Wetlands Regional Monitoring Program:

Standard Operating Procedures for Indicators 1 and 3

Cover Photo by Shira Bezalel

Produced by the San Francisco Estuary Wetlands Regional Monitoring Program Geospatial Workgroup

In active collaboration with committees representing the San Francisco Estuary Wetlands Regional Monitoring Program (WRMP)

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SOPs for Indicator 1 and 3

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OVERVIEW AND PURPOSE

This document describes the Standard Operating Procedures (SOPs) for developing the basemap and calculations to address the San Francisco Estuary Wetlands Regional Monitoring Program's (WRMP) **Indicator 1:** *Map of baylands habitat types (e.g., tidal marsh, tidal flats, diked bayland) and their key landform features (e.g., levees, channels, pannes), and related areas of permitted impacts, compensatory mitigation, and voluntary restoration projects;* and **Indicator 3:** *Map of estuarine-terrestrial transition zones and migration space.*

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GEOGRAPHIC FOCUS AND SCOPE

The geographic focus of the WRMP encompasses the "complete tidal marsh ecosystem" (CTME), as defined by the Baylands Ecosystem Habitat Goals Update (Goals Project 2015). The complete tidal marsh ecosystem (CTME) includes shallow subtidal areas to a depth of 12 ft (~3.7m) below local Mean Lower Low Water, tidal flats, fully tidal and muted tidal baylands, and the adjoining estuarine-terrestrial transition zone (T-zone). The boundaries between the different elevational zones of the CTME (i.e., shallow subtidal, tidal baylands, and the T-zone) are inexact in nature. Any assessment of the distribution, abundance, diversity, or condition of any habitat type of the ecosystem should consider that they are part of a continuum of physical, chemical, biological and ecological factors and processes that link the habitat types to each other and to the rest of the region. However, unless stated otherwise, the term, tidal marsh, pertains to the intertidal portion of the ecosystem that has a regular nexus with the tide and supports indicative, rooted, vascular vegetation (WRMP 2020).

Areas adjacent to the tidal baylands — such as the open waters of the Bay, diked baylands, and the uplands of the associated watersheds — will not be excluded from consideration, but the criteria for fit-gap evaluation will, at present, focus on a narrow elevation range of geography that is of primary concern for tidal wetland restoration, namely the CTME and diked baylands. The WRMP TAC has identified that it is important to include the diked baylands in the study areas for Indicators 1 and 3, even if they're conditions are not specifically being monitored through the WRMP at this time, because they have direct ecological relationships to the tidal baylands, and they represent the best opportunities to expand and restore the tidal marsh ecosystem in the foreseeable future. This approach hews closely to Management Question #1 and Science Priority #1 as expressed in the WRMP Program Plan: "Where are the region's tidal marsh ecosystems, including tidal marsh restoration projects, and what net changes in ecosystem area and condition are occurring?"[1] In fact, most of the projects and net change in the spatial extent of the tidal marsh ecosystem involve breaching diked baylands.

These SOPs are focused on data collection and mapping at the regional scale. However, in the future, we foresee opportunities for selective intensification by integrating site-specific maps. To facilitate this, the site-specific classifications will be made compatible with the more general regional classification system via a crosswalk.

1. ABOUT INDICATORS 1 AND 3

1.1. Indicators 1 and 3

The WRMP Program Plan describes how the WRMP is based on the Wetland and Riparian Area Monitoring Plan (WRAMP) framework, which utilizes the key management questions and programmatic information needs of decision makers (project funders, implementers, regulators, etc.) to drive program development. In the WRAMP framework, management questions help define specific monitoring questions, which are answered by indicators. Indicators 1 and 3 are among the primary mapping indicators that are necessary to address all of the Guiding [management] Questions of the WRMP, but especially Guiding Question 1: *Where are the region's tidal wetlands and wetland projects, and what net landscape changes in area and condition are occuring?*

[1] https://www.sfestuary.org/wp-content/uploads/2020/03/WRMP-Program-Plan_Final_Web2_New.pdf

Indicator 1 is a map of tidal and diked baylands (e.g., tidal marsh, tidal flats, diked bayland types) and their key landform features (e.g., levees, channels, pannes, etc.), as well as known areas of permitted impacts, compensatory mitigation projects, and voluntary restoration projects. Indicator 1 answers the monitoring question, *What is the distribution and abundance of the estuary's tidal wetlands and other baylands?* Indicator 3 is a map of estuarine-terrestrial transition zones and tidal wetland migration space. It answers the monitoring question, *Where do wetlands have space to migrate upslope?*

The WRMP considers Indicators 1 and 3 to be "primary" mapping indicators because, together with Indicator 2 (map of bayland elevations and elevation capital) and Indicator 7 (map of bayland vegetation alliances), they describe the fundamental physical and ecological conditions that drive many of the conceptual models upon which the WRMP is based (see Appendix F of the Program Plan). Other mapping indicators are secondary or "derivative" mapping products that will require the same data used to create the primary mapping indicators, but will require different data analysis procedures and/or the passage of time (to detect change). For example, maps of "complete" tidal wetland habitats require analyzing where tidal wetlands are adjacent to undeveloped estuarine-terrestrial transition zones and subtidal habitats within particular elevation bands. The relationship between these indicators can be summarized by **Figure 1** below.

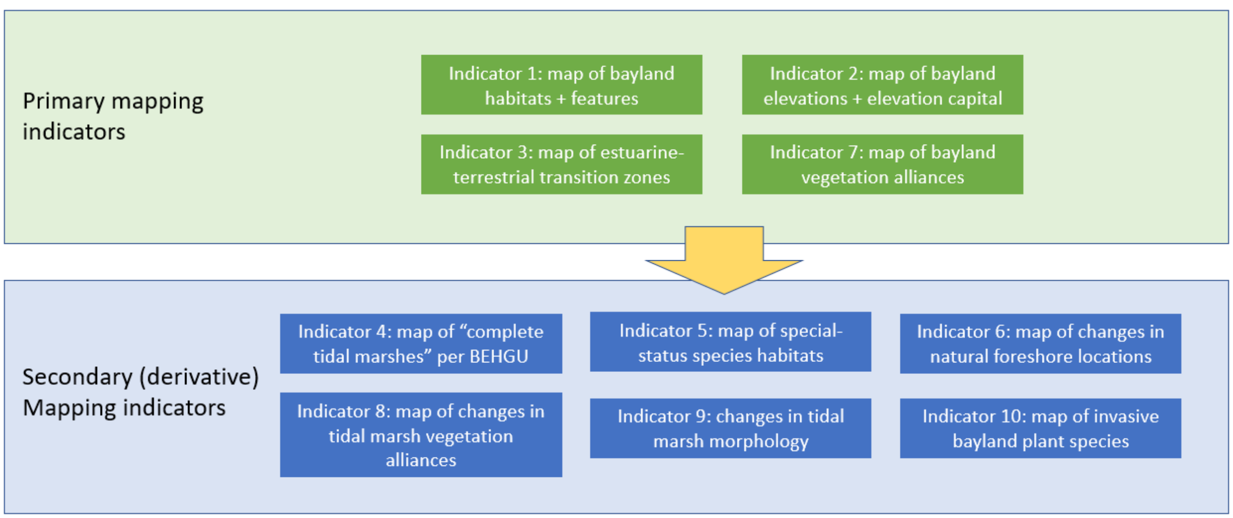

Figure 1. Indicators 1, 2, 3, 7 can be thought of as "primary" indicators, basic mapping products that together describe the fundamental components of bayland/tidal marsh morphology and vegetation. Indicators 4, 5, 6, 8, 9, 10 can be thought of as "secondary" or derivative indicators, which require the same data collected for the primary indicators, but utilize different data analysis procedures (and in some cases, require the passage of time to trigger change detection).

Key Assumptions:

- Indicators 1 and 3 require a regional mapping effort that is complimentary with site-specific mapping efforts.
- Project areas (such as compensatory mitigation projects and voluntary restoration projects) will be quantified through the use of polygons entered into Project Tracker, an online tool for the standardized data collection of wetland restoration, mitigation, and habitat conservation projects throughout California.

Table 1. *Minimum standard requirements to address Indicators 1 and 3 as determined by the WRMP TAC and Geospatial Workgroup after review of requirements noted in the Fit-Gap Analysis Report.*

Indi-cator No.	Indicator/Sub-indicator Name	Minimum mapping unit	Geospatial Extent	Frequency of Updates	Documentation / Data Quality
1	Map of baylands habitat types and their key features (See Habitat Type Classification section); impact areas and projects	Minimum mapping unit of about ~0.25 acres (~ 1000m^2) [2]	Entire SF baylands in initial phase, then later integration with Delta mapping	Every 5 years	Robust metadata with data sources, collection and processing steps, methodology, and data quality assurance steps/checks
3a	Map of developed space	Minimum mapping unit of about ~0.25 acres (~ 1000m^2)	Within upland buffer utilized by Adaptation Atlas	Every 2 to 5 years	Need complete metadata, processing and modeling methodology, and validation scores
3b	Map of undeveloped space	Minimum mapping unit of about ~0.25 acres (~ 1000m^2)	Within upland buffer utilized by Adaptation Atlas	Every 5 years	Need complete metadata, processing/modeling methodology, and validation scores
3c	Map of stream course	Polygons mapped for streams ≥ 30m wide. Stream lines mapped for channels with a length ≥ 25m.	Within upland buffer utilized by Adaptation Atlas, chanel network	Every 5 - 10 years	Need complete metadata and processing/modeling methodology

[2] Consistent with Pacific Veg map methodology for easily distinguishable vegetation classes. See habitat class list for class specific mmus.

It is important to note that only baylands, tidal and diked, will be newly mapped or derived under Indicator one. Features that are higher in elevation such as developed spaces, agricultural areas, and non-bayland aquatic features will be acquired from other datasets.

Minimum mapping accuracy standards are also important to consider. We propose following the National standards for positional accuracy/horizontal error (within 10m (33ft) of location in imagery) and completeness (90% of all wetlands 1.0 acre (0.4 ha) or larger depicted) regarding wetland mapping laid out by the United States Fish and Wildlife Service in the National Standards and Quality Components for Wetlands, Deepwater and Related Habitat Mapping (NOAA 2016; pp. 13-14). For attribute accuracy, 85% of the mapped features are correctly attributed according to the specified classification system. This level of accuracy is in line with Aquatic Resource Inventory Mapping previously conducted in the Bay Area (WRMP 2011) and in the Coastal Change Analysis Program (C-CAP) Regional Land Cover and Change products (NOAA 2016).

Positional accuracy or horizontal accuracy describes how closely the coordinate descriptions of features compare to their actual location. In this instance horizontal error relates to the delineation accuracy of the wetland on the landscape and is determined by the source map scale and digitizing precision. Attribute accuracy describes how thoroughly and correctly the features in the dataset are described. Completeness describes the percent of features represented in the imagery that are then delineated and included in the final dataset.

1.2. Habitats, Habitat Types, and Vegetation Alliance Mapping

In plant and animal ecology, a **habitat** consists of the resources and conditions present in an area that produce occupancy – including survival and reproduction – by a given organism or population of a species. Habitat is species-specific (Hall et al. 1997). Habitats in this sense are also referred to as functional or effective habitats. Indicators needed to map effective habitats will vary among their species. Many habitats can overlap through space and over time in any ecosystem.

Habitat types can contain any number of habitats, entirely or in part. Often they are groupings of similar habitats. Examples of habitat types include: tidal flats, tidal ponds, tidal channels, and tidal marsh. One Habitat Type can be defined as a recurring area of landscape easily distinguished from other areas of the same landscape based on its self-similarity, as generally expressed by its geology, hydrology, land use, and vegetation cover. In mapping a bayland habitat type, it is especially important to reference its vegetation alliance and associated local tidal elevation, and any landform features or characteristics that influence how water enters and leaves the area. In order to address WRMP Indicator 1 and 3, a map of habitat types is required.

A **vegetation alliance map** is not a fully suitable replacement for a map of habitat types. Vegetation alliances can cross the boundaries of bayland habitat types delimited by other factors, such as tidal elevation and management objective. Vegetation alliances can also shift within a habitat type due to changes in hydrology or water chemistry, especially salinity. However, given the strong influence of vegetation, including the species composition of vegetation cover, on the distribution and abundance of bayland plants and animals, vegetation mapping at the alliance level will be important for mapping habitats and habitat types. In fact, repeated mapping of vegetation alliances within habitat types will be important to understand shifts in tidal inundation and aqueous salinity due to climate change. However, given that salinity fluctuates throughout the Estuary over very broad temporal and spatial scales, even contributing to narrow zonation among vegetation alliances within habitat types, using vegetation alliances to delimit habitat types as a proxy for salinity is problematic. Additional comparisons between Habitat Type mapping and Vegetation alliance mapping may lead to additional insights into their relationships.

Vegetation alliance mapping will be needed to address WRMP Monitoring Questions 7, 8, and 10. Below are descriptions of these monitoring questions from the Master Matrix developed during Phase 1 of the WRMP:

- **Monitoring Question 7**: What is the current distribution, extent, and diversity of dominant vegetation communities in the estuary?
- **Monitoring Question 8**. What are the rates of change over time in the spatial extent and distribution of dominant vegetation communities (including native and non-native vascular plants) along the primary and secondary salinity gradients of the estuary
- **Monitoring Question 10**. Where are non-native species a significant component of the dominant tidal wetland vegetation community? Where are they expanding?

1.3. Potential Uses of Map

To assist with refining the habitat classification, below are a few potential uses of the map identified by regulators, practitioners, and WRMP advisory committee members:

- **Assist regulators** during their review of project plans, such as Environmental Impact Reports, to provide regional context, identify tidal marsh migration pathways, and make critical connections between watershed processes and the shoreline/baylands.

- Inform understanding of the **quantification of wetland/habitat type area change**. For example, "How many acres of a specific wetland type have we lost and why?" "How many acres of a specific wetland type have been gained through restoration efforts?" "Do we have more or less of habitat type x now compared to 5, 10, or 15 years ago?"
- Allow for **quantification of specific habitat types** within the Bay Area. For example, "How many acres of habitat type x are in the Bay Area?"
- Provide a **resource to help communities** to understand wetland habitats and change over time.

2. HABITAT TYPE CLASSIFICATION SYSTEM

2.1. Introduction

The Habitat Type Classification System for the San Francisco Estuary Wetlands Regional Monitoring Program (WRMP) was derived largely from the definitions of bayland habitat types and their key landform features adopted in 1997 by the multi-agency Resource Managers Group (RMG) of the San Francisco Bay Area Wetlands Ecosystem Habitat Goals Project (Goals Project 1999). The original classification system was developed by the Hydrogeographic Advisory Team (HAT)[3] with abundant input from the other Advisory Teams on behalf of the RMG. Chapters 3 and 4 of the original Goals Project Report explain the classification system and define its component habitat types. The system was spatially hierarchical; lower, more spatially limited habitat types were nested within higher, less spatially limited habitat types. The system met its main objectives to represent the effective habitats of hundreds of species of baylands plants and animals of conservation concern, as well as the broad categories of land use and management influencing Baylands conservation into the future.

The first regional baylands basemap was produced and published in 1999, based on the 1997 baylands definitions. Since then, SFEI has revised the definitions of bayland habitat types to align them with the California Aquatic Resources Classification System (CARCS) of the California Aquatic Resources Inventory (CARI), and two regional versions of CARCS pertaining to the

[3] Hydrogeomorphic Advisory Team (HAT) included Andree Breaux (S.F. Bay Regional Water Quality Control Board), Roger Byrne (University of California, Berkeley), John Callaway (San Diego State University), Josh Collins (San Francisco Estuary Institute), Jeff Haltiner (Philip Williams and Associates, Ltd.), Ray Krone (University of California, Davis), Doug Lipton (Levine-Fricke-Rincon, Inc.), Fred Nichols (U.S. Geological Survey), Nigel Quinn (U.S. Bureau of Reclamation), David Schoelhammer (U.S. Geological Survey), Stuart Siegel (Wetlands and Water Resources), and Richard Smith (U.S. Geological Survey).

Estuary, namely the Delta Aquatic Resources Classification System (DARCS) and the Bay Area Aquatic Resources Classification System (BAARCS). The updated definitions also include the Estuarine-Terrestrial Transition Zone (T-zone) defined by the Bay Area Ecosystem Habitat Goals Update (Goals Project 2015) and the Mapping the Transition Zone 2017 SFEI Report. The new WRMP classification system will be used to quantify net changes in baylands abundance, distribution, and diversity since the first basemap was completed in 1999, and to assess progress toward the existing and future baylands habitat goals.

The habitat types and their landscape features fit naturally into a hierarchy based upon physical geography (See **Figure 2**, **Appendix 3** for definitions of habitat types and their key landform features, and **Appendix 1** for the WRMP Habitat Classifications). All types exist throughout the region. The region is subdivided into 5 subregions, based on the Regional Monitoring Program for Water Quality in the San Francisco Bay (Bay RMP), in the open embayments of the Estuary. This helps align the WRMP and Bay RMP for their coordination and combined data syntheses. The subregions are further subdivided into Operational landscape Units (OLUs) based on distinguishing hydro-geomorphic factors. (See **Figure 2**). Every OLU consists of three contiguous (non-overlapping) elevation classes of waterscape and landscape extending between the bottom of the Estuary and the crests of its attendant watersheds. Each elevation class is represented by a unique set of habitat types, broadly representing known differences in ecological form and function. The habitat types include key landform features relating to the capacity of the habitat types to support key species of native wildlife. The features help infer habitat functions for each habitat type.

Figure 2. Bay Area Operational Landscape Units (OLUs) and Bay RMP subembayment boundaries (Dusterhoff et al. 2021).

The hierarchical format of the WRMP classification system is not intended to indicate the relative value of different habitat types. For example, the use of the term, level (as in Levels 1-5 of the system proposed), is not intended to indicate level of importance. It only indicates the level of spatial scale or landscape organization. Higher levels have lower numbers and incorporate the information of the lower levels. There are additional modifiers that can be added to further differentiate features from one another. Many of these modifiers require additional local or supplementary information and can not be fully attributed based on remote sensing data alone. .

The current geographic focus of the WRMP Classification System is the CTME and diked baylands within the jurisdiction of the San Francisco Regional Water Quality Control Board, inland or upstream of the Golden Gate. The focus can be expanded in the future, perhaps first to include inland surface waters of the watersheds draining to the San Francisco Estuary downstream of the Delta, and later to include the Delta, and eventually to cover the geographic scope of the San Francisco Estuary Comprehensive Conservation and Management Plan (CCMP 1993 and subsequent editions). The Classification system can be adapted to these increases in scope. Many of the habitat types outside the initial focus of the WRMP Classification system are already being mapped based on CARCS, which highlights the need for consistency between CARCS and the WRMP Classification System.

2.2. WRMP Classification System

It is important to determine the habitat type mapping classification system prior to settling on an approach that firmly establishes both the input data and the methodology. This is because the level of specification of the habitat type classes and minimum mapping unit will determine which approach and data inputs are appropriate. In deciding on a classification system consider repeatability, and the minimum level of classification specificity/cost and effort that is needed to address indicator requirements. Less detailed/more general mapping classifications will lead to more accurate products that may be less costly to map.

It is recommended to use the proposed Habitat Type Classification System for the San Francisco Estuary for the WRMP (see **Appendix 1** for a table of classes and habitat type definitions). This habitat type classification system is meant to be compatible with the existing California Aquatic Resource Classification System (CARCS) habitat type classification system that has been used in previous and ongoing Aquatic Resource Inventory mapping efforts and transition zone mapping standards (Robinson et al. 2017).

It is important for habitat types within reference and benchmark sites to be mapped in addition to the boundaries of the reference and benchmark sites. The classification used within these sites should be able to cross walk and/or roll up to the regional classification system proposed.

A hierarchical classification system where more detailed habitat type classes can roll up to a more general, more easily/less costly classification system is useful for allowing comparisons between more detailed site specific classification mapping with more general regional habitat type mapping. This approach could also allow for a more general regional map to incorporate and be compared to more detailed project specific habitat type mapping and monitoring.

2.3. Crosswalks

We will need to develop crosswalks with existing habitat type classification systems in order to make the maps comparable. Limitations due to differences in mapping scale, minimum mapping unit, input data type, methodology, and habitat type class definitions will be important to acknowledge during comparisons between different datasets. Having these crosswalks can help answer questions such as where are complete marshes located. Below is a list of existing habitat type classification systems being used in the Bay Area:

- Baylands Ecosystem Habitat Goals Update (BEHGU)
- California Aquatic Resource Classification System (CARCS)
- Coastal Change Analysis Program (C-CAP) Regional Land Cover and Change
- Coastal & Marine Ecological Classification Standard (CMECS)
- San Francisco Bay Joint Venture (SFBJV)
- San Francisco Bay Restoration Authority (SFBRA)

3. MAPPING PROCESSES

3.1. General Mapping Considerations

We propose making use of recent advances in automated mapping methodologies as they have proven useful for mapping wetlands in other parts of the nation (e.g., NAWM), as well as for vegetation mapping within the Bay Area[4]. This document recommends the use of automated mapping approaches paired with manual corrections for increased efficiencies in mapping large geographic areas (See the Data Processing section below). That said, advances in technology and mapping methodologies are expected to continue. The WRMP TAC should periodically review mapping methods in order to take advantage of improvements in mapping efficiencies, and accuracy over time. When considering adopting new methodologies the TAC should consider the degree of deviation from previous methods and thus potentially making comparisons and change detection to past mapping years problematic.

Appropriate methodologies and input imagery can be selected once habitat types and minimum mapping requirements (e.g., scale and repeat frequency) are defined. These requirements should be maintained across mapping years as much as possible to allow for comparison

[4] Pacific Vegetation Map effort by Kass Green and Tuckman Geospatial. https://pacificvegmap.org/.

between habitat type map products. Once these are defined, appropriate remote sensing input datasets can be selected based on their differences in accuracy, cost, spatial resolution, spectral resolution, and seasonal/tidal timing capabilities. All of these factors inform what is appropriate regarding input data, mapping schedule, and mapping methodology during the many years of wetland monitoring needed.

One of the main aims of this effort is to provide a new Baylands Habitat Type map frequently enough to inform adaptive management of the Bay Area baylands and timely assessment of relevant indicators. There are also reasons why one would aim to avoid too frequent of a mapping cadence, such as a lack of quantifiable change between maps, unnecessary increased costs, and potentially too time intensive of a mapping effort. The WRMP Geospatial Workgroup found that a five year cadence of mapping should strike a balance between these considerations. That said, the rate of change and impacts of climate change are likely to accelerate over time. Thus the TAC should reevaluate this mapping frequency if it proves insufficient in the future.

3.2. Recommended Mapping Approach

At a high level, this document recommends three different types of mapping efforts that may be required to fully address Indicators 1 and 3. These three types of mapping efforts result in an updated regional Bay Area habitat type map every five years while allowing for directed mapping efforts to address episodic events and adaptive management questions. These types of mapping efforts include a **Landmark Baylands Map**, where the entire baylands are newly mapped; alternating every five years with a **Baylands Change Update Map**, where change detection methods will be used to capture changes from the most recent Landmark Baylands Map; and lastly **Special Study** mapping at the direction of the WRMP TAC following episodic events.

The standardized and consistently conducted **Landmark Baylands Map** is probably the most important element to the recommended approach. For this product it is most critical to standardize the classification system, the habitat type landscape feature minimum mapping units, and accuracy standards. This allows the WRMP to assess changes in the abundance, diversity, and distribution of habitat types and their features without confounding them with changes in assessment methodologies. That said, as previously mentioned, it is anticipated that there will be technical advances regarding available methods and remote sensing products that should be incorporated into future versions of these SOPs. These changes should not be incorporated before a LandMark Baylands Map has been followed by a completed Baylands Change Update Map. The next Landmark Baylands Map would occur five years following the most recent Baylands Change Update Map (thus alternating between the two approaches every 5 years).

A **Baylands Change Update Map** would occur five years following the most recent Landmark Baylands Map. This map product allows for the detection and quantification of changes in bayland habitat types as well as providing insight into habitat type change processes and trends to inform adaptive management. The Baylands Change Update map would make use of change detection analysis to update the most recent Landmark Baylands Map. This approach would be more cost effective than fully remapping the entire study area, as is done for a Landmark Baylands Map, and allow for greater confidence that change between subsequent habitat type mapping products is due to real world changes rather than changes in mapping methodology.

In addition, The WRMP TAC could direct **Special Study,** or targeted mapping efforts, in response to episodic disturbance events, the completion of major bayland habitat restoration projects, and/or specific adaptive management questions. These mapping efforts may employ different methodologies depending on their goals, but should aim to maintain consistency with landmark mapping products as much as possible. See Section 3.3 below for more information regarding the criteria for which the WRMP TAC may determine if and when special study mapping is needed.

Site specific mapping efforts may occur between Landmark and Change Update mapping years and should be comparable to regional mapping efforts. These project site mapping efforts may be important for quantifying significant changes from year to year at a finer landscape scale. While these efforts should be complementary to regional mapping efforts, this level may be more suited for investigating wetland change processes.

It is important to note that the rate of change within the Baylands may change over time. Thus there may be needs to adjust the timing of regular mapping efforts to reflect those changes.

3.3. Triggers for Directing Special Study Mapping

With this proposed mapping approach, it is important to establish criteria for determining (1) if/when regional, subregional, or local episodic events, actions, or management decisions should trigger a special study mapping effort, and (2) the timing and geographic scope of the special study. The Spatial scope of Special Study mapping will depend on the anticipated geographic scope of impacts of a triggering episodic event. Below are example criteria that could trigger the WRMP TAC to direct special study mapping. This list is not meant to be exhaustive, and may be revised over time by the TAC.

Potential Triggers for a Regional, Subregional, or Local Special Study

- Rain storm/runoff event exceeds a threshold minimum size or duration for the region, a subregion, or an OLU (e.g., 50-yr recurrence interval or greater, extended period of high Delta outflows);
- Drought exceeds certain magnitude and duration for the region or a subregion (e.g., less than 50% of expected average total rainfall for two consecutive years within the region);
- An earthquake exceeding the magnitude threshold and proximity to the CTME for the region, a subregion, or an OLU (e.g., magnitude 6 or greater on the Richter Scale centered within the region, as determined by the USGS);
- A tsunami or other unusually significant wave event impacts the region, a subregion, or an OLU;
- A newly reported levee failure causing baylands flooding;
- Major new grading or construction in the baylands (e.g., tidal restoration; levee or seawall construction; shoreline armoring with riprap; baylands public access construction; storm drain outfall construction);
- A chemical or sewage spill or overflow into the baylands; and
- A major change in watershed conditions (e.g. wildfire, dam removal/failure) that could reasonably be expected to impact hydrologic and geomorphic conditions downstream.

Criteria to Decide If a Special Study Mapping Effort Is Warranted

- Direct observations of measurably significant impacts to habitats or dependent organisms (e.g. plants, fish, wildlife);
- Forecasts of measurably significant impacts are provided by accepted statistical, mechanistic, or conceptual models; and
- The study can utilize pre-event data to quantify pre-event conditions.

Criteria to Decide the Timing and Geographic Scope of a Special Study Mapping Effort

- Study will capture the complete tidal marsh ecosystem (CTME) response and recovery;
- Study will delimit the spatial extent of the measurably significant impacts within the region; and
- Study will consider the local OLU boundary for the geographic scope.

3.4. Data Collection

Considerations for Data Collection

The TAC and Geospatial workgroup make data type recommendations based upon matching data source characteristics to the project mapping requirements. These requirements stem from the proposed habitat type classification system (Section 2.2) and from the general mapping approach (See Section 3.1 and Section 3.2). Changes in project needs (be they technical, or logistical) and data source availability may result in different selections of input data collection.

Mapping Requirements/Assumptions

- A new or updated habitat type map is needed every 5 years.
- The minimum mapping unit for desired habitat type classes must be supported by the spatial resolution of input data.
- The habitat type classes must be able to be differentiated from the input data characteristics, such as spectral resolution and reflectance.
- Features exposed at low tide must be able to be mapped from input data.
- Both imagery and elevation data is necessary to differentiate between habitat type classes of interest.
- Habitat type classes are easier to map when data is collected at a consistently seasonality (recommendation of collecting imagery in the Summer[5]).
- Consistency of input data is especially important to maintain across pairs of Landmark Baylands Maps and subsequent Baylands Change Update Maps.
- Habitat Type mapping will be repeatable in the future.

Relevant Data Source Characteristics

- Data type (e.g. elevation data vs imagery)
- Cost of data
- Accuracy
- Spatial resolution
- Spectral reflectance and resolution
- Flexibility in timing of collection (regarding seasonality and tidal stage)
- Repeatability of data collection

A New Baylands Habitat Type Map Every Five Years (Alternating Between a Landmark Baylands Map with Baylands Change Update Map)

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[5] The Montezuma Remote Sensing Workgroup found that that imagery flown in the summer has worked best for mapping wetlands in Suisun Marsh and other areas in the San Francisco Bay Area. Summer also coincides with imagery flown to support the California Department of Fish and Wildlife's Vegetation Classification and Mapping Program (VegCAMP). See Montezuma related document "Remote Sensing Recommendations for Tidal Wetland Indicators", SFEI, April, 2021

In order to support a new baylands habitat type map every five years, ideally, standardized and comparable data should be collected every five years. It is especially important to have consistent data for each set of Landmark Baylands Map and following Baylands Change Update Map to ensure the to/from map class change detection analysis used, to update the most recent Baylands Habitat Type map, is detecting the actual extent and magnitude of differences of habitat types rather than differences of input data (or classification or methods). This is critical as during change detection analysis one attempts to capture the variation between the dates of input data (imagery and elevation data), while controlling for all non-change variation/differences between the dates (Green et al. 2017; Ch 11). Consistency of input data between Landmark Bayland Maps can help with realizing efficiencies in automated segmentation and classification, by making previously developed mapping models applicable to a higher degree to subsequent years.

Below you can find recommended data sources and types for the proposed approach of generating a new or updated habitat type map every five years. The selection of input data depends on practical considerations outlined above and how they align with the requirements of the habitat mapping. Listed is an option for more technically ideal, but more costly data collection options that provide benefits regarding flexibility in time of collection, spatial resolution, sometimes spectral resolution, and normalized data. We also list data sets that are less costly or even freely available, but that are often compromised in some of those areas previously mentioned.

Ideal Bayland Habitat Type Mapping Primary Input Data

- High resolution (15cm to 30cm), 4 band airborne/plane based imagery flown at low tide and at a consistent season across landmark years (ideally during the Summer for a similar vegetation phenotype signature).
- Similarly timed LiDAR data with first return and bare earth LiDAR products. Consider using LiDAR Elevation Adjustment with NVDI (Normalized Difference Vegetation Index) (LEAN)-corrected products.

This combination of high resolution four band (R,G,B,NI) plane based imagery, collected during the Summer at low tide paired with similarly timed, LEAN-corrected LiDAR imagery, collected every five years, would satisfy all mapping requirements and assumptions for the habitat type map necessary for Indicators 1 and 3. This approach would be expected to be more costly, however it would provide a critical Bay Area data resource that would be likely highly desirable for many local governments and other regional mapping efforts including mapping of vegetation alliances (e.g., Indicator 7). This represents a significant opportunity for coordination and cost sharing.

In addition to these two primary datasets, mappers should make use of local BAARI data stewards, project specific mapping, and Ancillary data (see section below) to inform habitat type maps.

Less Costly Landmark Mapping Data

If consistent acquisition of more ideal and more costly data is infeasible (atleast between a Landmark Baylands Map and subsequent Baylands Change Update Map pair), less costly input data may be necessary. Less costly input data could include data sources more in line with tested SFEI developed and implemented Aquatic Mapping Inventory methodologies which generally utilize NAIP and the most recent available LiDAR DEMS in addition to ancillary data (e.g., recent vegetation mapping). This approach would need to address any compromises in quality and ensure that the resulting mapping would satisfy the minimum monitoring requirements. Furthermore nonchange differences between Landmark Bayland Map data and Baylands Change Update Map data must be accounted for and controlled as much as possible. However, despite decreased control over data collection timing and compromises on spatial resolution of mapping products, this approach could still result in a useful bay-wide habitat type map that could address many needs of the region. It should be determined if these tradeoffs are worthwhile considering logistical constraints of mapping efforts, data availability, and data collection. This approach may need to rely more heavily on field training data or local knowledge. If existing LiDAR data was not already available for the landmark year to be mapped, newly collected LiDAR data would be the most costly input data.

Recommended Data

- NAIP (1m or possibly upgraded 0.5m). Note that NAIP collection may or may not coincide with low tide and there is limited confidence that NAIP will be collected at a consistent timing each year. Plane based imagery, compared to satellite imagery, can help control atmospheric variation.
- Planet (4 and 8 band imagery) at approximately 3.7m spatial resolution[6]. Ideally using imagery from Summer and aiming for consistent seasonality across years. Finding imagery taken at low tide and with low cloud/smoke cover can pose a challenge, as with all satellite imagery. This challenge is partially mitigated by the high return frequency.
- Most recent or newly collected LiDAR elevation data.

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[6] https://assets.planet.com/docs/Planet_Combined_Imagery_Product_Specs_letter_screen.pdf

- Possibly other satellite imagery, e.g. Sentinel 2 (4 bands, RGB and NI, at 10m), or WorldView 2 or 3 that have lower spatial resolution (WV2: 1.84m eight band, WV3: 1.24m multispectral, 3.7m short wave infrared), but may boast higher spectral resolution (8 bands for WorldView). Consider Pan sharpening (WV2: 46cm, WV3: 31cm) to segment or digitize at an increased spatial resolution.

Considerations Regarding Spatial Resolution of Primary Imagery

There are tradeoffs between using higher and lower spatial resolution primary imagery. Higher spatial resolution imagery offers greater intuitive understanding of the habitat form and appearance to mappers and users of the imagery. 15-30cm resolution imagery has been found to be critical for mapping wetland vegetation alliances in efforts related to the Pacific Vegetation map (communications with geospatial workgroup member, Kass Green). This higher resolution imagery is useful for segmentation when using textural and spectral signatures as well as useful for determining alliance level vegetation detection that can inform habitat type mapping. However, it is not recommended to use such high resolution imagery for directly classifying individual pixels. This is because with higher resolution imagery there is higher background short-term variability (e.g. wind movement of plants, water splashing) which may obscure or not be necessary for more generic indicators like percent water and percent vegetation cover. Furthermore there are challenges in increasing data set size when using higher spatial resolution imagery. Processing times can become longer and data storage must be planned for.

Elevation Data

LiDAR data is identified as a key input layer and will be potentially the most expensive dataset of these proposed. LiDAR data is extremely useful for increasing the accuracy for wetland mapping in general. In addition to first return LiDAR products, one should consider using LEAN-corrected LiDAR data to account for the impact of vegetation on LiDAR based Digital Terrain Models (often referred to as "bare earth" products). Due to the costs associated with collecting LiDAR, LiDAR availability may constrain how frequently mapping is able to be conducted. The inclusion of similarly timed LiDAR data may be necessary for addressing other Indicators (e.g. Indicators 2 and 7) regardless. Cost sharing and coordination between counties and municipalities would result in lower costs of data collection.

Ancillary Data

In addition to the primary digitizing data, ancillary datasets can be used to further refine and inform habitat type classification and increase certainty of mapping determinations. Some of these ancillary datasets overlap with the less costly data recommended, simply because they are freely available and provide additional context and support for classification decisions.

- Planet for high temporal resolution (free access through federal govt partners) - (4 band and 8 band products)
- Recent available vegetation maps (e.g. VegCamp and Pacific Veg Map)
- Previous habitat type maps (from this effort)
- Aboveground Biomass High-Resolution Maps for Tidal Marshes (Byrd et al. 2021); updated every 5 years
- Radar data (detect standing water underneath vegetation)
- See other ancillary data cited in CARI SOP

Note that some testing of methods using Planet as a primary mapping source for habitat types may be necessary.

Local Bay Area Stewardship Mapping

Local Bay Area habitat mapping regarding habitat impacted areas and projects is an important data set that should be maintained and consulted for refinement of habitat type maps. An example of local stewardship mapping include edits submitted through the California Aquatic Resource Inventory (CARI) Editor Tool as well as project specific mapping efforts. Project Tracker and local BAARI data stewards help to track ongoing updates of areas of permitted impacts, projects, and other local updates and corrections to habitat mapping. These local mapping efforts should be captured and ideally presented as a comprehensive map of pending changes. These changes should be reviewed and incorporated into the regular habitat type mapping. It is important to distinguish if proposed mapping adjustments are provided to correct previous habitat type mapping or rather represent real world changes in habitat types in the Bay Area baylands. Habitat Type mappers should incorporate this information, while aiming to maintain consistency in mapping methods and use habitat type classification that is supported by the majority of the data used for that mapping year/point in time. This allows for change detection which is critical to the goals of the WRMP.

3.5. Data Processing

Bayland Habitat Type Mapping Methods

Bayland habitat types should be mapped while taking into account previously employed methodologies as well as advances in technology and mapping standards. The most relevant historically employed baylands habitat type mapping is the bay regional aquatic resource inventory mapping such as the first Bayland Basemap (published in 1999 and the Bay Area Aquatic Resource Inventory (BAARI) mapping methods (BAARI v2.1 and BAARI Mapping Documentation). As of February 2022, BAARI was last updated in 2017. The mapping approach of regional Aquatic Resource Inventories datasets, that are associated with the California Aquatic Resource Inventory (CARI) generally consist of referencing the most recent versions of relevant existing datasets, such as NWI and NHD, and then using heads up digitizing using primary mapping sources such as NAIP and LiDAR, paired with ancillary datasets such as existing vegetation datasets, such as VegCAMP, for reference. While heads up digitizing methods can produce high quality datasets, such methods can be time consuming. There have been advances and standardization in automated mapping techniques that when paired with manual heads up digitizing refinements produce similar results with increased efficiency depending on the geographic scale and scope of the area (generally larger than 40.5 km^2 / 10,000 acres) and the specificity of the classes mapped. Furthermore, it is the consensus of the WRMP Geospatial Workgroup that automated delineation often produces more precise and accurate geometries than manual heads up digitizing and that machine learning classification methods, given sufficient high quality training data, is more consistent and accurate than visual interpretation. The WRMP Geospatial Workgroup also expects there to be advances in data processing and remote sensing, especially over the timeframes considered for this baylands habitat mapping effort. It is more important to maintain a consistent classification system, regarding class definitions and minimum mapping units, than a specific processing approach as the most suitable and efficient approach may change as advances are made in available software and hardware.

With this in mind, for **Landmark Baylands Maps**, the geospatial workgroup recommends this mixed approach of using automated mapping, Object Based Image Analysis Classification, paired with heads up digitizing, or manual editing, to further refine habitat type maps. Object Based Image Analysis Classification utilizes machine learning to cost effectively map larger areas and efficiently replicate mapping efforts over multiple years of collected datasets for monitoring changes in habitat type over time. The process involves image segmentation, field data collection, QA/QC, machine learning (such as Random Forest) model training, model testing, manual editing to produce the final habitat type map, and accuracy assessment. It is possible, depending on accepted tradeoffs regarding logistical constraints and acceptable accuracy levels, that some field data collection could be replaced and/or supplemented with consultation and review of remote sensing signatures with field biologists and/or wetland ecologist experts.

Some habitat type classes may require more manual refinement than others. This mixed approach is being used in the region currently for vegetation mapping (See Pacific Veg Map work by Kass Green and Tukman Geospatial), however some exploratory work may be required to fully refine models for habitat type classes.

Alternatively traditional heads up digitizing could be used following existing Aquatic Resource Inventory methods. However, the workgroup would expect comparatively lower efficiency in mapping the baylands during a recurring schedule as well as inconsistencies due to different individual mappers etc. This would lead to more problematic change detection comparisons.

For the **Baylands Change Update Maps,** the geospatial workgroup recommends an approach of using change detection to update the most recent Landmark Baylands Map. More specifically the workgroup recommends using Multitemporal Image-to-Map Comparison change detection analysis to update the most recent Landmark Baylands Map. We recommend using masking or post-classification change detection methods for this update. This masking method would consist of the following steps: (1) mapping changed and non-changed areas using image differencing or unsupervised classification methods; (2) convert changed and non-changed areas into a mask; (3) combine the mask with the previous Landmark Baylands Map; (4) for areas of no change, use the mapping from the most recent Landmark Baylands Map; (5) classify areas of change using the same methods used for the most recent Landmark Baylands Map but with the new year of imagery/elevation data; and (6) combine the non-changed areas from the most recent Landmark Baylands Map with the newly classified/mapped areas of change, resulting in the finished Baylands Change Update Map (Green et al. 2017; Ch 11).

Transition Zone Mapping Methods

Indicator 3 requires a map of estuarine-terrestrial transition zones and tidal wetland migration space to address the monitoring question, *Where do wetlands have space to migrate upslope?*

Transition Zones (T-Zones), like Riparian Zones, consist of a set of function zones. Transition Zones are not a habitat type and require different methods to map than the proposed semi automated object-based mapping method proposed out for Indicator 1 habitat type mapping. For indicator 3, Transition Zones should be mapped in an inclusive manner that includes space needed to support larger ecosystem functions and services of interest identified in the BEHGU report. Ideally the area captured should include zones that support "existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems" (BEHGU; Goals Project 2015). In order to achieve this goal, the recommendation of the geospatial workgroup is to adopt the Upper Boundary transition zone mapping methodology detailed in the 2017 report "Mapping the Transition Zone" (Robinson et al. 2017). The Upper Boundary method represents an inclusive approach that include "landscape connectivity for upland wildlife and broad habitat gradients." Generalized, this method consists of an inlandward buffer from an estimate of the lower edge of the transition zone, of a distance determined by the T-Zone landscape type. Generally 500m is used for hillslope, with some differences for riverine/stream and cliffs/bluffs (Robinson et al. 2017). For the lower boundary of the Transition zone, one could use a contour of MHHW + 0.31m elevation (Robinson et al. 2017), however one could also consider using a Z* value of 1.34, which is comparable to the highest astronomical tide (Beagle et al. 2019), to account for local tidal datums. Furthermore it is recommended to utilize a LEAN-corrected DEM to derive the MHHW contour or Z* layer. This Upper Boundary approach is consistent with the approach taken in the Adaptation Atlas and with BEGHU projects and products.

Migration space refers to areas at appropriate topographic elevations that could support estuarine-upland transition zones now and in the future with sea level rise. These are often natural wetland-upland transition zone areas adjacent to present and potential marshes that could be protected, enhanced, or restored to allow marshes to migrate landward as sea level rises. Lands that provide migration space are scarce and in demand as they are generally situated between the lower limits of developed upland areas and the upper limits of diked or tidal baylands" (Beagle et al. 2019). The method described in the Adaptation Atlas is appropriate for delineating these areas. This approach consisted of selecting undeveloped areas expected to be inundated with 2.0 m of sea level rise (CoSMoS Model SF Bay Product Suite, Barnard et al. 2014) that are above today's highest astronomical tide (z* > 1.34). Results can be refined by removing areas of existing tidal marsh by using the most recent bayland habitat type data to capture tidal ditch, tidal marsh flat, tidal panne, and tidal vegetation classification types.

Further migration space analysis can distinguish protected migration space from unprotected migration space using the California Protected Areas Database (CPAD). Land Use data could consist of NLCD, MTC or other high resolution updated land use data. Consider using land use crosswalks defining developed areas that are consistent with those used in the Adaptation Atlas analysis. Note that the 2.0 m sea level rise scenario is slightly less severe than the 2.1 m assigned 0.5% probability of occurring by 2100 under high emissions scenarios by OPC (2018). For more information, see the San Francisco Bay Shoreline Adaptation Atlas (2019) report (Beagle et al. 2019).

We do not expect the general Transitional Zone nor the elevation zone where Migration Space may occur to change quickly and likely doesn't need to be remapped frequently. However, land use, protection status, placement of water control structures, and habitat extents from projects are likely to change more quickly and can be used to reassess the distribution of transition zone development and protection status as well as the protection status of functional and potential migration spaces. This reassessment is recommended to occur every five years in conjunction with updated Bayland Habitat Type mapping. This timing allows for use of updated bayland habitat type maps as well as associated updated elevation data collected for bayland habitat type mapping. After this analysis is conducted one could expect to have the resulting data layers:

- Transition Zone
    - Developed
    - Undeveloped
    - Protected
    - Unprotected
    - Opportunity areas to reconnect upper watershed with baylands
- Migration Space
    - Developed
    - Undeveloped
    - Protected
    - Unprotected

Riparian Zone Estimator Tool (RipZET) and Bayland Transition Zone Mapping

The Riparian Zone Estimator Tool (RipZET) is a GIS tool that helps to estimate riparian functional zones along wetlands, including Baylands and Streams. RipZET represents an established methodology, that is consistent with the recommended state riparian definition, to capture riparian zones along waterways. Both riparian areas and transition zones consist of a set of functional zones and are conceptually compatible. This toolset could be further developed by adding a transition zone module to reflect the methods proposed here for Bayland transition zone mapping to more fully delineate the continuity of riparian areas and transition zones at the nexus of uplands and the estuary. The use of RipZET, how it compares with the Indicator 3. and how it could be used in conjunction with Indicator 1 proposed semi-automated habitat type mapping outputs is of interest and should be further explored.

3.6. Related GIS Data Not Newly Derived for Indicator 1

Indicator 1 and the WRMP in general is primarily designed to address habitats within the Estuary. There are, however, other features and areas of interest that are related to the concerns of the WRMP in the Riverine and Terrestrial Landscape Complexes. These features are not newly mapped/derived for Indicator 1 but should be collected to use in conjunction with the newly derived Indicator 1 mapping. Below are some examples of Habitat Types and Functional Habitat that can be acquired from other sources.

Fluvial Channels and Non-Estuarine Wetlands

These features can be collected from CARI which represents the collection and compilation of the most recent and accurate aquatic resource mapping across California using a standardized classification system.

Floodplain

The edges of the floodplain can be difficult to delineate. Thus floodplains are often modeled. For the purposes of the WRMP the floodplain will be defined as the most recent 100-year flood extent, areas with a 1%, or more, annual chance of flooding, published by FEMA.

Agricultural Areas

Agricultural areas, such as low intensity and high intensity agricultural, can be captured by other active Agricultural mapping efforts such as the California Important Farmlands dataset, or other more local or up to date mapping products (i.e., Land IQ Agriculture GIS data, County Agricultural GIS data, etc.).

Developed Lands

Developed areas can be captured by the most recent MTC Land Use layer if available. Other Land Use layers include NLCD, however pose challenges of having lower spatial resolution.

Wetland Management Data

In order to add information regarding management of wetlands and “ponds” within the Estuary, that can not be consistently determined from remotely sensed data, Project Tracker (ptrack.ecoatlas.org) can be used where wetland and project managers can add up to date information about their projects. This layer can be overlaid with Indicator 1 estuary habitat types from the most recent Baylands Map to track change in habitat types within projects as well as indicate what types of management is occurring within those habitat types. In some cases local knowledge may be required to update project tracker attributes and refine project boundaries. As this information was deemed critical from the WRMP TAC and Geospatial

Workgroup, efforts should be made to keep the information in Project Tracker correct and up to date.

3.7. Accuracy Assessments

Accuracy Assessment for Landmark Baylands Maps

When conducting accuracy assessments for the Landmark Baylands Maps, mappers are recommended to use an error matrix to more fully present accuracy for specific classes for both Producer's and User's accuracy calculations in addition to an overall accuracy percentage. Using a Fuzzy Error Matrix approach allows for the incorporation of the variation inherent in the classification scheme or resulting from the reference data collection process.

One could either use field visits or manual image interpretation for accuracy assessment reference data for assessing accuracy of automated classification methods. Generally manual image interpretation would be more cost effective, but potentially less accurate, which may further support a Fuzzy Error Matrix approach. This sort of manual imagery assessment should be conducted by a wetland specialist who is familiar with remotely sensed depictions of these classified features. Ideally the imagery and other remotely sensed data should be of higher resolution than is utilized for bayland feature classification. Collecting reference data via Field visits could consist of field visit classifications in addition to field visit classification training data. Traditionally these site visits consist of using releve plots for vegetation based classifications. For Bayland features it is recommended that class definitions follow a definition approach more aligned with the CRAM wetland class approach. Site visits could consist of boots on the ground surveys or potential UAS reconnaissance. Any form of reference data should be compared to verify the reliability of the reference labels interpreted from airborne imagery used in the Landmark Baylands Maps.

When determining your required sampling size of reference data, a general rule of thumb is 50 samples for each map class for maps less than 1 million acres in size and fewer than 12 classes. The number of samples for each class may be adjusted based on the relative importance of that class within the objectives of the mapping project, or the inherent variability within each of the classes ("Assessing the Accuracy of Remotely Sensed Data", Congalton and Green, 2020). Refer to "Assessing the Accuracy of Remotely Sensed Data" for more systematic approaches to determine the number of samples needed.

The timing of sampling for reference data is important to also consider and will likely determine if sampling can be directed equally across habitat type classes (i.e., one year after data collection) when habitat types have already been classified in the landmark map, or if a semi random sampling is sufficient and have reference data collected as close in time to data acquisition as possible, but before habitat type classes have been delineated and classified. By collecting reference data as close in time to data acquisition one will avoid potential significant error from on the ground changes in habitat types between reference data and imagery collection. See page 120 in "Assessing the Accuracy of Remotely Sensed Data" (Congalton and Green 2020), for a table of pros and cons to each approach.

For reference data's sampling unit it is recommended to use buffered points with a standardized area that fall fully within, ideally centered within, segmented polygons. This enables practitioners to avoid needing to use area weighted accuracy assessments. This also implies that most reference data will be developed after primary mapping imagery/data is collected and segmented. This is especially appropriate if manual image interpretation by bayland habitat type feature experts is used to develop reference datasets based upon similarly timed, or potentially the same, imagery. Otherwise potential error from this approach is swapped for potential error from on the ground changes in habitat types from the time primary data is collected and reference data is collected.

When creating a sampling scheme for reference data it is important to use the same classes as used in the Landmark Baylands Maps and use a "fuzzy" accuracy assessment method when there are classes that could be more easily conflated. In a "fuzzy" accuracy assessment, in addition to an absolutely correct class being assigned for a sample unit, a secondary or even tertiary acceptable option is collected or assigned.

Thus In order to assess the accuracy of the Landmark Bayland Map products the workgroup recommends using training and reference data collected through remotely sensed data manually interpreted by bayland habitat type experts or field collected reference and training data if budgets allow. A standardized sampling unit of a point with a standardized buffered radius should be used for reference data to avoid most issues that occur when independently delineated ground truthed area boundaries do not fall fully within the map segmented boundaries. Due to the difficulties that individuals have with accurately estimating percent cover over an area, "fuzzy accuracy assessments" (Congalton and Green 2020; Ch 10) become especially useful when habitat types that are more difficult to distinguish from one another. One can also help account for variability in human estimated percent ground cover by classifying a primary and second label/classification for each point where making that distinction is more difficult.

Accuracy Assessment of a Baylands Change Update Map

Overall accuracy of a change product is the multiplication of the errors of the 2 images being compared (Congalton and Green 2020; Ch 14, p. 239). Congalton and Green recommend using a Change Detection Error Matrix to assess accuracy of change between different combinations of habitat types versus just specific habitat classes. This method should be used when conducting the accuracy assessments for the Baylands Change Update Map. Reference data collection should be prioritized in change areas to avoid over sampling in non-change areas (Congalton and Green 2020; Ch 14, p. 239). Reference data should be collected in a similar manner as was recommended for Landmark Baylands Maps.

Target Classification Accuracy Levels

Following the use of fuzzy accuracy assessments, acceptable levels of misclassification are less than 15%. 15% is the cut-off in BAARI SOP. 85% classification accuracy is inline with Aquatic Resource Inventory Mapping previously conducted in the Bay Area (WRMP 2011) and in the Coastal Change Analysis Program (C-CAP) Regional Land Cover and Change products (NOAA 2016).

To increase accuracy, consider the tradeoffs between more and less general habitat type classes and how they affect accuracy and precision. One would expect higher accuracy using more general habitat type classes. It is important to use the minimum requirements of indicators as a minimum level of specificity for habitat type classes to gain the highest levels of accuracy possible.

Comparison Between Heads Up Digitizing and Manually Refined Automated Mapping Methods

Heads up digitizing was not ultimately recommended for consistent mapping of Bayland Habitat Types for the WRMP. This decision arose from a careful consideration of the trade-offs between heads up digitizing and automated mapping methodologies for mapping habitat types. Heads up digitizing makes use of humans' natural ability to discern patterns from visual images and ability to take into account information from multiple sources. However, heads up digitizing also suffers from the fact that people are notoriously poor at estimating percent ground cover as well as variation between individual mappers and even in decisions a single mapper might make on different days due to changes in physical and mental states. Automated mapping provides a standardized and consistent classification method that is applied across a study area. Automated mapping also provides gains in efficiencies than manual mapping when the study area covers a larger area. This is because automated mapping requires an upfront investment of setting up a model using ground truthed training data that then is applied to the study area with little increased investment to continue to apply the model to a larger area. Whereas manual mapping generally has a much more linear relationship between area mapped and time spent mapping. Another difference is that automated mapping, making use of automated segmentation methods produces much more accurate boundaries than manually drawn boundaries. For Automated methods there is perhaps a greater need for control of non-change or artificial variation in data when using automated mapping methods, although this is important for both methods for data interpretation and mapping.

Taking these considerations into account the geospatial workgroup recommended an automated segmentation and classification, with higher accuracy and consistency than mapping using heads up digitizing methods, that then makes use of manual corrections to refine the automated outputs. This final manual refinement allows opportunities to refine decisions made in automated mapping and incorporate information that may not be apparent in primary data sources. This approach also takes advantage of efficiencies realized by automated methods when mapping over large areas.

A comparison between manual refined automated mapping methods to heads up digitizing can still be useful to assess the differences in classification and feature delineation. This is particularly of interest when considering that heads up digitizing has historically been used for Aquatic Resource Inventory mapping methodologies in the region. A potential quantitative comparison between the two approaches is described below and could be adopted for Special Study Mapping efforts:

For a subset of the baylands, complete a habitat type map using heads up digitizing. Compare automated output and manually refined automated outputs using previously developed Aquatic Resource Inventory Accuracy Assessment ArcGIS tools, quantifying differences related to alignment, under-mapping, over-mapping, and feature attribution (classification), for both polygons and lines (See BAARI SOP, pg 23-27)[7].

1. Select a 10% random sample of baylands
2. For sample areas complete the following:
    - Traditional heads up digitizing of agreed upon habitat type classifications.
    - Refine automated output using manual editing.
3. Run SFEI Aquatic Resource Inventory Accuracy Assessment ArcGIS tool comparing the following maps to one another to assess differences regarding overmapping, under-mapping, and classification of polygons and lines.
    - Heads up digitized map

[7] SFEI has previously utilized existing Aquatic Resource Inventory Accuracy Assessment ArcGIS tools to test automated mapping outputs created by SIG for initial Tahoe Aquatic Resource Inventory mapping.

- Manually refined automated map (using Object Based Image Analysis Classification)

The differences between the two mapping products should be noted and should inform future method considerations and data set comparisons. It's the consensus of the WRMP Geospatial Workgroup that accuracy and consistency of segmentation and classification of habitat types will be higher for the manually refined automated mapping methods.

3.8. Derived Analytics / Metrics

The WRMP Program Plan identifies the following metrics[8]:

> **For Indicator 1:** *Total area (acres), size-frequency distribution, and average inter-patch distance for each habitat type, reported at the regional and subregional scales. .*
>
> **For Indicator 3:** *Elevations (ft NAVD) and elevation capital (Z*); relative to local MHHW) for diked baylands and selected land uses within sub-zones 3 and 4 (SZ3 and SZ4) of the T-zone.* Key to measuring landscape change will be the effort to align remotely detected landscape change, locally tracked changes, and changes reported by habitat restoration projects. Part of the challenge is marking the thresholds of habitat creation and conversion, which might be highly dependent on phenological changes and other confounding factors. The different forms of measurement and reporting might conceivably lead to divergent results.

Therefore, the proposed funding by the San Francisco Bay Restoration Authority would provide the opportunity to convene the interested parties to align their indicators tied to the measurement of restored and impacted habitats. Pending those discussions, the alignment of habitat restoration projects and remotely sensed habitat might remain divergent figures.

Calculations and measurements will be derived from key data sources, such as impact areas and project areas using the Project Tracker SOP, Remote Sensing Special Study, and the WRMP SOPs for Indicator 1 and 3 that will include using satellite LiDAR with ground-truthing for a regional comprehensive inventory.

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[8] The language for the metrics has been refined and may differ slightly from previous documents, such as the WRMP Program Plan.

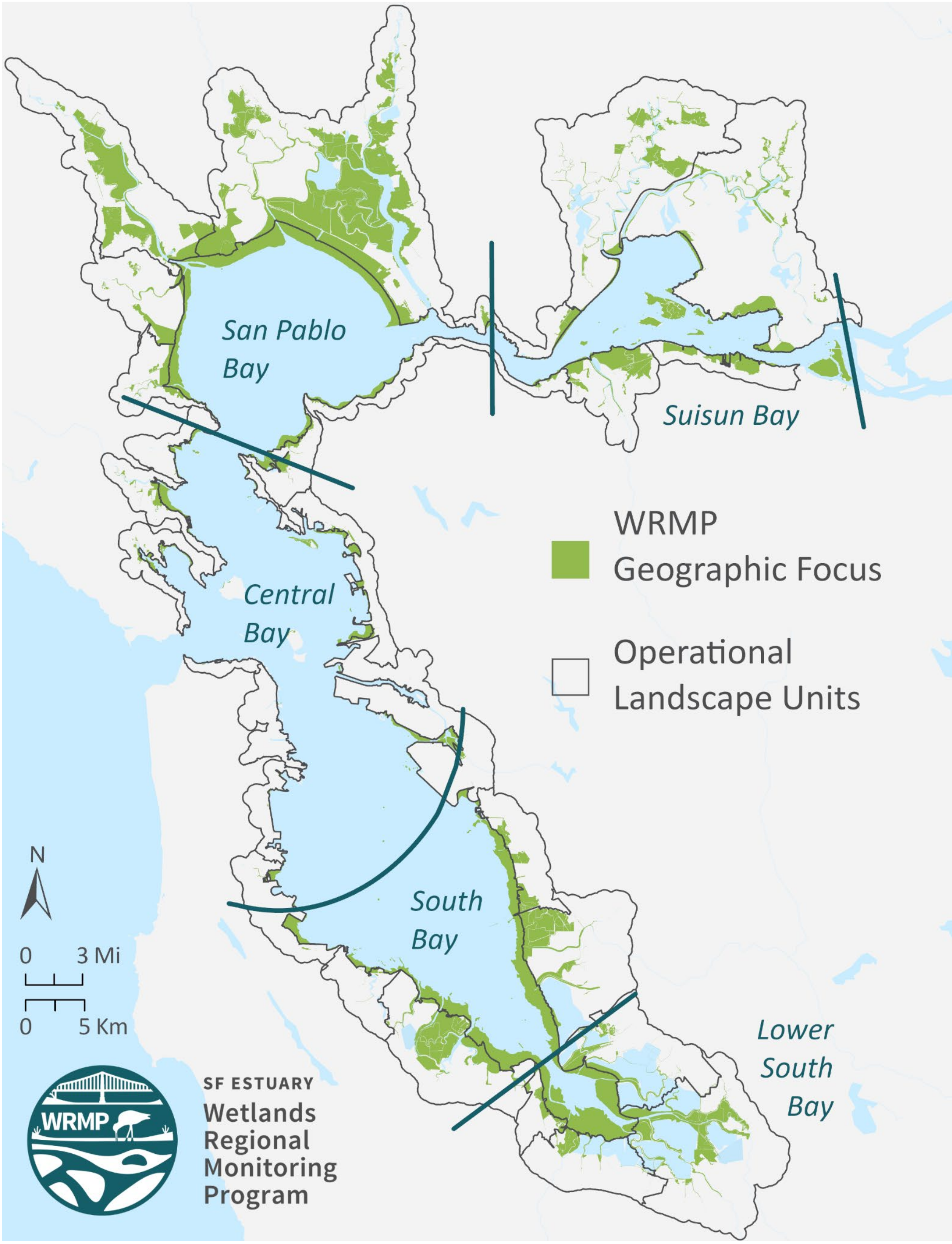

Figure 3. Map of tidal flats, tidal wetlands, and restored baylands of the lower San Francisco Estuary, including the WRMP subregions and OLU boundaries.
Map author: A. Thomsen. Data source: San Francisco Estuary Institute. 2021.

A couple of existing tools incorporate connectivity analysis metrics, including the patch size frequency, mean interpatch distance, nearest-neighbor distance (EcoAtlas Landscape Profile Tool, Mitigation Planning Tool, Landscapes Scenario Planning Tool. In the future, the WRMP Geospatial Workgroup will need to recommend the rules for delimiting patches and metric calculations. For example, what width of open water such as a tidal slough might separate one patch of tidal marsh from another? Rules used to calculate patch size frequency for tidal marsh for past editions of the State of the Estuary Reports might also be applied for this effort.

3.9. Data Hosting and Visualization / Cartography

Considerations for data hosting and visualization include:

- Develop plans for hosting the visualized data, key calculations, and the source datasets;
- Provide online platform for annual and baseline mapping and customized reporting and summary tools;
- Identify clear repeatable metrics with clear data sources to calculate metrics;
- Provide easy reference back to source data, e.g., data layer or suite of tools;
- Describe how we will integrate with other tools and data sources; and
- Calculate indicators on regular intervals for regional accounting strategy (e.g., annually published metrics in the State of the Estuary Report).

4. INDICATOR CALCULATIONS

Once there is a consensus by the WRMP Geospatial Workgroup on what needs to be mapped, we will be able to develop the Indicator Calculations and describe how to weight the metrics to derive an Indicator Score. For example, Ganju et al. 2017 and Wasson et al. 2019 researched measurable metrics or index for wetland loss using remote imagery and percent of greenness vs open water/ground.

5. RELATED DOCUMENTS

The following documents are forthcoming, based on these SOPs:

Indicator Calculation Document will show how specifically the data in various datasets are synthesized to produce essential metrics.

Standard Operating Procedures (SOPs) will document the required analyses for other individual indicators, such as Indicator 2: Map of tidal wetland elevations and elevation capital and Indicator 7: Percent cover, height, and patch characteristics of dominant vegetation groups.

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7. GLOSSARY OF TERMS

Attribute Accuracy: Attribute accuracy evaluates how thoroughly and correctly the features in the data set are described.

Automated Mapping/Object Based Image Analysis Classification: In this document automated mapping is referring to Object Based Image Analysis Classification which involves using GIS software (e.g., eCognition or potential ArcGIS Pro) to segment imagery into distinct polygons which are then categorized (e.g., given a habitat type class) based off of a model that is created, using machine learning (e.g., Random Forest model), that extrapolates from field data where site visits are used to define the correct classification for a representative sample of the segmented polygons. After iterations of model training, testing and accuracy assessments, there is an optional step of manual editing to further refine automated mapping output polygon boundaries and/or classifications.

Completeness: The decisions that determine what is contained in the data set.

Compete Tidal Marsh Ecosystem (CTME): The CTME includes shallow subtidal areas to a depth of 12 ft below local Mean Lower Low Water, (zero tide height), tidal flats, fully tidal and muted tidal baylands, and the adjoining estuarine-terrestrial transition zone (T-zone) within the jurisdiction of the Bay Area Regional water Quality Control Board inland or upstream of the Golden Gate.

Estuarine-Terrestrial Transition Zone (T-zone): The T-zone is the area of existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems.

Habitat: A habitat is the spatial distribution of physical conditions delimiting the niche of one animal or plant species. Any species has a unique habitat. For example, the area of tidal marsh and adjoining tidal flat and uplands utilized by Ridegway's Rails for feeding, nesting, refuge, and dispersal comprise its habitat. The WRMP Classification System and the basemap that it informs do not include habitats, although some habitats can be inferred from habitat types and structural elements.

Habitat Feature: A structural element is a common physical feature of a habitat type that contributes significantly to its overall physiography, is easily recognized in the field, and can be mapped using common means of remote sensing of vegetation and elevation. Structural elements can help infer habitat from habitat type. Tidal marsh channels and pannes are examples of structural elements.

Habitat Type: A habitat type is a recurring area of landscape easily distinguished from other areas based on its self-similarity, as generally expressed by its geology, hydrology, land use, and vegetation cover. A habitat type can contain any number of habitats, entirely or in part. Tidal marsh and tidal flat are examples of baylands habitat types.

Head of Tide (HoT): The HoT is the inland zone where the velocity of channelized water flow having a 50-yr recurrence interval and that enters the baylands during ebb phase of the tide becomes zero due to the incursion of the highest observed tide of a particular tidal epoch. In concept, it is the point or zone of zero velocity where the runoff meets the rushing tide to increase flood risks.

Indicator: An indicator shows or suggests the condition or existence of something. The WRMP addresses their guiding questions through a tiered sequence of management and monitoring questions that are in turn answered by a suite of key environmental indicators and metrics.

Landscape: A landscape consists of the habitat types and other geographic features that characterize a particular area of the Earth surface that can be viewed at one time from one place. The geographic extent of a landscape therefore depends on the means or method by which the Earth's surface is viewed. More extensive landscapes are evident in imagery provided by satellites than what might be viewed with unaided eyesight from an airplane or hillside.

Mosaic: A mosaic is a combination of habitats or habitat types that reoccurs within a region and can be used to define and delimit a landscape. The baylands landscape consists of a mosaic of the habitat types defined herein.

Operational Landscape Unit (OLU): An OLU is an area distinguished by certain physical characteristics that would benefit from being managed as a unit to provide particular desired ecosystem functions and services. OLUs can be identified anywhere across the earth's surface, with their size and composition depending upon the landscape in question and the ecosystem functions and services of interest. For the WRMP, Baylands OLUs are defined as connected areas along the shoreline of the San Francisco Estuary within the WRMP region that should be managed as coherent units for nature-based sea-level rise adaptation (Beagle et al. 2019).

Patch: A patch is a separate area of a habitat type, or of a habitat, that has a discernable shape and extent, and that can be mapped using common means of remote sensing of vegetation and elevation. In general, species-specific habitat patches are separated by areas of non-habitat that significantly inhibit the usual movements of individuals of the species to breed, forage, or seek refuge.

Positional Accuracy: How closely the coordinate descriptions of features compare to their actual location (USFWS 2004).

Tide: The tide is the periodic rise and fall of the SF Estuary waters resulting from gravitational interactions between Sun, Moon, and Earth. The tide is the vertical component of the particulate motion of a tidal wave. Although the accompanying horizontal movement of the water is part of the same phenomenon, this motion is termed the tidal current. For the purposes of the WRMP, the tide and its currents are together termed the tide. The National Tidal Datum Epoch (NTDE) is a 19-year time period established by the National Ocean Service for collecting observations on water levels and calculating tidal datum values (e.g. mean sea level, mean lower low water). The term, tidal, means directly subject to the tide. The term, intertidal, refers to an area above the local minimum low tide and below the local maximum high tide of a particular NTDE.

Vegetation Cover: Vegetation cover is the horizontal extent, average vertical height, species composition, and density of vegetative material (i.e., proportion of space between the ground surface and the top of the cover that is occupied by living or dead vegetation) within a patch of a habitat type. Wetland vegetation consists of facultative or obligate wetland plant species.

8. APPENDICES

Appendix 1: WRMP Habitat Classifications

Proposed WRMP Classification System with level, and minimum mapping unit. Descriptions of each habitat type and level are provided below the table. The minimum mapping unit (MMU) is originally based on standards used for the Pacific Veg map work that utilizes similar mapping methodologies (~ 0.25 acres or ~ 1000m^2) for polygonal features and 25m long for linear features following CARI standards. Linear features do not need to be fully connected to allow for hydrological modeling (i.e., incorporation of artificial paths etc.). CARI also suggests a mapping scale of 1:2500 which can be used for manual refinement of automated mapping outputs. Variation in MMU between habitat types may be deemed necessary by the WRMP TAC.

The final WRMP classification spreadsheet created by Christina Toms is located here. For the Baylands Change Basemap, we will only create polygons for derived classes shaded in blue. Boundaries for acquired classes shaded in red will be determined from bringing in separate layers that have been created by others (i.e., flood plains = 100 year flood boundary from FEMA).

WRMP Habitat Classification

Level 1: Geography	Level 2: Landscape Complex	Level 3: Hydrogeomorphic Setting	Level 4: Ecosystem Complex/Habitat Type	Level 4: MMU	Level 5: Functional Habitat	Modifier - Salinity	Modifier - Hydrology	Modifier - Geomorphology
Subregion	Estuarine (Derived)	Subtidal	Shallow Subtidal Embayment	1000m2	SAV/FAV Beds	Salt, Brackish, Fresh		Substrate (Sand, Mud, Shell, Hardpan, Pinnacle)
					Shallow Subtidal Embayment Without SAV			
			Deep Subtidal Embayment	1000m2	Deep Subtidal Embayment			
			Subtidal Slough	1000m2	Subtidal Slough			
		Intertidal -	Tidal Flat	1000m2	Tidal Flat			

		Fully Tidally Connected	Tidal Pond/Panne	100m2	Tidal Pond/Panne			
			Tidal Channel	30m wide and > 60m long	Tidal Channel			Order, Natural/Unnatural
			Tidal Marsh	1000m2	Tidal Marsh			High/Low, Centennial/Infill, Fringing, Wave-Built, Maturity/Complete?
		Intertidal - Not Fully Tidally Connected	Other Marsh	1000m2	Other Marsh		Non-Tidal, Muted Tidal, Managed Tidal	
			Other Open Water	1000m2	Managed Pond			
					Playa			
					Wastewater Pond			
					Salt Pond	Low (15-60 ppt), Medium (60 - 180 ppt), High (180-200), Crystallizer (200+)		
			Developed Baylands	n/a	Low Intensity Agriculture			
					High Intensity Agriculture			

					Developed/Urban			
		Supratidal	Levees	Levee of any length Lines and polygons (not to overlap wetlands polygons)	Levees			Armored/Not Armoried, NBS Type
			Beach	100m2	Beach			Substrate (Cobble, Gravel, Sand, Shell)
					Dune			
	Riverine (Acquired)	Fluvial Channel	River/Stream	n/a	River/Stream		Perennially/Seasonally Tidal	
			Flood Control Channel	n/a	Flood Control Channel			
		Floodplain	Floodplain	n/a	Agriculture			
					Woody Riparian			
					Point Bars/Unvegetated Flats			
					Floodplain Marsh			
	Terrestrial (Acquired)	Estuarine-Terrestrial Transition Zone	Depressional Wetland	n/a	Seasonal Wetlands			
					Vernal Pools			
			Hillslopes - Natural	n/a	Grassland			
					Shrubland			

					Woodland			
			Hillslopes - Developed	n/a	Low Intensity Agriculture			
					High Intensity Agriculture			
					Parks/Open Spaces			

Additional Notes and Considerations

Below are additional notes from WRMP TAC members on the proposed WRMP Classification System. These comments will be addressed in future iterations of the SOPs.

- **Beach:** Beaches can be Intertidal and Supratidal.
- **Channels:** Map as a line layer unless over 30m width (CARI). Allows to address area and length of channels.
- **Levees:** Map as a separate line layer like they were mapped in the SF Bay Shore Inventory dataset
- **Tidal Channel**: Currently, there is no standard classification for smaller intertidal features < 30m wide, such as tidal creeks or rivulets. The TAC suggested that clearer definitions for smaller tidal creek/rivulet features would be helpful. For example, these features determine marsh complexity, provide unique habitats used by marsh-obligate species, and serve as corridors that increase marsh-channel connectivity. It may be useful to add such classifications so that a standard language can be applied across WRMP SOPs (e.g., fish and wildlife surveys). One example of the value of these features can be found here: http://www.int-res.com/articles/meps/47/m047p303.pdf

  Point Blue's "cutoff for deciding whether a large channel emptying into the bay was considered open water or tidal marsh habitat from a rail's perspective was 30m. That seems narrow to me now, but that's what we used" (pers. comm. with Julian Wood, Point Blue). We may be able to capture more narrow channels in the mapping and will determine this in our testing areas. However, we could still distinguish channels at the 30m width cut off if helpful.

- **Transition Zones:** Refer to SFEI 2017 Transition zone mapping memo to be consistent with Bayland Goals work (pers. comm. with Jeremey Lowe, SFEI).

Level 1: Geography

Subregion

The geographic focus includes Suisun Marsh, North Bay, Central Bay, South Bay, Lower South Bay, and the Operational Landscape Geomorphic Unit Types of Headlands + Small Valleys, Alluvial Fans + Alluvial Plains, and Wide Alluvial Valleys.

Level 2: Landscape Complex

Estuarine (Derived)

Estuarine landscapes exist along the margins of tidal sloughs, bays, and estuaries. They are usually subject to daily or twice-daily tidal fluctuations in water height. These fluctuations might be fully natural or muted due to tide gates, culverts, weirs, etc. The water is a mixture of marine or ocean water and freshwater. Water salinity can range from fresh to hyper-saline (i.e., more saline than the ocean). Typical freshwater sources include rivers, streams, groundwater, point discharges (e.g., effluent from sewage treatment facilities), and storm drains. In the San Francisco Estuary, the influence of the tides typically ends farther upstream than the influence of marine salinity; the estuary therefore includes tidal marine, tidal brackish, and tidal freshwater habitats. The region’s estuarine landscapes include features such as beaches that can be outside the reach of daily tides but strongly influenced by estuarine processes such as waves and storm surge. Estuarine landscapes also include levees, which are outside the reach of daily tides but exert a significant influence on physical and ecological conditions and processes within those landscapes. Derived indicates that new polygons will be mapped versus acquiring the data from an existing source.

Riverine (Acquired)

Riverine landscapes are primarily influenced by the flow of water and sediment conveyed by natural or artificial channels such as rivers, streams, ditches, canals, and flood control channels. They can include channels that are perennial (always convey flow), ephemeral (convey flow in response to precipitation and runoff events), or intermittent (convey flow discontinuously along a channel gradient). Riverine landscapes can include diverse landforms such as active channels, floodplains, riffles, point bars, oxbow lakes, and berms that can shift in response to changes in flow, channel gradient, sediment size, and other physical characteristics. In the San Francisco Estuary, riverine landscapes prograde into estuarine landscapes where natural and artificial channels meet the head of tide (HoT, see Dusterhoff et al. 2014). The boundary between riverine and estuarine landscapes is rarely precise, and can shift over scales of space and time in response to storms, watershed changes, climate change, and other drivers. Acquired indicates that habitats will be mapped using existing data sources.

Terrestrial (Acquired)

Terrestrial landscapes exist largely outside the regular physical and ecological influence of estuarine and riverine landscapes, and are often referred to as "uplands." They include all the lands and waters of the watersheds draining above ground or below the ground surface to the Estuary, including the portions of the OLUs above and inland of the baylands. They include landforms such as hillslopes, younger and older alluvial fans, and plains. Anthropogenic activities and landscape-scale drivers such as climate change can gradually or suddenly convert terrestrial landscapes into estuarine or riverine landscapes, and vice-versa.

Level 3: Hydrogeomorphic Setting

Subtidal

Subtidal estuarine areas have elevations below the local Mean Lower Low Water (MLLW) tidal elevation contour.

Intertidal - Fully Tidally Connected

Intertidal estuarine areas have elevations between the local MLLW and Mean Higher High Water (MHHW). Fully tidally connected areas have unimpeded physical connectivity with source tides.

Intertidal - Not Fully Tidally Connected

Intertidal areas that are not fully tidally connected have physical connectivity with source tides impeded by structures such as levees, tide gates, and other obstructions. This category includes estuarine areas with muted and/or managed tides, as well as areas that have been completely cut off from tidal influences.

Supratidal

Supratidal estuarine areas have elevations above local MHHW but are nonetheless strongly influenced by estuarine processes such as tides and waves. Examples of supratidal estuarine areas include beaches, dunes, and levees.

Fluvial Channel

Fluvial channels are natural channels in riverine areas that meander and have variable width due to natural formative processes. These channels may have slight human modification. They convey the active flow of water, sediment, and associated watershed-derived materials during dominant (non-storm) flow conditions.

Floodplain

Floodplains are portions of riverine areas adjacent to fluvial channels that are only activated (convey the flow of water, sediment, and associated watershed-derived materials) during high-flow (storm) conditions.

Estuarine-Terrestrial Transition Zone

Estuarine-terrestrial transition zones are the areas of existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems (Goals Project 2015).

Level 4: Ecosystem Complex/Habitat Type

Shallow Subtidal Embayment

An area of wetland that is permanently covered by water and supports water column and benthic habitats. Shallow subtidal areas exist between local Mean Lower Low Water (MLLW) and the bottom contour 12 ft below MLLW. The wetland exists within a recess or indentation in the shoreline and typically has calmer water as compared to the open Bay. The benthic substrate is typically silts, muds, and clays, but can also have areas of rocky or artificial substrate. This habitat can support shellfish and other invertebrates, and various species of submerged aquatic vegetation. These habitats can be affected by temperature, salinity and turbidity of the water column.

Deep Subtidal Embayment

An area of wetland that is permanently covered by water and supports water column and benthic habitats. Deep subtidal areas extend between the deepest areas of the subtidal to the contour that is 12 ft below local Mean Lower Low Water (MLLW). The wetland exists within a recess or indentation in the shoreline and typically has calmer water as compared to the open Bay. The benthic substrate is typically silts, muds, and clays, but can also have areas of rocky or artificial substrate. These habitats can be affected by temperature, salinity and turbidity of the water column, and typically have lower sunlight penetration than shallow subtidal environments due to the greater water column depth.

Subtidal Slough

A channel including its bed and banks that delivers flow to and from other tidal habitats, that is permanently covered by water. The bed/thalweg of the slough is below Mean Lower Low Water (MLLW), and is never exposed. Sloughs are typically bordered by adjacent areas of tidal flat or tidal marsh.

Tidal Flat

Intertidal flats mostly exist between the local Mean Tide Level tidal datum (MTL) and the local Mean Lower Low Water tidal datum (MLLW), and support less than 10% cover of vascular vegetation, including eelgrass.

Tidal Pond/Panne

Tidal ponds tend to be well-defined, persistent, and shallow features that evolve on fully mature marsh plains (PWA and Faber, 2004). Tidal pannes are features of high tidal marshes that tend to store water between inundations by the tide. They may be perennial or seasonal. Most pannes have a persistent average depth over time less than 12 inches. They usually support less than 10% cover of vascular vegetation, although some brackish pannes support dense colonies of submergent vegetation, especially Ruppia maritima. Pannes often form on tidal marsh plains equidistant from tidal channels, and along the upland margins of tidal marshes.

Tidal Channel

A channel that flows through areas of tidal marsh, muted marsh, other marsh that delivers flows to and from the marsh. Channels are natural or artificial uncovered features through which flow the tide, upland runoff, effluent, or emergent ground water. A channel consists of its bed and its banks. Tidal channels carry bi-directional flow (flood tides and ebb tides) and typically have bed forms and bar forms. The bed/thalweg of a tidal channel is above MLLW and may be exposed during low tide conditions.

Tidal Marsh

An area of tidal bayland that supports at least 10% cover of wetland vegetation and has a nexus with the tides. Tidal marsh can exist between Mean Low Water tidal datum (MLW) and the Mean High Water tidal datum (MHW).

Other Marsh

Other marsh includes non-tidal, muted tidal, or managed tidal marsh.

Other Open Water

Other Open Water includes managed ponds, playas, wastewater ponds, and salt ponds.

Levee

Levees are natural or artificial embankments that mostly consist of natural sediments (although they might be unnatural and imported), and that extend above the attendant usual high water line, meaning the bankfull stage of rivers and creeks, the Mean Higher High Water (MHHW) tidal datum of tidal channels and tidal baylands.

Beach

Beaches are tidal baylands above Mean Lower Low Water (MLLW) that mostly consist of sand, gravel, or shell fragments that are deposited by wind waves and vessel wakes, and that support less than 5% cover of vascular plant growth.

Level 5: Functional Habitat

SAV/FAV Beds

Submerged aquatic vegetation (SAV) and floating aquatic vegetation (FAV) are highly valuable habitats that provide many ecological functions. Examples of SAV include *Zostera marina* (eelgrass), *Ruppia maritima* (widgeon grass) and *Potamogeton pectinatus* (sago pondweed) (San Francisco Bay Subtidal Habitat Goals Project, 2010). This habitat type provides nursery habitat, foraging grounds, and fish refuge, and can promote fish diversity, shape trophic relationships, enhance infaunal biomass and abundance, and remove nutrients and suspended sediments from the water column (SCWRP 2018).

Shallow Subtidal Embayment Without SAV

These wetlands are permanently covered by water but do not support submerged aquatic vegetation. They provide important benthic habitat that supports a variety of invertebrates within the substrate. The water column portion provides habitat for fish and other aquatic organisms, transports material and organisms between other habitats, and can vary in salinity, temperature and turbidity depending on location within the Bay.

Deep Subtidal Embayment

An area of wetland that is permanently covered by water and supports water column and benthic habitats. Deep subtidal areas extend between the deepest areas of the subtidal to the contour that is 12 ft below local Mean Lower Low Water (MLLW). The wetland exists within a recess or indentation in the shoreline and typically has calmer water as compared to the open Bay. The benthic substrate is typically silts, muds, and clays, but can also have areas of rocky or artificial substrate. These habitats can be affected by temperature, salinity and turbidity of the water column, and typically have lower sunlight penetration than shallow subtidal environments due to the greater water column depth.

Subtidal Slough

A channel (with bed and banks) that delivers flow to and from other tidal habitats, that is permanently covered by water. The bed of the slough is below Mean Lower Low Water (MLLW), and is never exposed. Sloughs convey water, nutrients, sediment and organic material between tidal habitats. Sloughs can support SAV and/or FAV, and provide important water column and benthic habitat for a variety of fish, invertebrates and other wildlife.

Tidal Flat

Intertidal flats mostly exist between the local Mean Tide Level tidal datum (MTL) and the local Mean Lower Low Water tidal datum (MLLW), and support less than 10% cover of vascular vegetation, including eelgrass. The tides alternately expose and flood the substrate. Can include mudflat, sandflat and shellflats, and typically occurs along the shallow edges of the Bay. This habitat can support an extensive community of diatoms, worms, snails and shellfish, as well as algal flora including green algae, red algae, and sea lettuce, providing food web support to fish and wildlife (Goals Project, 1999). When the tidal flat is submerged, it provides foraging habitat for fishes; when the flat is exposed it provides foraging for shorebirds. Tidal flats also provide biogeochemical processing of sediment and water (Goals Project, 1999).

Tidal Pond/Panne

Pannes and ponds typically exist in well-developed tidal marshes, and are infrequently flooded by tides. Pannes are typically shallowly flooded during the winter and spring, and intermittently flooded during the summer and fall (SCC and USFWS, 2003). Shallow, still water pannes can encourage mosquito breeding. Ponds and pannes can be vegetated or unvegetated. Those that support SAV, such as *Ruppia maritima* or filamentous algae, provide habitat for dabbling ducks, diving ducks, and geese (SCC and USFWS, 2003). Unvegetated ponds and pannes support habitat for invertebrates, which provide feeding opportunities for shorebirds.

Tidal Channel

A channel that flows through areas of tidal marsh, muted marsh, other marsh that delivers flows to and from the marsh. Channels are natural or artificial uncovered features through which flow the tide, upland runoff, effluent, or emergent ground water. A channel consists of its bed and its banks. Tidal channels carry bi-directional flow (flood tides and ebb tides) and typically have bed forms and bar forms. Tidal channels transport water, sediment, nutrients, organisms, and plant parts throughout the marsh, connecting the open water to the marsh plain. Water depths increase and decrease with the tidal stage, and channel beds in well-drained marshes are usually exposed or partially exposed during low tide. Tidal channels can support aquatic vegetation, shellfish beds, fish populations, a variety of benthic invertebrates, muskrats and mink and they even provide a pathway for harbor seals to access “haul out” locations.

Tidal Marsh

An area of tidal bayland that supports at least 10% cover of wetland vegetation and has a nexus with the tides. Vegetation communities are typically dominated by species that are emergent, halophytic, and herbaceous. The vegetation community within tidal marshes varies with salinity, substrate, wave energy, marsh age, sedimentation, and erosion (Goals Project, 1999). This habitat is divided into low tidal marsh, middle tidal marsh, and high tidal marsh depending on elevation. Marshes provide habitat for an extensive suite of fish and wildlife, and can also provide carbon sequestration and protection from shoreline erosion and flooding.

Other Marsh

Other marsh includes non-tidal, muted tidal, or managed tidal marsh. Marsh functions and habitat provided largely depend upon management of the marsh. For instance, some muted tidal marshes (such as abandoned salt ponds, farmed bayland or grazed bayland) can provide good quality habitat without actively being managed as wildlife habitat. Managed marsh areas are actively managed to provide wildlife habitat, but can be managed for specific species or suites of species (e.g. ducks) or for other purposes (e.g., floodwater storage basins), causing a wide variety of resultant habitats and functions. Additionally, the hydroperiod, including the frequency, duration, and spatial extent of inundation, will vary with the type of marsh.

Levee

Levees are natural or artificial embankments that mostly consist of natural sediments (although they might be unnatural and imported), and that extend above the attendant usual high water line, meaning the bankfull stage of rivers and creeks, the

Mean Higher High Water (MHHW) tidal datum of tidal channels and tidal baylands. While levees are not wetlands, they can provide important functions for adjacent wetlands or the wildlife that they support. Levees can control the amount of tidal influence that the habitat feature receives, and also the depth of water within the feature. They can also protect habitat features from waves, boat wake, or poor water quality from an adjacent channel, slough or open water area. Levees can provide refugia for birds, small mammals and reptiles during high tides or flooding events. But levees can also provide an entryway for predators or humans to access sensitive habitats.

Beach

Beaches are tidal baylands above Mean Lower Low Water (MLLW) that mostly consist of unconsolidated sand, gravel, or shell fragments that are deposited by wind waves and vessel wakes, and that support less than 5% cover of vascular plant growth. Beaches provide high tide or flood refugia for wildlife, provide unvegetated high tide shorebird roosts, and create well-drained high marsh habitat for tidal marsh plants (USFWS 2013).

Dune

An active accumulation of sand immediately landward of the shoreline or slightly inland due to wind-transport of sand. Sand deposition, accretion and erosion can cause various dune morphologies. Dunes can be vegetated or unvegetated, with vegetation typically increasing the stability of the dune. Dune vegetation is adapted to the low moisture and nutrient content of the sand, as well as the windy conditions. Dunes provide habitat for a variety of adapted plant species such as lupine and monkeyflower species, as well as wildlife such as lizards, voles, sand wasps, and bumblebees.

Appendix 2: Strengths and Weakness of Remote Sensing Imagery Types

Table 2. *Strengths and weaknesses of different remote sensing imagery data that support monitoring of large areas (From Montezuma Report, Kauhanen and Lowe 2021).*

Provider***	Spatial Resolution	Spectral Resolution	Cost sq. mile	Can be Confounded by Cloud Cover	License Restriction	Can be coordinated with the tidal phase or stage
New Airborne	15cm	Red (R),Green (G), Blue (B), Near Infra-Red (NIR)	$250-275*	No	No	Yes

New Airborne	30cm	R,G,B,NIR	$175-215*	No	No	Yes
Upgraded NAIP 2020	30cm	R,G,B,NIR	$10.59**	No	Yes	No. Hit-or-miss depending on the date and time-of-day of image collection.
Upgraded NAIP 2020	15cm	R,G,B,NIR	$21.18**	No	Yes	No. Hit-or-miss depending on the date and time-of-day of image collection.
Satellite	30cm	R,G,B,NIR + 4-8 more frequencies	$89.36**	Yes up to 15% cloud cover	Yes	No. depending on the date and time-of-day of image collection.

* Assumes an area of 100 square miles or more for new airborne data collection.
** Assumes single use license.
*** UAS collected imagery is not considered useful for large area vegetation mapping because current UAS capacity is too small, and FAA regulations are too restrictive to cost effectively use UAS data to map large areas.

Appendix 3: Definitions of Baylands Habitat Types and Their Structural Elements

The original classification system was developed by the Hydrogeographic Advisory Team (HAT)[9] with abundant input from the other Advisory Teams on behalf of the RMG. Chapters 3 and 4 of the original Goals Project Report explain the classification system and define its component habitat types. The system was spatially hierarchical; lower, more spatially limited habitat types were nested within higher, less spatially limited habitat types. The system met its main objectives to represent the effective habitats of hundreds of species of baylands plants and animals of conservation concern, as well as the broad categories of land use and management influencing Baylands conservation into the future. These definitions were used to assist with developing the definitions for the WRMP Habitat Classifications in **Appendix 1**.

Hierarchical List of Habitat Types and Their Structural Elements

Level 1: Geographic Context

There are three standard geographic contexts for all other levels of this classification system: Region, Subregion, and Operational Landscape Unit (OLU), as defined in the glossary.

Level Two: Landscape Complex

Estuarine

Estuarine landscapes are within or strongly influenced by a partially enclosed, coastal water body where freshwater from rivers and streams mixes with salt water from the ocean. In the San Francisco Estuary, the influence of salt water from the ocean generally ends farther downstream than the tidal influence from the ocean. Estuarine habitats in the region include those areas that have been cut off from tidal influence by levees, berms, dikes, unnatural fill, constructions, and any other unnatural features that block the landward excursions of the tide.

[9] Hydrogeomorphic Advisory Team included Andree Breaux (S.F. Bay Regional Water Quality Control Board), Roger Byrne (University of California, Berkeley), John Callaway (San Diego State University), Josh Collins (San Francisco Estuary Institute), Jeff Haltiner (Philip Williams and Associates, Ltd.), Ray Krone (University of California, Davis), Doug Lipton (Levine-Fricke-Rincon, Inc.), Fred Nichols (U.S. Geological Survey), Nigel Quinn (U.S. Bureau of Reclamation), David Schoelhammer (U.S. Geological Survey), Stuart Siegel (Wetlands and Water Resources), and Richard Smith (U.S. Geological Survey).

Riverine

Riverine landscapes are within or strongly influenced by the flow of water conveyed by natural or artificial channels

Terrestrial

Terrestrial landscapes are within or strongly influenced by plant communities.

Level Three: Hydrogeomorphic Setting

Subtidal

This is the area of the region that exists below the local Mean Lower Low Water (MLLW) tidal elevation contour.

Bayland

The baylands are all the lands within the range of intertidal elevation in the region, meaning that they exist between local Mean Lower Low Water (MLLW) and the highest observed local tides of a particular Tidal Epoch, or that would be intertidal tidal if not for levees, berms, dikes, unnatural fill, constructions, and any other unnatural features that block the landward excursions of the tide. The term, bayland, is a regional version of the more common term, tideland, used throughout the State to mean the lands that are situated between the ordinary high water mark and ordinary low water mark of the tide.

Supratidal

These are the lands within the region that extend inland and uphill from the baylands that are commonly referred to as the uplands. They include all the lands and waters of the watersheds draining above ground or below the ground surface to the Estuary, including the portions of the OLUs above and inland of the baylands.

Level Three: Landscape Type

Deep Subtidal

The deep subtidal areas of the region extend between the deepest areas of the subtidal to the contour that is 12 ft below local Mean Lower Low Water (MLLW).

Shallow Subtidal

The shallow subtidal areas of the region exist between local Mean Lower Low Water (MLLW) and the bottom contour 12 ft below MLLW. This is the area of the open embayments of the Estuary that are most commonly and directly affected by the actions of wind-waves and vessel wakes.

Tidal Bayland

The tidal baylands consist of the habitat types that have a direct physical nexus to the tide, however unnaturally modified the nexus might be.

Diked Bayland

The diked baylands are areas that previously were tidal baylands but no longer have a nexus to the tide due to the construction of levees, dikes, sea walls, or other water control structures. Areas of historical tidal baylands that have been unnaturally filled and thus elevated above the maximum height of the tide for the current NTDE are regarded as uplands rather than diked baylands. However, such areas can be part of the T-zone.

Lagoon

A Lagoon is an impoundment of surface water that at least occasionally has a nexus with the tide. A lagoon can be natural or artificial, meaning that its basin and nexus with the tide may be natural or constructed. A lagoon does not necessarily receive upland runoff, either as channelized flow or sheetflow. Belvedere Lagoon in Marin Country is an example of an artificial lagoon. Abbotts Lagoon in Marin County is an example of a natural lagoon.

Estuarine-Terrestrial Transition Zone (T-zone)

The T-zone is the area of existing and predicted future interactions among tidal and terrestrial or fluvial processes that result in mosaics of habitat types, assemblages of plant and animal species, and sets of ecosystem services that are distinct from those of adjoining estuarine, riverine, or terrestrial ecosystems (Goals Project 2015). The WRMP Classification System is focused on the portions of sub-zones 3 and 4 (SZ3 and SZ4) that extend inland and uphill from the baylands, including the reaches of drainage systems and their riparian areas downstream of their Heads-of-Tide (HOT; Dusterhoff et al. 2014).

Level Four: Habitat Type

Rocky, Sandy, or Muddy Shallow Subtidal

These areas of the shallow subtidal landscape are differentiated based on their dominant substrate materials, which strongly affect their habitat functions (see Level 6 for definitions of the substrates).

Eelgrass Bed

Eelgrass beds consist of colonies of *Zostera marina*, a vascular plant species mainly restricted to saline areas of tidal flats and the upper limits of the shallow subtidal environment having sandy or clay-sily substrates.

Tidal Flat

Intertidal flats mostly exist between the local Mean Tide Level tidal datum (MTL) and the local Mean Lower Low Water tidal datum (MLLW), and support less than 10% cover of vascular vegetation, including eelgrass.

Rocky Shore

A rocky shore is a tidal bayland above the Mean Lower Low Water (MLLW) that mostly consists of bedrock, cobbles, or boulders, and that support less than 5% cover of vascular plant growth.

Beach

Beaches are tidal baylands above Mean Lower Low Water (MLLW) that mostly consist of sand, gravel, or shell fragments that are deposited by wind waves and vessel wakes, and that support less than 5% cover of vascular plant growth.

High Tidal Marsh

High tidal marsh exists between the Mean High Water tidal datum (MHW) and the maximum extent of the tide, for the current NTDE, and supports at least 10% cover of vascular vegetation. Examples of high tidal marsh include the highest areas of the vegetated plain at Petaluma Marsh, Rush Ranch, and Browns Island.

Low Tidal Marsh

Low tidal marsh supports at least 10% cover of wetland vegetation and generally exists between the local Mean High Water tidal datum (MHW) and local Mean Tide Level

(MTL), or local Mean Low Water tidal datum (MLW), depending on the salinity regime. Low tidal marsh extends lower in the intertidal zone under less saline conditions. Eelgrass beds are not part of low tidal marsh.

Muted Tidal Marsh

A muted tidal marsh is an area of tidal bayland supporting more than 10% cover of tidal marsh vegetation, and a monthly or more frequent nexus with a muted tide, meaning that the depth or spatial extent of tidal inundation of the muted tidal marsh is lessened by artificial water control structures, such as constructed levees, seas walls, berms, tide gates, culverts, weirs, etc. The muted tide tends to attain a lesser height than the closest source of unmuted tide. The concept of a muted tide does not pertain to lands that are purposefully irrigated or inundated by the tide on either seasonal or annual schedules, such as some salt evaporation ponds, lagoons, or duck clubs, or that are occasionally or infrequently tidal to any extent, such as some lagoons. The concept also does not pertain to interior or inland reaches of tidal marsh that only experience an occasional nexus with the tide due to their existence at the upper limit of the intertidal zone, or near the maximum landward extent of the tidal wave, but not due to the influence of artificial water control structures. For example, Marta's Marsh in Marin County is a muted tidal marsh, whereas the Grizzly Island Unit of the Suisun Marsh is not a muted tidal marsh.

Farmed Bayland

Farmed baylands are diked baylands that are actively managed for some form of agricultural yield, such as hay or grapes.

Grazed Baylands

Grazed baylands are diked baylands that are actively managed as pasture for livestock, such as cattle, sheep, or horses.

Managed Marsh

Managed marshes are diked baylands or muted tidal marshes that support at least 10% cover of wetland vegetation, and that are actively managed to support native wildlife. Managed Marshes can include duck clubs, public wildlife refuges, and floodwater storage basins.

Diked Marsh

Diked marshes are diked baylands or muted tidal marsh that support at least 10% cover of wetland vegetation, and that have appreciable value as habitat for native wildlife, but are not actively managed as wildlife habitat. Some abandoned salt ponds and farmed or grazed diked baylands function as diked marsh.

Low Salinity Salt Pond

A low salinity salt pond is a diked bayland lacking at least 10% cover of vegetation, may be actively managed for salt production, and that usually has a maximum aqueous salinity less than 60 parts per thousand. These salt ponds are usually flooded, but they can be drained for periods of weeks.

Medium Salinity Salt Pond

A medium salinity salt pond is a diked bayland lacking at least 10% cover of vegetation, may be actively managed for salt production, and that usually has an aqueous salinity range between 60 and 120 parts per thousand.

High Salinity Salt Pond

A high salinity salt pond is a diked bayland lacking at least 10% cover of vascular vegetation, may be actively managed for salt production, and that usually has an aqueous salinity range between 120 parts per thousand and the typical salinity of crystallizer ponds.

Crystallizer Pond

A crystallizer pond is a diked bayland lacking at least 10% cover of vegetation and that is actively managed, or has been managed, to concentrate salts by natural evaporation for mechanical harvest. Crystallizer ponds achieve salinities that exceed the tolerances of vascular plants and vertebrate animals.

Inactive Salt Pond

An inactive salt pond is a diked bayland that lacks at least 10% cover of vegetation and was previously managed as a high, medium, or low salinity salt pond, but is no longer managed for salt production. Inactive salt ponds typically have seasonal ponds that provide wildlife habitat, such as foraging habitat for some species of shorebirds and waterfowl. Inactive salt ponds are distinguished from diked marsh or managed marsh by lacking at least 10% cover of vegetation.

Treatment or Storage Pond

Treatment or storage ponds are diked baylands that support less than 10% cover of vascular vegetation, and that have been constructed to seasonally or perennially treat or store industrial discharges, sewage effluent, or upland runoff.

CARCS Wetland Type

The supratidal landscape elevation class of the region includes most of the wetland types of the California Aquatic Resource Classification System (CARCS) of the California Aquatic Resource Inventory (CARI). The WRAMP Classification system will adopt the CARCS wetland types as habitat types for supratidal landscapes.

Riparian Zone

Riparian zones are areas through which surface and subsurface hydrology interconnect aquatic areas, including wetlands, and connect them with their adjacent uplands. They are distinguished by gradients in biophysical conditions, ecological processes, and biota. They can include wetlands and portions of uplands that significantly influence the conditions or processes of aquatic and wetland areas. The width of a riparian zone varies with its function. For any given function, riparian width is constrained by topographic slope, perpendicular to the aquatic area or wetland, and vegetation structure.

Immutable Land Use

These are areas of sub-zones 3 and 4 of the T-zone that are covered by a land use that the WRMP SC and TAC have decided is unlikely to be available as migration space for the CTME in the foreseeable future. These land uses can serve as habitat for native wildlife based on their design and management. This definition is based on the idea that not all uplands can serve as migration space and that some land uses within the T-zone will have to be defended against SLR. One way to approach this complexity is to run scenarios to answer MQ 3 that include/exclude different land use types.

Level 5: Habitat Feature

Channel

Channels are natural or artificial uncovered features through which flow the tide, upland runoff, effluent, or emergent ground water. A channel consists of its bed and its banks.

Levee

Levees are natural or artificial embankments that mostly consist of natural sediments (although they might be unnatural and imported), and that extend above the attendant usual high water line, meaning the bankfull stage of rivers and creeks, the Mean Higher High Water (MHHW) tidal datum of tidal channels and tidal baylands.

Overwash Berm

An overwash berm is a feature along the bayward margins of a tidal marsh or the landward margin of a beach that is created by the accumulation of suspended or floating material deposited by wind-waves and vessel wakes.

Panne

Pannes are features of high tidal marshes that tend to store water between inundations by the tide. They may be perennial or seasonal. Most pannes have a persistent average depth over time less than 12 inches. They usually support less than 10% cover of vascular vegetation, although some brackish pannes support dense colonies of submergent vegetation, especially *Ruppia maritima*. Pannes often form on tidal marsh plains equidistant from tidal channels, and along the upland margins of tidal marshes.

Perennial Pond

A perennial pond is a natural or artificial uncovered impoundment of standing water in diked baylands or adjacent uplands that lasts to some aerial extent throughout the year during most years. The non-vegetated, perennial, open water area of a salt pond, diked marsh, or depressional upland wetland qualifies as a perennial pond.

Seasonal Pond

A seasonal pond is a natural or artificial uncovered impoundment of standing water in diked baylands or adjacent uplands that does not last throughout the year during most years. Its occurrence usually corresponds to some portion of the wet season. The non-vegetated,non- perennial, open water area of a salt pond, diked marsh, or depressional upland wetland qualifies as a seasonal pond.

Vegetated Area

This is the area of any habitat type that supports at least 10% cover of vascular vegetation. Vegetated areas comprise most of the area of tidal marshes, managed marshes, eelgrass beds, and farmed and grazed diked baylands.

Level 6: Substrate Type

Rock, Sand-Gravel, Mud, Shellhash, Artificial

These are used to classify habitat types based on their dormant substrates. Rock refers to natural bedrock, cobble, or boulders, and to their unnatural analoges, such as cement rip-rap. Sand-gravel refers to substrates dominated by unconsolidated particles having a size range between -4 and 4 on the Krumbein phi (φ) scale, Mud is any combination of silts and clays, consolidated or not, having a size range between 4φ and 10φ. Shellhash is a substrate dominated by fragments of mollusk shells of any size. An artificial substrate is any unnatural material without an obvious natural analogue, including but not limited to cement poured in situ, and wood, metal liners, or plastic liners.

Vegetation Alliance

A vegetation alliance is a category of vegetation classification which describes repeating patterns of plant species across a landscape. Each alliance is defined by plant species composition, and reflects the effects of local climate, soil, water, disturbance, and other environmental factors. Alliances are commonly used in vegetation mapping.

Level 7: Age

Ancient

A habitat type or habitat feature is referred to as ancient if it has existed largely in its current form and structure and with its current suite of ecosystem services since before European or Asian contact in the region.

Centennial

A habitat type or habitat feature is referred to as centennial if it evolved naturally or artificially created, restored, or enhanced since European or Asian contact in the region.

New

A habitat type or habitat feature is referred to as new if it has yet to develop most of the physical and biological conditions of its mature analogues. Most restored habitat types and features less than 20 years old can be regarded as new.

Level 8: Naturalness

Natural or Naturalized

A habitat type or habitat feature is referred to natural or naturalized if it was established and is maintained mainly by natural process, or if it was artificially created, restored, or enhanced but largely has the form and structure and ecosystem services of its natural analogue.

Artificial

A habitat type or habitat feature is referred to as artificial if it was established and is maintained mainly by artificial process, although it may have the form and structure and ecosystem services of its natural analogue.

Appendix 4: Pending Decisions Addressed by the WRMP Geospatial Workgroup

During the preparation of these SOPs, the following Pending Decisions were reviewed and discussed by the WRMP Geospatial Workgroup. Responses were integrated into the text.

Pending Decisions: Minimum Requirements for Indicators 1 and 3

1.1.1. Does the Geospatial Workgroup agree with the minimum standard requirements for Indicators 1 and 3?

1.1.2. Does the Geospatial Workgroup agree with the proposed minimum mapping accuracy standards?

1.1.3. Are there additional assumptions that should be enumerated?

Pending Decisions: Habitat Type Classification System

2.2.1. A hierarchical classification system where more detailed habitat type classes can roll up to a more general, more easily/less costly classification system. Do you agree with this approach?

2.2.2. Are there habitat type classes that we can combine and still meet the needs of Indicator 1?

Pending Decisions: Crosswalks

2.3.1 We recommend developing crosswalks for existing habitat type classification systems, including CARI (CARCS), SFBJV, SFBRA, BEGHU, and C-CAP.

Are there any other relevant existing classification systems we should include in the crosswalks?

Pending Decisions: Triggers to Direct Special Study Mapping

3.2.1. We've recommended criteria for defining a regional, subregional, or local episodic event, and criteria for deciding if an episodic event should trigger a special study mapping effort and the timing and geographic scope of the mapping.

Are there additional criteria that should be considered?

Pending Decisions: Consistent Less Costly Mapping Approach

3.3.1. Are less costly data sources sufficient (spectral resolution, spatial resolution, consistency in timing etc.) to meet minimum requirements of WRMP Indicators?

3.3.2. Are there other data sources that we should consider for these proposed uses?

Pending Decisions: Baylands Habitat Type Mapping Approaches

3.4.1. Would automated object based mapping approach help to streamline, standardize, simplify, and reduce costs of traditional Aquatic Resource Inventory mapping methods?

> 3.4.1.1. Are automated mapping approaches sufficient to meet minimum mapping specificity/resolutions?
>
> 3.4.1.2. What level of manual correction is needed after automated methods are run to meet the minimum requirements to address Indicator 1?
>
> 3.4.1.3. Would a partially automated mapping approach require more standardized input data than NAIP and Planet? (method testing needed?) Or would efficiencies still be realized without being able to apply past year models to subsequent years of data?

Pending Decisions: Testing Viability of Automated Mapping Methods

3.4.2. Do you have any concerns regarding the viability testing of automated mapping methods?

3.4.2.1. Could the heads up digitized map (without further refinement) be used as the "true" map to compare other automated and manually corrected automated mapping products?

Pending Decisions: Uses of Map

3.6.1 The map will be used to calculate the number of acres, patch size-frequency, mean inter-patch distance, and locations for each habitat type (See **Appendix 1** and **Appendix 3**).

Are there other questions that the map will need to answer?

3.6.2. We recommend not differentiating in the map by salinity for tidal baylands, since this requires using additional datasets and the boundaries are not definitive. However, differentiating by salinity is important for diked baylands, especially salt ponds.

Do you have any concerns with this recommendation?

Pending Decisions: Geographical segments

3.6.3. We recommend summarizing the acres of restoration projects at the WRMP subregion level, while using Operational Landscape Units (OLUs) when geographically segmenting other metric results.

Do you have any concerns about these recommendations?

Pending Decisions: Hierarchical List of Habitat Types and Their Features

8.1.1. The Shallow Subtidal is defined as the area between MLLW and the bottom contour 12 ft below MLLW. Is 12 ft below MLLW the correct cut-off, or does this need to be updated?

8.1.2. Eelgrass beds (Level Three) consist of colonies of Zostera marina, a vascular plant species mainly restricted to saline areas of tidal flats and shallow subtidal areas with sand or clay-silt substrates. Is this definition consistent with what NOAA maps?

8.1.3. Level Four of this classification system identifies common types of tidal baylands based on hydro-geomorphic and ecological criteria. See **Appendix 1** for a list of habitat types and definitions. Which of these habitat types should we include? Are there other habitat types we should include?