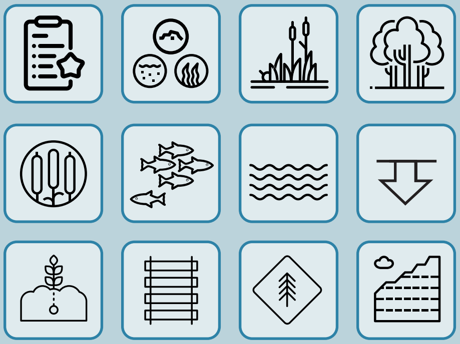
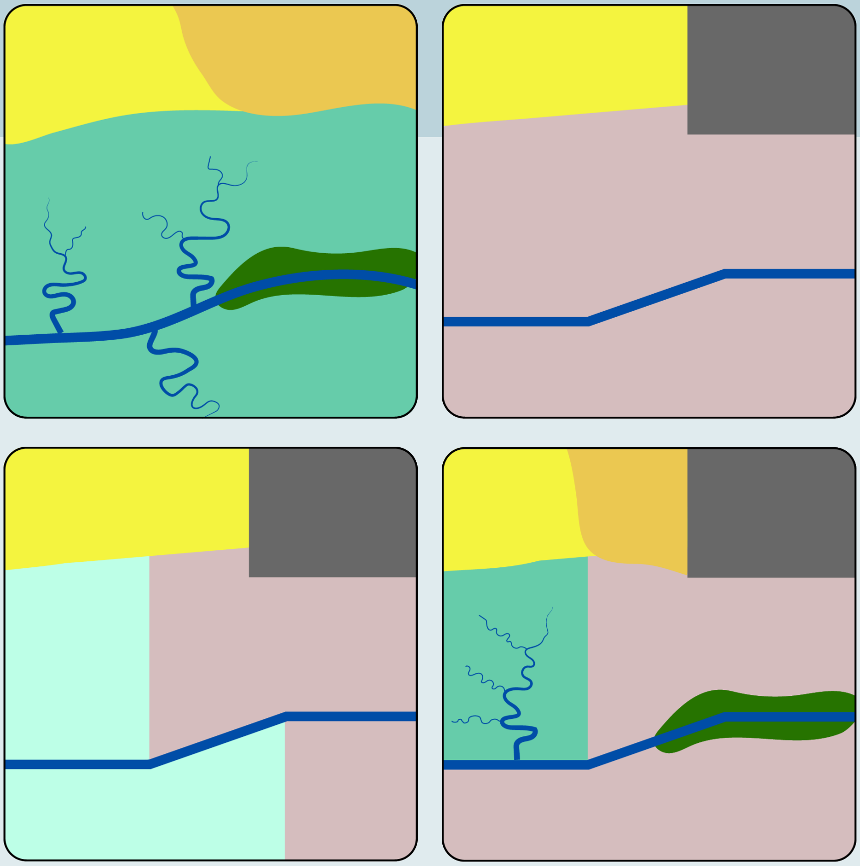
San Francisco Estuary Institute

April 2020

DELTA LANDSCAPES SCENARIO PLANNING TOOL
User Guide





SFEI San Francisco Estuary Institute

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VERSION

v. 1.0.0 (April 2020)

REPORT AVAILABILITY

The Delta Landscapes Scenario Planning tool and this user guide are available online at www.sfei.org.

IMAGE PERMISSION

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ACKNOWLEDGEMETNS

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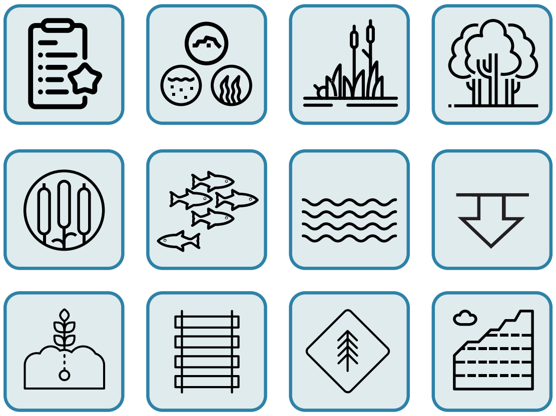

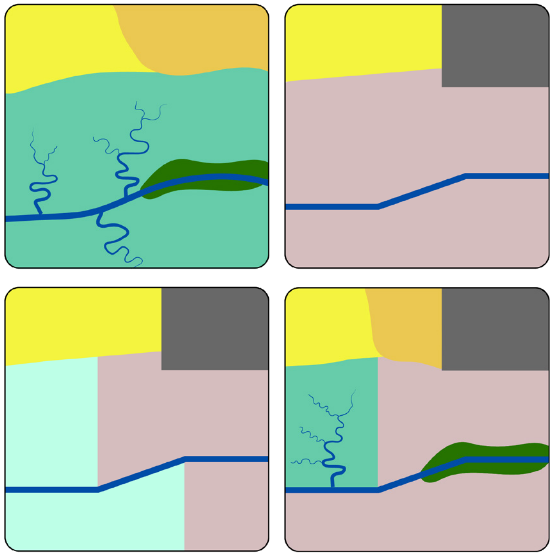

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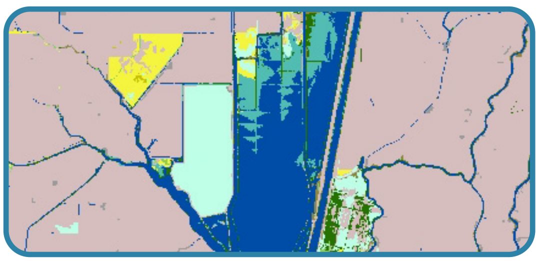
SUMMARY DELTA LANDSCAPES SCENARIO PLANNING TOOL

A standardized, science-based tool for analyzing and comparing Delta land-use scenarios.

How the tool works

- The tool takes data from **detailed landscape maps** to measure change in metrics of interest for Delta planners:
  - ecosystem function *(like support for native fish)*
  - landscape processes *(like flooding & subsidence)*
  - infrastructure
  - agriculture



Users can:

- Use packaged data sets & maps to build scenarios of future landscape change
- Compare how each scenario impacts key ecosystem functions, crop lands, and infrastructure
- Integrate results from multiple models
- Take advantage of science-based metrics in the planning process

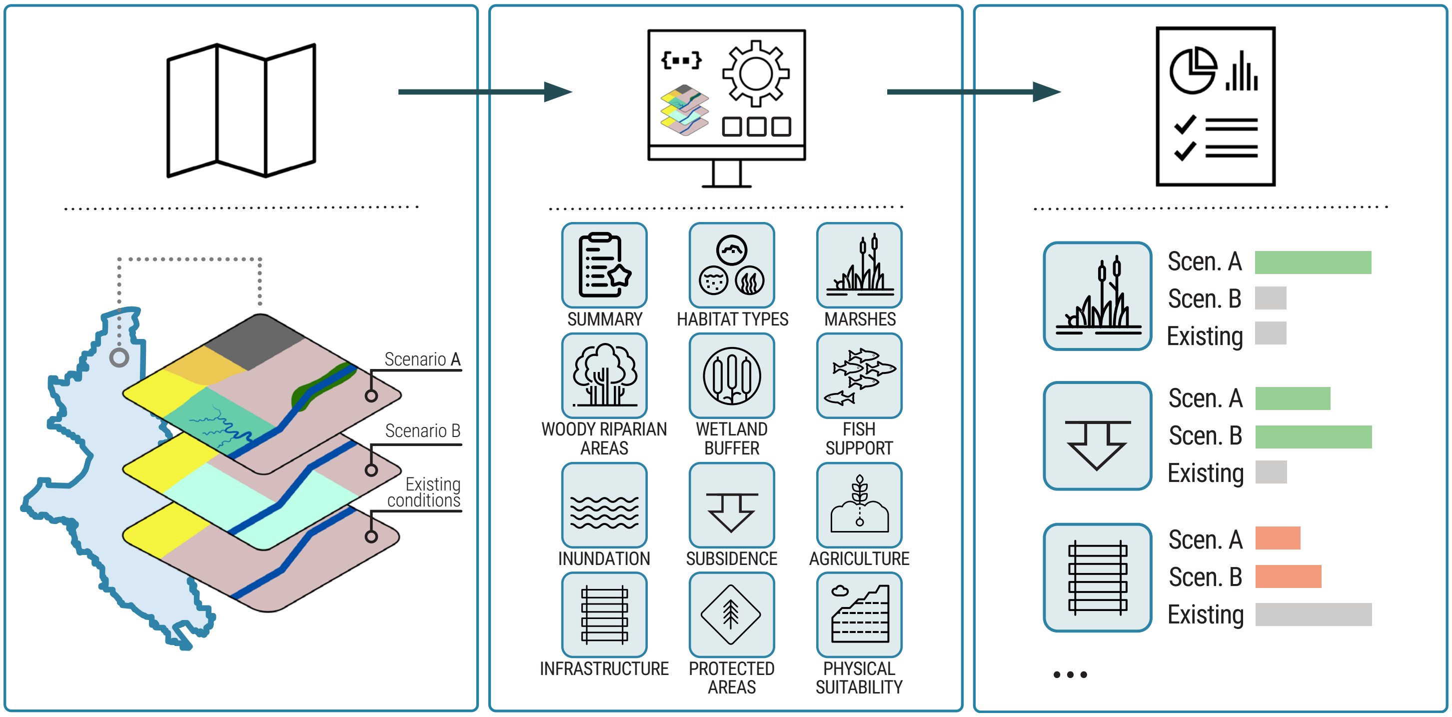
Helping decision makers to:

- Identify preferred alternatives for funding or implementation
- Quantify tradeoffs between scenarios
- Track cumulative progress toward performance measures
- Plan for long-term change, like sea-level rise and subsidence reversal

Existing conditions & alternative land-use scenarios input into tool

Tool evaluates scenarios with 12 analysis modules

Tool outputs report & files with quantitative differences



DLSPT VERSION 1.0.0 - APRIL 2020

Tool development: SFEI AQUATIC SCIENCE CENTER

Tool funding & support: Delta Stewardship Council

Contents

Tool Overview

Version

This user guide was written for version 1.0.0 of the tool. For the latest version of the tool and user guide, visit the project website (www.sfei.org/projects/delta-landscapes-scenario-planning-tool).

What is the Delta Landscape Scenario Planning Tool?

The Delta Landscapes Scenario Planning Tool (DLSPT) is a standardized, science-based resource for analyzing and comparing land-use scenarios in the Sacramento-San Joaquin Delta. The tool takes data from detailed landscape maps and calculates metrics related to ecosystem function (like support for native fish), landscape processes (like flooding and subsidence), infrastructure, and agriculture, along with other key topics relevant to restoration and land-use planning in the Delta.

The tool is modular by design, and currently supports 12 individual modules, each with a suite of analyses and metrics. The modular design means that, in the future, the tool can support new and additional analyses (including, for example, metrics related to carbon sequestration, water supply, flood control, recreation, and the economic implications of different scenarios). The tool is also spatially flexible, allowing users to analyze the landscape at multiple scales. For example, it can quantify how a single proposed project would alter metrics in its immediate surroundings, or how a larger regional strategy comprising many individual projects would cumulatively impact the whole Delta.

To assist with the process of scenario development (the creation and digitization of alternative restoration and land use scenarios), the tool comes packaged with several useful resources. These include standardized spatial datasets that can inform the development of science-based restoration scenarios, such as maps of elevation and historical and contemporary habitat types. Another set of resources are spatially explicit maps of restoration opportunities and landscape potential, based on SFEI's "A Delta Renewed" (SFEI-ASC 2016), which serve as a pre-developed menu of physically-appropriate potential projects for users developing their own alternative land-use scenarios. These resources have also been made available via a project web-map for use outside of the tool.

Who is the tool for and how can it be used?

The tool can help land-use planners, agency staff, and other stakeholders and decision-makers in a number of ways.

1) By quickly evaluating key metrics in a repeatable and standardized way, the tool can help people designing potential projects to anticipate how those projects will affect a suite of metrics, including performance measures tracked under the Delta Plan.
2) For those evaluating proposed projects, the tool can assist with identifying preferred alternatives for funding or implementation.
3) For regional planning, the DLSPT makes it easier to quantify the cumulative impacts of multiple potential projects and understand tradeoffs.
4) As projects are implemented and the landscape develops, the tool can be used to track on the ground progress by comparing past land-use with current land-use. The tool can also be used to plan for long-term change, like sea-level rise and subsidence reversal, by evaluating anticipated landscape changes associated with those processes.
5) The tool can be a vehicle for operationalizing the work of researchers. Specifically, models and analyses meant to inform restoration and land-use planning in the Delta can be integrated into the tool, where they can leverage results from other analyses and directly inform practitioners.

Tool licensing

This project is licensed under the GNU Lesser General Public License -- see the “License” file for details or the GNU website (https://www.gnu.org/licenses/gpl-3.0.en.html) for general information. In summary, you may copy this software, modify this software with changes tracked, and redistribute this software or derivative versions thereof as long as they remain under the GNU Lesser General Public License.

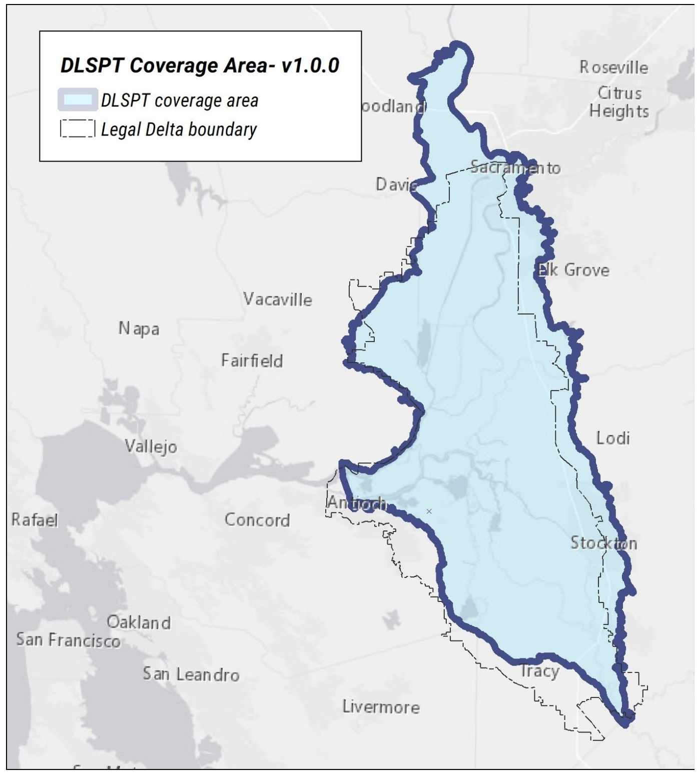
Tool format & installation

The Delta Landscapes Scenario Planning Tool is an ArcPy Toolbox designed for ArcGIS 10.x and Python 2.7.5 with ArcPy (installed with ArcGIS). It does not currently work with ArcGIS Pro / Python 3.x -- a ported version for ArcGIS Pro is in development. Python libraries used are either packaged by default with Python or pre-installed with ArcGIS/ArcPy (e.g. NumPy).

The DLSPT is meant to work out-of-the-box and no specific installation process is required aside from downloading and unzipping the tool contents. The ArcPy Toolbox can be downloaded by navigating to the project website (www.sfei.org/projects/delta-landscapes-scenario-planning-tool), clicking the “Resources” tab, and clicking the “Download tool” button, which will open a form to receive the tool download link via email. The zipped folder containing the tool should be unzipped in the user’s preferred directory, and then navigated to within ArcMap or ArcCatalog. See “Tool Workflow” for additional instructions.

Because of the analyses performed, an advanced license of ArcGIS is required to run the tool. Certain modules (fish support, inundation, and subsidence) also require the Spatial Analyst extension.

Tool coverage and analysis areas

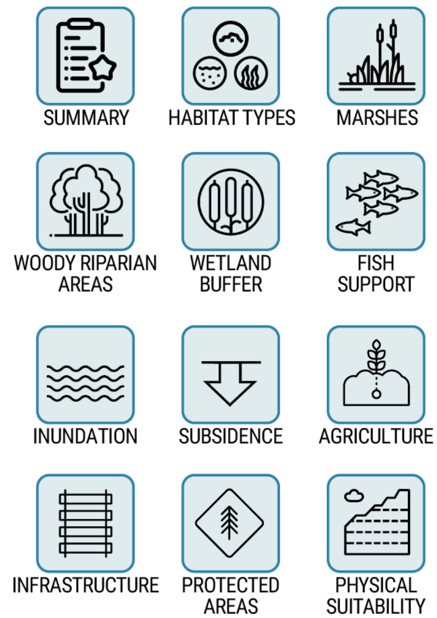


There are two relevant spatial domains when using the DLSPT: the maximum tool "coverage area" and the user-defined "analysis area/s." The maximum tool coverage area represents the geography supported by the tool. It is the area within which users can define scenarios that the tool is able to evaluate. The current coverage area of the tool is the SFEI Delta Landscapes study extent, which was defined by Whipple et al. (2012) as the contiguous lands in the Delta lying below the 25 ft (7.6 m) NAVD88 contour. This area is meant to capture the full extent of the Delta's historical tidal wetlands, adjacent non-tidal freshwater wetlands, and upland transitional areas. The study area was generally defined as "the contiguous lands lying below 25 feet (7.6 m) in elevation." This differs from the extent of the legal Delta and encompasses an area of about 800,000 acres, including parts of Sacramento, Yolo, Solano, Contra Costa, and San Joaquin counties. A map of the tool coverage area superimposed over the legal Delta is shown below:

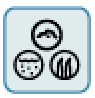
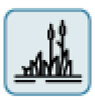
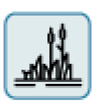
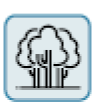
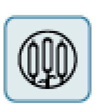
When a user runs the DLSPT, the impacts of their scenario are evaluated over the entire tool coverage area, no matter how small or constrained the modifications in the scenario might be. After these results have been processed, the user can then define a specific "analysis area" to clip and summarize the tool results to. This analysis area can be any geography within the coverage area, ranging from a project footprint to the full coverage area itself. With this framework, the effects of one scenario can easily be examined across multiple analysis areas and scales. The tool comes pre-packaged with a variety of potential analysis areas that users can select (including the portions of individual counties and the Legal Delta that lie within the coverage area), but users can also supply custom analysis areas. See the "Output Statistics" section below for how users set the analysis area.

Tool modules

The DLSPT is modular by design, and currently supports 12 individual modules, each with a suite of analyses and metrics. Users can choose to only run individual tool modules, or to run all in concert. The table below lists the modules and provides basic information on each, along with a summary of the needed data inputs. Modules that quantify a Delta Plan performance measure are also noted. Each module is described in more detail in the "Analysis Module" section below.



DLSPT analysis modules:

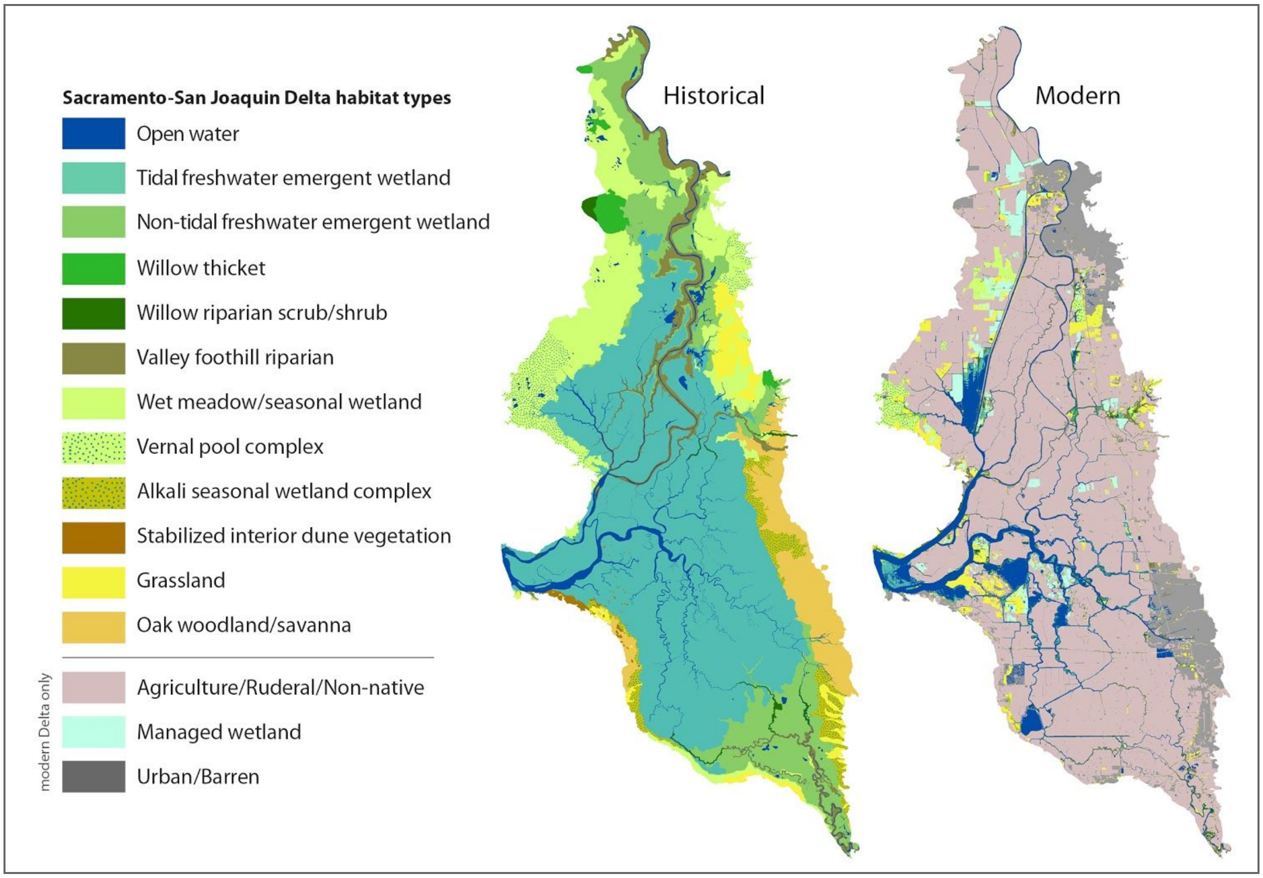
Module	Primary analyses	User-defined data inputs	Key pre-defined data inputs
Summary 	• Compiles results from all other modules and presents them in a single **integrated table**, facilitating comparison of scenarios • Performs other basic assessments (e.g., total extent of the analysis area and the counties it overlaps)	• Scenario land use modifications • Scenario levee centerlines (optional)	• County boundaries
Habitat types 	• Determines **total extent and net change of each habitat type** • Evaluates **progress towards Delta Plan performance measure acreage targets**	• Scenario land use modifications	• Historical Delta habitat types (Whipple et al. 2012) • Modern Delta habitat types (SFEI-ASC 2014)
Marshes 	Analyzes metrics related landscape ecology of marshes, including: • **Marsh extent** • **Marsh patch sizes** • **Marsh nearest large neighbor distance** • **Marsh shape** (core area ratio)	• Scenario land use modifications	• Historical Delta habitat types (Whipple et al. 2012) • Modern Delta habitat types (SFEI-ASC 2014)
Marsh network connectivity 	Analyzes **marsh network connectivity,** including where new/additional marshes would most improve connectivity (results are presented with Marshes in output report, but split into two modules in the tool due to computation time)	• Scenario land use modifications	• Delta 100 ha hex-grid (defines grid where each unit is analyzed for potential contribution to network connectivity)
Woody riparian area 	Analyzes metrics related landscape ecology of woody riparian areas, including: • **Woody riparian extent** • **Woody riparian patch sizes**	• Scenario land use modifications	• Historical Delta habitat types (Whipple et al. 2012) • Modern Delta habitat types (SFEI-ASC 2014)
Wetland buffer 	Analyzes metrics related to the wetland buffer (the area around open water and perennial wetlands), including: • **Wetland buffer extent** • **Wetland buffer composition** (natural vs. highly modified habitat types)	• Scenario land use modifications	• Historical Delta habitat types (Whipple et al. 2012) • Modern Delta habitat types (SFEI-ASC 2014)

Fish support	Analyzes metrics related to support for native fish, including: • **Marsh area** and **marsh to open water ratio** • **Connectivity of large wetlands** along fish migration corridors • The extent and quality of **channel edges** • **Water temperature**	• Scenario land use modifications • Scenario levee centerlines (optional)	• Historical Delta habitat types (Whipple et al. 2012) • Modern Delta habitat types (SFEI-ASC 2014) • Water temperature rasters (3 different rasters quantifying the number of days each cell is above a particular temperature threshold during a specified window of time) (Anchor QEA, LLC 2017)
Inundation	• Analyzes **baseline inundation conditions** using **Delta Plan performance measure** methods (including the extent of hydrologically connected and regularly inundated areas) • Evaluates how **scenario changes** in area of tidal marsh affect extent of inundation	• Scenario land use modifications	• Modern Delta habitat types (SFEI-ASC 2014) • Hydrologically connected areas (DSC 2019) • Regularly inundated areas (Pekel et al. 2016)
Subsidence	• Quantifies **extent of shallowly and deeply subsided lands** in analysis area • Quantifies proportion of subsided lands covered by **wetted habitat types** (which limit subsidence) • Estimates years for wetlands in subsided areas to reach sea level via **subsidence reversal**, considering sea level rise	• Scenario land use modifications	• Geomorphic zones (SFEI 2020) • Years for subsidence reversal wetlands to reach sea level (Deverel and Leighton 2010)
Agriculture	Quantifies basic metrics of scenario's impacts to agriculture, including: • Net change in extent of agricultural lands • Crop type of converted agricultural lands • Area converted from agricultural lands to urban development **(Delta Plan performance measure)**	• Scenario land use modifications	• Land IQ Delta Crop Types (CDWR 2016) • FMMP farmland grade (California Department of Conservation 2018)
Infrastructure	Quantifies the **extent of infrastructure** in the analysis area and **potential impacts** to infrastructure due to proposed changes in land-use. Infrastructure types evaluated include: • Roads • Railroads • Oil and gas wells	• Scenario land use modifications • Scenario levee centerlines (optional)	• Roads (U.S. Census Bureau 2016) • Rails (CalTrans Rail Database) • Oil and gas wells (California Department of

	• Gas pipelines • Transmission lines • Water diversions • Levees		Conservation 2017) • Gas pipelines (California Energy Commission) • Transmission lines (California Energy Commission) • Water diversions (CDFW 2019)
Protected areas 	Identifies the **extent and ownership of protected areas** within the analysis area and determines whether proposed land use modifications fall within the boundaries of these areas	• Scenario land use modifications	• Modern Delta habitat types (SFEI-ASC 2014) • CA Protected Areas Database (GreenInfo Network 2019) • CA Conservation Easements Database (GreenInfo Network 2018)
Physical suitability 	Performs basic screening to identify whether or not proposed habitat types are likely to be **physically suitable** in the location they were drawn, given the location's elevation	• Scenario land use modifications	• Geomorphic zones (SFEI 2020) • Habitat type-geomorphic zone suitability crosswalk (SFEI 2020)

Habitat types

The DLSPT recognizes a standard set of 16 individual habitat types when analyzing land use scenarios (see table below). This classification scheme was originally developed for the SFEI "Sacramento-San Joaquin Delta Historical Ecology Investigation" (Whipple et al. 2012) to map the historical and modern landscape using a consistent set of land use types, and was refined in subsequent reports (SFEI-ASC 2014). Crosswalks relating these classifications to other schema, including the National Vegetation Classification System (NVCS), California Wildlife Habitat Relationships (CWHR), Hydrogeomorphic Wetland Classification System (HGM), and the Cowardin wetland classification, are available (see Whipple et al. 2012). The classification system is also consistent with that used in the Delta Plan (DSC 2019). The tool is packaged with spatial layers mapping the historical and modern landscape with these classifications (see figure below).



Most users creating scenarios for analysis with the DLSPT should exclusively use this established classification scheme when mapping and analyzing alternative land use scenarios. Advanced users can add additional habitat types, but careful consideration needs to be given to how the new habitat type is treated in different modules and analyses. Custom tool modifications are needed to accommodate a new classification, including defining which habit type groups the new classification should be included in using the habitat types crosswalk document (see below). Refer to Adding a custom habitat type in the "Tool customization section" for additional details. Running the tool with an unsupported habitat type without taking these additional steps will result in an error.

Recognized habitat types and habitat type groups are defined in a single habitat types crosswalk table that can be reused each time it is needed. Analyses are written such that selections made with these habitat types are case-insensitive.

Currently recognized habitat type values are:

Habitat type
willow thicket
willow riparian scrub/shrub
valley foothill riparian
managed wetland
non-tidal freshwater emergent wetland
tidal freshwater emergent wetland
wet meadow/seasonal wetland
vernal pool complex
alkali seasonal wetland complex
stabilized interior dune vegetation
oak woodland/savanna
grassland
open water
agriculture/non-native/ruderal
urban/barren
unknown

For recognized habitat types, there are defined groups for use in different modules and analyses:

Habitat type group	Group description	Habitat types
Woody riparian	Utilized in the woody riparian and fish support modules.	willow thicket; willow riparian scrub/shrub; valley foothill riparian
Marsh	Utilized in the marshes, wetland buffer, and fish support modules.	non-tidal freshwater emergent wetland; tidal freshwater emergent wetland
Tidal wetland	Utilized in the fish support, inundation, and subsidence modules. In the fish support and subsidence modules this group is used to infer which open water polygons are hydrologically connected to Delta's main tidal channel network via surface water connections vs. which are hydrologically disconnected (e.g., located behind a levee on a subsided island). This step effectively assumes that open water areas that are contiguous with areas classified as tidal	tidal freshwater emergent wetland

	wetlands must be hydrologically connected to the main Delta channel network.	
Wetted habitat and open water	Utilized in the subsidence module. Includes habitat types that are generally wetted and thus help to halt ongoing land subsidence.	managed wetland; non-tidal freshwater emergent wetland; tidal freshwater emergent wetland; open water
Perennial wetlands and open water	Utilized in the wetland buffer module. Defines which habitat types to draw buffers around.	managed wetland; non-tidal freshwater emergent wetland; tidal freshwater emergent wetland; open water
Natural terrestrial	Utilized in the wetland buffer module. Used to distinguish "natural terrestrial" portions of the wetland buffer (those classified with habitat types that have analogs in the historical Delta) from "heavily modified" portions of the wetland buffer (those classified as either urban/barren or agriculture/non-native/ruderal).	willow thicket; willow riparian scrub/shrub; valley foothill riparian; wet meadow/seasonal wetland; vernal pool complex; alkali seasonal wetland complex; stabilized interior dune vegetation; oak woodland/savanna; grassland
Water	Used to select open water for various analyses. This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	open water
Agriculture	Utilized in agriculture module to define changed areas of agriculture. This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	agriculture
Urban	Utilized in agriculture module to determine areas of agriculture lost to urban. This group currently only includes one habitat type but is provided in case advanced users wish to add additional types.	urban/barren

Workspaces

Projects are defined in "workspaces", which at their most basic level consist of a workspace folder and file geodatabase. Workspaces are used to organize working data and track scenarios. This also simplifies the tool GUI and inputs required, as once the tool is pointed to an appropriate workspace, it can determine what data exist through expected naming structure and can determine what scenarios and analyses have been added via the tracking table inside each workspace.

The workspace is mainly for the tool's internal use, as the tool expects certain file structures and naming conventions. As such, while the user can examine datasets within the workspace, it is generally not recommended to edit files in the workspace.

The workspace structure itself consists of:

1. The workspace directory, given a name as defined by the user.
2. `workspace.gdb` -- the file geodatabase for the workspace itself.
3. `logfile.txt` -- the logfile for any processes run on this workspace/project.

Units

All attribute values for areal metrics are in units of hectares. The one exception is the automatically-generated *Shape_Area* field, which will conform to the units of the spatial reference (square meters due to enforced meters-based projection).

Length metrics are reported in kilometers -- that is, all length-based values in the output Landscape Scenario Summary Report will be converted to kilometers. However, all analyses are done in units of meters, when applicable, to better conform with the enforced spatial reference type. As such, all data fields in the workspace itself are given with length units of meters, where applicable. Output tables however, may vary. See individual analysis module sections in Analysis modules for specifics.

Developing Scenarios

Defining scenarios in the DLSPT

In the DLSPT, “scenarios” are **alternative land-use scenarios**. They are combinations of potential landscape modifications resulting from restoration, management, and other actions. Scenarios can include changes associated with one project/site or many. “Scenarios” in this context are not, as they are sometimes defined, possible alternative trajectories given other uncertain drivers of change (e.g. a high sea-level rise scenario vs. a low sea-level rise scenario). However, the way that individual land-use scenarios respond to different possible future conditions could be evaluated moving forward as part of new tool modules.

How scenarios are defined in the tool

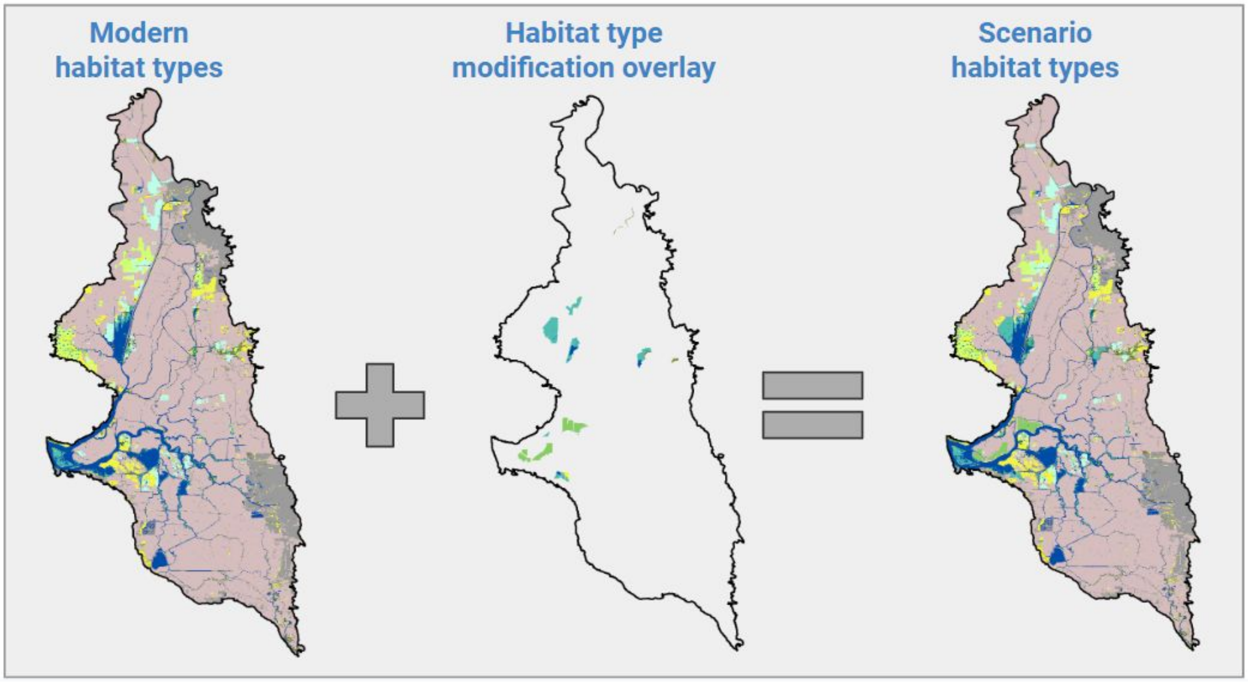
Scenarios are defined in the tool using two geospatial data layer inputs:

1. A habitat type modification overlay layer (required)
2. A modified levee network layer (optional)

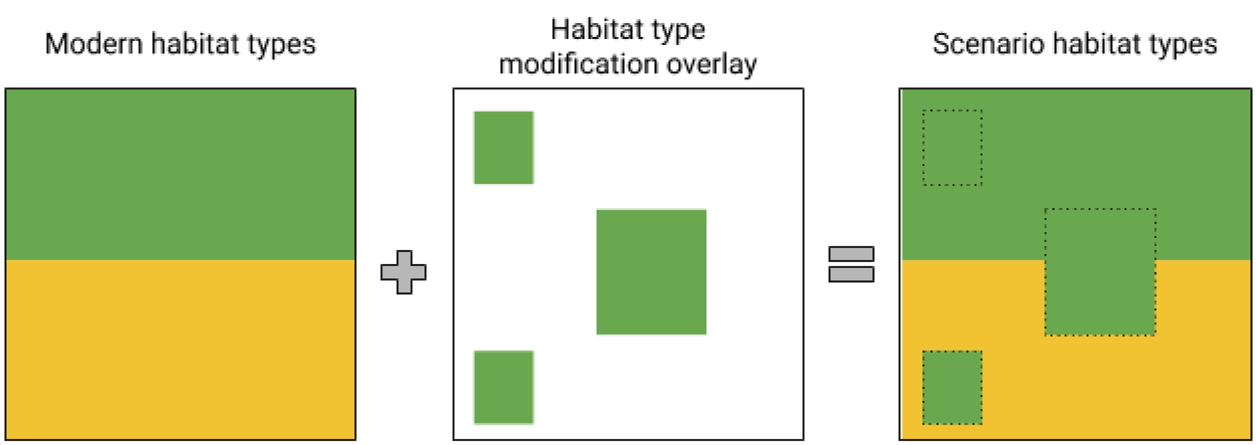
Habitat type modification overlay layer

The habitat type modification overlay layer (“overlay layer”) is the more important of the two layers the DLSPT uses to define a scenario. An overlay layer is simply a feature class or shapefile containing polygons with associated habitat types defined in a single field (see the “Habitat types” section above for a list of habitat types the tool currently accommodates by default). To generate the scenario, the DLSPT will “burn” the overlay layer into the modern habitat type layer, replacing the existing underlying habitat types with the habitat types defined in the overlay layer. Areas not included in the overlay layer will remain unchanged in the resulting scenario habitat type map. This process is illustrated below for an example scenario (the projects planned as part of California’s EcoRestore initiative). Note that the example overlay layer is packaged with the tool for reference and for use as a template (see the “Example_scenario_EcoRestore_overlay” feature class in the data package folder). The modern habitat types layer also comes packaged with the tool (see the “Habitat_types_modern_forDLSPT” feature class).

Using the modern habitat type layer and scenario habitat type modification overlay to generate the scenario habitat type map analyzed by the tool:



While the layer is called the habitat type "*modification*" overlay, note that it is acceptable to include a polygon (or a part of a polygon) in the overlay layer that has the same habitat type classification as the corresponding location in the modern habitat type layer. The tool will still burn the polygon in question into the modern habitat type layer, but this process will not result in a change in habitat type at the corresponding location, as illustrated below (colors in this figure represent different habitat types):

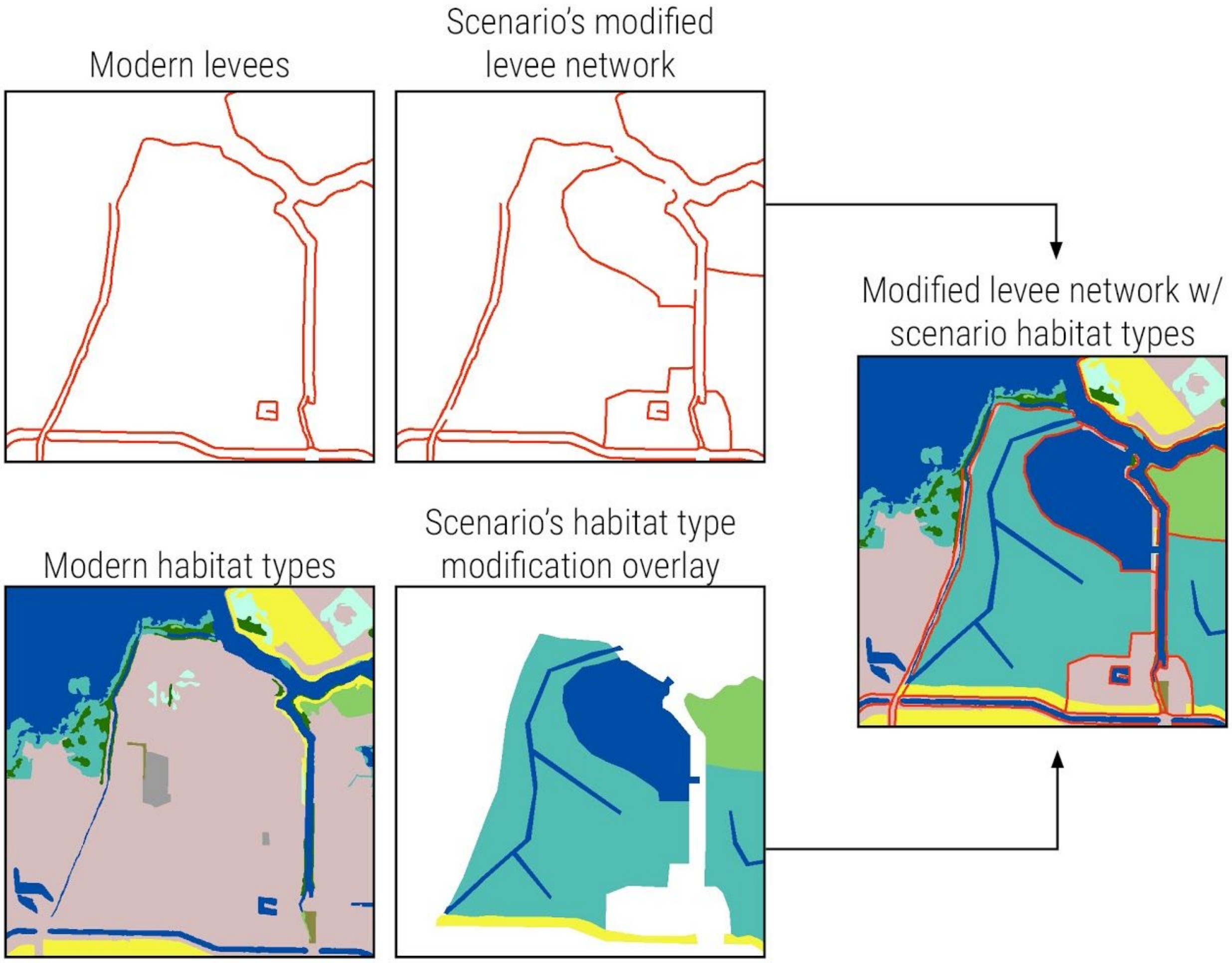


Defining scenarios with the overlay layer (instead of asking users to input the final scenario habitat layer and perform all modifications themselves), minimizes the risk of inadvertently introducing topological errors that can affect the tool's geospatial analyses. Specifically, burning in the features ensures there will not be any inadvertent "gaps" between digitized features or overlaps between modified and unmodified areas. However, it is still important for users to ensure that the scenario overlay *itself* does not contain any overlapping polygons. There is currently no automatic detection or correction of this topology issue and overlapping features will cause some analyses to behave unexpectedly (overlapping polygons will be double-counted in the habitat type extent analyses, for example). Refer to ArcGIS help files on defining, checking, and repairing topologies (available at this link; the key topology rule to enforce on habitat type overlays for use in the DLSPT is that features "must not overlap").

Additional guidance for those digitizing/developing overlay layers for use in the DLSPT can be found below in the "Digitizing scenarios" section.

Modified levee network layer

The modified levee network layer ("levee layer") is a line feature class or shapefile representing the position of levee centerlines in the user's scenario. Note that unlike the habitat type modification overlay, the levee layer should represent the final desired configuration of levees in the scenario (not just levees being added or removed). Changes in the levee network should generally correspond to changes in the habitat type modification overlay. For example, a user that creates a scenario with a new tidal marsh may wish to modify the levee network layer to include the breach required to restore tidal action to the proposed marsh. An example of this, taken from the EcoRestore scenario packaged with the tool, is illustrated below. In the modified levee layer, some levees have been breached while others have been added. These changes align with the scenario habitat type modification overlay.



The levee network assigned to a scenario only impacts a subset of the modules and analyses run in the DLSPT. If the following analyses are not of interest to a particular user, the user does not need to provide a modified levee layer.

- The levee network is used in the **Infrastructure module** to calculate the net change in length of levees within the analysis area. If a modified levee layer is not defined, this analysis is simply not performed, and the rest of the Infrastructure module analyses are unaffected. Users should include a modified levee layer if they are interested in quantifying the total length of new levees, the total length of removed levees, and resulting net change in length of levees that must be maintained in the proposed scenario.
- The levee network is used in the **Fish support module** to define which marsh and woody riparian habitat type polygons are potentially hydrologically connected to the Delta's channel network (and thus potentially provide resources to fish). Specifically, levee centerlines are slightly buffered and then erased from the wetland habitat types before the wetland polygons are dissolved into

contiguous features and then spatially selected to only include those that are directly adjacent to open water polygons (see the “Fish support” section for additional details). Portions of the wetlands that are entirely “behind” the levee centerline are separated from the open water by this sequence of steps and are not counted as accessible/providing resources to fish. This step is important because, in many locations, woody riparian vegetation covers both sides of a levee and then grades down into woody riparian or other impounded wetlands on the landward side of the levee (including in some cases down onto subsided islands). While these features might be contiguous with the Delta’s channel network as mapped in two dimensions, in reality they are hydrologically disconnected (at least via surface water flows) due to the presence of levee, and cannot be accessed by fish. Thus, if a user wishes to more accurately account for the hydrological connection of altered wetlands in the user scenario to evaluate support for fish, they should consider including a modified levee layer. Only wetlands on the “water side” of the levee will be counted when evaluating support for fish. **If no modified levee network layer is specified for a scenario by the user, the tool assumes the scenario entails no change in the levee layer and uses the modern levee layer for the “Fish support” calculations.**

Because the Infrastructure module determines the length of levees removed and added by erasing the modern levee layer from the scenario levee layer (and vice-versa), even slight shifts in the position of a levee will be treated as a wholesale removal of one levee and construction of another. To avoid this, **users developing their scenario’s levee layer should almost always start with a fresh copy of the modern levee layer and make edits to that copy directly**. Any attribute fields associated with the levee layer are ignored by the tool.

While only a few modules currently use the levee layer, this functionality expands the range of potential analyses that can be supported in future versions of the tool.

Tips and resources for digitizing scenarios

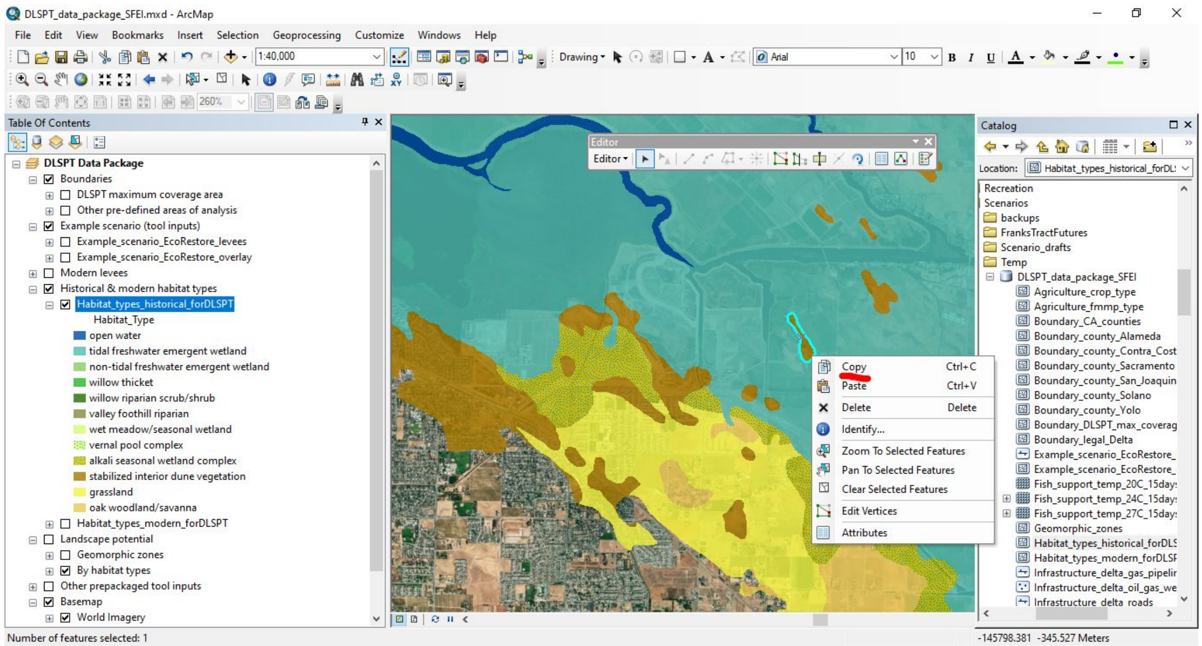
There is no one right way to develop scenarios for use in the DLSPT. In the examples below we highlight a few possible approaches, as well as resources that come packaged with the DLSPT to aid users developing their own scenarios.

Users with existing high-quality spatial data representing restoration designs should find it easy to adapt these files for use in the DLSPT, simply by adding an attribute field to their polygons and classifying the land cover using the DLSPT-supported habitat types. In absence of this, the easiest way to develop a scenario is perhaps to begin with another scenario. The tool is packaged with a habitat type modification overlay layer for the EcoRestore scenario (`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Example_scenario_EcoRestore_overlay`), which can be used as an example and template. By making a copy of this layer and opening it in an editing session, new polygons can be drawn or copied in from another layer in the same geodatabase (basic information on editing features is available on this ArcMap help page) and unwanted features can be deleted. An example of copying features between layers in an editing session is also provided below.

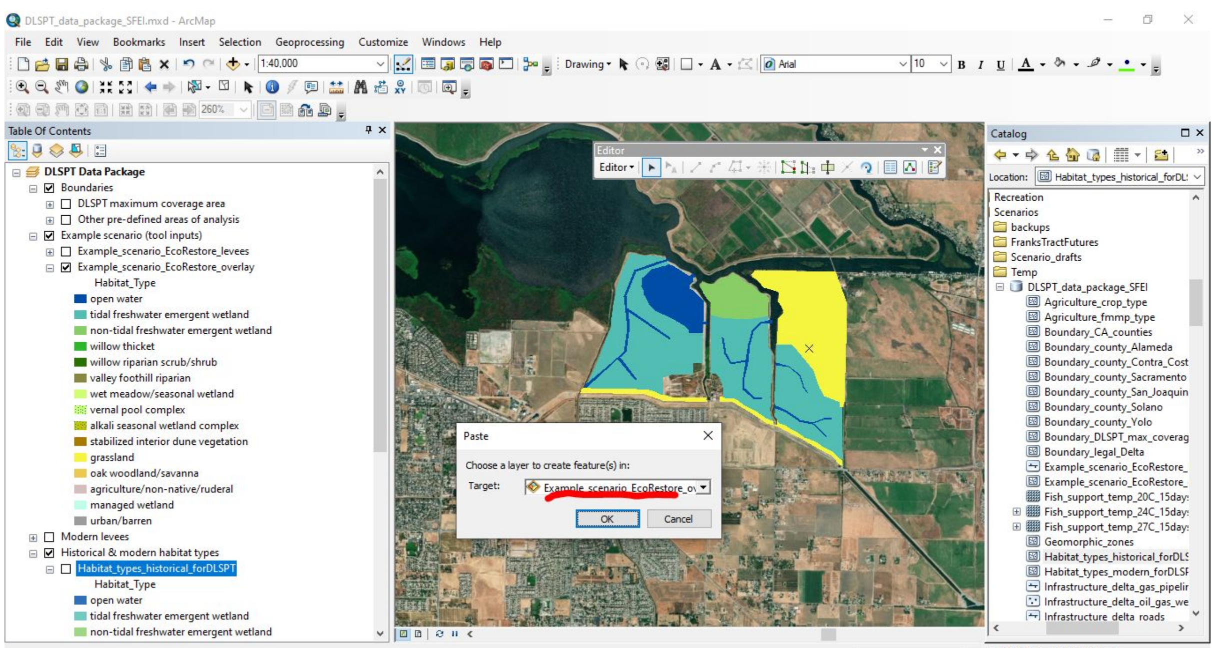
The example scenario layer includes a field titled “Habitat_Type" where the habitat type of each polygon is defined. This field is shared by other layers packaged with the tool and is always populated with the standardized set of habitat types supported by the DLSPT (see the “Habitat types” section above). This consistency makes it easy to copy features from these layers into your scenario while maintaining the habitat data attributes in the same field (note that the other fields are not required by the tool, but may be useful for documenting your work). Layers with populated “Habtiat_Type fields are as follows:

- **Historical habitat type layer** (`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Habitat_types_historical_forDLSPT`): This layer is a version of the historical Delta habitat types layer developed by Whipple et al. (2012) intended for use in the DLSPT. This version of the dataset is largely identical to the original Whipple et al. layer, but some fields have been added, removed, and altered. The primary modification was to incorporate the “Habtiat_Type” field with the simplified DLSPT habitat type classification system (the original classifications are recorded in the "Source_Classification" field). The tool uses this layer to compare scenarios to the historical, pre-development Delta (ca. 1800). **Tool users can use ArcMap editing tools to copy polygons or portions of polygons directly from this layer and into their own scenario if they wish to evaluate the effects of restoring a historical habitat type in its historical location.** This process is illustrated below and can also be replicated with other layers.

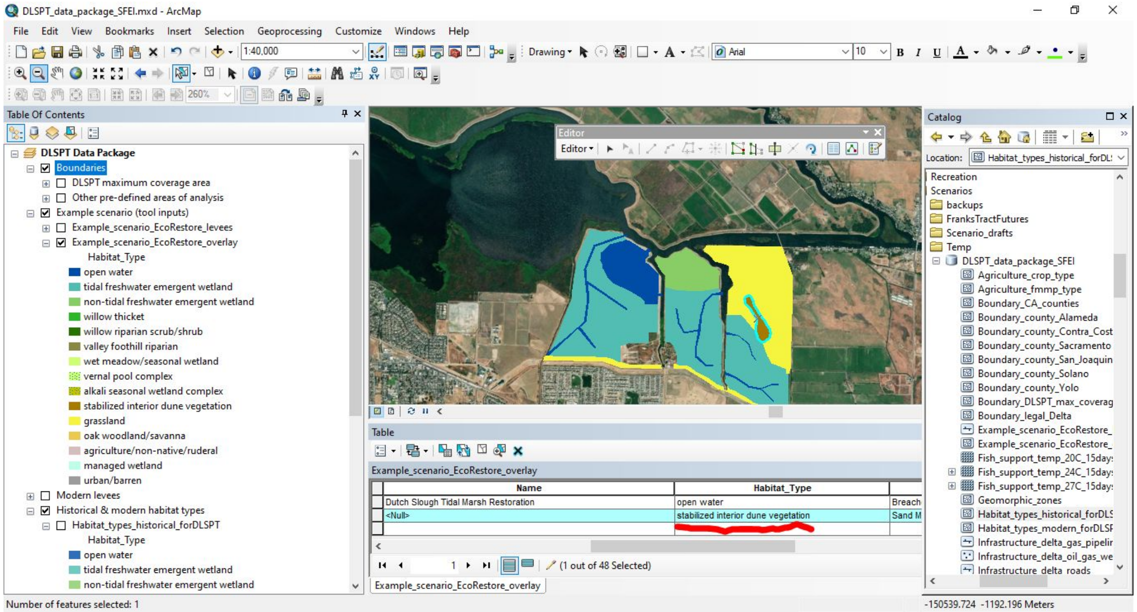
Step #1) In an edit session, copying the selected historical “Stabilized interior dune vegetation” polygon:



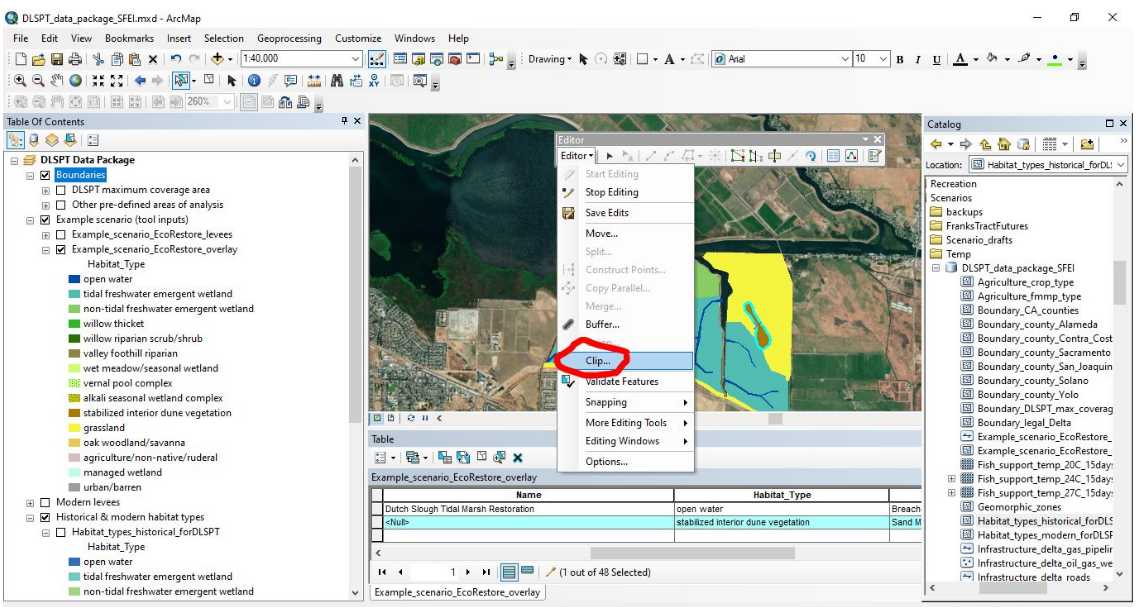
Step #2) Instructing ArcMap to paste this historical polygon into the example scenario habitat type modification overlay layer (CTRL+V with the scenario overlay layer turned on):



3) The resulting shape highlighted in the scenario overlay layer (with the habitat type pre-populated in the attribute table):



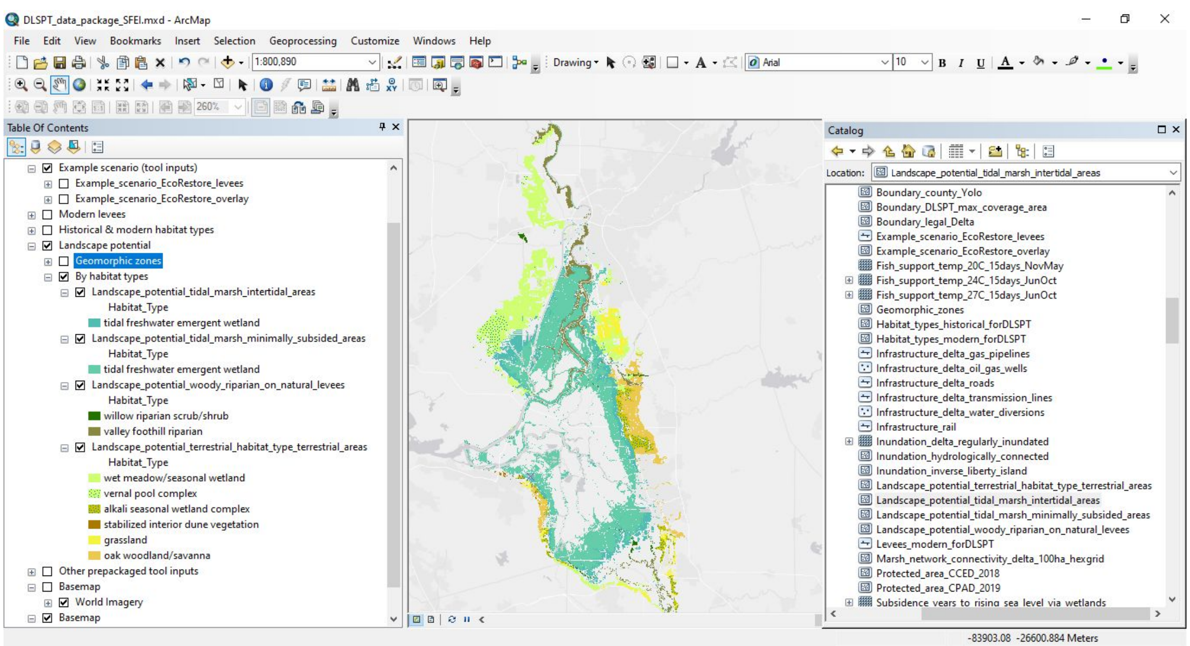
4) Erasing the underlying part of the grassland polygon (yellow) to avoid overlapping features in the overlay layer with the “Clip” function. Make sure “Discard the area that intersects” is selected in the next menu. This step could also be accomplished using topology tools:



- **Modern habitat type layer**
(`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Habitat_types_modern_forDLSPT`): This layer is a version of the modern Delta habitat types layer published in SFEI-ASC (2014) intended for use in the DLSPT. The tool uses this layer to compare scenarios to the modern Delta (ca.

2002). **Tool users can use ArcMap editing tools to copy polygons from the modern habitat type layer into their scenario and then alter the habitat type classification in the "Habtiat_Type" field to specify a habitat type conversion in the scenario.** This is convenient because it avoids the need to draw polygons from scratch, and the polygons from the modern habitat type layer already "fit" well with adjacent shapes/habitat types/features on the landscape.

- **Landscape potential layers:** The tool also comes pre-packaged with four "landscape potential" layers, which identify restoration opportunities based on their elevation. These layers were derived from a more detailed analysis to identify, map, and quantify opportunities for landscape-scale restoration in the Delta (Safran et al. 2020, version 3.1). Please refer to that document and the layer meta-data for additional information on the datasets and methods. They are also summarized below. Note that landscape potential in these layers is based primarily on physical elevation. The analysis does not consider ownership, infrastructure constraints, or any number of other considerations that influence the suitability/feasibility of potential land uses. **Tool users can use ArcMap editing tools to copy polygons from the landscape potential layers into their scenarios that are likely to be physically suitable, given their elevation.**



    - ***Landscape_potential_tidal_marsh_intertidal_areas***: This layer identifies areas in the intertidal zone (land with an elevation between local MLLW and local MHHW) that could potentially support tidal freshwater emergent wetlands. It does not include areas that already support freshwater emergent wetlands or areas currently classified as urban development. The layer has also been annotated with additional fields to further characterize the potential of each feature, including whether each patch of land at intertidal elevation is >100 ha in size ("Intertidal_patch_100ha"), >500 ha in size ("Intertidal_patch_500ha"), adjacent to a remnant blind channel network ("Adjacent_to_remnant_blind_Channel"), contiguous with non-urban transgression space ("Contiguous_with_undeveloped_transgression_space"), and adjacent to historical woody riparian patches ("Adjacent_to_historical_riparian"). The importance of these attributes are described in other resources (SFEI-ASC 2016; Safran et al. 2020).

- ***Landscape_potential_tidal_marsh_minimally_subsided_areas:*** This layer identifies areas in the shallowly subsided zone (areas with land surface elevations <8 ft below localMLLW) that could potentially support tidal freshwater emergent wetlands after subsidence-reversal efforts. It does not include areas that already support freshwater emergent wetlands or areas currently classified as urban development. For the purposes of the DLSPT, a new "Habitat_Type" field has been pre-populated with the "tidal freshwater emergent wetland" classification. Because restoring tidal freshwater emergent wetlands in shallowly subsided areas will require subsidence reversal, users developing near-term scenarios may want to instead consider classifying these areas as non-tidal freshwater emergent wetland or managed wetland. The layer has also been annotated with additional fields denoting whether each patch of land at intertidal elevation is >100 ha in size ("Minimally_subsided_100ha") and whether it is >500 ha in size ("Minimally_subsided_500ha").
- ***Landscape_potential_woody_riparian_on_natural_levees:*** This layer identifies areas with the potential to support woody riparian vegetation. Areas were included if they historically supported woody riparian vegetation on natural levees, are still located above the local elevation of MHHW, and do not currently support hydrologically connected woody riparian habitat types, urban development, or open water. The "Habitat_Type" field is populated with either "valley foothill riparian" or "willow riparian scrub/shrub," depending on the woody riparian habitat type that was supported historically. Removing areas currently classified as open water from this layer helped prevent areas where channels have migrated or been widened from being identified as opportunities for woody riparian restoration, even though they formerly supported woody riparian vegetation. This methodology makes the simplifying assumption that many areas that historically supported woody riparian vegetation could still do so today, at least with modifications to engineered levees that currently limit connections between streams and the adjacent land. Future phases of this work should refine this analysis, evaluating detailed present-day topographic, edaphic, and hydrologic conditions. The layer potentially underestimates opportunities in areas that did not historically support woody riparian

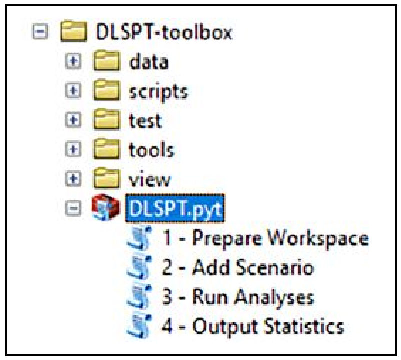
vegetation but could today given changes in environmental conditions (e.g. along new channel courses such as Paradise Cut).

- ***Landscape_potential_terrestrial_habitat_type_terrestrial_areas***: This layer identifies areas that are in either the tidal-terrestrial zone (areas <10 ft above MHHW; referred to as the “sea-level rise accommodation” band in the Delta Plan) or the terrestrial zone (>10 ft above MHHW; referred to as the “floodplain” elevation band in the Delta Plan), subtracting urban areas and existing natural habitat type types (including terrestrial habitat types, woody riparian types, non-tidal marshes, and open water), and then clipping the resulting layer to the areas that also historically supported terrestrial habitat types, including Wet meadow/Seasonal wetland, Vernal pool complex, Alkali seasonal wetland complex, Stabilized interior dune vegetation, Grassland, and Oak woodland/savanna (SFEI-ASC 2014). This land, predictably, falls mostly on the periphery of the Delta. In this analysis, we assume that areas that historically supported a particular terrestrial habitat could potentially support that habitat type again, but consideration of contemporary landscape conditions, such as groundwater and soil conditions, are also important and should be considered in future versions of this analysis. The "Habitat_Type" field has been pre-populated with the historical terrestrial habitat type.

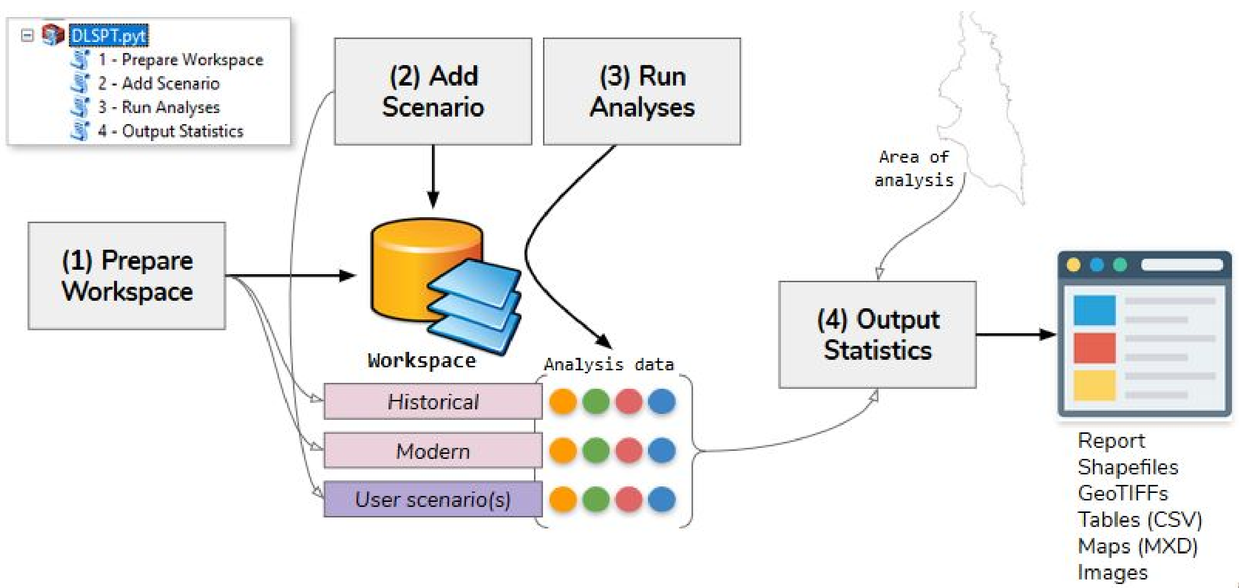
Some additional considerations for digitizing scenarios specific to each tool module are included in the “Key considerations and caveats” sub-sections in the “Analysis Modules” section.

Tool Workflow

To use the toolbox, simply navigate to the toolbox in ArcMap or ArcCatalog, either through the file catalog window or by adding a new toolbox to the toolbox window.

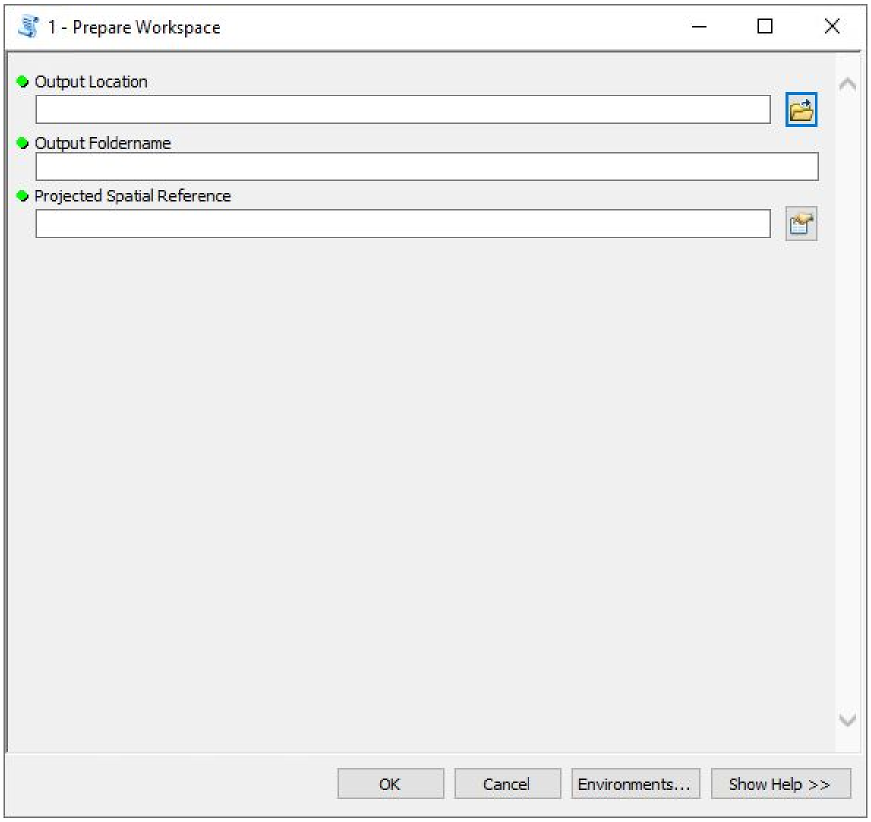


DLSPT consists of four specific tools. These are meant to be run in order, but certain tools can be repeated. Generally the procedure is as follows: (1) prepare the workspace, (2) add scenario(s) to the workspace, (3) run analyses, and (4) output statistics. The tool components and work flow are summarized in the figure below and described in detail on the following pages.



1. Prepare Workspace

Prepares the workspace for a project and prepares the historical and modern data.



Inputs:

- **Output Location** -- The location in which workspace will be created.
- **Output Foldername** -- The name of workspace folder to be created.
- **Projected Spatial Reference** -- An enforced spatial reference for all data (must be projected type with linear units of meters) -- a suggested spatial reference to use is California Teale-Albers NAD83 (EPSG: 3310), which is provided as a prj file in the main tool directory.

Processes:

- Copies datasets into workspace.
- Prepares historical/modern habitat types.
- Extracts open water.

Outputs:

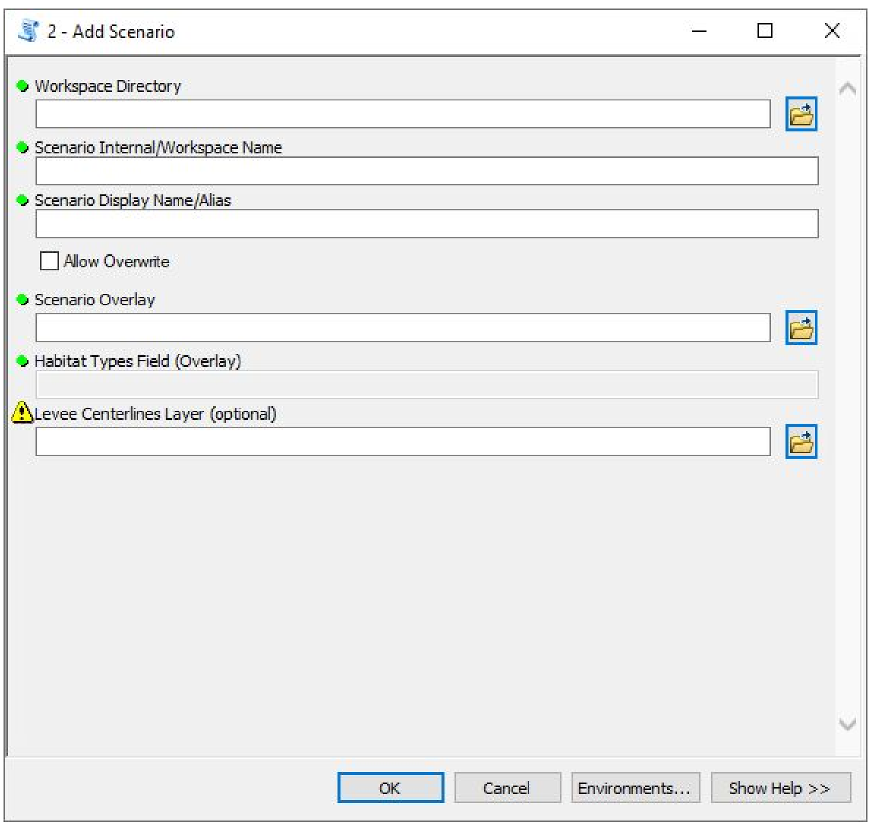
- The workspace folder with geodatabase
- Within the geodatabase:
  - `_tracking`
    - The tracking table for scenarios and analyses run on each.
  - `_alias`

            - The crosswalk table for scenario internal/workspace names to display names.
    - `historical_habitat`
    - `modern_habitat`
    - `historical_open_water`
    - `modern_open_water`

2. Add Scenario

Defines and adds a scenario to a workspace. This tool can be run multiple times for multiple scenarios. It can also be used to overwrite an existing scenario.

Note that if overwritten, the tracking table will be cleared for all analyses and the feature dataset for the scenario cleared. However, some vestigial datasets from past analyses on the previous scenario definition may still exist. They will not be factored in the outputs, however, as they are no longer being tracked in the tracking table (unless the analysis is rerun, in which case these datasets will be overwritten).



<u>Inputs:</u>

- **Workspace Directory** -- The directory of project workspace.

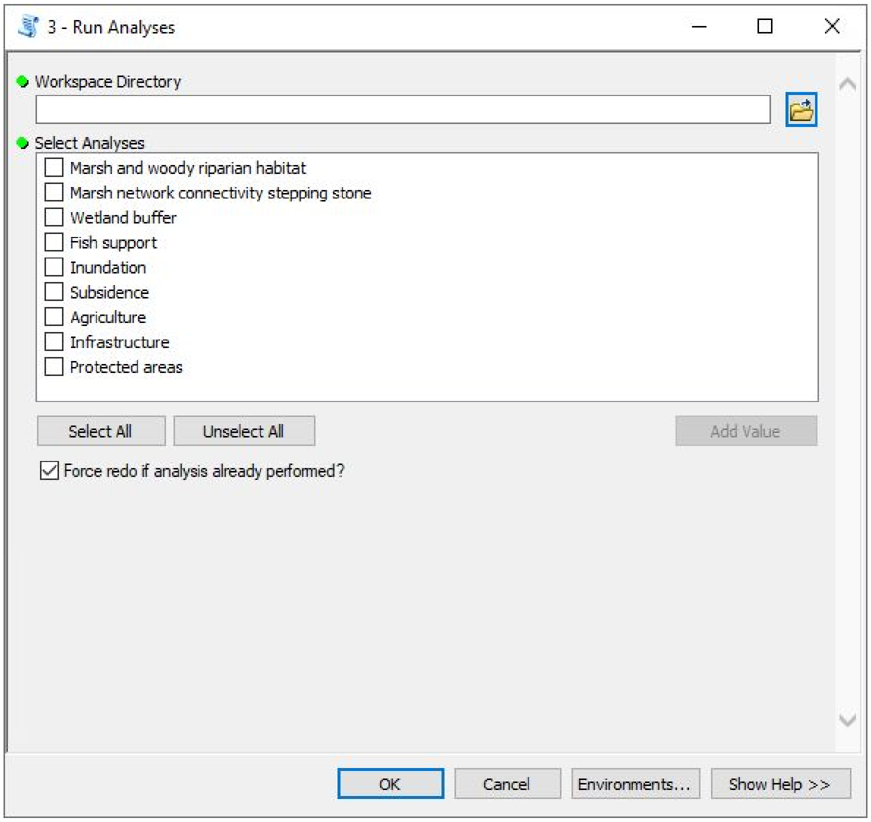
- **Scenario Internal/Workspace Name** -- The name for the scenario ,restricted to be filename safe for workspace/file-geodatabase file names (no spaces or special characters).
- **Scenario Display Name/Alias** -- The scenario name to be used in the tool output report (spaces and other special characters are ok).
- **Allow Overwrite** -- If checked, allows overwriting an existing scenario with the same internal/workspace name (if not checked, the tool will raise an error if a scenario with the same internal/workspace name already exists).
- **Scenario Overlay** -- Layer consisting of polygons of habitat type changes/modifications related to scenario.
- **Habitat Types Field (Overlay)** -- The field/attribute name in the overlay layer which defines habitat type. Habitat type values must be from the accepted/recognized list (not case sensitive -- see the Habitat types section).
- **Levee Centerlines Layer** -- An optional levees layer for the scenario.
    - If not supplied, no change from modern levees is assumed
    - Levees factor into Fish support analysis to define connectivity

Processes:

- Prepares habitat layer for the scenario by burning the scenario overlay layer into the modern habitat type layer.
- Performs basic habitat analysis on the resulting layer (see the Habitat section under "Analysis modules").
- Performs physical suitability analysis (see the Physical suitability section under "Analysis modules").
- Performs levee change analysis (see the Levees section under "Analysis modules").

3. Run Analyses

Runs analyses on all scenarios in the workspace. See section Analysis modules for further details on predefined inputs, predefined parameters, processes, and outputs.



Inputs:

- **Workspace Directory** -- The directory of project workspace.
- **Select Analyses** -- The name(s) of analyses to run.
- **Force redo if analysis already performed?** -- If checked runs analyses on all scenarios no matter what. If not checking, will skip redoing analysis if it was already performed on a scenario.

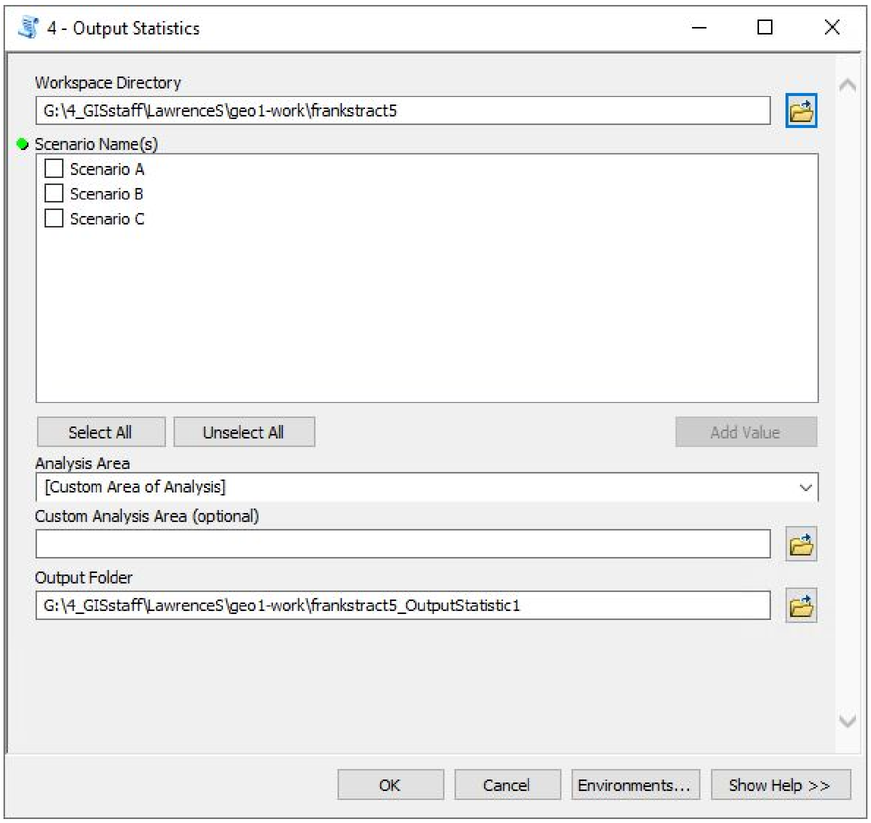
Certain analyses take longer than others. The most intensive analysis is “Marsh network connectivity stepping stone” -- hence, this analysis is separated from the Marshes section in which its outputs are included. Expect the “Marsh network connectivity stepping stone” analysis to take anywhere from 30-60+ minutes with one user scenario defined and an additional 15-30+ minutes for each additional user scenario. The next most time-consuming analyses are “Marsh and woody riparian habitat” and “Fish support,” each taking roughly 5-15+ minutes per scenario, including historical and modern, though runtime will vary by complexity of the layers and the power of the machine on which it is run.

If adding a new scenario after having run this tool, you will have to rerun **Run Analyses** to run analyses on the new scenario. However, you can uncheck **Force redo if analysis already performed?** to skip rerunning analyses for previous scenarios.

Note that DLSPT analyses performed in the **Add Scenario** and **Run Analyses** tools are always run over the full DLSPT coverage area. Smaller areas of analysis over which to subset/summarize the full results are then defined in the **Output Statistic**s tool (which can be run multiple times with different analysis areas, if desired).

4. Output Statistics

Outputs formatted data, shapefiles, and maps, which are clipped to a user-defined area of analysis and then consolidated into an dynamically-generated and interactive report.



Inputs:

- **Workspace Directory** -- The directory of project workspace.
- **Scenario Name(s)** -- Name(s) of scenario(s) desired to report on in output. Once the workspace directory is selected, this box will be populated with choices using the scenario display names.
- **Analysis Area** -- The area of analysis, which may be selected from this predefined list or defined as custom along with the next parameter.
- **Custom Analysis Area** -- If a custom area of analysis is selected above, use this to define the polygon shapefile or feature class demarcating the custom area of analysis.
- **Output Folder** -- The folder in which to place the formatted outputs and report.

Processes:

For each analysis that has been run in the workspace, for the scenario(s) specified:

- Clips relevant data to the area of analysis.
- Exports clipped data (as shapefiles or geoTIFFs).
- Calculates statistics on clipped outputs.
- Outputs tabular data (CSV) of statistics.
- Prepares map documents (MXD) and exports map images (PNG).
- Adds relevant data to report.

Outputs:

The folder `output` contains:

- Folder: `output/data`
  - Tabular data (CSVs).
- Folder: `output/map`
  - Map documents (MXDs).
- Folder: `output/shp`
  - Spatial data (shapefiles and geoTIFFs).
- For specific file outputs, see relevant subsections under the Analysis modules section.

The folder `report` contains the Landscape Scenario Summary Report, a web-browser-based, interactive application for viewing analysis results.

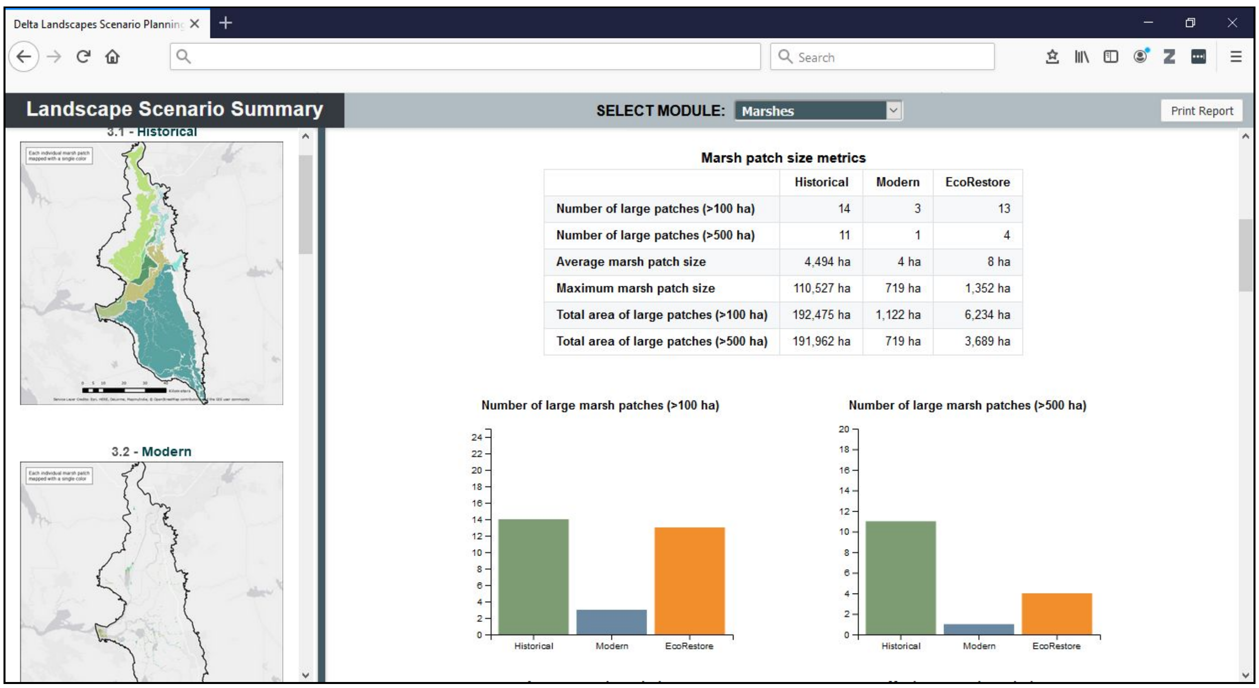
Viewing results

A note on the scenario naming format. Within the workspace, the naming format uses the internal/workspace name for scenarios as dataset name prefix. When applicable, data layers are stored in the feature dataset named after the scenario internal/working name (there are exceptions such as tables/rasters which cannot be stored in a feature dataset). For the output data from the final tool, for ease of creating dynamically-generated files and to avoid potential invalid filename errors, user scenarios in filenames are simply called “vision1”, “vision2”, “vision3”, etc. The formatted display names for the scenarios are applied in report and output table columns.

Results from the Output Statistics tool are organized into an output folder and a report folder. The output folder contains tabular data (as CSVs), spatial data (as shapefiles and geoTIFFs), and map documents (as MXDs). For a description of each raw tool output file refer to the “File inventory” sub-sections within the “Analysis Module” section below. For units of applicable attribute values, see section Units under “Tool overview.”

Note that shapefiles will occasionally show truncated attribute names due to the ten character limit. In these cases, it may be useful to refer to the raw dataset in the workspace, which does not have as restrictive an attribute length limit and will list attributes in the same order as the output. MXDs may have several hidden/broken layers -- these are intentional and are used to create the legend dynamically.

To view the Landscape Scenario Summary Report, simply open `report/results.html` in your web browser. It does not require an internet connection and the file can be shared via packaging and sending the contents of the report folder (i.e., zipping the entire folder and sharing it via email).



The Landscape Scenario Summary Report is organized into three main components. The top menu-bar has the controls for viewing the outputs of different modules. The button on the top-right opens the entire mode in a print-friendly layout for printing or saving to PDF.

The rest of the screen is devoted to side-by-side displays of the maps (left panel) and rest of the results (right panel). The panel widths may be adjusted by dragging the vertical bar separating the two panels to the left or right. When a different module is selected from the top menu-bar, the panels will automatically update.

For supported modules, a unit selection dropdown menu will appear floating in the upper right corner. Changing units here will update units in the tables to the appropriate type. However, it will not affect units in text boxes, graphs, or maps.

The Landscape Scenario Summary Report was built with Javascript, Vue.js (2.6.10), and D3.js (5.12.0). It should be supported on all modern browsers (e.g. Internet Explorer 11+, Edge, Firefox, Chrome, Safari).

Common errors

Scenario naming

The scenario internal/workspace name must abide by certain naming conventions. See name/alias rules in Defining feature class properties. Additionally, no special characters are recommended, as this may cause issues down the line in invalid layer or table names. As a general rule, stick to alphanumeric characters and underscores in the internal/workspace name.

You may supply a more properly-formatted name as the scenario display name/alias, which will be used in all formatted reports.

Finding more specific error messages

If the error message in the output is vague, it may be worth checking the log file (logfile.txt in the workspace directory) for a more detailed error message including full stack trace.

ERROR: Cannot create plan with name '_____', name is reserved

Certain scenario internal/workspace names are reserved within the workspace for internal use. These include “tmp”, “historical”, and “modern.”

ERROR: Could not create feature dataset with plan name. Ensure plan name is valid as a feature dataset name

The scenario internal/workspace name must abide by certain naming conventions. See “Scenario naming” subsection at the top of this section.

Error code: 00144

If an error message with the above error code appears, the version of ArcGIS running does not have the required license or extension. DLSPT requires the advanced license of ArcGIS for certain analysis tools (namely erase and near table). In addition, certain modules require the Spatial Analyst extension to be enabled.

Tool customization (modifying internal inputs/parameters)

Adding a custom habitat type

To add a new custom habitat type, add a new row to the habitat types crosswalk table located at `data\tables\habitat_types_crosswalk.csv`. The first column is habitat type label (case insensitive, but for consistency leave lowercase). For each of the other columns in this row, mark "1" where this new habitat type fits in the grouping defined by the column.

In most cases, data is passed to the summary report already grouped via the habitat types crosswalk, propagating changes made in the habitat type crosswalk table to the report. However, a few exceptions use hard-coded values or other crosswalk tables that must also be updated when applicable. The Delta Plan habitat targets table must also be updated if the custom habitat type falls under Delta PLan habitat type group. Additionally, habitat groups in the "Habitat change" section of the table in the "Summary" module are currently hard-coded, and updating these requires a modification and rebuild of the summary report application.

Additionally, map symbologies cannot be dynamically updated, and the habitat types and scenario overlay maps will not show custom habitat type classes unless the map template is manually modified to accommodate them.

Updating an input to a custom dataset

Updating an input dataset can have unexpected and undesirable results. As such, it is only recommended for advanced users, and all work should be properly backed up before saving changes.

To update a specific input, change the value associated with the relevant variable in the file `scripts/common/Inputs.py` to point to the new input dataset. There may be a relevant attribute field parameter to update as well. Note that some inputs are expected to have specific values and attributes which are hard-coded. Some of these are noted in comments above the variable assignment. Others may not be and will require looking into the scripts for the associated module analysis and output scripts.

Analysis Modules

The sections below provide additional information on each analysis module, including background information on why the module is relevant to landscape planning, details on the analysis methods, lists of the relevant inputs, outputs, and tool parameters, and other key considerations/caveats when using the module and interpreting its results.

Habitat Types

Summary:

Changes in the extent of different habitat types within the Delta are a basic way of understanding how the system has changed, and restoration goals are often linked to specific acreage targets for different habitat types. Habitat types, as discussed here, denote broad classifications of ecological communities determined largely by vegetation type, as well as climatic and hydrologic characteristics; these broad types are not meant to represent habitat for particular species. This module quantifies the extent of and net change in habitat types for user scenarios as compared to the modern and historical Delta . This module also compares the amount of habitat types expected under different scenarios to the Delta Plan's restoration goals for different natural communities.

Note that the habitat types analyses are prepared by default when adding scenarios. As such, it does not appear on the Run Analyses tool.

Tool analysis methods:

- For user scenarios, creates habitat vision by erasing the scenario overlay from modern habitat then merging the overlay on top (requires advanced license).
- Creates "change polygons" by determining wherever the scenario's habitat type differs from the modern habitat type.

Key considerations and caveats:

Habitat types used in these analyses are broad classifications and do not account for differences in habitat quality, including differences in hydrology or vegetation structure and composition, between polygons of the same habitat type.

Habitat types must be from one of the recognized values. See Habitat types in the Tool Overview section for more information.

As noted in the “developing scenarios” section It is important to ensure the scenario overlay contains no overlapping polygons. There is currently no automatic detection or correction of such topology issues and as a result, such overlaps will be double-counted in areal calculations.

File inventory:

All outputs in units of hectares (where applicable).

Input / Output	Name / Desc.	File Name	Source	Notes
input	Historical Delta habitat types	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Habitat_types_historical_forDLSPT`	Whipple et al. 2012	
input	Modern Delta habitat types	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Habitat_types_modern_forDLSPT`	SFEI-ASC 2014	
input	Delta Plan restoration targets	`data\tables\delta_targets.csv`	DSC 2019	
output - workspace	Copy of input user scenario overlays	`{scenario}_scenario_overlay`		
output - workspace	New habitat vision with scenario overlays	`{scenario}_habitat_vision`		
output - workspace	Open water in habitat vision for scenarios	`{scenario}_open_water`		
output - workspace	Changed habitat cover in habitat vision for scenarios	`{scenario}_changed`		
output - report	Habitat cover for scenarios	`{scenario}_habitat.shp`		
output - report	Habitat metrics for all scenarios	`habitat.csv`		
output - report	Copy of habitat targets	`habitat_targets.csv`		
output - report	Maps of habitat cover for scenarios	`{scenario}-habitat.mxd`		

Levees

Summary:

Note that levee analyses are executed by default when adding scenarios (assuming the optional levee layer is supplied) because of dependencies on levees in other modules (e.g. Fish support). While they are treated as their own analysis in the tool code, the results are grouped under the “Infrastructure” section in the report. See the “Infrastructure” below for more information.

The levee analysis is only run on user scenarios, as it measures change from modern conditions. If no levee layer is provided for a scenario, no related results are included in the Infrastructure section of the output report.

Tool analysis methods:

- Erases scenario levees from modern levees and vice versa to determine added and removed levee centerlines (requires advanced license).

Key considerations and caveats:

As noted in the "Developing Scenarios" section, change analysis on the inputted scenario levee layer is done via simple overlap/erase with the modern levee layer. As such, even a small offset will be treated as if the levee was removed and added a slight distance away. To avoid such errors, begin with the default modern levee layer packaged with this tool, and make modifications on a copy of that.

File inventory:

All outputs in units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name	Source	Notes
input	Modern delta levees	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Levees_modern_forDLSPT`	SFEI 2020 (this tool)	DLSPT modern levee layer derived from DWR 2015 levee layer
output - workspace	Copy of input user scenario levees	`{scenario}_levee_centerlines`		
output - workspace	Levee change (added) in scenarios	`{scenario}_levee_centerlines_added`		
output - workspace	Levee change (removed) in scenarios	`{scenario}_levee_centerlines_removed`		
output - report	Levees for scenarios	`{scenario}_levee.shp`		
output - report	Levee change (added) in scenarios	`{scenario}_levee_added.shp`		
output - report	Levee change (removed) in scenarios	`{scenario}_levee_removed.shp`		
output - report	Levee metrics for all scenarios	`levee_metrics.csv`		
output - report	Maps of levee change for scenarios	`{scenario}-levees.mxd`		

Marshes

Summary:

Tidal and non-tidal emergent wetlands (marshes) dominated the Delta landscape historically, but are largely absent from the Delta today. Marshes provide habitat for many species, and influence water quality, carbon storage, and nutrient cycling within the Delta. This module summarizes the extent and configuration of marsh patches in the user scenarios, as compared to the historical and modern Delta. This includes the size distribution of marsh patches, the distance of marsh patches to the nearest large patch, and the shape of marsh patches (core:edge ratio). In addition to the total amount of marsh in an area, the way that marshes are configured in the landscape also affects the benefits they provide. Large marsh patches support more habitat complexity, greater species diversity, and larger wildlife populations than smaller marsh patches. Connections between marsh patches are important for wildlife dispersal, gene flow, and population resilience. The average nearest large neighbor distance is a very simplified measurement of marsh connectivity. The shape of marsh patches affects their function. Areas of a patch close to its outer edge generally experience different abiotic conditions than areas within its "core," are less accessible to many predators of marsh wildlife, and are more buffered from human disturbance in the modern landscape. This module uses metrics developed as part of the Delta Landscapes project. More details about the methodology can be found in *A Delta Transformed* (SFEI-ASC 2014).

Note that in the Run Analyses tool, the Marshes module appears as "Marsh and woody riparian habitat" as the analyses are grouped to remove redundancy from certain overlapping processes. Because they are computationally expensive, this module does not run the marsh network connectivity analyses, which are instead split into a separate analysis in the Run Analyses tool. See the "Marsh network connectivity" section below for more information.

Tool analysis methods:

- Creates marsh patches:
  - Selects marsh habitat type group polygons.
  - Dissolves and splits into single-part polygons.
  - Aggregates polygons to determine grouping of nearby polygons.
  - Buffers and dissolves (single-part) to create individual features from groups.
  - Intersects above output with output from first dissolve to identify individual patch groups in original geometry.
  - Dissolves single-part polygons back into the final patch layer.
- Determines and marks large patches by query on patch area.

- Performs patch core analysis via inner buffer.
- Performs nearest neighbor analysis via near table tool (requires advanced license).

Key considerations and caveats:

This analysis assumes the areas identified as marsh in the user-defined scenarios will become or remain marsh. This may be less likely in certain areas due to climate change and sea-level rise or other factors.

By default, areas classified as “Managed wetland” are NOT included in the marsh habitat type group and therefore do not contribute to the “Marsh module” metrics. This is due to the fact that many areas classified as Managed wetland in the modern habitat type map are either largely open water, with only limited emergent vegetation, or are seasonally flooded herbaceous vegetation. We recommend that users classify managed wetlands in their scenarios that they expect or intend to be dominated by marsh vegetation (e.g., tule farms on subsided Delta islands) as “non-tidal freshwater emergent wetland.” The distinction between managed wetland and non-tidal freshwater emergent wetland is a known limitation of the modern habitat type map that should be resolved with updated Delta habitat type and wetland maps.

During the output/final step, limiting the outputs by the area of analysis will clip patches to the area of analysis. However, many statistics will be reported for the full patch sizes and full extent.

Determination of large patches and the statistics for average and maximum patch size, are computed assuming the full patch sizes of patches within the area of analysis (whether the full size is contained within the area of analysis or not). Conversely, areal totals are reported after clipping the patch size to the area of analysis. E.g. if a large patch (> 100 ha) is clipped such that only 4 ha of its intersection with the area of analysis remains, it is still counted as a large patch (> 100 ha) while only adding 4 ha to the total large patch area in the area of analysis.

Core area and core/edge area ratios are reported after clipping to the area of analysis.

Nearest distance statistics are reported for the entire dataset. I.e. the nearest distance value for a patch may be referring to a patch outside the area of analysis.

For outputs of the patches shapefile and the marsh metrics tables, all fields except “Patch_Marsh_CoreArea” and “Area_Hectares” are reporting original numbers before clipping to the area of analysis.

Predefined parameters:

For habitat types considered marsh, see “Habitat types” in the “Tool Overview” section.

Parameter	Value	Citation	Notes

Buffer tolerance	0.1 m		Needed to force polygons that are connected at one point to aggregate into a single patch
Patch aggregation distance	60 m	SFEI-ASC 2014	
Edge width	50 m	SFEI-ASC 2014	
Large marsh patch size	100 ha	SFEI-ASC 2014	
Mean black rail dispersal distance	5.48 km	Hall 2015	

File inventory:

All output metrics in length units of hectares and meters (where applicable), unless otherwise noted.

Input / Output	Name / Desc.	File Name	Source	Notes
output - workspace	Marsh patches for scenarios	`{scenario}_marsh_patches`		near distances in meters
output - workspace	Changed marsh patches for user scenarios	`{scenario}_marsh_patches_changed`		
output - workspace	Marsh patch cores for scenarios	`{scenario}_marsh_cores`		
output - workspace	Mash and water areas for scenarios	`{scenario}_marsh_water`		
output - report	Marsh patches for scenarios	`{scenario}_patches.shp`		Near distances in meters. Field `Patch_Marsh_Area` refers to the full patch area before clipping to the analysis area. Fields `Area_Hectares` and `Patch_Marsh_CoreArea` report area after clipping to analysis area
output - report	Changed marsh patches for user scenarios	`{scenario}_patches_changed.shp`		
output - report	Marsh patch cores for scenarios	`{scenario}_cores.shp`		
output - report	Open water areas for scenarios	`{scenario}_water.shp`		
output - report	Marsh metrics for scenarios	`{scenario}_marsh_metrics.csv`		
output - report	Open-water-to-marsh metrics for all scenarios	`openwater.csv`		
output - report	Maps of marsh patches for scenarios	`{scenario}-patches.mxd`		
output - report	Maps of marsh patch cores for scenarios	`{scenario}-patch-cores.mxd`		

output - report	Maps of open-water-to-marsh for scenarios	{scenario}-water.mxd		

Marsh network connectivity

Summary:

Connections between marsh patches are important for wildlife dispersal, gene flow, and population resilience. The likelihood that a marsh patch will be colonized (or re-colonized after a disturbance event) by native wildlife is expected to increase with proximity to other marsh patches. The functional connectivity of marshes in the Delta for wildlife depends on how each marsh is positioned on the landscape relative to every other marsh and how accessible each habitat patch is for dispersing animals. The analysis performed in this module assesses the probability that two marsh birds (black rails, *Laterallus jamaicensis coturniculus*) randomly placed in the Delta would end up in the same marsh patch (and hence reproduce) via dispersal. Here the black rail can serve as a useful proxy for other marsh wildlife to inform how the connectivity of the whole marsh network has changed over time. Due to its computationally intensive nature, this analysis is split out as the "Marsh network connectivity" analysis in the Run Analysis tool. However both are grouped under the Marshes section in the output report. The stepping stone analysis is not run for the historical scenario.

Tool analysis methods:

- Filters marsh patches to those greater than minimum considered patch size.
- Runs a graph-based network analysis to determine connectivity of filtered patches (see below for additional details)
- For stepping stone, runs a modified version of the above analysis on each Delta hex grid.

Marsh network connectivity metrics are based on the "probability of connectivity" index (PC; Saura and Pascual-Hortal 2007) using the area of aggregated marsh polygons and the distance, edge-to-edge, between these polygons. Dispersal probabilities between patches for Black Rails were estimated using the negative exponential of empirically-derived, mean natal dispersal distances (5.58 km; Hall et al. 2018). Ordered rankings for marsh patches for their importance to Delta-wide connectivity were calculated with dPC_k, which is the percentage of change in connectivity caused by removal of each individual patch from the Delta. In addition, for each patch we calculated the three additive components that comprise total connectivity as quantified by the dPC_k (Saura and Rubio 2010): (i) $dPCintra_k$, or the amount patch *k*'s area contributes to connectivity; (ii) $dPCflux_k$, or how well connected patch k is to other patches in the marsh network; (iii) $dPCconnector_k$ or patch *k*'s contributions to the connectivity between other patches, in other words, how well it serves as a stepping-stone habitat. Each of these connectivity components is attributed to each patch in the network in its own corresponding field, allowing advanced users to explore the results further.

While the contribution of each individual patch to the total network connectivity was determined by iteratively *removing* each patch from the network and quantifying the impact on connectivity, determining areas where new marshes would most improve connectivity as stepping stone habitat used the opposite process--iteratively *adding* individual hypothetical patches to the network and quantifying how much they increase stepping-stone connectivity ($dPCconnector_k$).

Key considerations and caveats:

This analysis uses a binary model of the landscape (marsh and non-marsh) that simplifies the complexities of how species interact with their surroundings.

To optimize the calculations, only patches over the minimum considered patch size are taken into account.

The output stepping stone connectivity is limited to the Delta as defined by the Delta 100 ha hex-grid. However, patches located outside of the grid can still influence the grid itself.

Predefined parameters

For habitat types considered marsh, see "Habitat types" in the "Tool Overview" section.

Parameter	Value	Citation	Notes
Minimum considered patch size	5 ha		
Area of analysis (for whole Delta)	3,164.26 sq km		
Mean black rail dispersal distance	5.48 km	Hall 2015	

File inventory:

All outputs use length units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name	Source	Notes
input	Delta 100 ha hex-grid (defines each feature analyzed for potential contribution to network connectivity)	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Marsh_network_connectivity_delta_100ha_hexgrid`	SFEI 2020 (this tool)	
output - workspace	Connectivity marsh patches for scenarios	`{scenario}_connectivity_patches`		
output - workspace	Near table of connectivity patches for scenarios	`{scenario}_connectivity_near`		

output - workspace	Connectivity stepping-stone hex grid for scenarios	`{scenario}_connectivity_grid`		
output - workspace	Connectivity stepping-stone near table for scenarios	`{scenario}_connectivity_grid_near`		
output - report	Connectivity marsh patches for scenarios	`{scenario}_connectivity_patches.shp`		
output - report	Connectivity stepping-stone hex grid for scenarios	`{scenario}_connectivity_grid.shp`		
output - report	Connectivity metrics for scenarios	`connectivity_{scenario}.csv`		
output - report	Maps of connectivity stepping-stone grid for scenarios	`{scenario}_conn-stepping-stone.mxd`		

Woody riparian areas

Summary:

Woody riparian areas interface between aquatic environments and more terrestrial areas and provide structurally complex environments that support diverse species. Woody riparian habitat in the Delta supports several endemic riparian species, provides shade and food resources for fish, and nesting and roosting sites for waterbirds. This module quantifies the extent and patch size distribution of woody riparian habitat types in the user scenarios, as compared to the historical and modern Delta. This module uses metrics developed as part of the Delta Landscapes project. More details about the methodology can be found in *A Delta Transformed* (SFEI-ASC 2014).

Under the Run Analyses tool, this appears as "Marsh and woody riparian habitat" as the analyses are grouped to remove redundancy from certain overlapping processes. However, the outputs are treated as separate sections in the report.

Tool analysis methods:

- Creates riparian patches using a similar process as in the marshes module, but starting with woody riparian habitat type group polygons.

Key considerations and caveats:

As opposed to marsh patch metrics, all woody riparian patch metrics are all given after clipping to the area of analysis.

Predefined parameters:

For habitat types considered woody riparian, see "Habitat types" in the "Tool Overview" section.

Parameter	Value	Citation	Notes
Patch aggregation distance	100 ha	SFEI-ASC 2014	

File inventory:

All outputs in units of hectares (where applicable).

Input / Output	Name / Desc.	File Name	Source	Notes
output - workspace	Woody riparian patches for scenarios	`{scenario}_riparian_patches`		
output - report	Woody riparian patches for scenarios	`{scenario}_riparian_patches.shp`		
output - report	Woody riparian patch metrics for all scenarios	`riparian.csv`		
output - report	Woody riparian patch maps for scenarios	`{scenario}-riparian-patches.mxd`		

Wetland buffer

Summary:

Terrestrial areas near perennial wetlands and open water provide a range of benefits, depending on various factors, especially that include their distance to the wetlands or open water. Protecting a buffer around wetlands and aquatic areas provides space for a variety of other important ecological processes operating across estuarine-terrestrial transition zones, including providing the terrestrial habitat required by semi-aquatic reptiles and amphibians. These buffers can also act as protection from environmental stressors such as contaminants and invasive species. This module quantifies the amount of terrestrial area near marsh and open water, and quantifies the amount of buffer composed of natural upland habitat types versus highly modified human dominated habitat types within the analysis area.

Tool analysis methods:

- Buffers polygons of perennial wetlands and open water habitat type groups.
- Intersects buffer with habitat to get habitat types in wetland buffer.
- Extracts land cover by habitat type of natural terrestrial in the wetland buffer; remainder is assumed to be highly modified.

Predefined parameters:

For habitat types considered “perennial wetlands and open water,” “natural terrestrial,” and “highly modified”, see “Habitat types” in the “Tool Overview” section.

Parameter	Value	Citation	Notes

Buffer width	290 m	Semlitsch and Bodie 2003	

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
output - workspace	Wetland buffer for scenarios	{scenario}_wtbuffer		
output - workspace	Habitat types in buffer zone for scenarios	{scenario}_wtbuffer_habitat		
output - workspace	Natural habitat in buffer zone for scenarios	{scenario}_wtbuffer_natural		
output - report	Wetland buffer for scenarios	{scenario}_marsh_water.shp		
output - report	Habitat types in buffer zone for scenarios	{scenario}_wtbuffer.shp		
output - report	Natural habitat in buffer zone for scenarios	{scenario}_wtbuffer_natural.shp		
output - report	Wetland buffer metrics for all scenarios	wtbuffer_metrics.csv		
output - report	Maps of wetland buffer for scenarios	{scenario}-wtbuffer.mxd		

Fish support

Summary:

Wetland loss and other landscape scale changes have dramatically altered fish habitats in the Delta. Historically, much of the Delta was characterized by slow-water habitat, highly productive floodplains, and marsh-influenced habitats that provided many resources and opportunities for native fish. In the Delta today, aquatic habitats are characterized by wider, deeper, straighter channels that are often leveed off from adjacent wetland and floodplain habitats. In addition, the fish community in the Delta today is dominated by non-native species, and many native species are in decline. This module assesses several aspects of fish habitat in the Delta that are thought to support native fish. These analyses include the amount of marsh area, the marsh to open water ratio, connectivity of large wetlands, extent and quality of channel edges, and percent of scenario wetlands that are within specified water temperature thresholds in the analysis area.These analyses build on metrics developed for the Delta Landscapes project (SFEI-ASC 2014) and work done in collaboration with the Collaborative Adaptive Management Team (CAMT) to identify suitable rearing habitat for Chinook salmon in the Delta (SFEI 2020). For juvenile salmonids migrating out through the Delta, the distribution of habitat types along their migratory pathways affects the likelihood and frequency of finding suitable conditions necessary for growth and survival.

This analysis requires the Marses module (which appears as “Marsh and woody riparian habitat” in the Run Analyses tool) to have been run first.

Tool analysis methods:

- Prepares hydrologically "connected wetland patches:”
    - Selects marsh habitat type and woody riparian habitat type group polygons from which to create contiguous wetland polygons.
    - Erases levee centerlines (buffered by 1 m) from selection (requires advanced license).
    - Filters, via a spatial selection, contiguous polygons intersecting with connected open water (water types contiguous with any features belonging to the tidal wetland habitat type group). Because levees were erased from the wetland patches above, this operation only selects parts of wetlands on the “water side” of the levee (most wetland areas on the landward side of the levees are no longer contiguous with connected open water areas after the levees are erased and are thus not selected).
    - Creates hydrologically “connected wetland patches” (same process as making patches in Marshes module).
    - Determines large wetland patches via query on patch area.
- Creates inter-wetland distance rasters using cost distance to connected wetland patches via open water (requires spatial analyst license).
- Clips connected wetland patches within 2 km of connected open water via buffer and clip.
- Channel edge analysis:
    - Selects marsh habitat type and woody riparian habitat type group polygons from which to create contiguous wetland polygons.
    - Erases levee centerlines (buffered by 1 m) from selection (requires advanced ArcGIS license).
    - Determines channel edges as boundaries of contiguous wetland polygons (after being split by levees) with connected open water via an intersection. This only attributes the area of the wetland polygons on the “water side” of the levee to the channel edge.
    - For each wetland polygon:
        - Calculates the total polygon area per length of channel edge.
    - For distinct channel edge line-part:
        - Calculates the assigned area as a proportion of its length to the total channel edge length of the polygon it is assigned.
        - Calculates the assigned area per length.
- Temperature analysis:
    - Only done for user scenarios.

- Converts temperature rasters to polygons, buffers warm water areas (as defined in each raster) 1 kilometer.
- Unions resulting layers with connected wetland patches (see "Prepares hydrologically "connected wetland patches" above) to identify which parts of patches are near (<1 km) from warm water and which parts are far (>1 km).

Key considerations and caveats:

Pixel size for raster analyses is fixed to 10 meters, for ease of subsequent calculations.

Channel edges are defined by intersecting open water polygons with adjacent habitat types. If a scenario is meant to include new channels, these features must be explicitly digitized as polygons and included in the scenario habitat type modification overlay to be captured by the tool. If users already have digitized channel lines, these features can be buffered by their typical width and then added to the overlay layer.

Predefined parameters:

Wetland patches are formed from habitat type polygons that are part of the "Marsh" or "Woody riparian" habitat type groups (see "Habitat types" in the "Tool Overview" section for more details).

Parameter	Value	Citation	Notes
Large wetland patch size	100 ha	SFEI-ASC 2014	

File inventory:

Unless specifically noted otherwise below, all length units for outputs and attribute data given in meters, including assigned area per channel edge in ha m^{-1}.

Input / Output	Name / Desc.	File Name	Source	Notes
input	Temperature exceedance 20° (>15 days Nov-May)	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Fish_support_temp_20C_15days_NovMay`	Anchor QEA, LLC 2017	
input	Temperature exceedance 24° (>15 days Jun-Oct)	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Fish_support_temp_24C_15days_JunOct`	Anchor QEA, LLC 2017	
input	Temperature exceedance 27° (>15 days Jun-Oct)	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Fish_support_temp_27C_15days_JunOct`	Anchor QEA, LLC 2017	
output - workspace	Copy of temperature exceedance raster	`20c_novmay_fish_temp_exceedance`		
output - workspace	Copy of temperature exceedance raster	`24c_junoct_fish_temp_exceedance`		
output - workspace	Copy of temperature exceedance raster	`27c_junoct_fish_temp_exceedance`		
output - workspace	Areas within 1 km of available temp. data	`27c_junoct_fish_temp_exceedance_avail_1km`		

output - workspace	Connected open water areas for scenarios	`{scenario}_open_water_connected`		
output - workspace	Connected wetland patches ("fish patches") for scenarios	`{scenario}_fish_patches`		
output - workspace	Subset of connected wetland patches ("fish patches") that have been altered in user scenarios	`{scenario}_fish_patches_changed`		
output - workspace	Subset of connected wetland patches ("fish patches") that are considered large in user scenarios	`{scenario}_fish_large_patches`		
output - workspace	Cost distance raster to connected wetland patches for scenarios	`{scenario}_fish_distance_patches`		- pixel units in meters
output - workspace	Cost distance raster to large connected wetland patches for scenarios	`{scenario}_fish_distance_large_patches`		- pixel units in meters
output - workspace	Portions of connected wetland patches within 2 km of connected open water	`{scenario}_fish_wetland_within_2km`		
output - workspace	Contiguous wetland polygons for channel edge analysis for scenarios	`{scenario}_fish_weighted_edge_patches`		
output - workspace	Channel edges for scenarios	`{scenario}_fish_weighted_edge_shoreslines`		- length and assigned area given in meters and ha/m
output - workspace	Connected wetland patches with temperature exceedance data for scenarios	`{scenario}_fish_temperature`		
output - report	Copy of temperature exceedance raster	`20c_novmay_temp_exceedance.tiff`		
output - report	Copy of temperature exceedance raster	`24c_junoct_temp_exceedance.tiff`		
output - report	Copy of temperature exceedance raster	`27c_junoct_temp_exceedance.tiff`		
output - report	Cost distance raster to connected wetland patches for scenarios	`{scenario}_fish_distance_all.tiff`		- pixel units in meters
output - report	Cost distance raster to large connected wetland patches for scenarios	`{scenario}_fish_distance_large.tiff`		- pixel units in meters
output - report	Connected open water areas for scenarios	`{scenario}_fish_connected_water.shp`		
output - report	Connected wetland	`{scenario}_fish_patches.shp`		

	patches for scenarios			
output - report	Large connected wetland patches for scenarios	{scenario}_fish_large_patches.shp		
output - report	Portions of connected wetland patches within 2 km of connected open water for patches	{scenario}_fish_wetland_within_2km.shp		
output - report	Channel edges for scenarios	{scenario}_weighted_shoreline.shp		
output - report	Subset of connected wetland patches that have been altered as part of user scenarios	{scenario}_fish_patches_changed.shp		
output - report	Connected wetland patches with temperature exceedance data for scenarios	{scenario}_fish_temp_patches.shp		
output - report	Connected wetland patches within 2 km of connected open water metrics for all scenarios	fish_wetland_within_2km.csv		
output - report	Distance to large connected wetland patch metrics for all scenarios	fish_distances_large.csv		
output - report	Average distance to connected wetland patch metrics for all scenarios	fish_avg_distance.csv		
output - report	Channel edge metrics for scenarios	{scenario}_fish_weighted_shorelines.csv		- length and assigned area given in meters and ha/m
output - report	Connected wetland patches with temperature exceedance metrics for all scenarios	fish_temperature.csv		
output - report	Maps of distance to connected wetland patches for scenarios	{scenario}-fish-distance-all.mxd		
output - report	Maps of distance to large connected wetland patches for scenarios	{scenario}-fish-distance-large.mxd		
output - report	Maps of channel edge for scenarios	{scenario}-weighted-shorelines.mxd		
output - report	Maps of connected wetland patches and temperature exceedances for scenarios	{scenario}-fish-temp-20c-novmay.mxd		
output - report	Maps of connected wetland patches and temperature exceedances for scenarios	{scenario}-fish-temp-24c-junoct.mxd		

output - report	Maps of connected wetland patches and temperature exceedances for scenarios	`{scenario}-fish-temp-27c-junoct.mxd`		

Inundation

Summary:

In the Delta, most wetlands and floodplains have been lost due to being drained and converted to agricultural land use (SFEI-ASC 2014). As noted in the Delta Plan (DSC 2019), restoring functional tidal and fluvial floodplains is expected to result in enhanced primary productivity, an improved food web, and improved transfer of nutrients that can better support a healthy and functioning ecosystem (Ahearn et al. 2006, Cloern et al. 2016). Some agricultural land and floodways, can provide functions similar to natural wetlands, including greatly increased aquatic food production compared to other converted land uses (Moyle, Crain, and Whitener 2007; Corline et al. 2017; Katz et al. 2017).

Restoration of land-water connections provide ecosystem benefits that require both physical or hydraulic connectivity for water to flow onto land and for sufficient flow of water to inundate these connected areas (Merenlender and Matella 2013). The Delta Plan thus considers both the area of “hydrologically connected” lands and the portion of these connected lands that are “regularly inundated”. This module quantifies the baseline area of hydrologically connected and regularly inundated areas within the analysis area for the modern habitat scenario using Delta Plan performance measure methods. The tool also estimates how scenarios are expected to alter these metrics based on changes in the mapped extent of tidal freshwater emergent wetlands. The tool does not estimate how the extent of fluvially connected or inundated areas will change, which is generally dependent on fine-scale levee configuration changes and water management actions that the tool cannot currently predict.

Tool analysis methods:

- Prepares inundation reclass polygon from inundation raster, removing Liberty Island (requires ArcGIS Spatial Analyst extension).
- Selects tidal wetland habitat type group.
- Unions inundation reclass polygon, tidal wetland layer, and hydrologically connected layer.
- Clips result by Legal Delta boundaries.

Key considerations and caveats:

The analysis is limited to the Legal Delta due to spatial limits of datasets used for analysis.

The analysis is based off of the most recent at time of development version of the Delta Plan Performance Measure 4.15 (DATE). This document is still in progress.

Predefined parameters:

For habitat types considered part of the tidal wetlands group see "Habitat types" in the "Tool Overview" section.

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
input	Hydrologically connected areas	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Inundation_hydrologically_connected`	DSC 2019	
input	Inundation raster	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Inundation_delta_regularly_inundated`	Pekel et al. 2016	
input	Liberty Island inverse	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Inundation_inverse_liberty_island`	SFEI 2020 (this tool)	- for removing Liberty Island from regularly inundated areas (now perennial open water)
input	Legal Delta	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Boundary_legal_Delta`		- for clipping inundation, marks spatial limit of analysis
output - workspace	Copy of hydrologically connected areas	`hydrologically_connected`		
output - workspace	Vectorized inundation	`inundation`		
output - workspace	Inundation for scenarios	`{scenario}_inundation`		
output - report	Inundation for scenarios	`{scenario}_inundation.shp`		
output - report	Copy of Legal Delta extent	`legal_delta.shp`		
output - report	Inundation metrics for all scenarios	`inundation_metrics.csv`		
output - report	Map of modern inundation	`Modern_inundation.mxd`		

Subsidence

Summary:

The majority of formerly tidal areas in the Delta are currently below sea level due to conversion of land to agriculture, urban development, management of wetlands, and other land uses. The low elevation of these areas makes them more susceptible to risk of flooding from rising sea levels or high intensity rain events. Subsided lands also put the reliability of the state's water supply at risk by increasing the likelihood of saltwater intrusion in the event of a levee-failure event. Land uses that keep soils dry most of the year—like some forms of agriculture and urban development— generally allow subsidence to continue, while those that keep the soils wet—like managed ponds and wetlands—generally limit, halt, or even reverse subsidence. Some forms of cultivation (notably rice and other wetland-based farming) may provide a compromise that allows for agricultural income with less impacts to elevation and greenhouse gas flux.

This module quantifies the current extent of deeply and shallowly subsided lands, the proportion of subsided lands covered by wetted habitat types, and the number of years it would take for existing subsided areas to reach sea level via subsidence reversal.

The analysis is only run on user scenarios with some preparation done on the modern scenario.

Tool analysis methods:

- Finds subsided lands not covered by connected open water.
- Clips subsided lands to wetted and open water habitat type group on subsided lands.
- Erases scenario's wetted and open water habitat types on subsided lands from the modern's equivalent and vice-versa to determine areas gained and lost in the scenario(requires advanced license).
- Extracts years to SLR raster by habitat vision and by wetted habitat types (not including open water) in the habitat vision (requires spatial analyst extension).

Predefined parameters:

For habitat types considered part of the wetted habitat and open water group see "Habitat types" in the "Tool Overview" section.

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
input	Geomorphic zones	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Geomorphic_zones`	SFEI 2020 (this tool)	See metadata for detailed description of source elevation and tidal datum datasets
input	Years to SLR	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Subsidence_years_to_rising_sea_level_via_wetlands`	Deverel and Leighton 2010	
output - workspace	Subsided lands	`modern_subsided_lands`		
output - workspace	Wetted habitat on subsided lands for scenarios	`{scenario}_wetted_habitat`		
output -	Wetted habitat gain on	`{scenario}_wetted_habitat_gain`		

workspace	subsided lands for user scenarios			
output - workspace	Wetted habitat loss on subsided lands for user scenarios	{scenario}_wetted_habitat_loss		
output - workspace	Years to sea-level-rise on subsided lands for user scenarios	{scenario}_subsidence_yrs_slr		
output - workspace	Years to sea-level-rise on new subsided lands for user scenarios	{scenario}_subsidence_yrs_slr_new		
output - report	Subsided lands	subsided_lands.shp		
output - report	Modern wetted habitat	wetted_habitat.shp		
output - report	Wetted habitat gain on subsided lands for user scenarios	{scenario}_wetted_habitat_gain.shp		
output - report	Wetted habitat loss on subsided lands for user scenarios	{scenario}_wetted_habitat_loss.shp		
output - report	Years to sea-level-rise on subsided lands for user scenarios	{scenario}_subsidence_slr.tif		
output - report	Years to sea-level-rise on new subsided lands for user scenarios	{scenario}_subsidence_slr_new.tif		
output - report	Subsidence metrics for all scenarios	subsided_land.csv		
output - report	Wetted habitat metrics for all scenarios	wetted_habitat.csv		
output - report	Years to sea-level-rise metrics for all scenarios	years_to_slr_all.csv		
output - report	Years to sea-level-rise on new subsided lands metrics for all scenarios	years_to_slr_new.csv		
output - report	Maps of wetted habitat for scenarios	{scenario}-wetted-habitat.mxd		
output - report	Maps of years to sea-level-rise for user scenarios	{scenario}-years-to-slr.mxd		
output - report	Maps of years to sea-level-rise on new subsided lands for user scenarios	{scenario}-years-to-slr-new.mxd		

Agriculture

Summary:

Agriculture dominates the Delta landscape, and is among the qualities that define the Delta as a special place. Agriculture is a primary land use, a food source, a key economic sector, and a way of life in the Delta. The Delta's agricultural economy is vital to the region and contributes to California's important agricultural economy. When planning and siting restoration projects, there is a need to balance ecosystem restoration with continued agriculture in the region. This module quantifies the change in extent of agricultural lands, the crop type of converted agricultural lands, and the extent of agricultural lands converted to urban areas (a Delta Plan performance measure).

The analysis is only run on user scenarios with some preparation done on the modern scenario.

Tool analysis methods:

- Extracts all agriculture in modern habitat using the agriculture habitat type group.
- Clips crop type and FMMP type layers by modern agriculture.
- For each user scenario, extracts agriculture in habitat vision by habitat type.
- Gets "changed agriculture" via union with modern agriculture.
- Determines areas where agriculture is lost to urban by intersecting "lost agricultural areas" with the scenario habitat types, and selecting urban habitat type group from the result.
- Gets crop type and FMMP type lost by clipping these datasets to the "lost agriculture" layer.

Key considerations and caveats:

Crop type and FMMP type loss is only analyzed within the spatial constraint of areas of agriculture lost according to habitat type. I.e., if the land cover in the modern habitat layer does not indicate it was previously agriculture but there is a crop type or FMMP type polygon there, it will not be counted. This ensures that the total areas of crop type or FMMP type lost cannot exceed the total area of agriculture lost by habitat change.

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
input	Crop type	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Agriculture_crop_type`	CDWR 2016	
input	FMMP type	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Agriculture_fmmp_type`	CA Dept. of Conservation 2018	
output - workspace	Agriculture habitat cover for scenarios	`{scenario}_agriculture`		

output - workspace	Modern crop types on agriculture	modern_crop_type		
output - workspace	Modern FMMP types on agriculture	modern_fmmp		
output - workspace	Agriculture habitat cover changed for user scenarios	{scenario}_agriculture_change		
output - workspace	Crop types lost for user scenarios	{scenario}_crop_lost		
output - workspace	FMMP types lost for user scenarios	{scenario}_fmmp_lost		
output - report	Agriculture habitat cover for scenarios	{scenario}_agriculture.shp		
output - report	Modern crop types on agriculture	modern_crop_type.shp		
output - report	Modern FMMP types on agriculture	modern_fmmp.shp		
output - report	Crop types lost for user scenarios	{scenario}_crop_lost.shp		
output - report	FMMP types lost for user scenarios	{scenario}_fmmp_lost.shp		
output - report	Agriculture habitat cover changed for user scenarios	{scenario}_agriculture_change.shp		
output - report	Agriculture habitat cover lost to urban for user scenarios	{scenario}_ag_lost_to_urban.shp		
output - report	Agriculture metrics for all scenarios	ag_metrics.csv		
output - report	Crop type metrics for all scenarios	ag_crop_metrics.csv		
output - report	FMMP type metrics for all scenarios	ag_fmmp_metrics.csv		
output - report	Maps of agriculture habitat cover changed for user scenarios	{scenario}-agriculture-change.mxd		
output - report	Maps of crop type lost for user scenarios	{scenario}-agriculture-crop-lost.mxd		
output - report	Maps of FMMP type lost for user scenarios	{scenario}-agriculture-fmmp-lost.mxd		

Infrastructure

Summary:

Infrastructure includes roads, levees, railways, transmission lines, water diversions and oil and gas wells. For a given land-use scenario, compatibility with existing infrastructure is an important factor determining the project's cost and feasibility. In some cases, it may be possible to change existing infrastructure in order to achieve a given land use scenario. In other cases, high cost or regulations limit the degree to which infrastructure may be altered or removed, limiting the set of feasible scenarios. This module quantifies the total extent of infrastructure in the analysis area and identifies infrastructure that might be impacted by changes in land-uses associated with each scenario..

The analysis is only run on user scenarios with some preparation done on the modern scenario. While the levee analysis is handled separately, it is put under the infrastructure section in the report.

Tool analysis methods:

- Copies inputs as modern.
- For each user scenario, extracts affected infrastructure via clip with habitat change layer.

File inventory:

All output metrics in length units of kilometers (where applicable).

Input / Output	Name / Desc.	File Name	Source	Notes
input	Roads	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_delta_roads`	U.S. Census Bureau 2016	
input	Railways	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_rail`	CalTrans Rail Database	
input	Oil and gas wells	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_delta_oil_gas_wells`	California Department of Conservation 2017	
input	Gas pipelines	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_delta_gas_pipelines`	California Energy Commission	
input	Transmission lines	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_delta_transmission_lines`	California Energy Commission	
input	Water diversions	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Infrastructure_`	CDFW 2019	

		delta_water_diversions		
output - workspace	Copy of roads	modern_roads		
output - workspace	Copy of railways	modern_rail		
output - workspace	Copy of oil and gas wells	modern_wells		
output - workspace	Copy of gas pipelines	modern_gaslines		
output - workspace	Copy of transmission lines	modern_tlines		
output - workspace	Copy of water diversions	modern_water_diversions		
output - workspace	Roads on changed habitat cover areas for user scenarios	{scenario}_roads		
output - workspace	Railways on changed habitat cover areas for user scenarios	{scenario}_rail		
output - workspace	Oil and gas wells on changed habitat cover areas for user scenarios	{scenario}_wells		
output - workspace	Gas pipelines on changed habitat cover areas for user scenarios	{scenario}_gaslines		
output - workspace	Transmission lines on changed habitat cover areas for user scenarios	{scenario}_tlines		
output - workspace	Water diversions within 1 km of changed habitat cover areas for user scenarios	{scenario}_water_diversions		
output - report	Copy of roads	modern_roads.shp		
output - report	Copy of railways	modern_rail.shp		
output - report	Copy of oil and gas wells	modern_wells.shp		
output - report	Copy of gas pipelines	modern_gaslines.shp		
output - report	Copy of transmission lines	modern_tlines.shp		
output - report	Copy of water diversions	modern_water_diversions.shp		
output - report	Roads on changed habitat cover areas for user scenarios	{scenario}_roads.shp		
output - report	Railways on changed habitat cover areas for user scenarios	{scenario}_rail.shp		
output - report	Oil and gas wells on changed habitat cover	{scenario}_wells.shp		

	areas for user scenarios			
output - report	Gas pipelines on changed habitat cover areas for user scenarios	`{scenario}_gaslines.shp`		
output - report	Transmission lines on changed habitat cover areas for user scenarios	`{scenario}_tlines.shp`		
output - report	Water diversions within 1 km of changed habitat cover areas for user scenarios	`{scenario}_diversions.shp`		
output - report	Infrastructure metrics (excluding water diversions) for all scenarios	`infrastructure_metrics.csv`		
output - report	Water diversion metrics for all scenarios	`diversion_metrics.csv`		
output - report	Maps of affected roads and railways for user scenarios	`{scenario}-roads-rail.mxd`		
output - report	Maps of affected oil and gas wells for user scenarios	`{scenario}-wells.mxd`		
output - report	Maps of affected gas pipelines for user scenarios	`{scenario}-gas-lines.mxd`		
output - report	Maps of affected transmission lines for user scenarios	`{scenario}-transmission-lines.mxd`		
output - report	Maps of affected water diversions for user scenarios	`{scenario}-diversions.mxd`		

Protected areas

Summary:

The Delta community has a long standing interest in focusing conservation efforts on existing public lands. This module quantifies areas designated as protected or held under a conservation easement (defined by the California Protected Areas Database and the California Conservation Easement Database), and notifies the user if any land use modifications in their scenarios occur within protected areas.

Three maps generated: existing protection status and land use; scenario changes in protected areas

The analysis is only run on user scenarios with some preparation done on the modern scenario.

Tool analysis methods:

- Imports inputs as modern and merges into combined protected areas layer.
- Intersects combined protected areas layer with modern habitat.
- For each user scenario, intersects combined protected areas layer with habitat vision and intersects separately with changed habitat layer.

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
input	CPAD fee/title units	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Protected_area_CPAD_2019`	GreenInfo Network 2019	
input	CCED easements	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Protected_area_CCED_2018`	GreenInfo Network 2018	
output - workspace	CPAD fee/title units	`modern_pareas_feetitle`		
output - workspace	CCED easements	`modern_pareas_easements`		
output - workspace	Merged protected areas	`modern_pareas_merged`		
output - workspace	Habitat types in protected areas for scenarios	`{scenario}_pareas_habitat`		
output - workspace	Changed habitat cover in protected areas for user scenarios	`{scenario}_pareas_changed`		
output - report	Merged protected areas	`modern_pareas_merged.shp`		
output - report	CPAD fee/title units	`modern_pareas_feetitle.shp`		
output - report	CCED easements	`modern_pareas_easements.shp`		
output - report	Habitat types in protected areas for scenarios	`{scenario}_pareas_habitat.shp`		
output - report	Changed habitat cover areas for user scenarios	`{scenario}_pareas_changed.shp`		
output - report	Changed habitat cover in protected areas for user scenarios	`{scenario}_pareas_in_changed.shp`		
output - report	Protected area metrics for modern	`protected_areas_metrics.csv`		
output - report	Protected area metrics for all user scenarios	`protected_areas_by_plan_metrics.csv`		
output - report	Map of CPAD fee/title units	`modern-pareas-feetitle.mxd`		
output - report	Map of CCED easements	`modern-pareas-easements.mxd`		

output - report	Maps of changed habitat cover areas and protected areas for user scenarios	`{scenario}-pareas.mxd`		

Physical suitability

Summary:

Not all potential actions to restore or enhance Delta ecosystem functions are physically suitable in all parts of the Delta. Individuals planning restoration and management actions must therefore carefully consider whether these actions are appropriate for a site's particular landscape position. Important factors that determine what types of activities are appropriate now and in the future include a site's elevation, degree of tidal and fluvial influence, salinity, soil type, and local effects of climate change (including expected sea-level rise and temperature changes), which all vary spatially across the Delta. This module evaluates the suitability of a location in the Delta for proposed scenario land use modifications. Suitability is determined from habitat type and geomorphic zone.

Geomorphic zones are defined based on a combination of land surface elevation and local tidal datums and are comparable to the "elevation bands" defined and mapped in the Delta Plan (DSC 2019). They include the deeply subsided zone (areas with land surface elevations >8 ft below MLLW), shallowly subsided zone (areas <8 ft below MLLW), intertidal zone (between MLLW and MHHW), tidal-terrestrial zone (areas <10 ft above MHHW; referred to as the "sea-level rise accommodation" band in the Delta Pan), and the terrestrial zone (>10 ft above MHHW; referred to as the "floodplain" elevation band in the Delta Plan).

The elevation data used to develop this dataset was a synthesis of multiple topobathymetric digital elevation models compiled and mosaiced by SFEI staff. These data sources were (in order of priority):

1. 2017 Delta LiDAR (DWR and USGS 2019)
2. 2017 USGS SF Bay Delta DEM 10-m (Fergoso et al. 2017)
3. 2012 DWR SF Bay Delta DEM 10-m (Wang and Ateljevich 2012)
4. 2013 USGS ConED Topobathymetric Model of San Francisco Bay, California (USGS 2013)
5. 2019 USGS National Elevation Dataset (USGS 2019)

Tidal datums were derived from a map developed by Siegel and Gillenwater (2019).

Elevation cutoffs between zones are in line with those defined in the Delta Plan. Work to define what landscape restoration and management actions are appropriate in each geomorphic zone is summarized in the Delta Plan (DSC 2019; Appendix 4A), as well as work by SFEI and partners (SFEI-ASC 2016, Delta

Conservancy 2019). Details about the suitability of each habitat type in each zone as defined in this module are also detailed in the table in Appendix 1.

This analysis is run only on the user's input scenarios. Development of this module was also supported by the US Fish and Wildlife Service.

Tool analysis methods:

- Intersects scenario overlay with geomorphic zones.
- Applies flag type and class to attributes based on habitat type and elevation zone.

File inventory:

Input / Output	Name / Desc.	File Name	Source	Notes
input	Geomorphic zones	`data\DLSPT_data_package_SFEI\DLSPT_data_package_SFEI.gdb\Geomorphic_zones`	SFEI 2020 (this tool)	See metadata for detailed description of source elevation and tidal datum datasets
input	Elevation flags crosswalk table	`data\tables\elevation_notifications_v5.csv`	SFEI 2020 (this tool)	See Appendix 1
output - workspace	Geomorphic zones	`geomorphic_zones`		
output - workspace	Physical suitability for user scenarios	`{scenario}_scenario_suitability`		
output - report	Geomorphic zones	`geomorphic_zones.shp`		
output - report	Physical suitability for user scenarios	{scenario}_suitability.shp		
output - report	Copy of elevation flags crosswalk table	`suitability_elevation_crosswalk.csv`		
output - report	Physical suitability metrics for user scenarios	`suitability_metrics.csv`		
output - report	Map of geomorphic zones	`geomorphic-zones.mxd`		
output - report	Maps of flagged areas for user scenarios	`{scenario}-suitability.mxd`		

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Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
tidal freshwater emergent wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Red	Land currently too low for proposed tidal emergent wetland	Tidal freshwater emergent wetland in a subsided zone	Not currently physically suitable. The land is currently too low to support tidal freshwater emergent wetland. The creation of tidal freshwater emergent wetlands in subsided areas will only be possible through fill placement or long-term sustained reverse subsidence via the creation of non-tidal managed wetlands. Subsidence reversal wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries). Note that even if they do not ultimately recover intertidal elevations, non-tidal wetlands managed for subsidence reversal can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, and provide habitat to waterbirds and other species.
tidal freshwater emergent wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Red	Land currently too low for proposed tidal emergent wetland	Tidal freshwater emergent wetland in a subsided zone	Not currently physically suitable. The land is currently too low to support tidal freshwater emergent wetland. The creation of tidal freshwater emergent wetlands in subsided areas will only be possible through fill placement or long-term sustained reverse subsidence via the creation of non-tidal managed wetlands. Subsidence reversal wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries). Note that even if they do not ultimately recover intertidal elevations, non-tidal wetlands managed for subsidence reversal can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, and provide habitat to waterbirds and other species.
tidal freshwater emergent wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Green	Land potentially suitable for proposed habitat type	Tidal freshwater emergent wetland in intertidal zone	Potentially suitable. Over the the near-term, the intertidal zone is an appropriate place to prioritize the restoration of tidal freshwater emergent wetlands. Over the long-term, with projected sea level rise, upland accommodation space will likely be needed to allow for marsh migration.
tidal freshwater emergent wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Land currently too high for proposed tidal emergent wetland, but potentially suitable over long-term	Tidal freshwater emergent wetland in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Although these areas are currently too high to support tidal marsh, they are likely to become intertidal with sea-level rise over the long-term, assuming there are no barriers to tidal flows. Over the near-term, seasonal wetland or terrestrial habitat types are likely to be more appropriate in this area and can transition to tidal marsh as sea levels rise (managers should prioritize the removal of future barriers to tidal flows).
tidal freshwater emergent wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Red	Land currently too high for proposed tidal emergent wetland	Tidal freshwater emergent wetland in terrestrial zone	Not currently physically feasible. This area is too high to support tidal freshwater emergent wetlands now and with an additional 10 ft of sea-level rise. Seasonal wetlands and terrestrial habitat types are likely be more appropriate in this area.
non-tidal freshwater emergent wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but will likely require management	Non-tidal freshwater emergent wetland in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that the land is currently too low to support non-tidal freshwater emergent wetlands in their natural landscape position (upstream floodplains) with unimpeded hydrologic connections to occasional floodplain-inundating fluvial flows. Non-tidal emergent wetlands in subsided areas will instead need to be remain saturated via high groundwater and the use of water management infrastructure. Though they would rapidly transition to open water in the event of a levee failure, non-tidal emergent wetlands in the subsided zone (especially managed ones) can help halt and reverse ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
non-tidal freshwater emergent wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but will likely require management	Non-tidal freshwater emergent wetland in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that the land is currently too low to support non-tidal freshwater emergent wetlands in their natural landscape position (upstream floodplains) with unimpeded hydrologic connections to occasional floodplain-inundating fluvial flows. Non-tidal emergent wetlands in subsided areas will instead need to be remain saturated via high groundwater and the use of water management infrastructure. Though they would rapidly transition to open water in the event of a levee failure, non-tidal emergent wetlands in the subsided zone (especially managed ones) can help halt and reverse ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
non-tidal freshwater emergent wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Non-tidal freshwater emergent wetland in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not non-tidal freshwater emergent wetland. Tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
non-tidal freshwater emergent wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Non-tidal freshwater emergent wetland in tidal-terrestrial zone	Potentially suitable. Note that fully functional non-tidal freshwater emergent wetlands should generally be located in areas that are hydrologically connected to fluvially-influenced channels and/or have artesian groundwater conditions. If this is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
non-tidal freshwater emergent wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Non-tidal freshwater emergent wetland in terrestrial zone	Potentially suitable. Note that fully functional non-tidal freshwater emergent wetlands should generally be located in areas that are hydrologically connected to fluvially-influenced channels and/or have artesian groundwater conditions. If this is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
managed wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Green	Land potentially suitable for proposed habitat type	Managed wetland in a subsided zone	Potentially suitable. Managed wetlands in subsided areas can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. Note that managed wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries).
managed wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Green	Land potentially suitable for proposed habitat type	Managed wetland in a subsided zone	Potentially suitable. Managed wetlands in subsided areas can help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. Note that managed wetlands are more likely to recover intertidal elevations in shallowly subsided areas than deeply subsided areas (with time frames on the order of decades instead of centuries).
managed wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Managed wetland in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not managed wetlands. Tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
managed wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Consider alternative habitat type: non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat type	Managed wetland in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Although these areas are currently too high to support tidal marsh, they are likely to become intertidal with sea-level rise over the long-term, assuming there are no barriers to tidal flows. Over the near-term, non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat types might be more suitable in this area than managed wetlands and not require active management. These habitat types could then potentially transition to tidal marsh as sea levels rise (managers should prioritize the removal of future barriers to tidal flows).
managed wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Yellow	Consider alternative habitat type: non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat type	Managed wetland in terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Over the near-term, non-tidal freshwater emergent wetland, seasonal wetland, or terrestrial habitat types might be more suitable in this area than managed wetlands and not require active management.

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
willow riparian scrub/shrub	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow riparian scrub/shrub	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow riparian scrub/shrub	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
willow riparian scrub/shrub	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow riparian scrub/shrub	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
valley foothill riparian	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
valley foothill riparian	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
valley foothill riparian	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
valley foothill riparian	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
valley foothill riparian	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow thicket	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow thicket	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Woody riparian habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Woody riparian habitat types can be sustained in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
willow thicket	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Woody riparian habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. If land in the intertidal zone is hydrologically connected to the channel network, it is likely to naturally support tidal freshwater emergent wetland, not woody riparian habitat types. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
willow thicket	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in tidal-terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.
willow thicket	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Woody riparian habitat type in terrestrial zone	Potentially suitable. Note that fully functional woody riparian habitat types in the Delta should generally be hydrologically connected to fluvially-influenced channels. If that is not feasible, other seasonal wetland or terrestrial habitat types might be more suitable in this location.

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
vernal pool complex	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [1]
vernal pool complex	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [2]
vernal pool complex	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult to restore. Seasonal wetland habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
vernal pool complex	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
vernal pool complex	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.
wet meadow/seasonal wetland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [3]
wet meadow/seasonal wetland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [4]
wet meadow/seasonal wetland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult to restore. Seasonal wetland habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
wet meadow/seasonal wetland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
wet meadow/seasonal wetland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
stabilized interior dune vegetation	Terrestrial zone	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [5]
stabilized interior dune vegetation	Terrestrial zone	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
stabilized interior dune vegetation	Terrestrial zone	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making terrestrial habitat types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
stabilized interior dune vegetation	Terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
stabilized interior dune vegetation	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
alkali seasonal wetland complex	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [6]
alkali seasonal wetland complex	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Seasonal wetland habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the subsided zones of the Delta and would be difficult and cost-prohibitive to restore. These habitat types are more suitable in the tidal-terrestrial and terrestrial zones. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
alkali seasonal wetland complex	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Seasonal wetland habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Seasonal wetlands habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making seasonal wetlands vulnerable in this location over the long-term. Additionally, seasonal wetlands require particular physical processes and edaphic/hydrologic conditions (e.g. hardpan development and a perched groundwater table for vernal pool complexes) that generally do not currently exist in the intertidal zone of the Delta and would likely be difficult to restore. Seasonal wetland habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, particularly given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
alkali seasonal wetland complex	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in tidal-terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands. Note that seasonal wetlands in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
alkali seasonal wetland complex	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Seasonal wetland habitat type in terrestrial zone	Potentially suitable. Seasonal wetland habitat types (like wet meadow/seasonal wetland, vernal pool complex, and alkali seasonal wetland complex) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain seasonal wetlands.
grassland	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [7]

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
grassland	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
grassland	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making terrestrial habitat types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
grassland	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
grassland	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
oak woodland/savanna	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future. [8]
oak woodland/savanna	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Terrestrial habitat type in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in subsided zones, but would rapidly transition to open water habitat in the event of a levee failure event, making this habitat type vulnerable in this location over the long-term. Managed and non-tidal wetlands might be more suitable in this location to help halt ongoing subsidence, reduce the risk of levee failure, sequester carbon, provide habitat to waterbirds and other species, and potentially enable the restoration of tidal freshwater emergent wetlands in the future.
oak woodland/savanna	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Consider alternative habitat type: tidal freshwater emergent wetland	Terrestrial habitat type in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) could conceivably be created in the intertidal zone, but would be expected to transition to tidal freshwater emergent wetland if hydrologically connected to the Delta's channel network (such as in the event of a levee failure event), making terrestrial habitat types vulnerable in this location over the long-term. Terrestrial habitat types are generally more suitable in the tidal-terrestrial and terrestrial zones. Hydrologically connected tidal freshwater emergent wetlands might be more suitable in this location, especially given the relatively limited extent of the intertidal zone (where tidal freshwater emergent wetland restoration is feasible).
oak woodland/savanna	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in tidal-terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types. Note that terrestrial habitat types in the tidal-terrestrial transition zone would be expected to transition to tidal freshwater emergent wetlands over the long-term as sea-levels rise. Managers should generally plan for and accommodate this transition by removing barriers to tidal flows and ensuring ample terrestrial habitat will remain in areas above the tidal-terrestrial transition zone.
oak woodland/savanna	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Terrestrial habitat type in terrestrial zone	Potentially suitable. Terrestrial habitat types (like grassland, oak woodland/savanna, and stabilized interior dune vegetation) are suitable in the tidal-terrestrial and terrestrial zones, where they were historically located, and where it is likely most feasible to restore prerequisite hydrologic, geomorphic, and biologic processes needed to sustain terrestrial habitat types.
open water	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Green	Land potentially suitable for proposed habitat type	Open water in a subsided zone	Potentially suitable. Specific types of hydrologically connected open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes (including "flooded islands"). Note that multiple factors, including the degree of subsidence, local turbidity, and resulting flows will influence the ecological characteristics of any newly flooded islands and the resulting value to native aquatic species (Durand 2017). In hydrologically disconnected areas (e.g. on subsided islands protected by levees), suitable open water types include non-tidal ponds.
open water	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Green	Land potentially suitable for proposed habitat type	Open water in a subsided zone	Potentially suitable. Specific types of hydrologically connected open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes (including "flooded islands"). Note that multiple factors, including the degree of subsidence, local turbidity, and resulting flows will influence the ecological characteristics of any newly flooded islands and the resulting value to native aquatic species (Durand 2017). In hydrologically disconnected areas (e.g. on subsided islands protected by levees), suitable open water types include non-tidal ponds.
open water	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in intertidal zone	Potentially suitable. Specific types of open water suitable in the intertidal zone include tidal channels and tidal ponds or lakes.
open water	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in tidal-terrestrial zone	Potentially suitable. Specific types of open water suitable in the tidal-terrestrial zone include tidal and fluvial channels, tidal and nontidal perennial pond or lakes, and tidal and nontidal intermittent pond or lakes.
open water	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Open water in terrestrial zone	Potentially suitable. Specific types of open water suitable in the terrestrial zone include fluvial channels, nontidal perennial pond or lakes, and nontidal intermittent pond or lakes.
urban/barren	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.

Appendix 1: Habitat type suitability by geomorphic zone for Physical Suitability module

Habitat type	Geomorphic zone (SFEI)	Elevation zone (Delta PLan)	Flag type	Flag class (simple)	Habitat type & geomorphic zone	Flag description
urban/barren	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Urban area in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Potentially suitable, but proposed anthropogenic habitat type will need to be protected from sea-level rise over the long term	Urban area in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Urban areas located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. This tool does not evaluate the suitability of urban development in any particular location beyond noting the flood risk inherent in locating urban development in these zones. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely.
urban/barren	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Urban area in terrestrial zone	Potentially suitable. Urban development is subject to myriad local, county, and state regulations, including Delta Plan policies requiring new commercial, residential, and industrial development in the Delta to be located wisely. There are a variety of ways to increase support for native wildlife in and around urban areas, including urban greening and native plantings, low-impact development, beneficial reuse of wastewater, and construction of water-treatment wetlands.
agriculture/non-native/ruderal	Tidal zone (deeply subsided)	Deeply subsided (more than 8 ft below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources--will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal zone (minimally subsided)	Shallowly subsided (up to 8 feet below MLLW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in a subsided zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources--will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal zone (intertidal)	Intertidal (between MLLW and MHHW)	Yellow	Potentially suitable, but land too low to support proposed habitat type in the event of a levee failure event	Agriculture in intertidal zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources--will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Tidal-terrestrial zone	Sea level rise projection (0 to +10 ft MHHW)	Yellow	Potentially suitable, but proposed anthropogenic habitat type will need to be protected from sea-level rise over the long term	Agriculture in tidal-terrestrial zone	Potentially suitable, but there are important complicating factors to consider. Note that agriculture located in the subsided, intertidal, and tidal-terrestrial zones must be protected from flooding and sea-level rise with levees and other flood control infrastructure. Certain crop types, including rice, can help reduce the rate of ongoing subsidence and thereby limit future increases in levee instability and flood risk, while also providing some benefits to native wildlife. Working landscapes – agricultural lands managed to support biodiversity and provide habitat resources--will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat, reverse subsidence, and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).
agriculture/non-native/ruderal	Terrestrial zone	Floodplain (more than 10 feet MHHW)	Green	Land potentially suitable for proposed habitat type	Agriculture in terrestrial zone	Potentially suitable. Working landscapes--agricultural lands managed to support biodiversity and provide habitat resources--will play an important role in achieving ecosystem goals in the Delta. There are opportunities for agricultural lands in all zones to incorporate wildlife-friendly agriculture practices, including seasonally flooding fields; modifying levees to support marsh or woody riparian channel margin habitat (Davenport et al. 2016); integrating perennial managed wetlands into the agricultural matrix to provide habitat and generate revenue through the carbon market (e.g., Deverel et al. 2014; American Carbon Registry 2017); and implementing other best management practices/techniques (e.g., agroforestry and diversified farming) to improve habitat and connectivity for wildlife (Kremen and Merenlender 2018).