TIDAL WETLANDS RESTORATION POTENTIAL USING DREDGED SEDIMENTS: a methodology for assessment with examples from the North Bay Area

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Long-Term Management Strategy

Final Report

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1.0 EXECUTIVE SUMMARY

This report presents a numerical methodology to rank parcels of diked baylands of the San Francisco Estuary as potential sites for tidal marshland restoration using dredged sediments. This methodology is designed to identify sites of relatively high potential based upon empirical measures of minimum site-specific constraints for engineering, ecology, and land use. The intent is to provide a reasonable and fair overview of how different areas of diked baylands might be prioritized for tidal wetland restoration using dredged sediment, and to identify which constraints might be addressed to elevate the rank of any parcel. The geographic scope of this report is restricted to the baylands of the North Bay Area, including the diked baylands that surround San Pablo Bay, Central San Francisco Bay, and that attend the local rivers and creeks.

An atlas of the baylands of the San Francisco Estuary has been constructed as part of the proposed methodology, and to help facilitate other regional wetlands planning efforts. The Baylands Atlas shows the distribution and abundance of mudflats, tidal marshlands, and diked historical tidal marshlands downstream of the Delta. Individual parcels of baylands are defined by physiographic features, such as tidal channels and roadways, rather than ownership. Useful attributes of the Baylands Atlas for the North Bay Area include overlays of major infrastructure, land use zonation, seasonal ponding patterns, and regional data sets for avian resources. The Baylands Atlas exists on a vector-based Geographic Information System (ArcInfo) at the San Francisco Estuary Institute.

The proposed methodology attempts to account for differences in ecological, engineering, and human social constraints within and among the parcels of diked baylands. Existing ecological constraints are represented by the amount and pattern of seasonal or perennial ponding, and the potential ecological effects of tidal marshland restoration on adjacent waterways. Engineering constraints are represented by the existing amount and kinds of infrastructure, sediment fill capacity, and the ease of access to anchorage for off-loading dredged sediment. Human social constraints are represented by the potential conflicts between tidal marsh restoration and existing land use zonations. The proposed methodology scores each parcel for each of these constraints. The total score for each parcel is used to assess its overall potential for tidal marsh restoration using dredged sediment.

The methodology is illustrated with four example scenarios for tidal marsh restoration. The scenarios reveal some of the potential limitations of the Baylands Atlas, important gaps in scientific information, and obvious interactions between wetlands policy and the selection of parcels for tidal marsh restoration. The scenarios also reveal that subdividing or combining parcels can affect their restoration potential. The criteria for delimiting parcels should be revisited in this regard. The most critical gaps in scientific information surround the subject of suspended sediment supply. Simply stated, much more information is required about the sources, amounts, and distribution patterns of suspended sediment to remove uncertainty about the best available predictions of local sedimentation rates used in this report. A better understanding about local and regional supplies of suspended sediment will improve the predictions of sedimentation rate, which, in turn, will improve policies about the location, size, and schedule of tidal marsh restoration projects.

2.0 ACKNOWLEDGMENTS

This report was made possible through careful project management by Mr. Eric Larson of the San Francisco Bay Conservation and Planning Commission, and Mr. Rick Olejniczak, P.E., of Gahagan & Bryant Associates (GBH). Important technical contributions were made by Mr. Eric Polson of GBH for the analysis of fill capacities and off-loading distances, and by Ms. Sue Huse of the University of California at Berkeley, Department of Landscape Architecture, for levee mapping. Production of this report depended upon the Geographic Information System operated at the San Francisco Estuary Institute by Mr. Ted Daum. Despite the abundant contributions of these people, any incorrect statements contained in this report should be attributed to Mr. Joshua N. Collins, Ph.D., the principal investigator and lead author.

3.0 INTRODUCTION

Sediments that are dredged from the San Francisco Estuary could be used within the estuary to restore tidal marshlands. The careful placement of dredged sediments could re-establish appropriate intertidal elevations of the ground surface in diked baylands that have subsided, before they are returned to the tides. In this report, diked baylands are defined as areas of historical tidal mudflats and marshlands that have been isolated from the tides by the construction of dikes, levees, weirs, or other water control structures.

This potentially beneficial use of dredged sediments could be appropriate if natural sedimentation through tidal action is deemed too slow, relative to ecological or administrative schedules. For example, an urgent need to recover endangered species of tidal marshlands could lead to a decision to use dredged sediments to nurture tidal marshland accretion, or a legal agreement for mitigation might stipulate that certain elevations of some restored marshlands must be achieved faster than would probably occur through natural sedimentation.

Successful restoration of tidal marshlands requires clear ecological goals, for both the project specifically, and for the surrounding region (CCMP 1994, RMG 1995). For tidal marsh restoration projects using dredged sediment, ecological goals will dictate fill elevations. This is because tidal elevation strongly controls ecological functions. By dictating fill elevations, ecological goals will also affect project economics. This is because fill elevation affects sediment storage capacity, which affects the cost/benefit ratio of projects.

This report presents a numerical methodology to rank parcels of diked baylands of the San Francisco Estuary as potential sites for tidal marshland restoration using dredged sediments. This methodology is designed to identify sites of relatively high potential based upon empirical measures of site-specific constraints for engineering, existing ecology, and land use. The intent is to provide a reasonable and fair overview of how different areas of diked baylands might be prioritized for tidal wetland restoration using dredged sediment, and to identify which constraints at which sites might be addressed through site preparation or project design.

The methodology is illustrated with four restoration scenarios that vary with regard to ecological goals and fill elevation. The results from these scenarios should not be regarded as final planning directives in any case. Although the scenarios are useful illustrations of the how number and distribution of potential projects can depend upon ecological goals and fill elevation, using the results to make final selection of project sites is severely constrained by the unavailability of some important data. The results of the scenarios are particularly weak with regard to the assessment of dredged sediment fill capacity and tidal sedimentation rates. These weaknesses exist because accurate information about the tidal elevation of most of the diked baylands, and about their potential suspended sediment supplies, is not available. Collection of new information of this kind was beyond the scope of this report. Although the methodology may be appropriate, the results from the illustrative scenarios reported here should be regarded as preliminary.

Sites that have been identified herein as having high priority for tidal marsh restoration using dredged sediment should be subject to more thorough examination. The proposed methodology cannot replace more detailed site investigations of all the kinds of constraints generally treated here, and of other constraints that might also require investigation.

This is not an environmental impact assessment. The obvious alternative not to restore tidal wetlands or not to dispose of dredged sediments in diked baylands is not considered herein. The findings of this report cannot preclude specific investigations within a project site or other studies required to assess the impacts of tidal marsh restoration or dredged sediment disposal projects. This report is most useful to indicate what additional information must be compiled to improve the methodology and site assessments.

The results of the proposed methodology pertain only to the North Bay Area. For the purposes of this report, the North Bay Area is defined as the estuarine diked baylands surrounding San Pablo Bay and Central San Francisco, between the San Francisco Bay Bridge in the South, the Golden Gate Bridge in the West, the tidal reaches of Petaluma and Napa Rivers in the North, and the Carquinez Bridge in the East. Approximately 41,600 acres of diked baylands exist in the North Bay Area. Trial results of the proposed methodology are presented graphically as a series of maps produced in GIS ArcInfo (see the enclosed Appendices 3-7), and in tabular form as an Excel spread sheet (Appendix 1).

4.0 OUTLINE OF THE METHODOLOGY

The proposed methodology to assess and prioritize parcels of diked baylands for tidal marsh restoration using dredged sediment is briefly outlined below. Parcels of diked baylands are defined in Section 5.0. The details of the proposed methodology are provided in Sections 6.0 and 7.0. In the outline provided below, Parts A-C involve compilations of background information that can be conducted concurrently. The amount of time required to apply the methodology will vary with the geographic scope of the application and the availability of suitable input data.

The proposed methodology gives highest priority to parcels with the highest numerical assessments, which are the parcels where tidal marshland restoration using dredged material would be least constrained by existing ecology, engineering, and land use.

Part A: Ecological Constraints

A1. Measure the potential on-site wetlands resources as the areas of diked baylands, excluding unnatural ditches, that tend to be saturated or covered by standing water during some part of the wet season of most years.

A2. Using a standard table or schedule, score the parcel with regard to the amount of wet season ponding on the ground surface.

A3. Also measure the potential on-site wetlands resources as the shoreline development, or ponding complexity, of the ponding area. Ponding complexity is measured as the ratio between the observed length of shoreline, and the minimum length of shoreline, for the observed ponding.

A4. Using a standard schedule, score the parcel for ponding complexity.

A5. Measure the potential off-site ecological impacts as the length of adjacent tidal channels that would be affected. Channel length is measured from the edge of the parcel to the nearest major tidal source, which is either the shoreline of a river or a bay.

A6. Using a standard table or schedule, score the parcel with regard to distance to tidal source.

Part B: Engineering Constraints

B1. Measure the off-site engineering constraints as the distance along a straight line from the center of the parcel to the nearest place in a bay or river to anchor barges for off-loading dredged sediment.

B2. Using a standard table or schedule, score the parcel with regard to off-loading distance.

B3. Based upon the parcel elevation and selected fill elevations, determine the on-site engineering constraints as the capacity of the parcel for dredged sediment. Determine capacity corresponding to three potential fill elevations: local Mean High Water (MHW), 0.5 feet below local MHW (MHW - 0.5 ft), and 0.5 feet above local Mean Higher High Water (MHHW + 0.5 ft). These datums approximate the fill elevations to meet different sets of ecological objectives, as explained in Section 7.0 of this report.

B4. Using a standard table or schedule, score the parcel with regard to fill capacity for each of the three selected fill elevations.

B5. Also measure the on-site engineering constraints as the number of different kinds of buried or above-ground physical infrastructure, such as roads, electrical transmission lines, or buried pipelines, that exist at the parcel and could be obstacles to tidal marsh restoration.

B6. Using a standard table or schedule, score the parcel with regard to physical infrastructure.

Part C: Social Constraints

C1. Identify and map the different kinds of land use zones that exist within the parcel, or at its boundaries.

C2. Using a standard table or schedule, score the parcel with regard to land use compatibility to tidal marsh restoration.

Part D: Parcel Ranking

D1. Sum all the scores for each parcel.

D2. Rank the parcels based upon their total scores.

Part E. Example Scenarios of Tidal Marsh Restoration

E1. Based upon the best available information about parcel elevation, and about the distribution and abundance of suspended sediment in the tides, estimate the potential, natural rate of sedimentation for each diked baylands parcel.

E2. Use the Regional Wetlands Ecosystem Goals or other guidelines as a geographic template for preliminary selection of diked baylands parcels as candidate sites for tidal marshland restoration using dredged material.

E3. Based upon the results of E1 above, and according to the prevailing consensus of opinion about the minimum amount of time appropriate to achieve the target elevation through natural sedimentation, identify which of the parcels selected in step E2 would receive dredged sediments.

5.0 DIKED BAYLANDS PARCEL DEFINITION AND IDENTIFICATION

The diked baylands of the North Bay Area are catalogued in GIS (Geographic Information System) ArcInfo (ESRI, Inc.) at the San Francisco Estuary Institute as the Baylands Atlas (SFEI; see Appendix 2). The version of the Baylands Atlas used for this report is based upon the Digital Line Graphs (DLG's) of the U.S. Geological Survey (USGS), the most recent USGS 7.5 minute quadrangle sheets, the USGS historical uplands boundary of tidal marshlands (Nichols and Wright 1971), and 1:58,000 false color infra-red (CIR) photography dated April 1985. The CIR photography was produced by the National Aeronautics and Space Administration (NASA) High Altitude Mission Program at the Ames Research Center (NASA-Ames), under contract to the U.S. Fish and Wildlife Service (FWS) for the National wetlands Inventory (NWI; Peters and Bohn 1987).

The DLG's were used to portray the roadways, bridges, pipelines and overhead utility lines that traverse the baylands. The USGS 7.5 min. quadrangle sheets were used to digitize the systems of levees that immediately surround and subdivide the diked baylands. The historical upland boundary of tidal marshlands was used as the uplands boundary for diked baylands, when other indications such as levees or roadways were not apparent. The bayward shoreline or tidal boundary of diked baylands was adopted from the NWI. The NASA-Ames CIR photography was used to detect wetlands features within the diked baylands (e.g., see Sections 6.1.1 and 6.1.2 below).

Combinations of the following kinds of tidal channels and unnatural levees were used to delimit individual parcels of diked baylands: perimeter levees (i.e., levees that keep the tides out); internal levees that support a light-duty truck road (i.e., a gravel or maintained dirt road); or larger roadway (i.e., a highway or a railroad), tidal channels that extend from the bayshore to the upland; and tidal channels that are connected to the bayshore at both ends, such that they surround a bayland and make it an island. Parcels of diked baylands do not necessarily correspond to real estate parcels.

Some small parcels of diked baylands were excluded from the version of the Baylands Atlas used for this report. A small parcel is less than 15 acres in area, based upon engineering and economic constraints (see Section 6.2.2 below). Parcels smaller than 15 acres were combined with other parcels less than 0.25 miles apart. Isolated small parcels farther apart than 0.25 miles have engineering and economic constraints that cannot be mitigated, and these parcels were therefore deleted from the list of candidate sites for tidal marshland restoration using dredged sediment.

The resulting Baylands Atlas was reviewed by the federal, California state, and regional agencies with regulatory or major operational interests in the baylands, and by representatives of the non-governmental organizations most concerned about wetlands conservation in the Bay Area, including the Save San Francisco Bay Association, the Citizens Committee to Complete the Refuge, and the Marin Chapter of the Audubon Society. The purpose of the review was to verify the boundaries and the classification of the baylands. The comments from reviewers achieved this purpose, and were incorporated into the Baylands Atlas. However, incorporation of the comments does not indicate that the reviewers necessarily agree with this report. The Baylands Atlas for the North Bay Area is presented as Appendix 2.

6.0 DATA CLASSIFICATION AND PARCEL SCORES

Each diked baylands parcel was scored with regard to seven different kinds of constraints. Three relate to ecology; three relate to engineering; and one relates to social issues. The ecological constraints are represented by: (1) average area of ponded water within the parcel; (2) shoreline development, or ponding complexity, of the average ponded area; and (3) off-site potential losses of wetlands. The latter constraint relates to the potential scour of existing tidal marshlands within tidal channels adjacent to a restoration site. The engineering constraints are represented by: (4) on-site existing infrastructure; (5) existing fill capacity; and (6) off-loading distance. The latter relates to the practicality of getting dredged sediments to a site. The social constraints are represented by: (7) existing and potential land use conflicts.

Discrete classes or groups of data were identified for each of the seven kinds of constraints. The data were classified to distinguish between high, low, and intermediate levels of each constraint. The distribution of the data for each constraint was continuous, however, with few obvious breaks in distribution that could be used to define discrete classes. The form of the distribution varied among the constraints, but was not normal in any case. Therefore, the identification of data classes mostly relied upon intuitive reasoning about the number of classes that would be useful to represent the variability of each kind of constraint, and professional judgment about the relationship between levels of a constraint and the practicality of tidal marshland restoration using dredged sediment. The chosen number of classes and their rationale has been reviewed by sponsoring agencies for this report and their peer review teams. A discussion about the subjectivity and flexibility of the classification is included in this report (see Section 8.0 below).

The number of data classes was mainly set with regard to engineering. The rationale to classify the data are especially evident for fill capacity and off-loading distance. Eight classes were chosen to reasonably represent the apparent variability in these two constraints. The number of data classes was standardized among all seven kinds of constraints to create a balanced treatment without undue weighting of one constraint relative to another. No attempt was made to prioritize or emphasize any kind of constraint.

A linear scale from 1 to 8 plus zero (i.e., 0,1,2,4,5,6,7,8) was used to score each of the eight data classes for each of the seven kinds of constraints. Non-linear scales were rejected because they necessarily involve large assumptions about scale effects on the relationship between the levels of a constraint and the associated costs or benefits of tidal marshland restoration. While it may be predicted that the financial costs associated with engineering constraints decrease rapidly for sites larger than some threshold size, the data are not available to identify that threshold, or to predict how parcel size affects local or regional ecological functions. Furthermore, reasonable expectations about such scale effects can be represented by a linear set of scores. For example, a linear scale can be applied to a series of data classes representing increasingly large levels of constraint. The use of a zero value score permits the identification of sites that have very low potential for tidal marshland restoration using dredged sediment.

A total score for restoration potential was calculated for each diked bayland parcel as the sum total of values 0 through 8 assigned to each of the seven kinds of constraints. The highest possible total score for a site is therefore 56. A high total score indicates greater restoration potential. Each total score is dependent upon its component scores, but the total scores for different parcels are independent of each other. No assumption or analysis is made of how the constraints or opportunities for tidal marshland restoration at one parcel affect that of another parcel, although effects of these kinds among parcels might be expected.

6.1 Ecological Constraints

The ecological constraints are chosen to fairly represent the expected major ecological support functions that could be diminished by conversion of diked baylands into tidal marshlands. The major ecological support functions can be classified as on-site and off-site.

The on-site constraints relate mainly to the support of plants and wildlife of seasonal or perennial wetlands. Emphasis on the wetland functions of the diked baylands is not meant to discount the value of terrestrial natural resources that are supported by some diked baylands. For example, the levees of some diked baylands support colonies of burrowing owls, and the grasslands of some diked baylands may be important forage and breeding habitats for terrestrial songbirds and small mammals. Terrestrial ecological support functions are not well documented for the diked baylands, however. The wetlands resources are better documented, are relatively easy to represent (see section 6.1.1 below), and are the natural resources most often cited as rationale for the conservation of the diked baylands.

The emphasis on wetland functions is also not intended to discount the value of farming, ranching, or recreation. These human social functions are herein regarded as human social constraints on tidal marsh restoration (i.e., existing and potential land use; see Section 6.3 below).

This report regards the loss of some existing tidal marshland, and declines in regional support of waterfowl and shorebirds, as the primary potential off-site ecological impacts that might be negatively affected by conversion of diked baylands to tidal marshland. The potential for these negative impacts depends upon the design and schedule of tidal marsh restoration for the region, which is unknown at this time, and therefore cannot be represented numerically as a constraint. The possible local losses in tidal marshland can be represented, however, based upon the expected pattern of scour and erosion of tidal marshland in channels near the restoration sites. Estimates of this possible loss are therefore used to represent the off-site ecological constraints.

6.1.1 On-Site Ecological Constraint #1: Average Area of Ponding

The amount of ecological support provided by a parcel of diked bayland is expected to be positively related to the area of ponded water. However, ponding varies seasonally and from year-to-year. High-resolution color infra-red (CIR) photography is the chosen tool to integrate across this temporal variability in ponding pattern. CIR aerial photography reveals a signal from edaphic (i.e., soil) conditions that are caused by repeated saturation. The same photography also reveals spatial variations in plant species vigor and plant community composition that can be used to help delimit wetlands. Ponding pattern is illustrated in Appendix 3.

The evidence of ponding consists of color patches indicative of either standing water or sediments that have been saturated repeatedly during the wet seasons of many years. CIR aerial photography can therefore be used to develop a measure of ponding that integrates across the temporal variability. The evidence was collected from the NASA-Ames CIR aerial photography (scale 1:58,000) dated April 1985. The photography was scanned at 600 to 800 dpi and 24 bit color, using a Microtek Scan Maker III. The digital image was then imported to Photoshop 4.0. Using tools provided by Photoshop, individual areas that are usually subject to ponding were outlined. The smallest areas outlined were less than 0.25 acres small. The outlines of areas that tend to have ponded water were imported to ArcInfo, and geo-rectified using the Baylands Atlas.

All efforts to measure the plan view form (e.g., as seen from above in orthogonal aerial photographs) of wetlands areas share the problem of having to define the wetlands boundary. Wetland boundaries tend to be "feathered", due to small-scale spatial variations in micro-topography, soil conditions, and plant cover. The problem can be simplified through the use of small-scale aerial photography that does not reveal unnecessary detail about the wetlands margin. For the purposes of this report, the CIR photography provided by NASA-Ames meets this objective, by showing patches of wetlands less than 0.25 acres with distinctive outlines that can be easily traced or digitized. The problem can be complicated, however, by the fractal nature of wetlands in plan view. The length of a fractal boundary varies with the unit of measurement, with shorter units of measurement producing longer measures of length. Image scale and the unit of measurement were therefore standardized. Using Photoshop 4.0, the CIR images were enlarged to a standard operating scale 1:12,000. The wetlands boundaries were digitized at a frequency of 200 measurements per inch of cursor travel.

The wetlands boundary thus defined probably omits some amount of the ecotone between the wetland and the upland, such that the total acreage of what might be formally, or legally delineated as wetland is underestimated. Comparable pictures of wetland extent have been produced, however, through this method and field reconnaissance. Visits to parcels SP163, SP208, SP299, and SP2004 during March and April 1994, February 1995, and during December 1995 validated the photographic evidence.

The ecological meaning of this ponding measure varies among the parcels. For parcels that support farming or grazing, the measure represents potential support for dabbling waterfowl, shorebirds, and other resources associate with shallow, seasonal wetlands. For parcels with large amounts of perennial open water, such as salt evaporators, the measure might also represent potential support for diving birds, wading birds, and some fishes. The species composition of these resources might vary with either soil or aqueous salinity regime.

The schedule of scores for the eight data classes that represent the average amount of ponding is presented below as Table 1 below. Figure 1A (see page 11) shows the correlation between ponding area and parcel size. The two kinds of measures are not statistically related to each other, except in the cases of salt evaporators and other unnatural structures designed as seasonal or perennial water storage compartments. In these cases, parcel size and ponding area are either the same, or positively auto-correlated.

6.1.2 On-Site Ecological Constraint #2: Ponding Complexity

The amount of ecological support provided by diked baylands is also expected to relate positively to the complexity of the wetland boundary. More complex boundaries indicate more environmental variation per unit area of space, which should result in steeper species-area curves and greater species richness overall (Pielou 1969, Forman and Godron 1986, and many others). Ponding complexity is therefore an indirect assessment of potential biological diversity of wetland living resources.

The conventional index of shoreline development (Wetzel 1975) was used to assess ponding complexity. The index is a comparison between two ratios: the numerator is the ratio of circumference to surface area for a patch of wetland, and the denominator is the same kind of ratio for a perfect circle of the same surface area as the wetland patch. Thus, a circular wetland has an index of 1.0. The schedule of scores for the eight data classes that represent ponding complexity is presented below as Table 2. Ponding pattern is revealed in Appendix 3.

Table 1: Schedule of scores for parcel classes based upon the on-site ecological constraint #1: average area of ponding.

ACRES OF PONDING	SCORE
0	8
1 - 5	7
6 - 10	6
11 - 15	5
16 - 20	4
21 - 50	3
51 - 110	2
111 - 200	1
201 or more	0

Table 2: Schedule of scores for parcel classes based upon the on-site ecological constraint #2: ponding complexity.

PONDING COMPLEXITY INDEX	SCORE
0	8
1.0 - 1.9	7
2.0 - 2.9	6
3.0 - 3.9	5
4.0 - 5.9	4
6.0 - 7.9	3
8.0 - 10.9	2
11.0 -12.9	1
13.0 - 16.0	0

Figure 1: Correlation between (A) parcel size and the average area of ponding within parcels of diked baylands; (B) pond shoreline complexity and average area of ponding; and (C) parcel scores for pond complexity and ponding area.

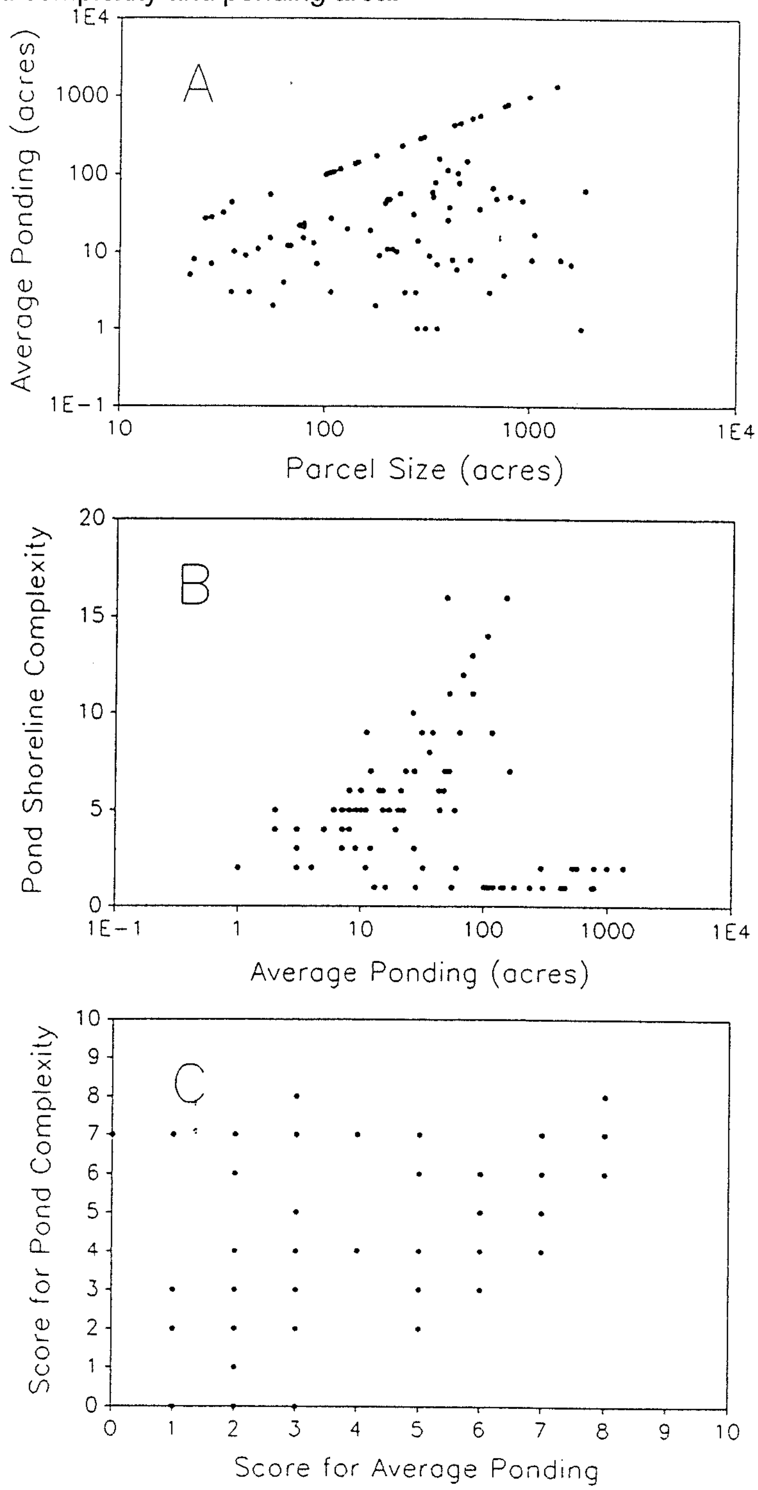


Figure 1B above shows the relationship between pond complexity and ponding area. The two measures show a weak positive correlation, which may partly be a scale effect. The small-scale spatial variability that dominates the outline of small wetlands might not be revealed in the aerial photography that was used to measure ponding complexity. Furthermore, some of the larger areas of ponding represent aggregations in GIS of many smaller areas with complex shorelines. The index of ponding complexity is probably biased in favor of natural wetlands, since they tend to be more complex.

Figure 1C above shows the correlation between the scores for ponding area and the scores for pond complexity. Although the data for the two measures are weakly correlated (see Figure 1B), their scores are not.

6.1.3 Off-Site Ecological Constraint: Distance to Tidal Source

The geomorphic suitability of a diked bayland parcel for tidal marshland restoration can be represented by a single measure, the minimum distance between the parcel and an adequate tidal source. This simple measure assumes that tidal elevations at the site would be controlled by sediment placement. Sites further removed from the bay shoreline or river edge are usually less suitable for tidal restoration. This is because distant sites are usually adjacent to remnants of historical sloughs that have become shallow and narrow in response to reclamation of surrounding tidal marshlands, and the concomitant loss of tidal prism. The remnant sloughs are mostly incompetent as tidal sources for the purpose of large-scale tidal marshland restoration. Some diked bayland parcels are essentially land-locked at this time. Furthermore, the down-sizing of the sloughs in response to nearby reclamation is accomplished by the formation of mudflats and tidal marshlands within the historical watercourses. These kinds of newly evolved intertidal environments can represent some important ecological resources that can be scoured away by the increase in tidal flows promoted by adjacent tidal marshland restoration.

The simple measure of distance from bayshore or river edge disregards the direct relationship between size of parcel and size of tidal source required to restore the parcel as tidal marshland. A small parcel might be serviced by a small channel. Almost all parcels in the North Bay Area are large, however, as depicted by the Baylands Atlas (see Appendix 2 and acreage column of Appendix 1), requiring greater tidal flow for restoration than the remnant tidal marshland channels can provide, without modification. The relatively small parcels together do not comprise significant potential for dredged sediment storage in the North Bay Area.

The distance between a parcel and the nearest river edge or bay shoreline can be measured across land or along the course of an historical slough. The preferable measure is not obvious. Use of an historical slough as a tidal source might incur the loss of some recently evolved tidal marshland, as explained above, but might cost less than the excavation of a new watercourse. The difference in cost is also not obvious, since either approach would involve some excavation and levee maintenance. Based upon practical experience, the unit cost of constructing a new channel is expected to be greater than the cost to adjust an existing slough. Furthermore, any construction of a new channel from one parcel across an adjacent parcel might impose constraints upon what could be done to facilitate restoration of the adjacent parcel. These considerations lead to the decision to use the existing network of tidal channels as a template for measuring distance to the nearest tidal source, except for parcels that are landlocked behind one or more other parcels. In such cases, the shortest distance across the land to the nearest tidal channel or shoreline was measured.

Table 3: Schedule of scores for parcel classes based upon the off-site ecological constraint: distance to tidal source.

DISTANCE (ft)	SCORE
0 - 100	8
101 - 500	7
501 - 1000	6
1001 - 5000	5
5001 - 10,000	4
10,001 - 15,000	3
15,001 - 25,000	2
25,001 - 35,000	1
35,001 or further	0

The method outlined above may be contrary to existing plans for tidal marshland restoration at some diked baylands. For example, there is a preliminary recommendation to construct one or more channels through tidal marshlands south of Highway 37, to provide tidal action to SP163 (Culinan Ranch) directly from San Pablo Bay (Johnson et al. 1994). But according to the method outlined above, the nearest tidal source for SP163 is the Napa River, via Dutchman Slough. For the purposes of this report, the Napa River is assumed to be the tidal source for parcel SP163. A difference in selected tidal source also affects the prediction for sedimentation rate, since the shallows of San Pablo Bay adjacent to Highway 37 probabaly carry more suspended sediment than either the Napa River or Dutchman Slough (see section 8.2 below for further discussion of sediment supply).

6.2 Engineering Constraints

The engineering constraints have been selected to represent two different practical aspects of using dredged sediment to convert diked baylands into tidal marshland: on-site constraints imposed by fill capacity and existing infrastructure, and off-site constraints imposed by distance to off-loading locations.

6.2.1 On-Site Engineering Constraint #1: Infrastructure

Infrastructure consists of the total of physical facilities, excluding buildings, that have been constructed to support human society. At the scale of landscapes, typical elements of infrastructure include pipelines, sewer lines, roadways, electrical transmission lines, and telephone cables. These kinds of features are included on USGS 7.5 min. quadrangle topographic sheets, and can therefore be represented by digital data with reference to spatial coordinates. Certain kinds of these features that represent lines across the landscape, such as roadways and transmission lines, are available as public domain digital data. In addition to these data files, information on the locations of effluent discharge structures and historical and existing landfills has been compiled. Together these data comprise a picture of major infrastructure for each diked baylands parcel throughout the North Bay Area. These data have been imported into ArcInfo as data layers of the Baylands Atlas. Information that might be useful in future assessments of restoration potential would include maps of diked baylands that are dedicated to flood water storage.

Infrastructure tends to constrain opportunities for tidal marsh restoration by increasing costs for project design, implementation, and maintenance. In many cases, infrastructure must be moved or protected to permit adequate tidal exchange across a site. In these regards, surface and overhead infrastructure is less of a constraint because it can be elevated. Buried infrastructure is a greater constraint because it often cannot be elevated without great expense, and it usually cannot be subjected to additional weight, as would result from placement of dredged sediment over the buried infrastructure, or from natural sedimentation by the tides. Infrastructure can also increase the risk of ecological problems. For example, roadways can be barriers to wildlife migration and dispersal, and they can also be corridors for invasive terrestrial predators. Overhead electrical transmission lines can physically interfere with the movements of waterfowl and raptors. Discharge structures and historical landfills can be especially important as point-sources of contaminants. The schedule of scores for infrastructure is presented below as Table 4 (see page 15).

6.2.2 On-Site Engineering Constraint #2: Fill Capacity

The existing tidal elevation of diked bayland parcels in the North Bay Area is a critical factor to determine their suitability for tidal restoration. Once the average tidal elevation of a parcel is determined, then the depth of fill or excavation required to modify the parcel to intertidal habitat can be calculated. Sediment storage capacity can be derived from the calculated depth of fill.

For the purpose of this analysis, the two appropriate tidal datums are local Mean Higher High Water (MHHW), and local Mean High Water (MHW). These are convenient datums of known precision and historic convention for reckoning tidal elevations of the land surface. However, most existing data for the elevations of diked baylands refer to the National Geodetic and Vertical Datum of 1929 (NGVD 1929), as established by the National Geodetic Survey (NGS), not to tidal datums. The estimated elevations of parcels relative to MHHW and MHW therefore depend upon a calibration between MHHW and NGVD 1929, and between MHW and NGVD 1929. A reasonable calibration is evidenced by published data for the North Bay Area as presented below in Table 5 (see page 15).

Table 4: Schedule of parcel scores with regard to the on-site engineering constraint #1: infrastructure. For this constraint, each parcel was given a starting score of 8, and then whole integer values were subtracted based upon the expected level of landscape resistance to restoration due to infrastructure, according to the following schedule. The starting score could be reduced by more than one subtracting value.

INFRASTRUCTURE	SUBTRACT VALUE
levees only	0
light-duty road	1
1 overhead transmission tower	1
2 or more overhead towers	3
railroad or highway	3
buried utilities	4
landfill	6

Table 5: Relationship of MHHW and MHW to NGVD 1929 for selected subordinate stations of the National Oceans Survey (NOS) in the North Bay Area.

NOS Station	Description	MHHW (ft) as NGVD 1929	MHW (ft) as NGVD 1929
914-4873	Point San Quentin, San Francisco Bay	3.00	2.54
914-4881	Point San Pablo, San Pablo Bay	3.02	2.43
914-5056	Point Pinole, San Pablo Bay	2.94	2.34
914-5165	Mare Island Straight	3.21	2.66
914-5252	Petaluma River Entrance, San Pablo Bay	3.28	2.66
914-5338	Sonoma Creek, San Pablo Bay	3.39	2.84

The tidal elevations of some diked baylands remain uncertain for at least four reasons. First, many of the parcels have not been surveyed. Second, elevations reported on Untied

Stated Geological Survey (USGS) topographic maps are interpolations between broad contours that do not usually extend below 0.0 NGVD 1929 and are also estimates. Third, the accuracy of existing survey data cannot be ascertained in every case. Fourth, the relationship between NGVD 1929 and tidal datums, as reported by the NOS for subordinate tide stations, is not strictly reliable due to lags in time between recertification of NOS and NGS benchmarks. For example, the NOS does not usually determine the integrity of NGS benchmarks used to refer MHHW and MHW to NGVD 1929. Given these uncertainties about tidal elevations, and given that the tidal regimes among the parcels once restored is largely unknown, the following approximations of NGVD 1929 elevation for MHHW and MHW were used (see Table 6 next page).

The average existing elevations of diked bayland parcels were determined from USGS 7.5 minute quadrangle topographic maps, existing information from LTMS reports and other governmental documents, and limited field reconnaissance. For parcels that lacked topographic data, elevations were extrapolated from information for adjacent parcels.

The sediment storage capacity of a diked bayland is equal to the product of parcel size and the difference between fill elevation and the existing average ground elevation, plus the additional capacity created by ground or foundation consolidation. The existing foundation soils at most sites consist of organic soils of the historical tidal marshlands. These types of soils will consolidate and compress under the weight of dredged sediment. Therefore, foundation consolidation must be considered in estimates of sediment storage capacity, and to insure that final fill elevations are consistent with ecological goals.

Table 6: Sub-regional calibration for the relationship of MHHW and MHW to NGVD 1929.

SUBREGION OF THE NORTH BAY AREA	**MHHW (ft) as NGVD 1929**	**MHW (ft) as NGVD 1929**
Between U.S. Highway 101 and State Highway 29, North of the South Fork of Galinas Creek, and North of Carquinez Straight	3.2	2.7
East side of San Pablo Bay, between Point San Pedro and Pinole Point	3.0	2.3
West side of San Francisco Bay between Point San Quentin and San Clemente Creek	3.0	2.4

For the purpose of this report, estimates of foundation consolidation are conservative (on the low side) to avoid over estimating storage capacity. The estimates of storage capacity only reflect the short term consolidation that would typically occur during the first two years after tidal restoration. Longer term consolidation would be slower, and could be offset by natural sedimentation. The amount of short term consolidation assumed in this analysis is a function of the thickness of the fill, regardless of parcel size, as reported below in Table 7.

Table 7: Schedule of foundation consolidation.

FILL. THICKNESS (ft)	CONSOLIDATION (ft)
Less than 3.0	0.0
Less than 7.0	0.5
Less than 11.0	1.0
11.0 or more	1.5

For the purpose of this report, two types of habitat are considered. For high tidal marsh (including the vegetated high marsh plain and areas of tidal ponds or other seasonal wetlands), a fill elevation of MHHW plus 0.5 feet was used. For low tidal marsh, a fill elevation of MHW minus 0.5 feet was used. Storage capacities for all sites were calculated for both high and low marsh. The data for sediment storage capacity were classified according to an economic rationale. Parcels with very large capacity have a much lower unit cost. Thresholds between data classes were selected to minimize borderline cases. The schedule of scores for fill capacity is shown below as Table 8.

Table 8: Schedule of parcel scores for the on-site engineering constraint #2: fill capacity.

PARCEL CAPACITY (cubic yards)	SCORE
Less than 100,000	0
Less than 250,000	1
Less than 500,000	2
Less than 1,000,000	3
Less than 2,000,000	4
Less than 3,000,000	5
Less than 4,000,000	6
Less than 5,000,000	7
5,000,000 or more	8

6.2.3 Off-Site Engineering Constraint: Off-loading Distance

The cost to deliver dredged sediment to a parcel may constrain the potential of the parcel for tidal marshland restoration relative to other parcels, based on cost/benefit considerations. The cost of sediment delivery is related to the ease of access to an off-loading area, and the distance from the off-loading area to the parcel. In the North Bay Area, dredged sediment would usually be delivered to an off-loading area in a barge or scow, and pumped from there to the parcel through a pipeline, as a water-sediment slurry.

Areas for off-loading dredged sediment are selected for safe anchorage, minimum obstruction of navigation, minimum ecological disturbance, and minimum distance to the parcel. An off-loading area should also be located with consideration to the number of parcels that can be effectively serviced, to avoid the cost of frequently moving the equipment.

There are two basic kinds of access to off-loading areas. A deep water access has a minimum depth of 15 ft below Mean Lower Low Water (MLLW), and will accommodate a fully loaded large scow (i.e., 3,000 cubic yard capacity). A restricted or shallow water access has a minimum depth of 8 ft below MLLW, and will usually accommodate a fully loaded small scow, a partially loaded large scow, and may accommodate a fully loaded large scow on extreme high tides.

The optimal distance of the pipeline route from an off-loading area to a parcel is not always the shortest distance, due to a variety of factors. Many potential problems must be avoided, including those listed below. Based upon the available information about these kinds of potential problems, the optimal pipeline routes between the parcels and known or potential off-loading areas were selected.

- Disturbance of ecologically sensitive areas;
- Long stretches of open water where floating pipelines tend to be subject to wind and wave damage;
- Blocking or restricting navigation channels;
- Costs and problems associated with crossing roadways, railroads, and other infrastructure;
- Commercial and residential areas involving safety and liability hazards;
- Significant changes in elevation that affect pumping costs.

Parcel scores for off-loading constraints reflect both the ease of water access to an off-loading area and the pumping distance to the parcel. Deep water access provides the highest score because it decreases the number of required scow trips and generally increases the cost effectiveness of sediment delivery. For pumping distances greater than approximately

1.5 to 2.0 miles, a booster pump is typically required. The use of a booster pump will substantially increase sediment delivery costs. The schedule of scores for the off-loading constraints data is presented below as Table 9.

Table 9: Schedule of parcel scores based upon the off-site engineering constraint: off-loading distance. Separate schedules are used for deep water and shallow water off-loading areas.

Pumping Distance (statue miles)	**Score Deep Water Access**	**Score Shallow Water Access**
Less than 1.0	8	6
Less than 2.0	7	5
Less than 3.0	5	3
Less than 4.0	4	2
Less than 5.0	2	1
Less than 6.0	1	0
6.0 or more	0	0

6.3 Social Constraint: Existing and Potential Land Use Conflicts

Significant policy conflicts can arise when proposed land uses do not complement existing land uses, or contradict land use zonation. For the purposes of this report, land use is measured as the dedication of land to human operations classified into the following general categories: secure greenbelt, rural uses including agriculture, commercial or industrial uses, military uses, and residential uses.

Lands of secure greenbelt were recently delineated by the Greenbelt Alliance during 1993. This is a rigorous data layer that reflects ownership by natural resource agencies, open space districts, land trusts, or other organizations dedicated to natural resource conservation. This data layer has been updated by including diked bayland parcels which have recently been dedicated as open space. For example, the secure greenbelt includes the salt evaporators of the Napa marshlands recently purchased by conservation interests.

Geographic data about the other categories of land use were recently published by the Association of Bay Area Governments, based upon the County General Plans as of 1991 (ABAG 1991). These data have been used to indicate the number and kinds of potential land uses for each diked baylands parcel in the North Bay Area.

Military lands deserve special consideration. In general, lands owned by the military benefit from a level of protective environmental management not afforded to other lands outside of the secure greenbelt. Military lands cannot be sold without public notice, and other federal agencies including the U.S. Fish and Wildlife Service have early opportunities to acquire the lands through title transfer between federal agencies. Furthermore, special status species are more likely to be managed for their protection on military lands. In the North Bay Area, classification of military lands with regard to tidal marshland restoration potential is complicated by military base closure plans. It is likely that some base closure lands will become available for tidal marshland restoration.

Lands dedicated to residential uses or that border major residential developments present special ecological threats that can severely constrain the tidal restoration potential. Residential lands are sources of disturbance, including uncontrolled noise, lights, pollution, and visitation by people and pets. Frequent visitation by feral or domestic dogs and cats is a major cause of wildlife decline in some tidal marshlands. Furthermore, the close proximity of tidal marshlands to residential areas presents difficult mosquito abatement problems. Table 10 below presents the schedule of scores for land use.

Table 10: Schedule of parcel scores based upon the social constraint: potential and existing land use conflicts. For this constraint, each parcel was assigned a starting score of 8, and whole integer values for landscape resistance due to potential land use conflicts were subtracted according to the following schedule. The starting score could be reduced by more than one subtracting value.

LAND USE CATEGORY	SUBTRACT SCORE
secure greenbelt	0
mostly rural/agriculture	1
base closure lands	2
mostly commercial/industrial	5
mostly residential	8
small part residential	4
non-operational military	1
small part commercial	2
borders major residential	2

7.0 TOTAL SCORES AND PARCEL RANKS

The total score for each parcel was calculated as the sum of all its scores for the seven kinds of constraints. The total scores are not independent of their component scores. Parametric statistical analyses are therefore inappropriate to examine how the total scores are affected by the scores for each kind of constraint. The most direct examination is graphical, and simply compares how the scores for each kind of constraint are distributed among the parcels. The highest scoring parcels tend to have high scores for most or all seven kinds of constraints. This is apparent in Figures 2-5, which show the distribution of scores among the parcels, for each of four different restoration scenarios used to illustrate the proposed methodology. The restoration scenarios are explained in section 7.1 below.

7.1 Four Example Scenarios for Tidal Marshland Restoration

In this section of the report, the proposed methodology to assess and rank parcels of diked baylands of the North Bay Area with regard to their potential for tidal marshland restoration using dredged sediment is illustrated with four restoration scenarios. Three of the four scenarios involve an example regional template for tidal marsh restoration, and example decisions about project duration and fill elevation. Such decisions are matters of policy, not strictly matters of science. They were made by the sponsors of this report, and are not final at this time. The purpose of these scenarios is only to illustrate how the methodology can benefit the decision-making process.

For each restoration scenario, the distribution of scores among the parcels is plotted for each of the seven kinds of constraints (see Figures 2-5). These plots reveal how the scores for each kind of constraint generally contributed to the total scores. The data are also presented in tabular form (see Appendix 1), such that the relationships between the total score and the scores for each kind of constraint can be examined for each parcel.

The distribution of total scores among the parcels, and the cumulative frequency distribution of the total scores is also plotted for each scenario (Figures 8-11). These plots are especially informative. They reveal which total scores belong to any given percentile of the combined scores for all the parcels. Parcel membership in a percentile can then be determined, based upon the total parcel scores presented in Appendix 1. For example, there might be interest in the parcels that belong to the 75th percentile (i.e., the parcels that have higher scores than 75% of all the parcels). Figures 8-11 reveal which total scores belong to the 75th percentile, and Appendix 1 reveals which parcels have those total scores.

Ranking the parcels involves decisions about the number of ranks and the distribution of the ranks among the population of total scores. Figures 8-11 show that the total scores are not normally distributed. Breaks in the distribution of total scores are explained by various combinations of scores for the different kinds of constraints, as indicated in Figures 2-5. While some total scores are certainly higher than others, the cutoff between high scores and low scores is not obvious.

Figure 2 : How the scores for seven kinds of constraints are distributed among the parcels for Restoration Scenario 1

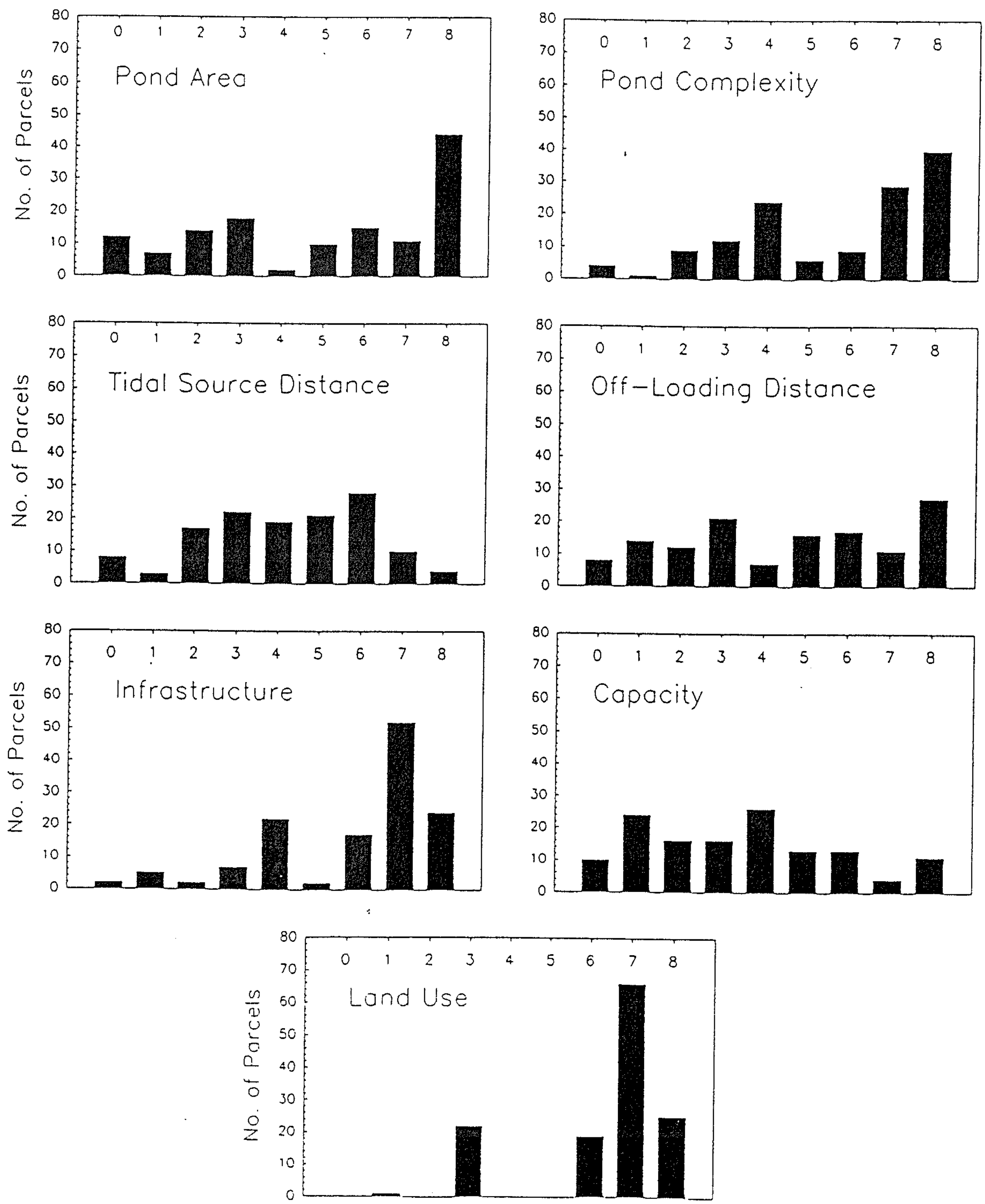


Figure 3: How the scores for seven kinds of constraints are distributed among the parcels for Restoration Scenario 2.

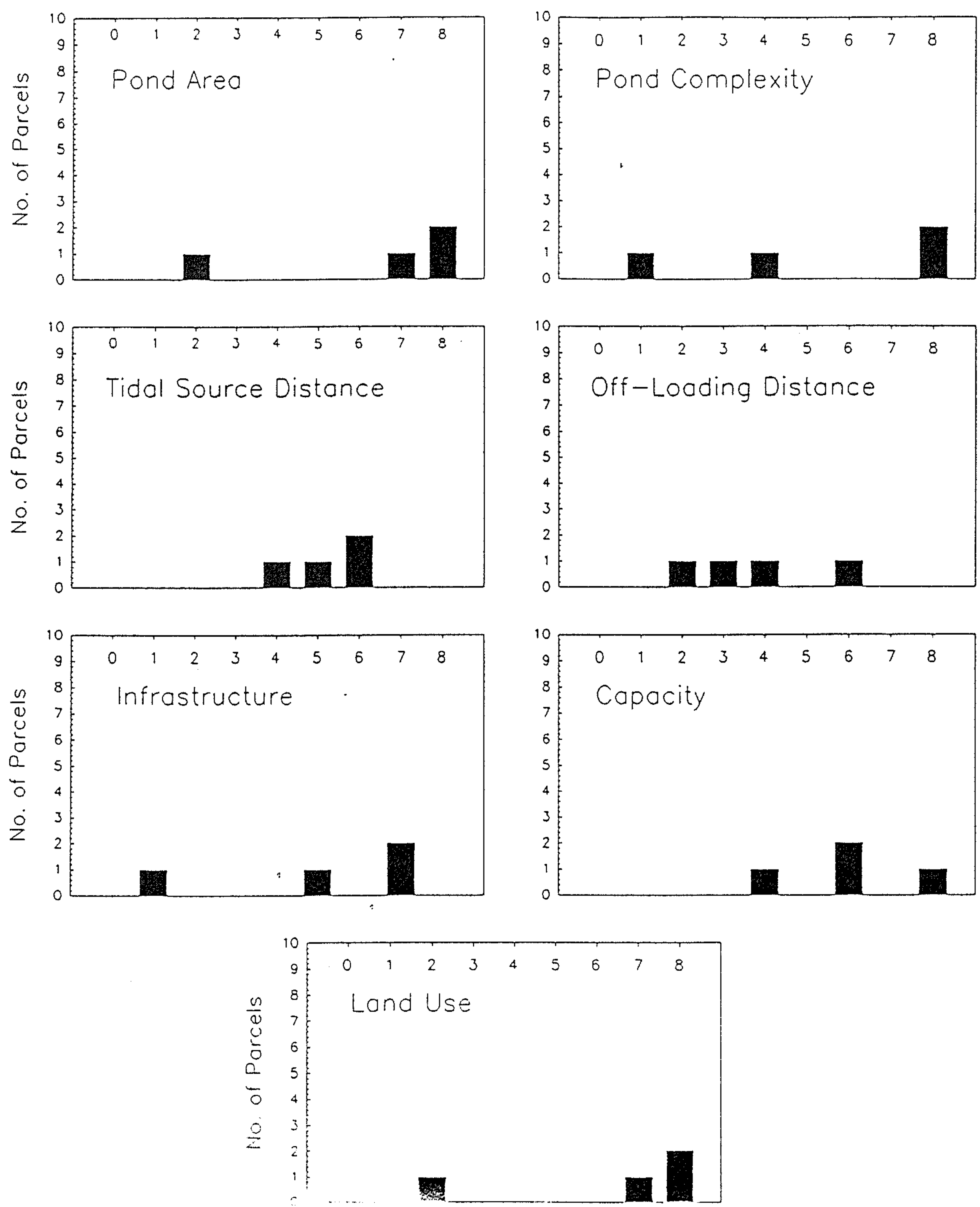


Figure 4: How the scores for seven kinds of constraints are distributed among the parcels for Restoration Scenario 3.

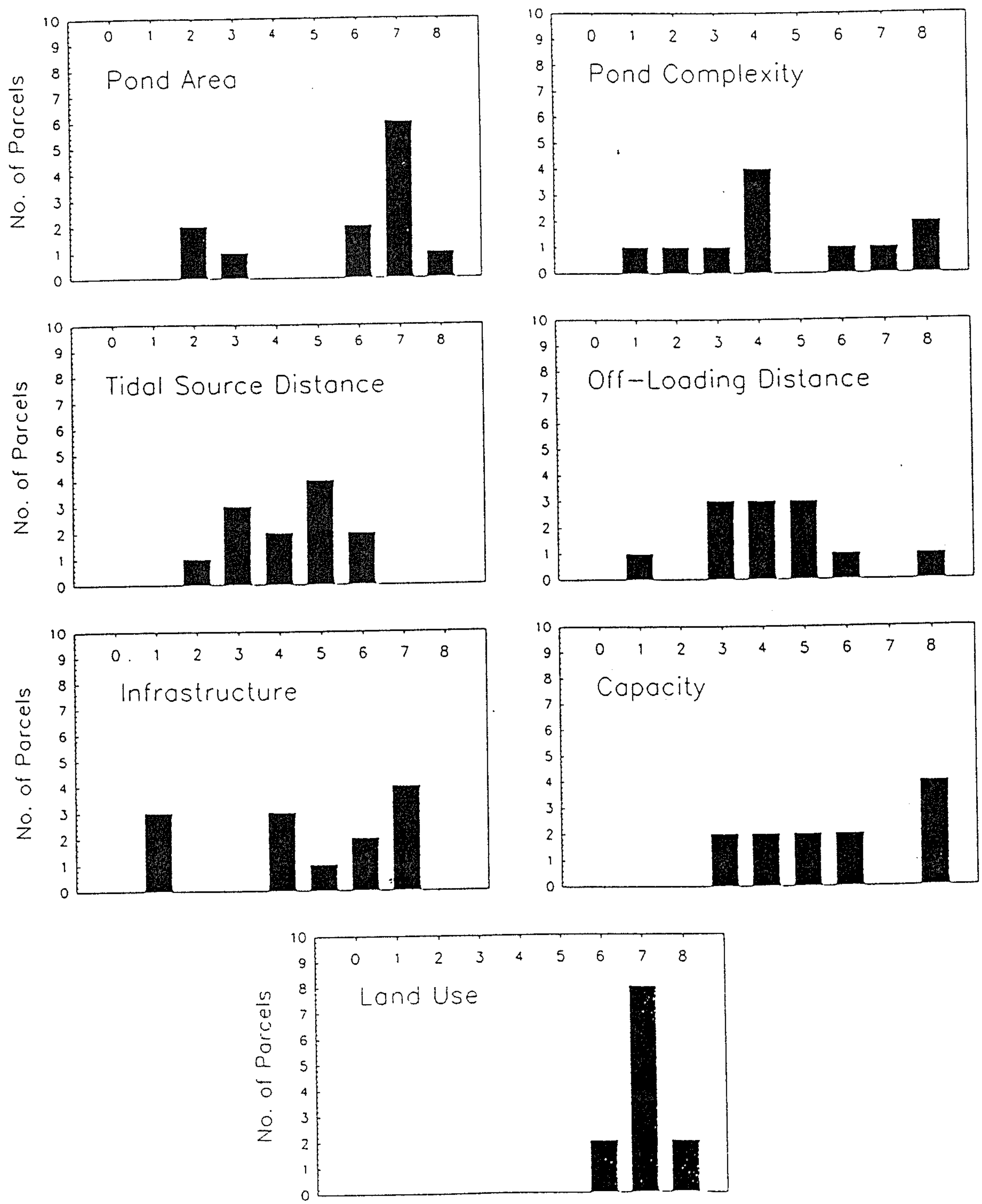
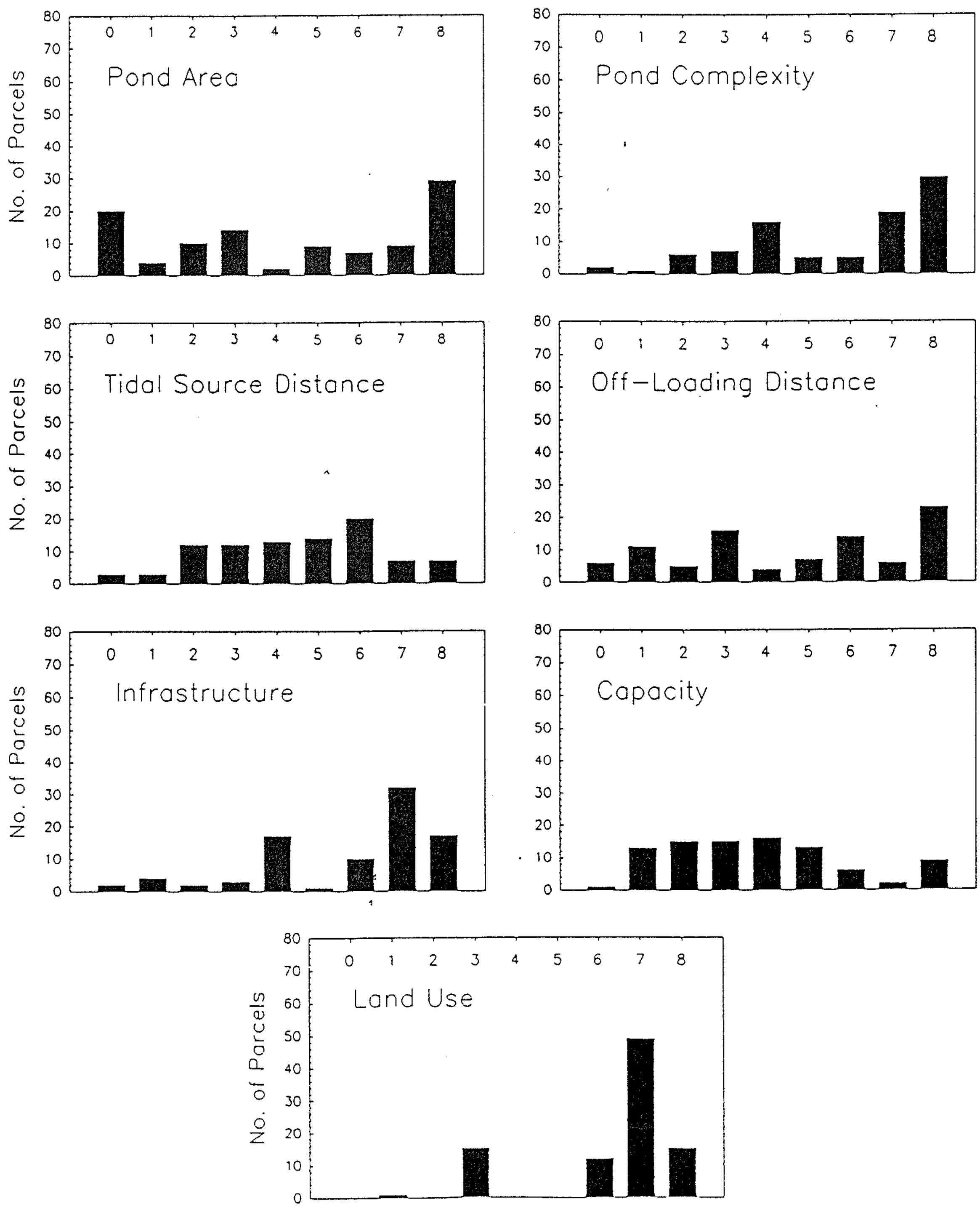


Figure 5: How the scores for seven kinds of constraints are distributed among the parcels for Restoration Scenario 4.



For the purposes of this report, the following arbitrary rules were used to rank the parcels with regard to their potential for tidal marshland restoration. Each parcel was assigned to one of four ranks. The ranks are bounded above by the 25th, 50th, 75th, and 100th percentiles. Thus, 75% of the parcels have higher scores than the parcels ranked low; 50% have higher scores than the parcels ranked medium low; 25% have higher scores than the parcels ranked medium high, and 75% have lower scores than the parcels ranked high. The distribution of parcels among these ranks is obviously controlled by how the ranks are defined.

7.1.1 Restoration Scenario 1: Augmented Tidal Wetlands Maturation for All Parcels - Fill Elevation is MHW

Under the rules of Scenario 1, all diked baylands parcels are considered as potential sites for tidal wetlands restoration using dredged material, with a fill elevation of local MHW. The ecological goals for this scenario might include some ecological functions of low tidal marsh, especially as provided by tidal channels, and some other functions of high tidal marsh, especially as provided by the vegetated high marsh plain and by natural ponds on drainage divides. The results of Scenario 1 are shown in Appendix 4. For this Scenario 1, the estimated total fill capacity for the high rank parcels is about 58 million cubic yards.

7.1.2 Restoration Scenario 2: Natural Tidal Wetlands Maturation for Some Parcels - 20 Years or Longer

Under Scenario 2, the treatment varies among the parcels. An example of a regional geographic template for tidal marshland restoration is used to select which diked baylands would be restored to the tides. For this example, a template was constructed that favors tidal marsh restoration adjacent to the rivers and open bays of the estuary (see column 2 of Appendix 1). The template was used to determine a-priori (i.e., before ranking) which parcels would be restored to tidal marshland. Thus, the template reduces the number of candidate sites for tidal marsh restoration, with or without dredged sediment.

The parcels selected to be restored according to the example geographic template, were further classified based upon the expected rate of tidal marshland maturation. For the purposes of this report, maturation is defined as vertical accretion up to local MTL. This is the tidal elevation at which vascular plants are expected to colonize the restoration site (Entrix et al 1991, Johnson et al 1994, and many others). The major ecological objective of this scenario is the restoration of abundant low tidal marsh, with an emphasis on natural sedimentation and a great density of tidal channels.

A family of equations was developed for SFEI by Dr. Kent Dedrick to predict vertical accretion, based upon suspended sediment concentration and tidal elevation (Figure 6). The equations involve the assumptions that all suspended sediment settles from the water column during each tidal cycle, and that plant growth does not contribute to marsh accretion. An adjustment is already included to account for the difference is density between sediments that are in suspension and sediments that have settled out of the water column of the tides.

Figure 6: Models to predict accretion rates of tidal marshlands, courtesy of Kent Dedrick.

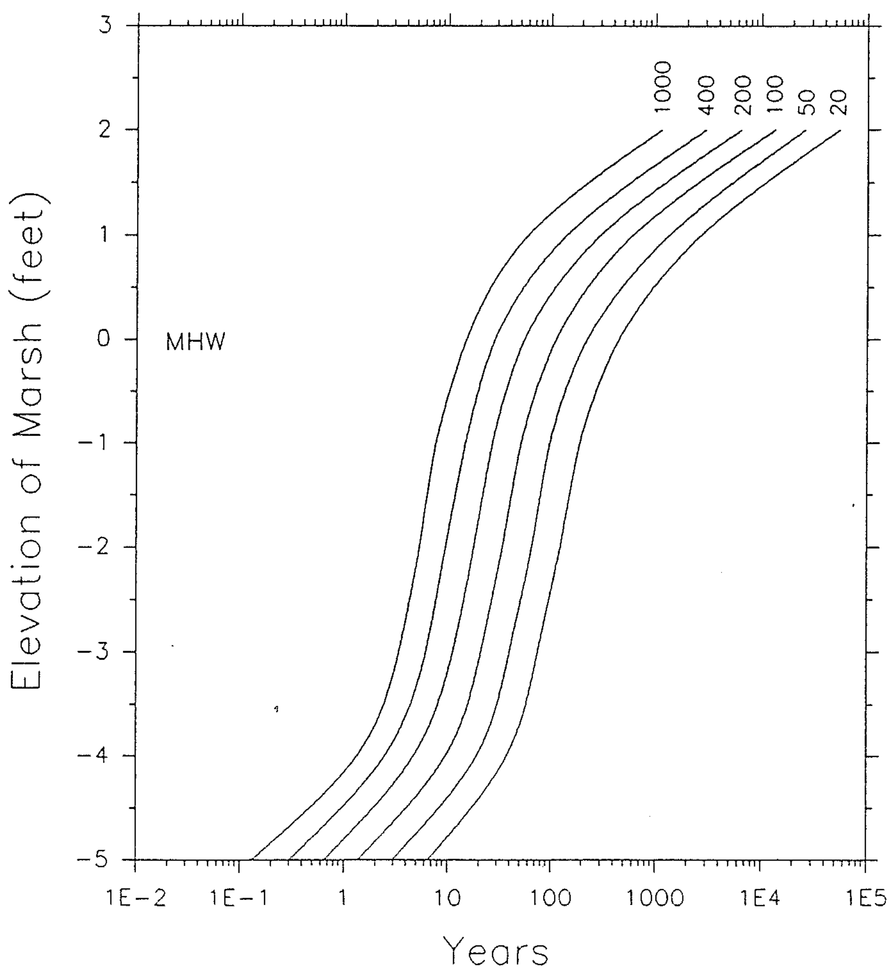
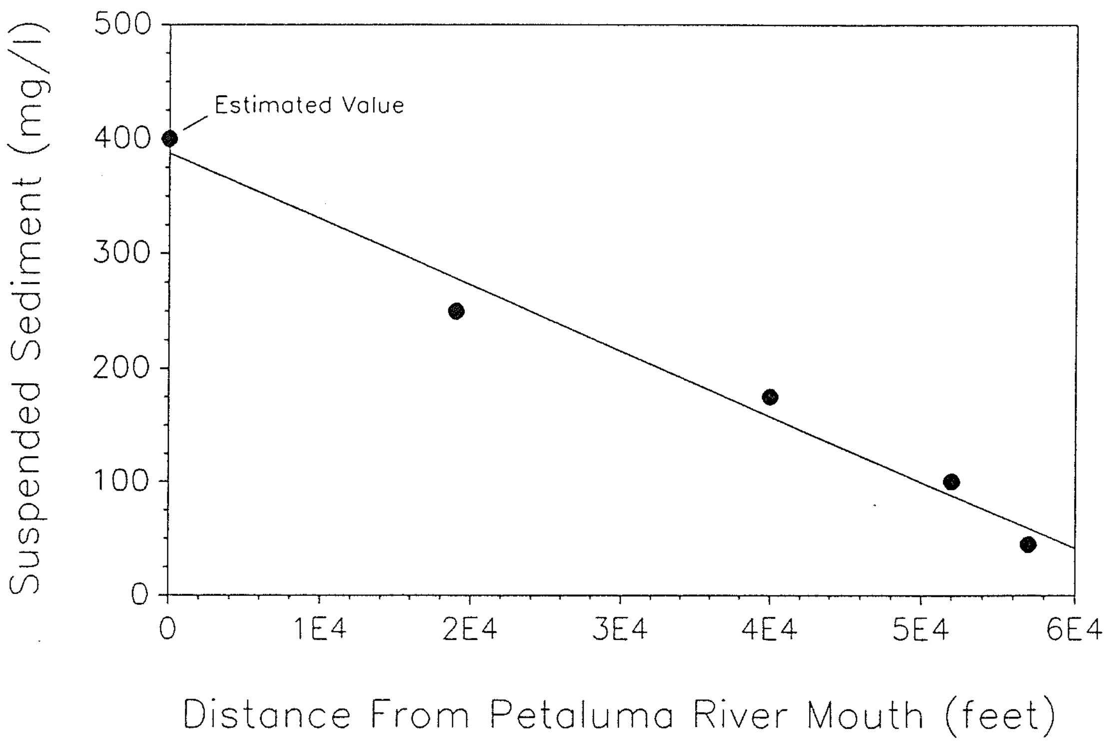


Figure 7: Relationship between suspended sediment concentration and distance along the pathway of tidal excursion from zero distance at the entrance to Petaluma River to the headward reaches of Tule Slough, nearly 10 miles upstream.



Problems associated with the first assumption of the sedimentation model can be mitigated if necessary by decreasing the input value for suspended sediment that drives the model. However, the model provides estimates of sedimentation rate that agree well with other estimates recently developed for the North Bay Area (Entrix et al. 1991, Ogden Beeman & Associates 1992), especially for depths between about MHW-4.0 ft to MHW+1.5 ft. The equations of Entrix et al (1991) were used to estimate sedimentation rates at depths below MHW-4.0 ft. The second assumption of the sedimentation model is reasonable because the model is only used to estimate sedimentation up to local MTL, which is the elevation of plant colonization. Below this elevation, living vegetation does not contribute materially to vertical or horizontal accretion of tidal marshland.

The model that is used to predict sedimentation rate requires knowledge of suspended sediment concentration and diked bayland elevation. In both regards, the data sets are weak at this time. The quality of the elevation data is discussed above (see section 6.2.2 above). Values for suspended sediment concentration were developed from empirical data that show how suspended sediment load varies with distance along one tidal tributary system upstream of San Pablo Bay. Leopold et al. (1994) provide values for suspended sediment concentration that are averaged over depth for flood tides along Tule Slough, a tributary of the Petaluma River. Extrapolation downstream from Tule Slough to the mouth of the Petaluma River produces a value for the river entrance of about 400 mg/l (Figure 7), which agrees reasonably well with independent estimates for the same location (Entrix et al. 1991), as well as for the mouth of the Napa River (Johnson et al. 1994). Apparently, 400 mg/l is a common concentration of suspended sediment along the northern shoreline of San Pablo Bay. It is assumed that the empirical relation between suspended sediment concentration and distance upstream from San Pablo Bay (see Figure 7) holds for other local tributary systems as well as for the Petaluma River. Recent data for the middle reaches of the open bays of the estuary indicate substantial spatial and seasonal variability in suspended sediment load (SFEI 1996). While the use of Tule Slough as a general model for two-dimensional suspended sediment distribution is questionable, the data for Tule Slough are the only suitable data available at this time.

Based upon the tenuous relationship between suspended sediment concentration and distance along the path of tidal excursion across the shallows of San Pablo Bay and into the adjacent marshlands (see Figure 7), and given data for that distance and for tidal elevation (see Appendix 1), then the rate of tidal marshland vertical accretion can be estimated (see Figure 6). While the estimates are perhaps the best available at this time, they should be adjusted with new data for depth-integrated suspended sediment concentration collected throughout the tidal reaches of the Petaluma River and the Napa River, including dendritic channel networks that are tributaries of these rivers.

The estimates of accretion rate were used to classify the parcels that were selected a-priori for tidal marshland restoration, based upon the assumed geographic template. In this Scenario 2, the classification was based upon the following arbitrary rule. Parcels expected to require *more than 20 years* to achieve MTL were considered candidates to receive dredged sediments to nurture natural accretion for tidal marshland restoration. Parcels expected to require *20 years or less* to achieve MTL through natural sedimentation were disqualified as candidates to receive dredged sediment. The rationale for this rule mainly involves two common observations. First, significant plant colonization begins when the tidal lands achieve

MTL. Second, tidal restoration projects in the region that are commonly regarded as successful first began to support abundant vascular vegetation within 20 years.

Applications of the example geographic template and the 20 year time threshold eliminated all but a few parcels as candidates for tidal marsh restoration using dredged sediment. The results of Scenario 2 are shown in Appendix 5. For this Scenario 2, the estimated total fill capacity for the parcels ranked high is about 1.5 million cubic yards. The estimated total capacity for all the parcels ranked is about 16.5 million cubic yards.

7.1.3 Restoration Scenario 3: Natural Tidal Wetlands Maturation for Some Parcels - 10 Years or Longer

Scenario 3 is a simple modification of Scenario 2. The same example geographic template is used for both Scenario 2 and Scenario 3. However, Scenario 3 reflects a different possible policy decision about what constitutes an adequate rate of tidal marshland maturation. For this Scenario 3, the threshold of time to achieve MTL was changed from 20 years to 10 years. One obvious consequence of this hypothetical change in operational policy is that Scenario 3 includes more parcels than Scenario 2. However, the number of parcels selected for tidal marsh restoration using dredged sediment remains rather small. The results of Scenario 3 are shown in Appendix 6. For this Scenario 3, the estimated total fill capacity for the parcels ranked high is about 12.0 million cubic yards. For all parcels of all ranks combined, the estimated total capacity is about 56 million cubic yards.

7.1.4 Scenario 4: Tidal Marshland Restoration for All Parcels - Various Fill Elevations and Maturation Times

Under Scenario 4, a complex mosaic of low tidal marsh (average elevation below MHW), and high tidal marsh (average elevation above MHHW) would be restored through both natural sedimentation and the placement of dredged sediment. This Scenario 4 emphasizes the creation of low tidal marsh for the support of fish and other functions associated with tidal marsh channels, and the creation of high tidal marsh for the support of waterfowl, shorebirds, and other functions associated with a vegetated high marsh plain and with shallow intertidal ponds. Although the construction of such ponds has not been tried at a large scale, they are featured in current plans for some tidal marsh restoration projects, and they represent the dominant kind of historical waterfowl and shorebird habitat around San Pablo Bay.

For this Scenario 4, parcels within the example geographic template for tidal marshland restoration that have sufficient sediment supply to naturally mature within 20 years *would not* receive dredged sediment (see Scenario 2 above). Parcels within the example template that have insufficient sediment supply to mature within 20 years *would* receive dredged sediment. These parcels would have a low fill elevation of MHW-0.5 ft. The other parcels of diked baylands that are not designated for tidal marsh restoration according to the example template would be converted to tidal marshland using dredged sediment, but with a high fill elevation of MHHW + 0.5 ft. This high fill elevation is probably consistent with the formation and natural maintenance of shallow, intertidal ponds that can serve as feeding and resting habitats for shorebirds and waterfowl. Thus, the basis for Scenario 4 is Scenario 2, with the change that diked baylands outside of the example geographic template for tidal marshland restoration are restored to high tidal marshland, using dredged sediment. The results of Scenario 4 are shown in Appendix 7. For this Scenario, the estimated total fill capacity for the high rank parcels is about 23.25 million cubic yards.

8.0 DISCUSSION and CONCLUSIONS

8.1 The Baylands Atlas

The Baylands Atlas is a convenient base map for cataloguing and displaying spatial information about the baylands of the San Francisco Estuary. The Baylands Atlas could be used to examine many different approaches and possibilities for baylands management, from both local and regional perspectives. The proposed methodology to assess and rank parcels of diked baylands with regard to their potential for tidal marsh restoration using dredged sediment is one example of many possible uses of the Baylands Atlas. Some limitations or precautions apply, however.

Decisions about the boundaries of the baylands parcels can affect their assessment and ranking as tidal marshland restoration sites. For the Baylands Atlas, the parcels have been delineated by existing perimeter levees, roads, and some major internal levees. But the existing system of internal levees is more complex than the Baylands Atlas indicates. Some of the minor internal levees that are not included in the Baylands Atlas could be used to spatially isolate some areas of constraints and thereby minimize their effects on tidal marsh restoration potential. For example, existing minor internal levees are available in some parcels to isolate transmission towers, and railroads are in some cases probably too high above the tides to constitute a serious constraint. Some adjacent parcels could be consolidated based upon the assumption that levees separating the parcels would be removed, breached, or allowed to deteriorate over time. Such consolidation of parcels would create a larger parcel with more sediment fill capacity, which could tip the balance between costs and benefits in favor of tidal marsh restoration using dredged sediments.

The parcels depicted in the Baylands Atlas are convenient constructs. But their ecological meaning is not fixed. Many ecological functions probably transcend the parcel boundaries as depicted. For example, raptors and red foxes move freely among the parcels, and may not make the same distinctions among the parcels that are apparent in the Baylands Atlas. It is not possible to know whether a flock of migratory waterfowl sees the same mosaic of baylands depicted by the Atlas, or some other mosaic. A difference in ecological function between 40 acres of ponding in a 1000 acre parcel and 40 acres of ponding in a 100 acre parcel cannot be assumed. Appendix 3 shows that some clusters of ponds are larger than most parcels, which suggests that some parcels could be combined, based upon their similar ponding patterns. Alterations of the Baylands Atlas should reflect careful decisions about local and regional ecological goals and management objectives.

Figure 8: Cumulative frequency distribution of total scores for Restoration Scenario 1, showing the threshold scores for low, medium low, medium high, and high ranks.

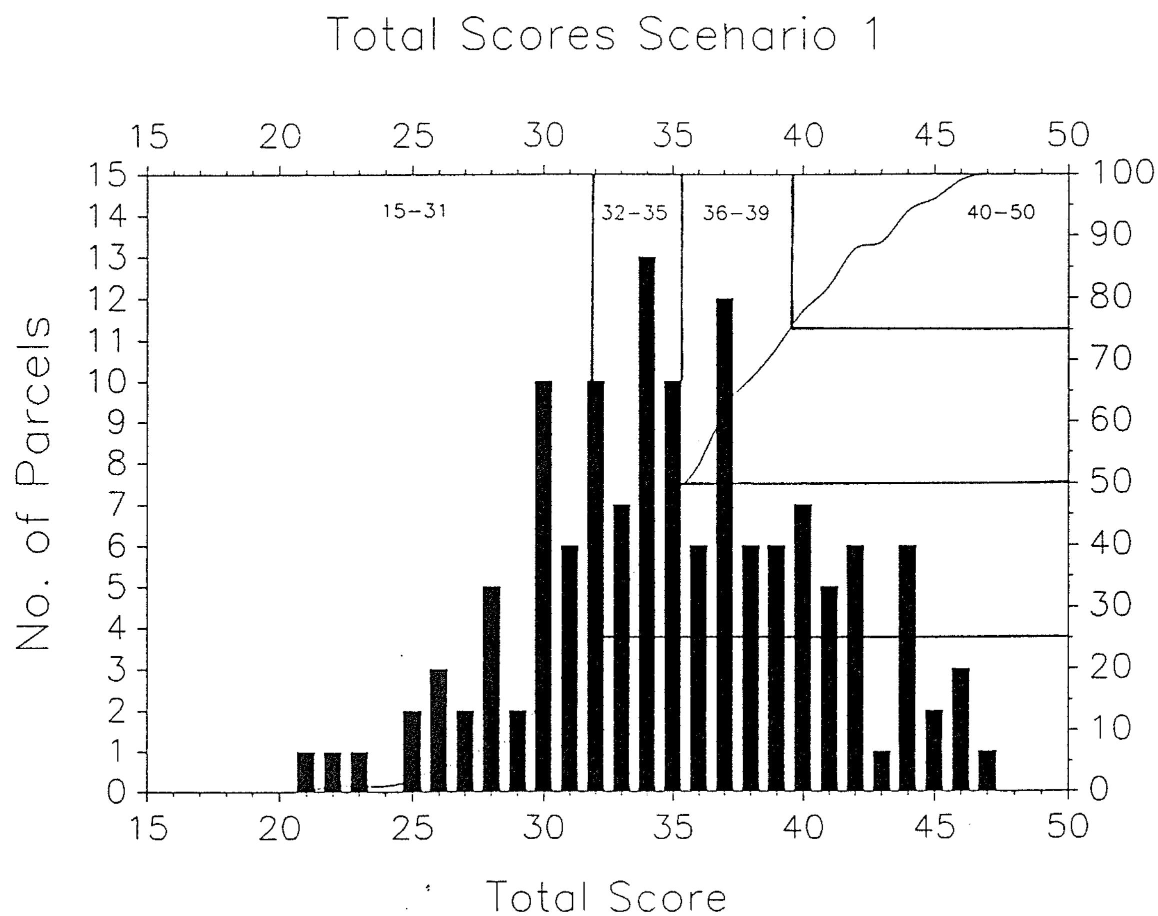


Figure 9: Cumulative frequency distribution of total scores for Restoration Scenario 2, showing the threshold scores for low, medium low, medium high, and high ranks.

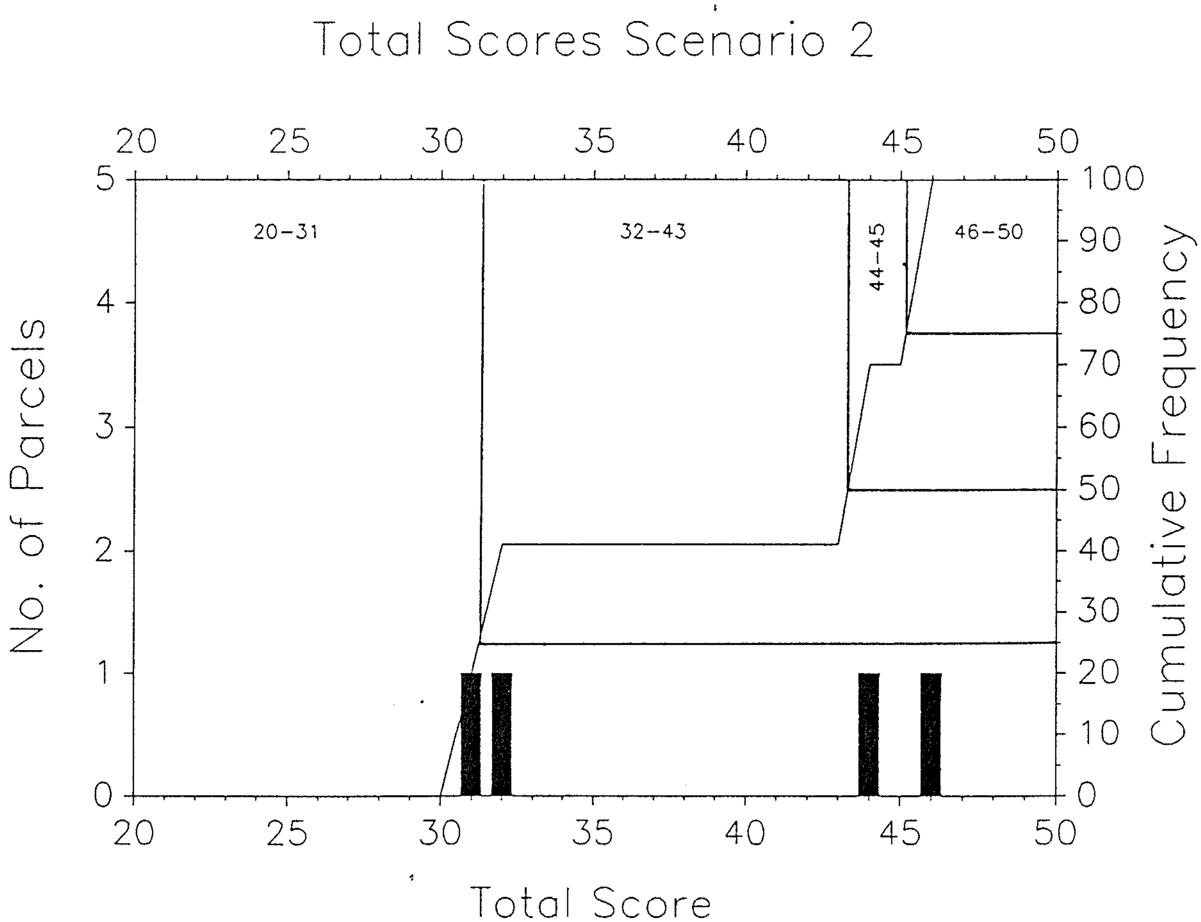


Figure 10: Cumulative frequency distribution of total scores for Restoration Scenario 3, showing the threshold scores for low, medium low, medium high, and high ranks.

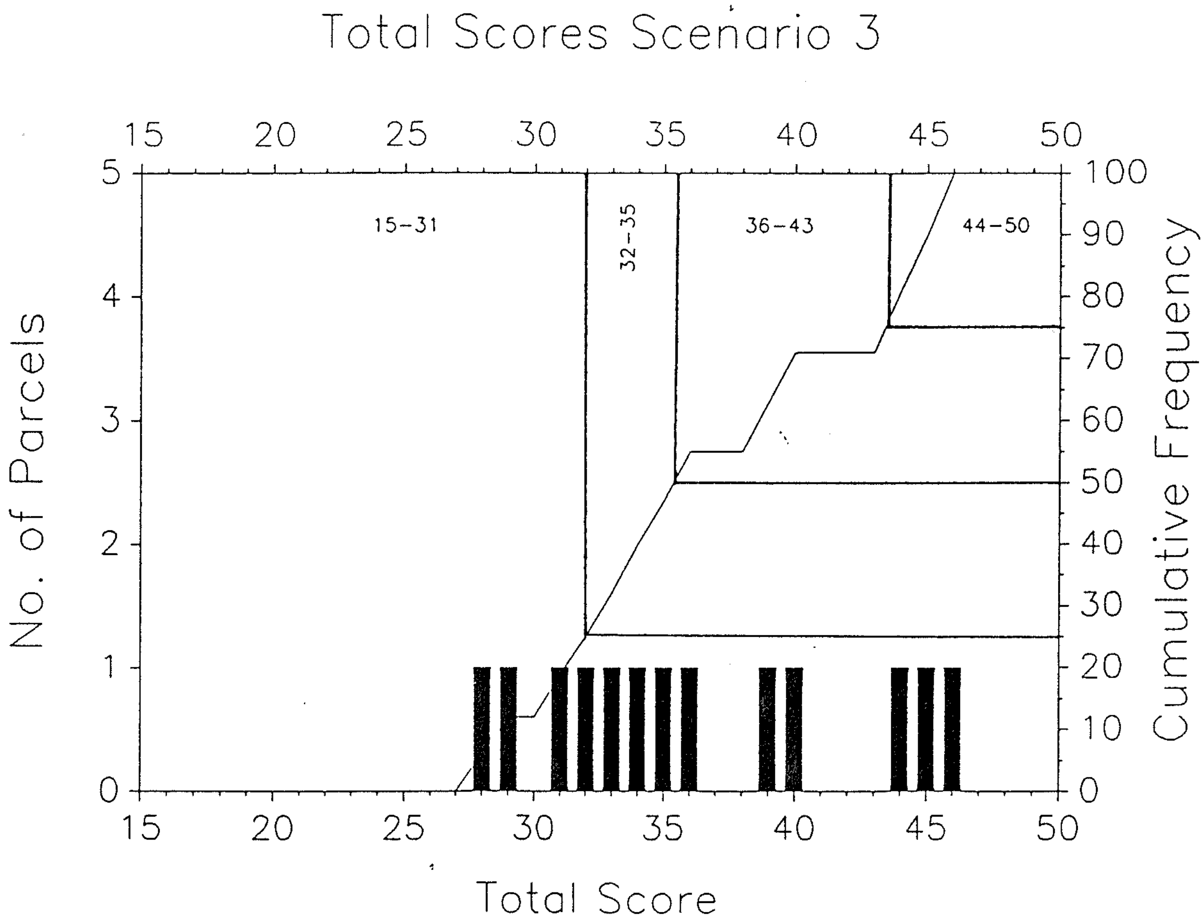
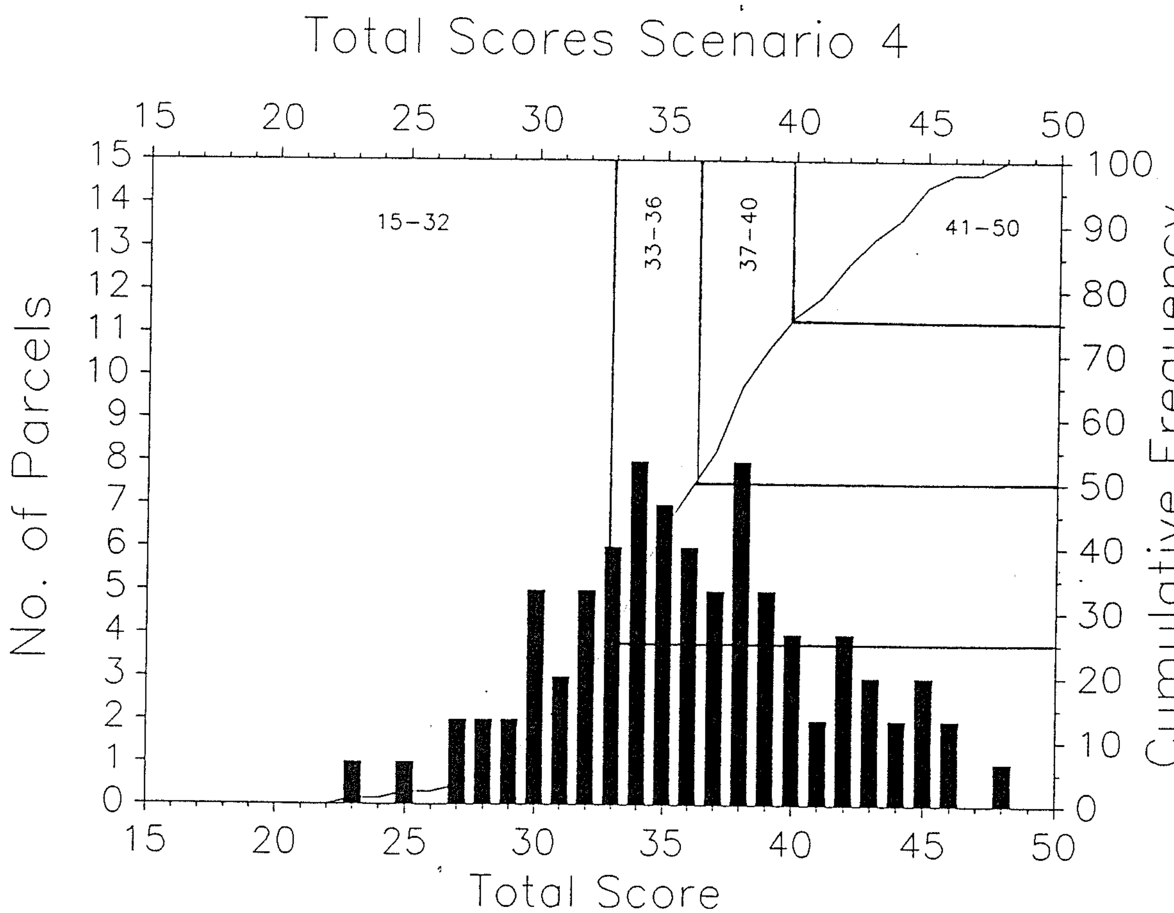


Figure 11: Cumulative frequency distribution of total scores for Restoration Scenario 4, showing the threshold scores for low, medium low, medium high, and high ranks.



A new template for wetlands restoration is expected to result from the ongoing effort to establish regional wetlands habitat goals (RMG 1995). A different geographic template than the one used here would alter the geographic basis for the analysis of restoration potential. Based upon the fundamental tenets of conservation biology and wildlife refuge design, it might be anticipated that a better restoration template would indicate tidal marshland restoration projects that have a larger average size than the parcels of diked baylands depicted by the Baylands Atlas at this time.

Future efforts to restore tidal marshland are likely to result in new concepts about restoration designs. As in Scenario 4 above, fill elevations might exceed local MHHW in some sites to create intertidal ponds for waterfowl and shorebirds. New regional templates about tidal marshland restoration, and new ideas about restoration project designs, can be accommodated by this assessment and ranking methodology.

8.2 Estimates of Sedimentation Rates

The estimates of sedimentation rate used here are in reasonable agreement with other estimates for the northern shoreline of San Pablo Bay. However, this does not necessarily mean that they are correct, or applicable to other areas. Recent studies of mature tidal marshlands in the North Bay Area indicate that vertical accretion above MTL is a complex interaction between inorganic sedimentation and primary production, which challenges the assumptions of inorganic dominance used in this report. Furthermore, sediment concentration varies among subregions of the Estuary, varies with depth in the tidal water column, and varies with distance from tidal source in tidal marshland (USGS 1995; SFEI 1995, 1996). While more measures of the variability in sediment supply across a number of spatial and temporal scales are expected, the critical topics about sediment transport between the bays and marshlands, and about local watersheds as sediment sources, are not being addressed at this time. Until such information becomes available, the estimates of sedimentation rate developed for this report should be used as the "best guesses" about the relative differences in potential sedimentation rate among diked baylands in the North Bay Area.

8.3 Obvious Interactions between Policy and Parcel Ranks

Different rules for ranking the parcels could follow from policy decisions about thresholds for ecological support, engineering constraints, or land use conflicts. For example, the evolving policy about wetlands might reflect decisions about minimum support levels for target functions, or minimum allowable impacts of conversion between diked baylands and tidal marshland. These policy decisions could be represented by changes in the schedule of scores for the individual constraints, or by changes in the distribution of ranks among the total scores. Furthermore, selected constraints could be emphasized by weighting their scores. These kinds of modifications of the assessment methodology will require more information about the constraints and their relationships to restoration potential than is available at this time.

Ranking may not be necessary to proceed with tidal marshland restoration using dredged sediment. Restoration could begin with the parcel that has the highest total score, and then proceed to the parcel with the next highest score, and so on. If ranking is required, then it must follow from obvious criteria. For example, if the need exists to restore at least 10,000 acres of tidal marshland, then the high rank would include only the highest scoring parcels with a combined area of 10,000 acres. A different group of parcels would be ranked high if it is also stipulated that each of the parcels has to be at least 1200 acres large. The methodology presented here shows that thresholds between high and low potential are not self-evident, and should reflect management policies. For the purpose of demonstrating the methodology, arbitrary rules for ranking were adopted. Future applications of the methodology should involve rules for ranking that are carefully formulated to reflect the policies of agencies that are charged with wetlands protection.

Some parcels of diked baylands may be selected for tidal marshland restoration, even if their rank is not high. For example, a parcel might be selected because its restoration would greatly reduce habitat fragmentation, or because it represents unusually large capacity for dredged sediment. In such a case, the assessment of restoration potential could be used to identify which kinds of constraints must be addressed to raise the parcel rank. In any case, the assessment should be followed by more careful investigations of selected parcels.

8.4 Critical Information Needs

The assessments of tidal marshland restoration potential contained in this report are most useful to illustrate the methodology, and to identify the information needs. Empirical data are needed to determine the average tidal elevations of each of the diked baylands, and to determine suspended sediment loads of the tides along pathways of sediment transport that involve the local watersheds, open bays, mudflats, and channels of tidal marshlands. Without these data, predicted rates of local sedimentation and maturation for tidal marshland restoration sites will be tenuous at best, and the influence of tidal marsh restoration on the sediment budget for the Estuary cannot be assessed.

Further testing of the methodology and its eventual application should involve all of the diked baylands of the San Francisco Estuary. Based upon the methodology presented here, variations in restoration potential among subregions could be detected. Important opportunities to use dredged sediment to restore tidal marshlands or to enhanced diked baylands may be missed, if the assessment of restoration potential is restricted to one part of the diked baylands.

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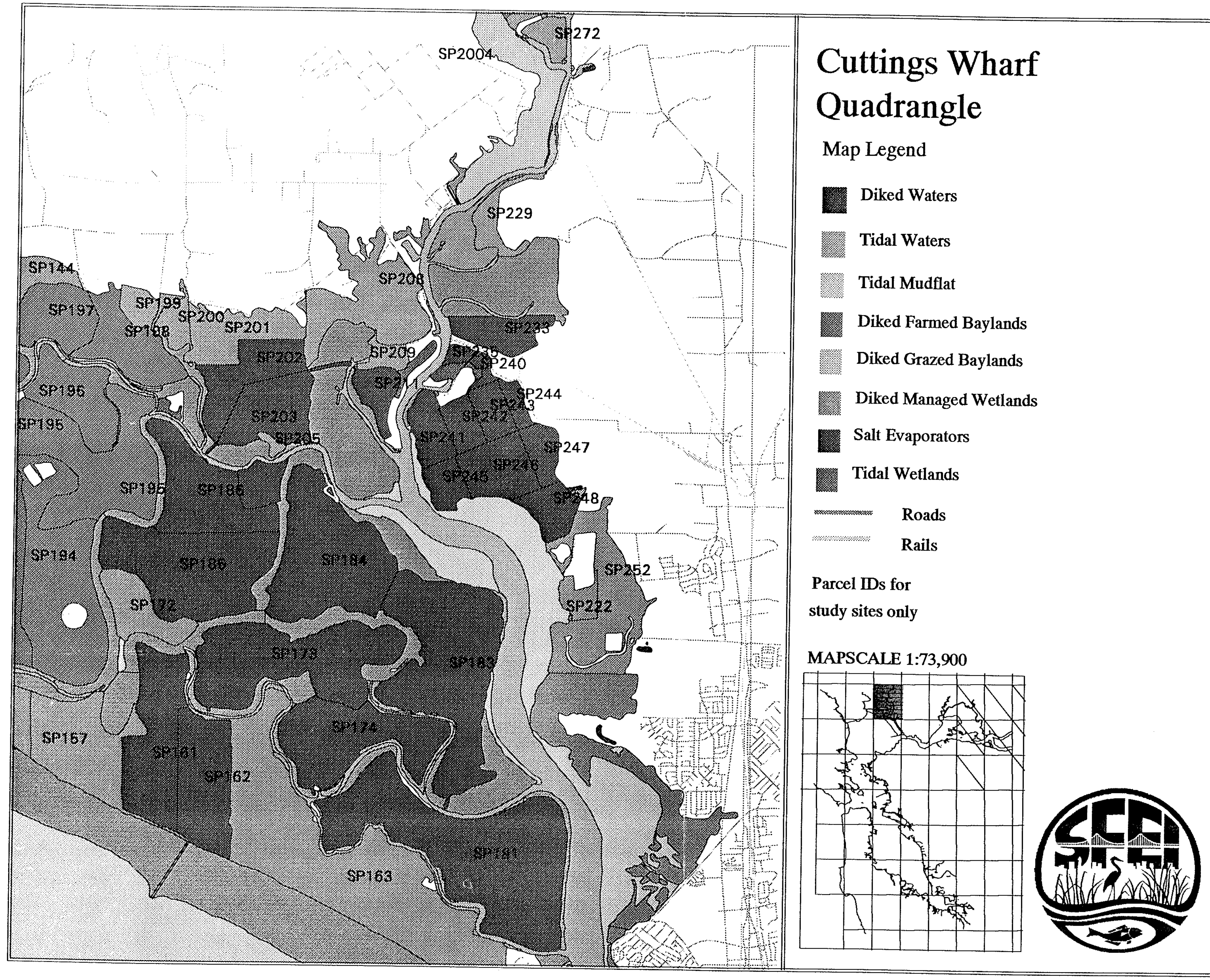
APPENDIX 1: Tabular Results

This Appendix 1 contains the output of the Excel spread sheet used to manage the data and to compute the scores for each diked baylands parcel. The spread sheet has 36 columns. The data for the parcels listed in column 1 (the far left column) on page 1 are continued on pages 2 and 3; the data for parcels listed on page 4 are continued on pages 5 and 6; and so on.

* Parcels that are included within the example regional geographic template for tidal marshland restoration are indicated with an asterisk in column two.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Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for study sites only
MAPSCALE 1:73,900
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SP2004
SP229
SP144
SP208
SP197
SP199
SP200
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SP198
SP235
SP202
SP209
SP240
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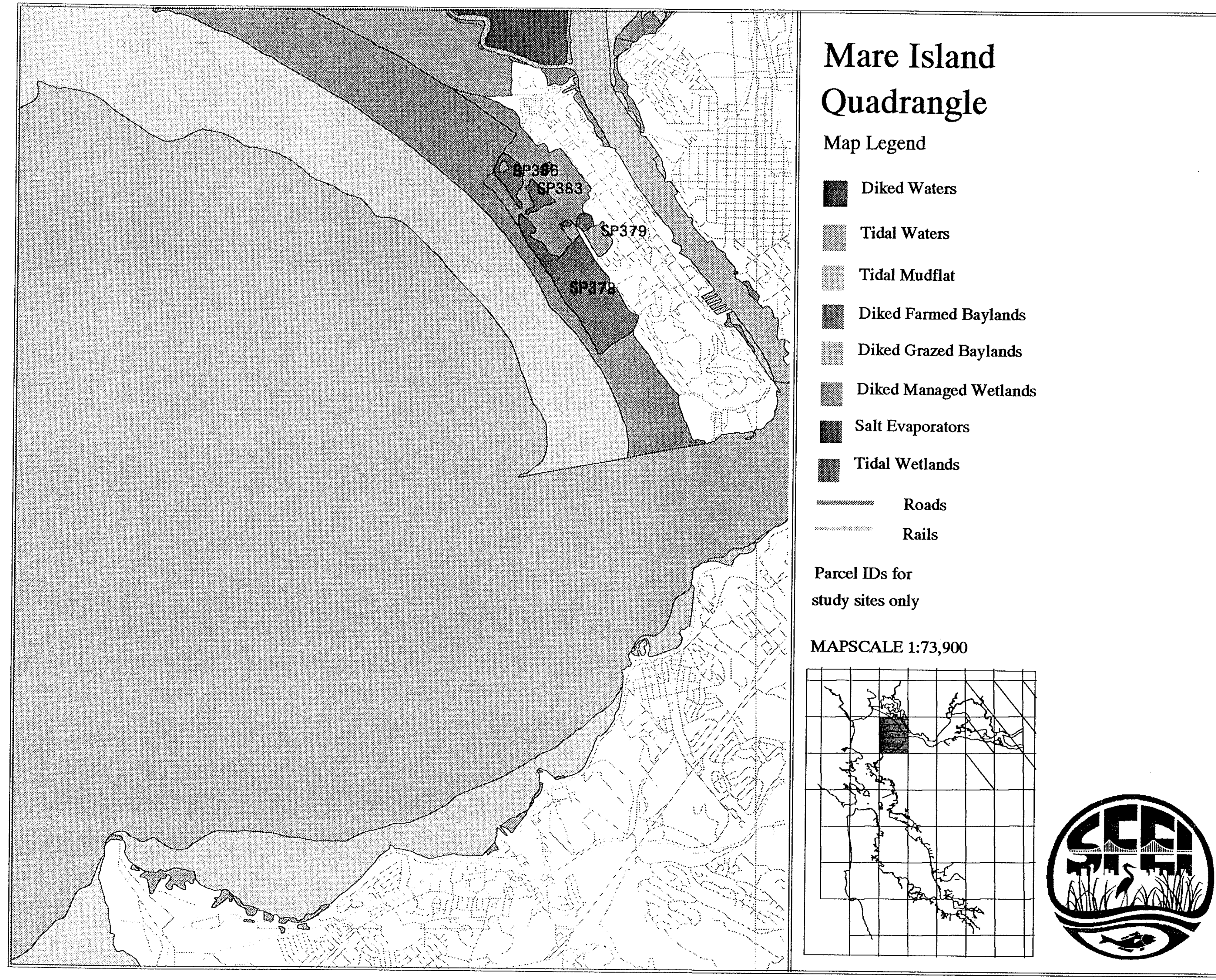
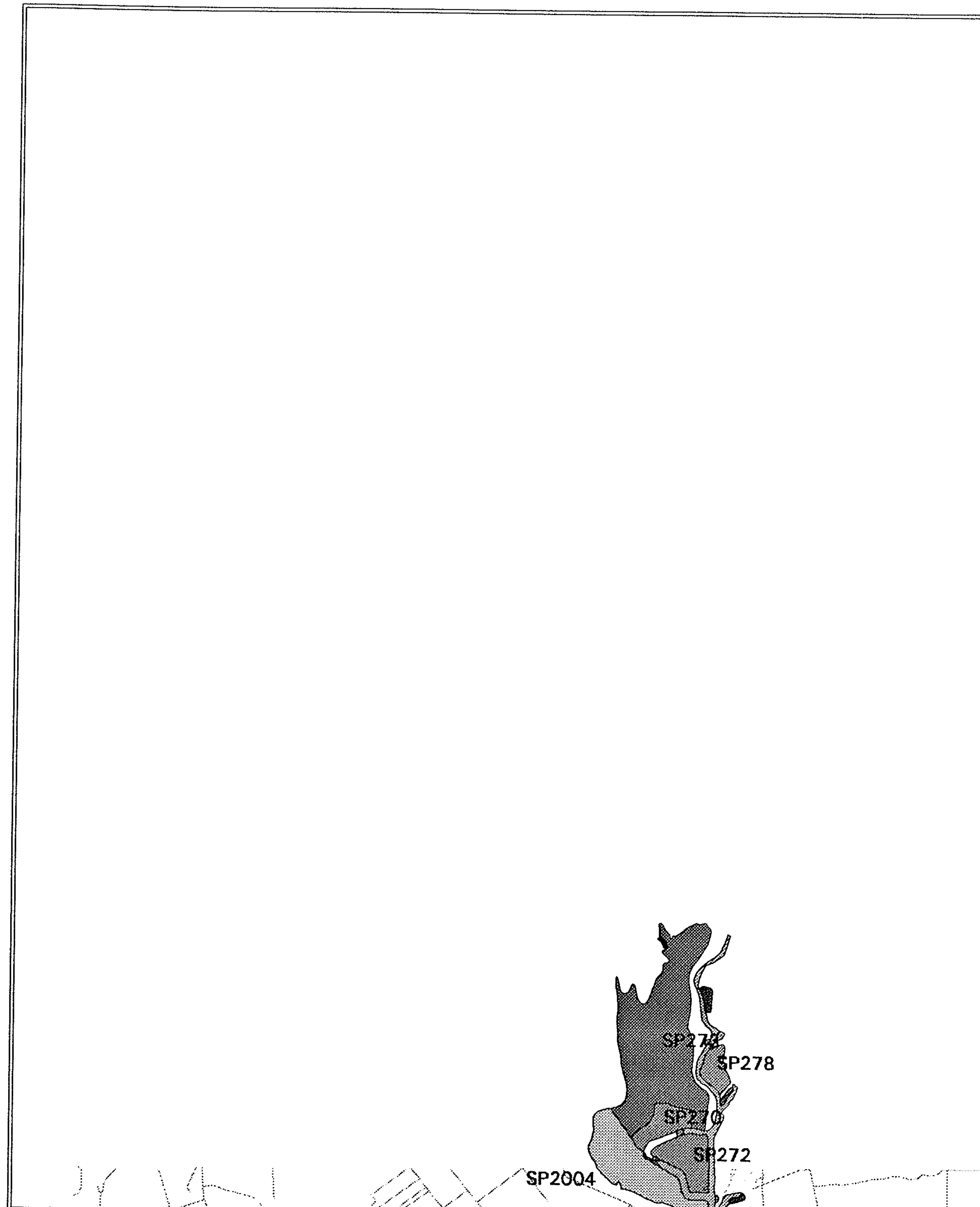
SP161
SP162
SP181
SP163



SP383
SP379
SP378
Mare Island
Quadrangle
Map Legend
Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for
study sites only
MAPSCALE 1:73,900



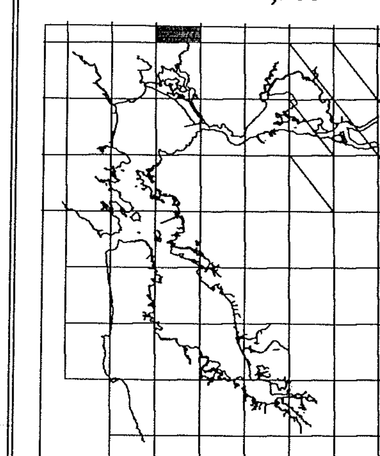
Napa Quadrangle

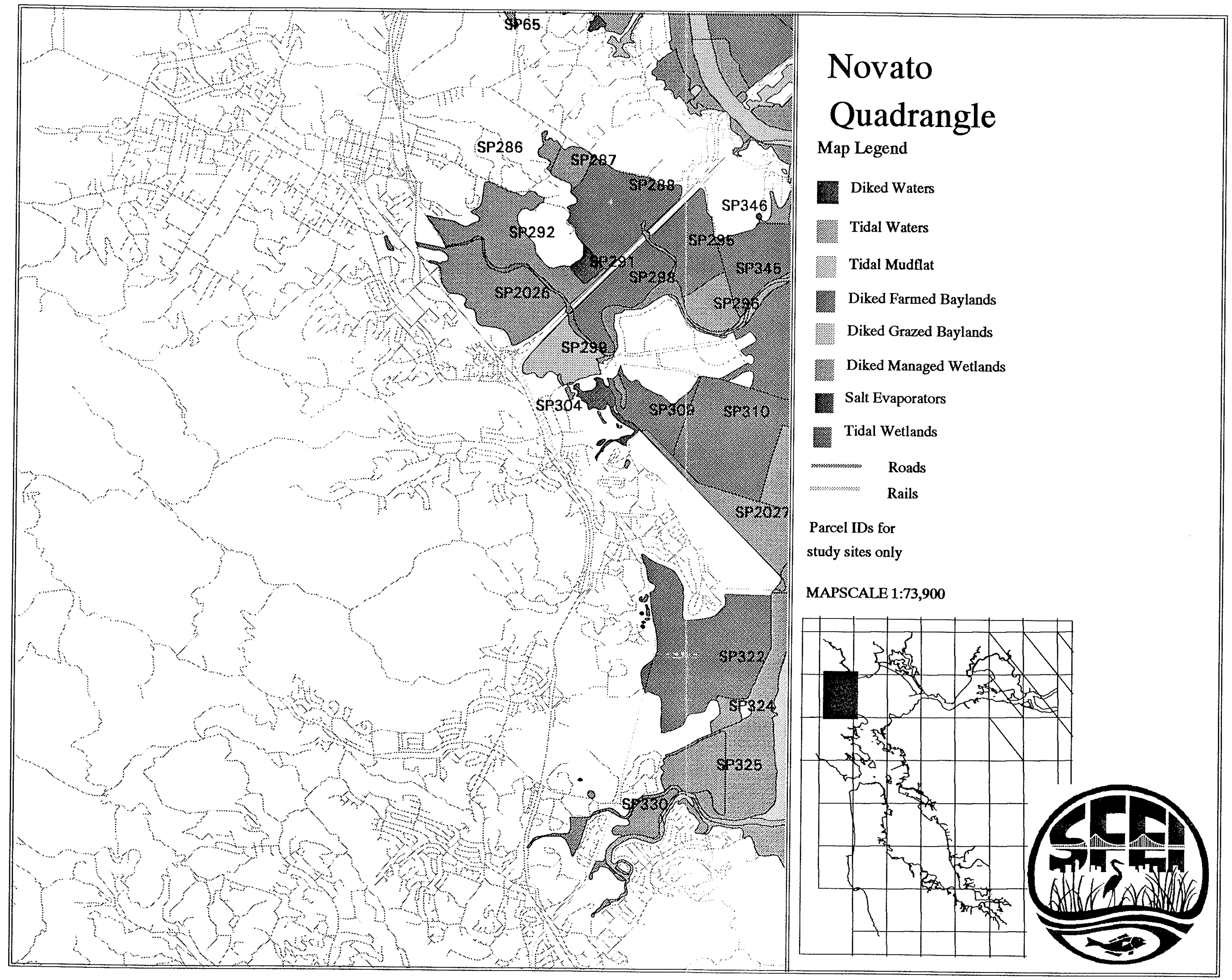
Map Legend

- Diked Waters
- Tidal Waters
- Tidal Mudflat
- Diked Farmed Baylands
- Diked Grazed Baylands
- Diked Managed Wetlands
- Salt Evaporators
- Tidal Wetlands
- Roads
- Rails

Parcel IDs for
study sites only

MAPSCALE 1:73,900




Novato
Quadrangle
Map Legend
Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for
study sites only
MAPSCALE 1:73,900
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SP287
SP288
SP346
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SP291
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SP2026
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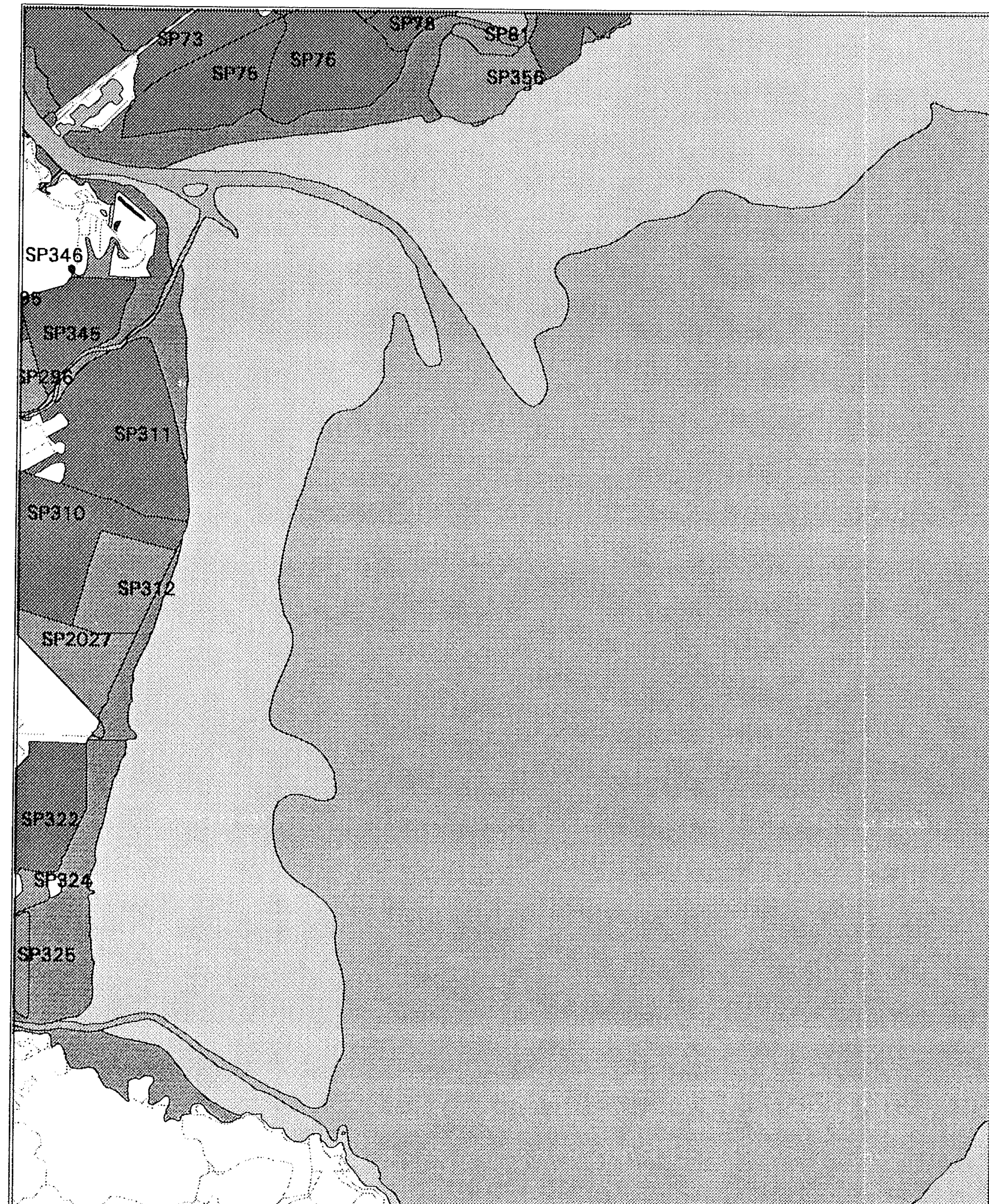
SP309
SP310
SP2027
SP322
SP324
SP325
SP330



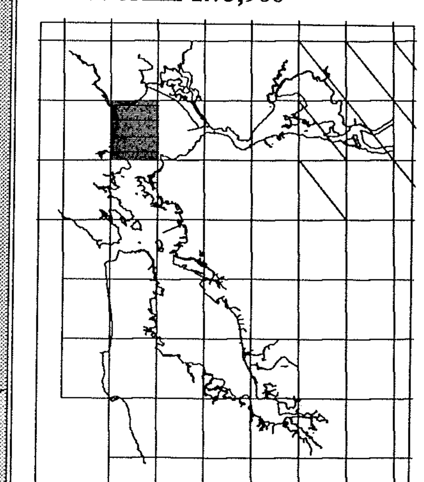
Petaluma Point Quadrangle

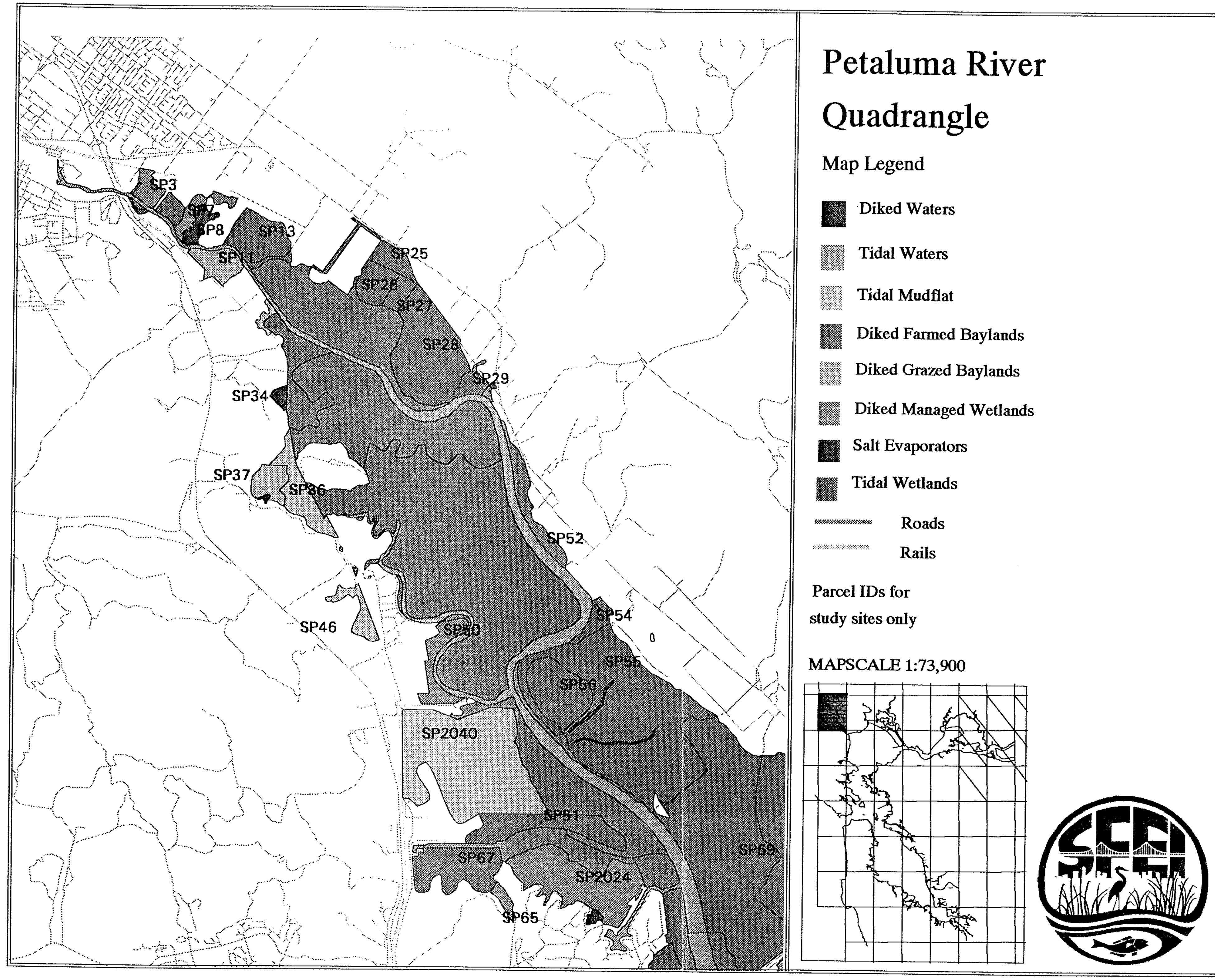
Map Legend

- Diked Waters
- Tidal Waters
- Tidal Mudflat
- Diked Farmed Baylands
- Diked Grazed Baylands
- Diked Managed Wetlands
- Salt Evaporators
- Tidal Wetlands
- Roads
- Rails

Parcel IDs for study sites only

MAPSCALE 1:73,900




Petaluma River Quadrangle
Map Legend
Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for study sites only
MAPSCALE 1:73,900
SP3
SP8
SP13
SP11
SP25
SP26
SP27
SP28
SP29
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SP56
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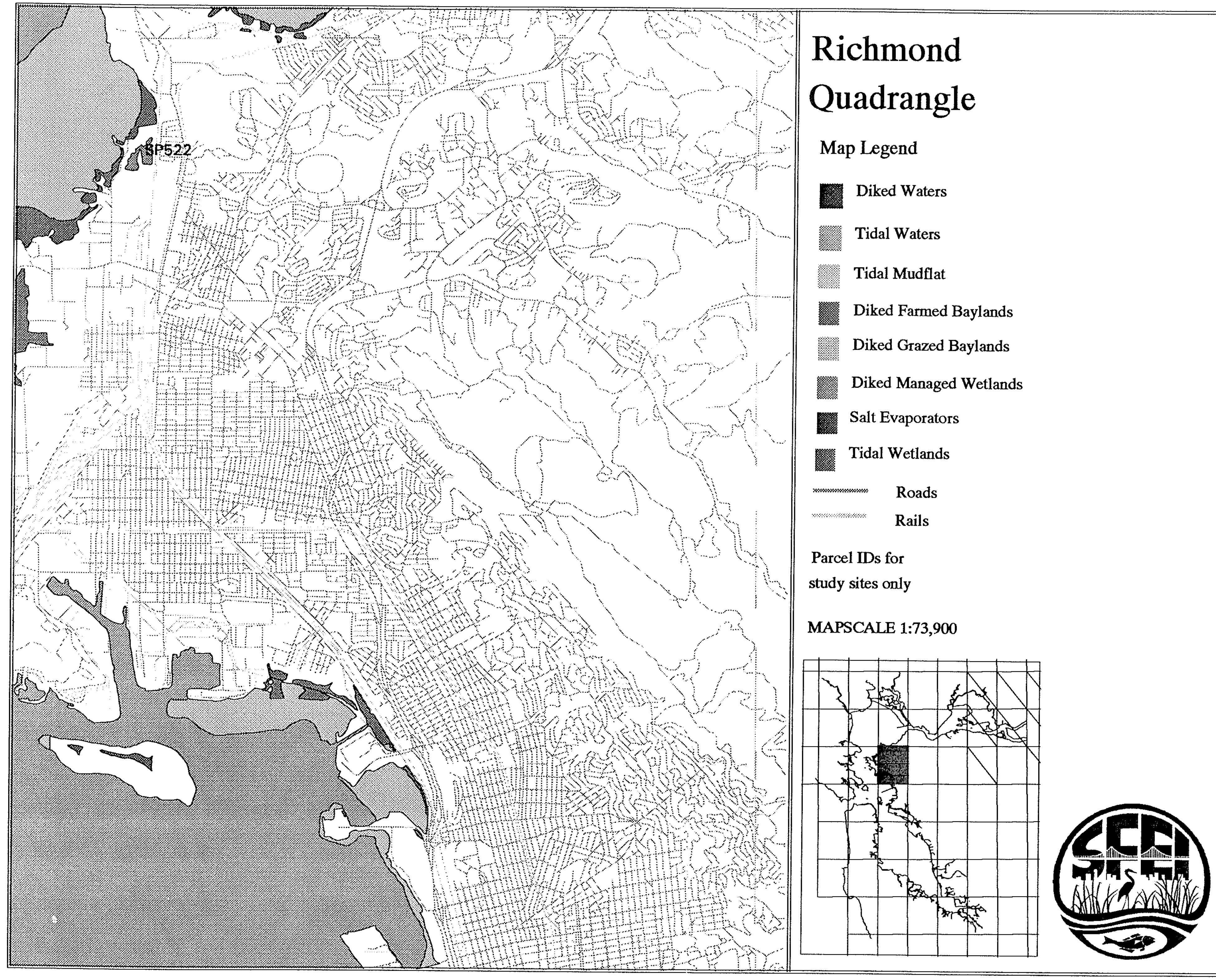
SP522
Richmond
Quadrangle
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Diked Farmed Baylands
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Roads
Rails
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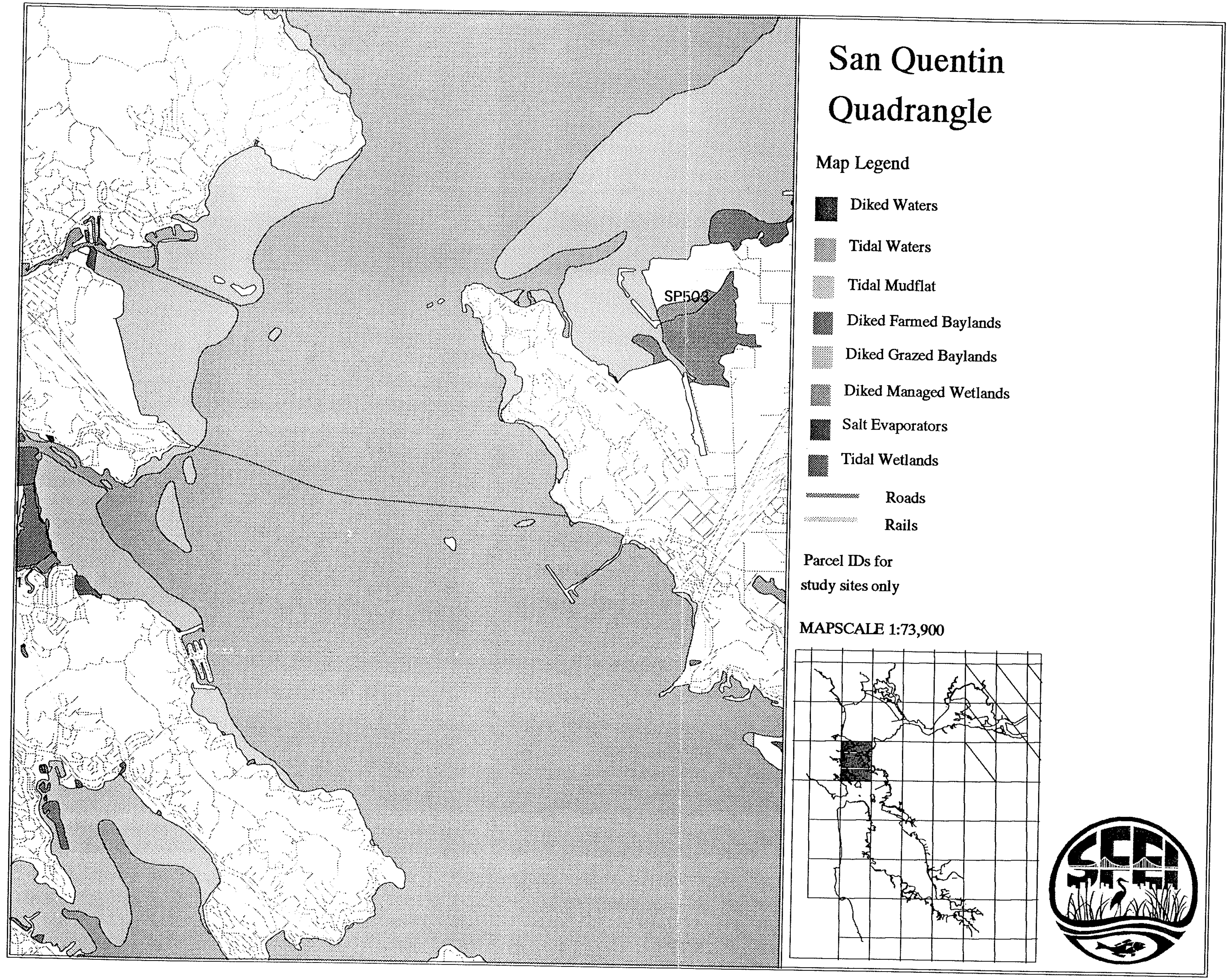
San Quentin
Quadrangle
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Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for
study sites only
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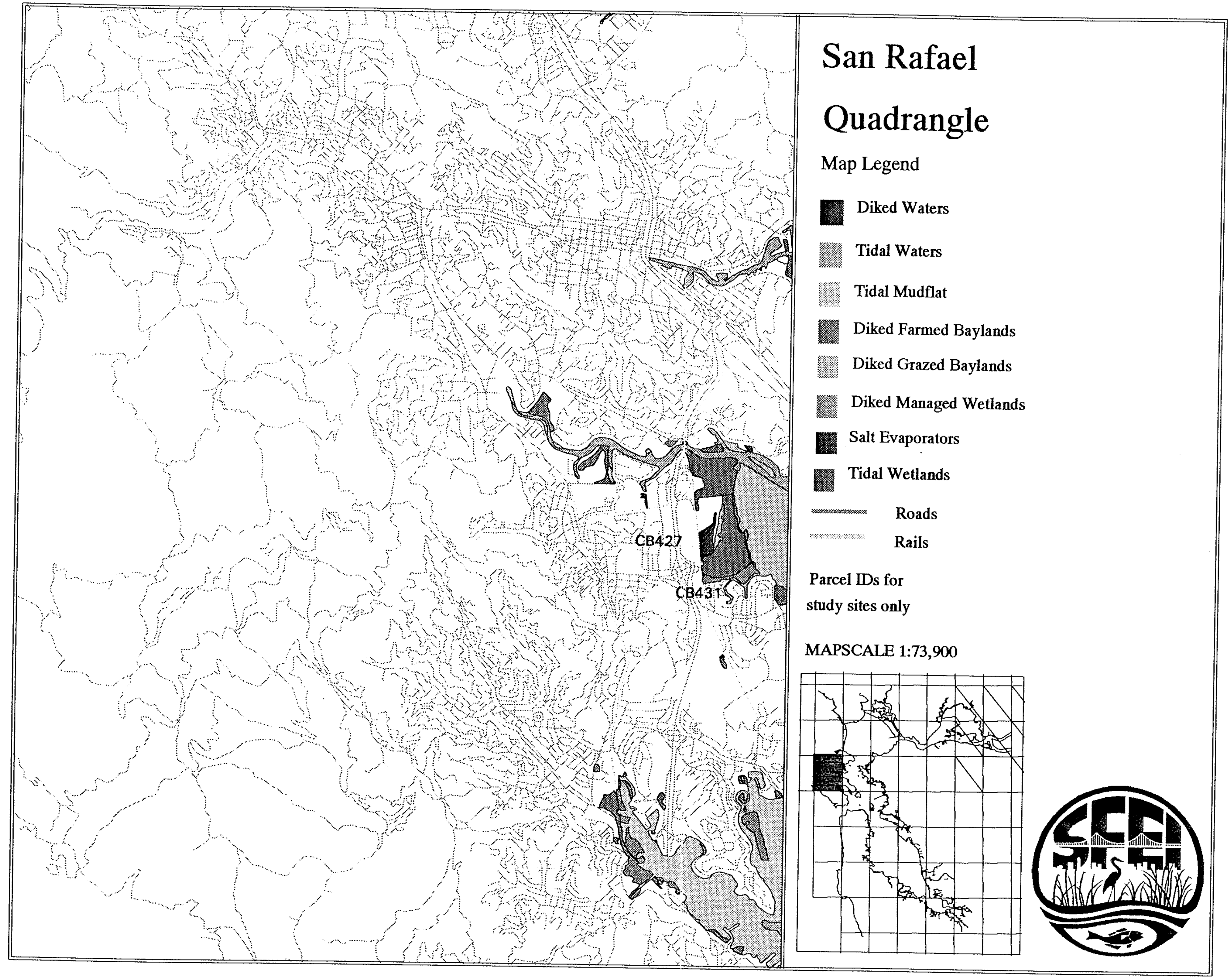
San Rafael
Quadrangle
Map Legend
Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for
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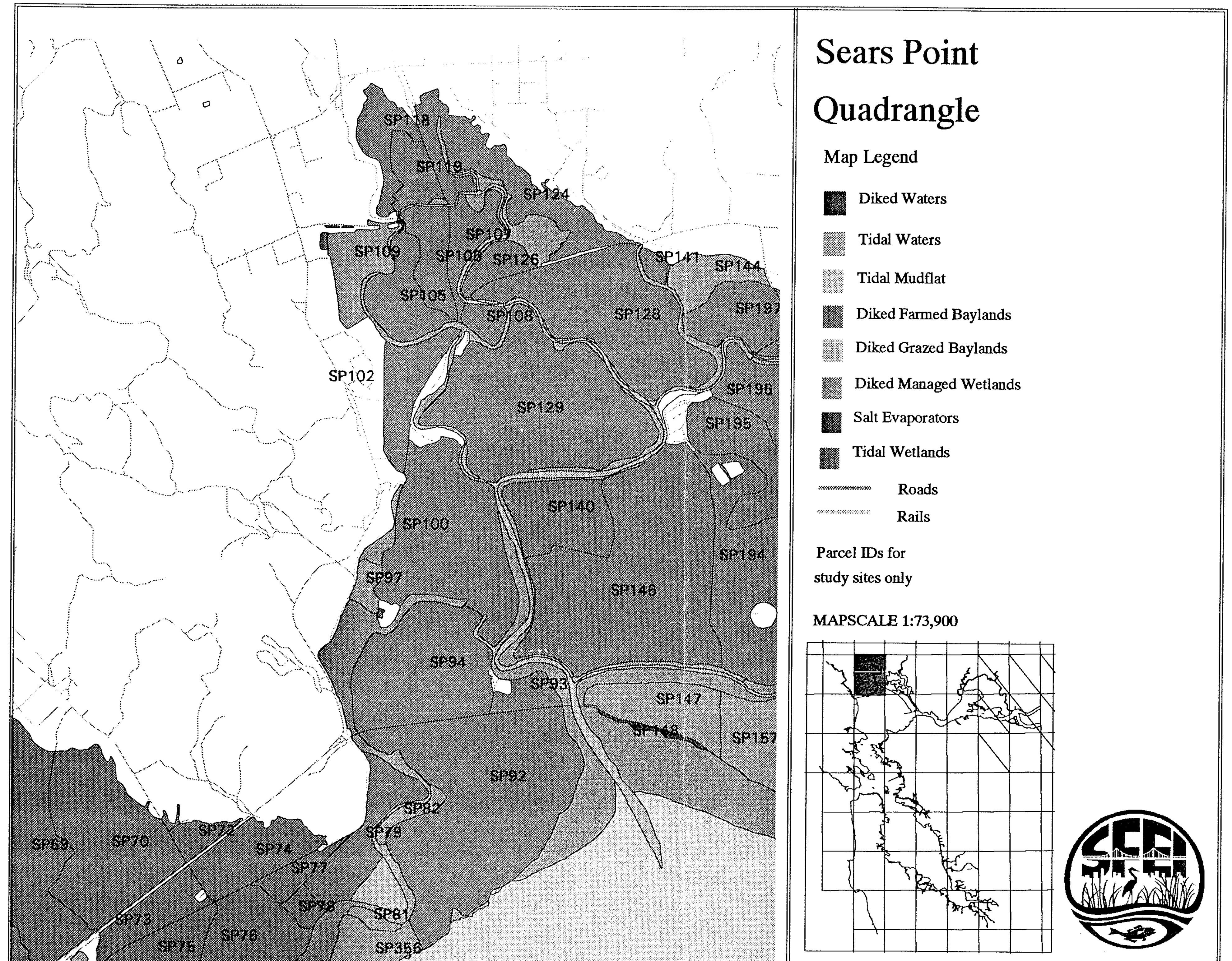
CB427
CB431


Sears Point
Quadrangle
Map Legend
Diked Waters
Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for
study sites only
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SP119
SP124
SP107
SP109
SP126
SP105
SP108
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SP144
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SP196
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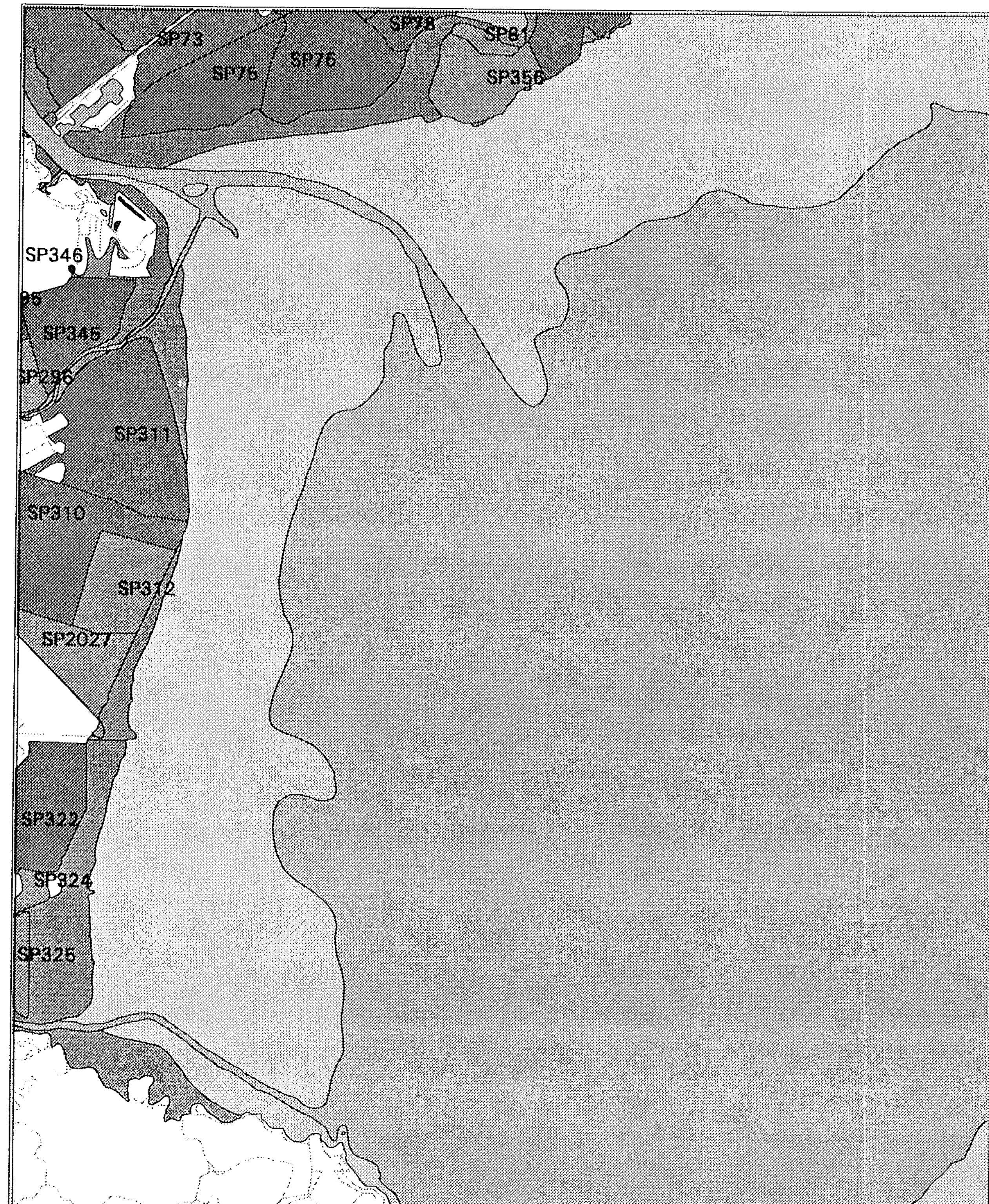
SP76
SP356



Petaluma Point Quadrangle

Map Legend

- Diked Waters
- Tidal Waters
- Tidal Mudflat
- Diked Farmed Baylands
- Diked Grazed Baylands
- Diked Managed Wetlands
- Salt Evaporators
- Tidal Wetlands
- Roads
- Rails

Parcel IDs for study sites only

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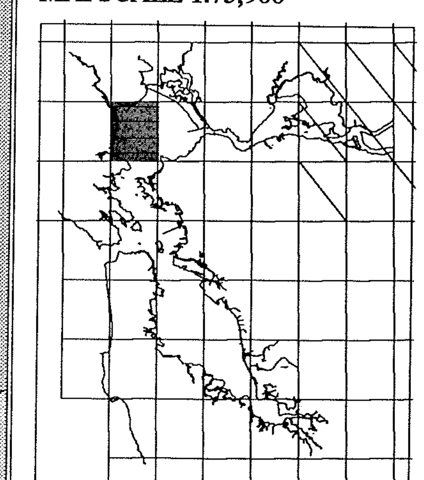

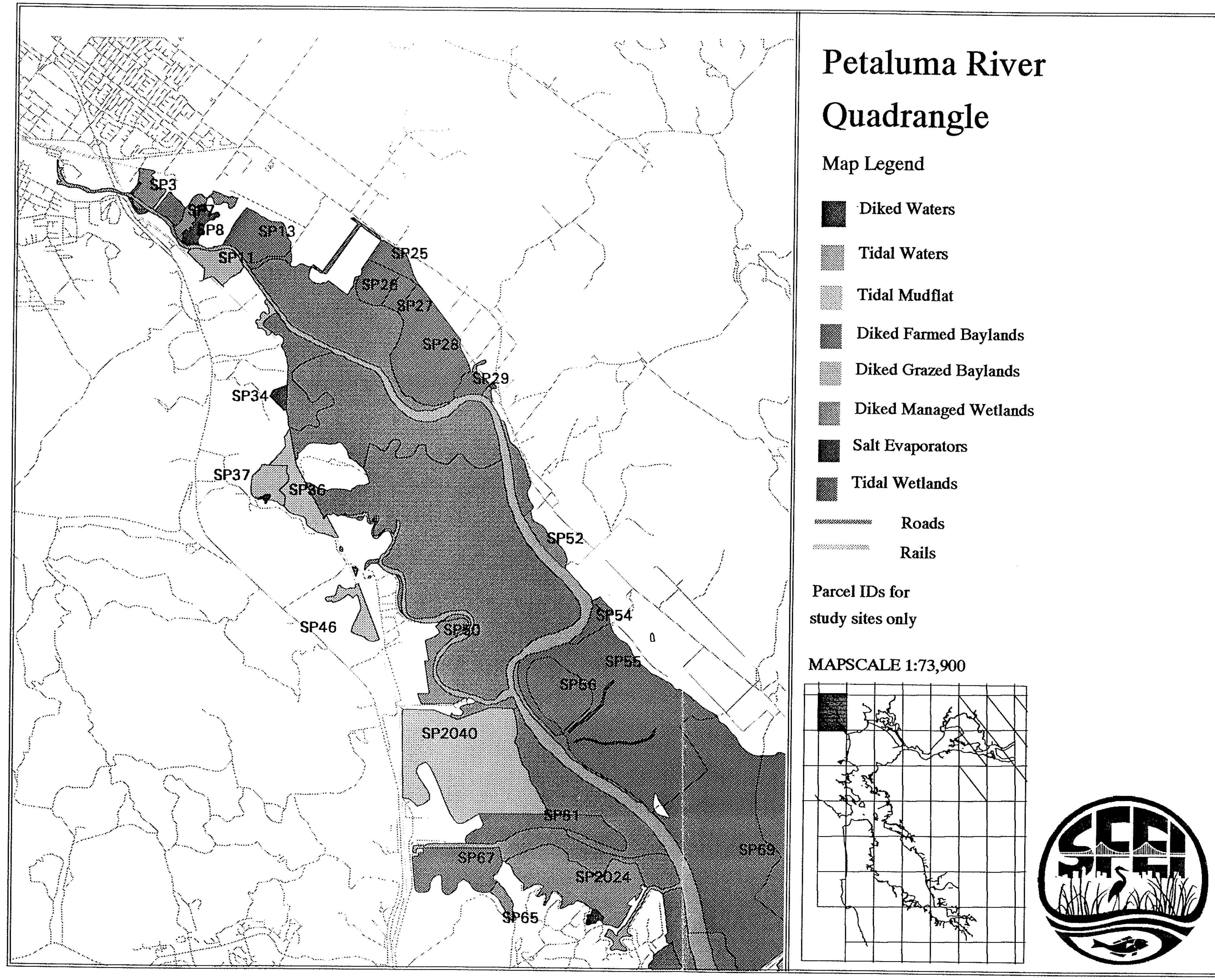

Petaluma River Quadrangle
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Diked Waters
Tidal Waters
Tidal Mudflat
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Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for study sites only
MAPSCALE 1:73,900
SP3
SP7
SP8
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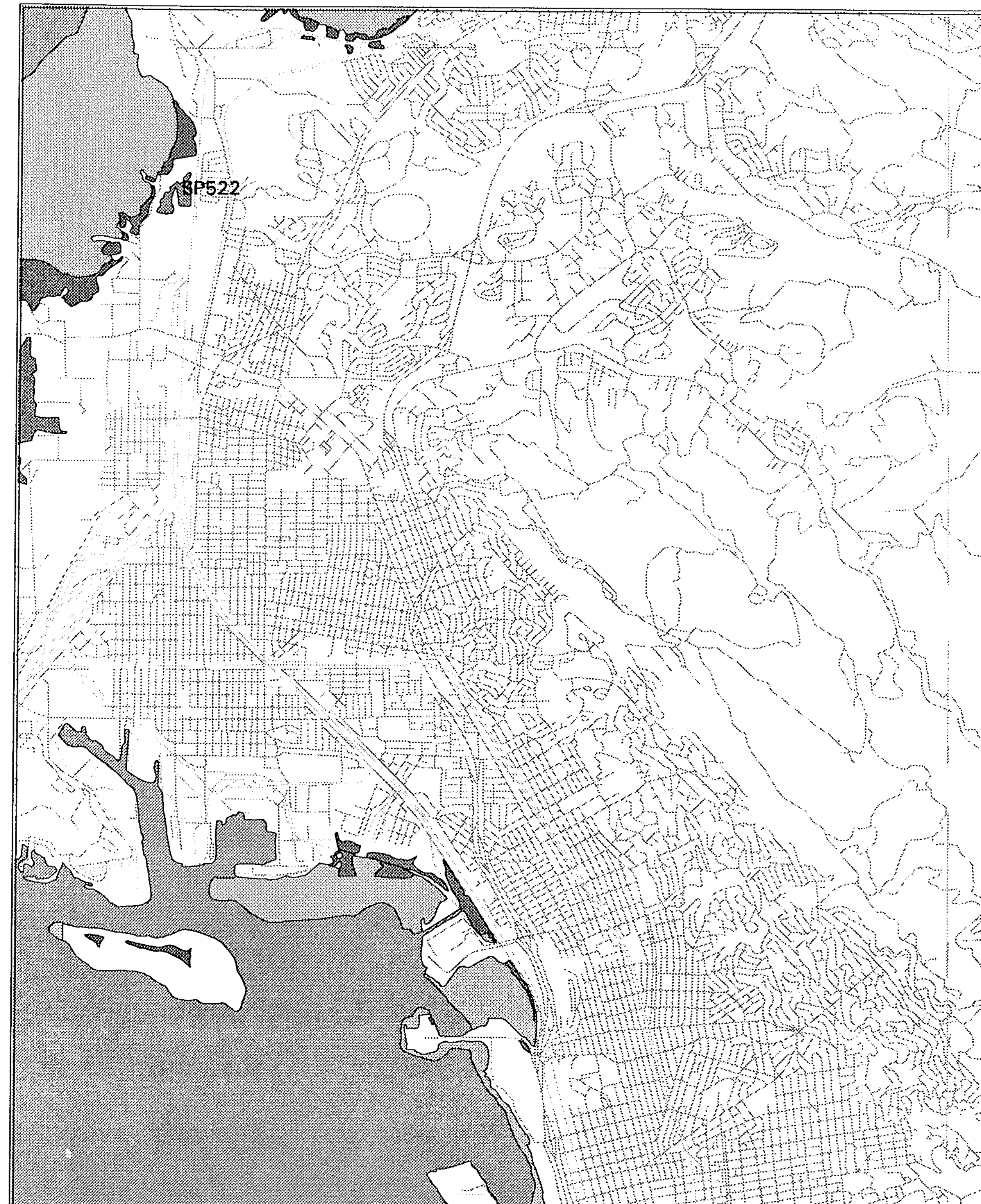

Richmond Quadrangle

Map Legend

- Diked Waters
- Tidal Waters
- Tidal Mudflat
- Diked Farmed Baylands
- Diked Grazed Baylands
- Diked Managed Wetlands
- Salt Evaporators
- Tidal Wetlands
- Roads
- Rails

Parcel IDs for
study sites only

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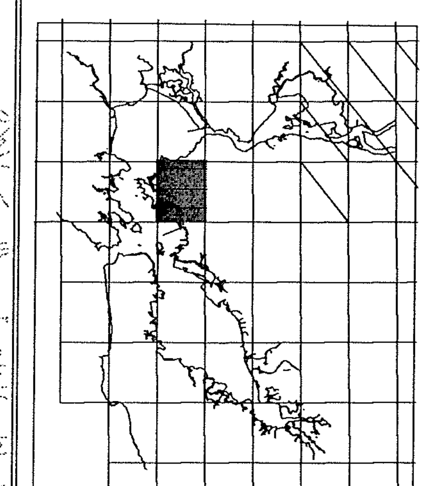

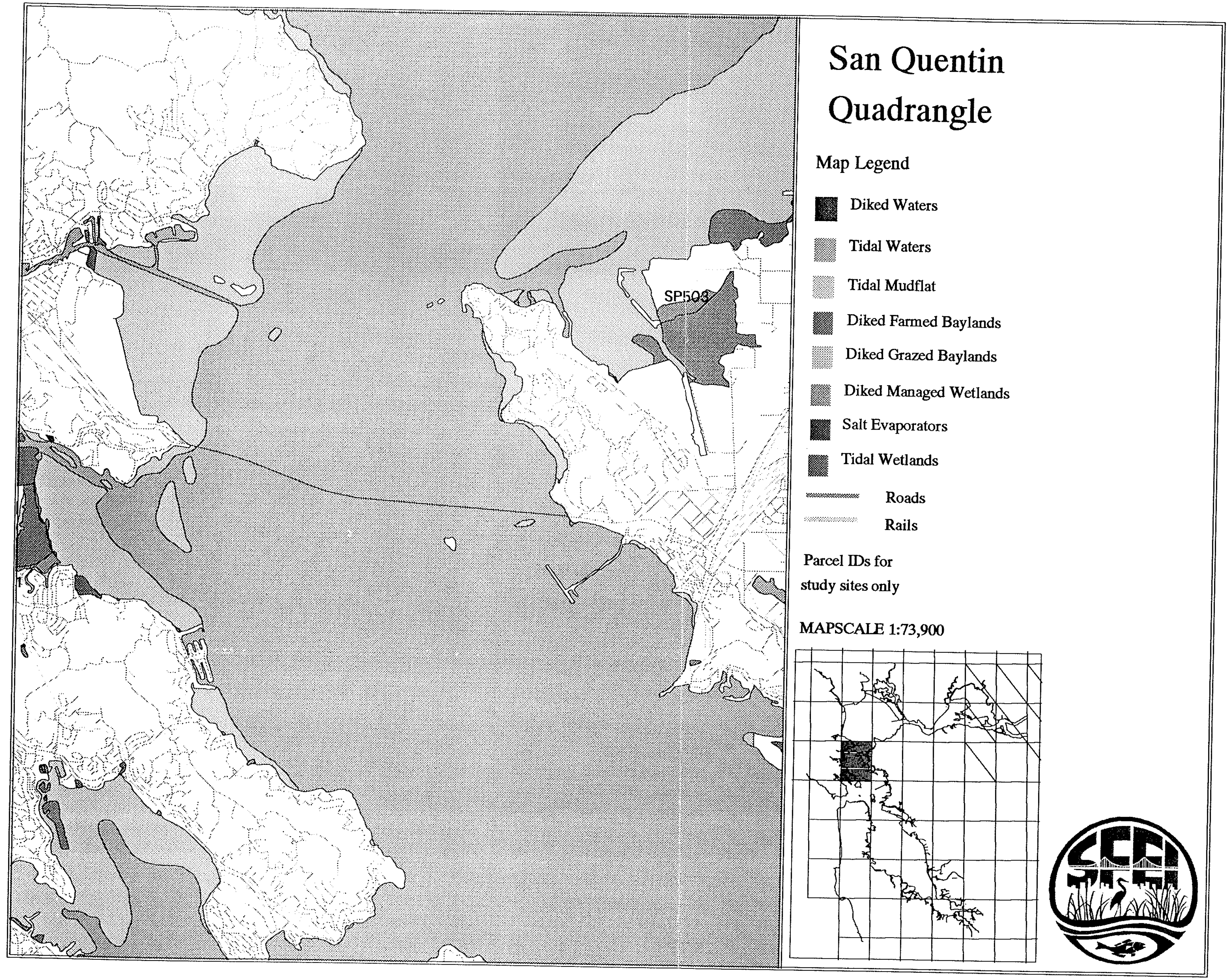
San Quentin Quadrangle
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Salt Evaporators
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Roads
Rails
Parcel IDs for study sites only
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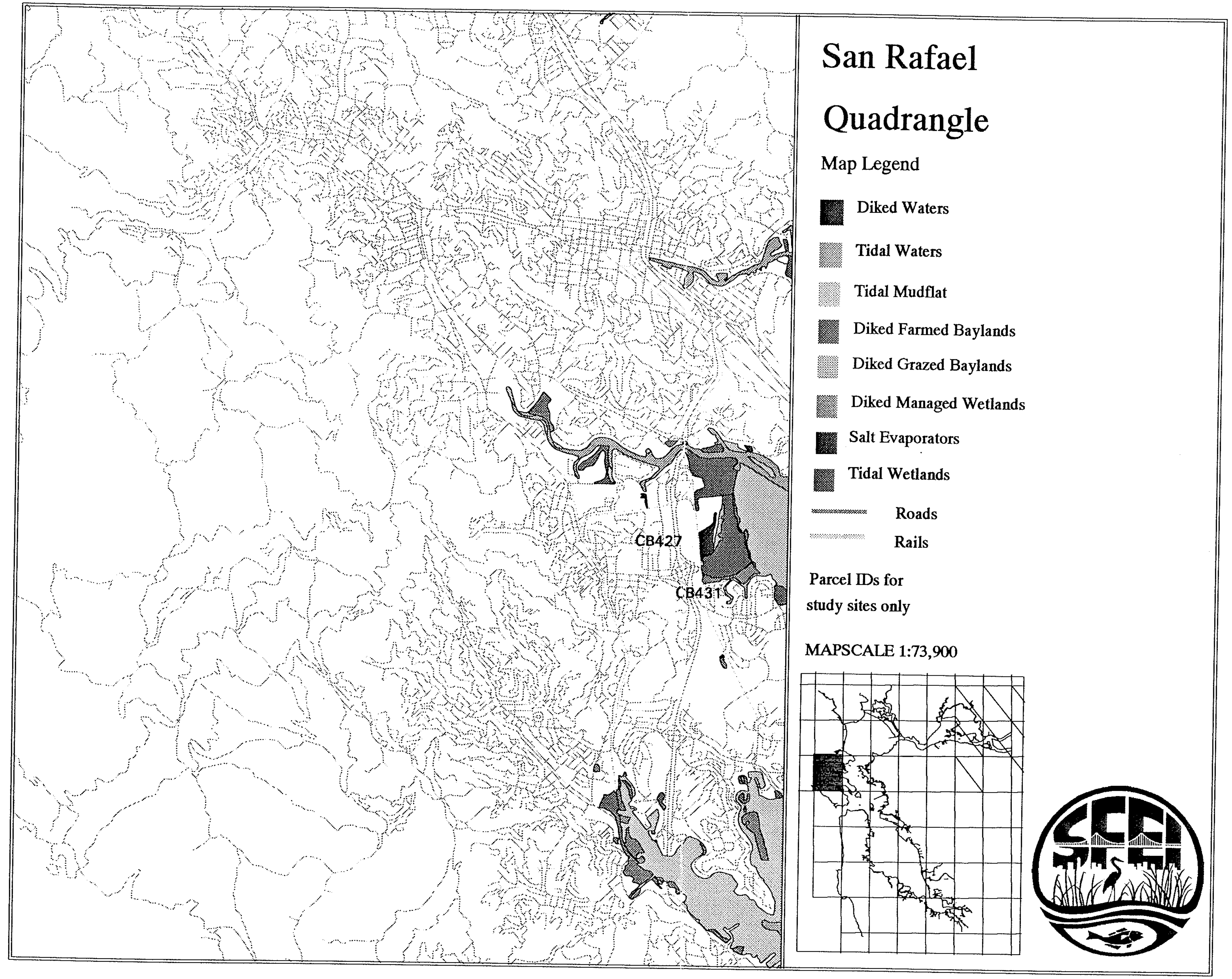
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Quadrangle
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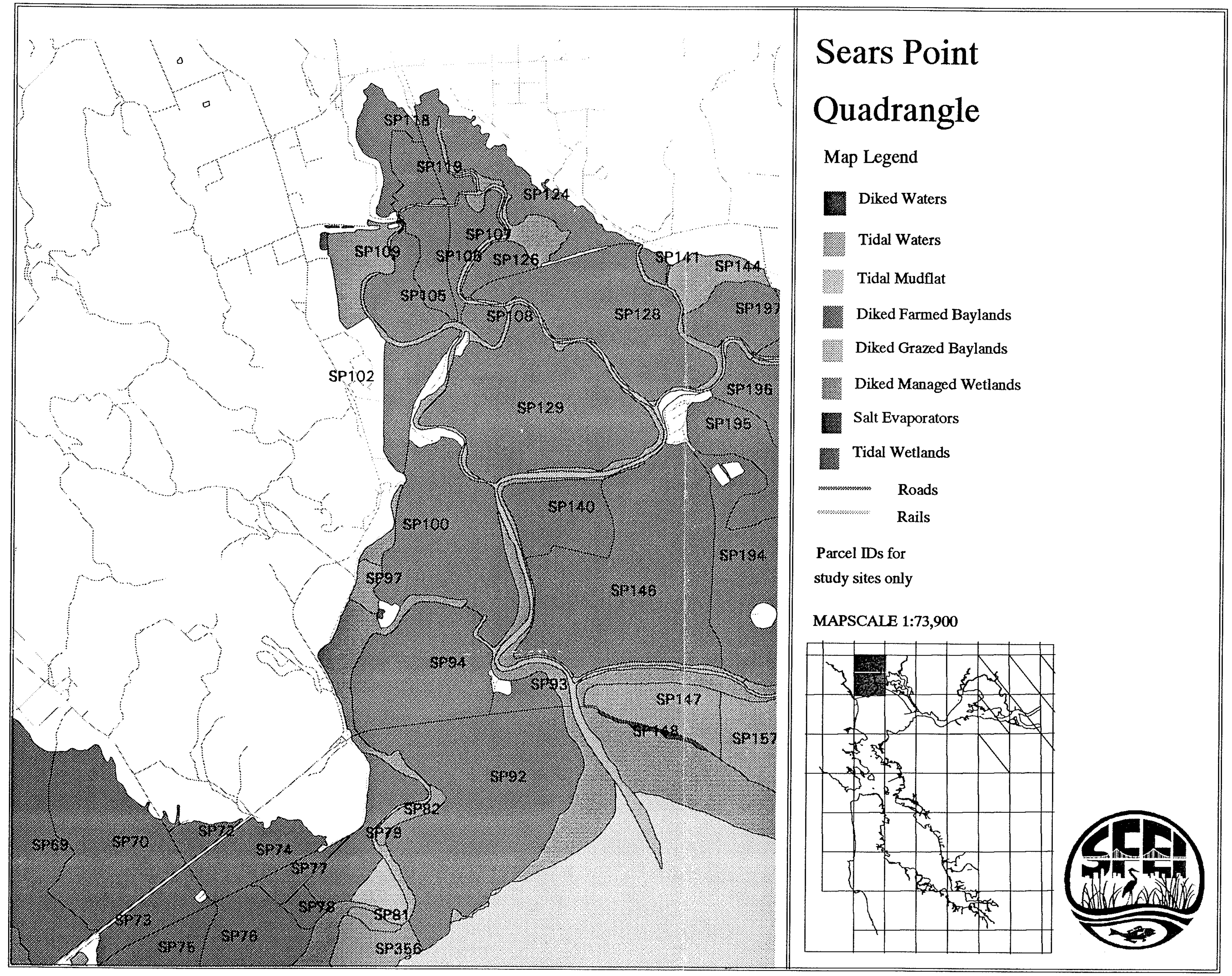
Tidal Wetlands
Roads
Rails
Parcel IDs for
study sites only
MAPSCALE 1:73,900



Sears Point Quadrangle
Map Legend
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Tidal Waters
Tidal Mudflat
Diked Farmed Baylands
Diked Grazed Baylands
Diked Managed Wetlands
Salt Evaporators
Tidal Wetlands
Roads
Rails
Parcel IDs for study sites only
MAPSCALE 1:73,900
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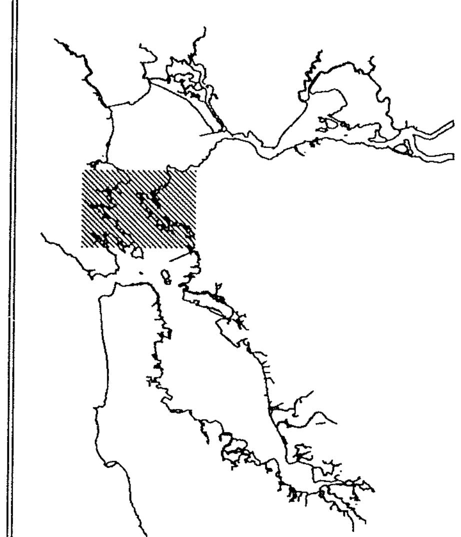
APPENDIX 2: Map of the Ponding Patterns Of Diked Baylands
(3 sheets)

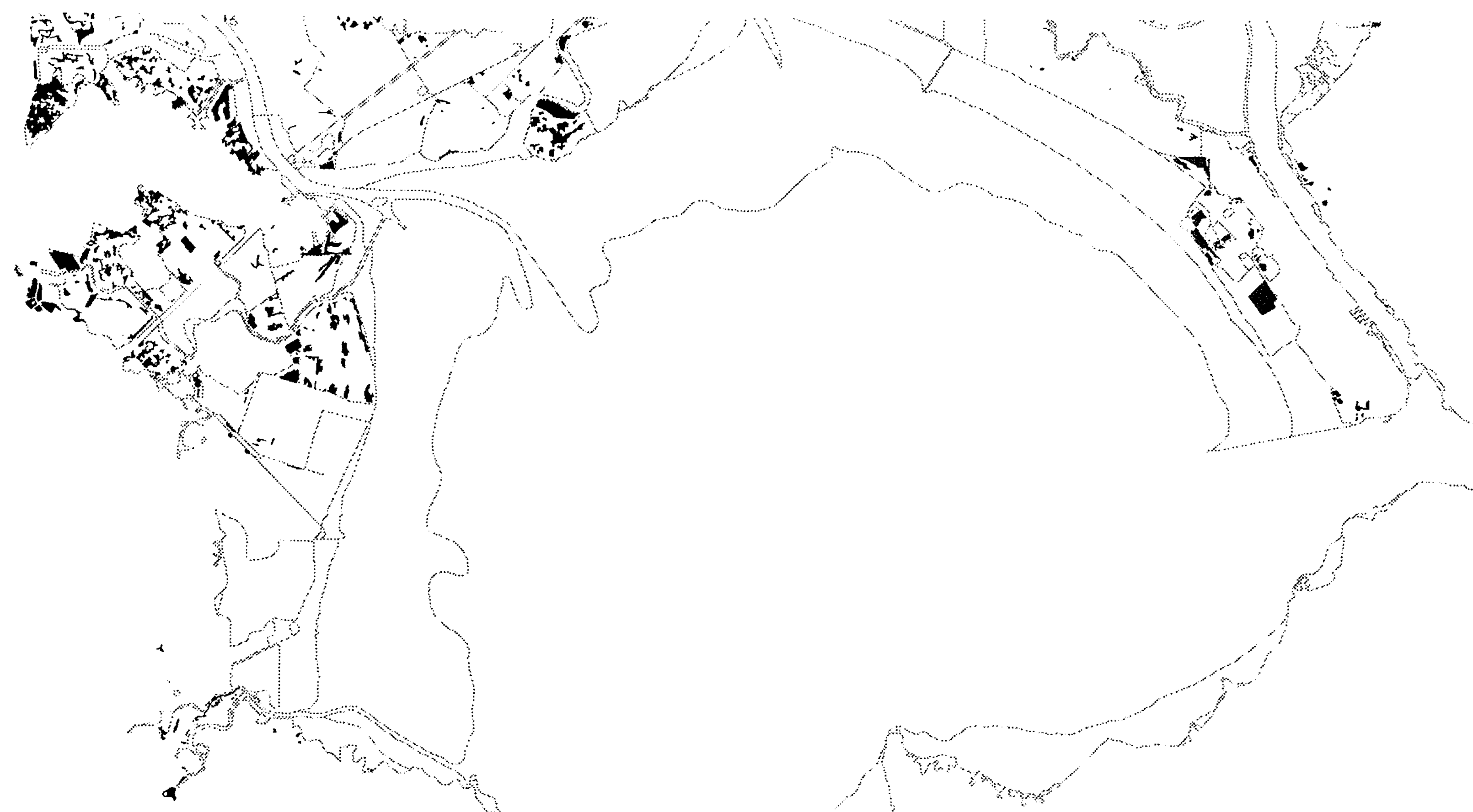
Ponding in Diked Baylands

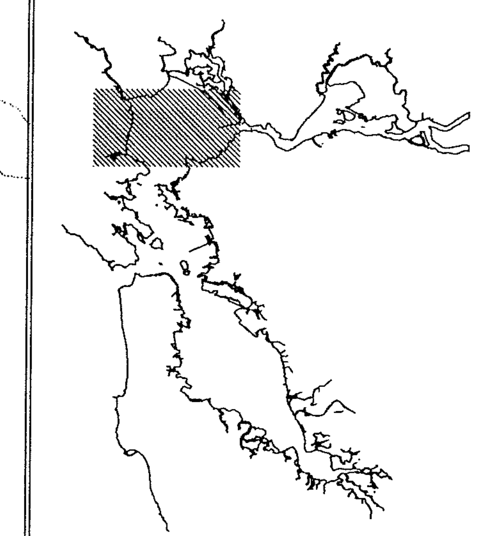
Mapscale 1:97,300



Ponding in Diked Baylands

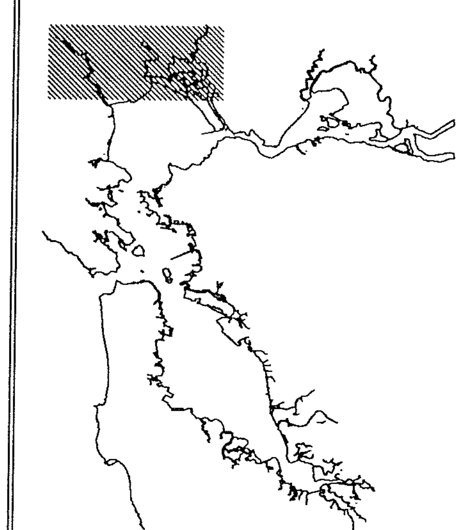
mapscale 1:139,900





Ponding in Diked Baylands

Mapscale 1:156,600



APPENDIX 3: Map of Ranking Results for Scenario 1
(3 sheets)

Ranking Scenario 1

Mapscale 1:97,300

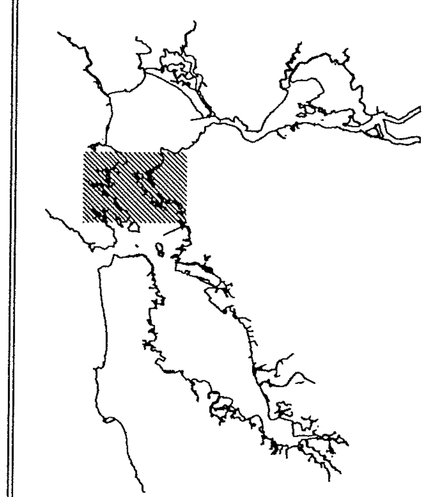
Ranking Legend

low

medium low

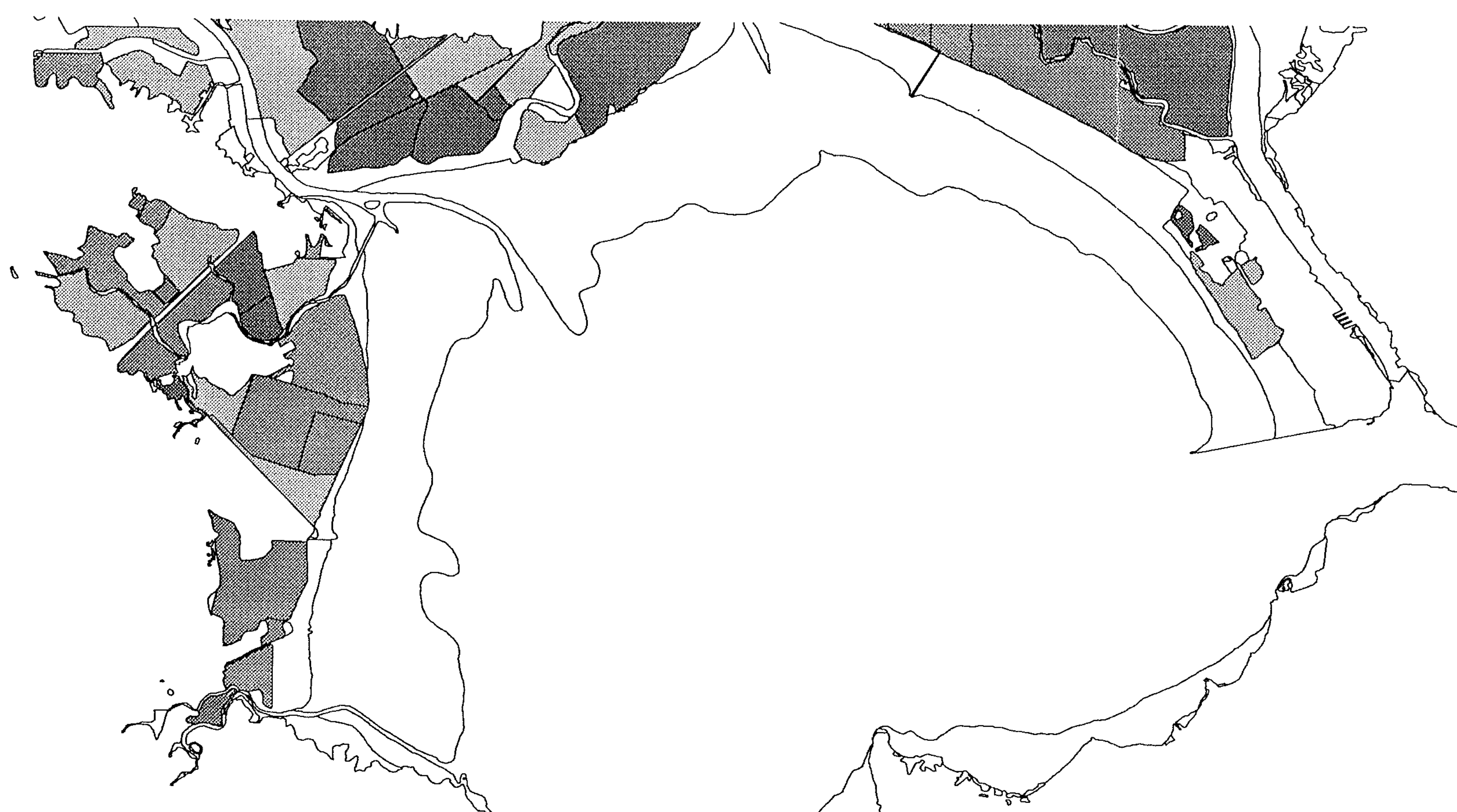
medium high

high



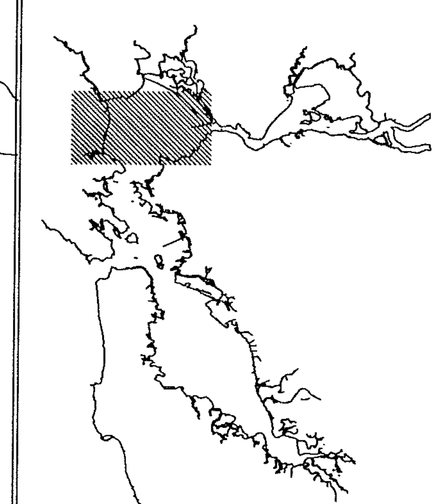
Ranking Scenario 1

Mapscale 1:139,900



Ranking Legend

- low
- medium low
- medium high
- high

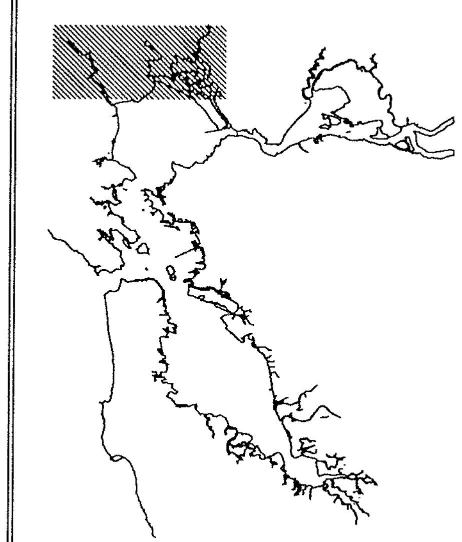


Ranking Scenario 1

Mapscale 1:156,600

Ranking Legend

- low
- medium low
- medium high
- high



APPENDIX 4: Map of Ranking Results for Scenario 2
(2 sheets)

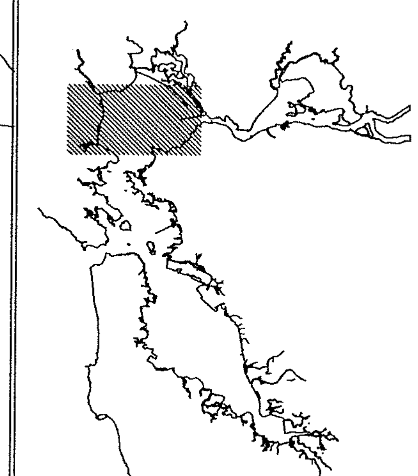
APPENDIX 4: Map of Ranking Results for Scenario 2
(2 sheets)

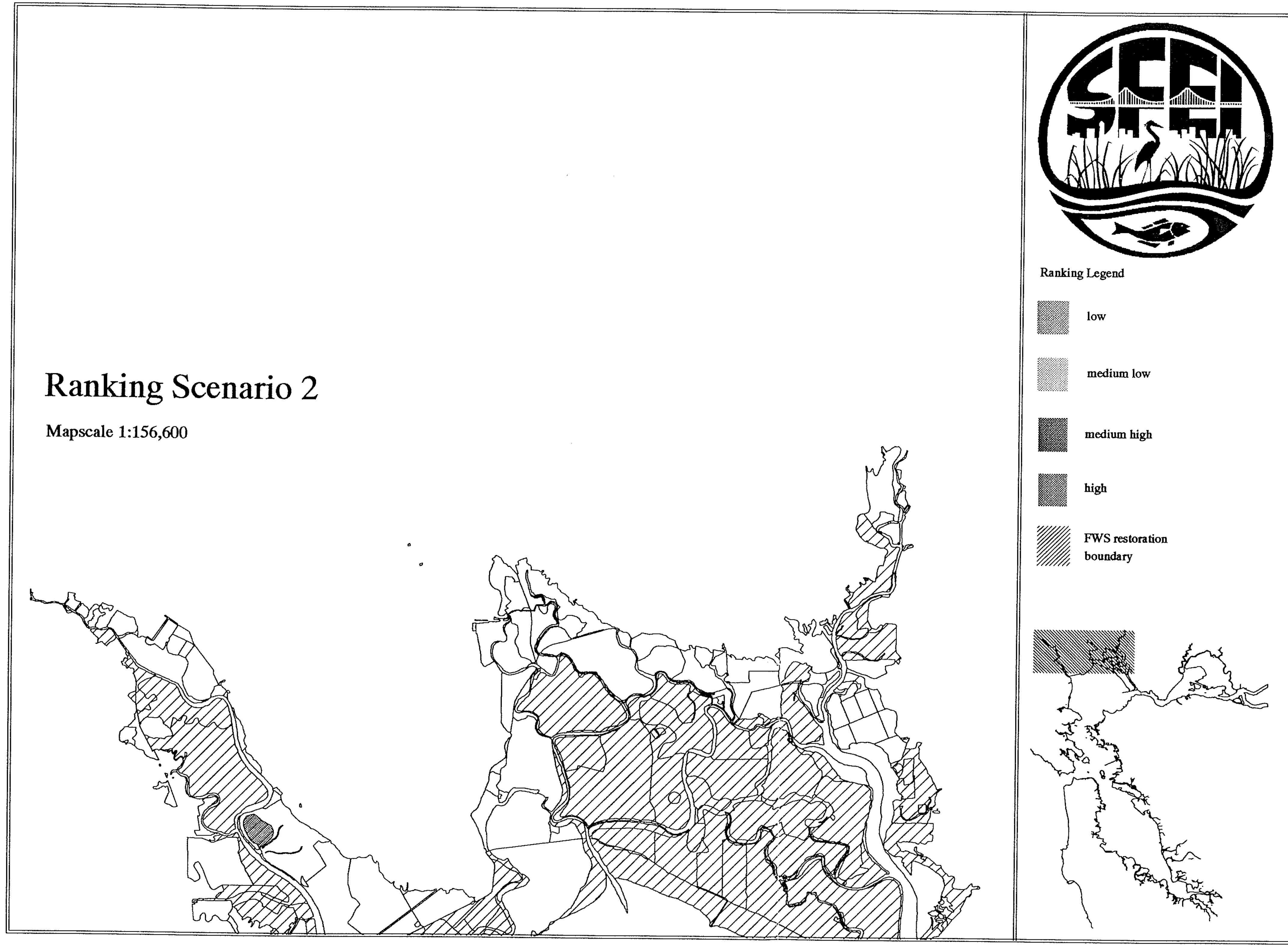
Ranking Scenario 2

Mapscale 1:139,900

Ranking Legend

- low
- medium low
- medium high
- high
- FWS restoration boundary





Ranking Scenario 2
Mapscale 1:156,600
Ranking Legend
low
medium low
medium high
high
FWS restoration boundary

APPENDIX 5: Map of Ranking Results for Scenario 3
(2 sheets)

Ranking Scenario 3

Mapsclae 1:139,900

Ranking Legend

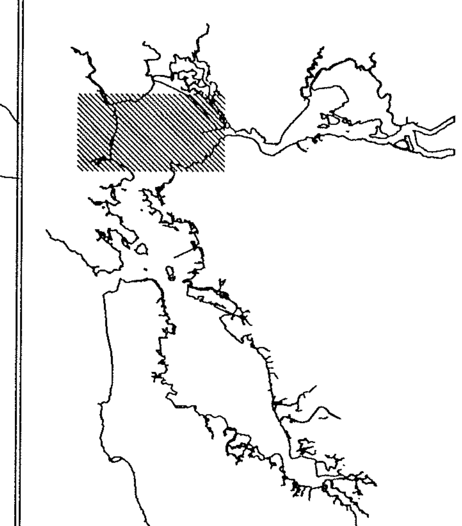
low

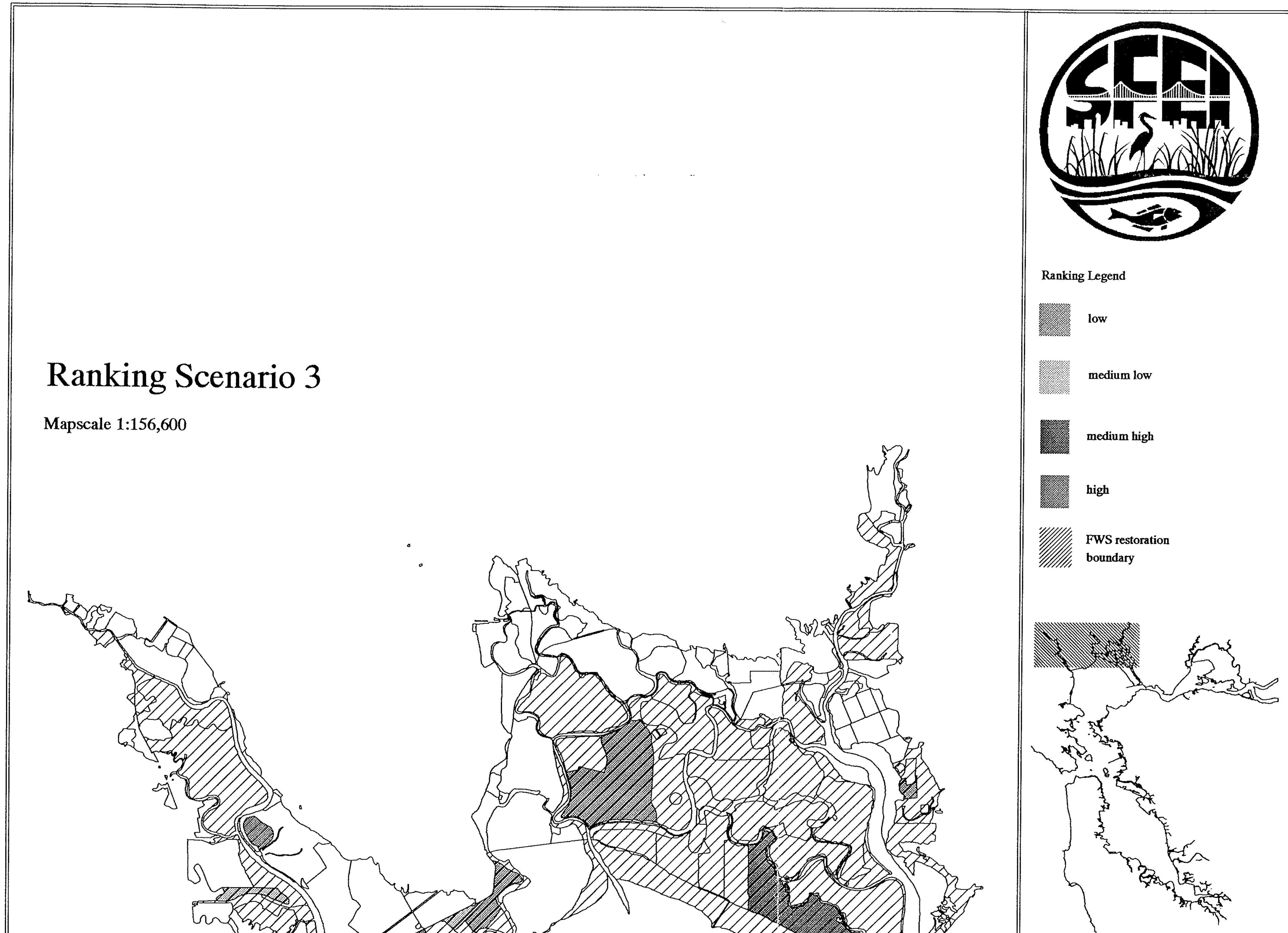
medium low

medium high

high

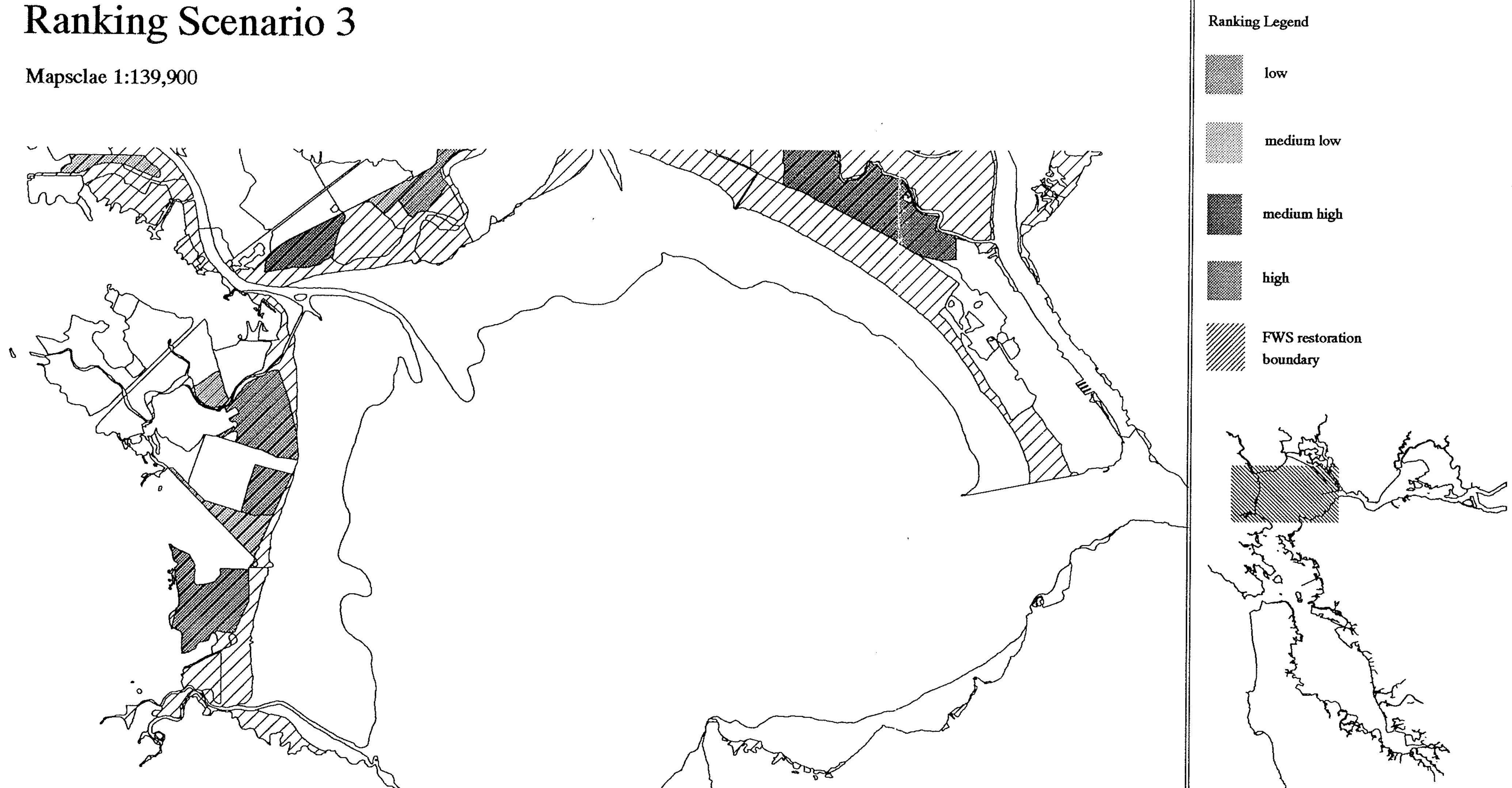
FWS restoration boundary

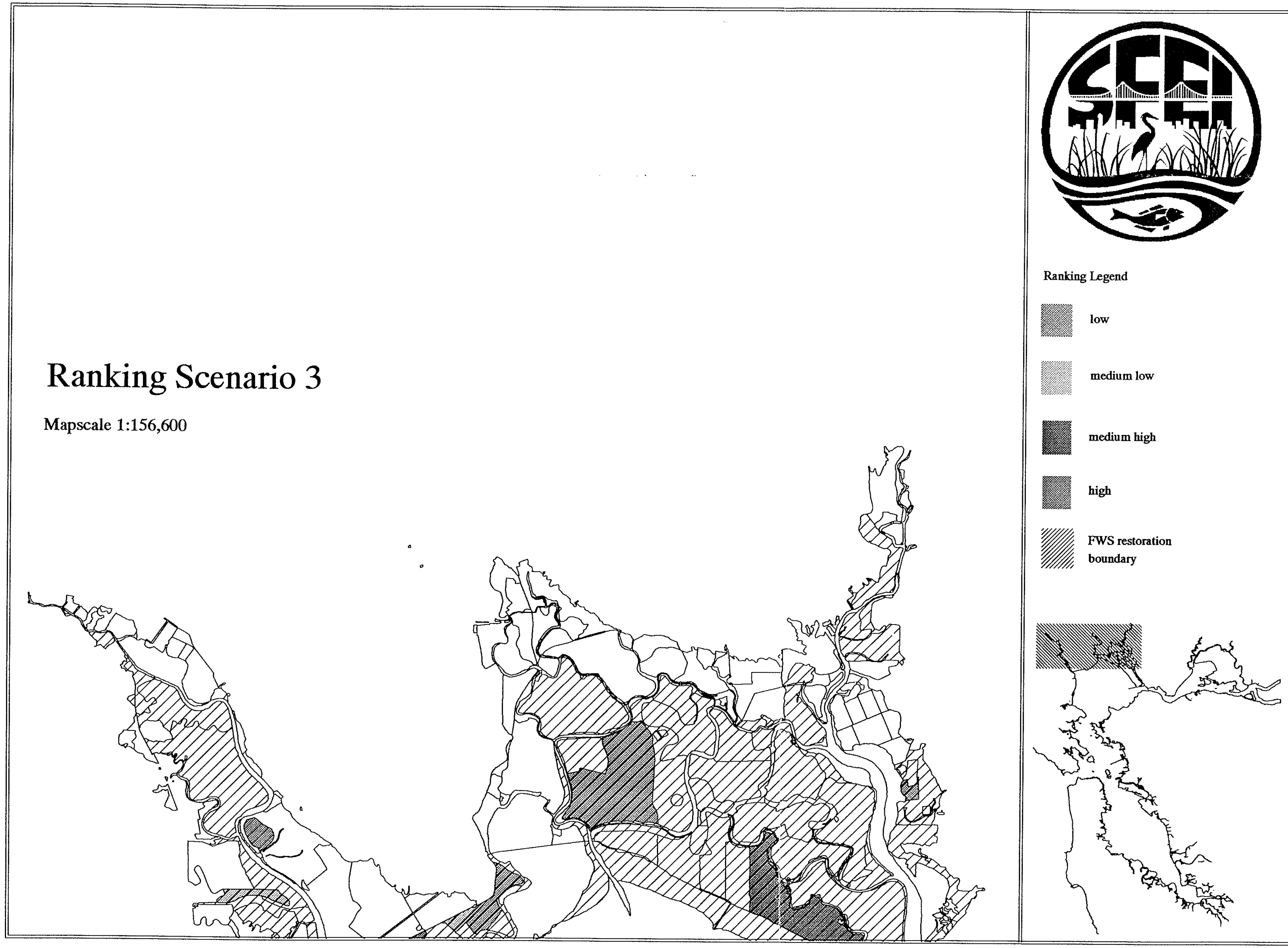



Ranking Scenario 3
Mapscale 1:156,600
Ranking Legend
low
medium low
medium high
high
FWS restoration boundary

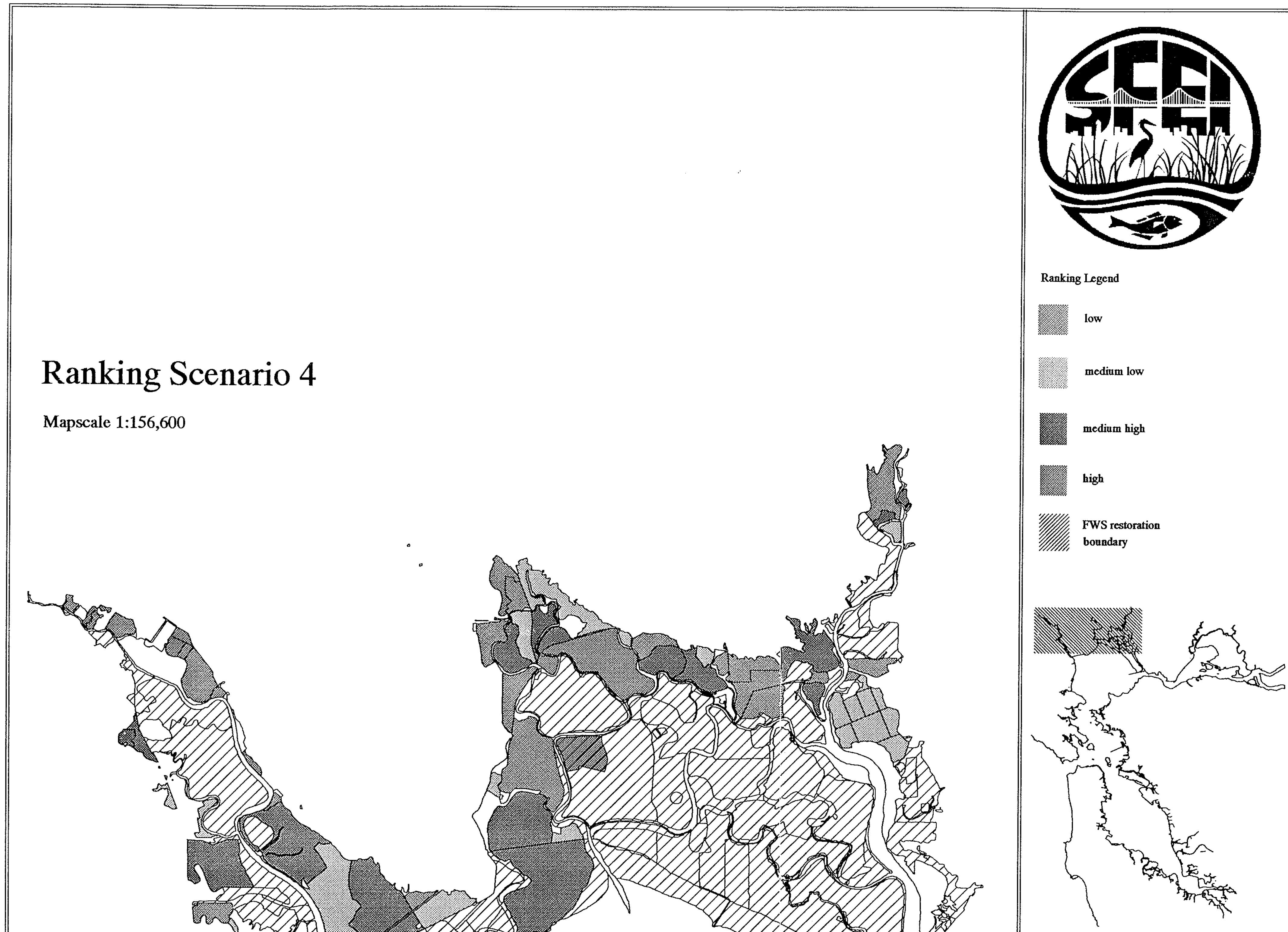
Ranking Scenario 3

Mapsclae 1:139,900



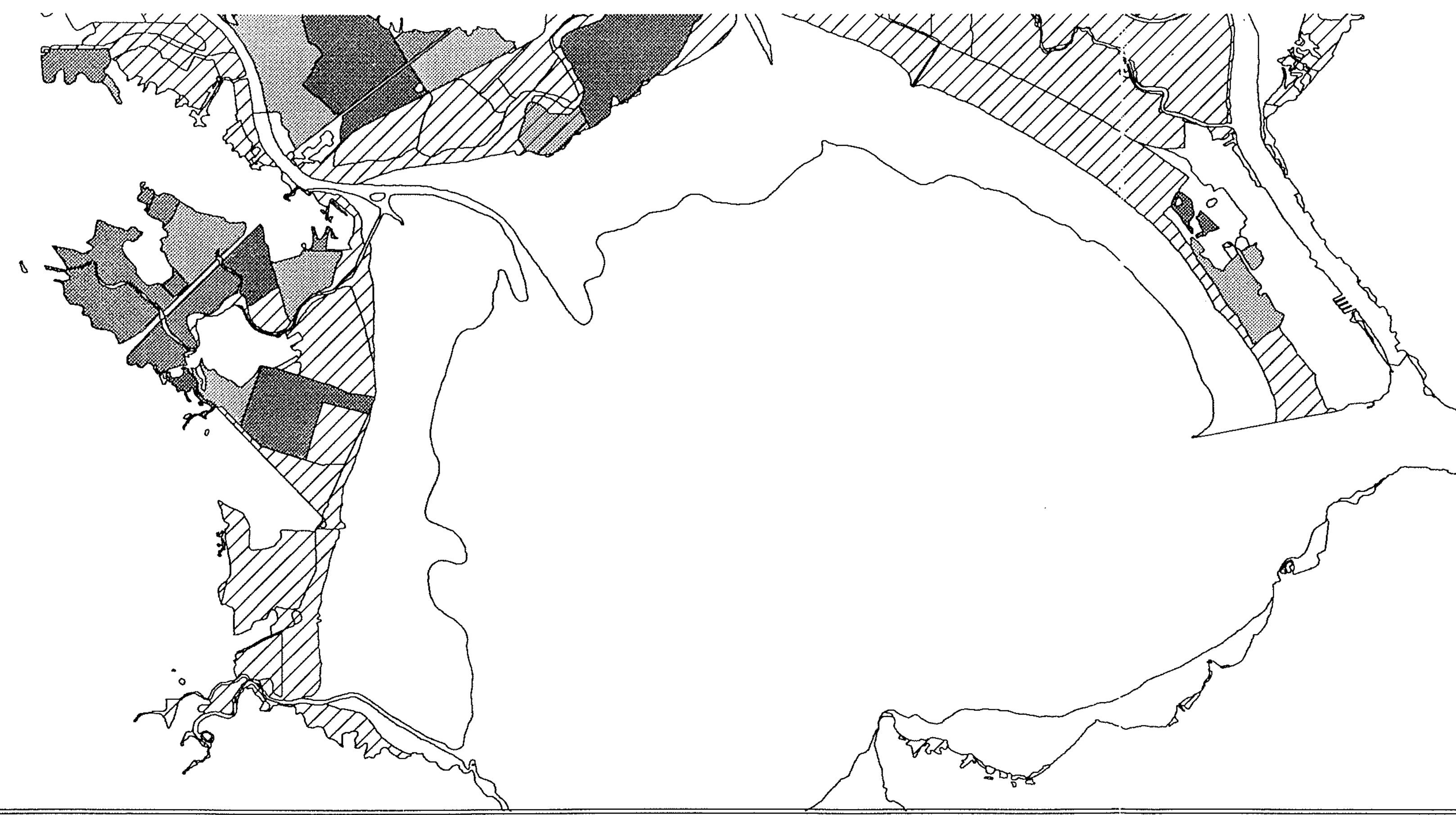

Ranking Scenario 3
Mapscale 1:156,600
Ranking Legend
low
medium low
medium high
high
FWS restoration boundary

APPENDIX 6: Map of Ranking Results for Scenario 4
(2 sheets)


Ranking Scenario 4
Mapscale 1:156,600
Ranking Legend
low
medium low
medium high
high
FWS restoration boundary

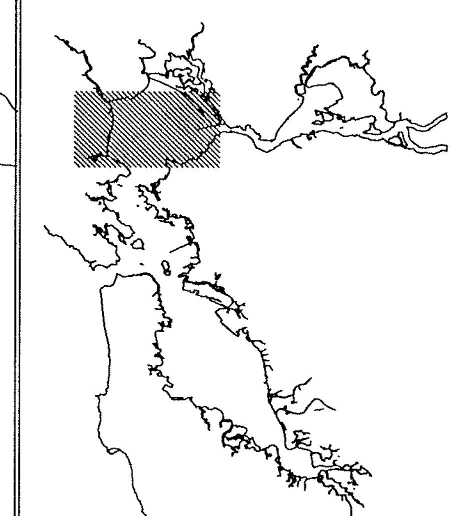
Ranking Scenario 4

Mapscale 1:139,900



Ranking Legend

- low
- medium low
- medium high
- high
- FWS restoration boundary



APPENDIX 7: Tabular Results

This Appendix 7 contains the output of the Excel spreadsheet used to manage the data and to compute the scores for each diked baylands parcel. The spreadsheet has 36 columns. The data for the parcels listed in column 1 (the far left column) on page 1 are continued on pages 2 and 3; the data parcels listed on page 4 are continued on pages 5 and 6; and so on. Parcels that are included within the draft regional geographic template for tidal marsh restoration are indicated with an asterisk in the second column.

SFEI-ID		BCDC-ID	name	area in acres	landuse category	landuse score	infrastruc-ture score	ponding acres	ponding score	ponding complexity	pond comp-lexity score	ditches acres	distance ir shore
CB427	*	mr54	-	25	secure greenbelt	8	7	0	8	0	8	0	1774
CB431	*	mr54	-	24	secure greenbelt	8	7	8	6	4	5	0	1056
SP100		sn21	-	1026	small part residential	3	7	8	6	5	4	49	15278
SP102		sn20	-	284	small part residential	3	4	1	8	2	6	5	20762
SP105		sn13	Camp Island No. 2	294	mostly rural/agr	7	6	0	8	0	8	11	27470
SP106		sn13	Camp Island No. 2	225	mostly rural/agr	7	4	10	6	6	4	8	28588
SP107		sn12	Camp Island No. 2	188	mostly rural/agr	7	3	0	8	0	8	6	29146
SP108		sn12	Camp Island No. 2	83	mostly rural/agr	7	7	0	8	0	8	0	24794
SP109		sn18	-	232	small part residential	3	7	58	2	5	4	6	29864
SP11	*	sn50	-	71	small part comm	6	4	0	8	0	8	0	48055
SP118		sn16	-	214	mostly rural/agr	7	4	11	5	5	4	7	35257
SP119		sn14	-	166	mostly rural/agr	7	4	19	4	4	4	7	33167
SP124		snb	-	571	mostly rural/agr	7	4	36	3	8	2	0	32246
SP126		sn11	-	129	mostly rural/agr	7	6	0	8	1	7	7	27932
SP128		sn9	-	1022	mostly rural/agr	7	6	0	8	0	8	40	24285
SP129	*	sn10	Camp Island No. 3	1413	mostly rural/agr	7	4	8	6	6	4	44	20661
SP13		sn45	-	137	mostly rural/agr	7	6	0	8	0	8	0	49843
SP140		sn4	Skaggs Island	419	base closure lands	6	6	8	6	6	3	8	13976
SP141		sn7	-	43	mostly rural/agr	7	7	3	7	2	6	3	27044
SP144		sn55	-	196	mostly rural/agr	7	4	43	3	6	3	8	26653
SP146	*	sn4	Skaggs Island	1837	base closure lands	6	6	63	2	9	2	62	10683
SP147	*	na	-	363	mostly rural/agr	7	3	161	1	7	3	0	4359
SP148	*	na	-	27	secure greenbelt	8	8	27	3	3	5	0	3362
SP157	*	na	-	396	mostly rural/agr	7	7	115	1	9	2	13	4412
SP161	*	na	-	522	mostly rural/agr	7	7	522	0	2	7	0	6278
SP162	*	na	-	427	mostly rural/agr	7	7	427	0	1	7	0	5842
SP163	*	s116	Cullinan Ranch	1583	secure greenbelt	8	6	7	6	5	4	30	5911
SP172	*	na	Cargill West	200	small part residential	3	7	48	3	7	3	0	12080
SP173	*	na	Cargill West	780	mostly commercial/indust	3	7	780	0	2	7	0	13779
SP174	*	na	-	568	mostly rural/agr	7	7	568	0	2	7	0	11444
SP181	*	na	Cargill West	1344	mostly rural/agr	7	7	1344	0	2	7	0	9358
SP183	*	na	Cargill West	990	mostly commercial/indust	3	6	990	0	2	7	0	17099
SP184	*	na	Cargill West	776	mostly commercial/indust	3	8	776	0	1	7	0	19309
SP185	*	na	Cargill West	750	mostly commercial/indust	3	6	750	0	1	7	0	15026
SP186	*	na	-	458	mostly commercial/indust	3	6	458	0	1	7	0	18762
SP194	*	sn3	-	799	base closure lands	6	6	52	2	7	3	34	11916
SP195	*	sn2	-	747	mostly rural/agr	7	7	5	6	4	4	10	18368
SP196	*	sn2	-	323	mostly rural/agr	7	8	9	6	5	4	3	21268
SP197		sn1	-	307	mostly rural/agr	7	6	0	8	0	8	10	24761

SFEI-ID		ı feet from: river	score geomorph	pumpout dist miles	engineering score	existing average elevation (ft) (NGVD 1929)	years to MTL	MHW-0.5 ft site capacity (cy)	score MHW-0.5 ft	MHW site capacity (cy)	score MHW	MHHW+0.5 ft site capacity (cy)
CB427	•	4221	6	1.6	7	1.5	0	15,926	0	35,834	0	79,631
CB431	•	6061	6	2.6	5	1.5	0	15,252	0	34,316	0	76,258
SP100		3096	4	6.6	0	1.0	-	1,986,073	4	2,813,604	5	4,468,665
SP102		7203	2	7.9	0	1.0	-	549,974	3	779,193	3	1,237,441
SP105		2922	5	5.4	1	-1.5	-	1,992,360	4	2,229,666	5	2,703,917
SP106		1761	6	5.4	1	-1.5	-	1,521,893	4	1,703,162	4	2,065,426
SP107		656	7	5.4	1	-1.5	-	1,270,660	4	1,422,006	4	1,724,467
SP108		1000	7	5.4	1	-1.5	-	562,021	3	628,962	3	762,743
SP109		5300	3	7.4	0	1.0	-	449,312	2	636,447	3	1,010,952
SP11	•	581	7	0.2	6	0.0	8	252,881	2	310,276	2	482,773
SP118		2867	5	5.4	1	-1.5	-	1,449,662	4	1,622,329	4	1,967,399
SP119		1804	6	5.4	1	-1.5	-	1,125,473	4	1,259,526	4	1,527,428
SP124		433	8	5.4	1	-1.5	-	3,868,359	6	4,329,111	7	5,249,915
SP126		869	7	5.4	1	-1.5	-	874,402	3	978,550	3	1,186,689
SP128		1227	6	5.4	1	-1.5	-	6,924,631	8	7,749,409	8	9,397,713
SP129	•	3165	4	5.7	1	0.0	8	5,014,720	8	6,154,428	8	9,573,556
SP13		1217	6	0.5	6	2.0	-	44,312	0	170,001	1	376,648
SP140		1998	6	0.5	8	-1.2	-	2,635,598	5	2,973,515	5	3,649,290
SP141		4894	3	4.7	2	-1.0	-	258,872	2	293,873	2	363,821
SP144		6858	2	4.7	2	-2.0	-	1,488,981	4	1,330,660	4	1,647,383
SP146	•	5468	3	5	1	-1.2	10	11,553,989	8	13,035,357	8	15,997,831
SP147	•	3575	4	6.6	0	-1.0	7	2,163,664	5	2,456,604	5	3,040,826
SP148	•	2778	5	6.6	0	-1.0	6	159,036	1	180,568	1	223,510
SP157	•	7760	3	5.6	1	-1.0	7	2,363,893	5	2,683,634	5	3,322,227
SP161	•	11385	2	4.4	2	-1.0	7	3,112,542	6	3,533,122	6	4,374,384
SP162	•	14340	3	4.4	2	-1.0	8	2,548,391	5	2,892,741	5	3,581,523
SP163	•	11631	3	2.4	5	-1.7	13	11,231,362	8	12,507,846	8	15,060,235
SP172	•	15446	0	4.3	2	0.0	5	710,625	3	872,131	3	1,356,648
SP173	•	10529	0	1.6	7	0.0	6	2,769,372	5	3,398,775	6	5,286,984
SP174	•	7383	2	1.6	7	0.0	6	2,015,839	5	2,473,984	5	3,848,420
SP181	•	5212	3	0.8	6	0.0	6	4,767,777	7	5,851,427	8	9,102,120
SP183	•	2457	5	0.7	8	0.0	9	3,512,881	6	4,311,451	7	6,706,409
SP184	•	4864	3	0.7	8	0.0	8	2,753,080	5	3,378,928	6	5,255,881
SP185	•	11605	0	2.2	5	1.0	0	1,452,003	4	2,057,026	5	3,267,008
SP186	•	10138	0	2.2	5	1.0	0	887,137	3	1,256,791	4	1,996,059
SP194	•	10339	0	3.4	4	0.0	6	2,836,972	5	3,494,779	6	5,416,037
SP195	•	6134	2	3.4	4	0.0	8	2,651,974	5	3,266,885	6	5,062,859
SP196	•	5369	3	3.4	4	0.0	8	1,146,594	4	1,412,454	4	2,188,952
SP197		6409	2	3.6	4	-1.0	-	1,832,651	4	2,080,384	5	2,575,617

SFEI-ID		score MHHW+0.5 ft	total score scenario 1	rank scenario 1	total score scenario 2	rank scenario 2	total score scenario 3	rank scenario 3	total score scenario 4	rank scenario 4
CB427	•	0	44	high	-	-	-	-	-	-
CB431	•	0	37	med high	-	-	-	-	-	-
SP100		7	29	low	-	-	-	-	31	low
SP102		4	26	low	-	-	-	-	27	low
SP105		5	40	high	-	-	-	-	40	med high
SP106		5	32	med low	-	-	-	-	33	med low
SP107		4	38	med high	-	-	-	-	38	med high
SP108		3	41	high	-	-	-	-	41	high
SP109		4	22	low	-	-	-	-	23	low
SP11	•	2	41	high	-	-	-	-	-	-
SP118	.	4	30	low	-	-	-	-	30	low
SP119		4	30	low	-	-	-	-	30	low
SP124		8	32	med low	-	-	-	-	33	med low
SP126		4	39	med high	-	-	-	-	40	med high
SP128		8	44	high	-	-	-	-	44	high
SP129	•	8	34	med low	-	-	-	-	-	-
SP13		2	42	high	-	-	-	-	43	high
SP140		6	40	high	-	-	-	-	41	high
SP141		2	34	med low	-	-	-	-	34	med low
SP144		4	25	low	-	-	-	-	25	low
SP146	•	8	28	low	-	-	28	low	-	-
SP147	•	6	23	low	-	-	-	-	-	-
SP148	•	1	30	low	-	-	-	-	-	-
SP157	•	6	26	low	-	-	-	-	-	-
SP161	•	7	31	low	-	-	-	-	-	-
SP162	•	6	31	low	-	-	-	-	-	-
SP163	•	8	40	high	-	-	40	med high	-	-
SP172	•	4	21	low	-	-	-	-	-	-
SP173	•	8	30	low	-	-	-	-	-	-
SP174	•	6	35	med low	-	-	-	-	-	-
SP181	•	8	38	med high	-	-	-	-	-	-
SP183	•	8	36	med high	-	-	-	-	-	-
SP184	•	8	35	med low	-	-	-	-	-	-
SP185	•	6	26	low	-	-	-	-	-	-
SP186	•	4	25	low	-	-	-	-	-	-
SP194	•	8	27	low	-	-	-	-	-	-
SP195	•	8	36	med high	-	-	-	-	-	-
SP196	•	5	36	med high	-	-	-	-	-	-
SP197		5	40	high	-	-	-	-	40	med high

SFEI-ID	BCDC-ID	name	area in acres	landuse category	landuse score	infrastruc-ture score	ponding acres	ponding score	ponding complexity	pond comp-lexity score	ditches acres	distance ir shore
SP198	sn1	-	313	mostly rural/agr	7	6	1	8	2	7	12	24623
SP199	np22	-	78	mostly rural/agr	7	7	15	5	6	4	1	26673
SP200	na	-	75	secure greenbelt	8	7	22	3	5	4	1	26683
SP2004 •	na	-	444	mostly rural/agr	7	7	105	2	14	0	3	43178
SP201	np20	-	270	secure greenbelt	8	7	31	3	9	2	4	27050
SP202	na	Cargill West	291	mostly commercial/indust	3	7	291	0	2	7	0	25292
SP2024 •	na	-	339	mostly rural/agr	7	7	52	2	11	2	9	12011
SP2026	na	-	399	borders major residential	6	4	26	3	10	2	12	17974
SP2027 •	na	Hamilton AFB	279	base closure lands	6	1	3	7	4	4	4	3178
SP203	na	Cargill West	303	mostly commercial/indust	3	7	303	0	1	7	0	24210
SP2040	na	-	688	mostly rural/agr	7	7	49	3	16	0	49	20434
SP205 •	na	Cargill West	19	mostly rural/agr	7	8	0	8	0	8	0	22507
SP208	np16	-	517	mostly rural/agr	7	4	8	6	5	4	5	37264
SP209	np17	-	63	mostly rural/agr	7	7	0	8	0	8	0	29254
SP211	na	Edgerley Island	119	mostly rural/agr	7	7	119	1	1	7	0	28211
SP222 •	np1a	-	79	mostly rural/agr	7	1	21	3	6	3	0	23731
SP229 •	np7	-	107	small part residential	3	7	27	3	7	3	6	38586
SP233	na	-	178	mostly commercial/indust	3	4	178	1	1	7	3	33768
SP235	na	-	28	mostly commercial/indust	3	1	28	3	1	7	0	31770
SP240	na	-	32	mostly commercial/indust	3	7	32	3	2	7	0	31622
SP241	na	Cargill East	145	mostly commercial/indust	3	8	145	1	1	7	0	27582
SP242	na	Cargill East	101	mostly commercial/indust	3	8	101	2	1	7	0	28684
SP243	na	Cargill East	110	mostly commercial/indust	3	8	110	2	1	7	0	29976
SP244	na	Cargill East	54	small part comm	6	7	55	2	1	7	0	30730
SP245	na	Cargill East	104	mostly commercial/indust	3	7	104	2	1	7	0	25561
SP246	na	Cargill East	238	mostly commercial/indust	3	7	238	0	1	7	0	27427
SP247	na	Cargill East	106	mostly commercial/indust	3	8	107	2	1	7	0	29274
SP248	na	Cargill East	140	mostly commercial/indust	3	7	140	1	1	7	0	26722
SP25	sn43	-	55	mostly rural/agr	7	8	0	8	0	8	0	43831
SP252 •	np1b	-	492	borders major residential	6	7	148	1	16	0	8	23983
SP26	sn43	-	79	mostly rural/agr	7	8	0	8	0	8	0	43043
SP27	sn42	-	38	mostly rural/agr	7	8	0	8	0	8	0	42056
SP270	np11	-	55	mostly rural/agr	7	7	15	5	5	4	2	48675
SP272	na	-	80	mostly rural/agr	7	7	23	3	7	3	1	48587
SP273	np11	-	452	mostly rural/agr	7	8	79	2	13	0	4	53310
SP278	na	-	36	secure greenbelt	8	7	10	5	5	4	0	52391
SP28	sn42	-	363	mostly rural/agr	7	7	0	8	0	8	0	38701
SP286	mr23	-	26	borders major residential	6	7	7	6	4	4	0	10978
SP287	mr23	-	68	borders major residential	6	7	12	5	7	3	0	10119

SFEI-ID	ı feet from: river	score geomorph	pumpout dist miles	engineering score	existing average elevation (ft) (NGVD 1929)	years to MTL	MHW-0.5 ft site capacity (cy)	score MHW-0.5 ft	MHW site capacity (cy)	score MHW	MHHW+0.5 ft site capacity (cy)
SP198	9099	1	3.6	4	-1.0	-	1,869,820	4	2,122,578	5	2,627,856
SP199	10427	0	0.9	8	-1.0	-	464,819	2	527,977	3	653,259
SP200	12316	0	1.2	7	-2.0	-	569,167	3	326,968	2	508,617
SP2004 *	1250	6	0.2	8	0.5	0	1,218,541	4	1,576,936	4	2,652,119
SP201	9240	1	1.2	7	-2.0	-	2,044,521	5	1,174,512	4	1,827,019
SP202	7990	2	1.7	7	0.0	-	1,032,518	4	1,267,181	4	1,971,170
SP2024 *	4553	3	1.1	7	-0.5	0	1,474,808	4	2,020,977	5	2,567,258
SP2026	991	7	3.2	4	-2.0	-	3,026,543	6	3,347,345	6	3,992,461
SP2027 *	9194	4	3.8	4	-4.5	23	3,236,725	6	3,686,270	6	4,135,815
SP203	6567	2	1.7	7	0.0	-	1,075,339	4	1,319,734	4	2,052,919
SP2040	3677	4	0.7	8	-2.0	-	5,219,083	8	5,774,304	8	6,884,747
SP205 *	6573	2	1.6	7	1.0	0	36,422	0	51,598	0	81,949
SP208	3014	4	1.2	7	0.0	-	1,832,908	4	2,249,478	5	3,499,188
SP209	4011	3	1.2	7	-2.0	-	480,145	2	275,828	2	429,066
SP211	1328	6	0.7	8	0.0	-	420,821	2	516,477	3	803,385
SP222 *	2585	5	0.5	8	-2.0	18	597,764	3	216,240	1	343,396
SP229 *	1335	6	0.2	8	0.0	8	379,990	2	466,373	2	725,436
SP233	2729	5	0.7	8	0.0	-	631,931	3	775,566	3	1,206,413
SP235	630	7	0.5	8	0.0	-	98,752	0	121,198	1	188,527
SP240	1909	6	0.5	8	0.0	-	114,539	1	140,573	1	218,666
SP241	1082	6	0.5	8	0.0	-	514,442	3	631,370	3	982,116
SP242	3083	4	0.5	8	0.0	-	359,410	2	441,101	2	686,146
SP243	3516	4	0.5	8	0.0	-	390,927	2	479,782	2	746,316
SP244	4359	3	0.5	8	0.0	-	193,389	1	237,344	1	369,197
SP245	1309	6	0.5	8	0.0	-	369,822	2	453,880	2	706,024
SP246	3195	4	0.5	8	0.0	-	846,306	3	1,038,665	4	1,615,676
SP247	4953	3	0.5	8	0.0	-	375,976	2	461,432	2	717,773
SP248	2988	5	0.5	8	0.0	-	498,297	2	611,555	3	951,294
SP25	5389	3	0.8	8	0.2	-	177,110	1	221,387	1	354,220
SP252 *	3736	4	0.5	8	1.0	0	952,230	3	1,349,161	4	2,142,518
SP26	4018	3	0.8	6	0.2	-	254,364	2	317,954	2	508,728
SP27	3765	4	0.8	6	0.2	-	123,197	1	153,996	1	246,394
SP270	2270	5	0.2	8	0.5	-	149,819	1	193,883	1	326,076
SP272	977	7	0.2	8	2.0	-	25,687	0	89,903	0	218,343
SP273	2165	5	0.3	8	5.0	-	0	0	0	0	145,934
SP278	699	7	0.2	8	2.0	-	145,934	1	40,285	0	97,849
SP28	2355	5	0.8	8	0.2	-	1,172,486	4	1,465,605	4	2,344,973
SP286	8476	0	2.5	3	0.0	-	91,110	0	111,816	1	173,937
SP287	7951	2	2.5	3	0.0	-	240,072	1	294,634	2	458,319

SFEI-ID		score MHHW+0.5 ft	total score scenario 1	rank scenario 1	total score scenario 2	rank scenario 2	total score scenario 3	rank scenario 3	total score scenario 4	rank scenario 4
SP198		5	38	med high	-	-	-	-	38	med high
SP199		3	34	med low	-	-	-	-	34	med low
SP200		3	31	low	-	-	-	-	32	low
SP2004	*	5	34	med low	-	-	-	-	-	-
SP201		4	32	med low	-	-	-	-	32	low
SP202		4	30	low	-	-	-	-	30	low
SP2024	*	5	33	med low	-	-	-	-	-	-
SP2026		6	32	med low	-	-	-	-	32	low
SP2027	*	7	32	med low	32	med low	32	med low	-	-
SP203		5	30	low	-	-	-	-	31	low
SP2040		8	37	med high	-	-	-	-	37	med high
SP205	*	0	40	high	-	-	-	-	-	-
SP208		6	37	med high	-	-	-	-	38	med high
SP209		2	42	high	-	-	-	-	42	high
SP211		3	39	med high	-	-	-	-	39	med high
SP222	*	2	28	low	-	-	30	low	-	-
SP229	*	3	32	med low	-	-	-	-	-	-
SP233		4	31	low	-	-	-	-	32	low
SP235		1	30	low	-	-	-	-	30	low
SP240		1	35	med low	-	-	-	-	35	med low
SP241		3	36	med high	-	-	-	-	36	med low
SP242		3	34	med low	-	-	-	-	35	med low
SP243		3	34	med low	-	-	-	-	35	med low
SP244		2	34	med low	-	-	-	-	35	med low
SP245		3	35	med low	-	-	-	-	36	med low
SP246		4	33	med low	-	-	-	-	33	med low
SP247		3	33	med low	-	-	-	-	34	med low
SP248		3	34	med low	-	-	-	-	34	med low
SP25		2	43	high	-	-	-	-	44	high
SP252	*	5	30	low	-	-	-	-	-	-
SP26		3	42	high	-	-	-	-	43	high
SP27		1	42	high	-	-	-	-	42	high
SP270		2	37	med high	-	-	-	-	38	med high
SP272		1	35	med low	-	-	-	-	36	med low
SP273		1	30	low	-	-	-	-	31	low
SP278		0	39	med high	-	-	-	-	39	med high
SP28		5	47	high	-	-	-	-	48	high
SP286		1	27	low	-	-	-	-	27	low
SP287		2	28	low	-	-	-	-	28	low

SFEI-ID		BCDC-ID	name	area in acres	landuse category	landuse score	infrastruc-ture score	ponding acres	ponding score	ponding complexity	pond comp-lexity score	ditches acres	distance ir shore
SP288		mr23	-	406	secure greenbelt	8	7	38	3	9	2	10	8420
SP29		sn41	-	35	mostly rural/agr	7	8	0	8	0	8	0	37864
SP291		mr23	-	36	secure greenbelt	8	8	0	8	0	8	0	13373
SP292		mr24	-	345	secure greenbelt	8	6	80	2	11	2	2	13865
SP295		mr20	-	245	secure greenbelt	8	4	3	7	4	5	11	7767
SP296	*	mr19	-	128	secure greenbelt	8	6	20	3	5	4	2	7118
SP298		mr22	-	229	secure greenbelt	8	4	0	8	0	8	30	11395
SP299		mr29	-	125	mostly rural/agr	7	7	0	8	0	8	0	14990
SP3		sn46	ɘtaluma Drying Ponc	39	mostly residential	1	0	0	8	0	8	0	53143
SP304		mr31	-	60	secure greenbelt	8	3	0	8	0	8	0	12070
SP309		mr33	-	177	mostly rural/agr	7	4	2	7	5	4	10	9709
SP310		mr33	Bell Marin Keys	642	mostly rural/agr	7	7	3	7	4	5	7	5212
SP311	*	mr12	Bell Marin Keys	659	mostly rural/agr	7	5	67	2	12	1	24	2496
SP312	*	mr33	amilton Antenna Fie	261	non-operational	7	7	0	8	0	8	0	1811
SP322	*	mr34	St. Vincent	758	mostly rural/agr	7	7	0	8	0	8	0	3966
SP324	*	mr35	-	43	secure greenbelt	8	8	0	8	0	8	0	2375
SP325	*	mr37	-	190	secure greenbelt	8	7	0	8	0	8	0	928
SP330	*	mr38	-	83	borders major residential	6	7	0	8	0	8	0	5468
SP34	*	sn53	-	16	mostly rural/agr	7	8	0	8	0	8	0	40829
SP345		mr18	-	285	secure greenbelt	8	4	14	5	6	3	15	4316
SP346		mr17	-	35	borders major residential	6	4	44	3	5	4	0	4536
SP356		sn27	Tubb's Island	207	secure greenbelt	8	8	48	3	7	3	0	1499
SP36		na	-	123	mostly rural/agr	7	8	0	8	0	8	0	36274
SP37		sn54	-	65	mostly rural/agr	7	8	0	8	0	8	0	37671
SP378		s113	ɔre Island Drying Por	337	base closure lands	6	4	60	2	2	6	0	1902
SP379		s113	ɔre Island Drying Por	35	base closure lands	6	4	3	7	2	7	0	3818
SP383		s113	ɔre Island Drying Por	26	base closure lands	6	4	0	8	0	8	0	2562
SP386		s113	ɔre Island Drying Por	48	base closure lands	6	7	11	5	2	6	0	2207
SP46		mr2	-	56	mostly rural/agr	7	6	2	7	4	5	2	29021
SP50		mr5	-	89	mostly rural/agr	7	2	13	5	1	7	0	25755
SP503	*	cc9	-	47	secure greenbelt	8	7	0	8	0	8	0	1302
SP52		sn39	-	41	mostly rural/agr	7	8	9	6	3	6	0	27545
SP522	*	na	-	24	borders major residential	6	3	0	8	0	8	0	6232
SP54		sn37	-	34	mostly rural/agr	7	8	0	8	0	8	0	22632
SP55		sn37	-	920	mostly rural/agr	7	7	47	3	6	3	28	17709
SP56	*	sn38	Hog Island	171	mostly rural/agr	7	7	0	8	0	8	9	20228
SP61	*	mr8	-	184	mostly rural/agr	7	4	9	6	5	4	6	15462
SP65		mr11	-	22	secure greenbelt	8	8	5	7	4	4	0	14999
SP67		mr9a	-	200	small part comm	6	7	11	5	9	2	7	17315

SFEI-ID		ı feet from: river	score geomorph	pumpout dist miles	engineering score	existing average elevation (ft) (NGVD 1929)	years to MTL	MHW-0.5 ft site capacity (cy)	score MHW-0.5 ft	MHW site capacity (cy)	score MHW	MHHW+0.5 ft site capacity (cy)
SP288		5064	3	2	3	-2.0	-	3,077,859	6	3,405,291	6	4,060,155
SP29		351	8	0.8	6	0.2	-	113,862	1	142,327	1	227,724
SP291		1850	6	1.9	5	-2.0	-	276,181	2	305,388	2	364,324
SP292		1351	6	2.9	3	-1.0	-	2,057,726	5	1,501,576	4	2,335,797
SP295		2890	5	1.4	5	-1.5	-	1,661,943	4	1,859,794	4	2,255,494
SP296	•	1214	6	1.9	5	-2.0	18	967,768	3	1,070,705	4	1,276,630
SP298		1043	6	2.2	3	-2.0	-	1,739,251	4	1,924,278	4	2,294,331
SP299		1118	6	3.2	2	-2.0	-	943,927	3	1,041,345	4	1,245,180
SP3		1050	6	0.2	6	1.0	-	75,963	0	107,701	1	170,916
SP304		2499	5	3.6	2	-3.0	-	554,656	3	603,310	3	700,618
SP309		3611	4	2.9	3	-4.5	-	2,055,326	5	2,340,788	5	2,626,250
SP310		5123	3	2.9	3	-2.0	-	4,870,459	7	8,497,396	8	9,533,664
SP311	•	2745	5	2.1	3	-5.0	25	8,717,084	8	9,248,614	8	10,311,673
SP312	•	16600	6	3.4	2	-5.0	25	3,458,643	6	3,669,539	6	4,091,322
SP322	•	7314	4	4.9	2	-3.0	12	6,971,777	8	7,583,336	8	8,806,455
SP324	•	5314	5	4.4	2	0.0	3	152,551	1	291,234	2	360,576
SP325	•	4526	7	4.8	2	-1.0	5	1,132,215	4	1,285,130	4	1,591,221
SP330	•	918	7	5	1	0.0	5	294,535	2	361,474	2	562,293
SP34	•	3132	4	0.8	6	0.0	8	57,708	0	70,843	0	110,170
SP345		6029	3	1.2	5	-1.0	-	1,702,124	4	1,935,493	4	2,392,174
SP346		3638	4	0.7	6	0.0	-	124,337	1	240,576	1	293,887
SP356		15354	6	2.9	3	0.0	-	734,729	3	901,784	3	1,402,665
SP36		6209	2	2.6	3	0.0	-	435,698	2	327,363	2	831,788
SP37		7278	2	2.6	3	-2.0	-	495,336	2	174,208	1	442,641
SP378		11395	6	1	5	0.0	-	1,197,213	4	1,531,000	4	2,285,588
SP379		8879	4	0.6	6	0.0	-	124,183	1	152,363	1	237,076
SP383		6675	5	1	5	0.0	-	91,189	0	111,919	1	174,087
SP386		5753	5	0.9	6	0.0	-	168,559	1	206,887	1	321,794
SP46		1856	6	2	3	0.0	-	198,797	1	244,335	1	379,522
SP50		328	8	1.1	5	1.0	-	171,504	1	242,974	1	385,883
SP503	•	4756	6	2.1	3	1.5	0	22,759	0	60,695	0	151,725
SP52		410	8	0.1	6	0.0	-	146,980	1	180,363	1	280,598
SP522	•	1384	6	2.3	3	0.8	0	39,024	0	58,565	0	105,364
SP54		492	8	0.9	6	0.0	-	119,245	1	146,346	1	227,649
SP55		3159	4	0.9	6	0.0	-	3,264,211	6	4,006,078	7	6,231,676
SP56	•	1725	6	0.3	6	-3.0	25	1,570,174	4	1,707,908	4	1,983,377
SP61	•	2804	5	1.5	5	-2.0	13	1,396,970	4	802,617	3	1,248,356
SP65		7262	2	2.5	3	0.0	-	78,666	0	96,609	0	150,181
SP67		7505	2	2.4	3	-1.0	-	1,194,623	4	1,389,627	4	1,678,929

SFEI-ID		score MHHW+0.5 ft	total score scenario 1	rank scenario 1	total score scenario 2	rank scenario 2	total score scenario 3	rank scenario 3	total score scenario 4	rank scenario 4
SP288		7	32	med low	-	-	-	-	33	med low
SP29		1	46	high	-	-	-	-	46	high
SP291		2	45	high	-	-	-	-	45	high
SP292		5	31	low	-	-	-	-	32	low
SP295		5	38	med high	-	-	-	-	39	med high
SP296	*	4	36	med high	-	-	35	med low	-	-
SP298		5	41	high	-	-	-	-	42	high
SP299		4	42	high	-	-	-	-	42	high
SP3		1	30	low	-	-	-	-	30	low
SP304		3	37	med high	-	-	-	-	37	med high
SP309		5	34	med low	-	-	-	-	34	med low
SP310		8	40	high	-	-	-	-	40	med high
SP311	*	8	31	low	31	low	31	low	-	-
SP312	*	7	44	high	44	med high	44	high	-	-
SP322	*	8	44	high	-	-	44	high	-	-
SP324	*	2	41	high	-	-	-	-	-	-
SP325	*	4	44	high	-	-	-	-	-	-
SP330	*	3	39	med high	-	-	-	-	-	-
SP34	*	1	41	high	-	-	-	-	-	-
SP345		5	32	med low	-	-	-	-	33	med low
SP346		2	28	low	-	-	-	-	29	low
SP356		4	34	med low	-	-	-	-	35	med low
SP36		3	38	med high	-	-	-	-	39	med high
SP37		2	37	med high	-	-	-	-	38	med high
SP378		5	33	med low	-	-	-	-	34	med low
SP379		1	35	med low	-	-	-	-	35	med low
SP383		1	37	med high	-	-	-	-	37	med high
SP386		2	36	med high	-	-	-	-	37	med high
SP46		2	35	med low	-	-	-	-	36	med low
SP50		2	35	med low	-	-	-	-	36	med low
SP503	*	1	40	high	-	-	-	-	-	-
SP52		2	42	high	-	-	-	-	43	high
SP522	*	1	34	med low	-	-	-	-	-	-
SP54		1	46	high	-	-	-	-	46	high
SP55		8	37	med high	-	-	-	-	38	med high
SP56	*	4	46	high	46	high	46	high	-	-
SP61	*	4	34	med low	-	-	35	med low	-	-
SP65		1	32	med low	-	-	-	-	33	med low
SP67		4	29	low	-	-	-	-	29	low

SFEI-ID	BCDC-ID	name	area in acres	landuse category	landuse score	infrastruc-ture score	ponding acres	ponding score	ponding complexity	pond comp-lexity score	ditches acres	distance ir shore
SP69	sn36	-	1056	mostly rural/agr	7	3	17	4	5	4	17	10585
SP7	sn45	-	46	secure greenbelt	8	8	0	8	0	8	0	51306
SP70	na	-	930	mostly rural/agr	7	3	16	4	1	7	24	9280
SP72	sn31	-	91	mostly rural/agr	7	3	7	6	3	5	0	8151
SP73	sn33	Leonard Ranch	235	secure greenbelt	8	1	0	8	0	8	9	5606
SP74	sn30	-	367	mostly rural/agr	7	0	0	8	0	8	0	7065
SP75 *	sn33	Sonoma Baylands	355	secure greenbelt	8	1	1	7	2	7	20	2234
SP76 *	sn29	North Point	442	mostly rural/agr	7	5	6	6	5	4	16	2955
SP77 *	sn26	-	108	mostly rural/agr	7	4	3	7	3	6	2	5779
SP78 *	sn26	-	63	mostly rural/agr	7	7	4	7	2	6	2	3893
SP79 *	sn26	-	354	mostly rural/agr	7	4	7	6	4	4	8	6668
SP8	sn45	-	39	secure greenbelt	8	8	0	8	0	8	0	50358
SP82 *	sn25	-	66	secure greenbelt	8	7	12	5	3	6	0	5993
SP92	sn25	Tubbs Island	1770	mostly rural/agr	7	6	1	8	2	6	94	4313
SP93	sn23	-	113	borders major residential	6	3	0	8	0	8	7	6258
SP94	sn23	-	841	mostly rural/agr	7	2	0	8	0	8	39	11959
SP97	sn22	-	68	mostly rural/agr	7	7	0	8	0	8	5	17400

SFEI-ID		ı feet from: river	score geomorph	pumpout dist miles	engineering score	existing average elevation (ft) (NGVD 1929)	years to MTL	MHW-0.5 ft site capacity (cy)	score MHW-0.5 ft	MHW site capacity (cy)	score MHW	MHHW+0.5 ft site capacity (cy)
SP69		2230	5	1.2	5	-2.3	-	8,513,631	8	4,597,361	7	11,408,265
SP7		2296	5	0.3	6	0.0	-	162,358	1	199,170	1	309,956
SP70		5750	3	0.7	6	0.0	-	3,300,245	6	4,050,301	7	6,300,468
SP72		20261	1	2.1	3	-1.0	-	540,683	3	613,748	3	759,878
SP73		5606	3	1.1	5	-2.0	-	1,781,920	4	1,994,290	4	2,350,618
SP74		17942	2	2.2	3	-2.0	-	2,785,320	5	3,081,632	6	3,674,252
SP75	•	3667	5	1	5	-2.3	10	2,864,153	5	3,150,568	6	3,723,399
SP76	•	7596	5	1.7	5	-2.0	8	3,351,397	6	3,707,929	6	4,420,992
SP77	•	11785	3	2.8	3	-2.0	12	818,107	3	921,379	3	1,079,205
SP78	•	10952	4	2.8	3	-2.0	8	477,870	2	538,193	3	630,382
SP79	•	12513	2	2.8	3	-2.0	12	2,685,077	5	3,024,022	6	3,542,016
SP8		1151	6	0.3	6	0.5	-	107,714	1	139,463	1	234,436
SP82	•	9830	3	3.8	2	0.0	6	234,659	1	287,910	2	447,986
SP92		6573	3	4.3	1	-2.7	-	15,418,756	8	16,833,467	8	19,701,744
SP93		1735	6	5.3	0	-3.0	-	1,036,919	4	1,134,238	4	1,309,792
SP94		3893	4	5.3	0	-3.0	-	7,732,190	8	8,457,889	8	9,766,977
SP97		7662	2	6.1	0	1.0	-	132,396	1	187,590	1	297,890

SFEI-ID		score MHHW+0.5 ft	total score scenario 1	rank scenario 1	total score scenario 2	rank scenario 2	total score scenario 3	rank scenario 3	total score scenario 4	rank scenario 4
SP69		8	35	med low	-	-	-	-	36	med low
SP7		2	44	high	-	-	-	-	45	high
SP70		8	37	med high	-	-	-	-	38	med high
SP72		3	28	low	-	-	-	-	28	low
SP73		5	37	med high	-	-	-	-	38	med high
SP74		6	34	med low	-	-	-	-	34	med low
SP75	*	6	39	med high	-	-	38	med high	-	-
SP76	*	7	38	med high	-	-	-	-	-	-
SP77	*	4	33	med low	-	-	33	med low	-	-
SP78	*	3	37	med high	-	-	-	-	-	-
SP79	*	6	32	med low	-	-	31	low	-	-
SP8		1	45	high	-	-	-	-	45	high
SP82	*	2	33	med low	-	-	-	-	-	-
SP92		8	39	med high	-	-	-	-	39	med high
SP93		4	35	med low	-	-	-	-	35	med low
SP94		8	37	med high	-	-	-	-	37	med high
SP97		2	33	med low	-	-	-	-	34	med low