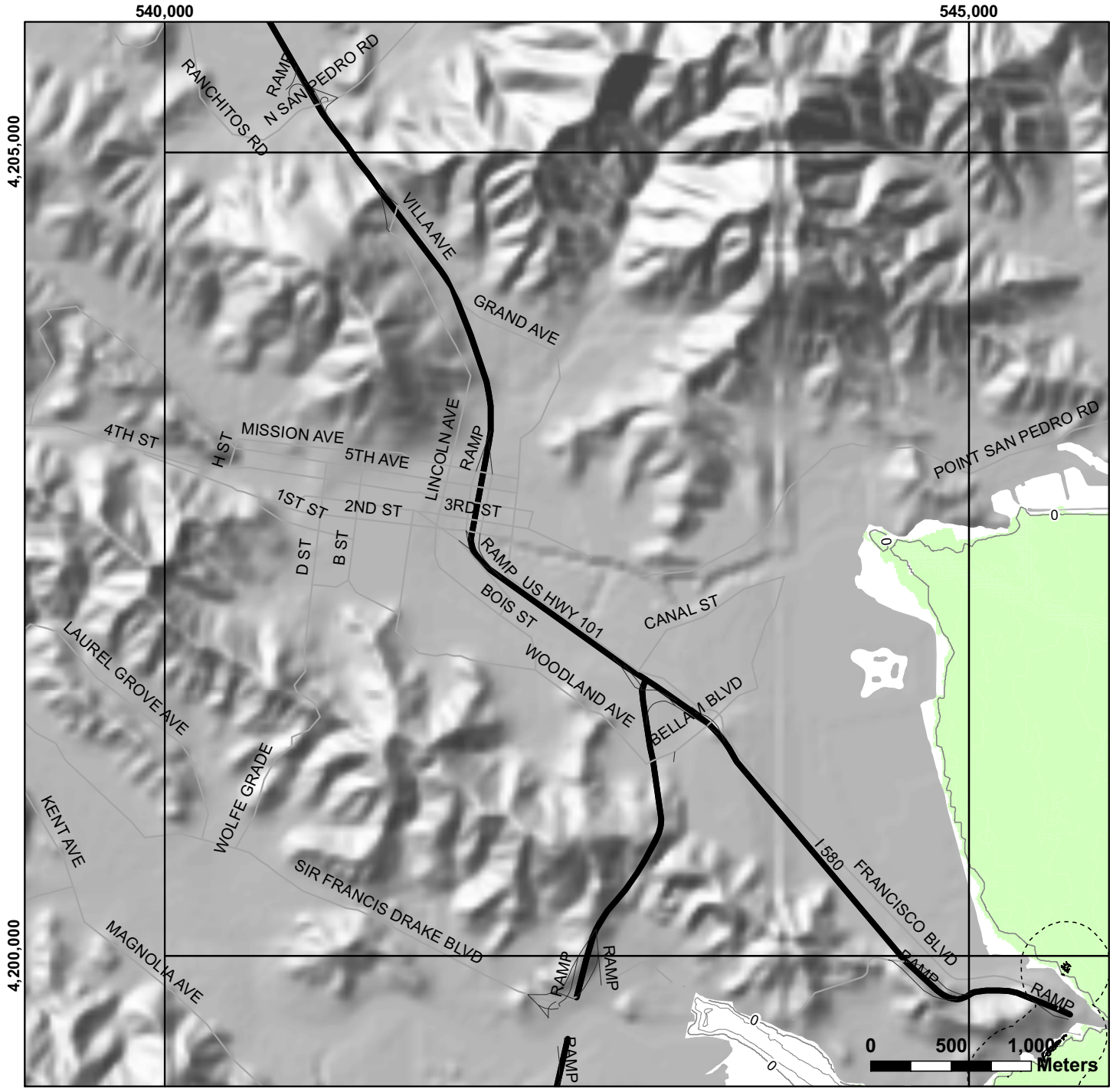
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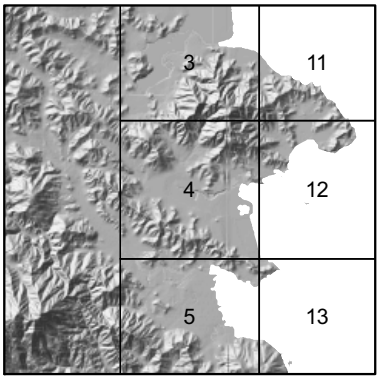
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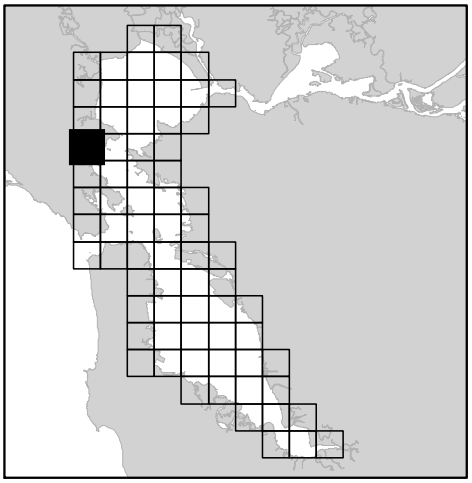
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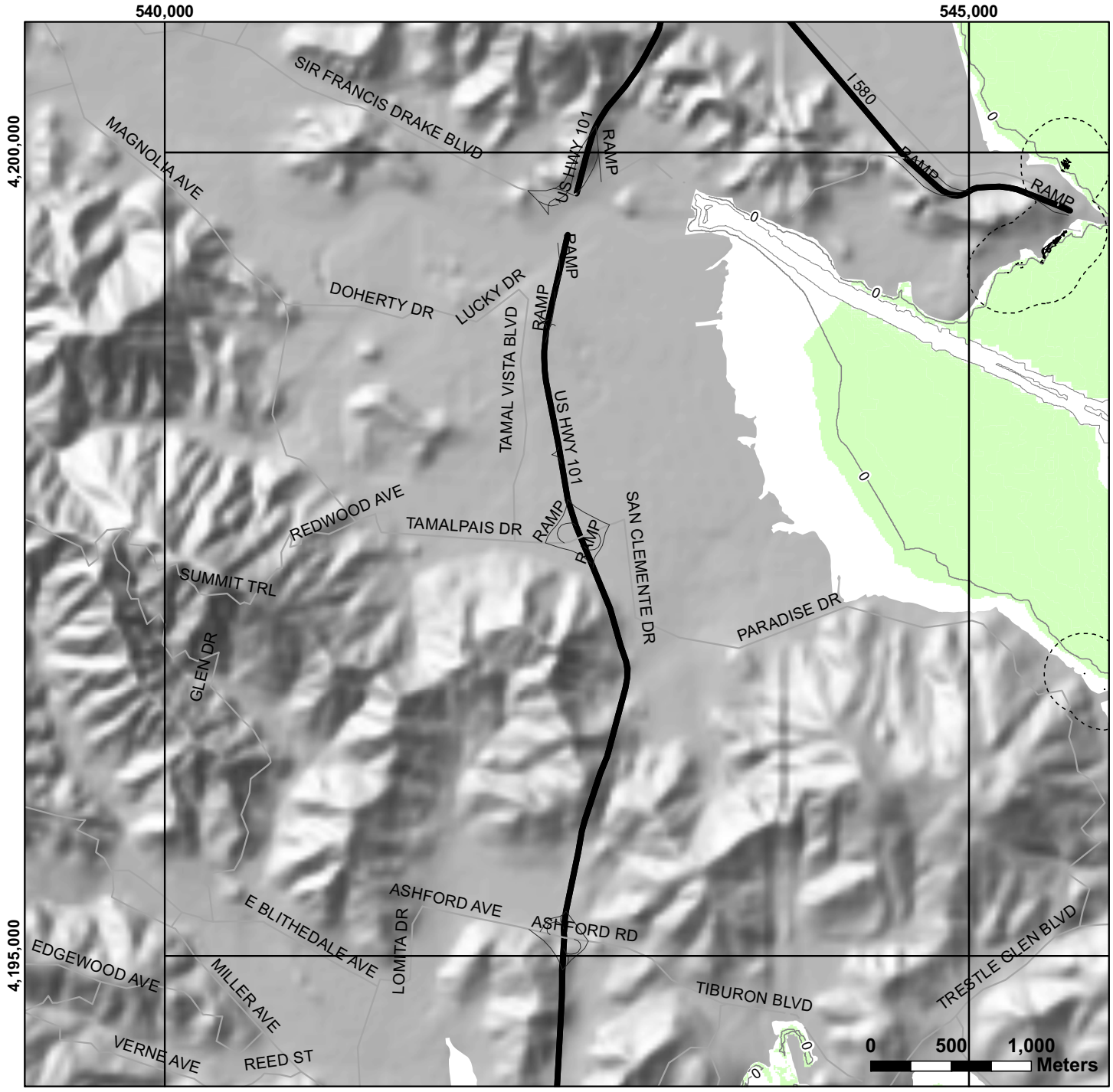
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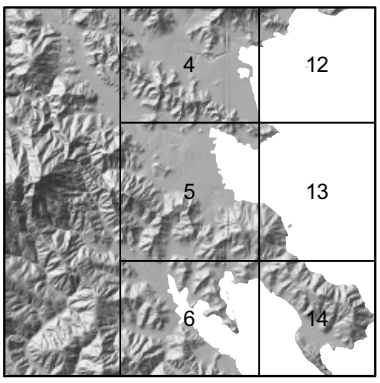
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Eelgrass 2009

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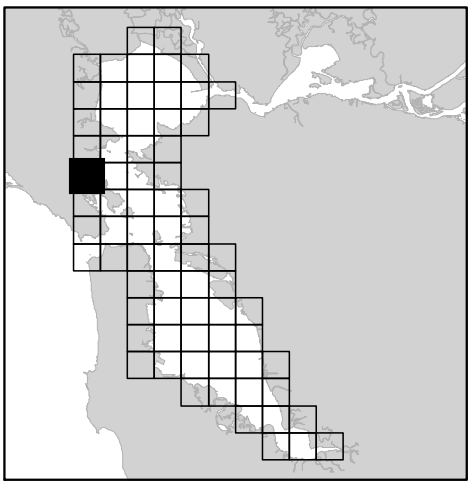
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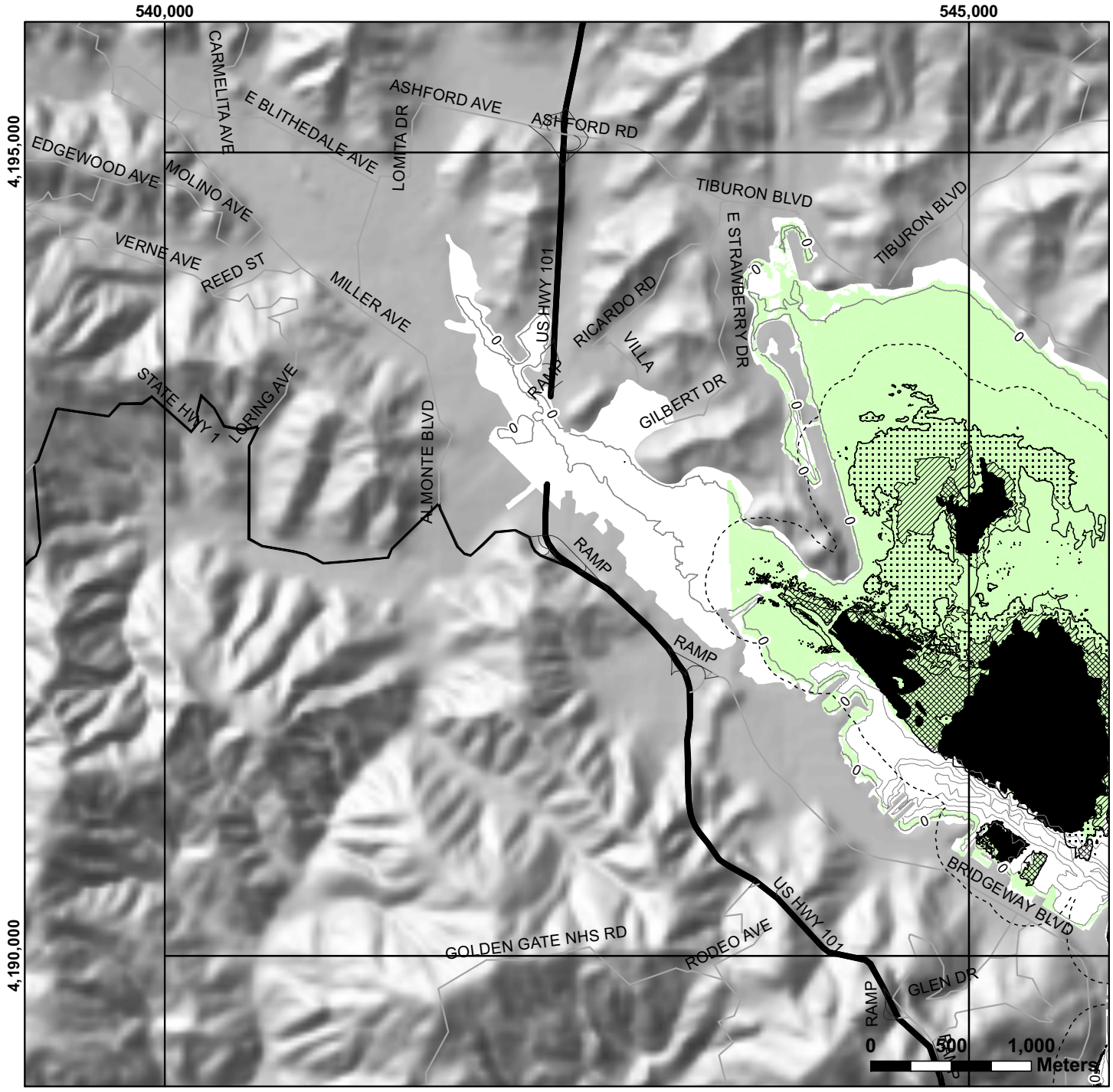
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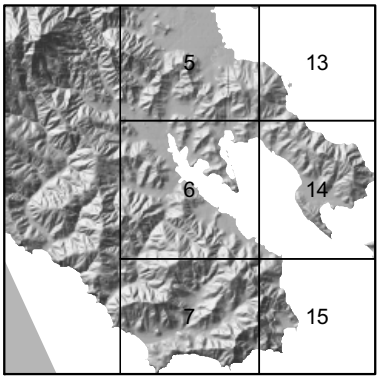
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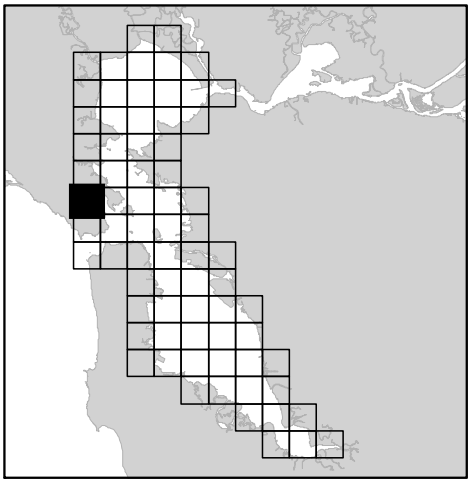
Horizontal Datum: UTM NAD83 Zone 10N
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SHEET VICINITY



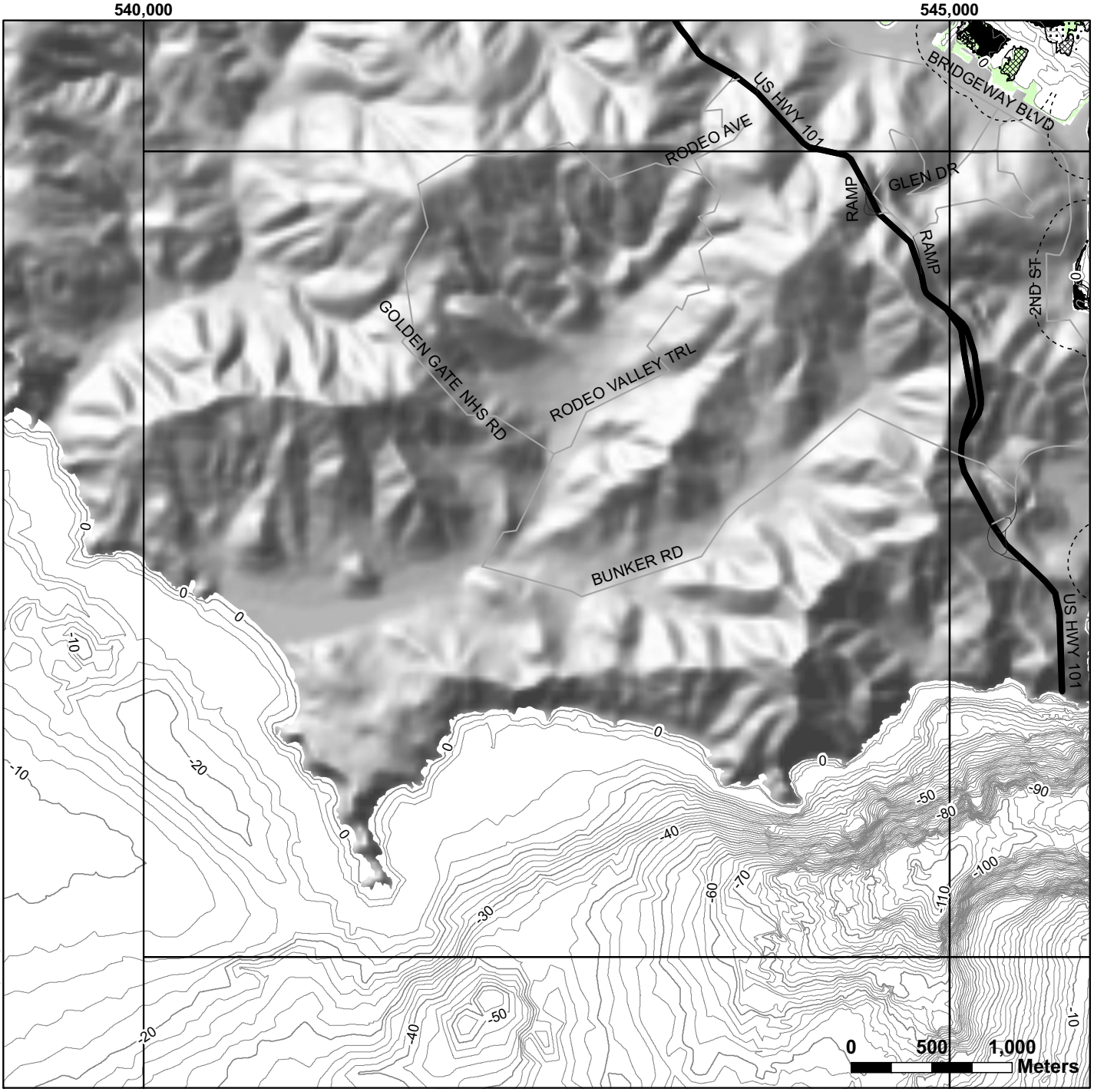
SHEET LOCATOR



Eelgrass Coverage

- 1-5%
- 6-20%
- 21-40%
- 41-100%

- Max Documented Eelgrass Extent
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- ELVS Predictive Model 2009



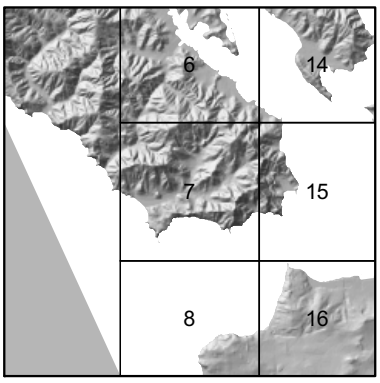
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

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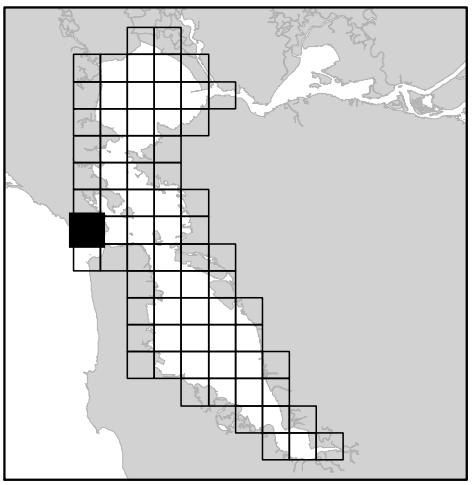
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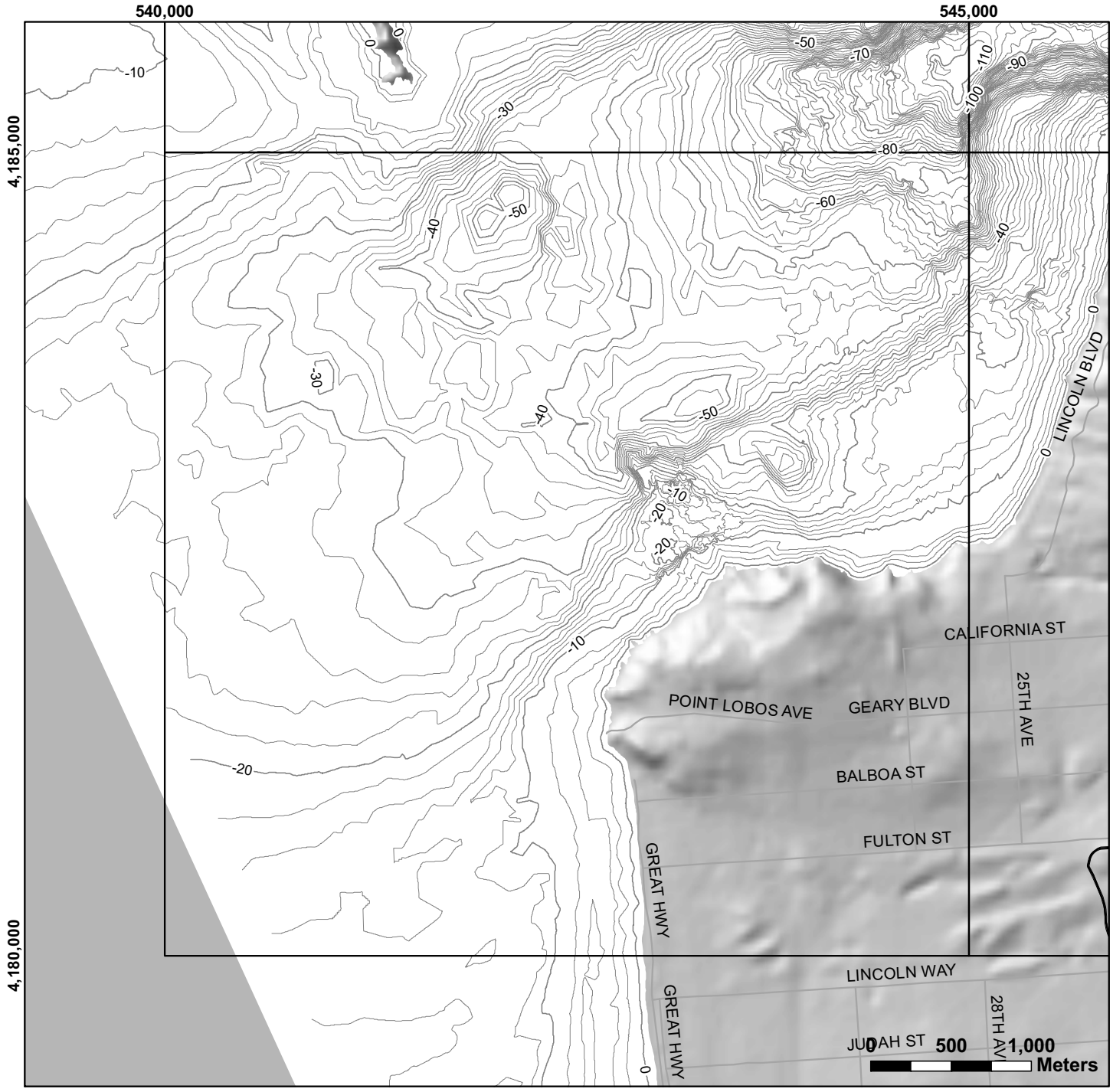
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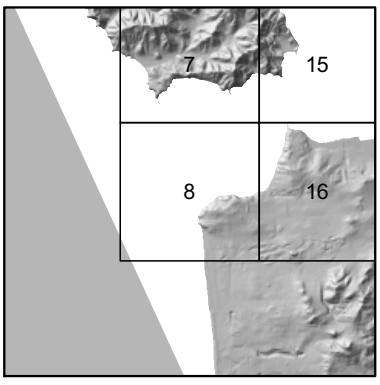
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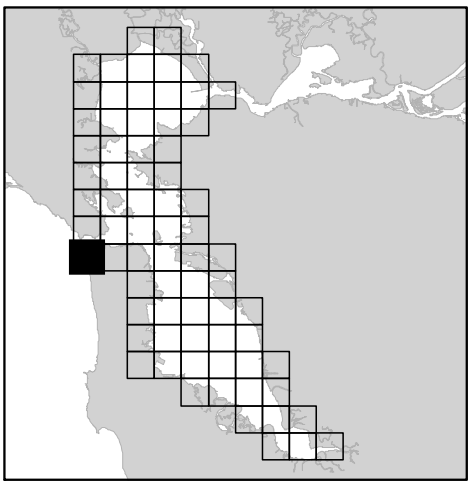
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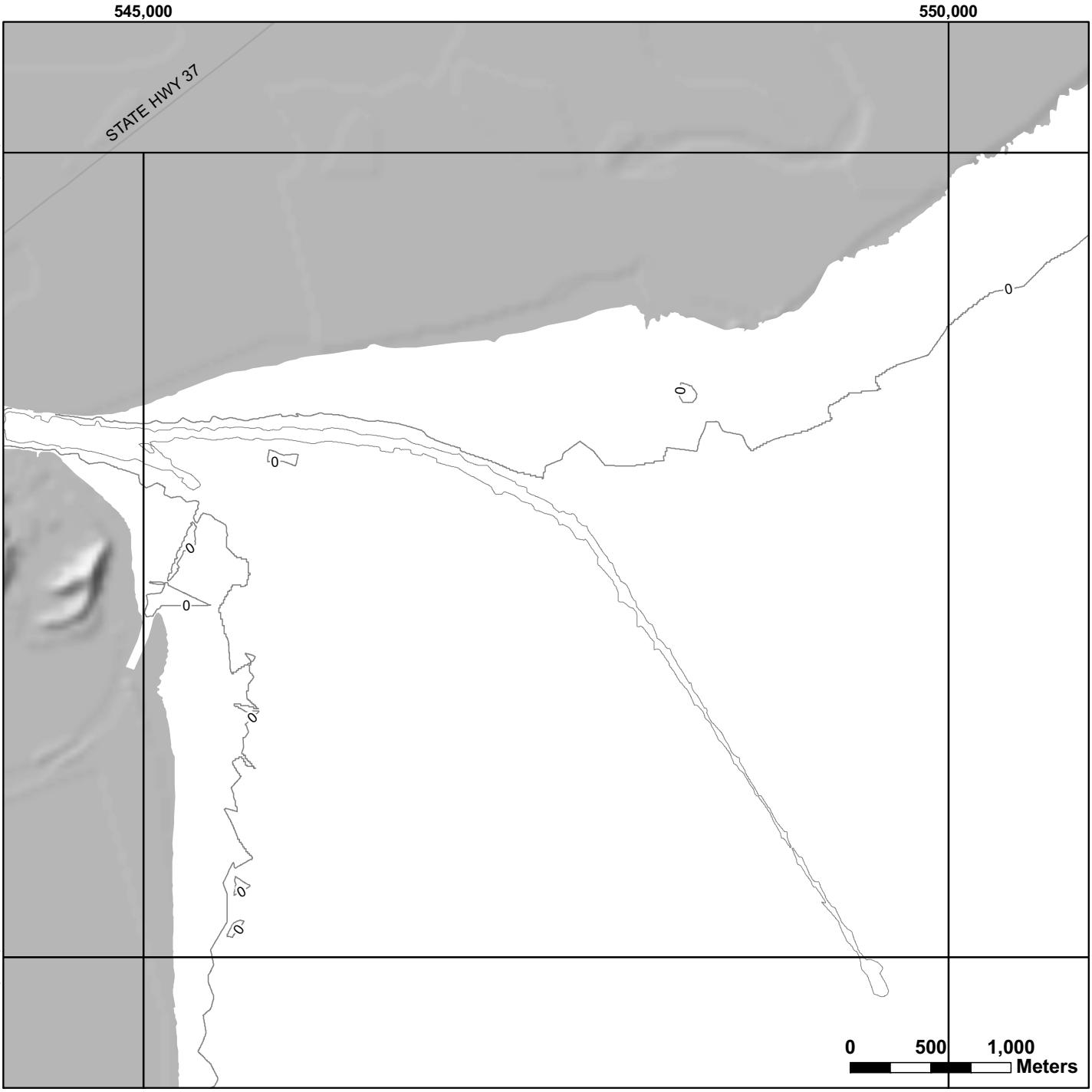


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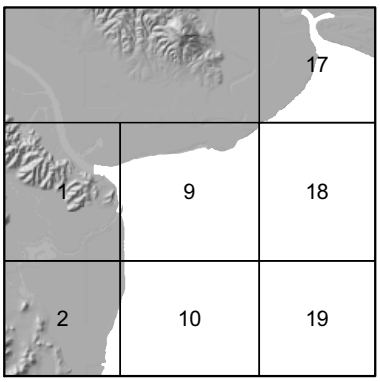
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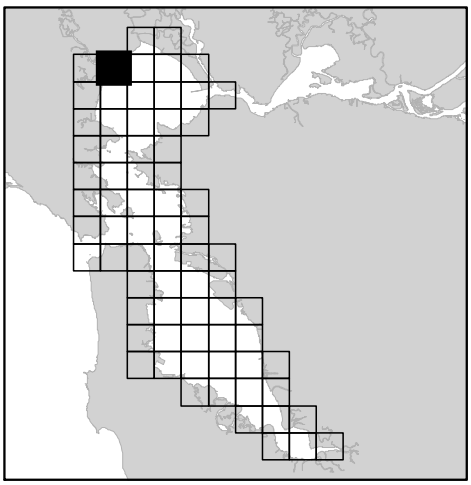
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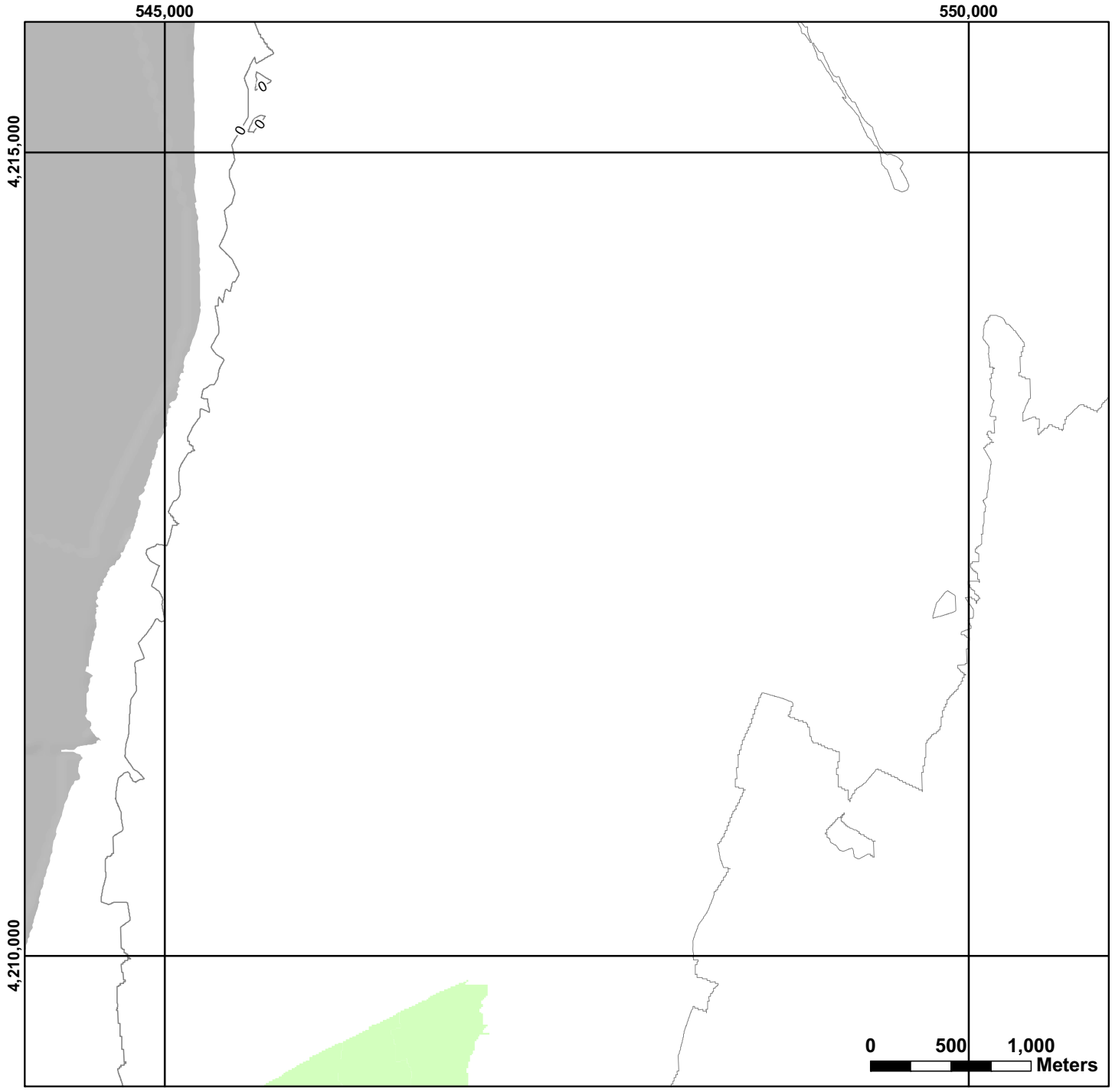




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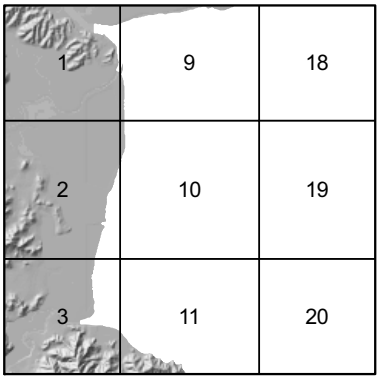
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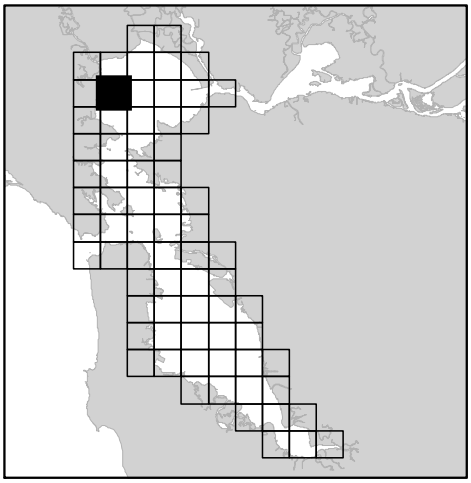
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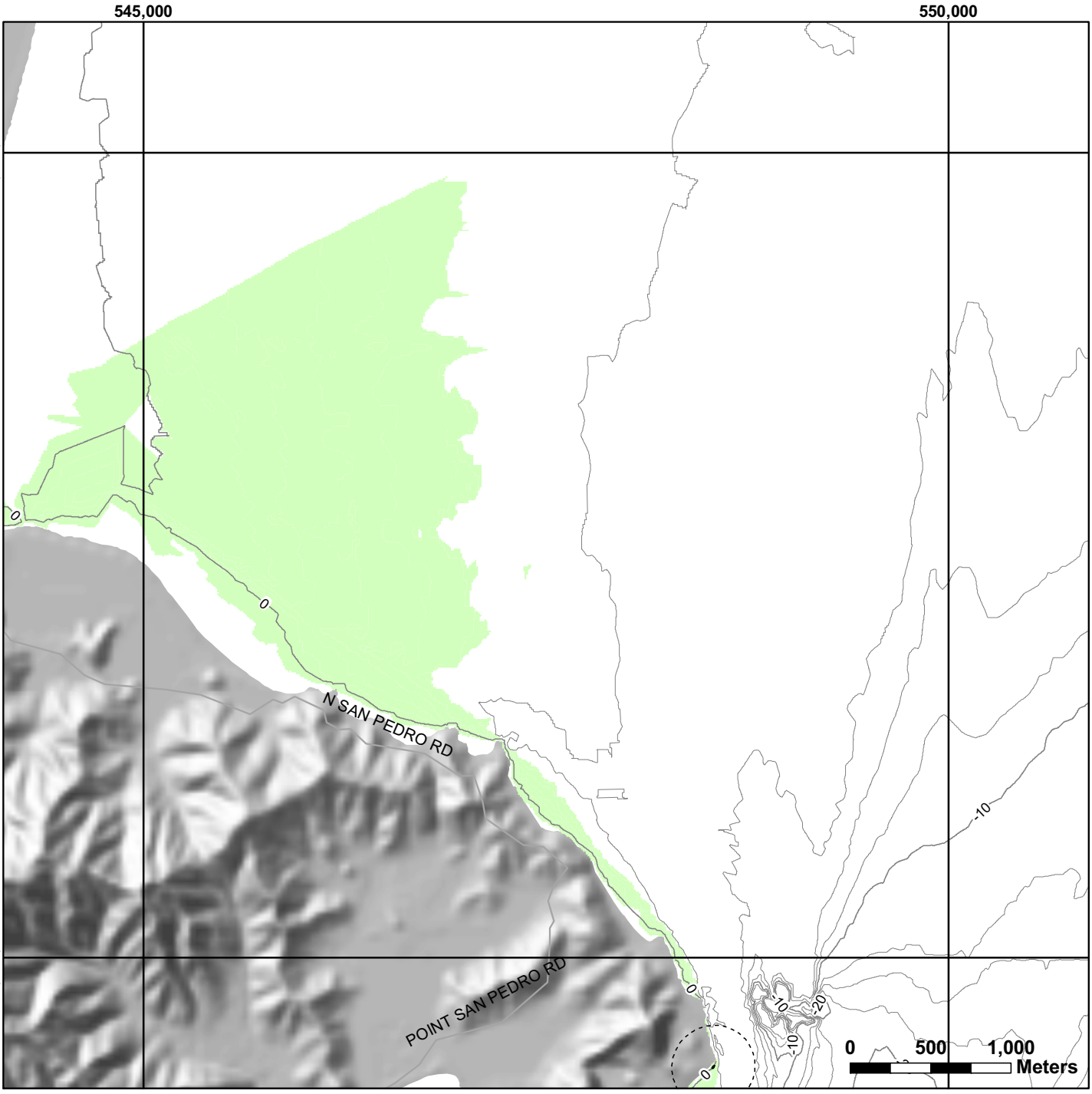




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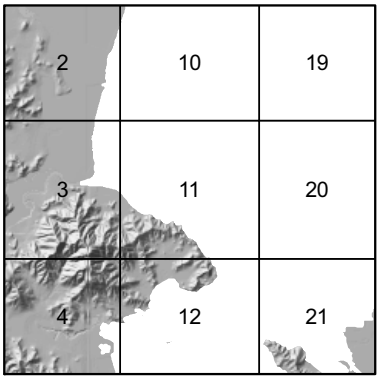
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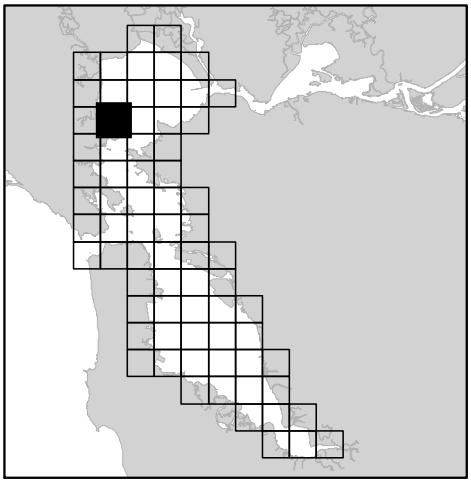
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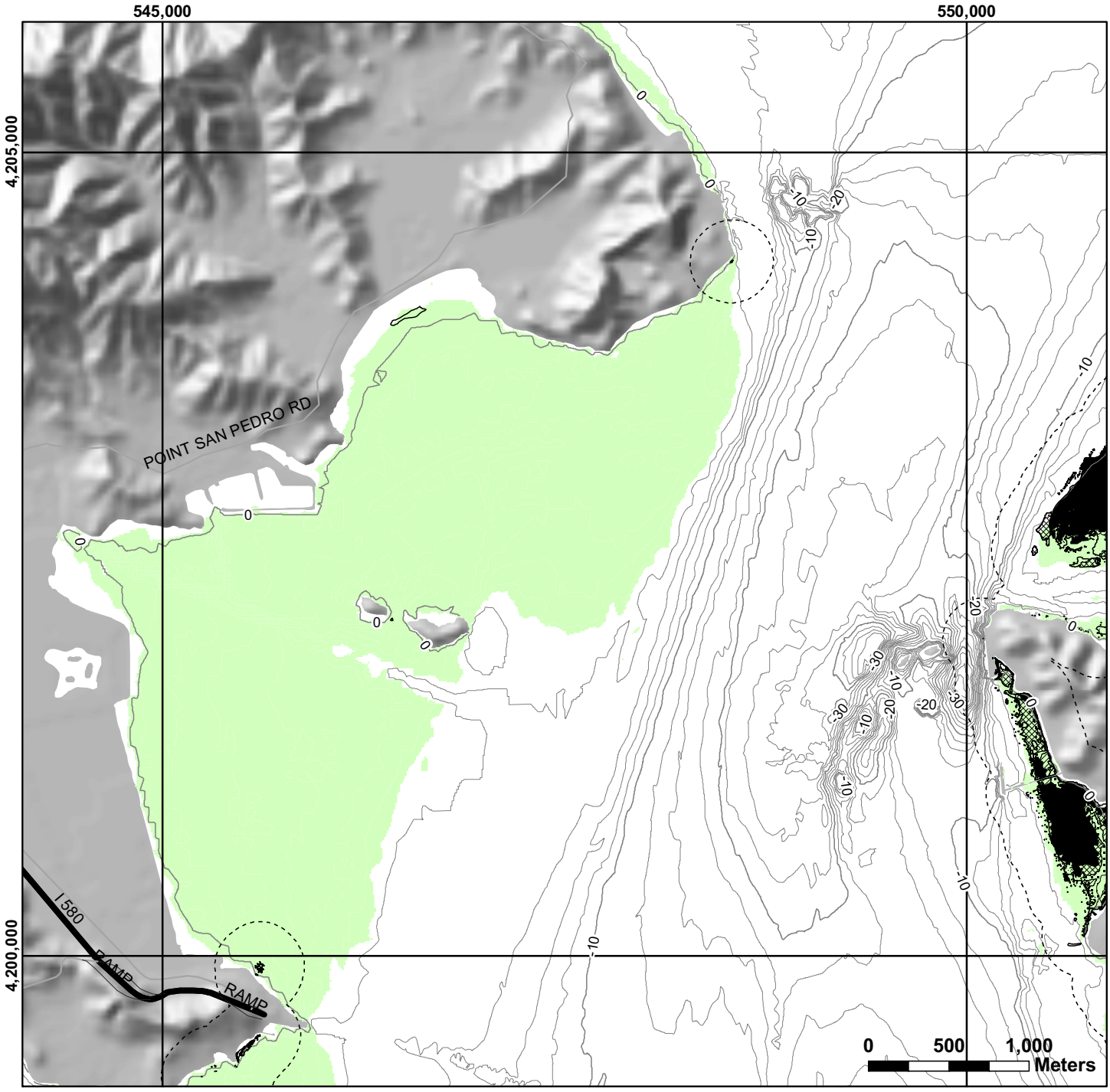
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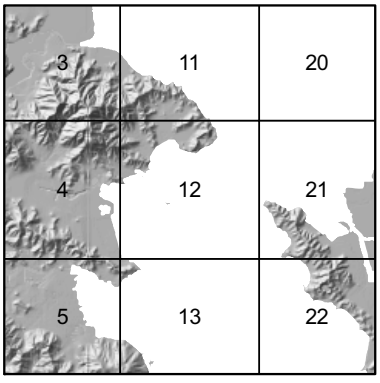
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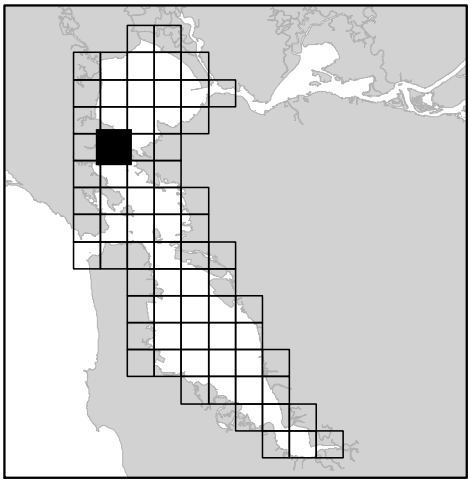
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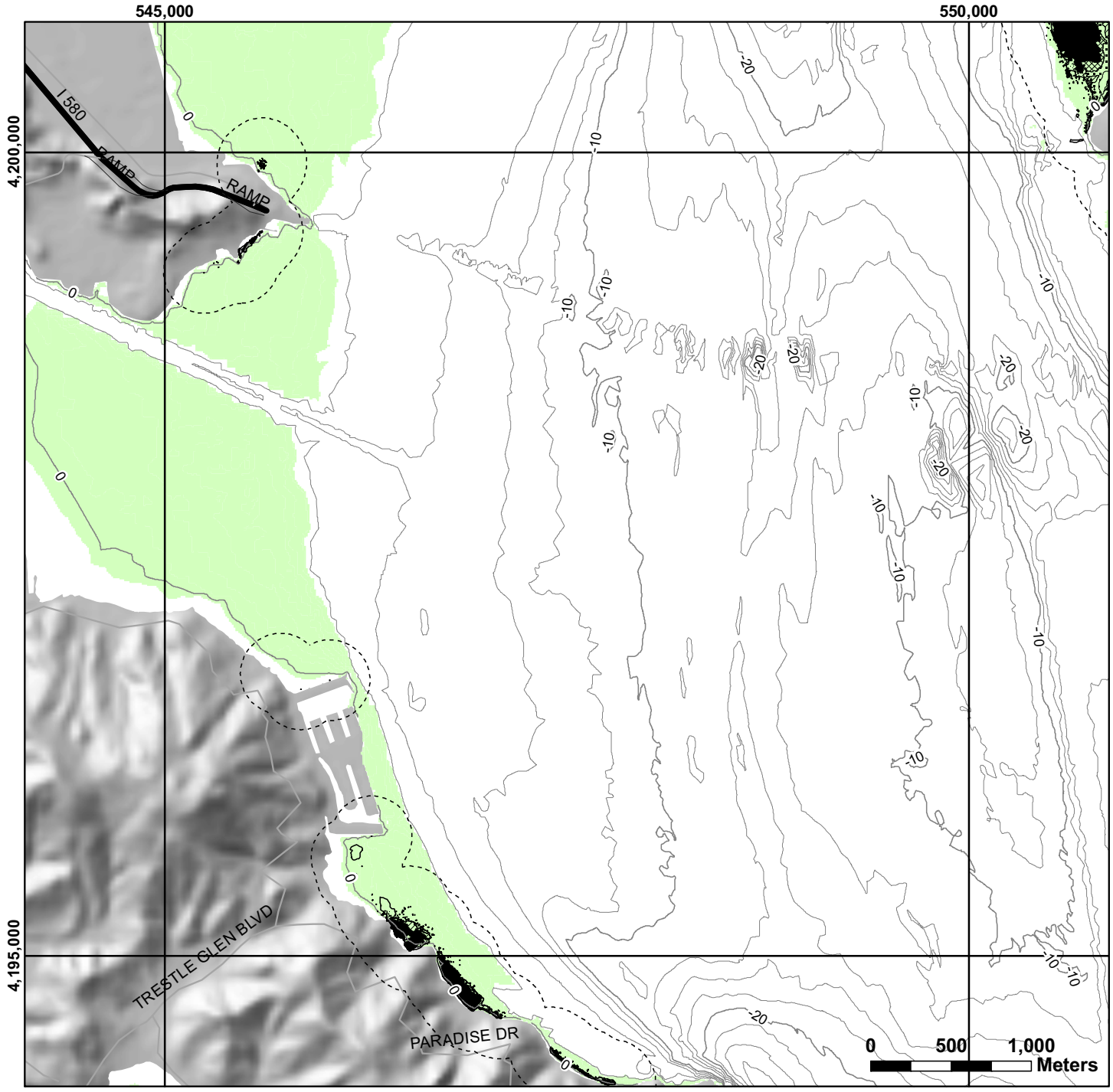
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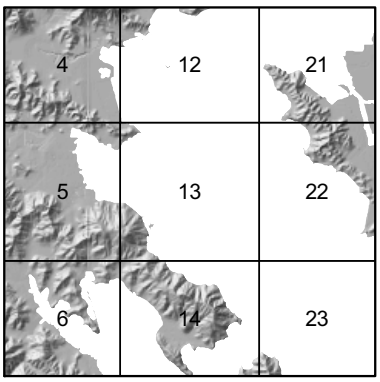
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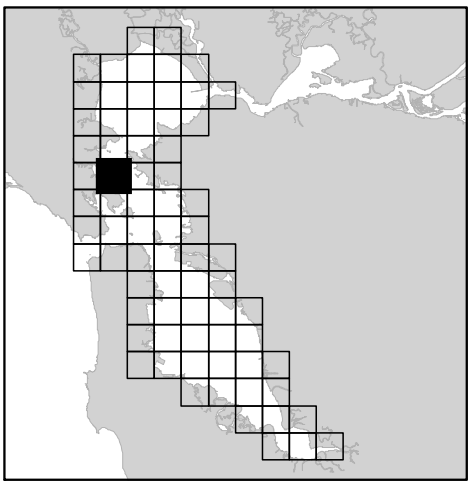
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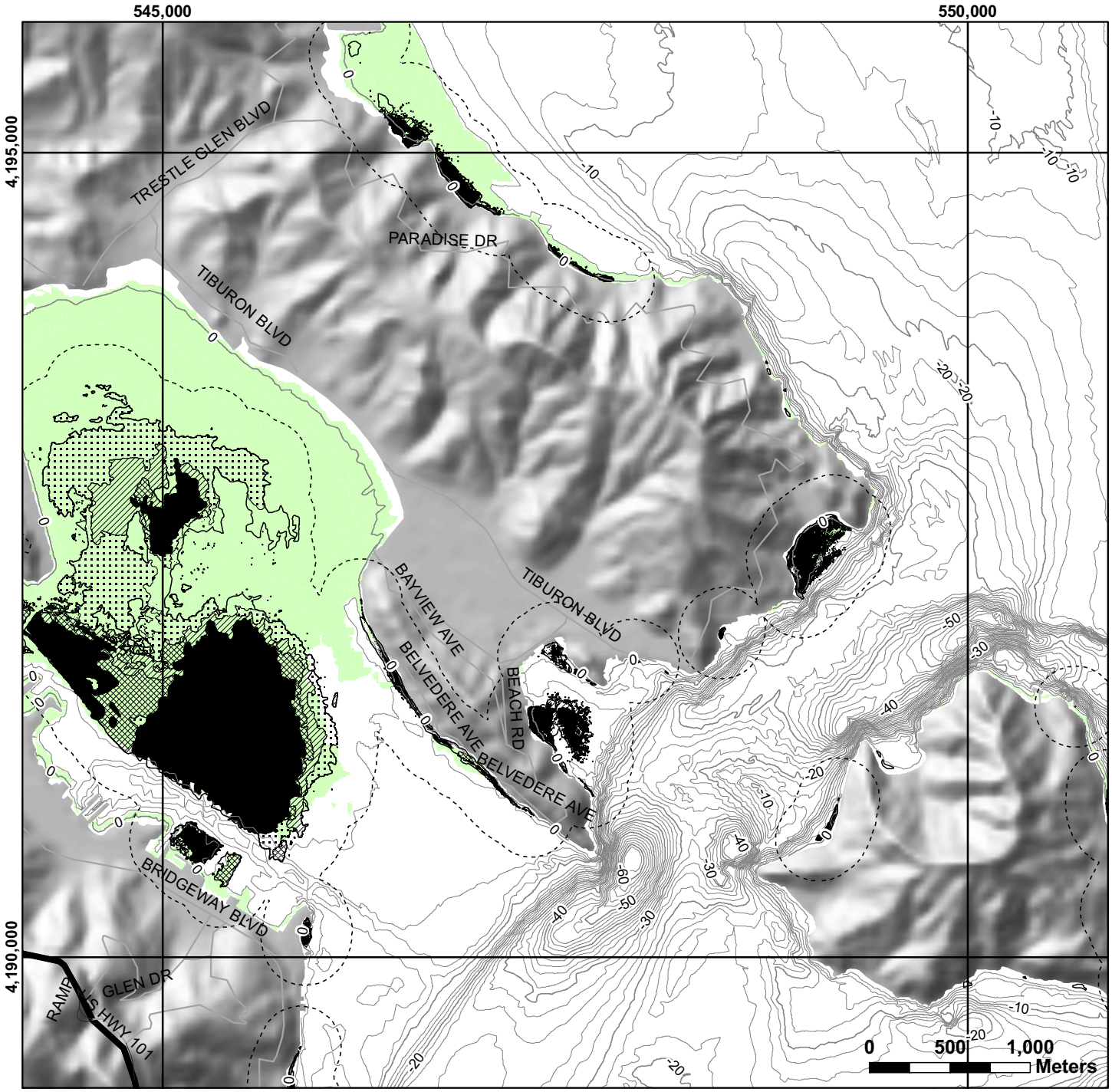


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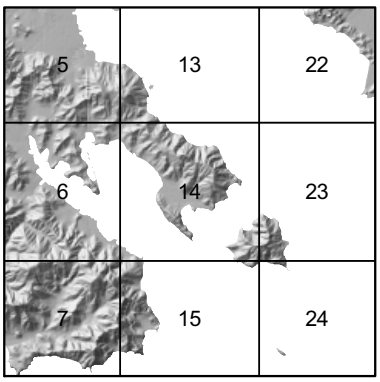
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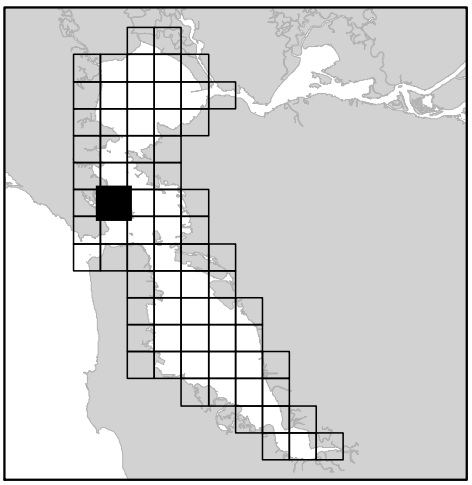
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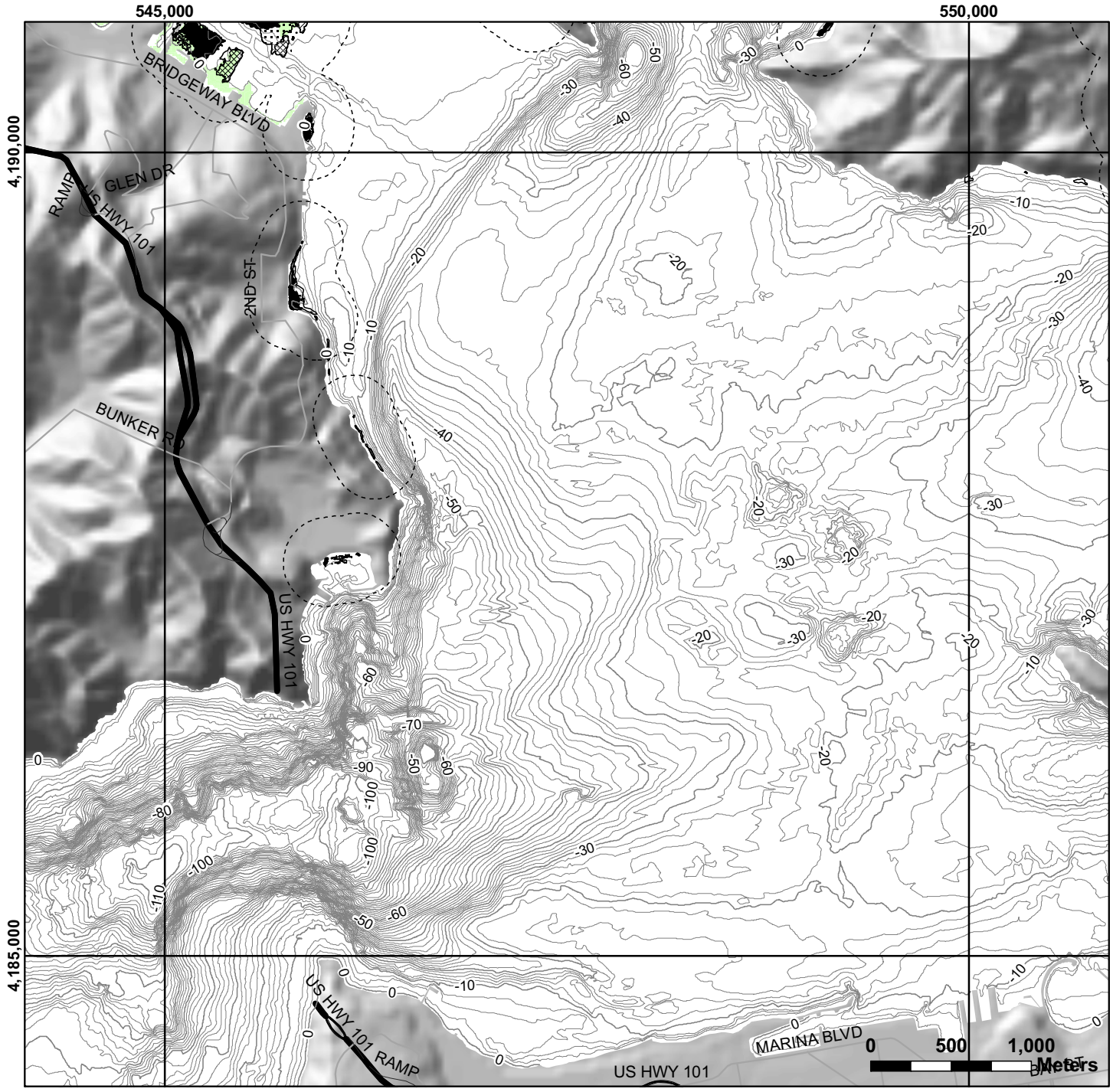
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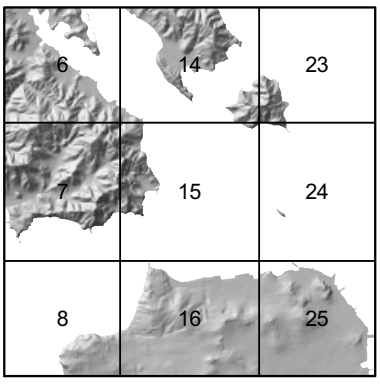
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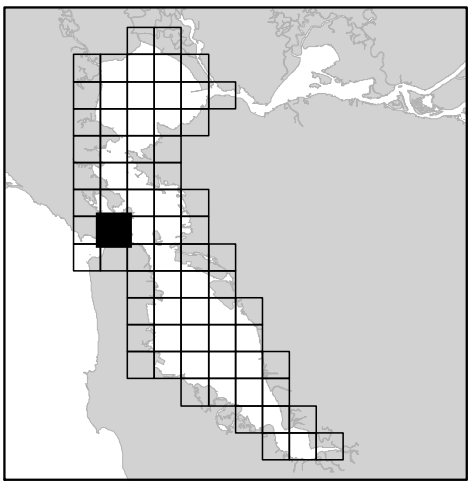
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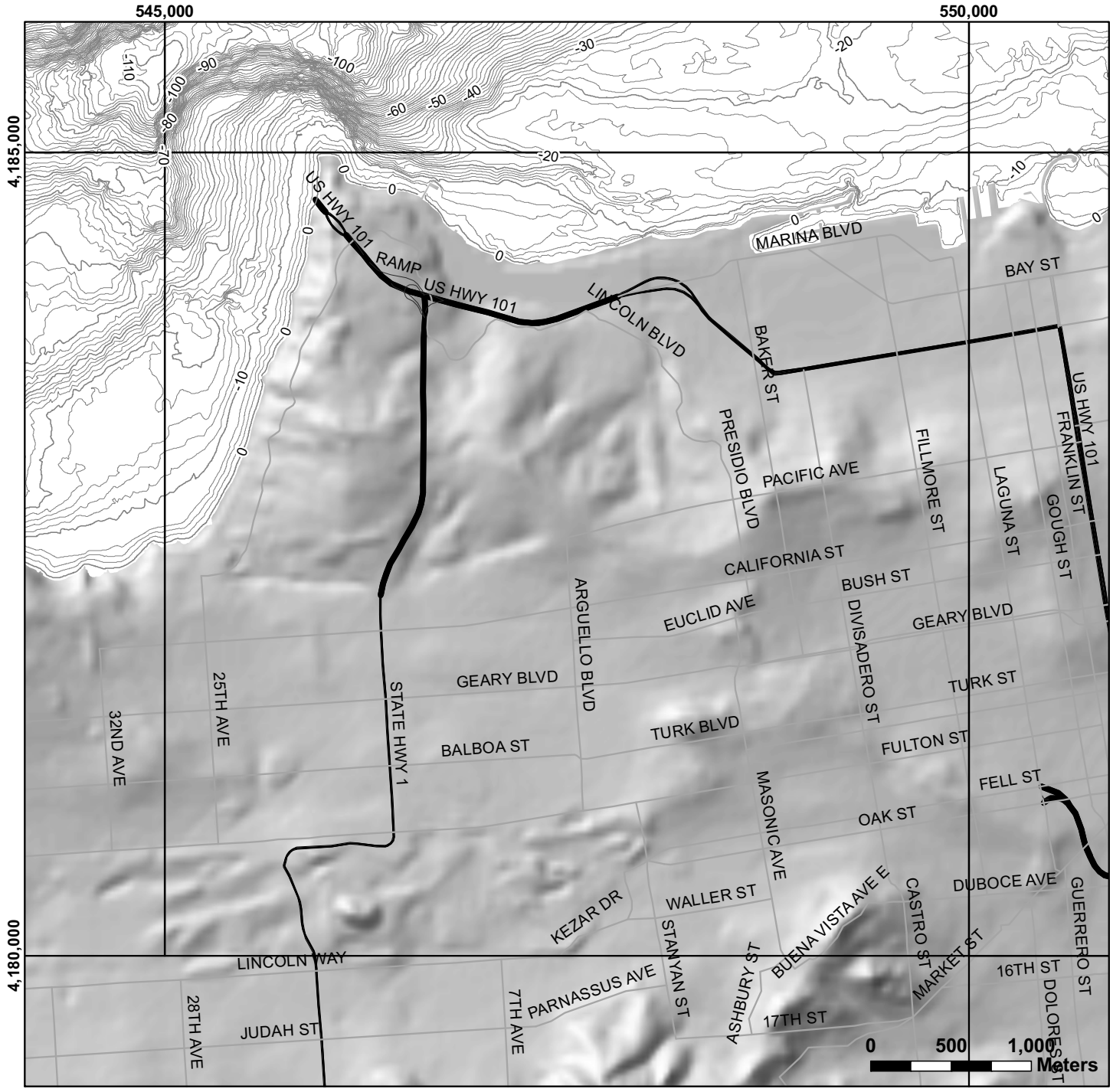
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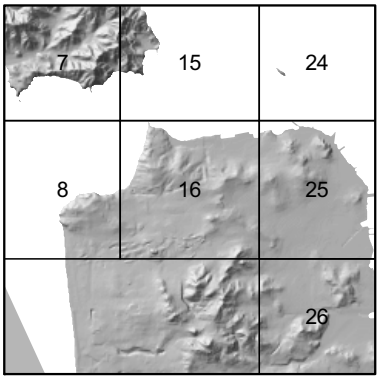
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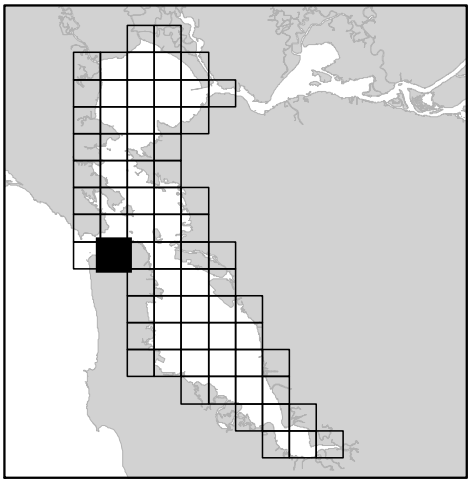
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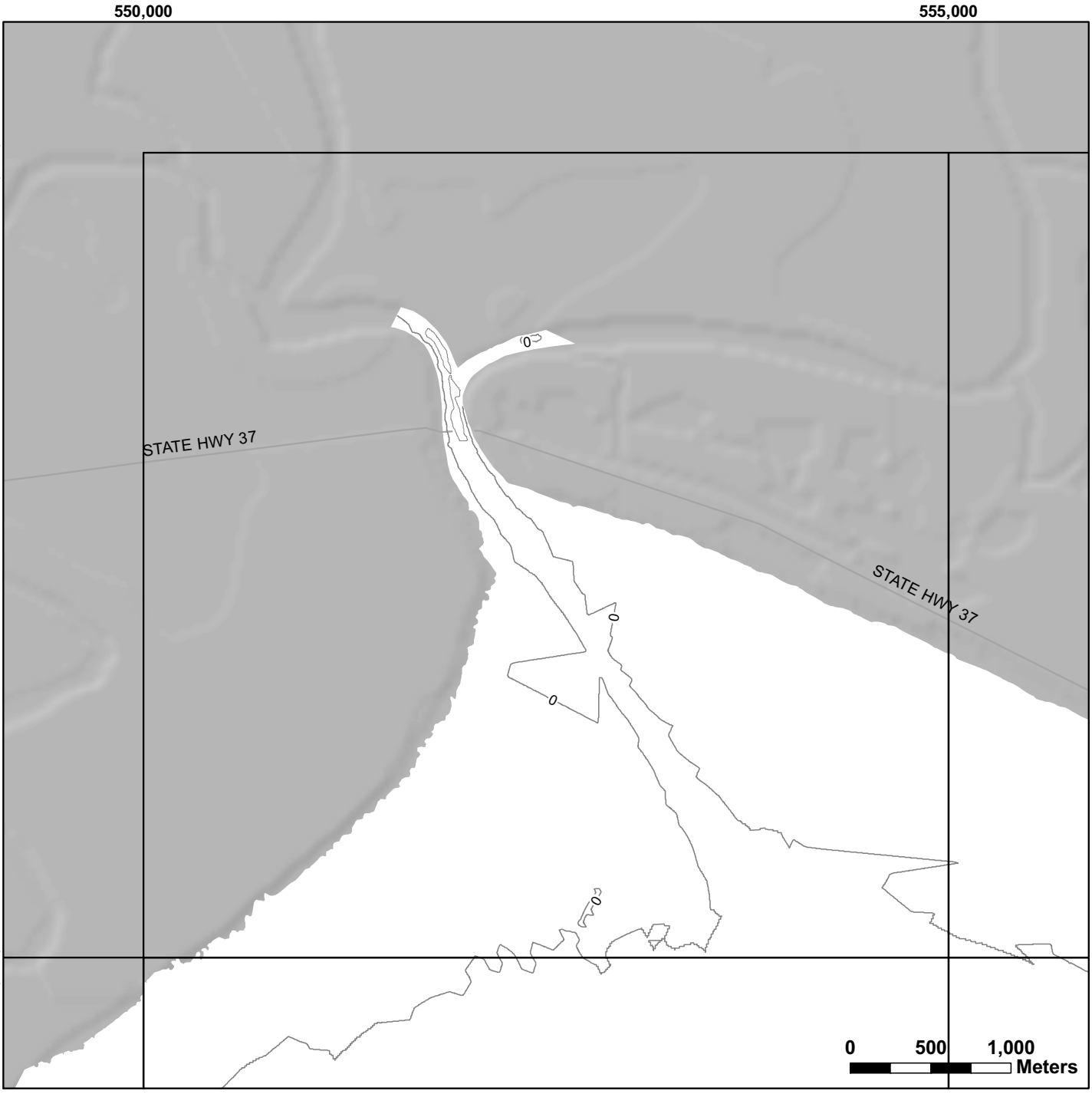
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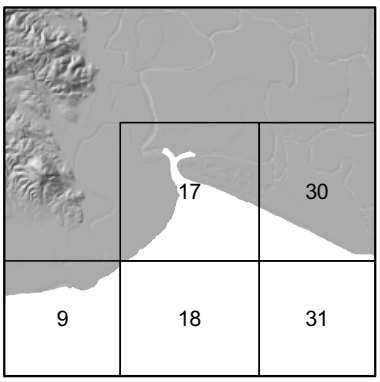
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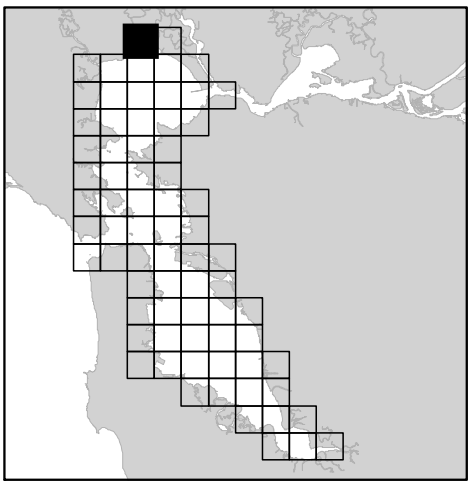
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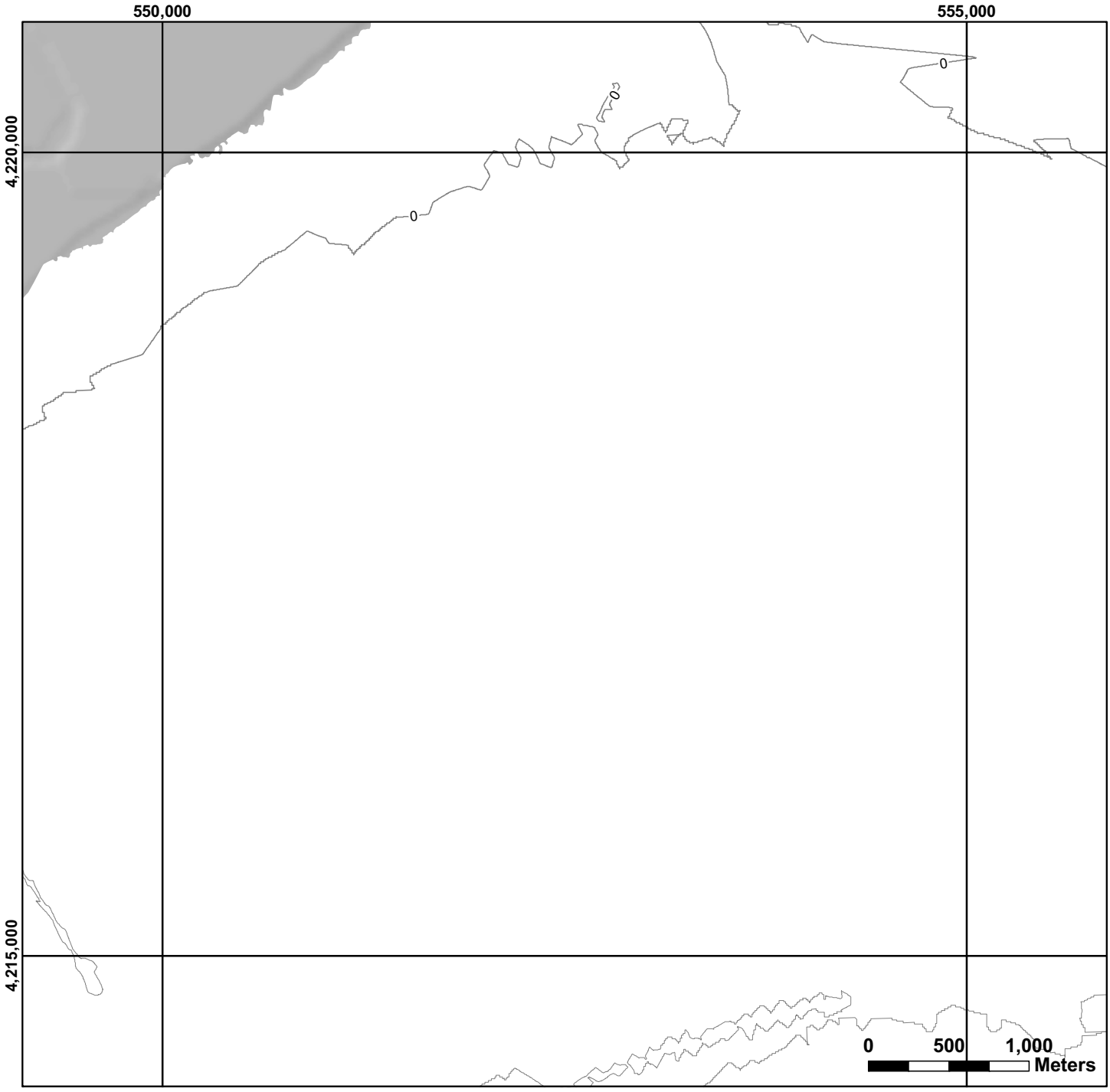




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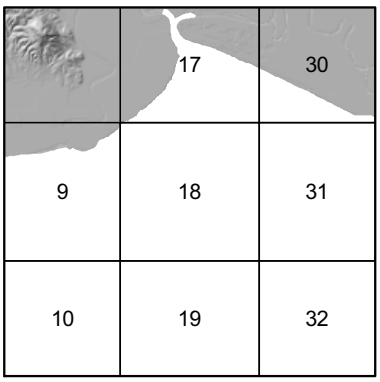
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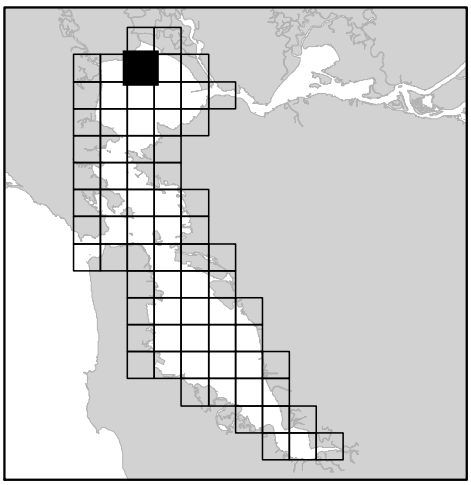
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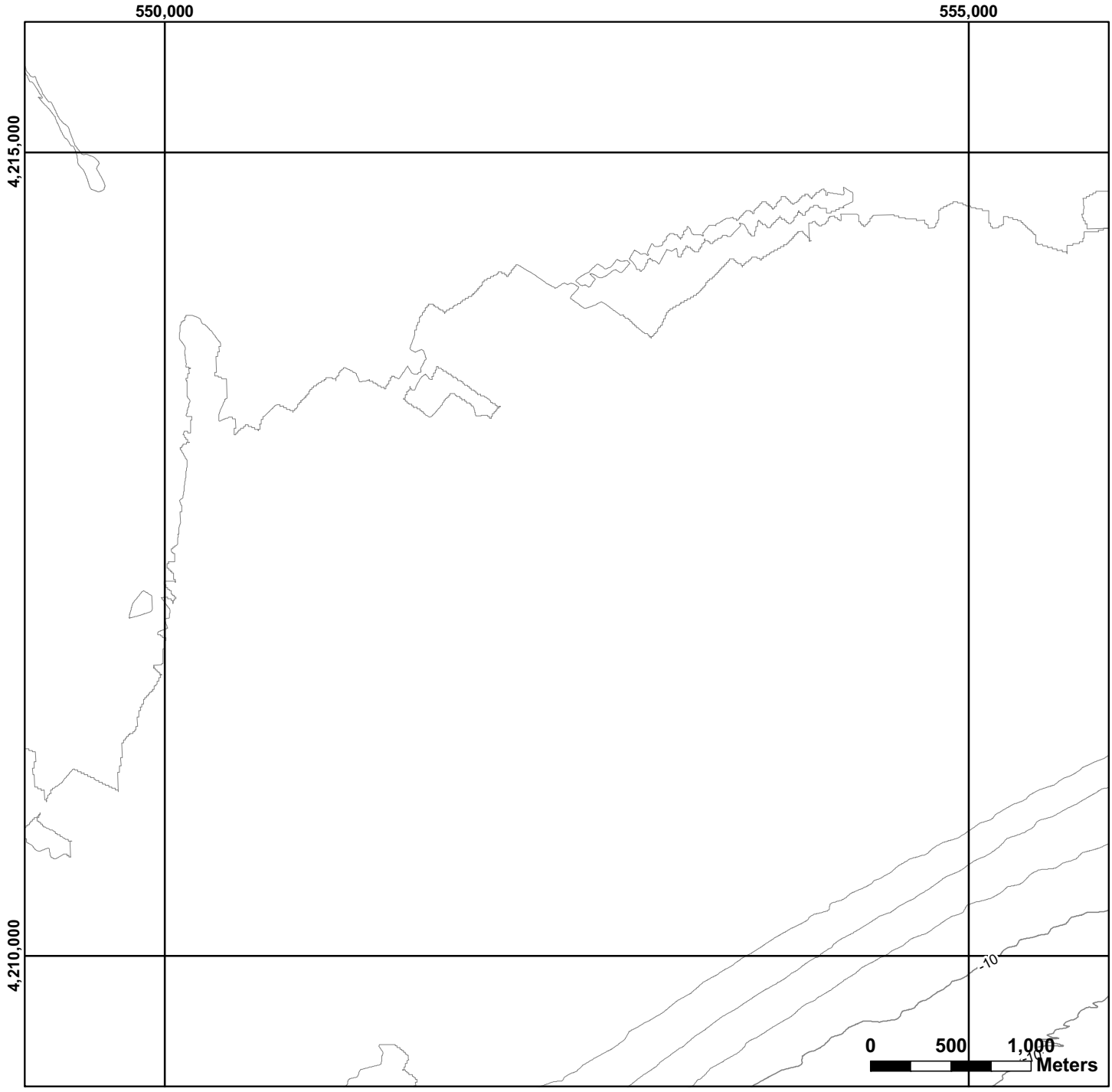
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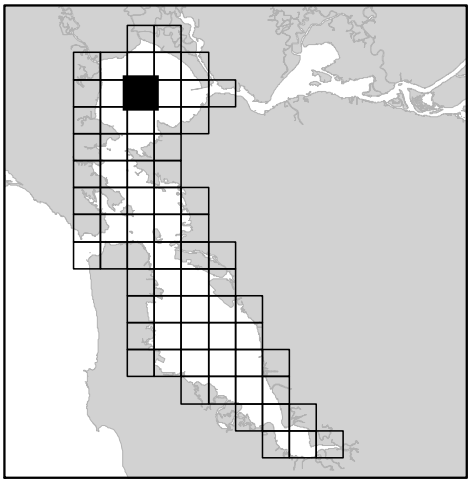
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SHEET VICINITY

9	18	31
10	19	32
11	20	33

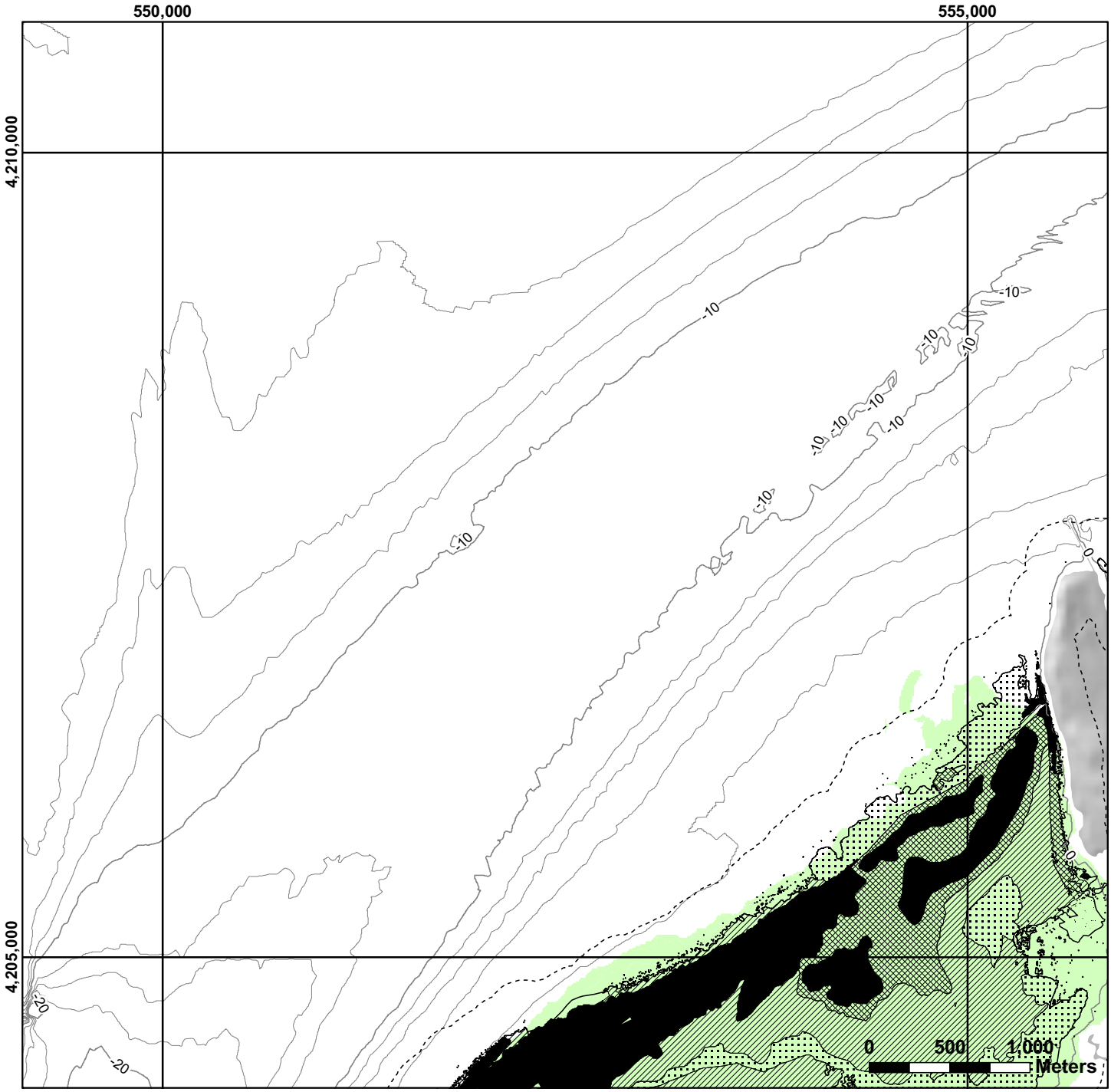
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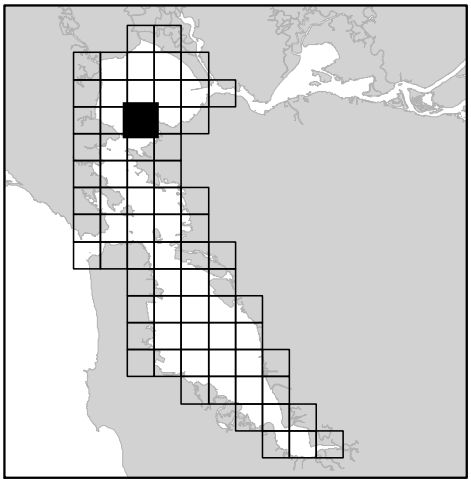
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SHEET VICINITY

10	19	32
11	20	33
12	21	34

SHEET LOCATOR

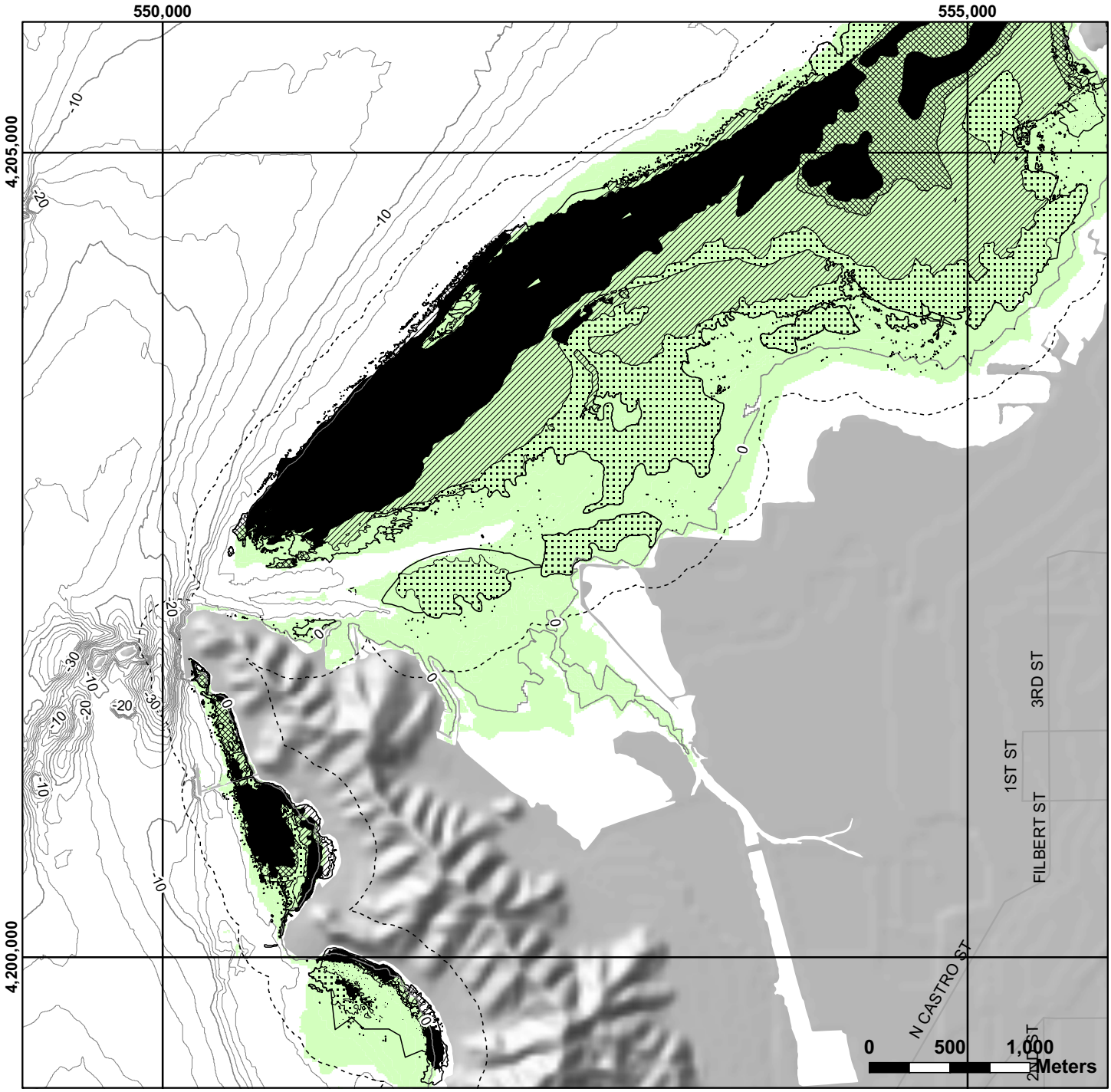


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Eelgrass Coverage

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- 6-20%
- 21-40%
- 41-100%

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- 2009 Eelgrass 250m buffer
- ELVS Predictive Model 2009



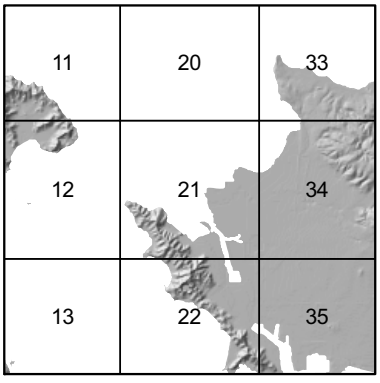
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

Merkel & Associates, Inc.
San Diego, CA - Tel: (858) 560-5465

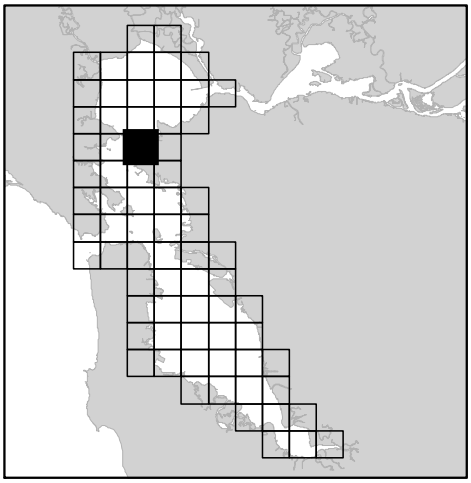
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Vertical Datum: MLLW (meters)

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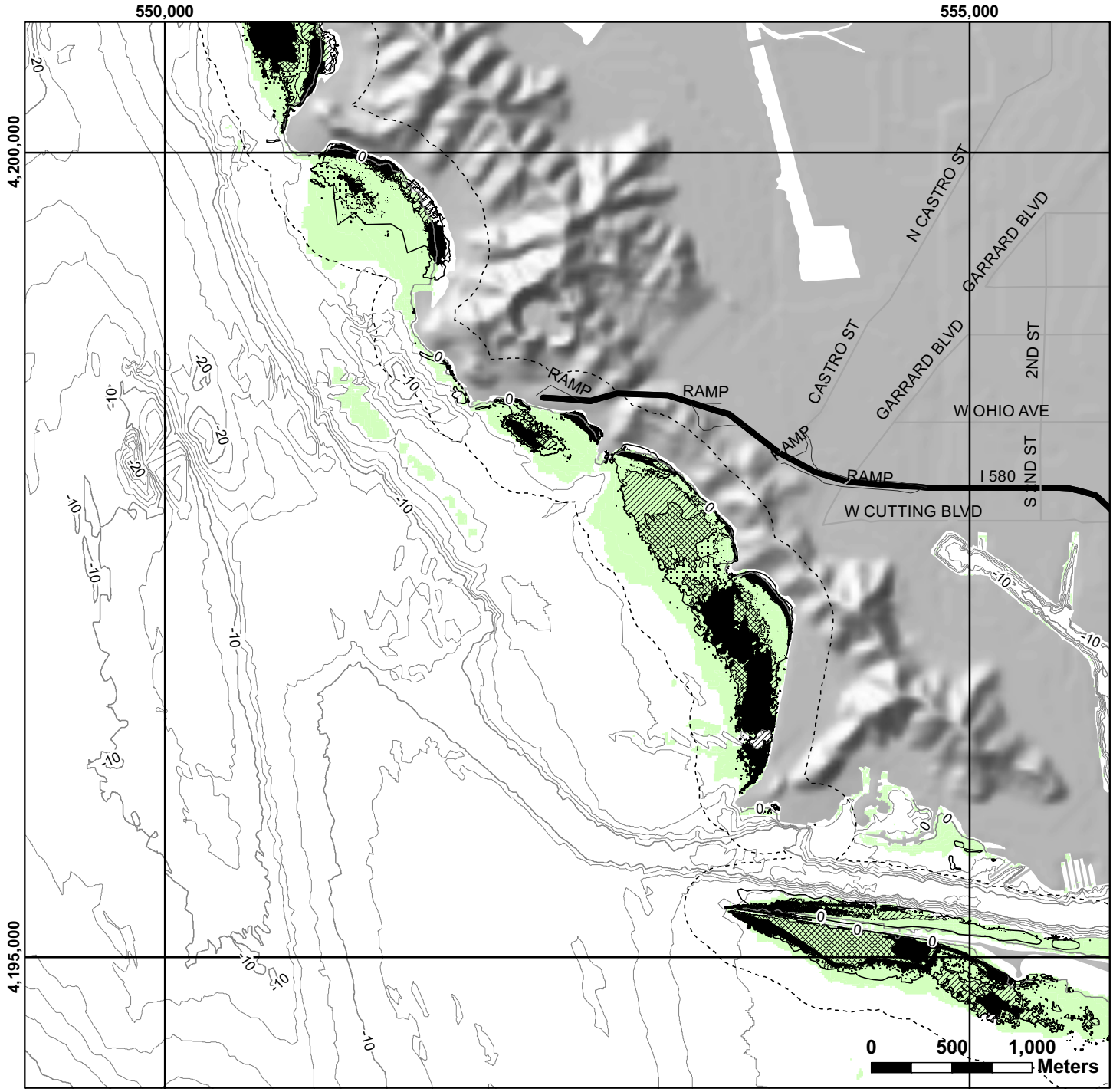
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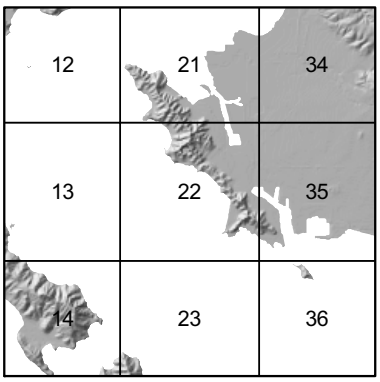
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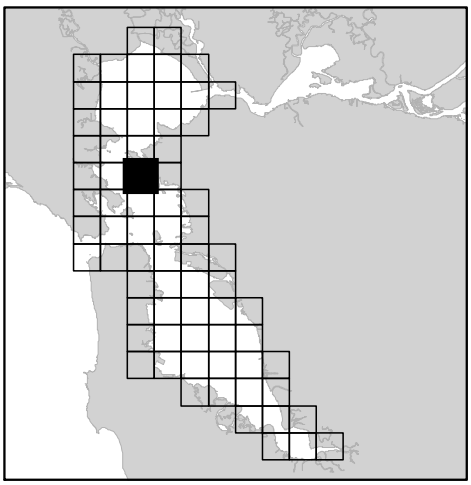
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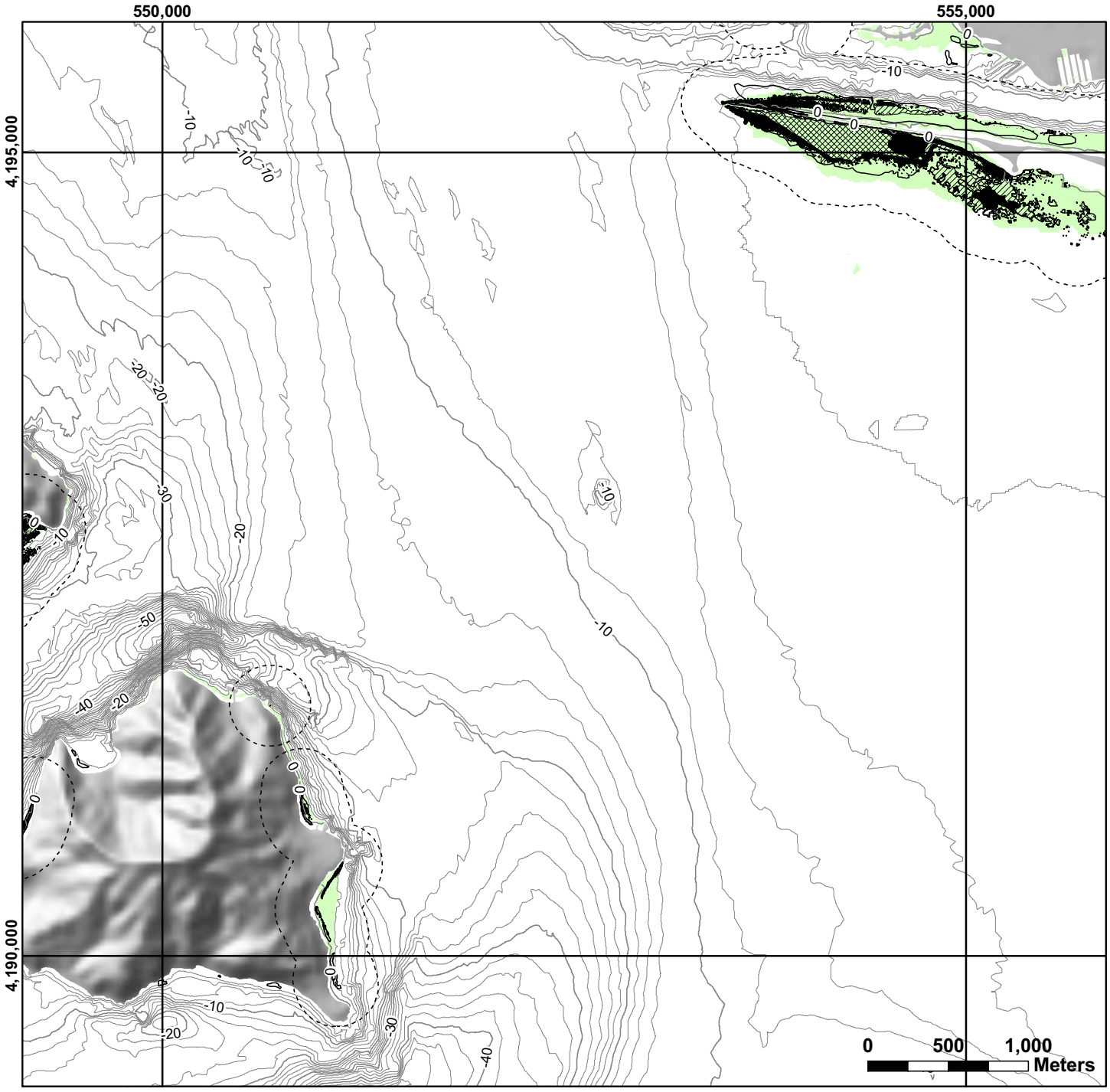
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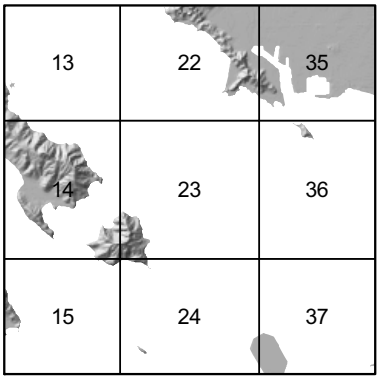
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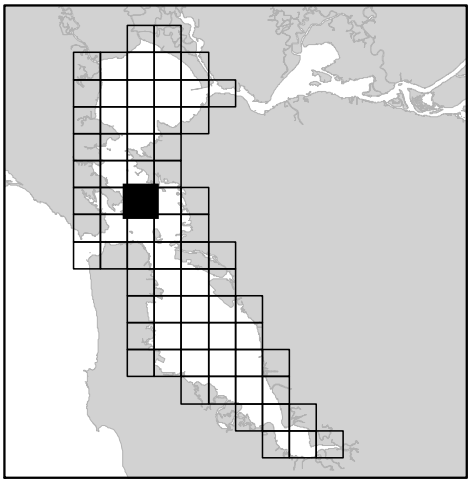
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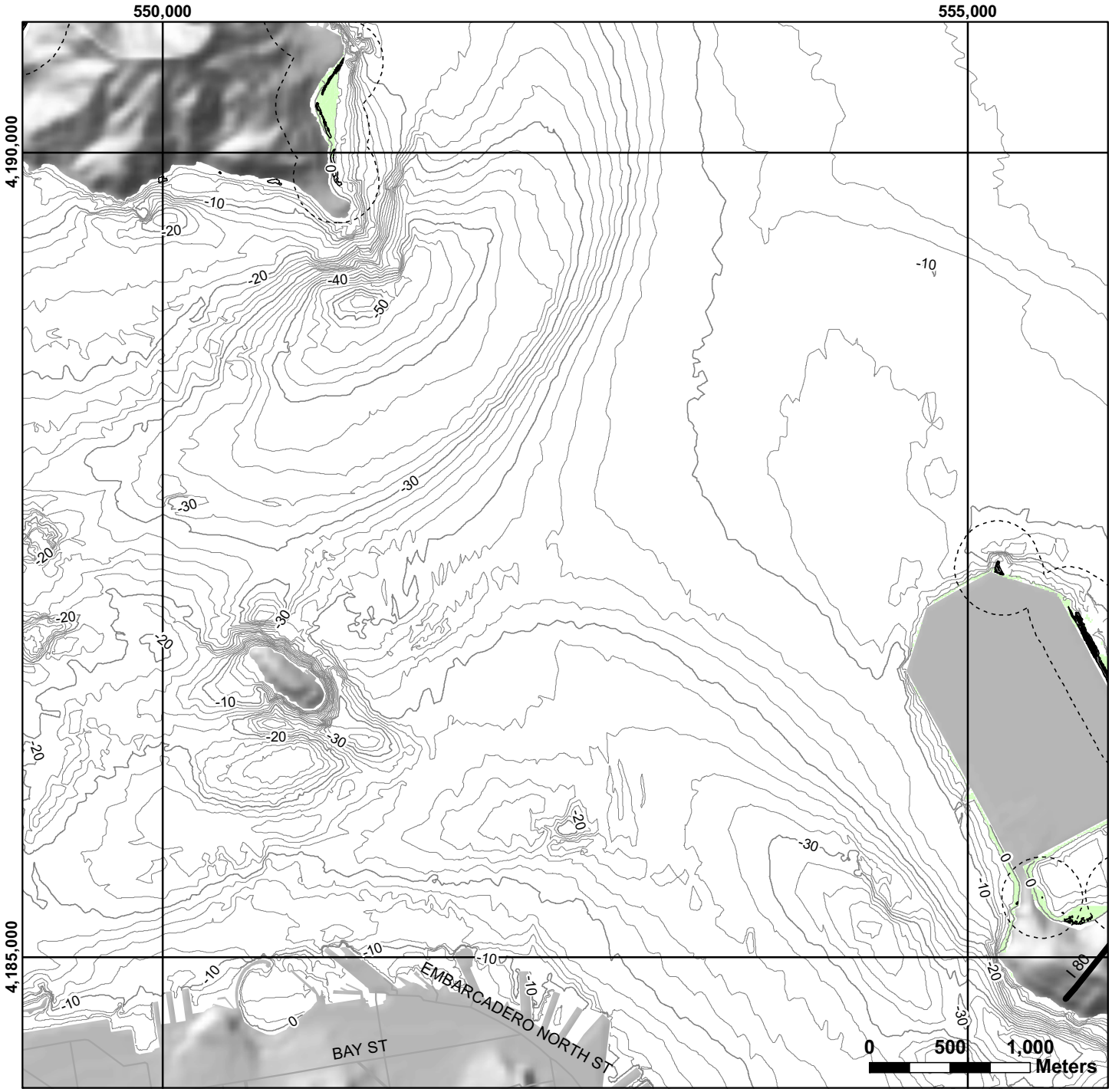
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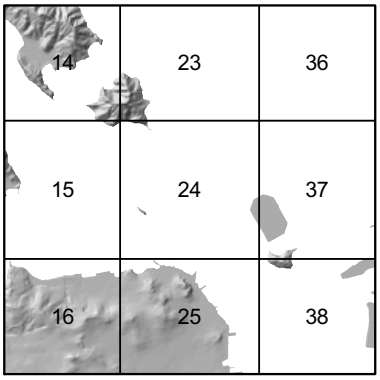
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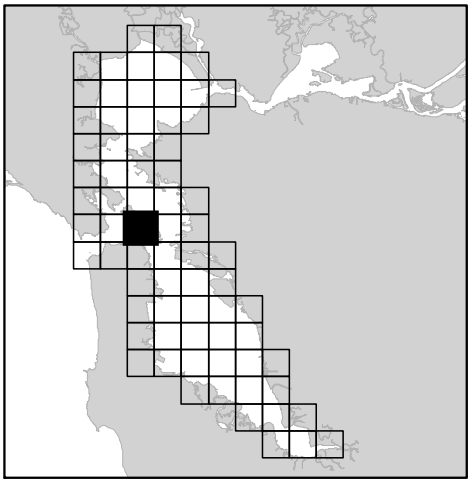
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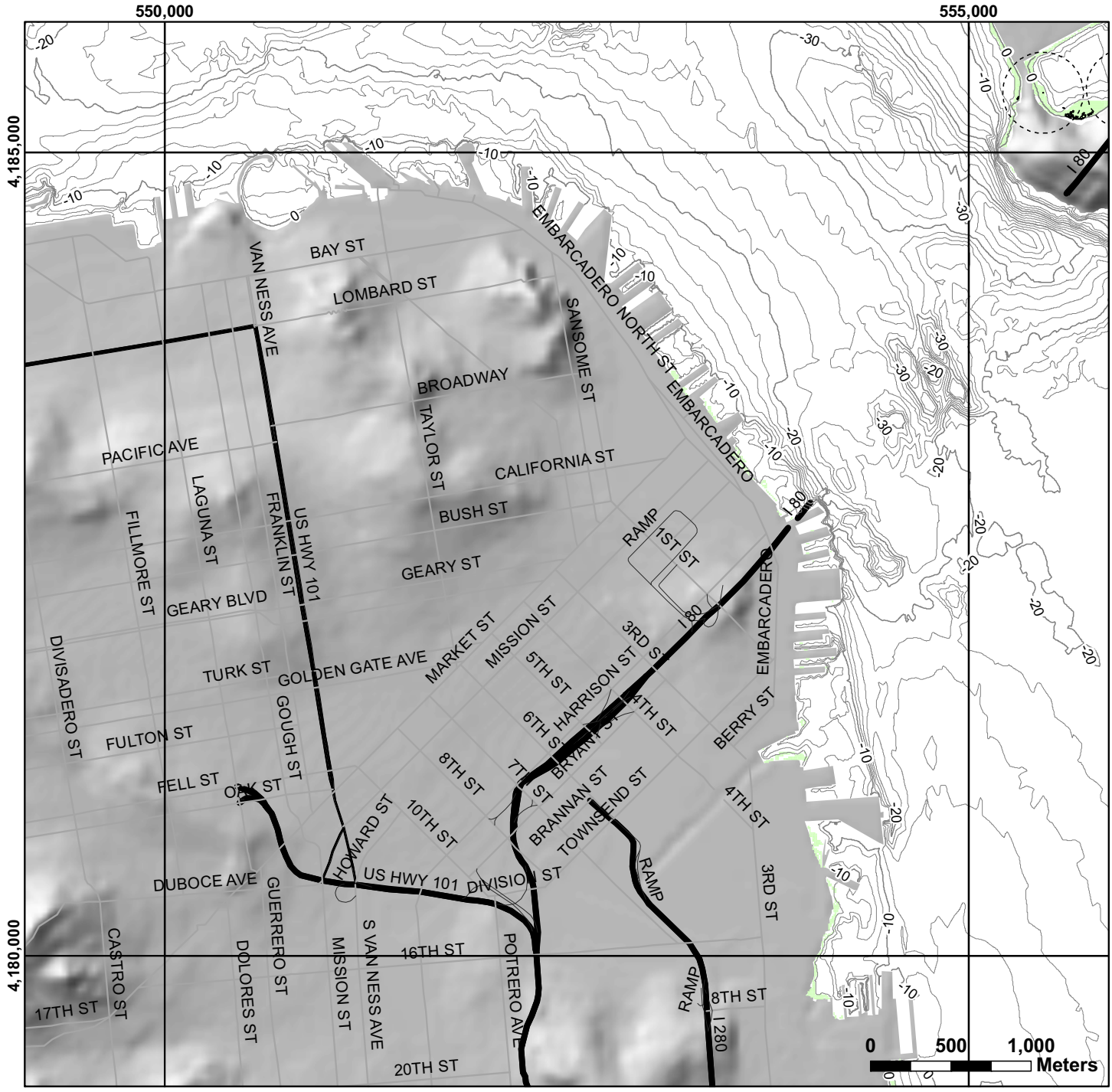


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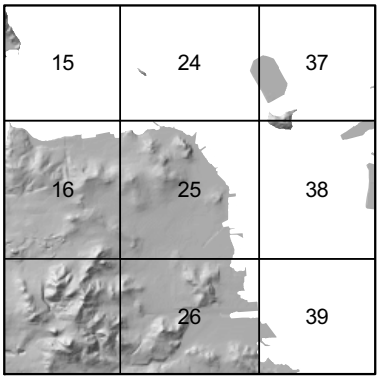
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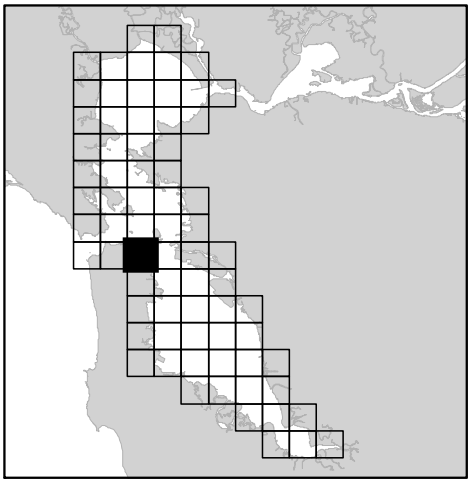
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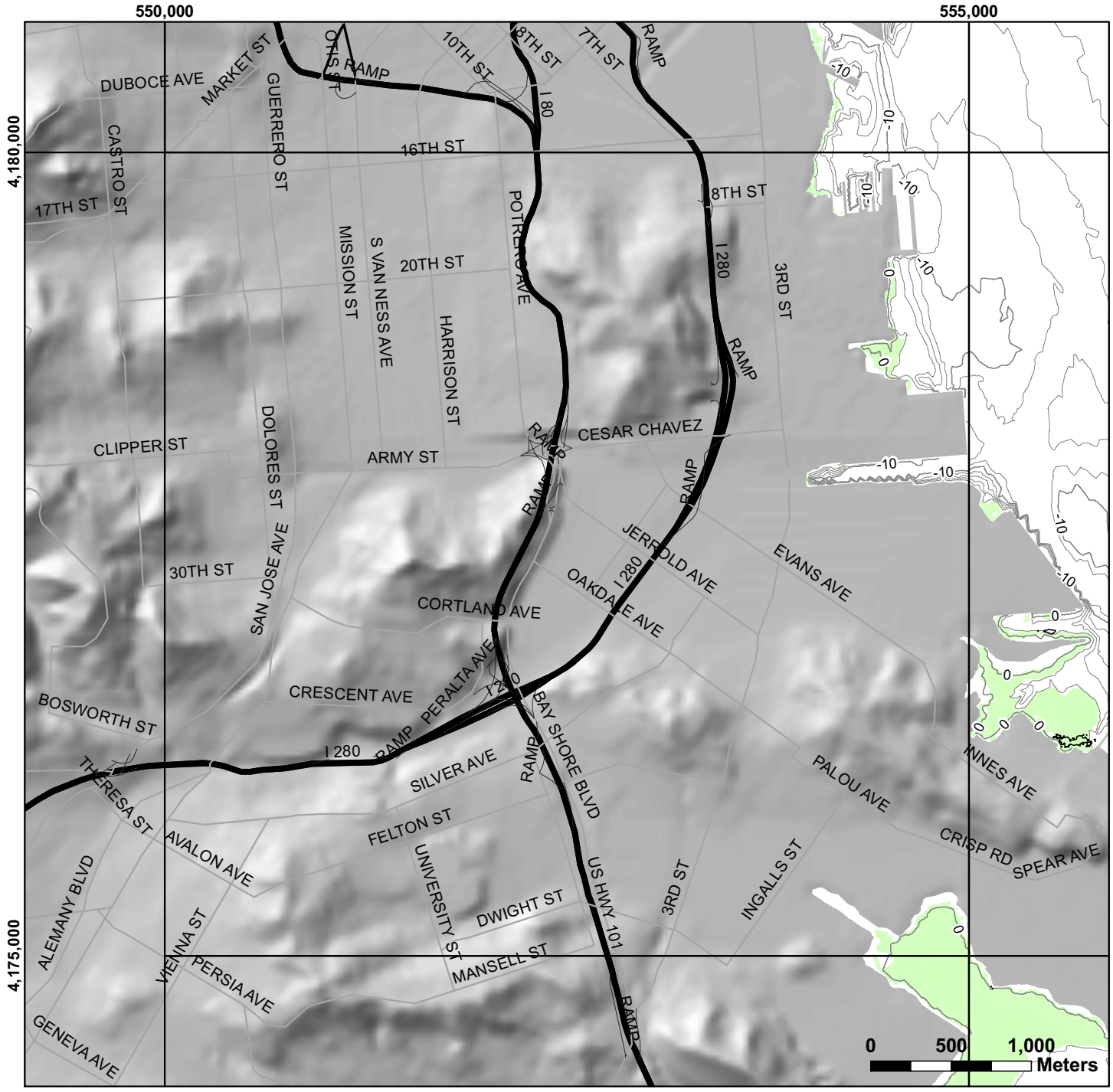
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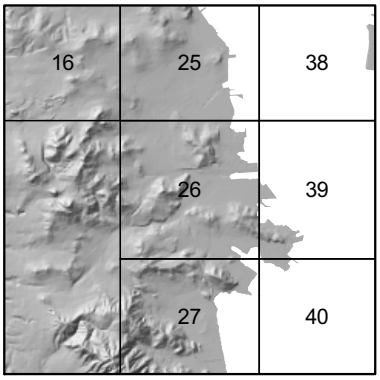
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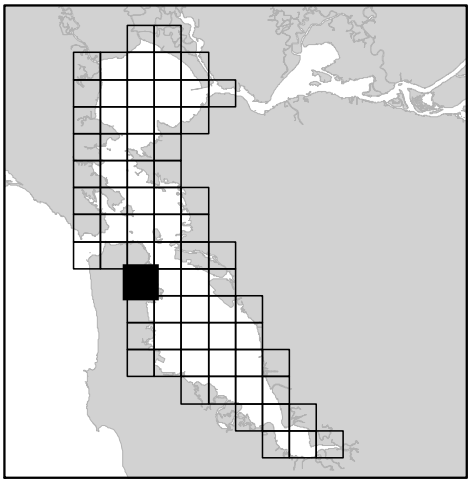
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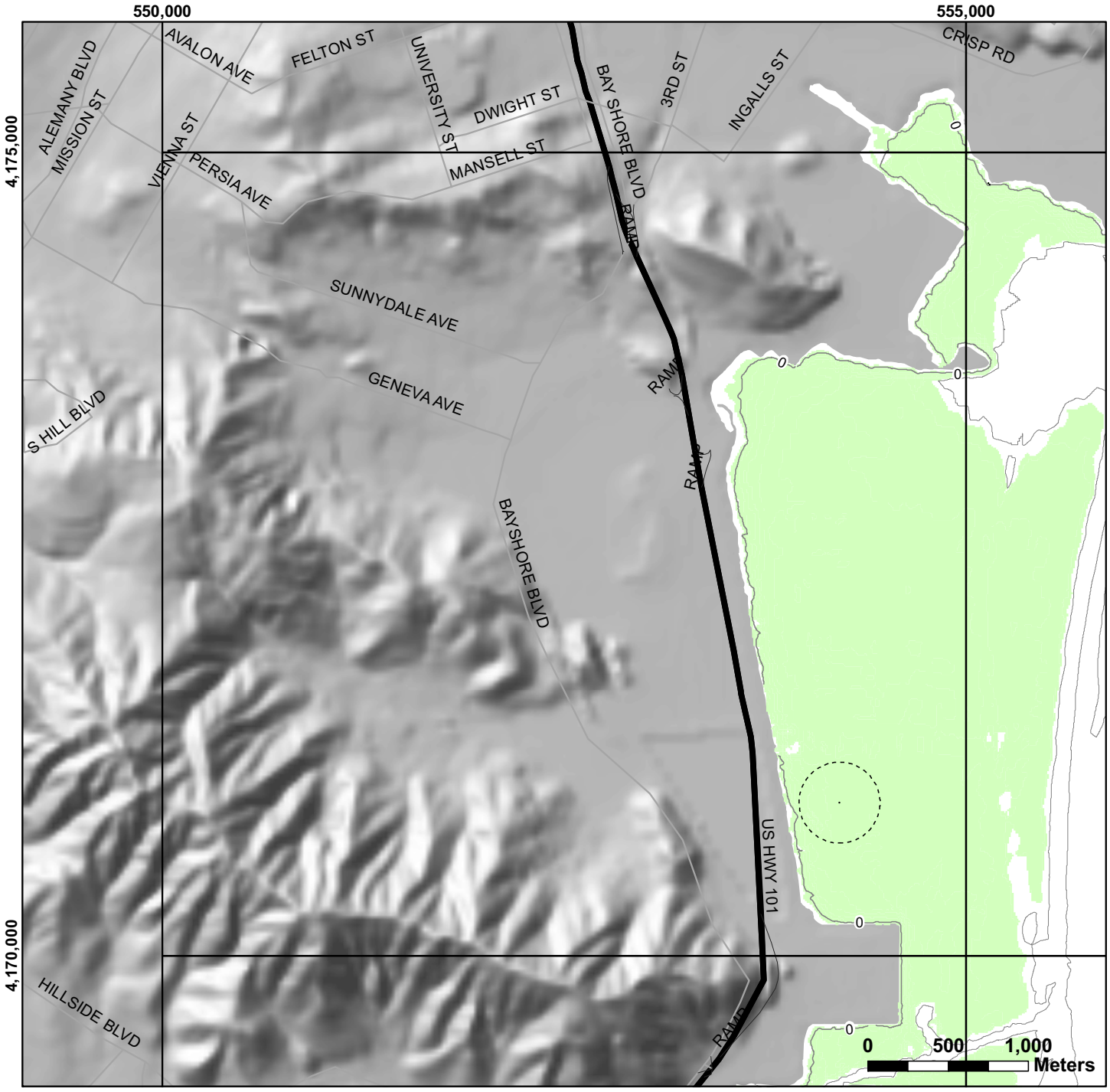
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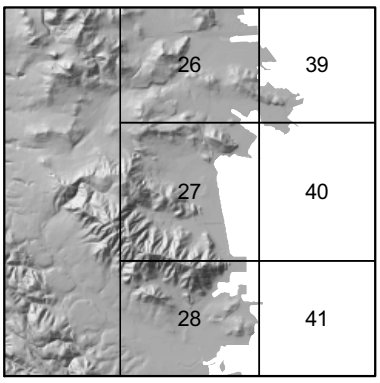
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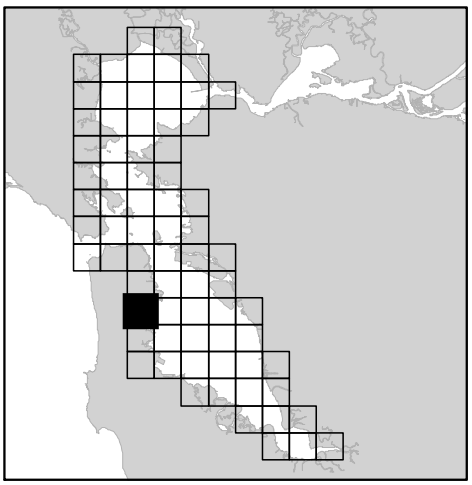
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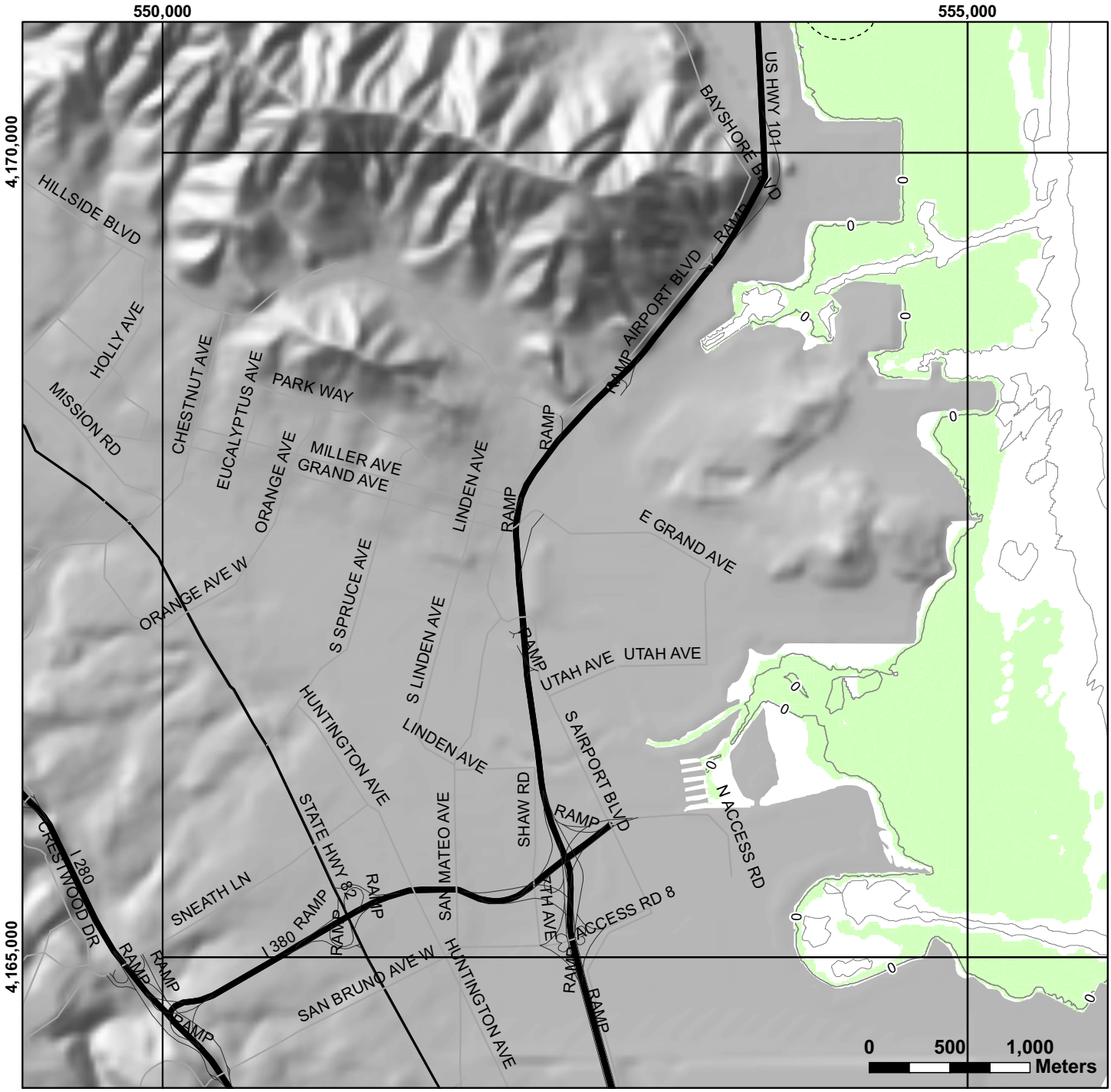
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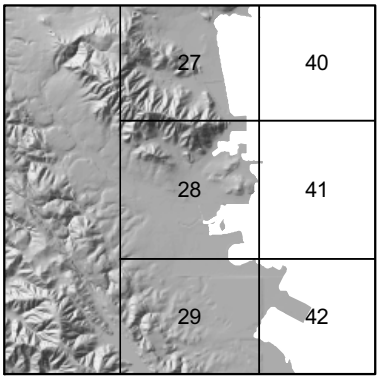
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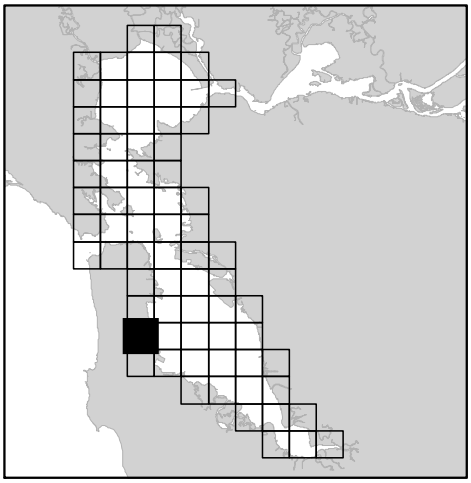
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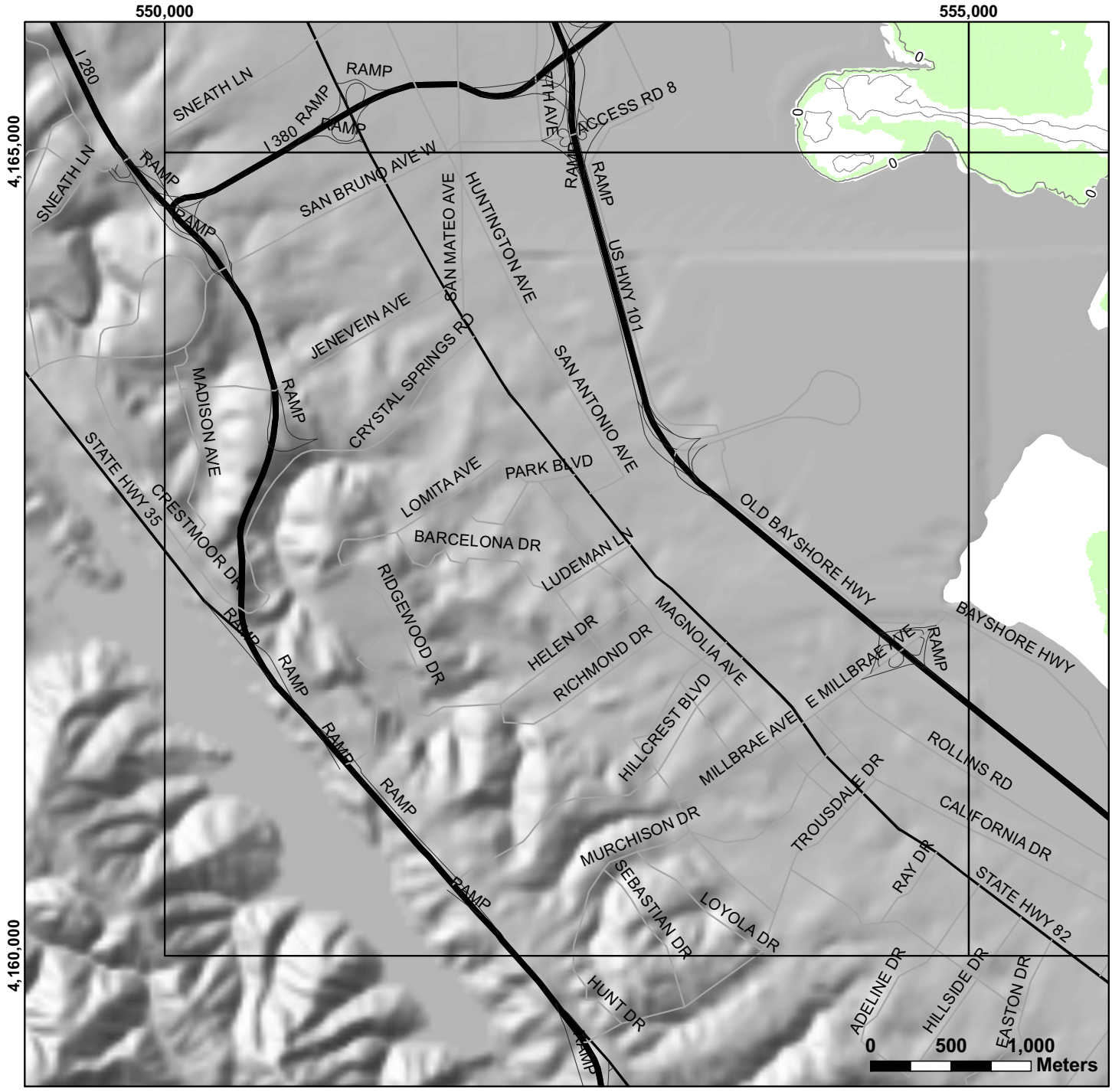
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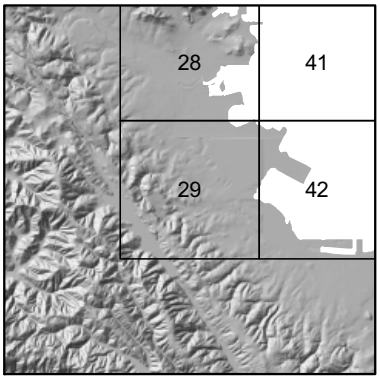
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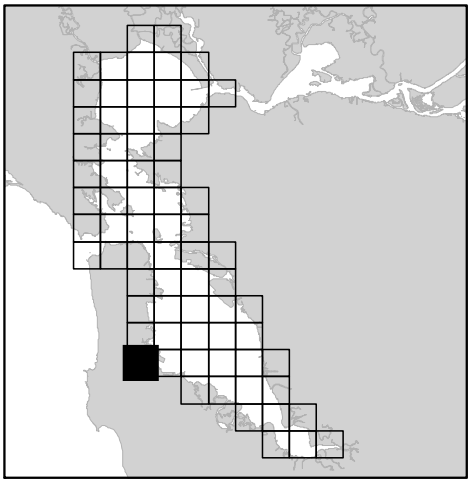
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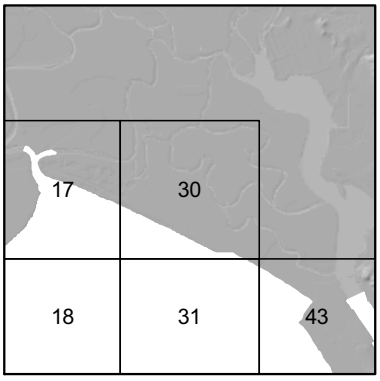
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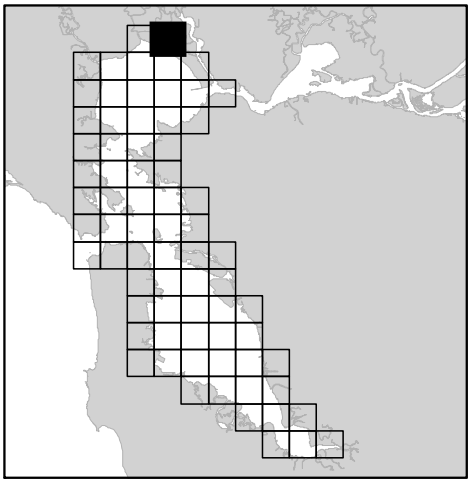
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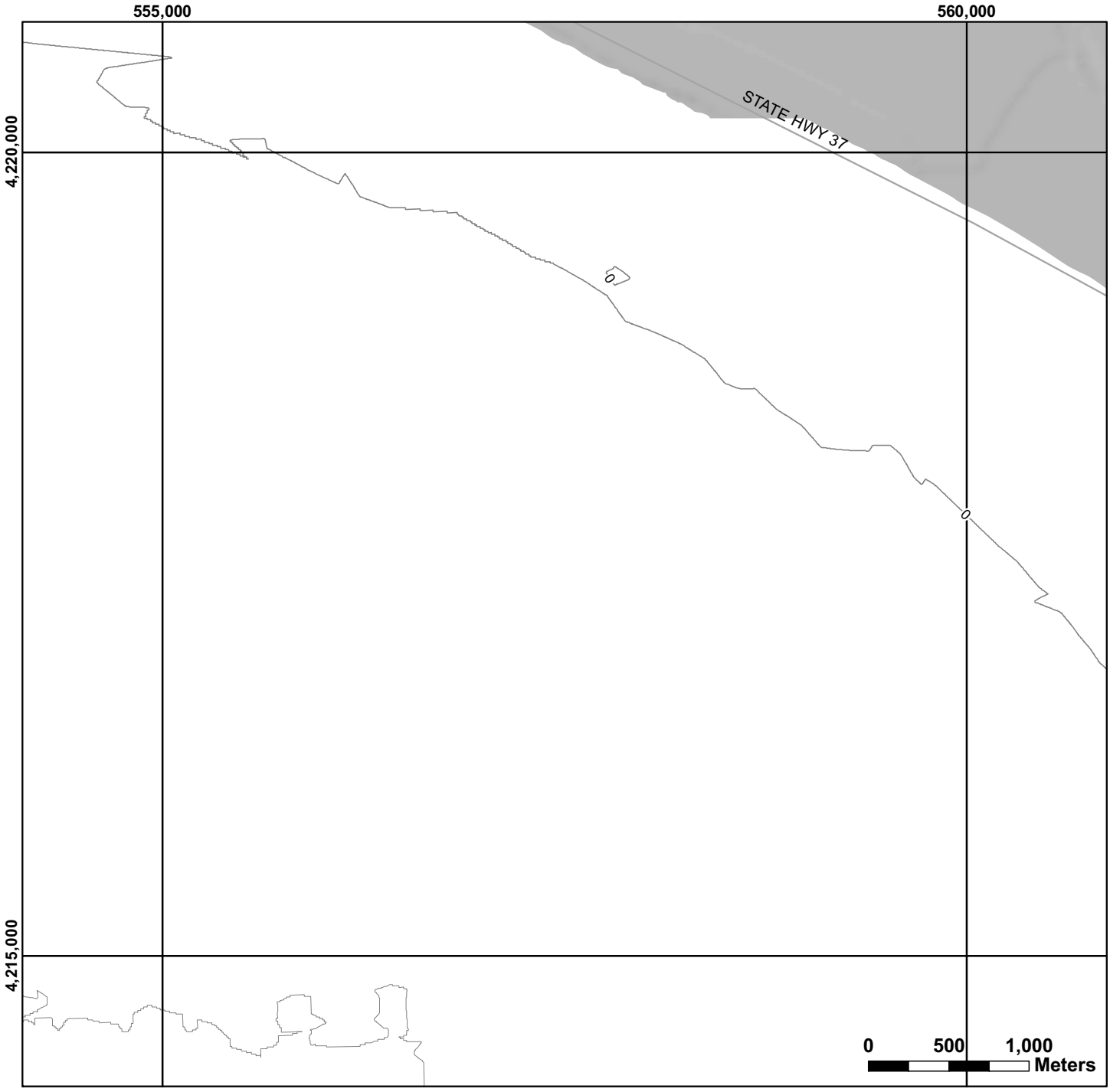




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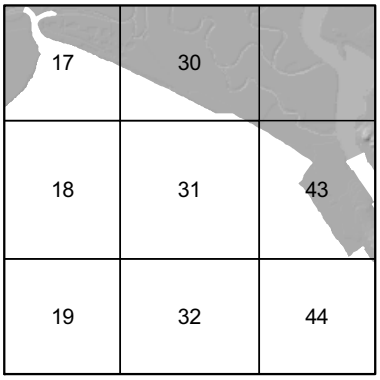
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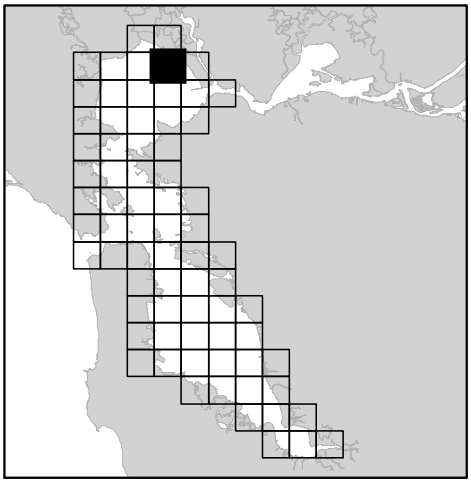
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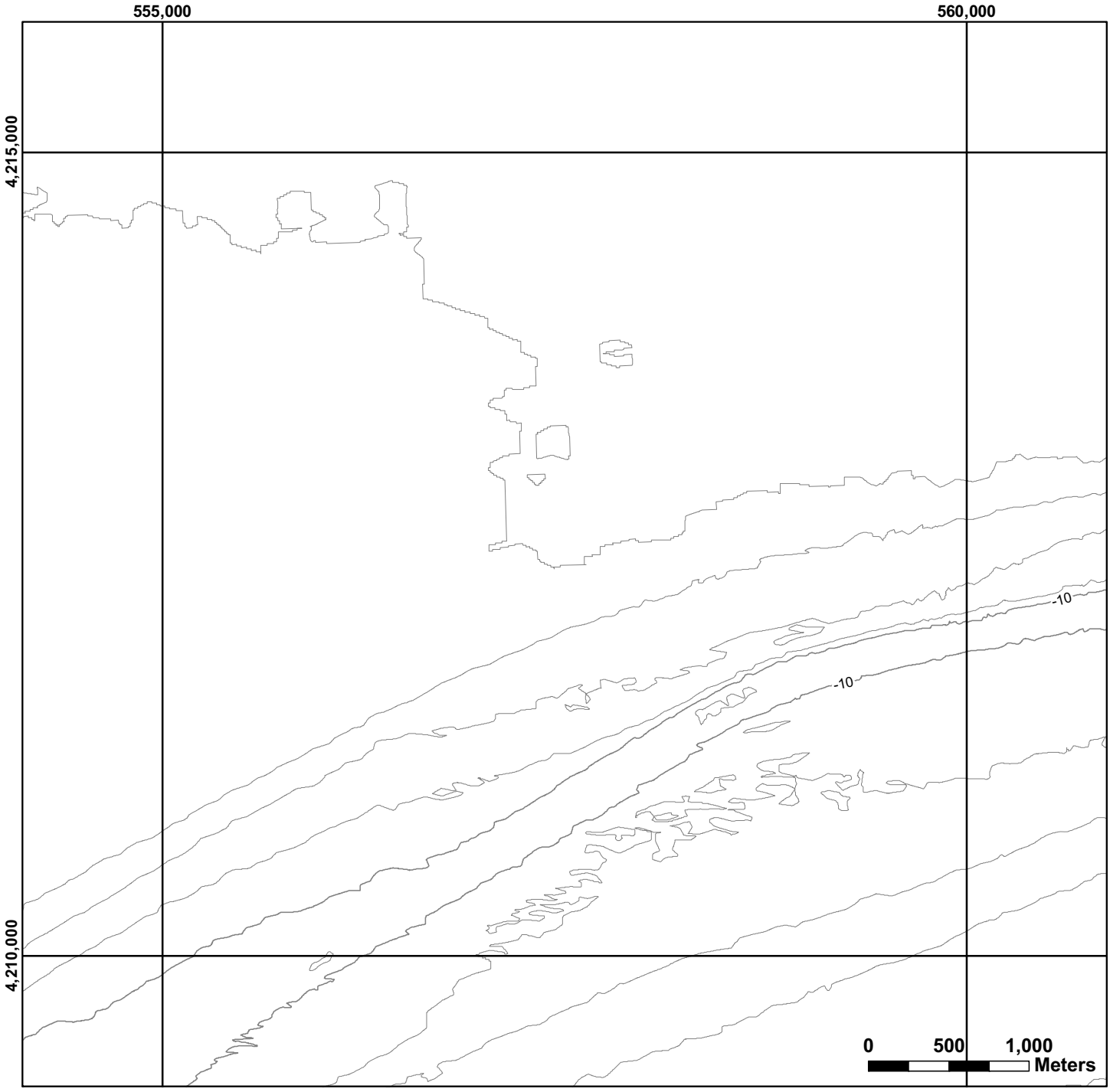




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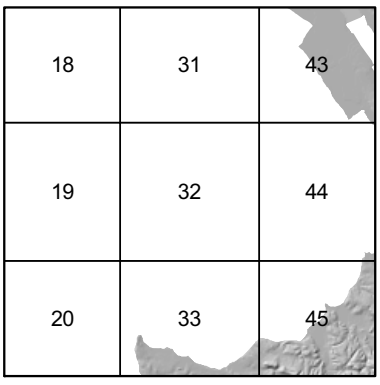
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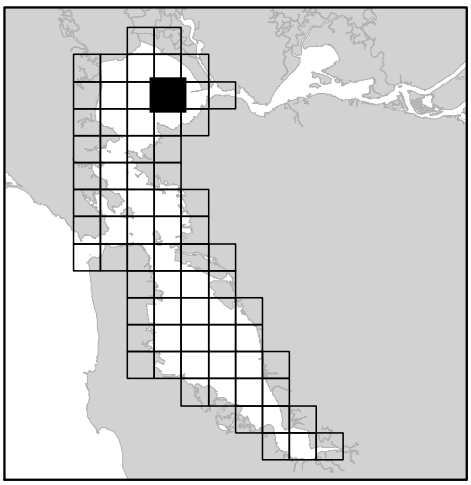
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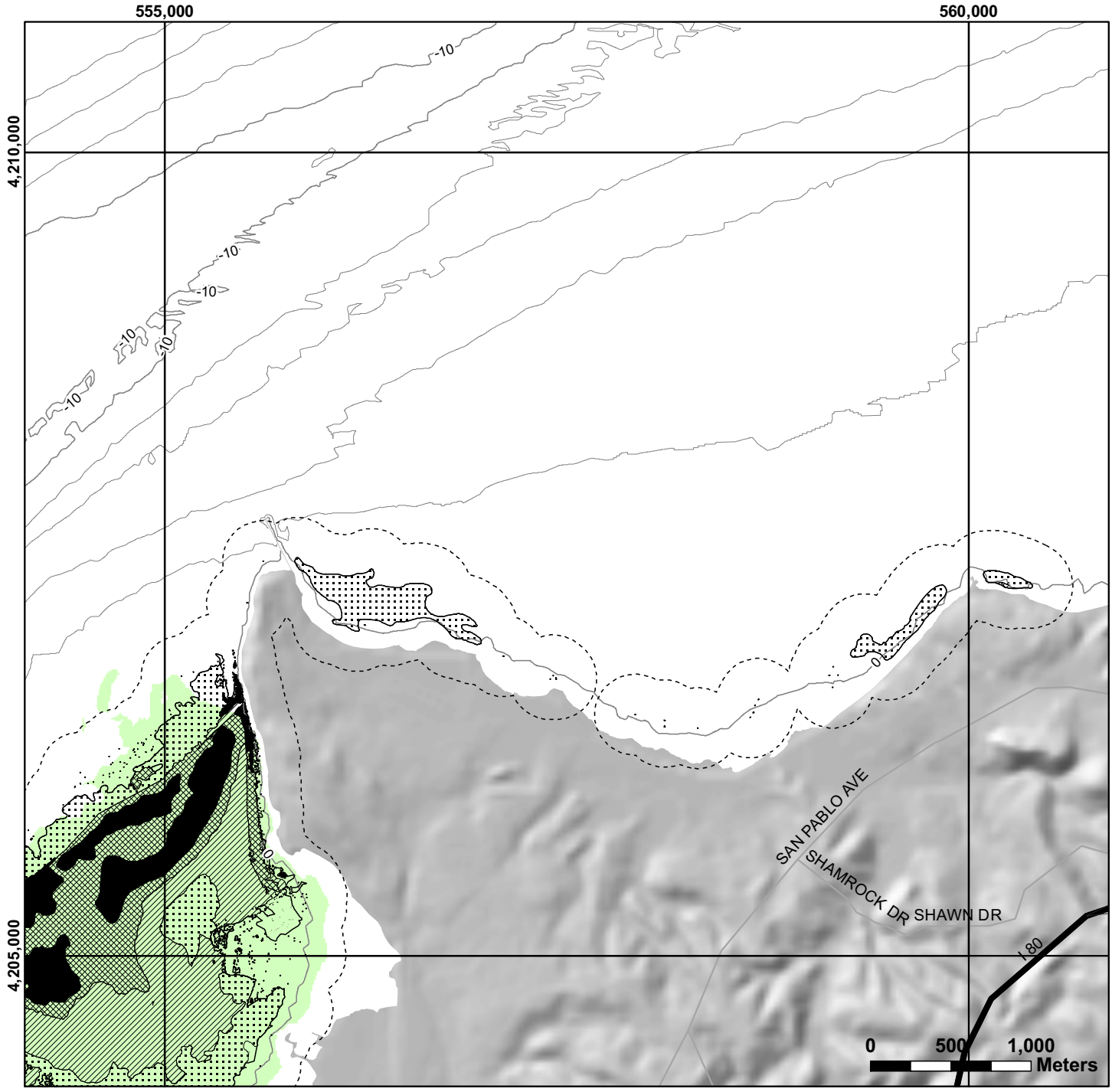
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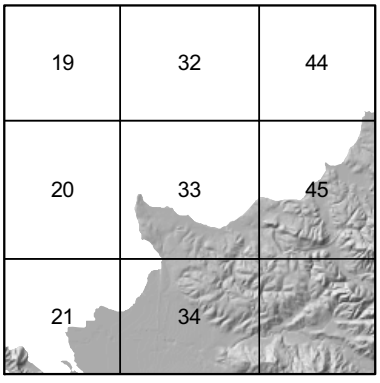
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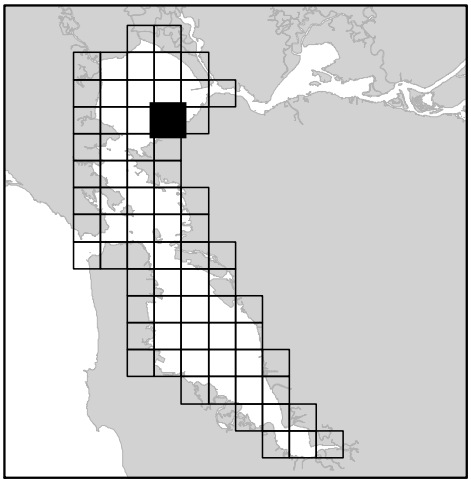
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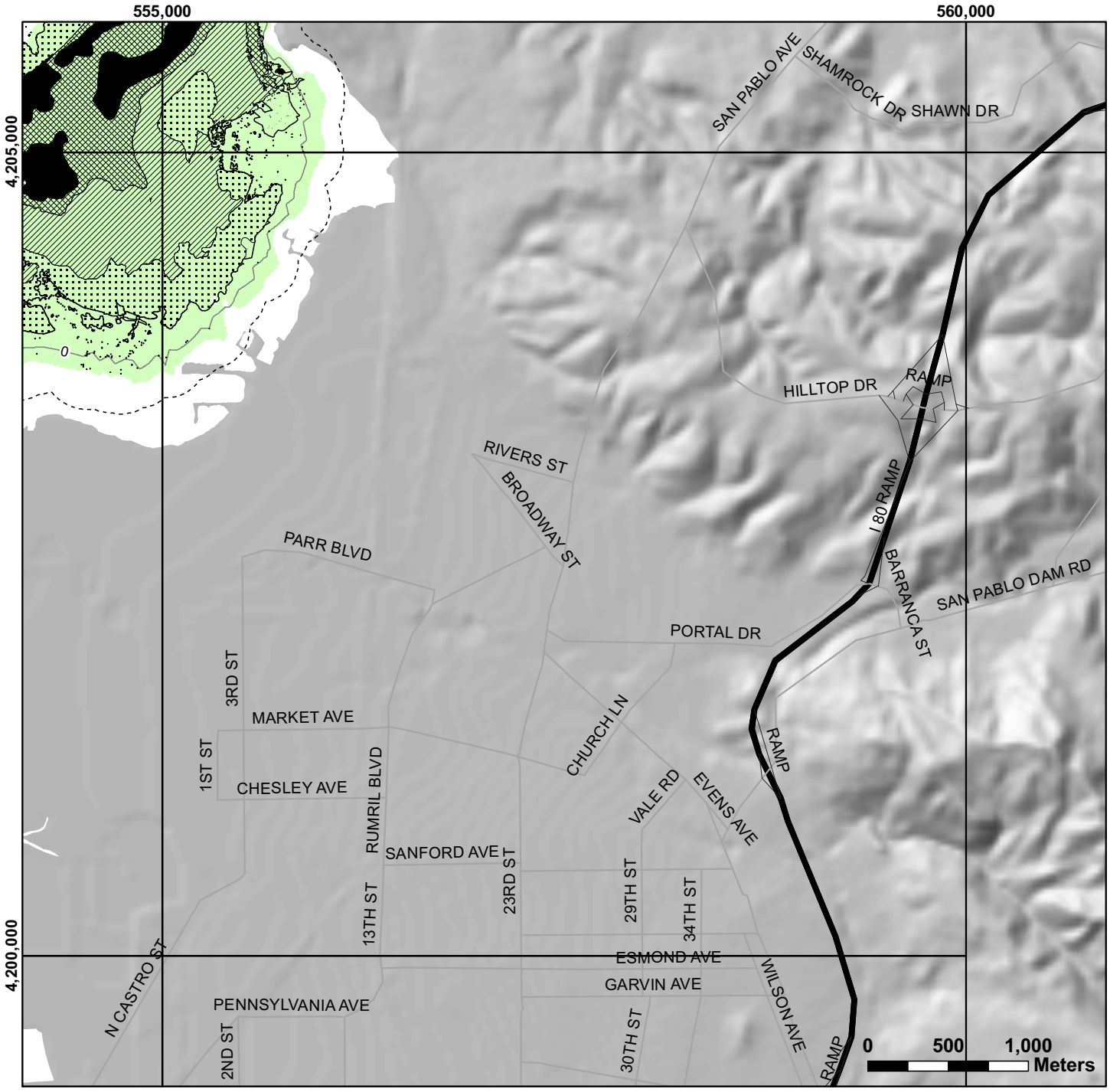




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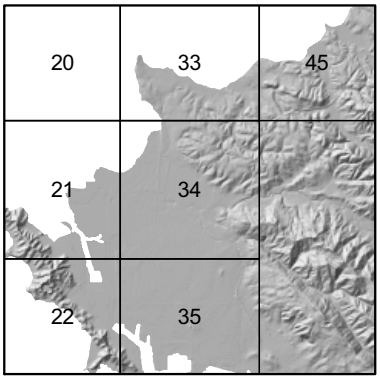
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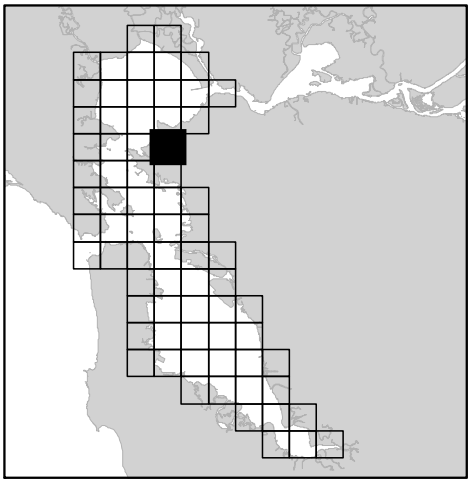
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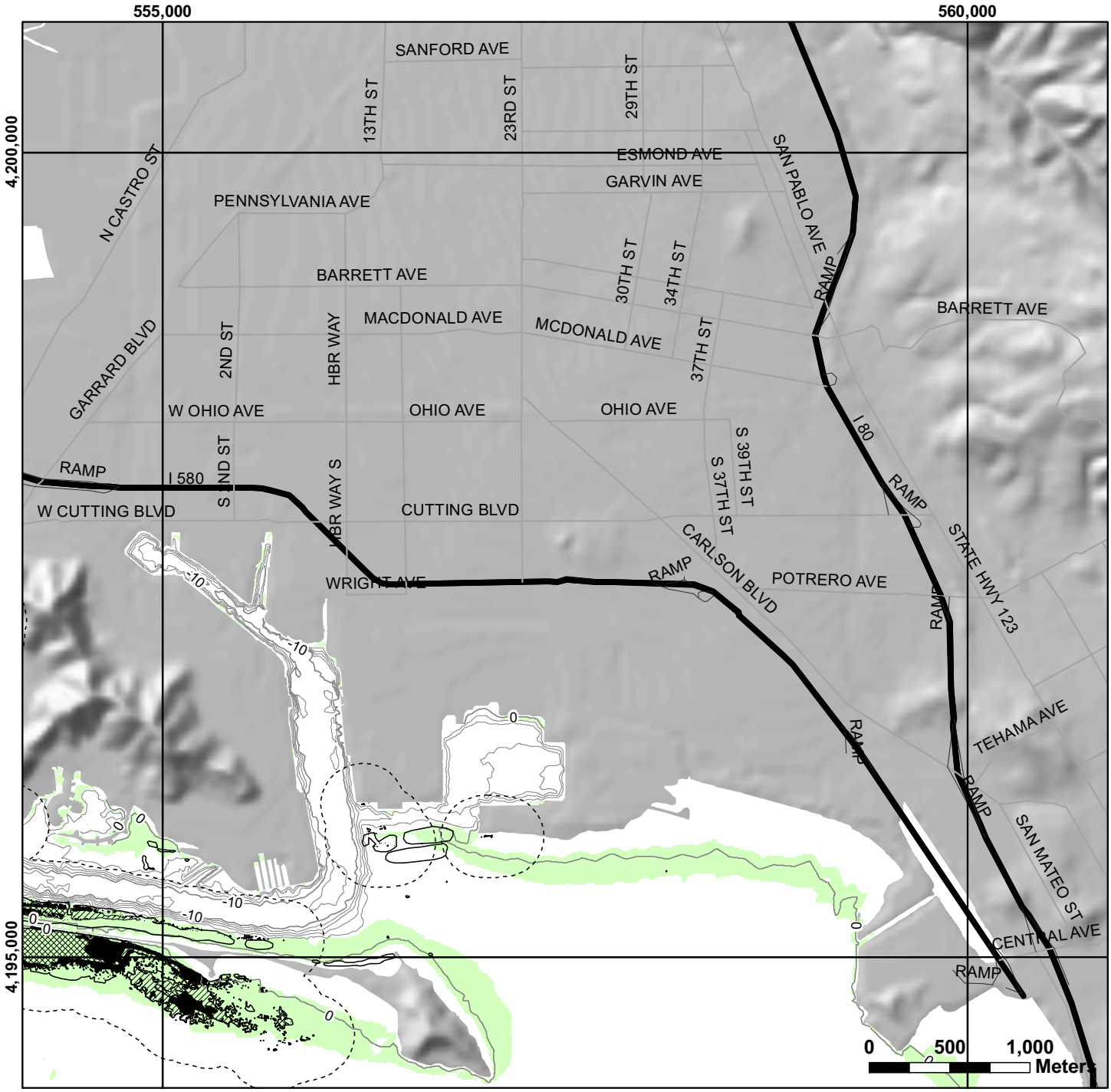
SHEET LOCATOR



Eelgrass Coverage

- 1-5%
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- 21-40%
- 41-100%

- Max Documented Eelgrass Extent
- 2009 Eelgrass 250m buffer
- ELVS Predictive Model 2009



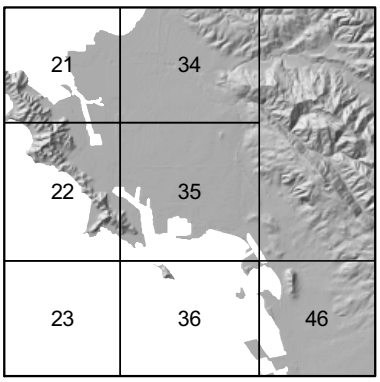
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

Merkel & Associates, Inc.
San Diego, CA - Tel: (858) 560-5465

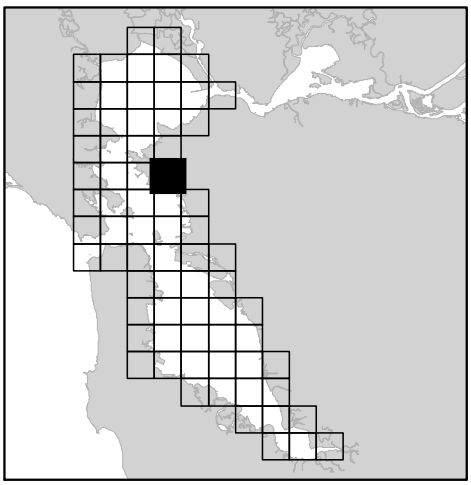
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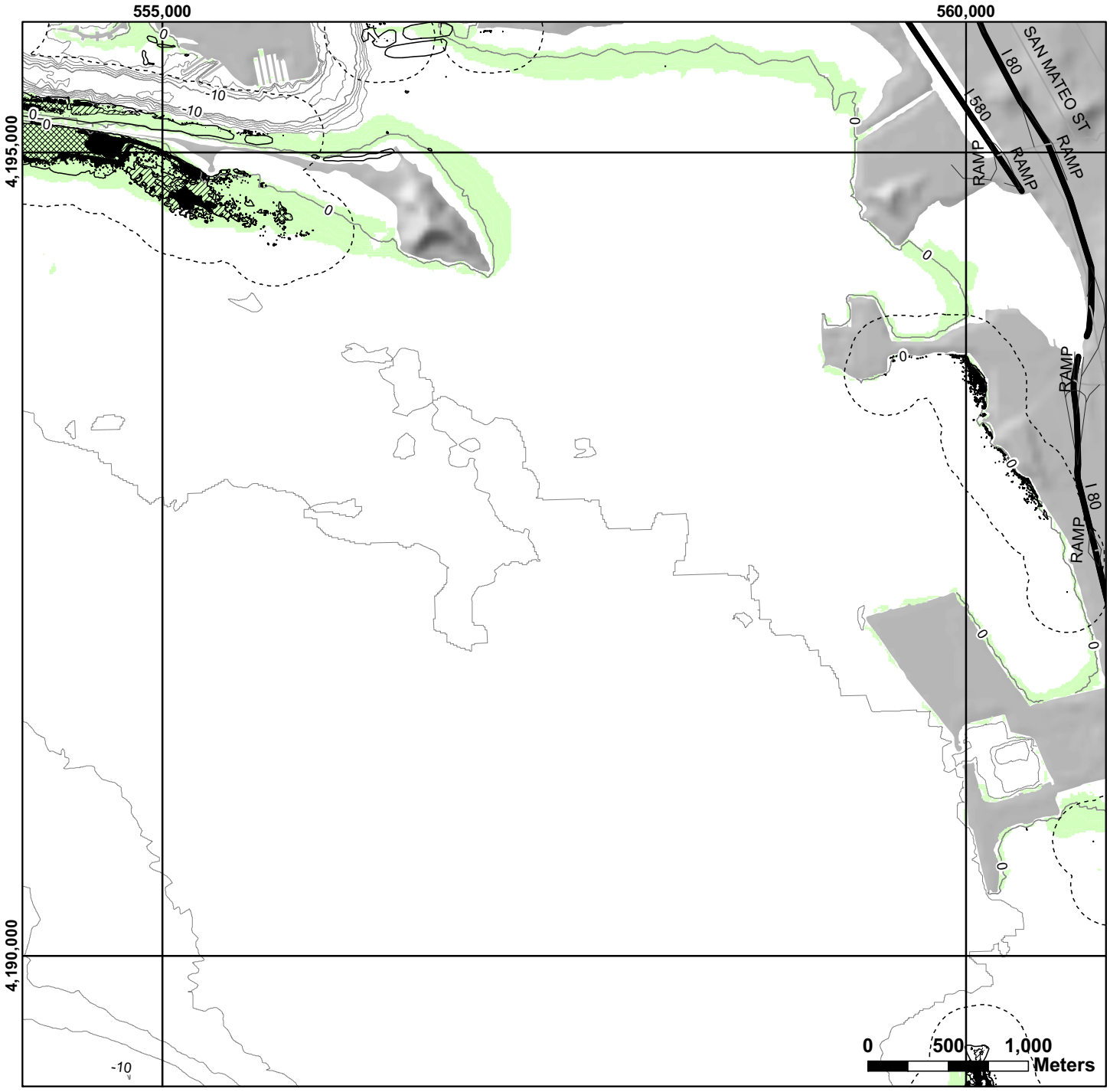
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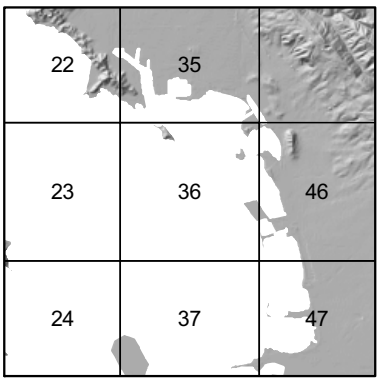
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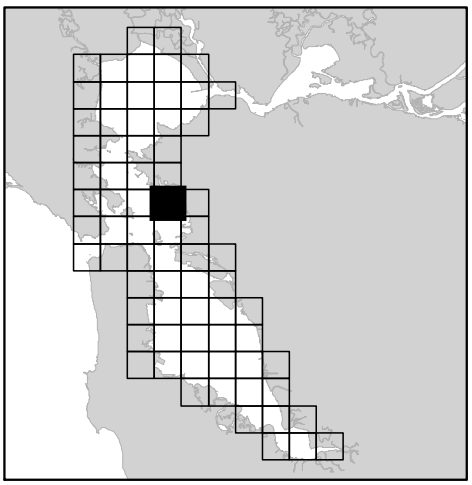
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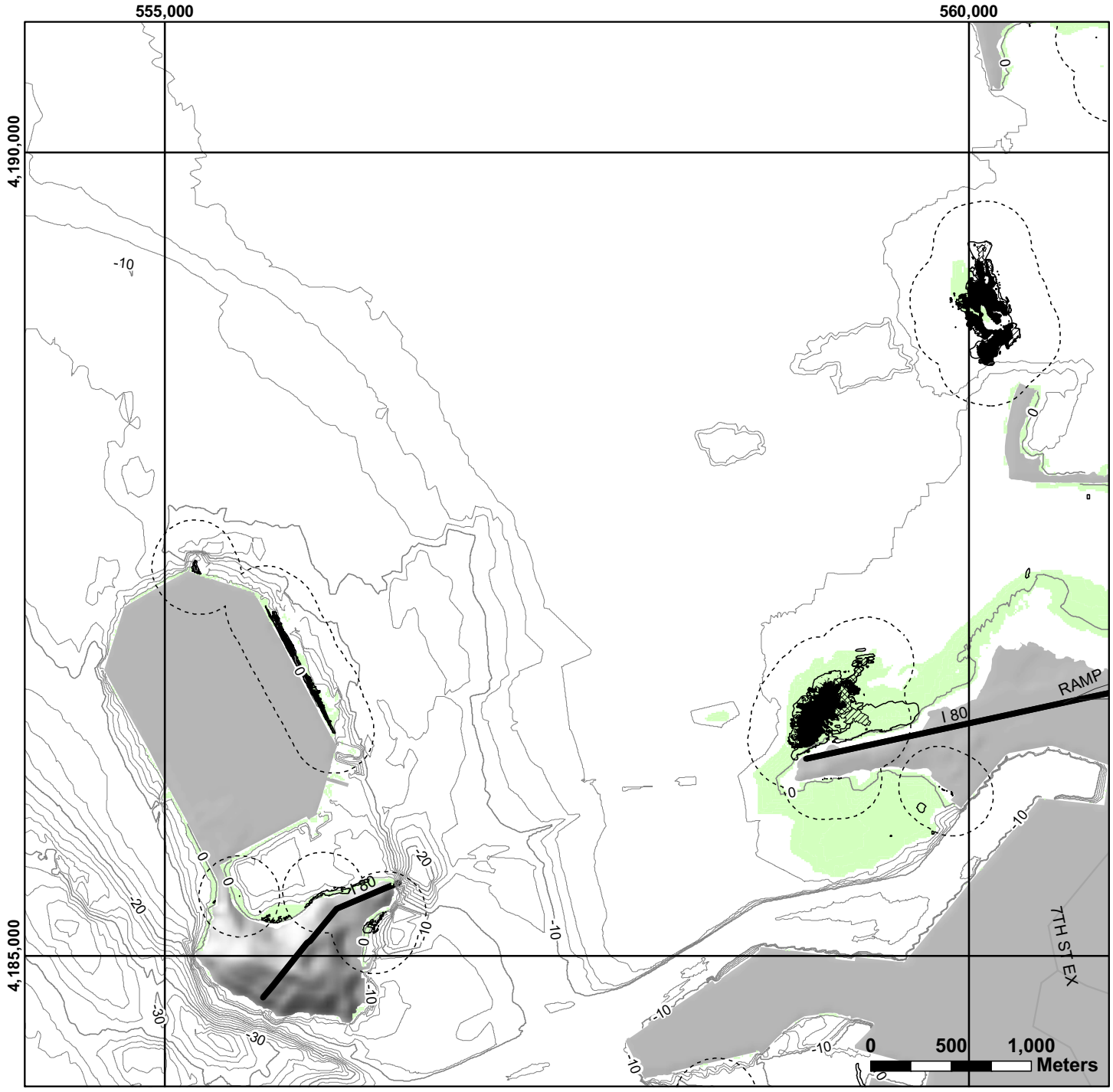


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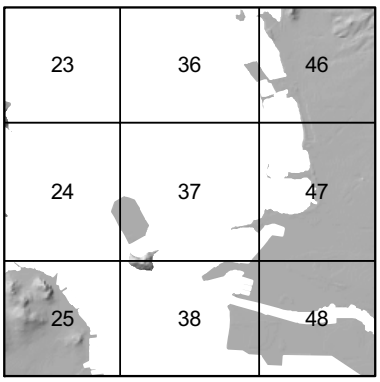
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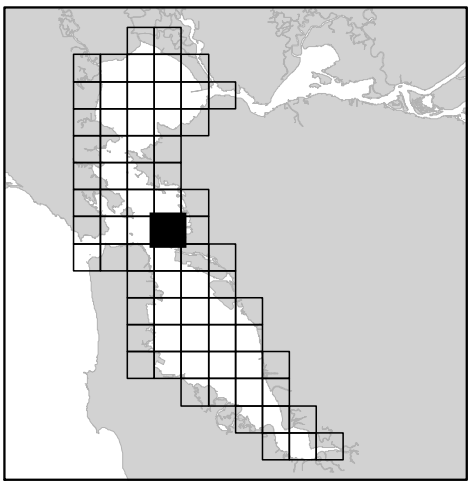
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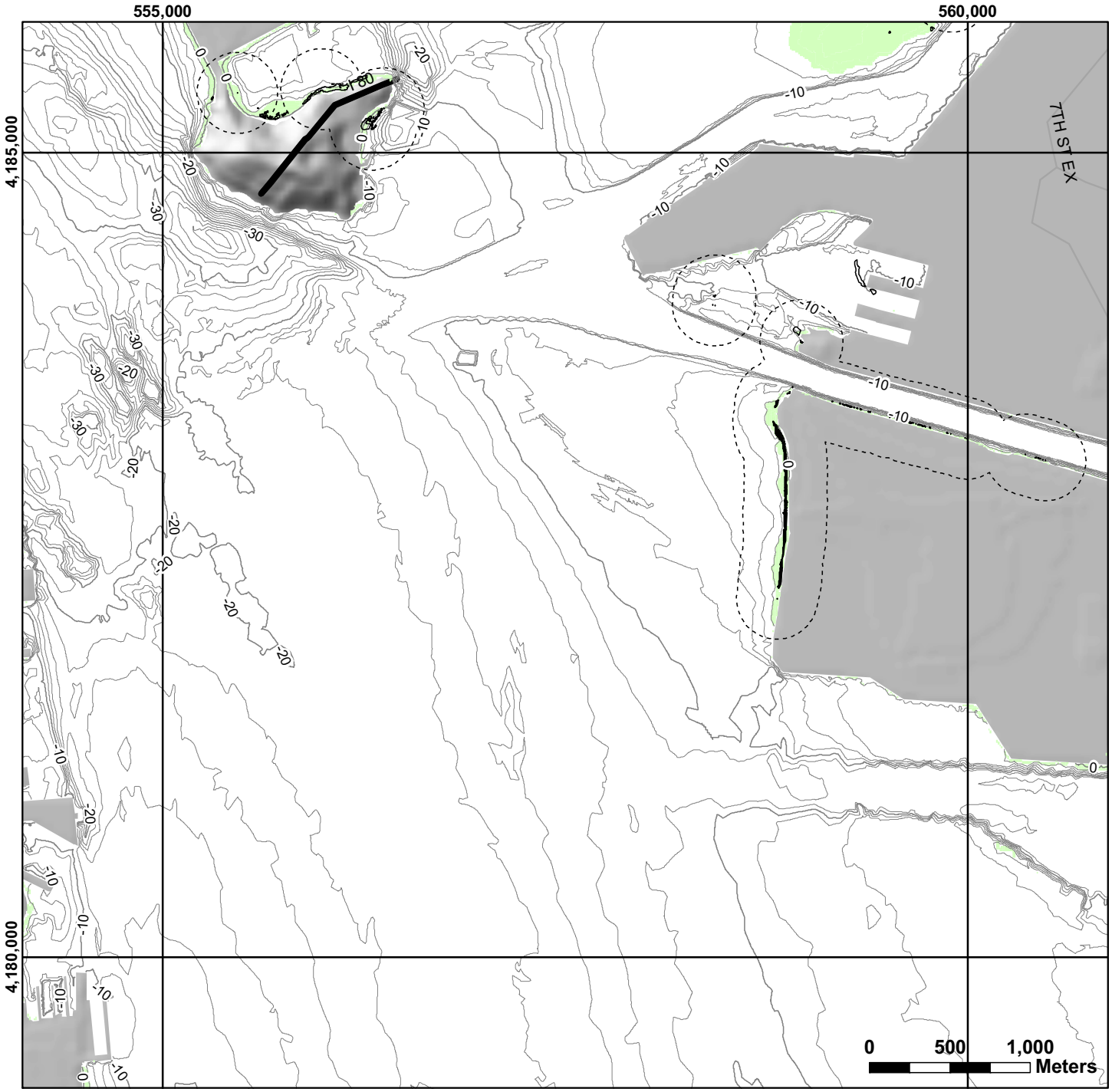
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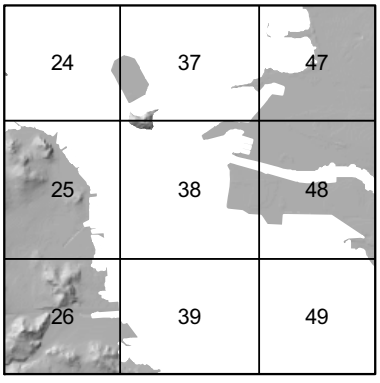
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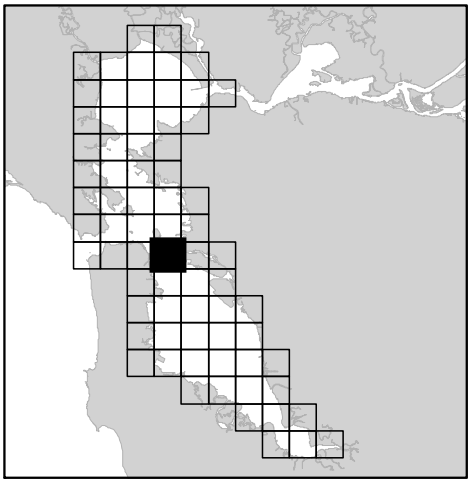
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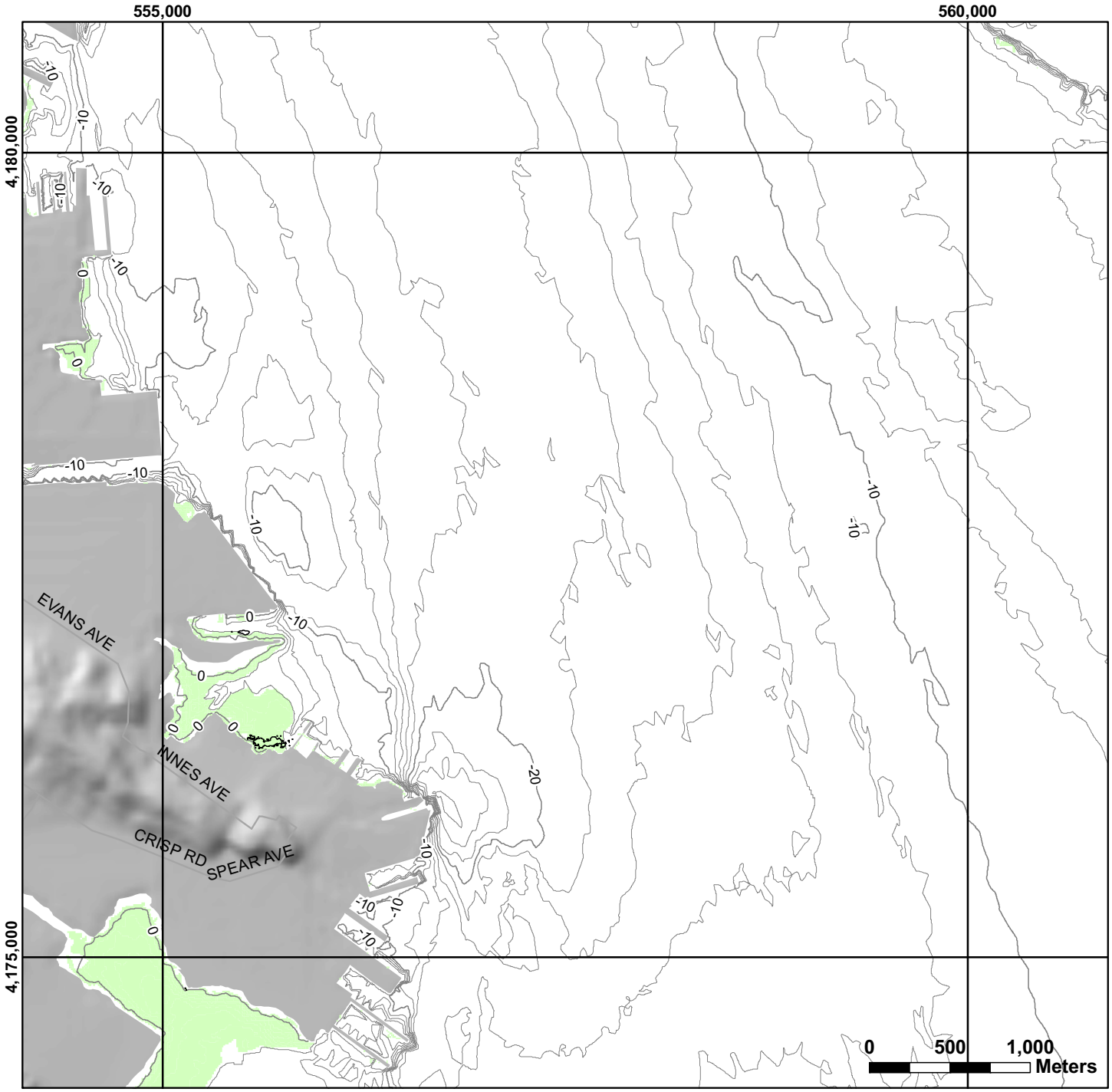
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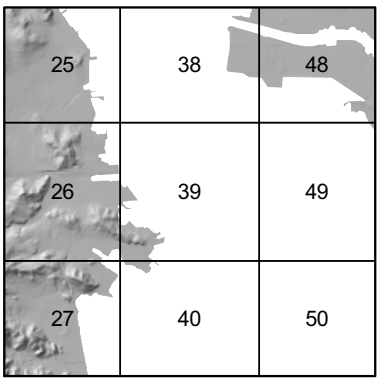
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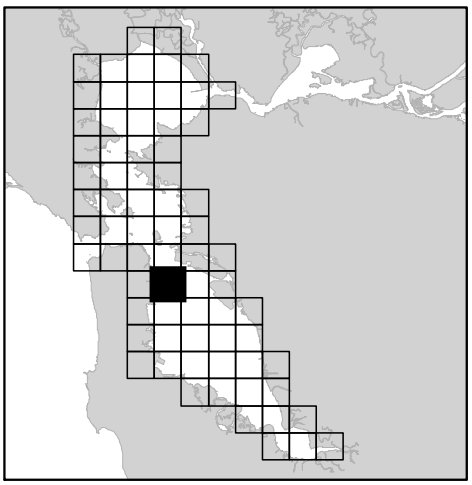
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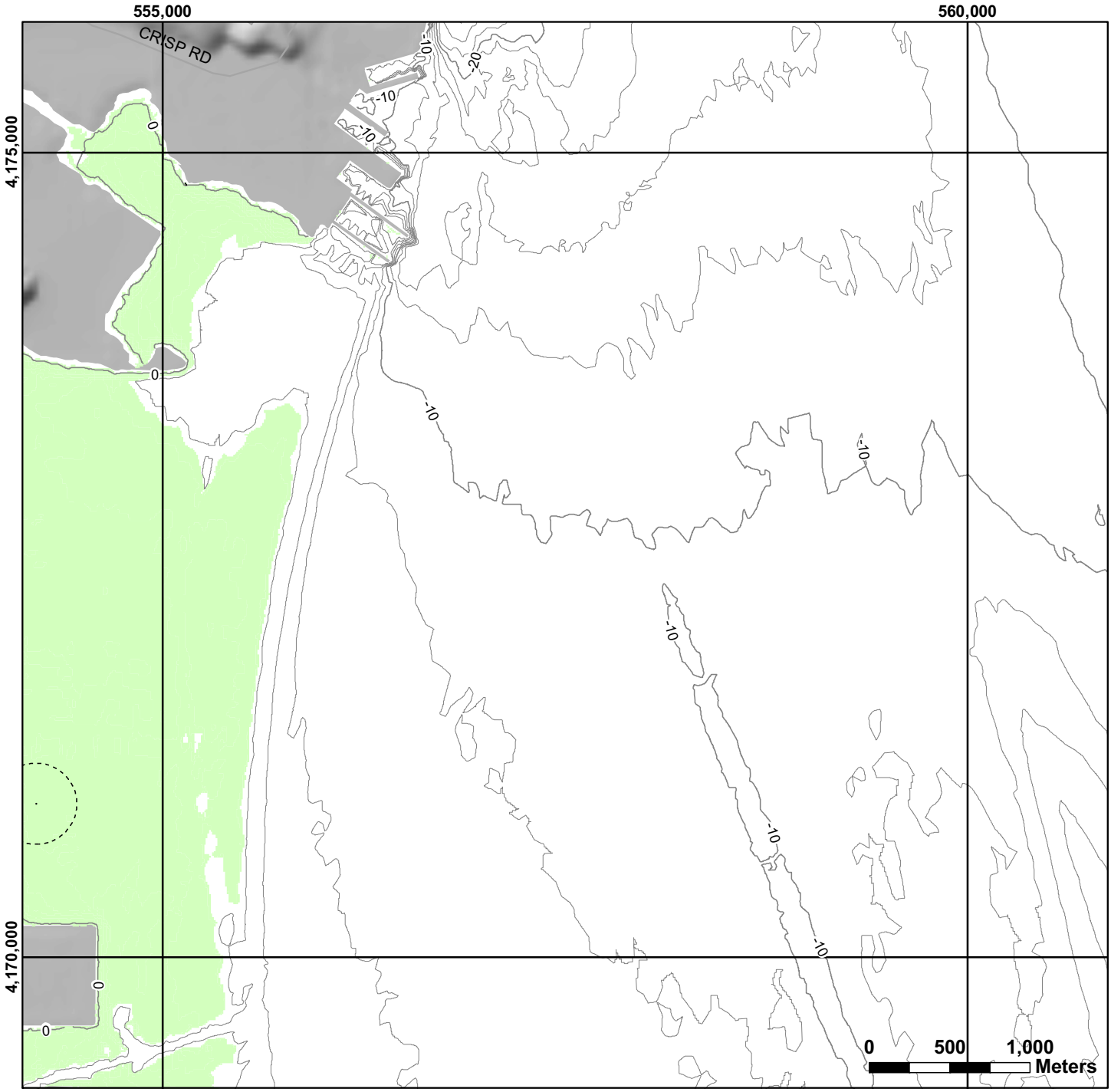


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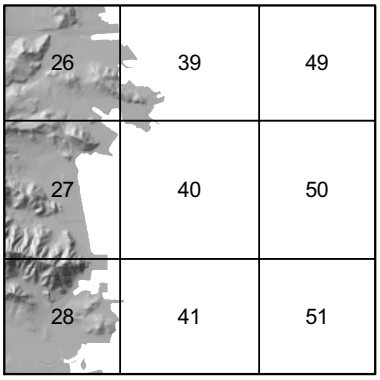
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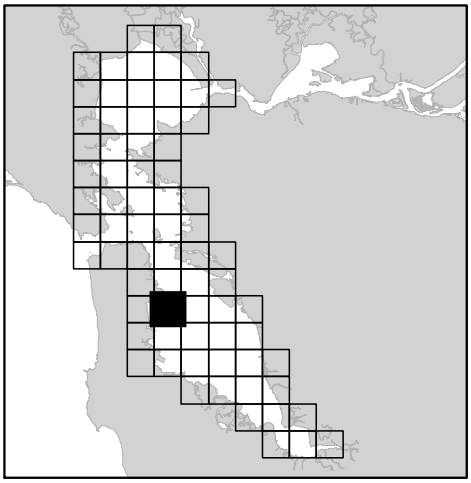
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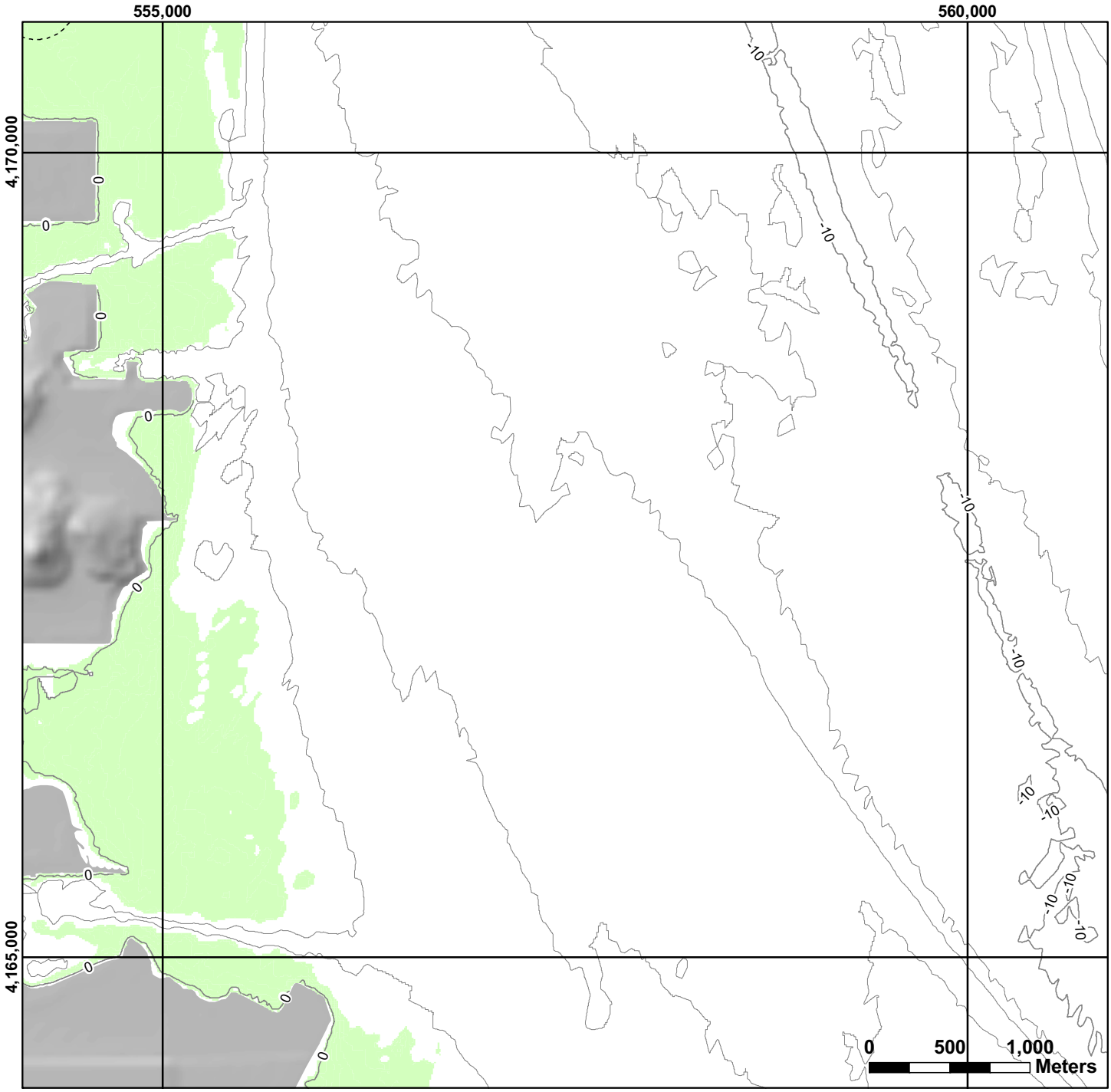
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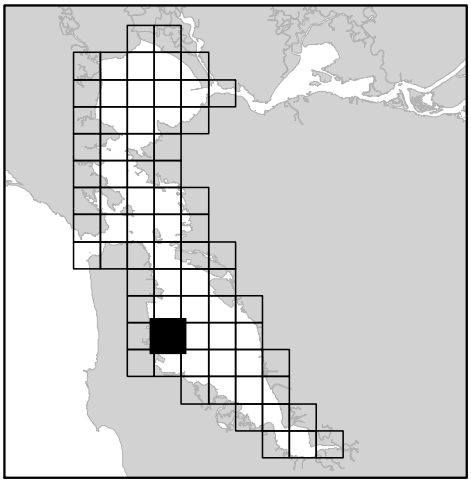
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SHEET VICINITY

27	40	50
28	41	51
29	42	52

SHEET LOCATOR

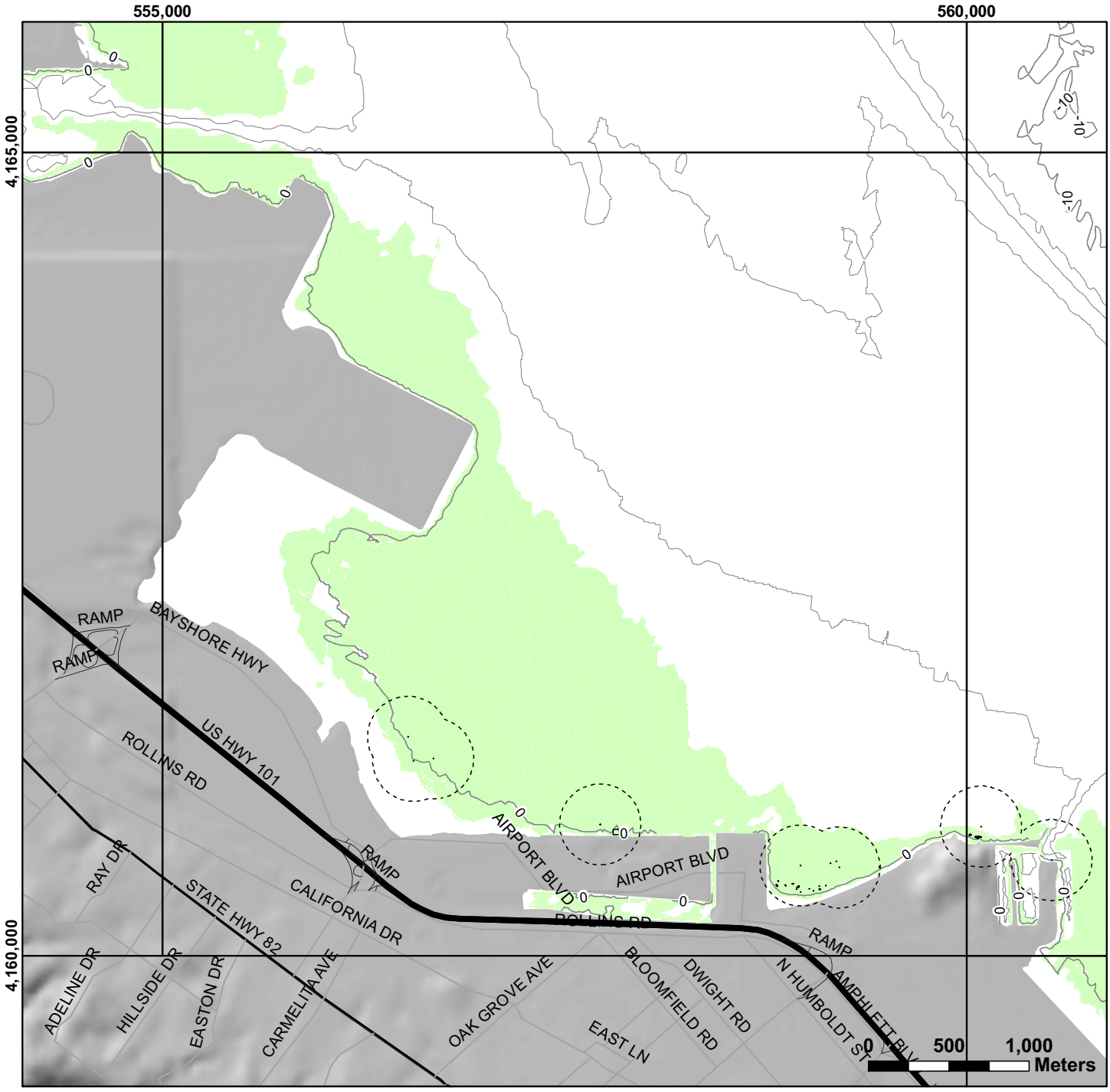


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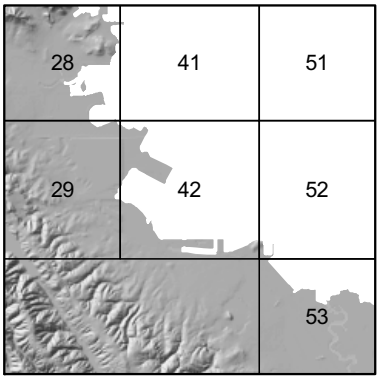
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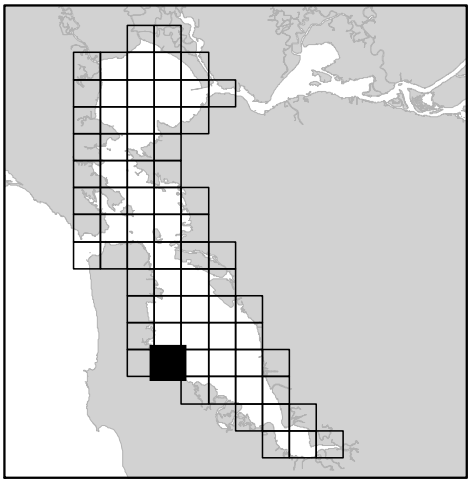
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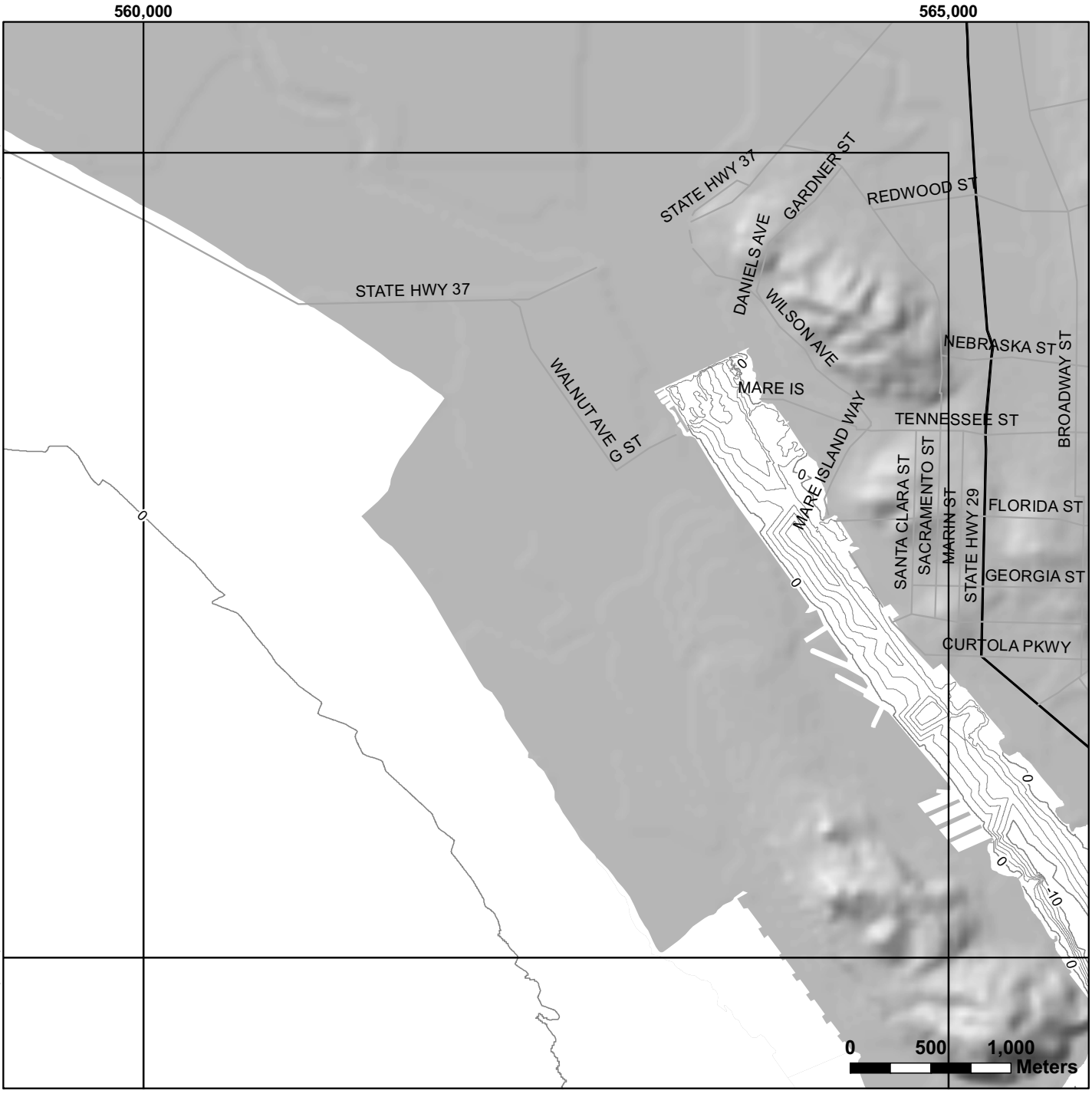
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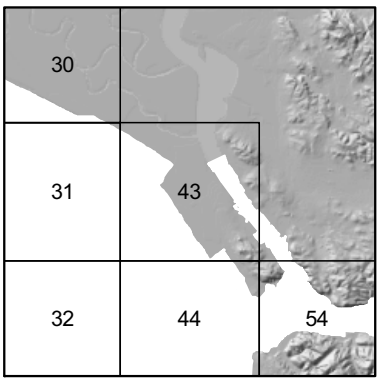
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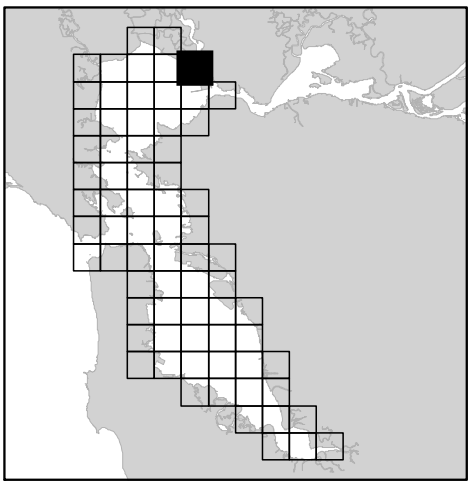
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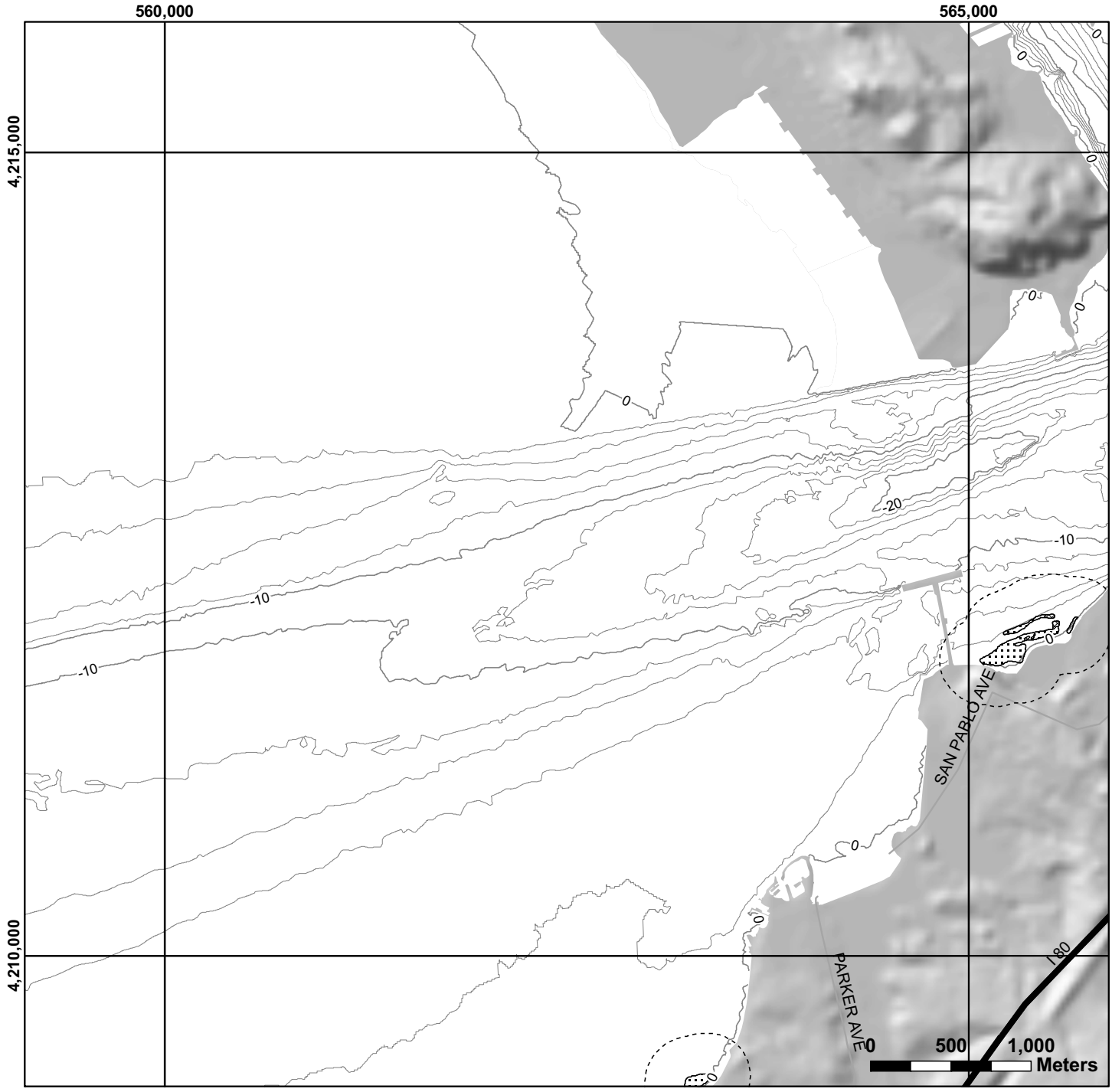
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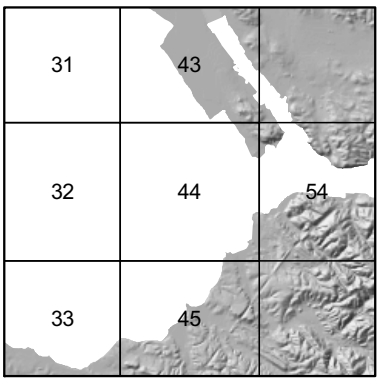
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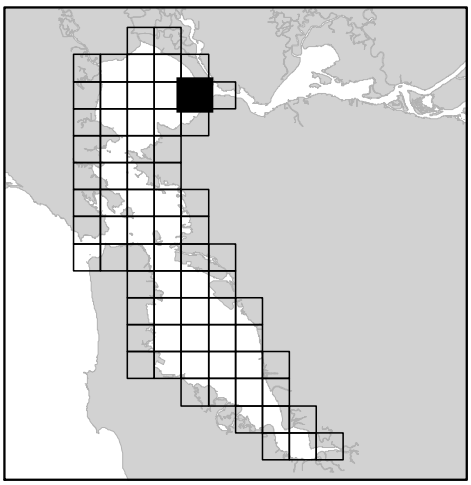
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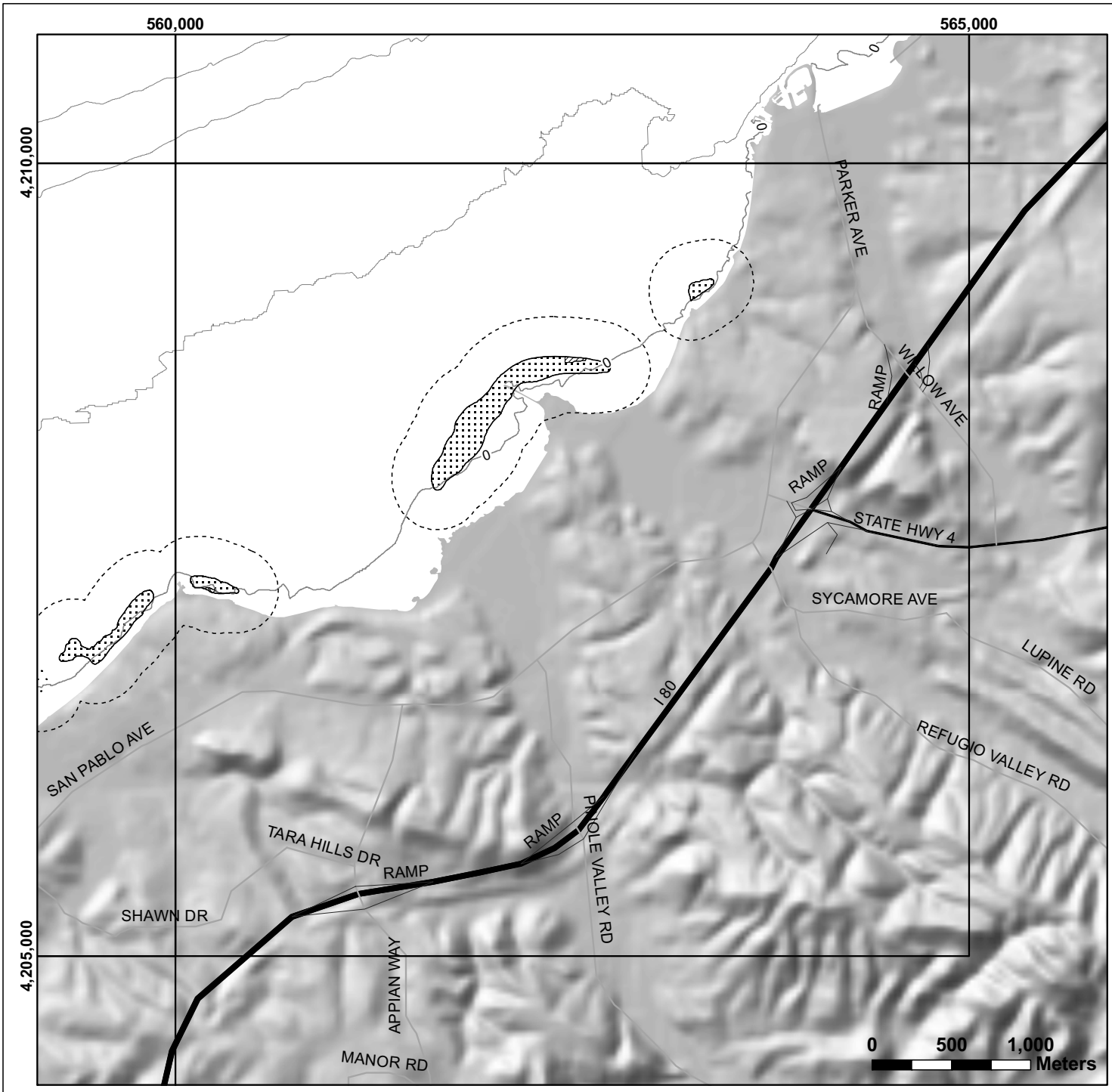
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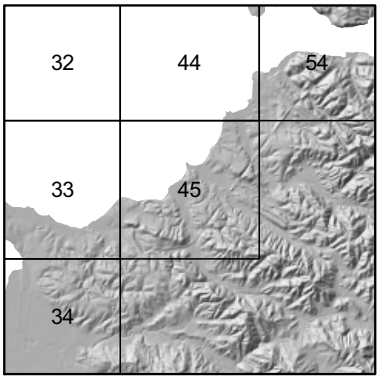
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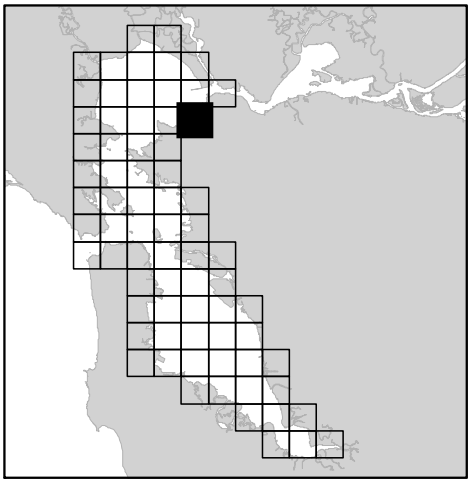
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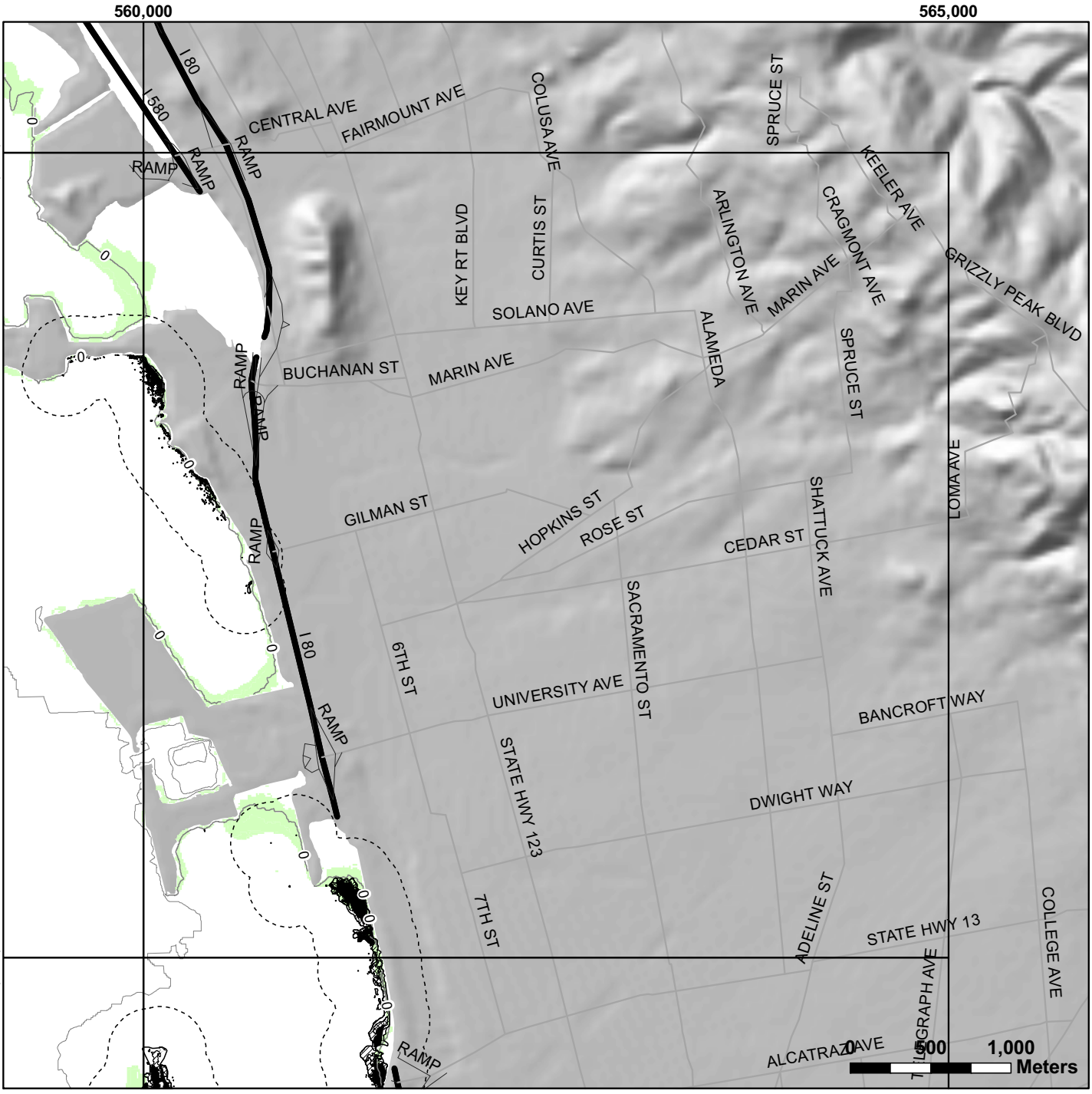
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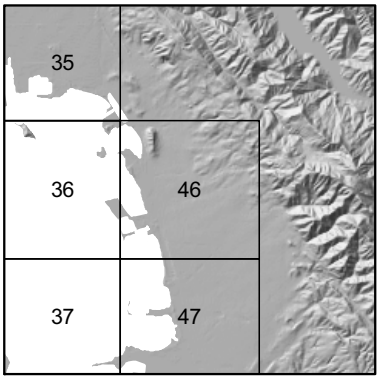
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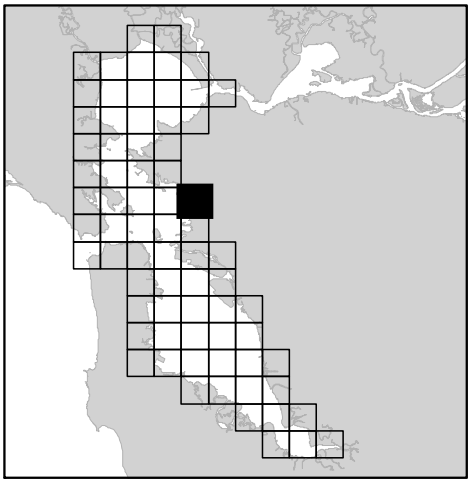
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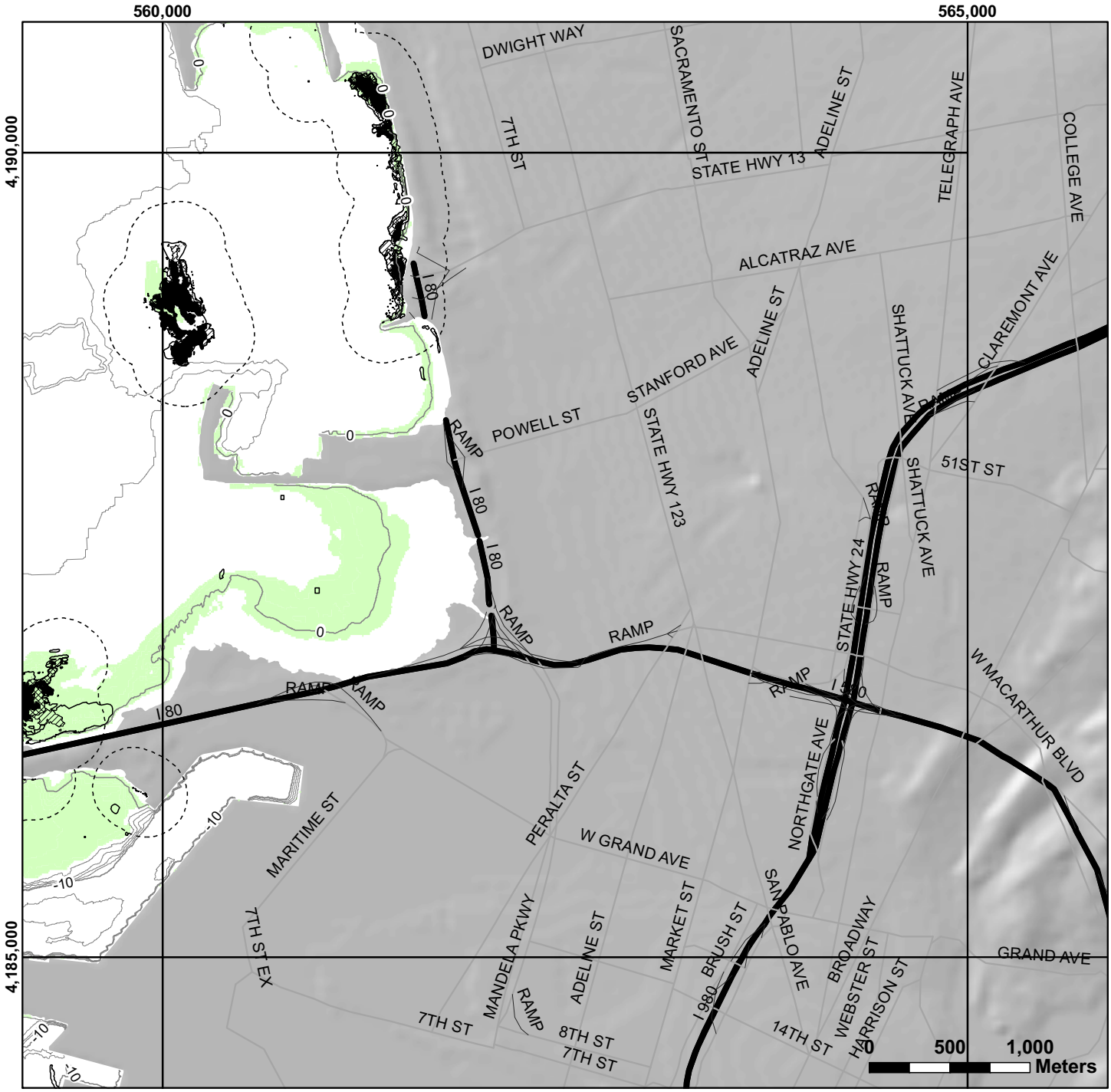


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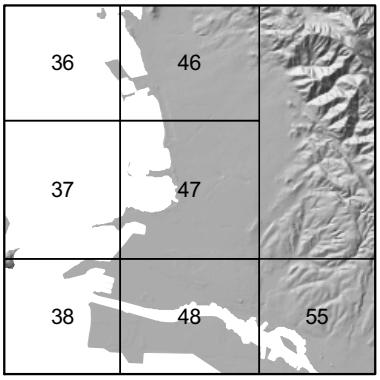
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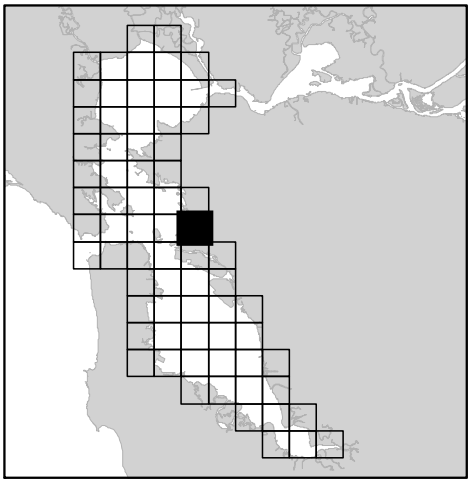
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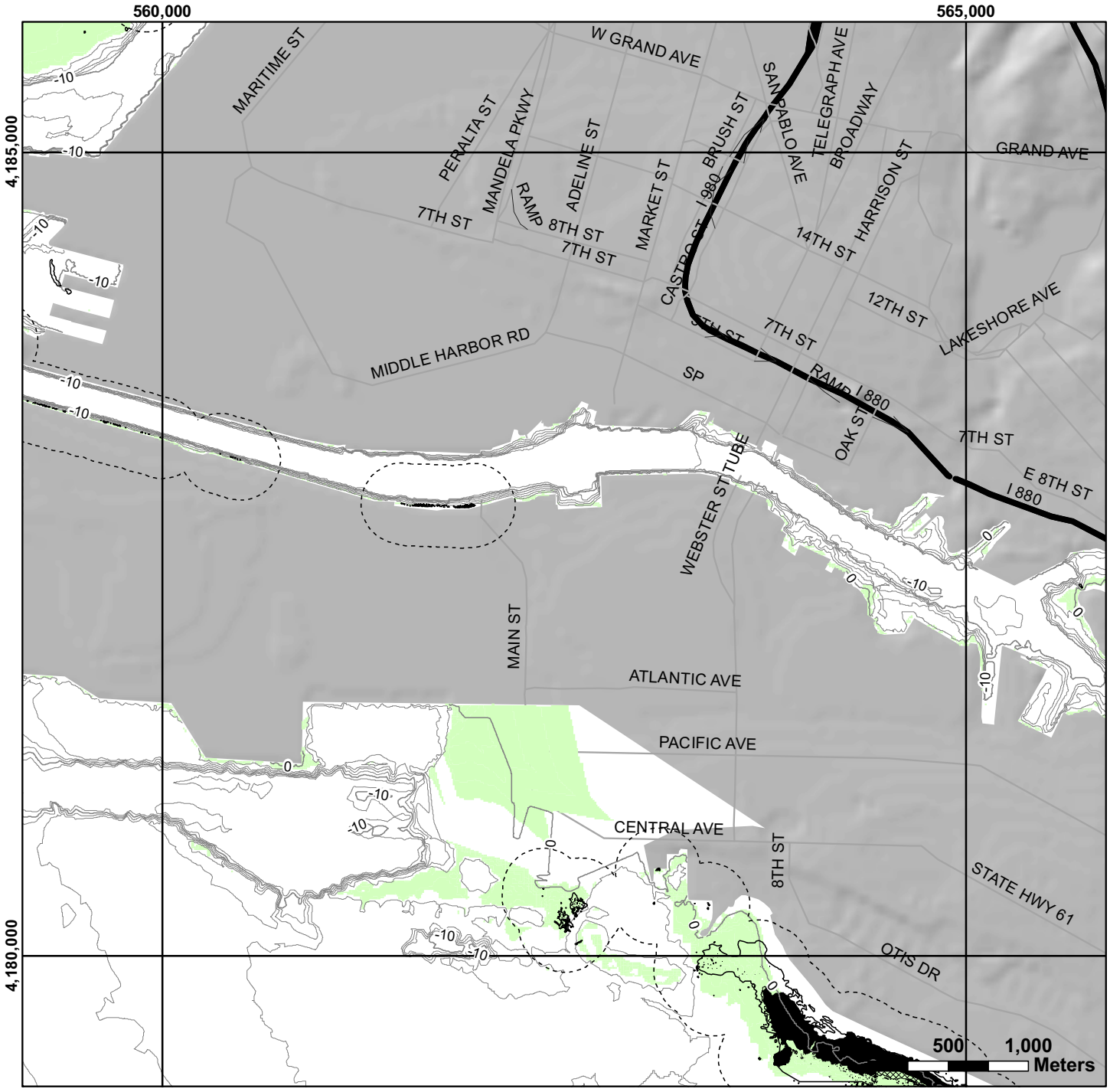
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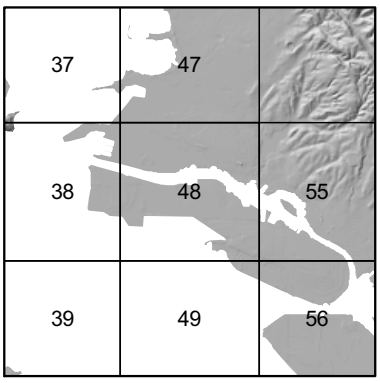
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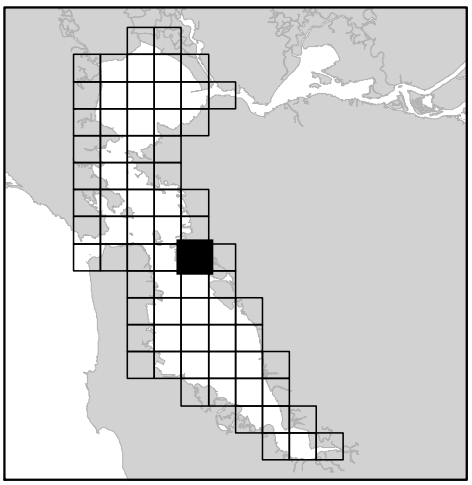
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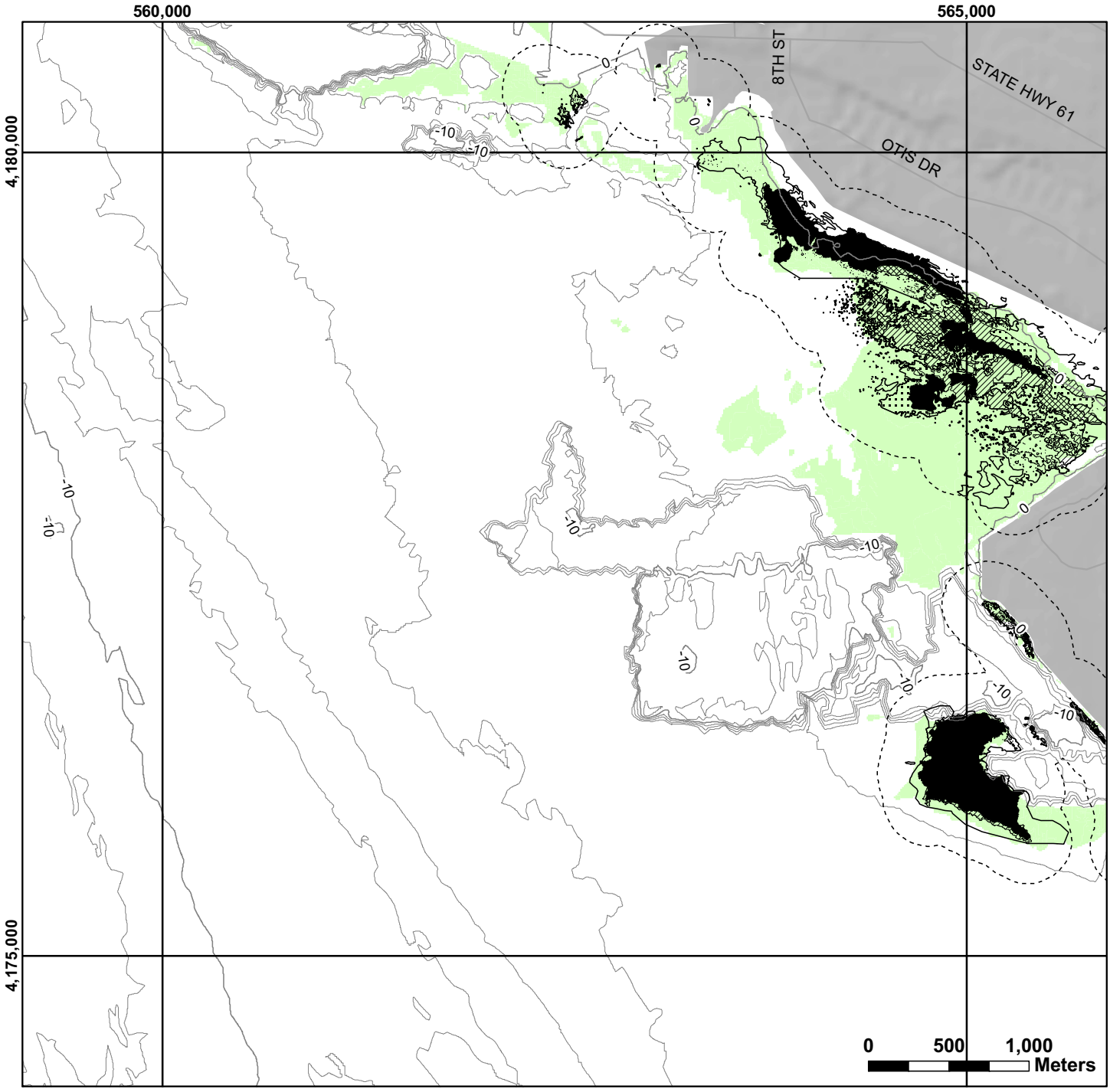
SHEET LOCATOR



Eelgrass Coverage

- 1-5%
- 6-20%
- 21-40%
- 41-100%

- Max Documented Eelgrass Extent
- 2009 Eelgrass 250m buffer
- ELVS Predictive Model 2009



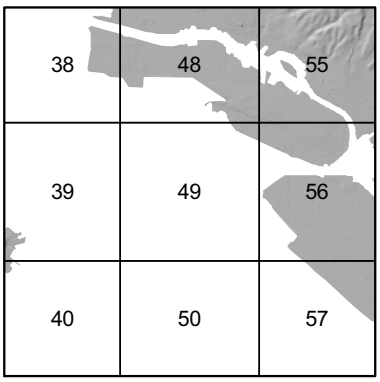
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

Merkel & Associates, Inc.
San Diego, CA - Tel: (858) 560-5465

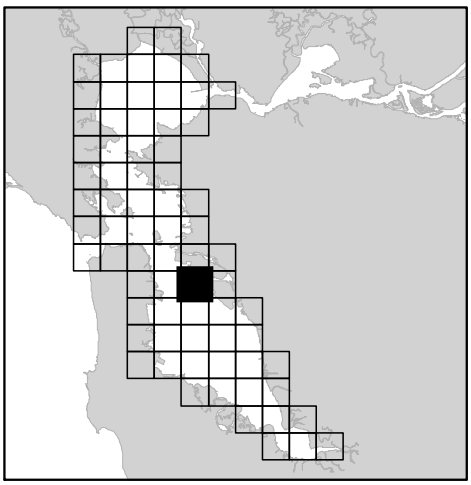
Horizontal Datum: UTM NAD83 Zone 10N
Vertical Datum: MLLW (meters)

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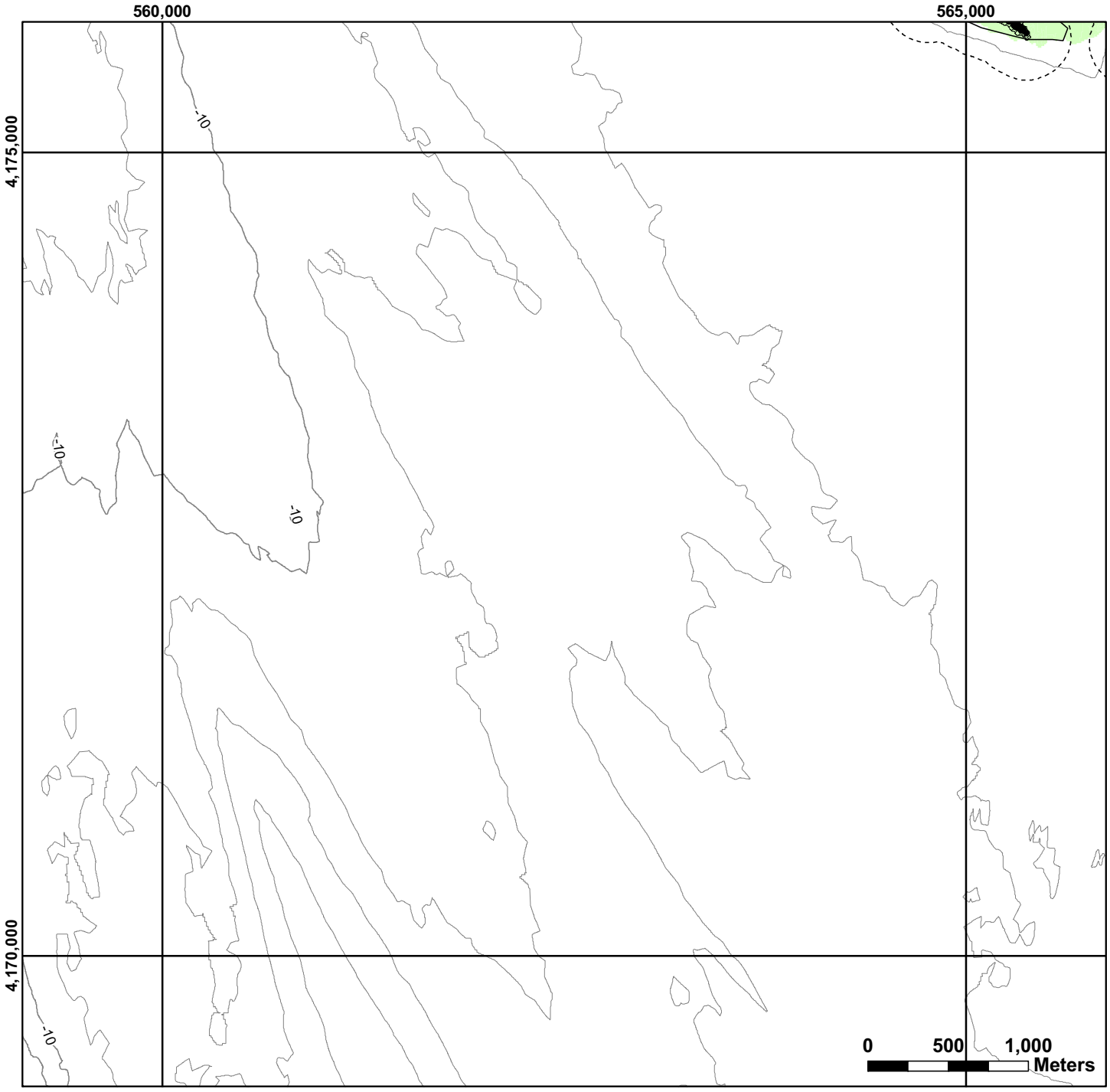
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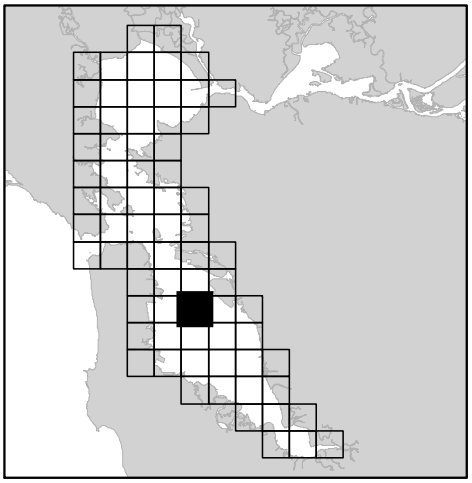
Horizontal Datum: UTM NAD83 Zone 10N
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SHEET VICINITY

39	49	56
40	50	57
41	51	58

SHEET LOCATOR

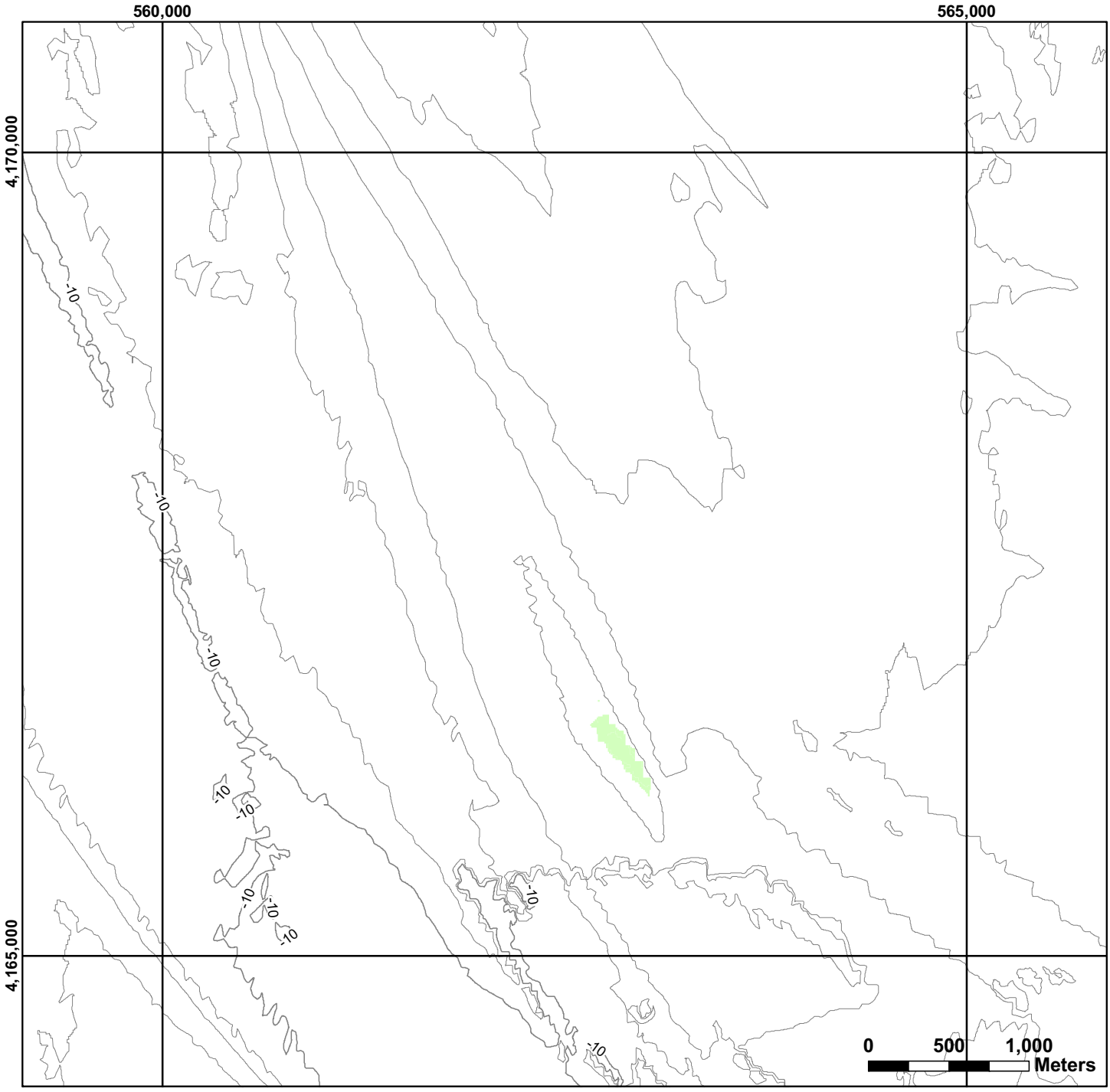


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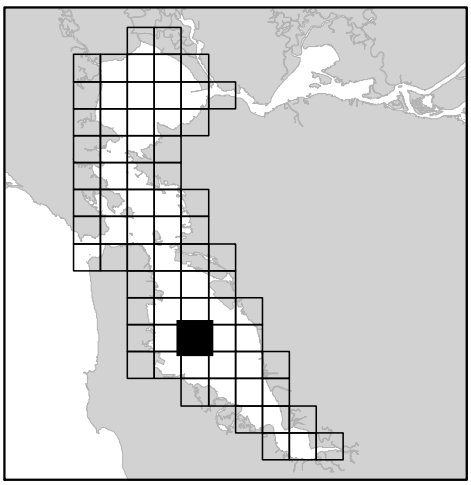
Horizontal Datum: UTM NAD83 Zone 10N
Vertical Datum: MLLW (meters)

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SHEET VICINITY

40	50	57
41	51	58
42	52	59

SHEET LOCATOR

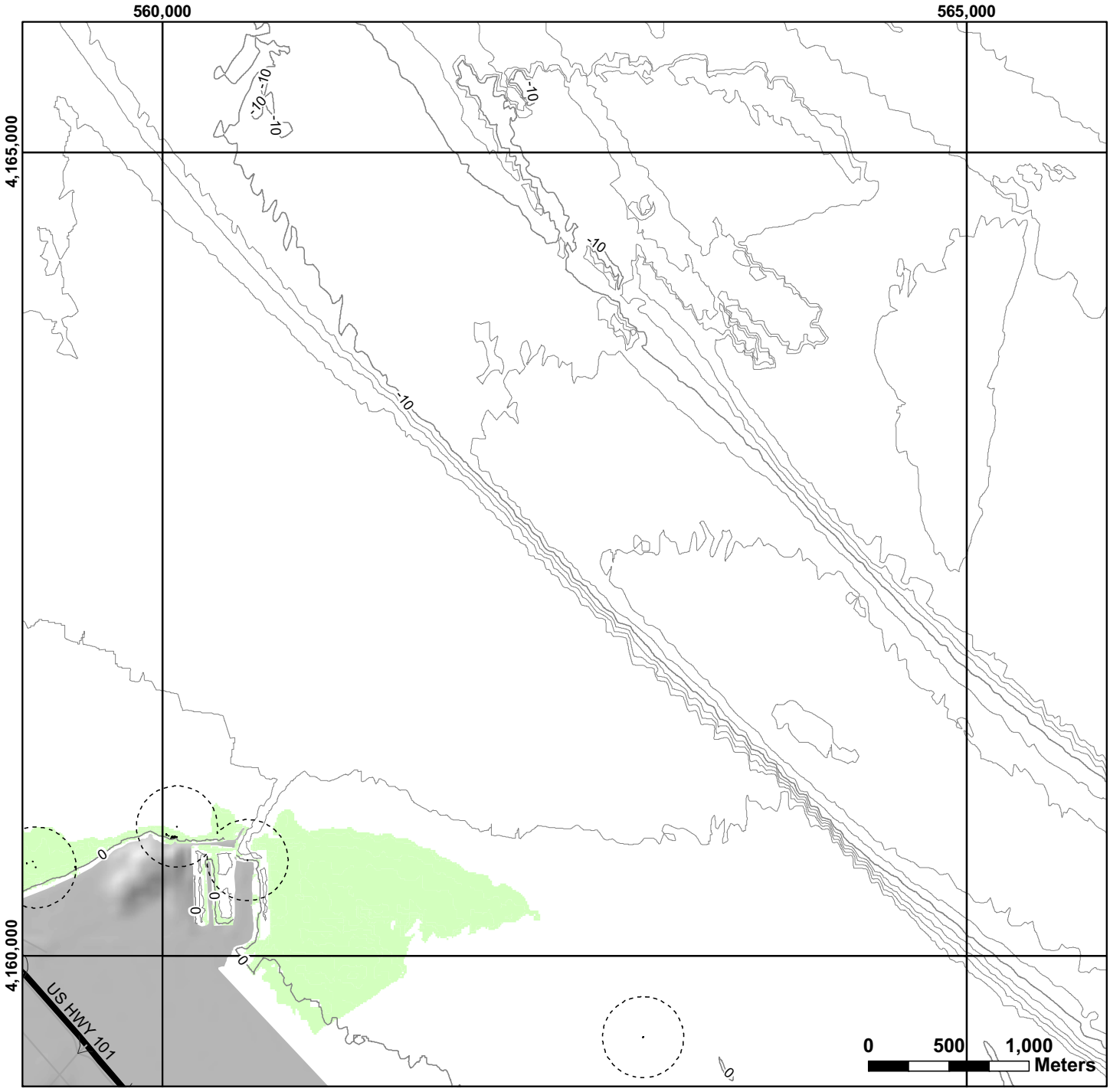


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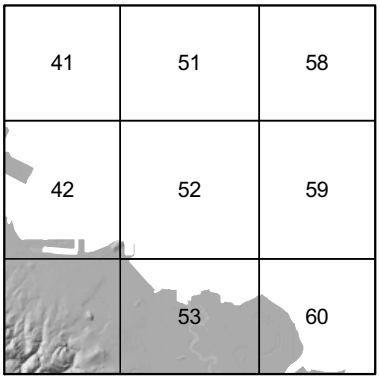
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Eelgrass 2009

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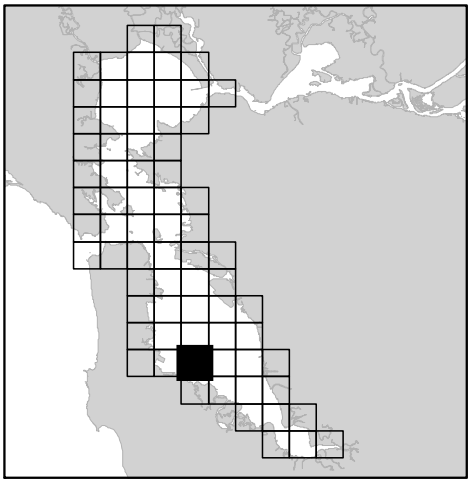
Horizontal Datum: UTM NAD83 Zone 10N
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SHEET VICINITY



SHEET LOCATOR

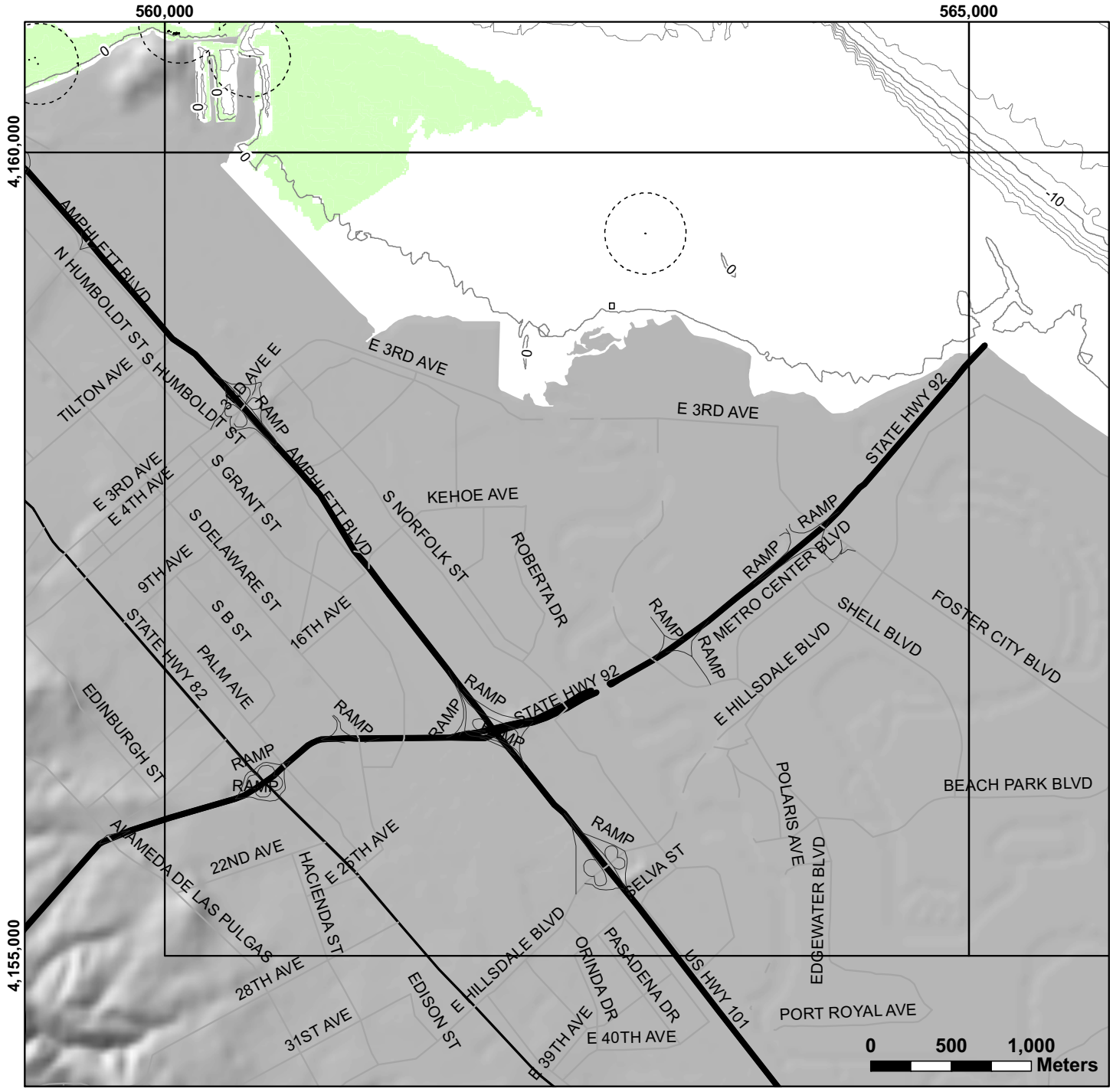


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Eelgrass 2009

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Horizontal Datum: UTM NAD83 Zone 10N
Vertical Datum: MLLW (meters)

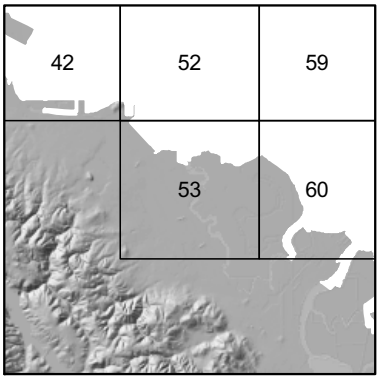
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Eelgrass Coverage

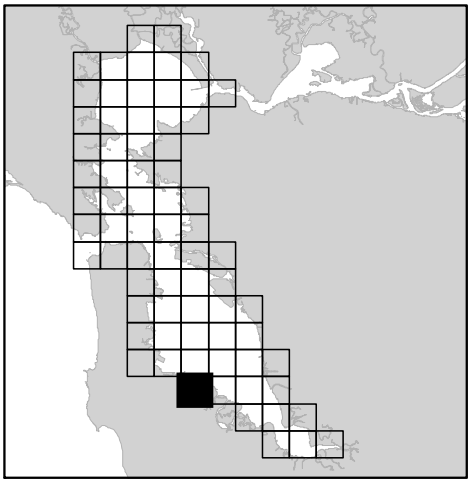
- 1-5%
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- 41-100%

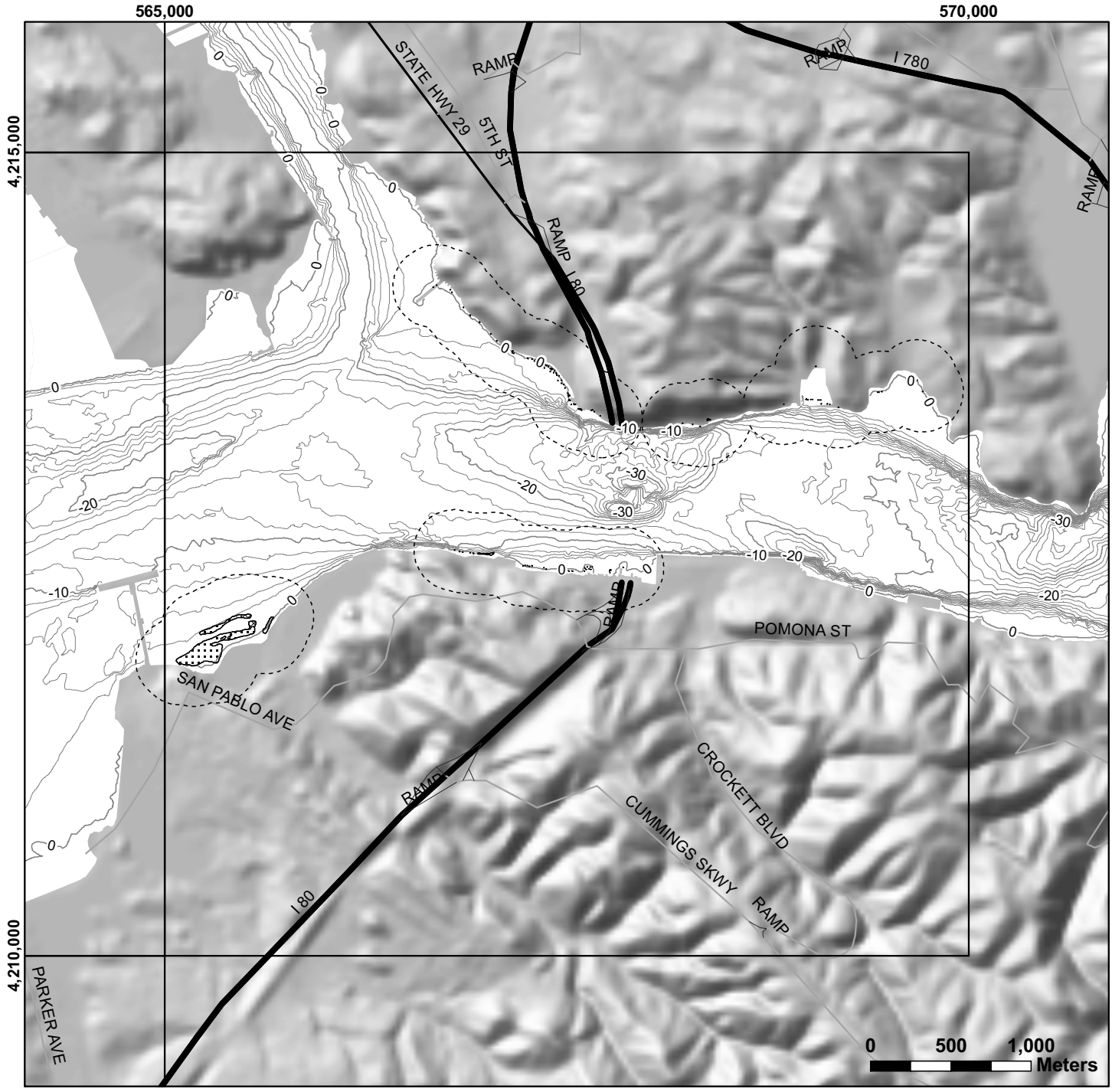
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SHEET VICINITY



SHEET LOCATOR





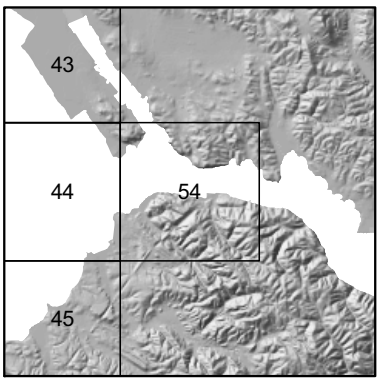
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Eelgrass 2009

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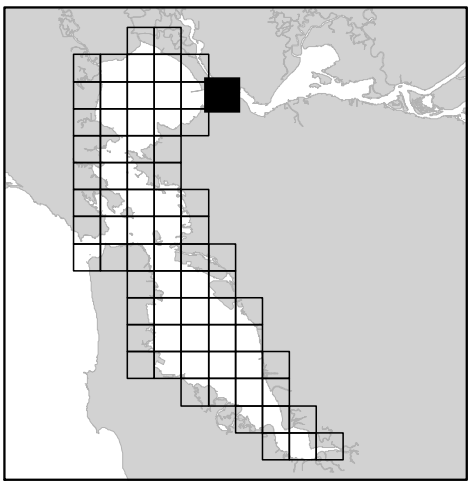
Horizontal Datum: UTM NAD83 Zone 10N
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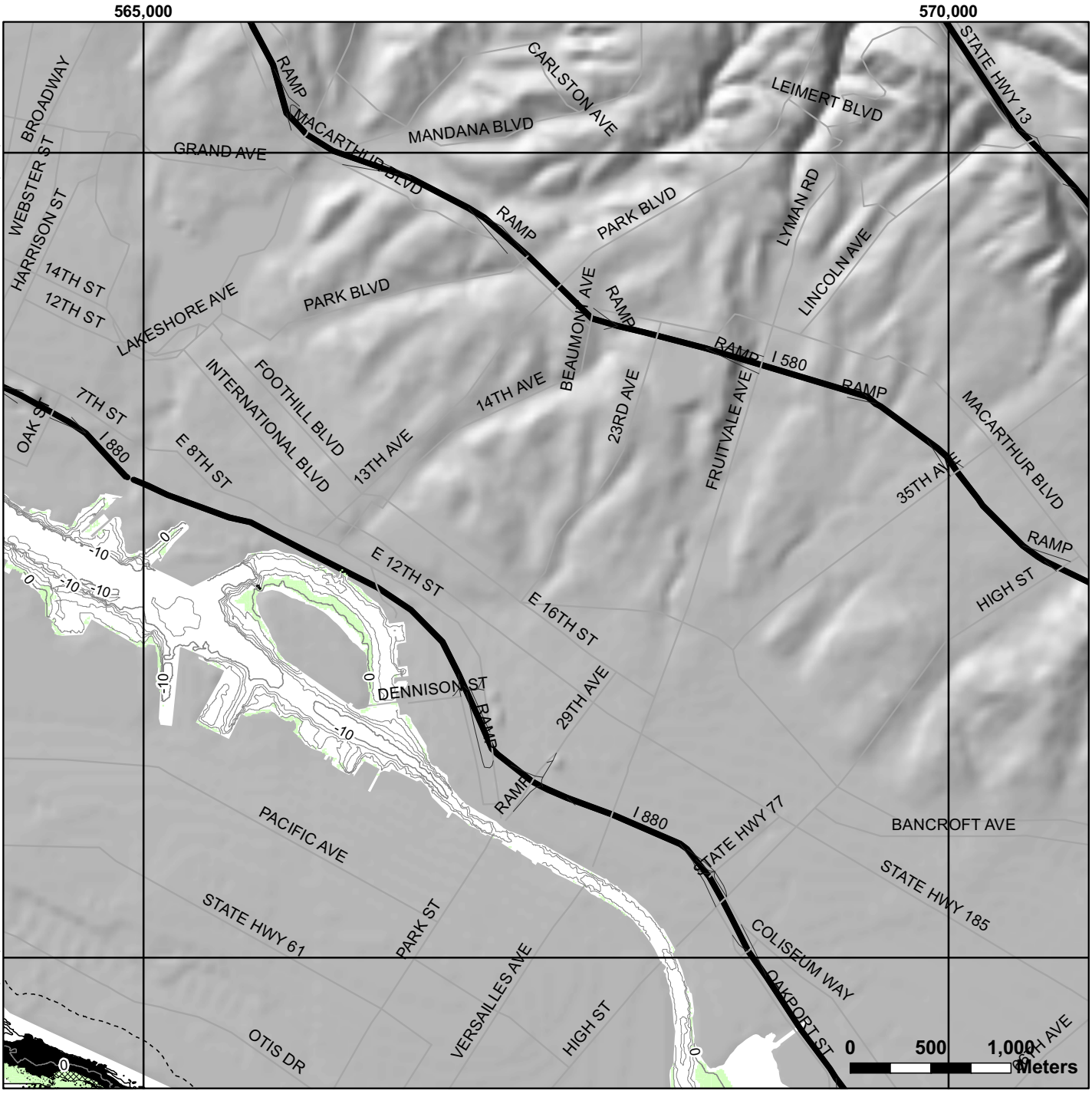
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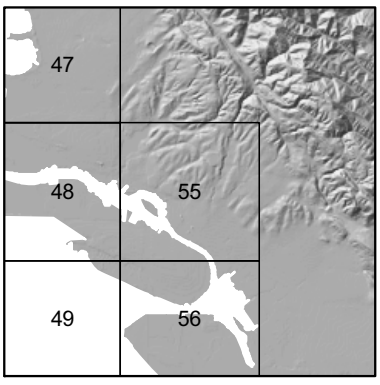
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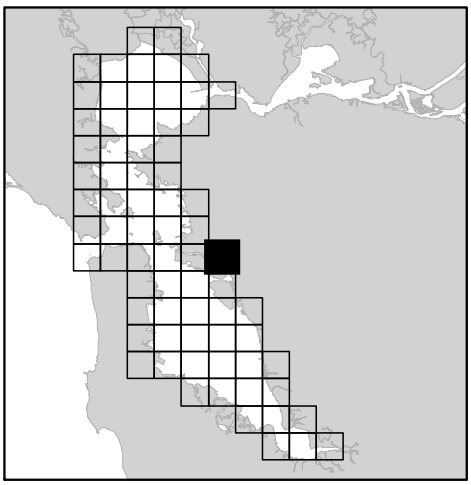
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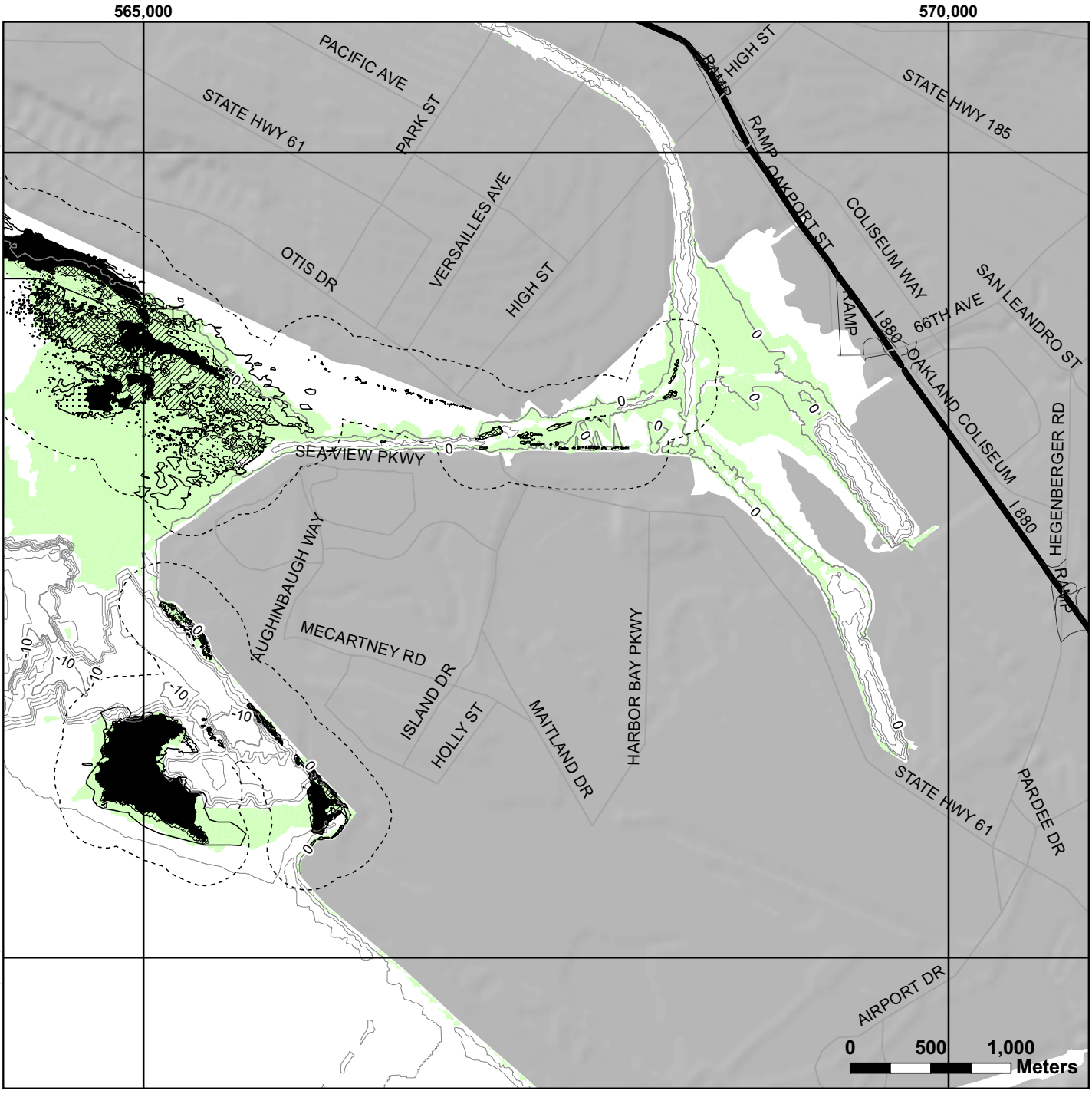


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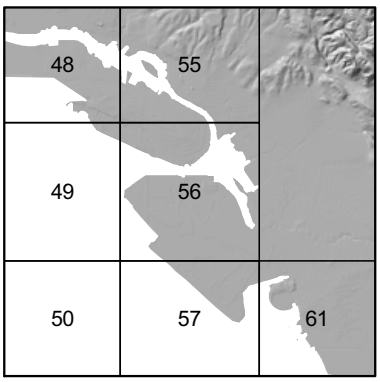
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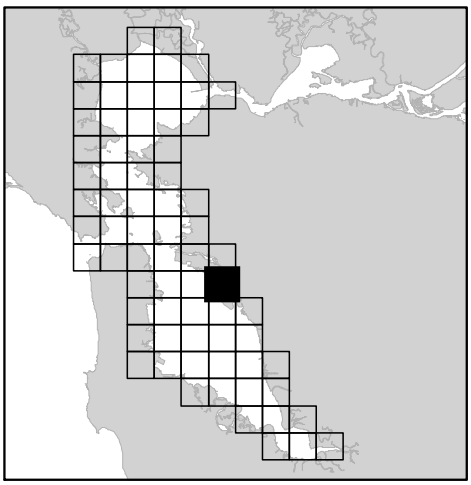
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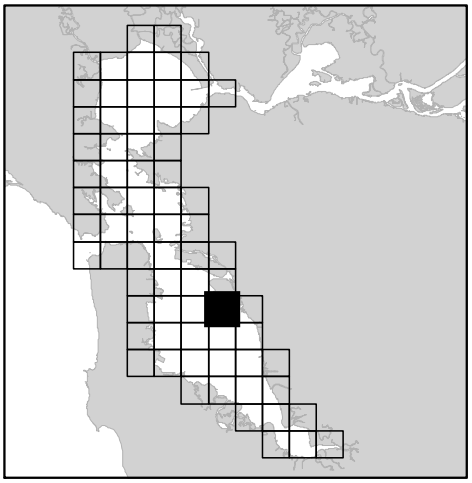
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SHEET VICINITY

49	56	
50	57	61
51	58	62

SHEET LOCATOR

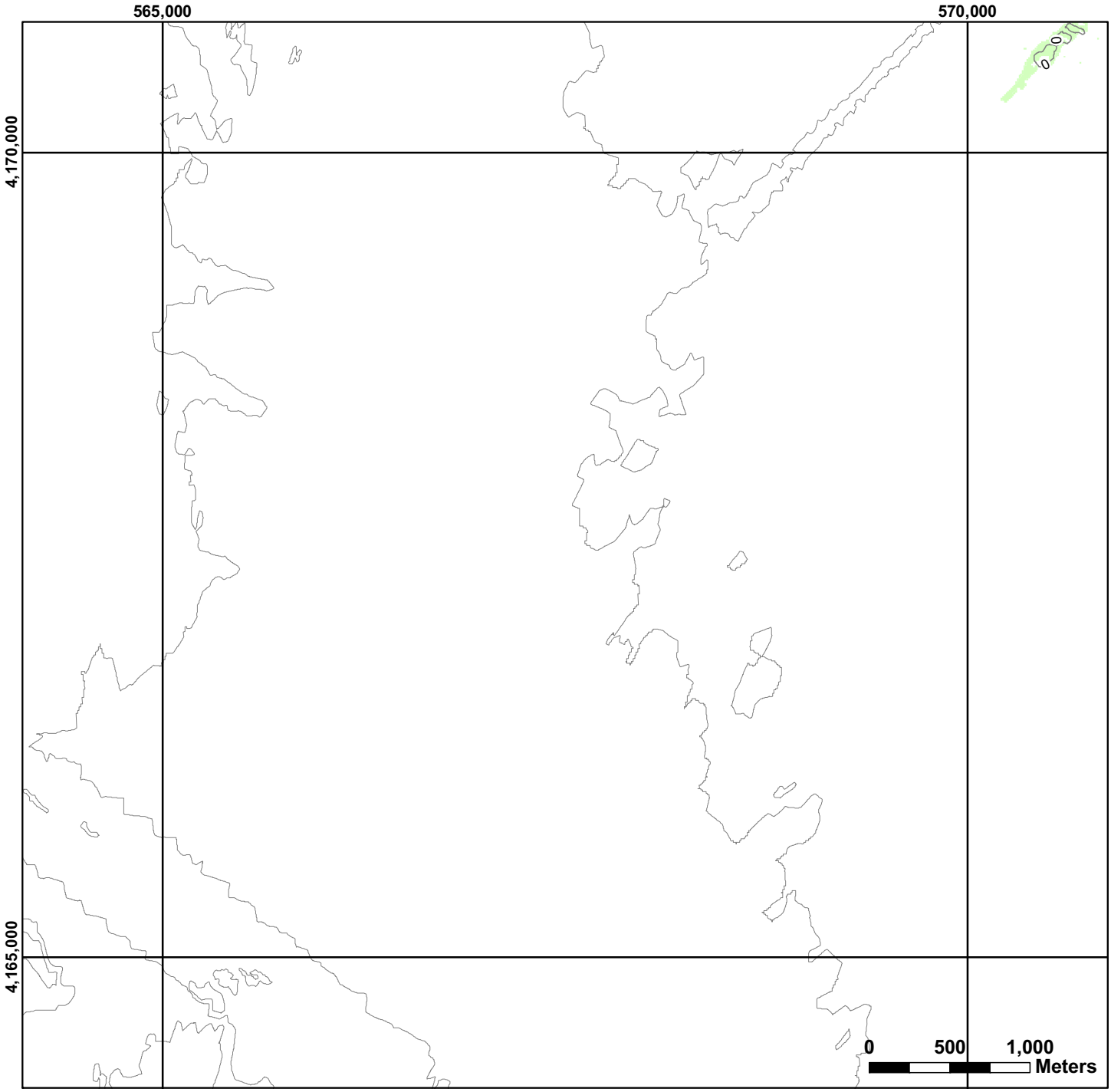


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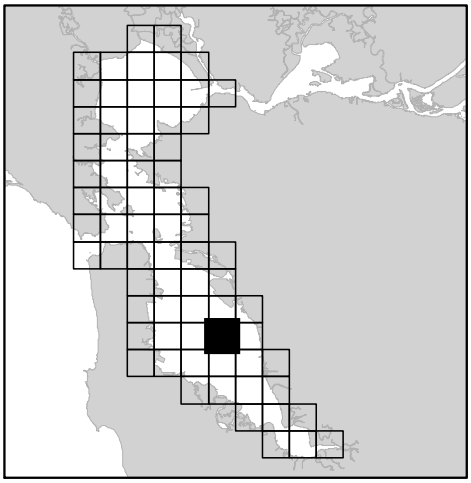
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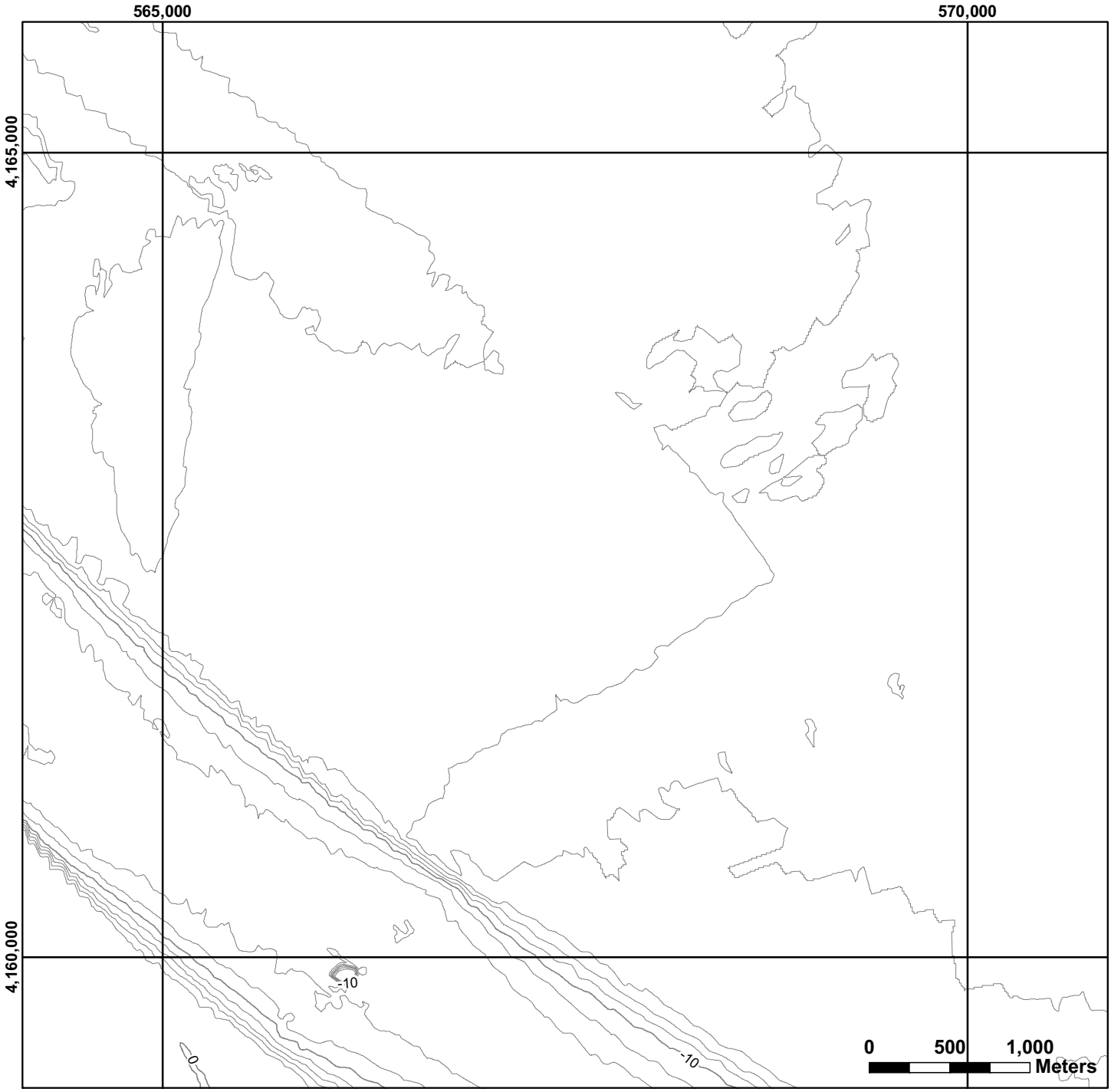
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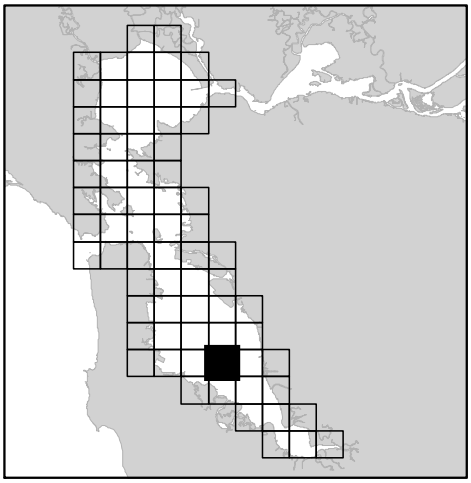
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SHEET VICINITY

51	58	62
52	59	63
53	60	64

SHEET LOCATOR

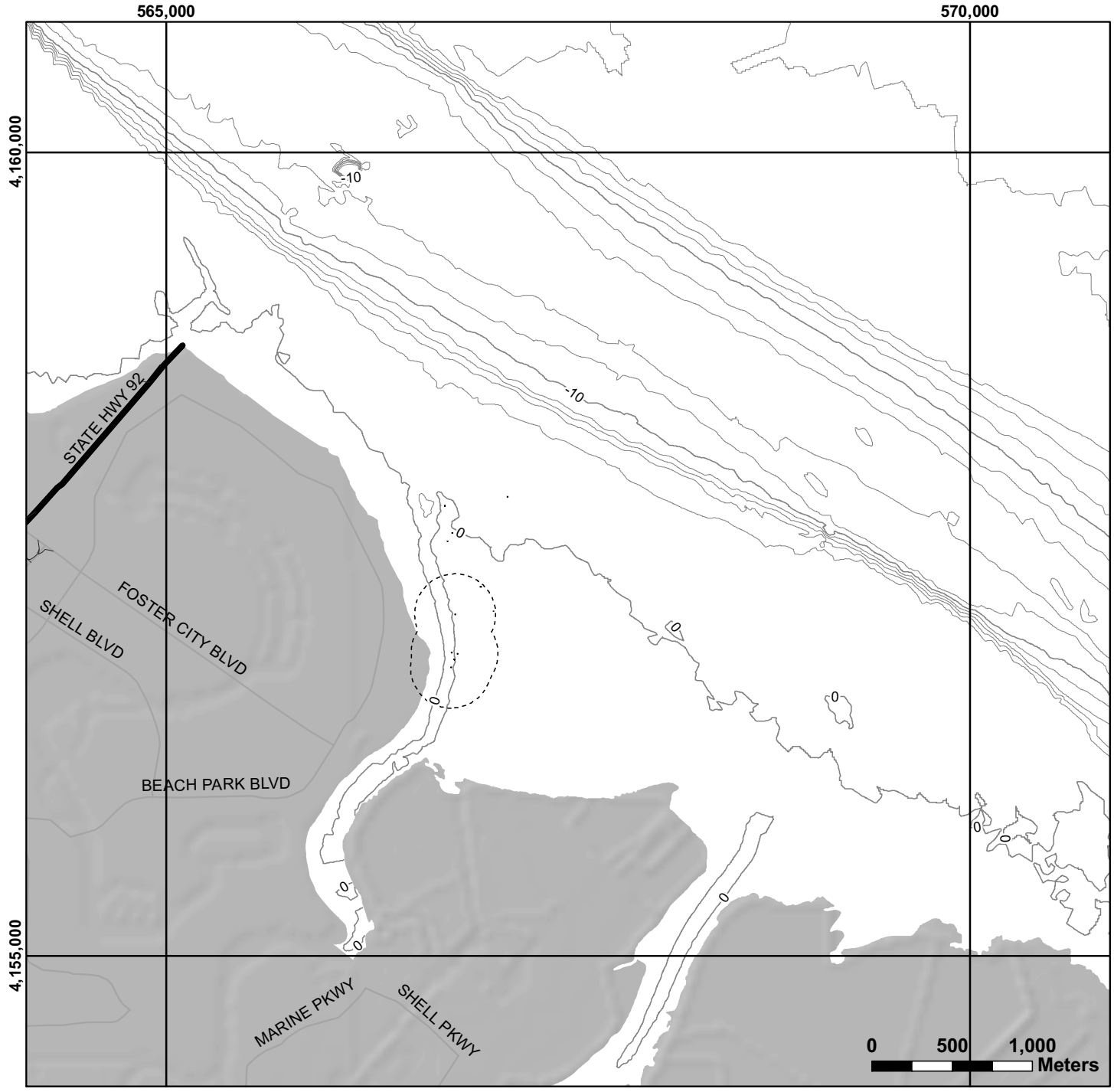


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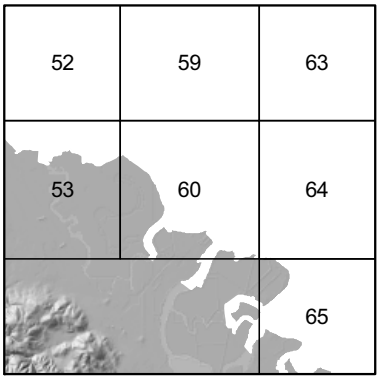
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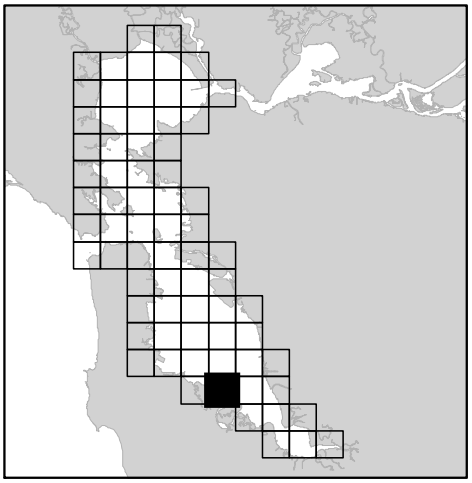
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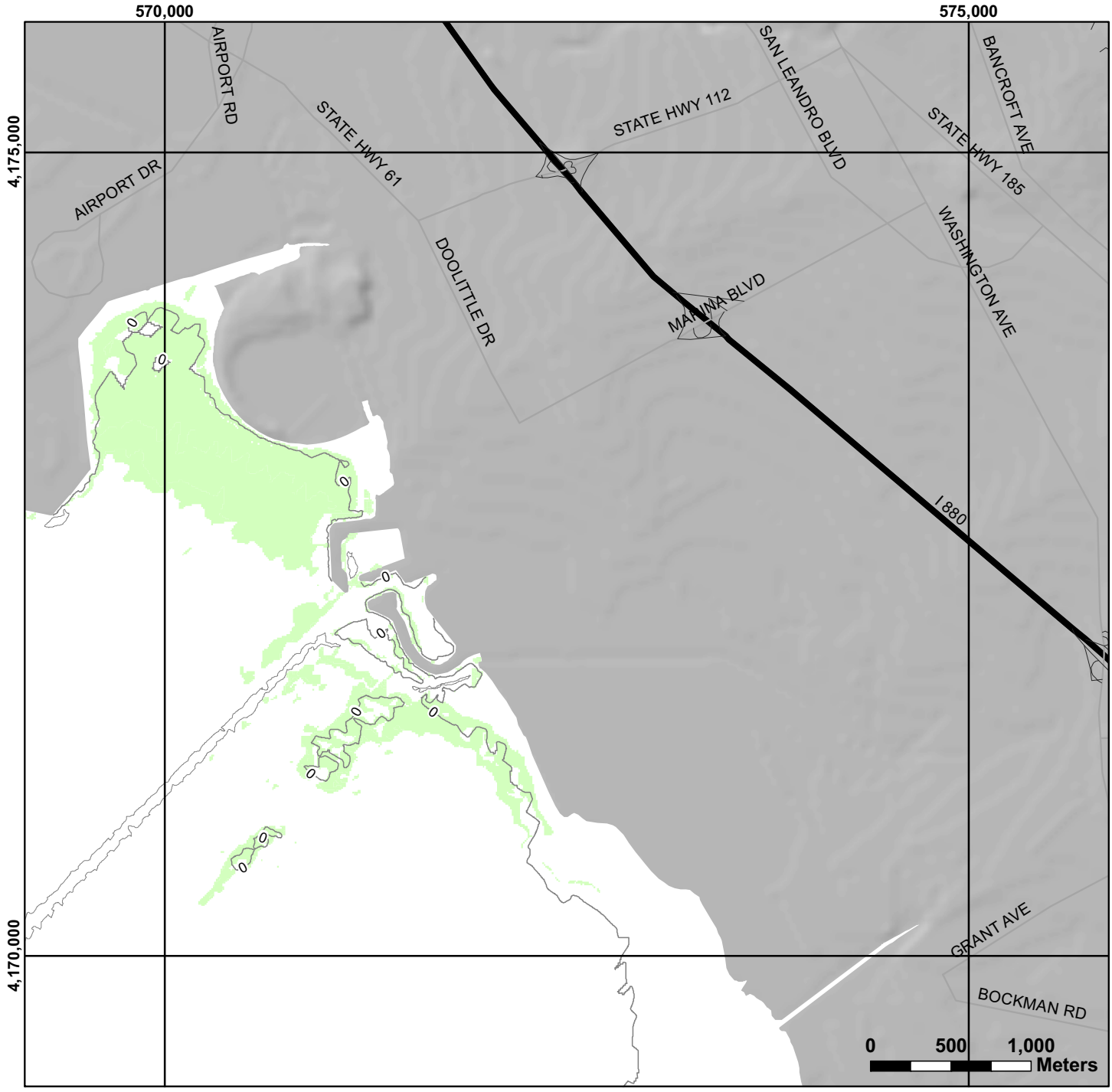
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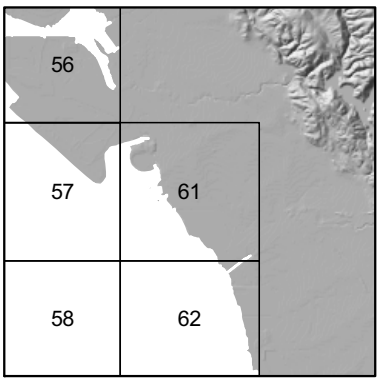
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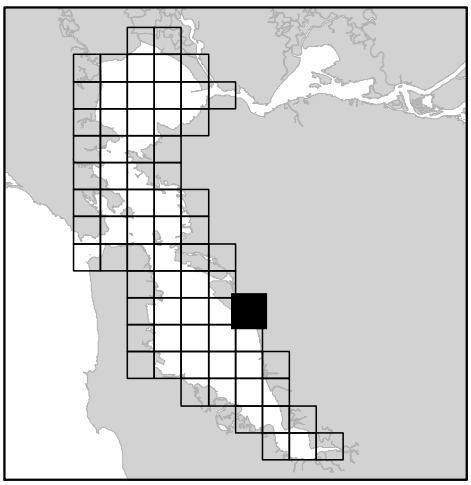
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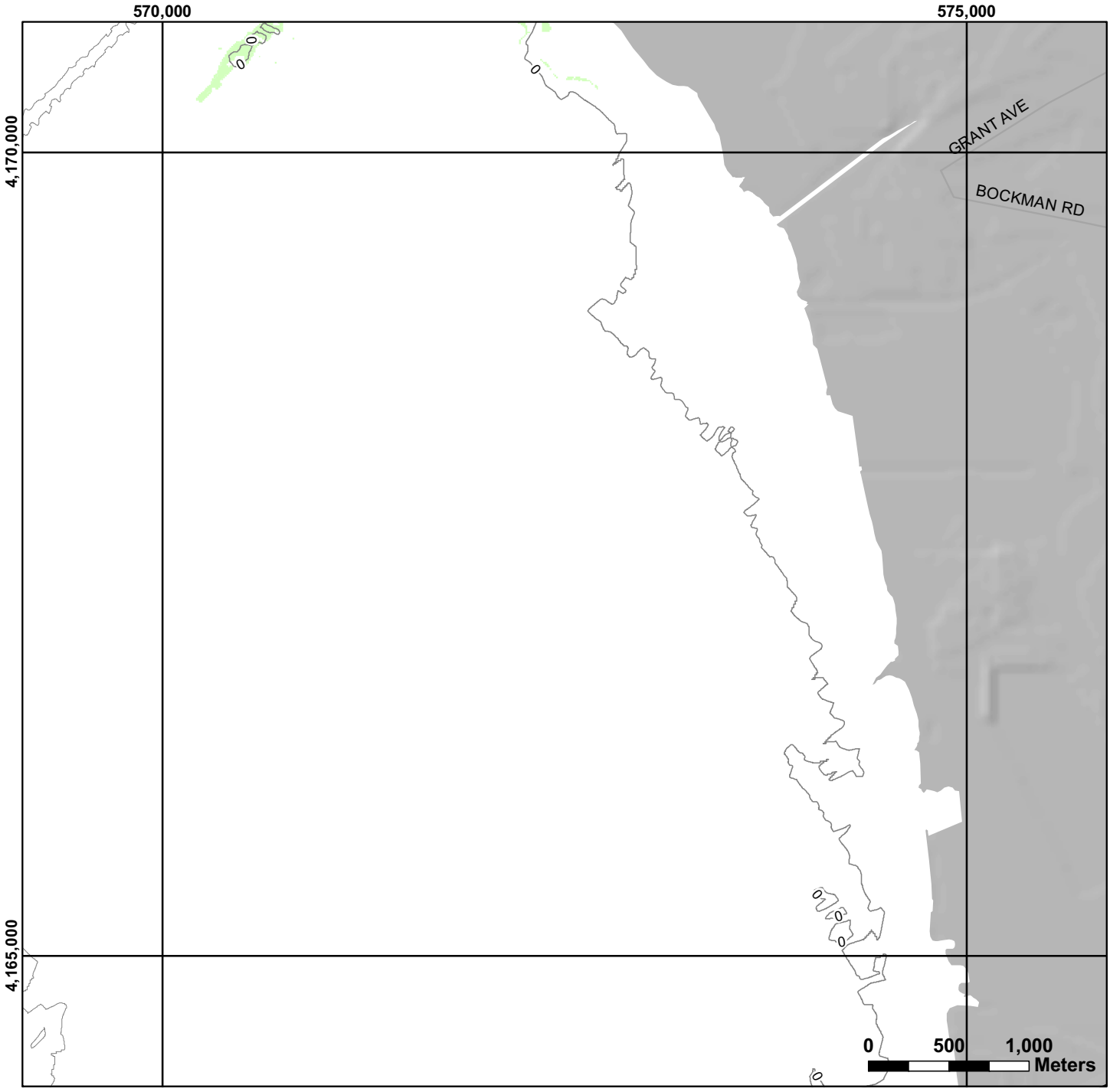
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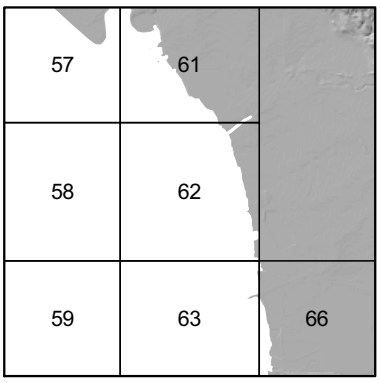
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Eelgrass 2009

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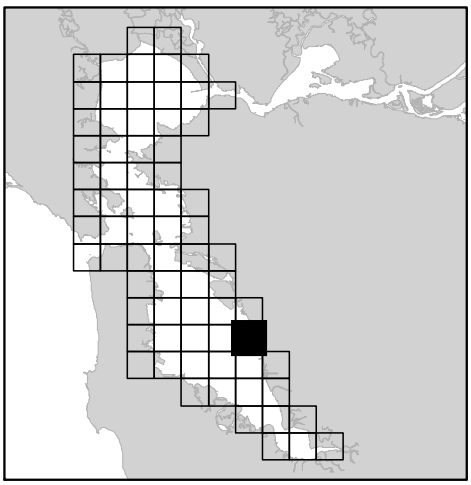
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SHEET LOCATOR

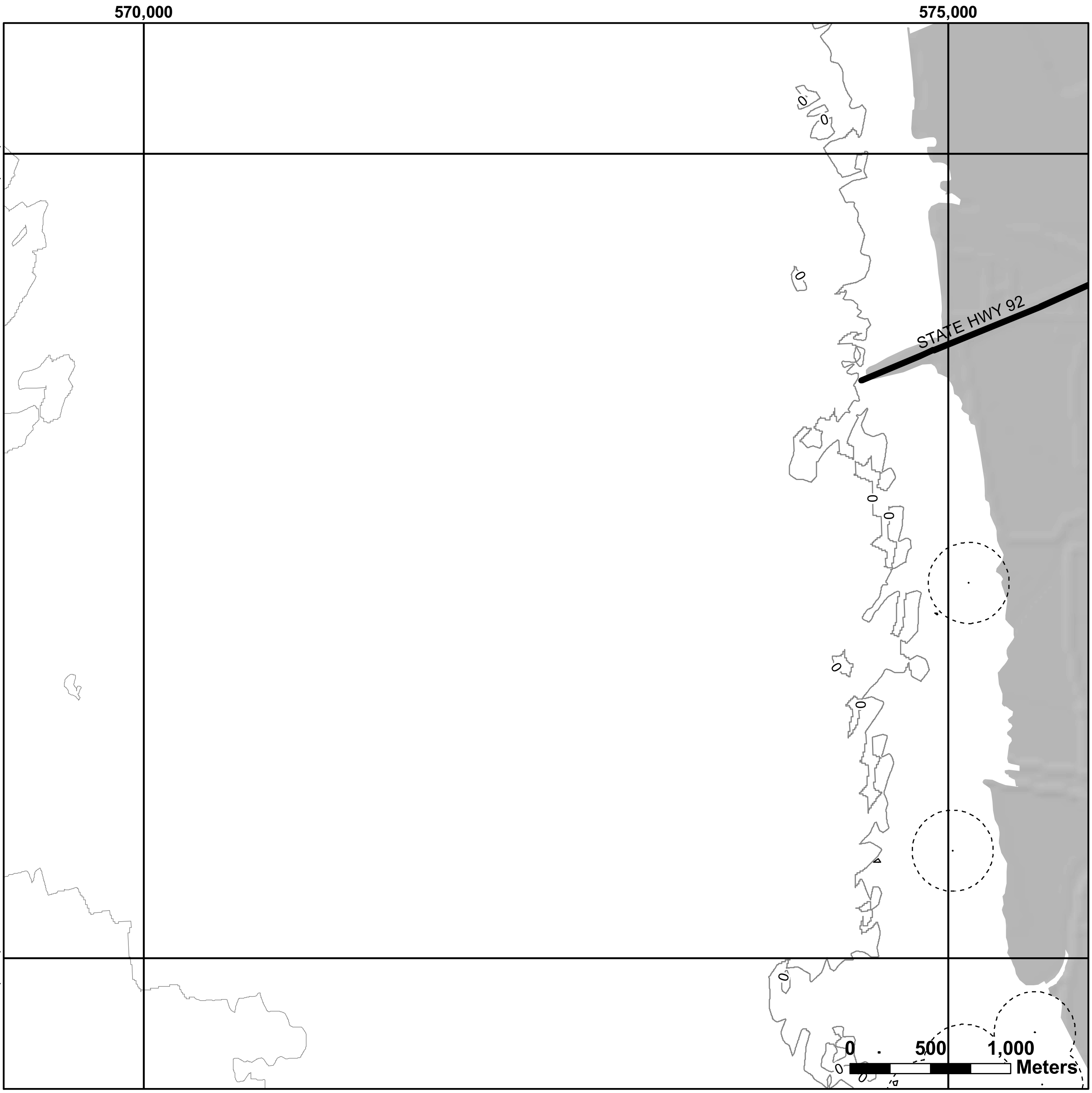


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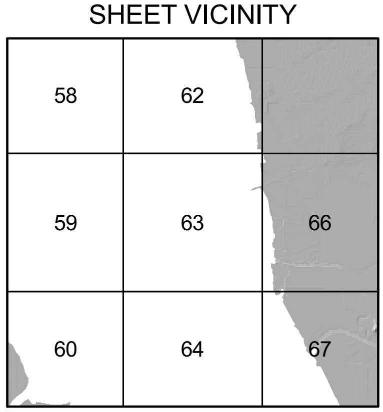
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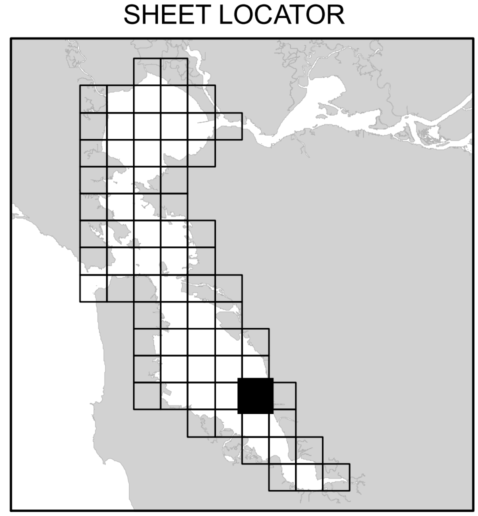
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Vertical Datum: MLLW (meters)

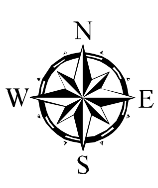
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SHEET VICINITY



SHEET LOCATOR

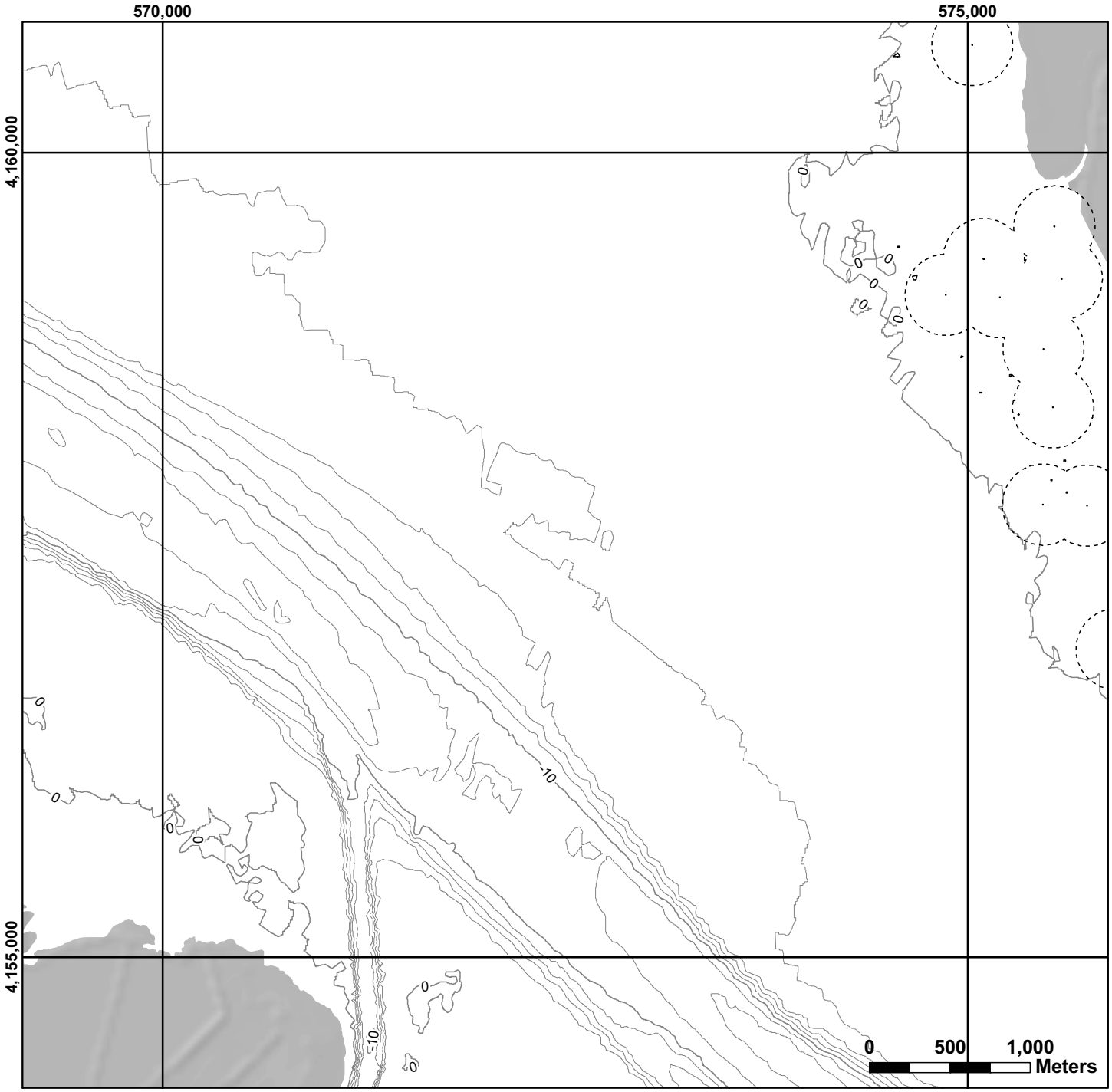




Eelgrass Coverage

1-5%
6-20%
21-40%
41-100%

Max Documented Eelgrass Extent
2009 Eelgrass 250m buffer
ELVS Predictive Model 2009



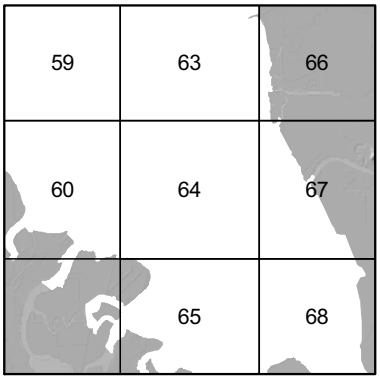
SAN FRANCISCO BAY, CALIFORNIA
Eelgrass 2009

Merkel & Associates, Inc.
San Diego, CA - Tel: (858) 560-5465

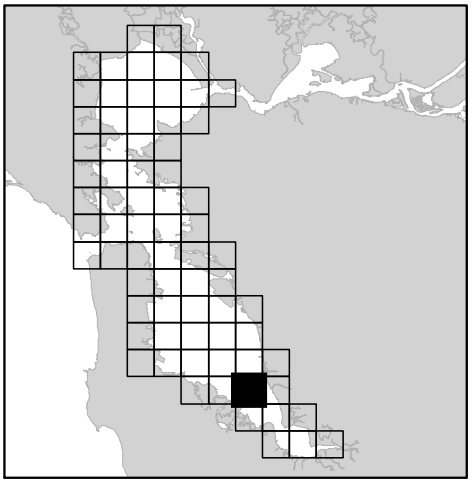
Horizontal Datum: UTM NAD83 Zone 10N
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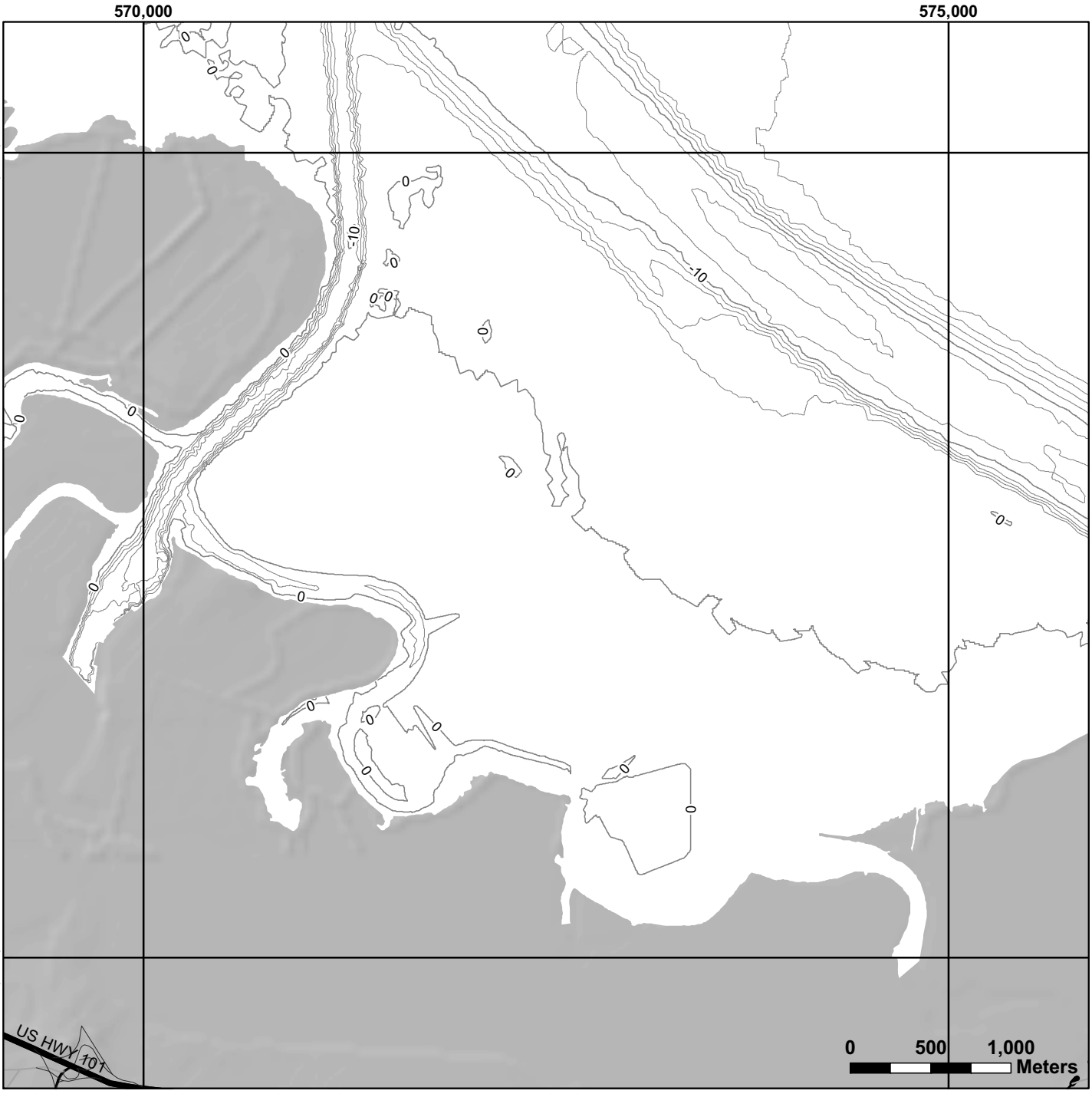




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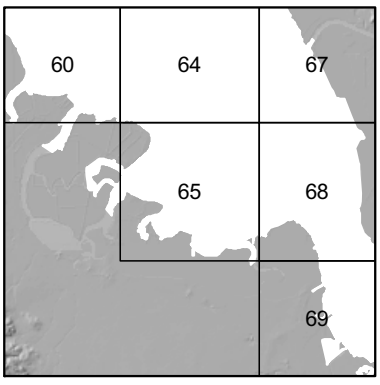
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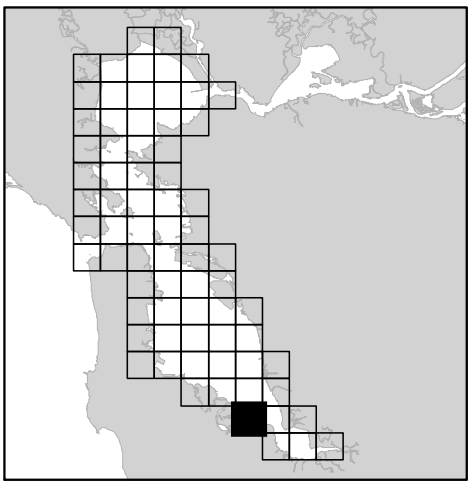
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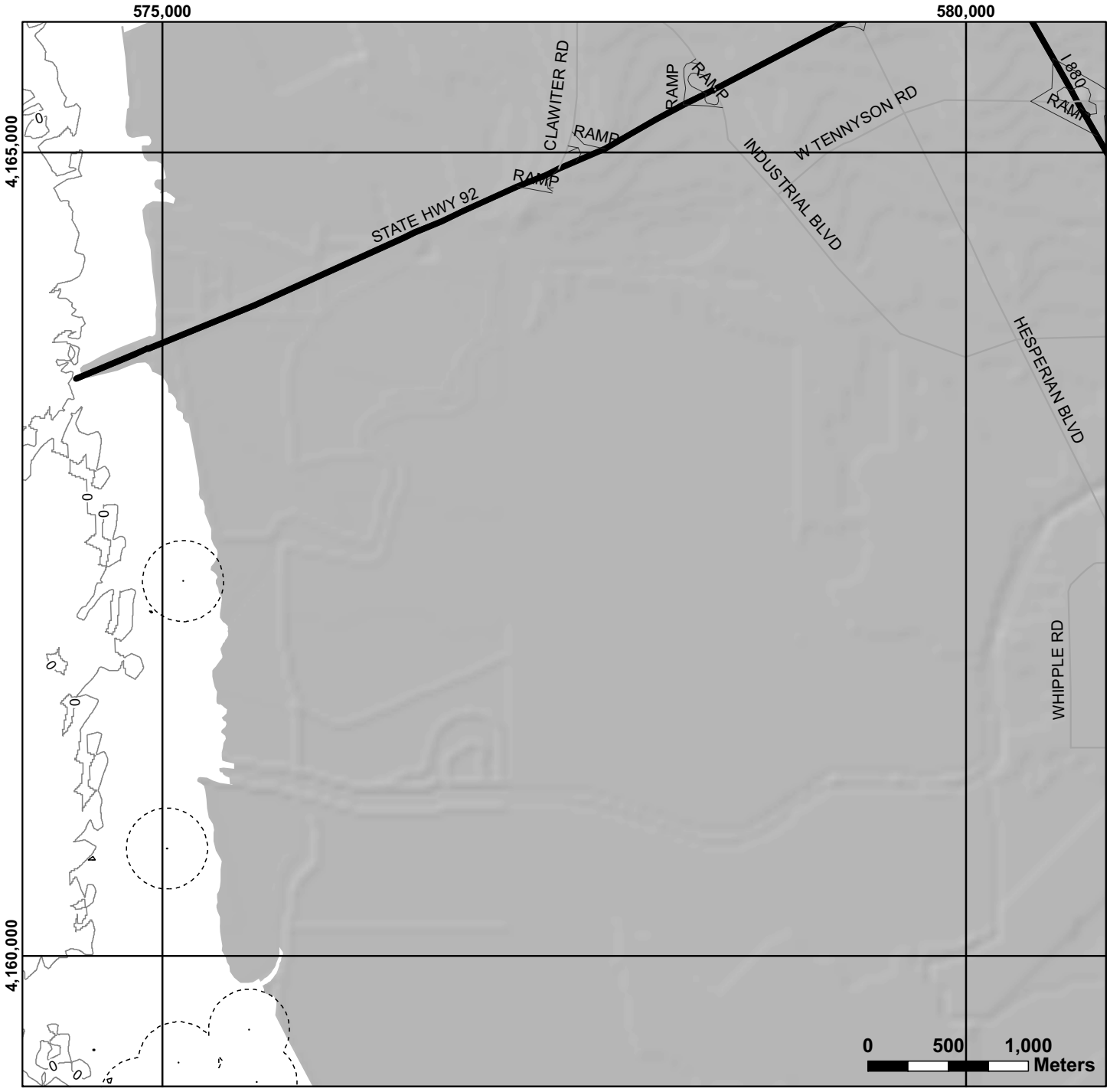




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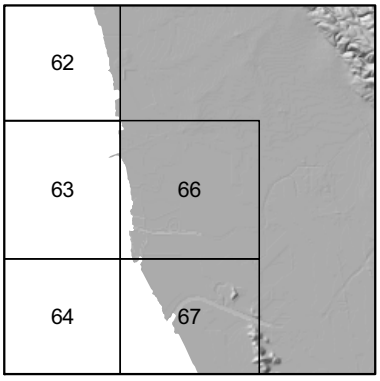
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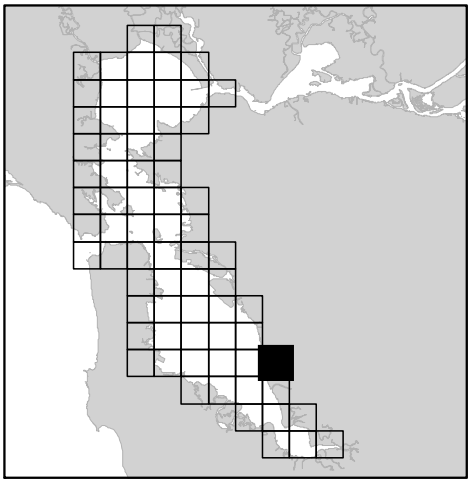
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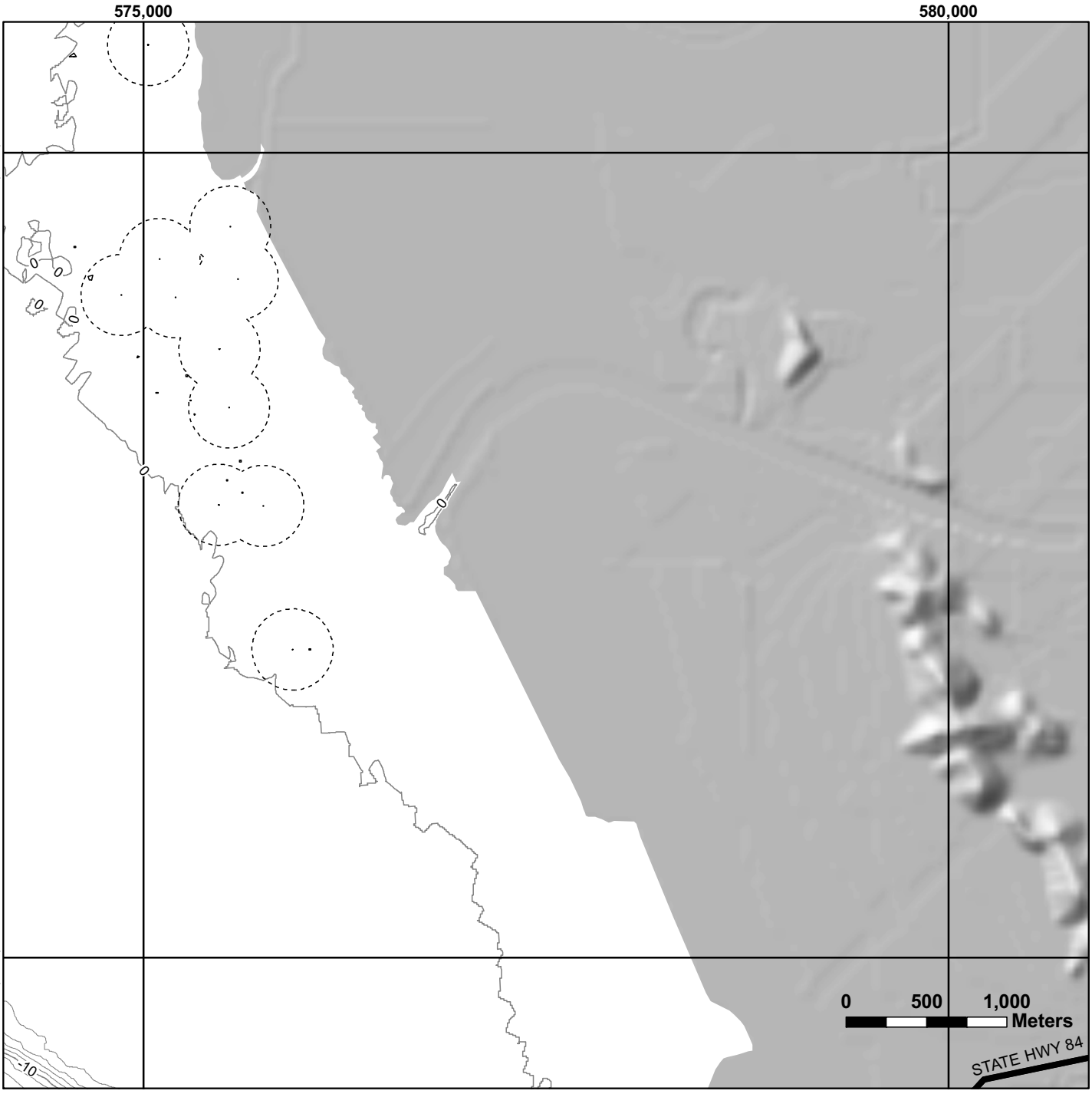




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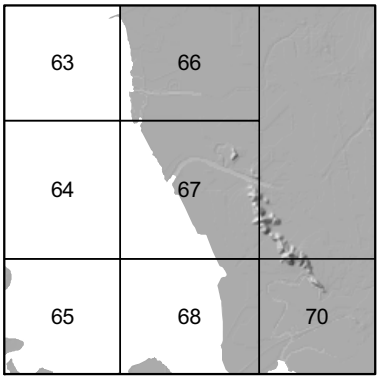
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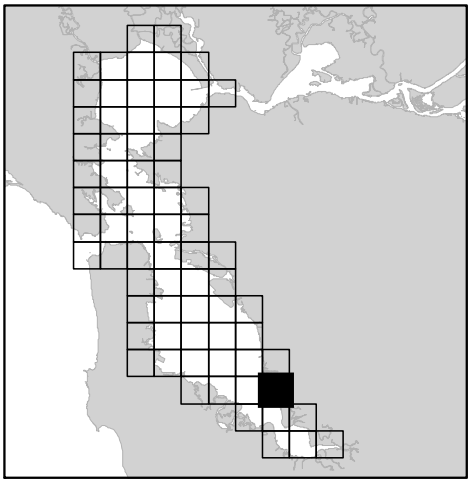
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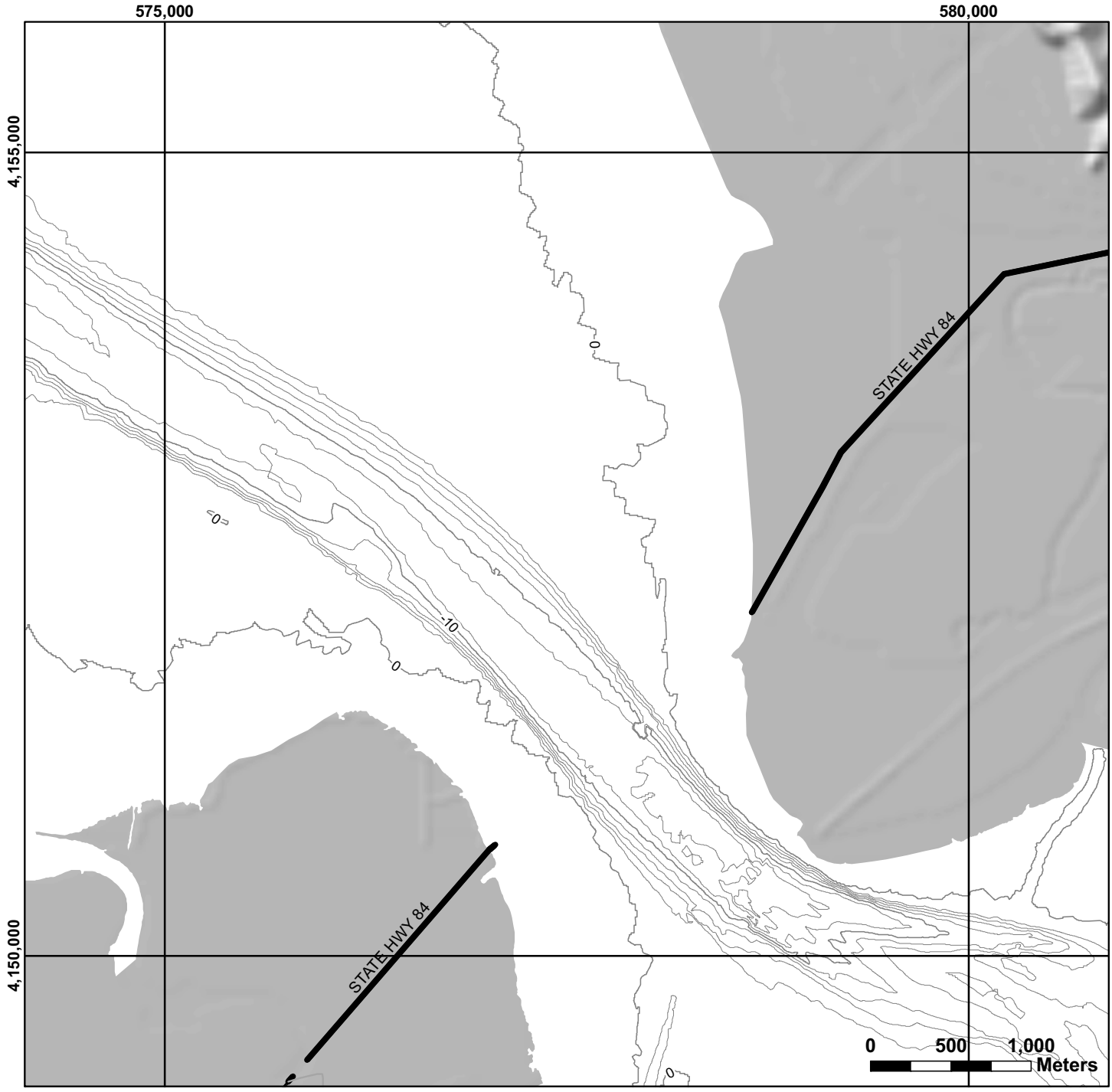


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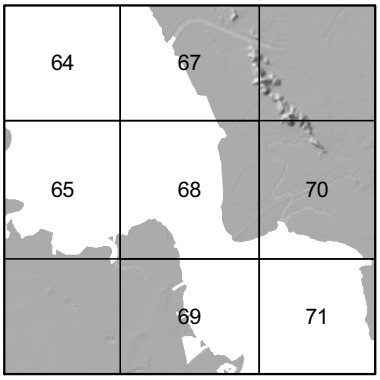
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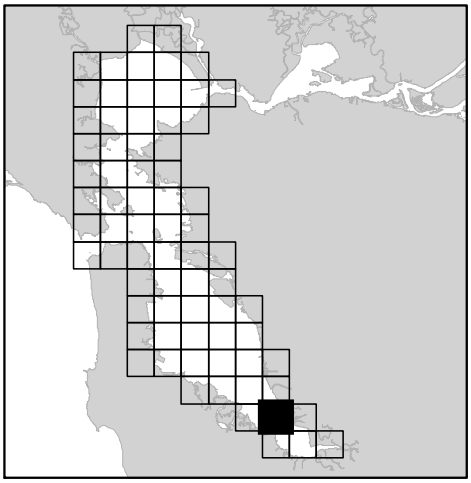
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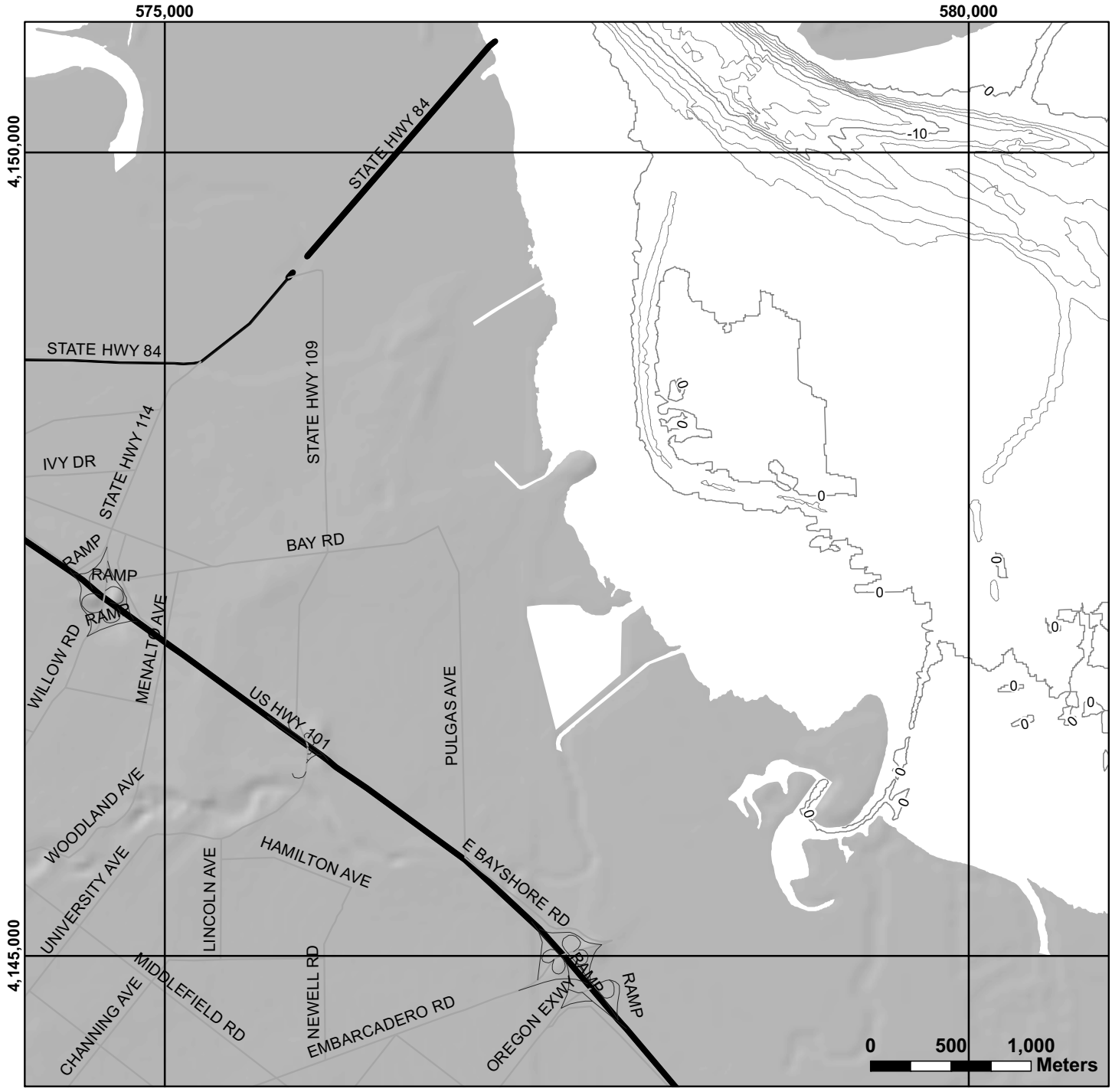




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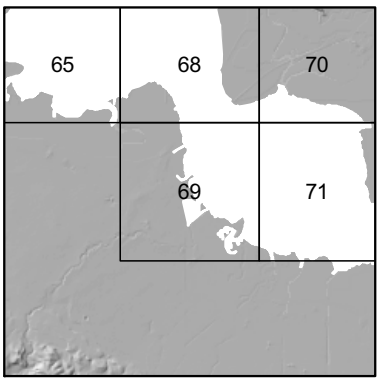
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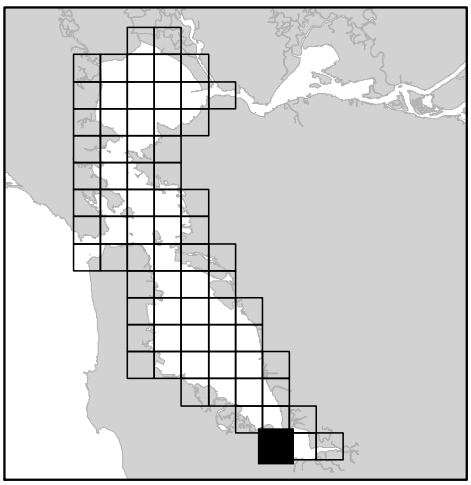
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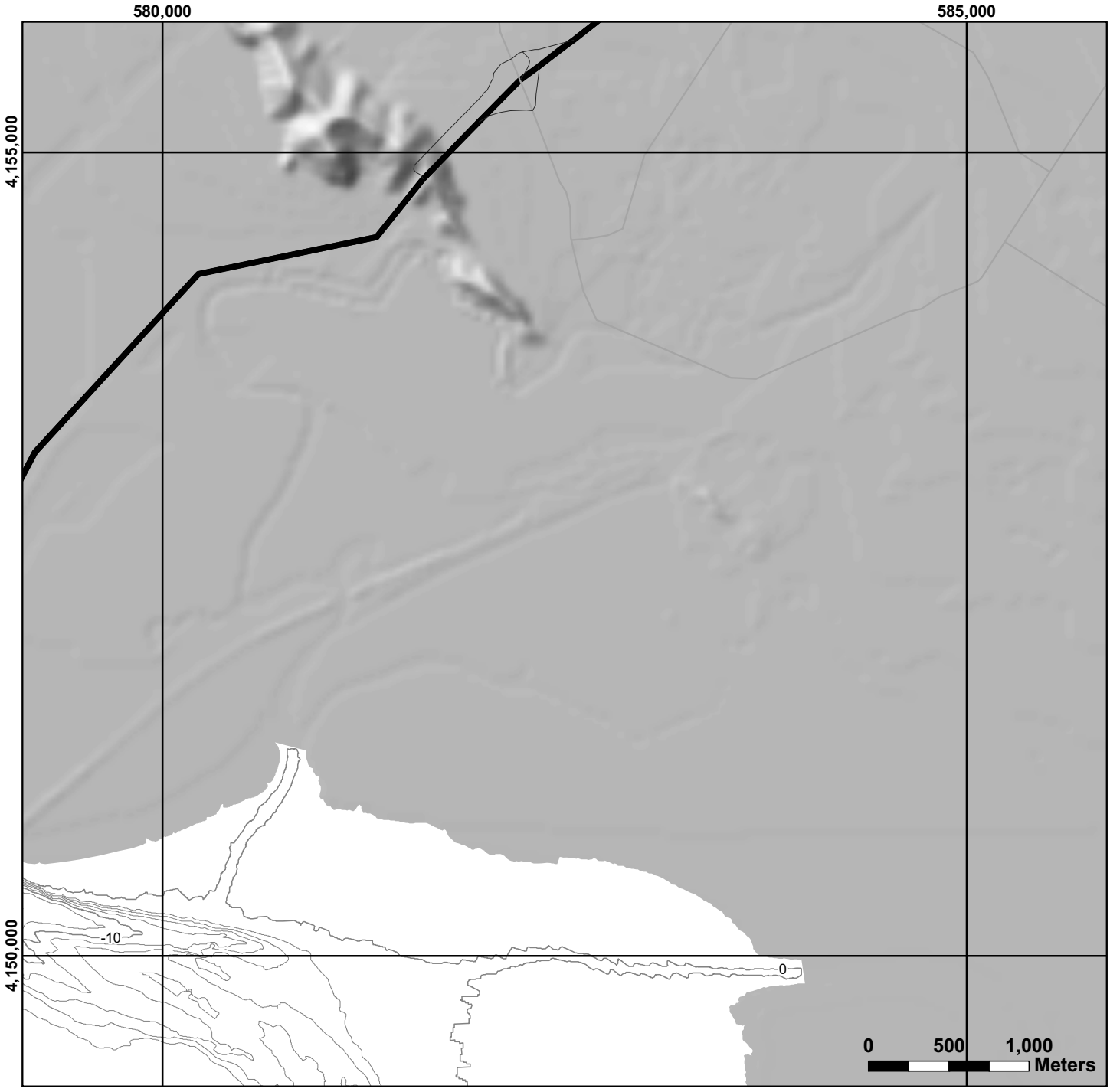
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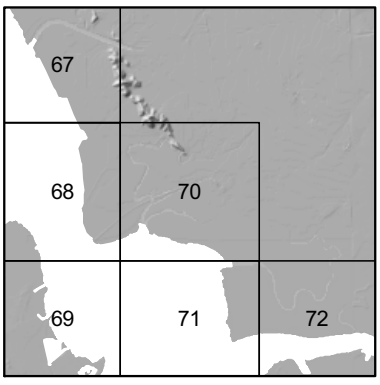
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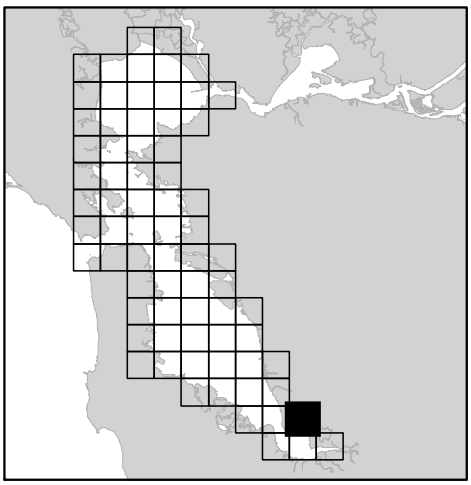
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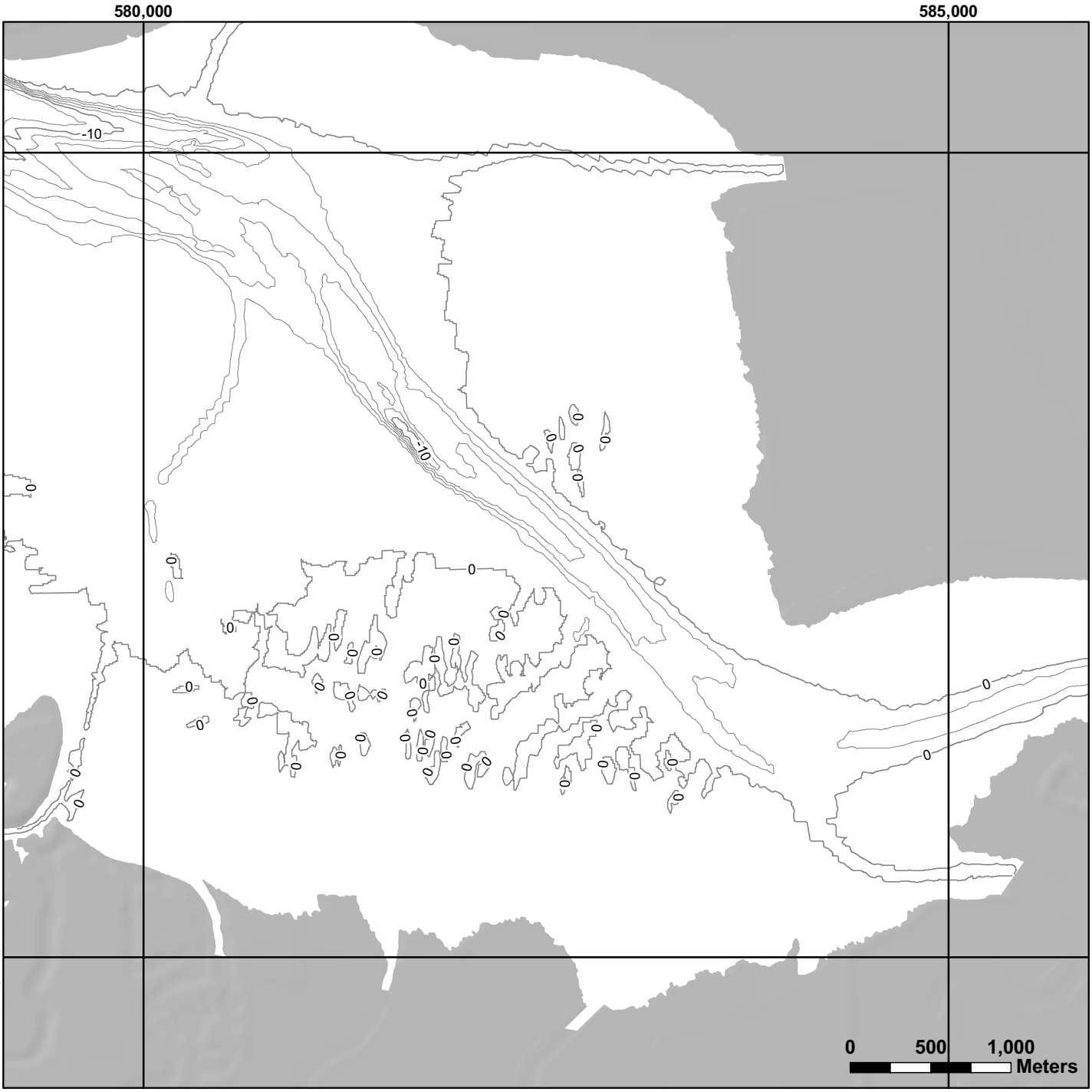




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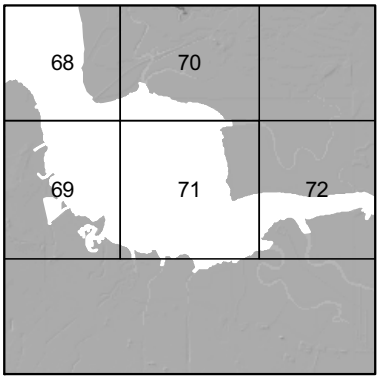
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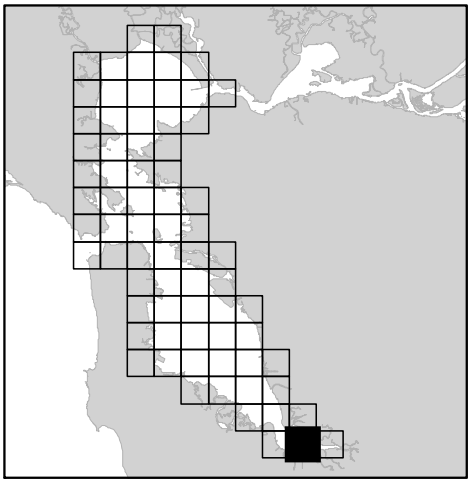
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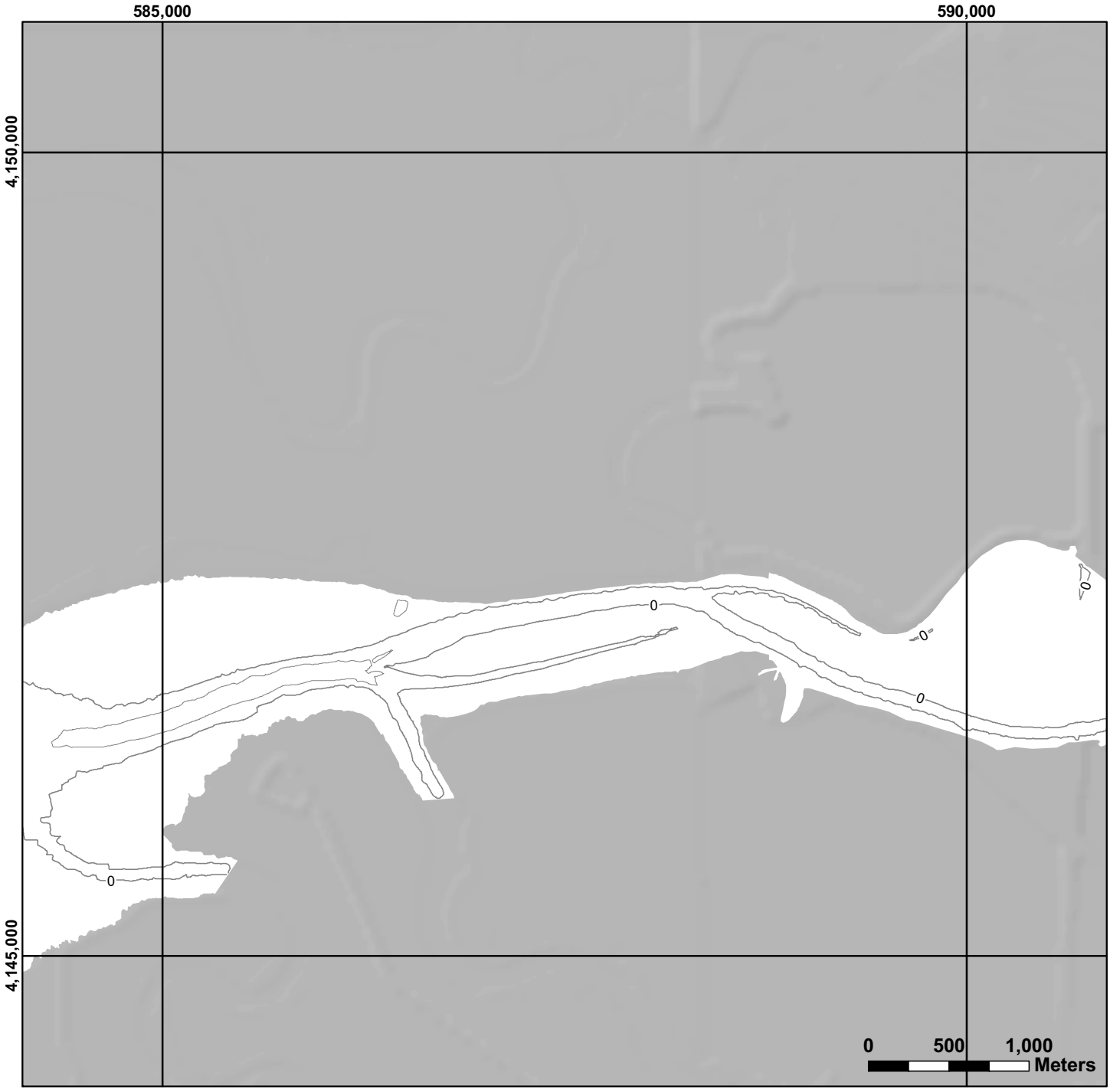
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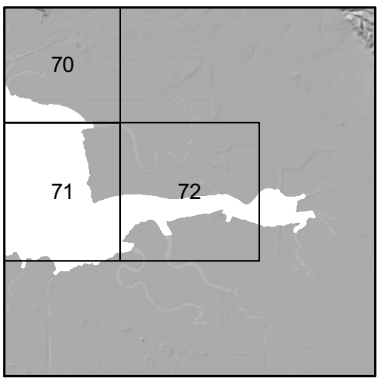
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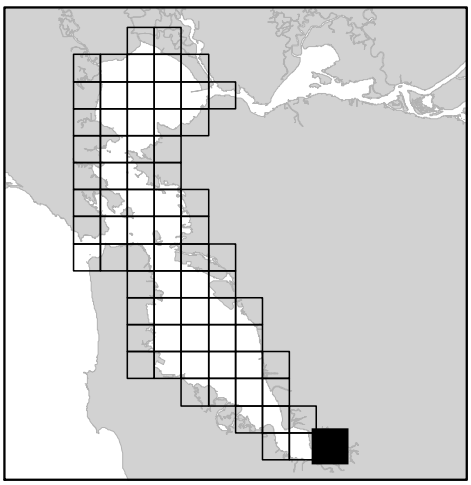
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