When is Aquatic Resource Type Conversion Appropriate: A Framework for Cleaning Sand out of the Gears and a Case Study for McInnis Marsh

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Wetland and stream restoration projects may sometimes involve converting one "type" of aquatic habitat to another "type" (e.g., managed salt ponds into tidal marshes, depressional wetlands into streams, marsh into transition zone habitat). This "type conversion" may be necessary and beneficial in the context of addressing watershed plans or regional restoration goals, or in achieving resiliency to climatic changes (Goals Project 2015). Conversion can also occur through other large-scale, complex actions (e.g., mitigation banking initiatives). Whether driven by habitat restoration goals or compensatory mitigation needs or both, regulatory oversight typically governs the process. Holistically assessing such conversion through the regulatory lens is challenging for permitting programs. The challenge stems from how to accurately determine the overall value of an aquatic resource based on site-specific ecological properties and in the context of larger regional ecosystem management and goals. This is further compounded when assessing aquatic habitats that provide intrinsically different functions and services. Assessments must also account for the fact that wetlands and streams are not static ecosystems, but rather dynamically changing through time due to natural and anthropogenic factors, many of which are difficult to control or even accurately assess (e.g., sea level rise). These challenges are further exacerbated due to urbanization, conflicting human-environment goals, and the evolving state of habitat restoration science.

Type conversion (i.e., replacing one aquatic type with a different aquatic habitat type) is recognized by agencies as a "sand in the gears" problem that can stymie planning and permitting because such actions typically require multiple agency authorizations (which may or may not be consistent with internal policies), habitat resource trade-offs, and consensus on ecosystem goals. The lack of consistent, defensible analysis based on transparent evaluation has been shown to impede critically needed habitat restoration (Bourgeois 2018; SFBRA 2022). To address this challenge, an interagency team of federal and state regulators and resource managers in California developed a structured and transparent approach for evaluating the appropriateness of aquatic resource type conversion. The resulting framework can support project planning and inform regulatory evaluation by helping to answer: 1) what loss or gain of function is expected from various aquatic resource type conversions, and 2) whether conversion might be ecologically (or functionally) appropriate. The framework is not intended to inherently value one type of aquatic resource over another, nor to supersede regulatory mandates. Rather, the intent is to support agencies' technical and regulatory decisions by providing a standardized, transparent set of tools and approaches that can inform discussions between agencies and with project proponents during the project evaluation phase, with a goal of ensuring that projects are not only permittable, but environmentally beneficial.

The framework consists of three modules that can be done either sequentially or in parallel. Together they can be used to assess the feasibility/suitability, functions, and regional context of a proposed type conversion project (Figure 1).

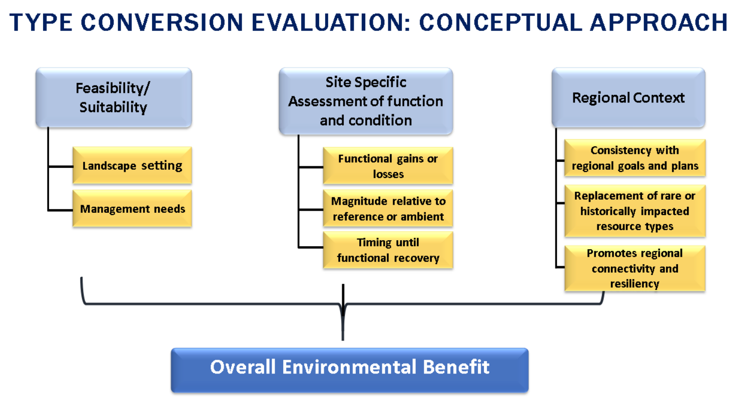

Figure 1. Conceptual approach for evaluating aquatic resource type conversion.

MODULE 1: ASSESSING FEASIBILITY & SUITABILITY

Due to historic alterations of hydrology and changes in land use restoring to a different aquatic resource type will be successful only if the physical requirements of the new aquatic resource type are compatible with the current landscape setting. Therefore, it is important to compare the requirements of the new target aquatic resource type with existing landscape characteristics. Often, restored wetlands require ongoing management to maintain certain functions over time. The level of intensity (or ease) of necessary ongoing management is also an important feasibility consideration. Wetlands that require more intensive, difficult, frequent, or costly management will be less likely to remain healthy and to perform their expected functions over time. Assessing feasibility also serves as a mechanism for consideration of uncertainty; type conversion plans with more questionable feasibility are inherently more uncertain.

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Feasibility depends on suitability of the new aquatic resource type for the landscape position where it is being established, major physical drivers, and the level of management necessary to sustain the new resource. Ideally, systems would be self-sustaining over the long-term, but that may not always be possible given anthropogenic constraints and climatic fluctuations. Thus, there are numerous design elements to consider when type conversion is anticipated to determine the relative suitability of the landscape to support both the existing and the expected future aquatic resource types:

- Landscape setting
- Hydrology
- Geomorphic setting (topography, substrate)
- Sediment sources, supply, and processes [erosion (both natural and because of engineering) and ag gradtion] and typical sediment type (sands, gravels, fines)
- Amount and quality of buffer (invasive plants, roads, agriculture, soil compaction, barriers, other bufer stressors)
- Connectivity (linkages for animal movement or seed dispersal between habitat types)
- Ability to control stressors from the adjacent landscape

Feasibility is evaluated using a standardized checklist to rate how well various criteria have been met, along with justifications for each assigned rating. The feasibility assessment is comprised of two parts, each of which is scored separately: 1) suitability for the landscape position, and 2) difficulty or intensity of management necessary to support the future aquatic resource type after construction and in perpetuity.

MODULE 2: EVALUATING SITE SPECIFIC FUNCTION & CONDITION

Wetlands and other aquatic habitats perform a variety of functions and services. However, these functions may be different from one wetland type to another or occur to different levels depending on the wetland condition. For example, wet meadows generally have high primary productivity compared to estuarine sandy fringe habitat, but wet meadows typically provide no function as fish nurseries. Consequently, type conversion has the potential to result in both a change in the level of function and shift in the types of functions that are performed. The second portion of the framework provides an approach for evaluating the relative change in function between the original and ultimate wetland type to support an evaluation of whether such a change is acceptable and/or desirable. Unlike the previous module, Module 2 does not address likelihood of success but focuses on potential implications of type conversion on wetland functions.

The intent of this section of the framework is not to facilitate "trading" of functions between different aquatic habitat types. Therefore, change in function is assessed in a relative fashion whereby the existing aquatic resource is assessed against available ambient or reference data from a watershed or regional basis for the same type of resource (e.g., vernal pools are only compared with vernal pools, tidal marsh to tidal marsh, mudflats to mudflats, and so on). The same analysis is conducted for the proposed aquatic habitat type. Once those two separate analyses are complete, then the change in a given function is compared between the original and proposed type. A relative comparison allows agency staff to evaluate relative gains and losses of different functions associated with type conversion and avoids direct functional comparisons between aquatic resource types by evaluating where along the gradient of function (or condition) each wetland type exists.

When comparing relative functional gains and losses between aquatic resource types, it is important to identify the functions that are most environmentally relevant (e.g., providing habitat for endangered species, sea level rise adaptation, and nutrient retention), as well as the indicators or assessment tools that can be used to measure their gains and losses. Functions develop over different time scales (some on the order of decades) to reach conditions like those found at reference sites (Steyer et al. 2003). Type conversion may result in temporary loss of functions due to site disturbance (e.g., earth moving and vegetation removal), with recovery happening over a period of years following restoration. The time required for a site to reach maturity can lead to functions increasing or decreasing over different timeframes. Temporal differences in development of functional maturity may or may not be problematic depending on the importance of the function from a site-specific and regional context. This module of the framework also documents temporal factors so they can be considered when an agency determines if type conversion is acceptable or desirable. Including a consideration of temporal loss also provides a way to account for uncertainty in proposed type conversion because that uncertainty increases with the time necessary for those functions to develop.

MODULE 3: CONSIDERING REGIONAL CONTEXT

Aquatic resources do not occur in isolation but exist as an integrated set of systems that collectively perform greater functions than what occurs at each individual site. For example, aquatic-dependent species may rely on different types of systems for different aspects of their life history, such as depressional wetlands for breeding and riverine wetlands for foraging and cover (Mitsch and Gosselink 2007; USEPA 1995). Similarly, energy dissipation, organic matter cycling and sediment processes rely on combinations of aquatic resources that are distributed, yet connected through the landscape (Cole et al. 2007; Craft and Casey 2000; Krause et al. 2017). The third module of the framework provides a process to consider how type conversion may support or detract from the larger regional functions and connections that individual aquatic resources contribute to.

Proposed type conversion should be considered in the context of landscape-scale functions. Converting from one aquatic resource type to another should promote larger landscape functions by increasing diversity and complexity of the landscape, promoting physical, biogeochemical, or hydrologic connection, and facilitating migration or biological linkages (Smith et al. 2018). Type conversion should also support (and be consistent with) watershed or regional goals where they have been established (Goals Project 2015).

Contribution to regional condition can be assessed using statewide, regional, or watershed plans and associated data and/or by review of regional maps and aerial photographs. Effects of type conversion to regional goals and function should be assessed based on:

- Consistency with regional or watershed goals
- Replacement of regional rare aquatic resource types
- Progress toward replacement of historical losses
- Regional connectivity of habitats and overall landscape complexity
- Regional water quality, recharge, recreation, or other social benefits
- Resiliency relative to landscape constraints and stressors

OVERALL DETERMINATION OF APPROPRIATENESS OF TYPE CONVERSION

The ultimate determination on the expected environmental outcome should be based on a review of all three modules. As a general rule, the following decision tree can be used to help make a determination of "Overall Environmental Benefit":

A. If either of the feasibility criteria are negative, the type conversion should be considered undesirable/negative

B. If neither of the feasibility consideration is negative, then:

   a. If both site-specific function and regional context are positive →net benefit

   b. If either site-specific function or regional context are positive and the other is indeterminate → net benefit

   c. If either site-specific function or regional context are positive and the other is negative → indeterminate

   d. If either site-specific function or regional context are negative and the other is indeterminate → undesirable/negative

   e. If both site-specific function and regional context are negative → undesirable/negative

   f. If both site-specific function and regional context are indeterminate → default to the result of the feasibility analysis

CASE STUDY

The authors conducted a detailed case study of a proposed type conversion restoration project in the San Francisco Bay Region of California to demonstrate application of the framework. The McInnis Marsh restoration project aims to restore tidal exchange to a 180-acre parcel located in the margins of the San Francisco Bay (a.k.a., Baylands; Figure 2). The parcel is a typical example of tidal marsh historically cut off from both the Bay and upper watershed creeks by levees and is currently substantially subsided aquatic habitat that is disconnected from adjacent creeks. Restoration would require aquatic resource conversion from seasonal, non-tidal wetlands and open water to tidal marsh wetlands and high marsh transitional habitat (ecotone levees). Restoring connectivity between tidal Baylands, adjacent upslope lands and alluvial creek sediments provide opportunity for natural adaptation (upslope movement) of the system in response to climate drivers (rising tides and increasing storm magnitude and frequency), as well as increased habitat connectivity and diversity for wildlife species. Specifically, the project would create hydraulic connections via extensive levee breaches to reconnect the wetland to San Pablo Bay, Miller Creek, and Las Gallinas Creek and construction of interior marsh channels, while reusing dredged material to raise base elevations and build transitional ecotones (Figure 2). As conceived, this project facilitates multi-beneficial Bayland management, consistent with regional goals, that seeks to improve current ecological functions and the long-term resiliency of both infrastructure and ecological habitat.

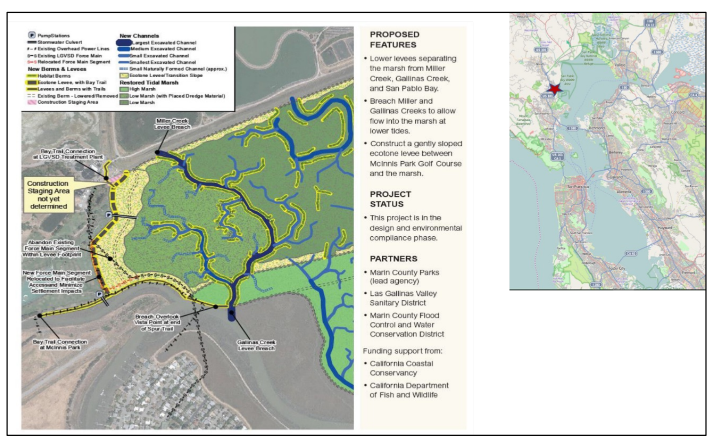

Figure 2. Proposed McInnis Marsh restoration project. Inset map denotes project location within larger San Francisco Bay.

The McInnis Marsh project was specifically chosen to pilot the type conversion framework because the project requires substantial fill into the wetland to achieve its goals of providing significant climate adaptation, wildlife tradeoffs, and habitat transition zones. Transitional ecotone habitats in the form of horizontal levees are of particularly interest in a regulatory context, and in the larger context of habitat conversion and valuation. The placement of sediment into heavily subsided marshes and adjacent uplands can provide significant long-term resiliency (e.g., sea level rise adaptation, creating marsh migration space in a constrained landscape, and flood attenuation), and results in short-term opportunity costs to ensure the larger ecosystem success (BCDC 2019; Goals Project 2015). Agencies must assess when and where incorporating these ecotones is appropriate to protect and restore Bayland processes now and into the future. This pilot analysis addresses ecotone habitat throughout the three modules as a critical component of future wetlands (i.e., the slopes of the ecotone are evaluated as future marsh rather than as their current condition as uplands to reflect future expected conditions). The fill of open water or existing marsh for wetland transition habitat is encapsulated in the scoring under the "Feasibility and Suitability" module given the increase in hydrologic and habitat connectivity and sea level rise resilience. In the "Site Assessment of Function/Condition" module, the ecotone is scored as wetland with higher functions related to sediment retention, shoreline stabilization, and support for partially aquatic species. The "Regional" module reflects the reality of the need for complex ecotones in areas around the Bay to accomplish greater marsh outcomes.

Pilot analysis was conducted during pre-application coordination and planning with all regulatory and wildlife resource agencies, based on preliminary design drawings, basic habitat mapping, and limited species surveys. Tables 1 through 6 below demonstrate application of the framework analysis for McInnis Marsh, starting with evaluation of Modules 1 – 3 (Tables 1-4) and then final compilation to determine overall environmental outcome of the proposed type conversion action (Tables 5-6).

Module 2 is the most complex of the three modules, thus we provide an illustration of the analysis behind several functions shown in Table 2. We chose two functions - Wholly Aquatic Habitat and Species Support and Carbon Sequestration. The former is identified as a critical, high-priority function related to the McInnis Marsh project outcomes, while the latter is a function that is rarely directly measured in the field on a project-by-project basis. For this project, both functions were assessed qualitatively.

When using indirect measures or qualitative assessments, relative change in function can be evaluated based on the change in "functional categories" between the current and expected future wetland types. An increase in functional category (e.g., low to medium or high) would be considered positive, a decrease would be considered negative, and no change would be considered indeterminate (Figure 3). Another simple approach is to utilize reference condition data for evaluation of relative functional gains and losses: plotting the ratio of observed function to reference expectations for the current wetland type against the ratio of expected function to reference expectations for the proposed future wetland type (Figure 4). If the current vs. future relative function point falls above the upper dashed line it would be considered positive, if it falls below the lower dashed line, it would be considered negative, and if it falls between the two, it would be considered indeterminate.

Carbon Sequestration

The relative ability of the existing and proposed future wetland type to sequester carbon was based on a comparison of estimated relative plant biomass and relative saturation area from regional observations (Figure 3). Based on this analysis, the proposed type conversion at McInnis Marsh would increase expected carbon sequestration from Low to Medium.

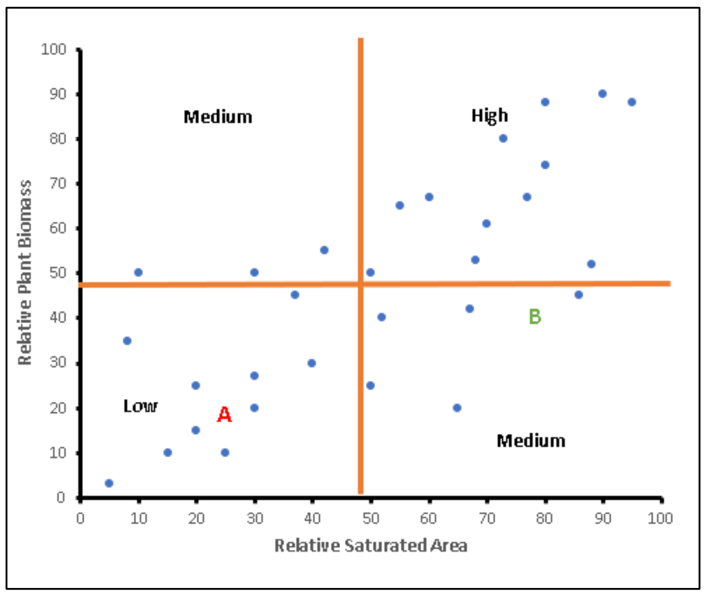

Figure 3. Estimate of change in carbon sequestration capacity between (A) current and (B) expected future wetland type, as based on a combination of relative plant biomass and saturated area as a proxy for carbon sequestration.

Wholly Aquatic Species

Type conversion will result in different fish assemblages in the restored tidal marsh compared to the existing riverine environment. Fish species richness, as an indicator of aquatic species support, was evaluated relative to expected reference conditions for rivers (existing type) and connected riverine-tidal marsh (proposed future type) using local data sources (Kamman Hydrology and Avocet Research 2016; NRCD 2020; Tetra Tech and ESA 2021). Existing conditions were based on observed fish species richness in Miller and Gallinas Creeks. Expected future conditions were based on the proposed restoration design in comparison to both marsh and river "reference" condition (Table 3). The analysis suggests that relative fish richness will improve following conversion to the new wetland type, likely due to improved habitat diversity and increased wetland size (vs. current conditions), both of which would contribute to higher richness (Figure 4).

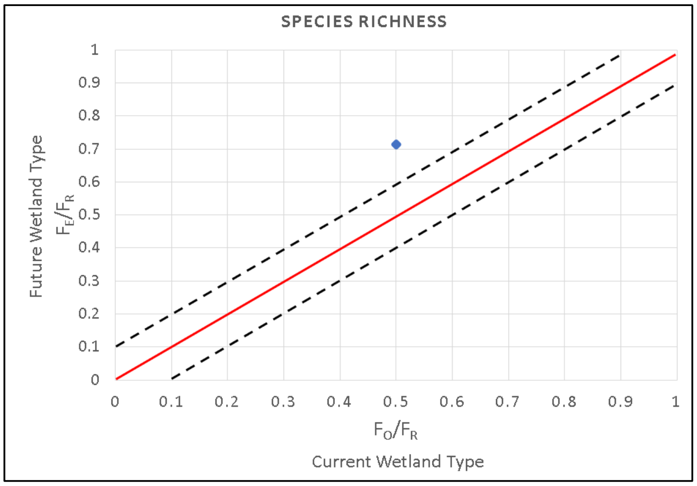

Figure 4. Comparison of relative richness of fish species. Each axis represents richness relative to expected reference conditions. The point above the red line indicates a net benefit of relative richness associated with the type conversion.

REGULATORY APPLICATION OF FRAMEWORK

Consideration of type conversion from one aquatic resource type to another is one of numerous project elements already accounted for in Clean Water Act (CWA) regulatory programs. However, as demonstrated in the literature review (Stein et al. 2019), this is usually a subjective analysis by individual staff and no specific guidance exists for how to scientifically evaluate and document type conversion determinations. Conversion is generally discouraged unless justified based on a watershed approach, regional rarity, or other factors, but again there is no structured approach for agency determinations and the outcome of type conversion cannot be assumed to result in either a negative or positive impact. A lack of consistent guidance and shared technical approach amongst regulators makes permitting alignment difficult. Further compounding the issue, the increased pace and scale of threats to ecological resiliency require agencies to conduct change analysis under higher levels of risk and uncertainty. This framework highlights type conversion as a critical aspect that will become more prominent over time, and potentially contentious for regulators. The framework is intended to be an analytical structure applied by project proponents and reviewed by regulators (ideally during the pre-application phase) to improve decision efficiency and efficacy. It can also be a tool for analysis of alternatives and to help highlight areas of incongruency. It is important to note that the framework does not require collection of new data; it uses the same data sources compiled for any CWA permitting application. The analysis can be updated as new data becomes available and/or if there are significant changes in the project proposal or design.

We caution users to carefully consider the threshold of significance for application of this framework. The framework is built to consider all levels of ecological scale, from site-specific to landscape to regional. This holistic context is required to accurately assess inherently complex ecological relationships over both short- and long-term. The framework yields the most value for effort expended when applied to complete ecosystem modifications that address fundamental changes in watershed habitat distribution, not just one component of a system.

The complete framework document can be found here: https://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/1110_ConversionFramework.pdf.

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Table 1. Module 1, Feasibility and Suitability.

Criteria	Question/Consideration	Landscape Suitability (1= No not suitable, 2= Yes suitable)	Ease of Management (1= High Level of Management to sustain system, 2= Moderate Level, 3= Low Level)
Landscape Setting	**Watershed processes are not adversely altered for the intended aquatic resource type within the hydrologic unit.** Recreation of tidal marsh from diked wetlands in same historic landscape setting; reconnection of the marsh with upper watershed via creeks would restore historic process. Natural hydraulics & elevation are highly modified & subject to current land-use constraints (primarily residential housing, infrastructure) – restoring tidal hydraulics will require levee breaching & berms placement, which may require ongoing maintenance (sediment redistribution & augmentation due to subsidence). Tidal flow & circulation will increase with action. Adjacent southern areas currently receive 0-2ft flooding on King tides; med-high SLR predictions (2100: 42" + 100yr storm surge) will result in 6-10ft flooding for these southerly areas – analysis did not specifically look at adjacent flood risk w/project, but peak water elevations only expected to increase slightly [@10 & 100yr tidal & fluvial floods: Miller Crk reduced by 0.1-1ft, N & S Forks Gallinas Crk increase by 0.1ft]. Modeled increase for Gallinas Crk due to scour from the project breaching; may have indirect LT impacts to southern creek levee that currently protects infrastructure.	2 Rationale: restoration of tidal marsh in original landscape setting	2 Rationale: Internal berms require potential LT management due to subsidence. Both a reduction (less creek dredging, tidal gates removed) & potential increase (offsite levee scour in Gallinas Creek) in maintenance of proposed watershed processes
	Will the conversion result in an aquatic resource of the appropriate class in that landscape setting? Current wetland classes are depressional/slope & high tidal marsh. Restoration of complex tidal marsh would occur in historic landscape setting with reconnection of suitable source water (riverine and tidal). Establishment of ecotone will provide necessary migration space for wetlands, as well as wildlife biodiversity, refugia, and adaptability.	2 Rationale: restoration of historic class -complex tidal marsh	3 Rationale: low level of management to maintain tidal marsh complex -quality of that marsh will depend on other factors

Hydrol-ogy	**Will the primary source of water to the site be appropriate for the new aquatic resource type without engineering a delivery system that requires long-term control or maintenance?** Reconnection of tidal and fluvial flows via breaching. Removal of current tidal gates. 90% Miller Crk flow re-routed to site and then connected to Gallinas (similar to historic). Tidal flow & circulation will increase – will increase water quality and balanced sediment retention.	2 Rationale: reconnection of historic tidal & fluvial flows	3 Rationale: once constructed, passive delivery system of tidal & fluvial flows
	Does the site have the ability to adapt to accommodate future hydrologic conditions associated with climate change or expected change in water use practices? Muted tidal action (70%) for first few decades after construction until outboard marsh breach scouring can increase to 100%. *[Note, remaining uncertainty associated with this muted tidal action in terms of scouring potential.]* Will eventually double the tidal prism in the creeks. Stormwater culverts (2) will be relocated & one will be attenuated through the ecotone; operating pumps will be needed. Fluvial scour on Miller Crk elbow will require design consideration for O&M needs. Offsite Gallinas levee may need further adaptation design for SLR resiliency. Without habitat ecotone & room for migration, high future risk of conversion of the outboard mature marsh to subtidal habitat by 2100, and submergence of internal wetlands**.**	2 Rationale: breaching and scouring processes will adapt over time	2 Rationale: appropriate reuse/ finishing/flow attenuation of stormwater to marsh, but pumps needed. Scour processes may cause indirect impacts that need management. Mature marsh cannot accommodate SLR changes w/o project.
Geo-mor-pholog	**Does the site have the appropriate underlying geology, and will the site maintain hydric soils (if appropriate)?** Restoring creek & tidal connections will reduce frequency of needed dredging due to scour processes. Within the Gallinas Baylands, the project and adjacent areas have physically similar characteristics (tidal range, geology, habitat types) and land-use pressures. Underlying geology of project area is filled & subsided hydric soils, so should develop easily once flows reintroduced. Both creeks would increase in width by 60%. Ecotone will provide geomorphic stability and adaptability for SLR pressure.	2 Rationale: occurring in historic geomorphic setting, already has hydric soils	3 Rationale: breaching will re-engage natural geomorphic processes; already has hydric soils; no active management for geomorphology factors

Sedi- ment	**Is the anticipated sediment supply to the site appropriate to maintain geomorphic stability for the new aquatic resource type?** Reconnection to floodplain will allow marshes to receive coarse sediment from Miller & Gallinas Creeks, as well as receive suspended sediment (SSC) from tidal action. Current wetland is 3-5ft subsided as compared to adjacent marshes; requires fill to initially increase elevation in some portions of the site (from onsite cut & fill, & reuse of dredged material from creeks to fill area west of the new main channel – uncertainty of volume available & needed). Some onsite & offsite adjacent areas may need LT sediment augmentation (e.g., habitat berms, Gallinas Crk flood protection levee) as scouring increases over time due to project. Ecotone will provide upland-marsh transition stability and adaptability for SLR pressure.	2 Rationale: reconnection of more natural, historic sed sources (tidal, fluvial); ecotone, tidal channels, & berms provide stability	2 Rationale: moderate uncertainty for ongoing fill amount to maintain elevations, particularly berms & levees.
	Will anticipated sediment processes (e.g., accretion, scour) provide appropriate elevations for the new aquatic resource type? 80% of the site is subsided to 1-2ft NAVD. Moderately favorable conditions for marsh accretion - estimated at 3mm/yr w/200mg/L SSC as based on north Bay reference sites [muted tidal will take longer to accrete]; this will yield mix of low and mid-marsh system. Modeling indicates elevations should maintain pace w/SLR depending on other factors with moderate to high uncertainty (exact SLR heights, SSC changing in Bay). Time to reach tidal marsh elevation estimated at 10-20yrs. Some levees may need LT management as scouring increases in creeks to reach equilibrium. Subsidence of internal habitat berms possible.	2 Rationale: reconnecting systems to allow natural sediment processes in the project areas.	2 Rationale: Moderate frequency of LT interventions may be needed, although this is ameliorated by the more natural project design connecting sedimentary processes.

Con-nected-ness	**Is the site connected or in close proximity to other aquatic resources or uplands that will support species and habitats for the new aquatic resource type?** Site w/in San Pablo Bay Wildlife Area; adjacent to Gallinas Crk Baylands that support high quality habitat for tidal marsh obligate birds; outboard mature marsh; regionally significant ESA populations nearby; Bayside linkage with other green spaces (China Camp, San Pedro Mtn, Sears Point, Hamilton Wetlands, San Pablo Bay National Wildlife Refuge). McInnis Park is a protected area. Miller Crk supports critical steelhead population & would benefit from estuarine habitat restoration.	2 Rationale: site located w/in & adjacent to protected habitats that support desired focal species	3 Rationale: no management actions needed to improve location
	Does the site have adequate buffers to help reduce effects of stressors from the adjacent landscape? Design includes increasing spatial & elevational buffers (ecotone) and reducing the perimeter-area ratio which results in more robust natural buffers (dense, complex, native vegetation, tidal channels). Adjacent to lower-impact land-uses: open space golf course, Bay Trail, wastewater treatment facility. Will still have WQ impact pressures and proximity to urban landscape. Focusing on relocating the main trial (Bay Trail) to upland/high-marsh elevation to avoid low-marsh impacts; however, many informal trails in area may persist.	1 Rationale: Somewhat increasing buffer capacity through actions, but not much room to substantially increase.	2 Rationale: moderate management needed to maintain buffers (veg management on ecotone, human use of trails)
Stressor control	**Can the site be designed to control aggressive plant species and/or reduce invasion by feral or non-native predators?** Reconnection of hydrology and natural processes should help reduce invasive veg species. Ecotone maintenance will include reclaimed water to potentially reduce drought-tolerant upland veg nuisance species. Reducing perimeter-area ratio & disconnecting levees should reduce access points into marsh proper. High efforts needed to control feral predators due to high proximity to urban landscape (cats, racoons, raven/crow, etc).	2 Rationale: designed to reduce invasion (ecotone, building appropriate elevations & complexity)	1 Rationale: will need high level of management to control predators; moderate level to control invasive veg until marsh veg is established
	Will the site be designed to minimize effects of excessive human visitation, grazing, or other source of persistent disturbance? Moving Bay Trail and onsite infrastructure to reduce human disturbance; but still have many informal trails – will need to discuss further from design perspective. Ecotone width will provide high tide refugia for species; tidal marsh habitat is a deterrent. No grazing on site.	2 Rationale: designed to reduce anthropogenic disturbance (ecotone, creating large marsh, moving trails)	2 Rationale: will need moderate level of management to control off-trail human visitation & indirect effects from trash, etc. of an urban marsh
	Total Score	21	25

Table 2. Module 2, Site Specific Function and Condition.

Function	Priority		Evaluation Method		Function Relative to Ambient/Reference		Direction & Relative Magnitude of Change		
	Rank	Rationale	Direct	Indirect	Pre-Conversion (Current Conditions)	Post-Conversion (Expected Future Conditions)	Timeframe (score)	Relative Change (score)	Net Change
Wholly aquatic habitat and species support (e.g., fish, amphibians)	High	Project would re-establish diverse tidal marsh connected to upper watershed creeks; this would create new habitat to support fish rearing/ spawning (marsh channels w/ refugia)	Opportunistic Fish observations	Qualitative (regional indices of fish and invertebrate condition)	Steelhead in Miller Crk	Per Biological Assessment Report (BA) - up to 20% increase in sensitive fish species	2yrs (3)	20% (1)	3
Partially aquatic habitat and species support [Birds]	High	Function provided varies for different species in seasonal vs tidal system (e.g., ducks to wading birds); Project targeting ESA species (rails)	Bird surveys	Qualitative (Extent of key habitat based on vegetation, elevation, etc.)	Approximately 10 special status bird species observed onsite	Per BA, up to 50% increase in special status bird species	3-4 yrs (2)	50% (2)	4

Partially aquatic habitat and species support [Mammals]	High	Both wetland types can support mammals but project targeting ESA species (Salt Marsh Harvest Mouse [SMHM]); new ecotone critical for better buffer & refugia to SMHM. Evaluated separately from birds due to management importance of SMHM.		Qualitative (Extent of key habitat for target SMHM)	SMHM occurs in adjacent Baylands	mammal usage expected to be relatively comparable; however, ecotone and berms will provide uplift in available refugia	> 5 yrs (1)	20% (1)	1
Biodiversity support	High	both pre and post project wetland types will support biodiversity, but level of support may differ.		CA Rapid Assessment Method (CRAM) – conditional index scores	65%	78%	> 5 yrs (1)	20% (1)	1
Surface water storage	Low	both pre and post project wetland types support water storage but at different levels		Qualitative	Low due to low residence time in the creeks; mod storage in seasonal wetlands	High due to larger area accessible for open water and tidal channels for water retention	1-2 yrs (3)	(2)	6
Organic matter/ nutrient cycling	Low	both pre and post project wetland types support nutrient cycling but at different levels		Qualitative	Mod due to lotic creeks and seasonal wetlands	High due to longer water residence times in marsh with higher generation of organic matter & biomass	4-5 yrs (2)	(2)	4

Removal of elements and compounds	Low	both pre and post project wetland types support element cycling but at different levels		Qualitative	Mod filtration In current system due to low water flow/flushing some emergent vegetation	High due to longer residence times, tidal flushing, more area for inundation, and higher biomass	3-4 yrs (2)	(1)	2
Sediment/ particulate retention	Mod	sediment retention will occur at different levels in the pre vs. post project wetland type. This function can be assessed quantitatively, but there is no standard index or assessment approach available		Qualitative (Inundation hydroperiod, plant density)	<10 acres of muted seasonally inundated marsh	120 acres of tidally inundated marsh	4 yrs (2)	> 50% (2)	4
Groundwater recharge	Low	both pre and post project wetland types support groundwater recharge		Qualitative	Mod due to residence time in seasonal wetlands	Some additional freshwater input flushing from Miller Crk, but negligible	N/A	0	0

Carbon sequestration	Low	Tidal wetlands have high sequestration potential, as opposed to seasonal wetlands.		Qualitative (Area x biomass)	Low	Moderate - tidal marshes in CA sequester ~0.08% of annual GHG, and ~23% of the annual CO2 emissions	> 5 yrs (1)	(1)	1
Shoreline stabilization/energy dissipation	Mod	Proposed design expected to enhance function – the ecotone will stabilize and protect transitional margins; the strategic breaches and marsh channels will allow for flow energy stabilization.	Can be quantitatively assessed from detailed modeling, but there is no standard index or assessment approach available.	Qualitative (Extent of ecotone (width) and vegetation density)	Current levee slope provides 75 ft. of transgression space with minimal vegetation density	Wider horizontal levees to provide ~1,000 ft. of transgression space with high density and diversity of vegetation	2 yrs (3)	> 50% (2)	6
Recreation and aesthetics	Mod	The post-project condition aims to enhance recreational condition of trails and ecotone.	recreational use surveys		currently <10,000 visitors/year	expect 30,000 visitor/year @ post restoration	0-2 yrs (3)	> 50% (2)	6
TOTAL									38

Table 3. Relative fish richness in existing and proposed future wetland type.

Site/Condition		Fish Species Richness
McInnis Marsh (current)	F_O	7
McInnis Marsh (future)	F_E	21 (Mean of River & Marsh Reference)
Napa River (reference)	F_R River	14
Hamilton Wetlands (reference)	F_R Wetland	28

Table 4. Module 3, Regional Context.

Criterion	Direction of Change	Explanation
1. Consistency with regional goals	Positive	Site identified as high priority for conservation (high value habitat for marsh bird species particularly rails that require patch sizes of >247ac, potential species extirpation w/higher SLR predictions) and as future San Pablo Bay tidal restoration action. Meets regional tidal marsh restoration goals, lies within Priority Conservation Area, and per Adaptation Atlas site identified as high potential to provide migration space for Baylands.
2. Replacement of regional rare resource types	Neutral	Current resource type (seasonally ponded, diked Baylands) is not 'rare'. New resource is not necessarily rare. No rare resources are impacted by substantive sediment placement for ecotone and berms.
3. Replacement of historical losses	Positive	Shifts landscape profile closer to historical condition (at present, only 34% of historic tidal marsh abundance in San Francisco North Bay exists).
4. Regional connectivity and complexity of habitats	Positive	Would connect fragmented watershed habitat along shoreline, increase patch size, and restore tidal marsh complexity (increase tidal channels, veg cover & structure); Miller Crk is identified as a top stream for area with Priority 2 & 3 stream conservation goal.
5.Contribution to regional water quality	Positive	Miller Crk is a 303(d) impaired waterway, restoring complex marshes will capture sediment & urban contaminants in Gallinas & Miller Creeks, & allow for WQ finishing treatment for San Pablo Bay as well. Methyl mercury may result in the ST and is an unavoidable issue for Bayland restoration.
6.Contribution to regional groundwater recharge	Neutral	Novato Valley Groundwater Sub-basin is one of 2 GW basins in Marin that supplies limited GW for community supply – basin is listed as low to very low priority to develop LT sustainability plans; saline intrusion in this region is an issue in areas bordering San Pablo Bay. No apparent difference w/current and proposed habitat.
7.Contribution to recreational or social benefits	Neutral	Current open space that will remain open to public with appropriate restrictions to not compromise ecological functions; will help with completing a segment of the Bay Trail (complementary mission goals with wetland restoration – support for wildlife oriented public access). Loss of direct connection to Bay edge due to removal of existing public and informal access trails on the outboard bayward levee.
8. Resiliency relative to landscape constraints and stressors	Positive	Classified as watershed with moderate vulnerability to development (less than 45% urban/industrial); several factors improve site's resiliency to SLR and current habitat stressors: ecotone design (buffer), return to natural wetland/stream processes in appropriate landscape, increased habitat connectivity in watershed for wildlife (migration potential). Current CRAM scores for nearby estuarine wetlands are generally in good category, so likely no relative regional change. However, regional stream health is lower so will be a positive relative regional shift with project implementation. High suitability for restoring diked Baylands and increasing wetland migration space as less urban density along shoreline.
Total Positive	5	

Table 5. Module Summary Scoring Table.

Module	Number of Criteria	Scoring of each Criterion	Threshold(s)	Categories
Module 1. Feasibility Landscape Suitability	11	No = 1 Yes = 2	Sum 17	Suitable ≥ 17 Unsuitable <17
Module 1. Feasibility Management Intensity	11	Difficult = 1 Moderate = 2 None needed = 3	Sum 25 Sum 20	Positive ≥ 25 Indeterminate 20-24 Negative < 20
Module 2. Site Specific Function	11	% Change ≤ -50% = -2 -50% to -15% = -1 -15% - +15% = 0 15 to 50% = 1 ≥ 50% = 2 Timeframe > 5 yr = 1 3-5 yr = 2 0-2 yr = 3 Combined Scoring = Change score x Time score	Sum 11 Sum 5	Positive ≥ 11 Indeterminate 5-11 Negative ≤ 5
Module 3. Regional Context	8	Negative or Neutral = 0 Meets Goal = 1	Sum 4 Sum 2	Positive ≥ 4 Indeterminate 2-3 Negative < 2

Table 6. Overall Environmental Outcome: the proposed McInnis Marsh type conversion from seasonal, mixed wetlands to tidal marsh-connected riverine complex is deemed to be overall positive and a net benefit to the environment regarding numerous ecological functions and values.

	Positive	Indeterminate	Negative	Rationale
Feasibility – landscape suitability	X			Historic tidal marsh setting that was diked off; will restore high connectivity for restoration components and tidal marsh goals; high adaption strategy to SLR with substantial ecotone and strategic breaching
Feasibility – ease of management	X			Moderate amount of adaptive, ongoing sediment augmentation/manipulation may be needed after initial construction; lack of control over some stressors
Site-specific Function	X			Top high priority functions show an increase over time; weighted functions also show increase in functions. No negative net changes.
Regional Context	X			Overall support for the regional context with change from current to proposed wetland