be sinuous or braided; for steep marshes, channels tend to be straighter. Channel density, the amount of channel habitat per acre of marshplain, is directly related to *tidal prism*, the volume of water that flows into and out of the marsh. An upper marsh with a small tidal prism typically will have fewer channels than a lower marsh with a larger tidal prism. (Goals Project 2000~~.~~)

A *microtidal marsh* is a tidal marsh that receives a small tidal range, including marshes with naturally small tidal ranges (e.g. Gulf of Mexico). Tidal *choking* occurs when less than full tidal flow occurs because of a physical impediment. ~~Areas that do not receive full tidal flow are frequently~~ These areas are also referred to as being "muted." This muting can result from the presence of natural formations such as a sand bar or of human-made structures such as tide gates, culverts, or other water control structures. Muted tidal marshes exhibit many of the same features of fully tidal marshes, although they frequently lack the same range of plant diversity. Muted tidal marshes may be important to some wildlife groups such as shorebirds during the fall migration, but may also exclude other species. (Goals Project 2000~~.~~)

Also according to the Goals Report, a high-quality marsh has

- a natural transition to adjacent uplands,
- wide upland buffers to minimize human disturbance,
- connections with other large patches of tidal marsh that enable marsh-dependent birds and small mammals to move safely between them,
- pans in the marshplain and along the marsh/upland transition,
- other wetland types and mudflats nearby,
- a dominance of appropriate species of native plants and animals, and
- a minimum of uplands or structures intruding into or fragmenting the marsh to discourage predator access.

Tidal Wetland Restoration

Tidal wetland restoration involves hydrology, civil engineering, biology, and other scientific and engineering disciplines. This section provides a brief overview of the processes and factors involved in tidal wetland restoration. These factors were considered in developing the habitat restoration options described later in this section.

Tidal wetland restoration is a long-term process. As stated in the *Baylands Ecosystem Habitat Goals* report, produced by the San Francisco Bay Area Wetlands Ecosystem Goals Project (Goals Project 1999) (pp. 149–150):

> Tidal wetlands take time to develop; when a site is restored, the initial set of habitat components will evolve for many years. After establishment, a tidal marsh with adequate sediment typically evolves in the following ways: (1) the drainage network becomes less complex, (2) remaining channels become deeper and narrower, (3) salinity gradients across the marsh plain become more variable

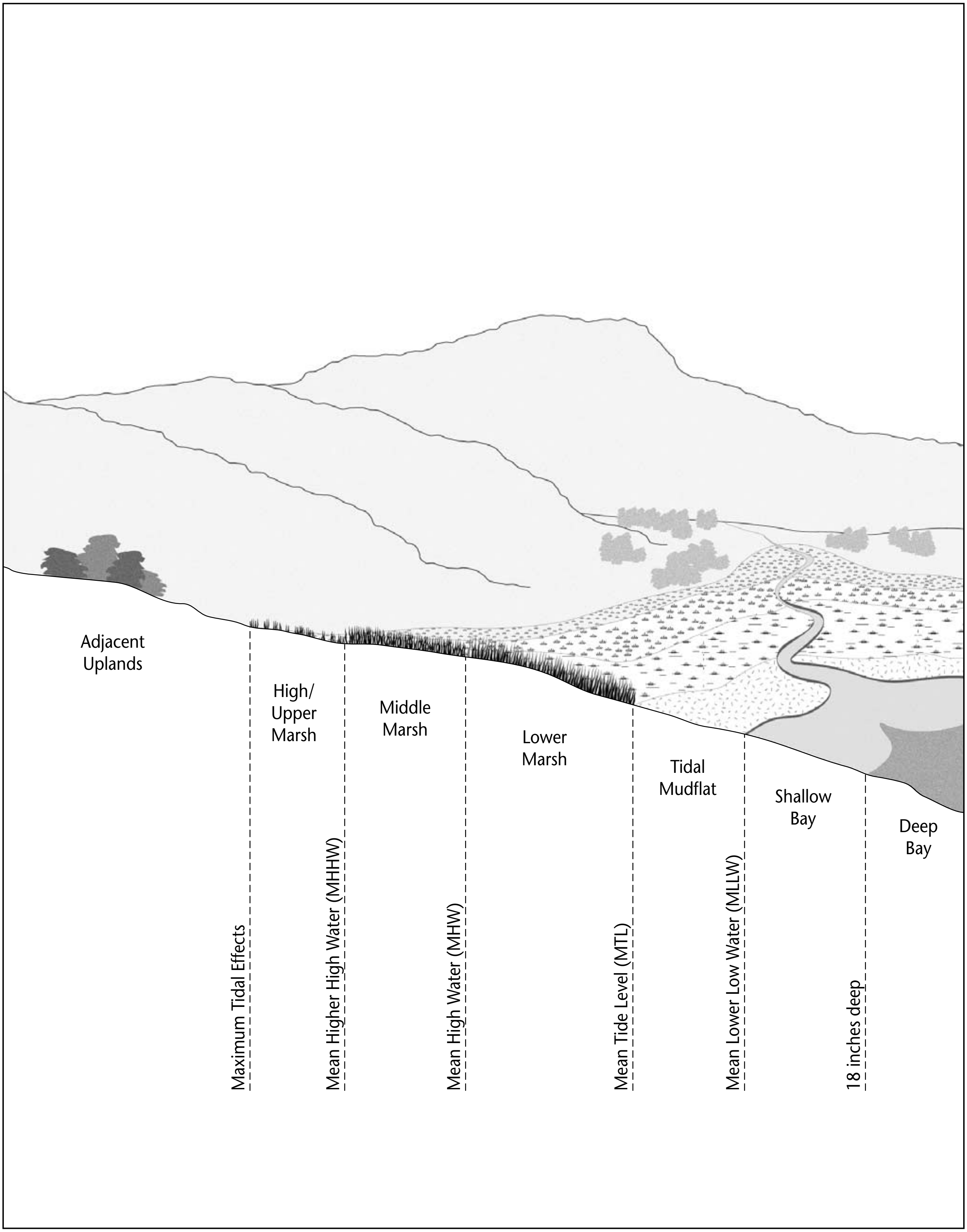

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Figure 2-13
Marsh Tidal Elevations

and steeper, (4) the amount of marsh plain that is not directly serviced by any channel increases, (5) surface drainage decreases, and (6) the amount of pans increases. Even at restoration sites where there is rapid sedimentation (e.g., Pond 2A in North Bay and the Petaluma River Marsh), it may take many years, even decades, before the marshes exhibit a full array of habitat features.

~~Also according to the Goals Report, a high-quality marsh has~~

- ~~a natural transition to adjacent uplands,~~
- ~~wide upland buffers to minimize human disturbance,~~
- ~~connections with other large patches of tidal marsh that enable marsh-dependent birds and small mammals to move safely between them,~~
- ~~pans in the marshplain and along the marsh/upland transition,~~
- ~~other wetland types and mudflats nearby,~~
- ~~a dominance of appropriate species of native plants and animals, and~~
- ~~a minimum of uplands or structures intruding into or fragmenting the marsh to discourage predator access.~~

Tidal Habitat Evolution

During the evolution of subtidal areas (the elevations of most pond bottoms are at or below mean tide level [MTL]) to fully functioning marsh, there are typically a series of successive habitats. Initially, sediment is deposited in the subtidal areas and intertidal mudflats develop. As sediment continues to deposit, portions of the area reach elevations where colonization by lower marsh vegetation is feasible. Once lower marsh vegetation is established, it continues to trap sediment and organic detritus, and the elevation of the site increases further to middle marsh plain. Upper marsh may also form along the upland edge (preexisting high ground) such as the levees.

The habitat restoration options were analyzed by PWA to better characterize the evolution of the site over the next 50 years. Evolution of the project area was evaluated in terms of creation and loss of subtidal, intertidal mudflat, lower marsh, middle marsh (marshplain), and upland/transition habitats, both within the breached ponds and in the remnant slough channels between ponds. The analysis assumed that the rate at which marshes evolve after being opened to the tide is a function of

- initial site elevation;
- vegetation colonization elevations; and
- sedimentation rates, which vary depending upon suspended sediment supply, tidal inundation, and wind/wave resuspension.

The analysis also assumed good low-tide drainage within the ponds. Poor drainage can limit delivery to the ponds and impede establishment of vegetation.

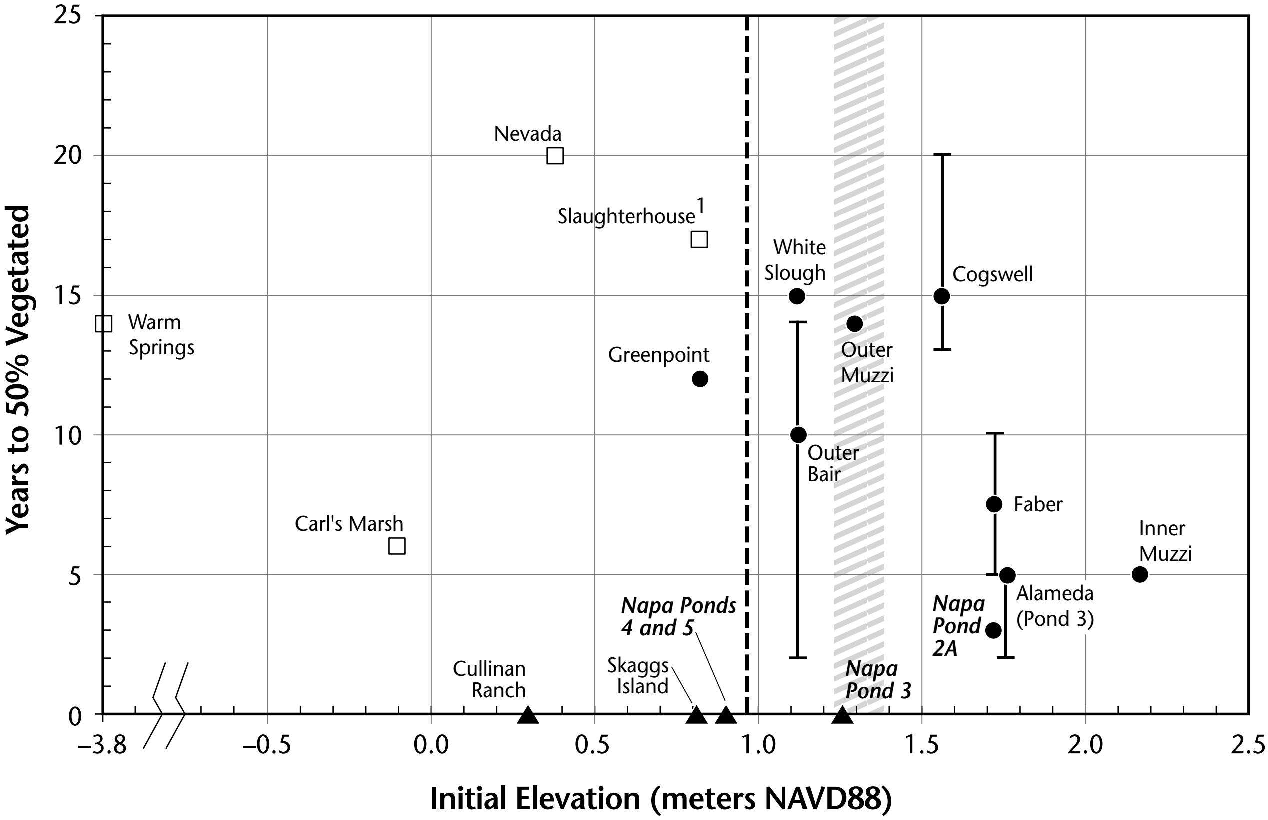
The initial site elevation of a restoration site greatly influences how quickly the site can be restored. Sites that are at or near the height required for initial vegetation colonization typically are restored much more quickly. Figure 2-14 compares initial elevation of restoration sites in the San Francisco Bay to the time it took for the site to reach 50% vegetative cover. The initial site elevations of the ponds in the Napa River Unit are shown in Figure 2-3. A digital elevation model of the pond interiors was used to calculate colonization as a function of elevation (Figure 2-15). As can be seen from Figure 2-15, all ponds are subsided below the level where vegetation colonization is expected to occur and Pond 3 is the closest to reaching an elevation suitable for vegetation colonization.

Vegetation colonization observed at other restored marshes in San Francisco Bay has been used to predict vegetation rates, patterns, and colonization relative to tidal elevations. It has been assumed for the ponds that initial colonization by lower marsh species (predominantly cord grass, bulrush, and cattail) would occur only on high-elevation mudflats, 0.3 meter above MTL and higher. Vegetation would extend to lower elevations through lateral colonization, down to MTL. Lower marsh vegetation is assumed to gradually increase in percent coverage. Once fully established (100% coverage), lower marsh is assumed to transition to middle marsh after 10 years. Middle marsh vegetation up to mean higher high water (MHHW) has been assumed to increase more quickly, from 0% to 100% over 3 years from initial colonization.

Since the ponds are subsided below vegetation colonization elevations in many areas, sedimentation rates will control the evolution of tidal habitats once the ponds are breached. According to the *Baylands Ecosystem Habitat Goals* report (p. 19),

> Although deposition rates vary around the Bay, tidal marshes eventually reach intertidal heights suitable for plants, and later, with the addition of organic sediment that the plants provide, the marshes reach equilibrium with sea level rise. Initial accretion rates of more than two feet per year are common in deeply subsided areas, but these rates decrease as the marsh plain rises… Tidal marsh restoration projects underway at several sites in the Estuary indicate that substantial accretion and re-colonization by marsh vegetation can occur quickly. For example, the Petaluma River Marsh has accreted sediment at a rate of about 1.5 feet per year since the site was opened to tidal action in 1996, and marsh vegetation is becoming well established (Siegel 1998). Marsh vegetation began to colonize Pond 2A in the Napa Marsh within six months after it was opened to tidal action in 1995 (Swanson, pers. comm.).

An initial assessment of existing sediment fluxes to the system compared to projected sediment demand by year with the restoration indicates that the current influx of sediment is more than the maximum demand. However, existing sediment supply may not be sustainable once the restoration occurs, because of the increased sediment sink and changes in the regional sediment budget. Conversely, sediment supply may actually increase as a result of the erosion of the existing tidal sloughs that run through the site. The uncertainty in the long-term sediment supply is considered in the phasing of the habitat restoration options.



● Age when 50% vegetated

□ Current age if not 50% vegetated (as of Year 2000)

▲ Planned Napa River Salt Marsh restorations

Notes:

Shaded vertical bar identifies the approximate *Spartina foliosa* colonization elevation.

Dashed vertical line indicates the minimum elevation for the lateral colonization of bulrush.

Error bars represent the range of uncertainty based on the data available to bracket the timeframe.

NAVD88 elevations are approximate.

[1] Damped tides for many years have slowed site evolution at the Slaughterhouse site.

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Source: Philip Williams and Associates 2002.

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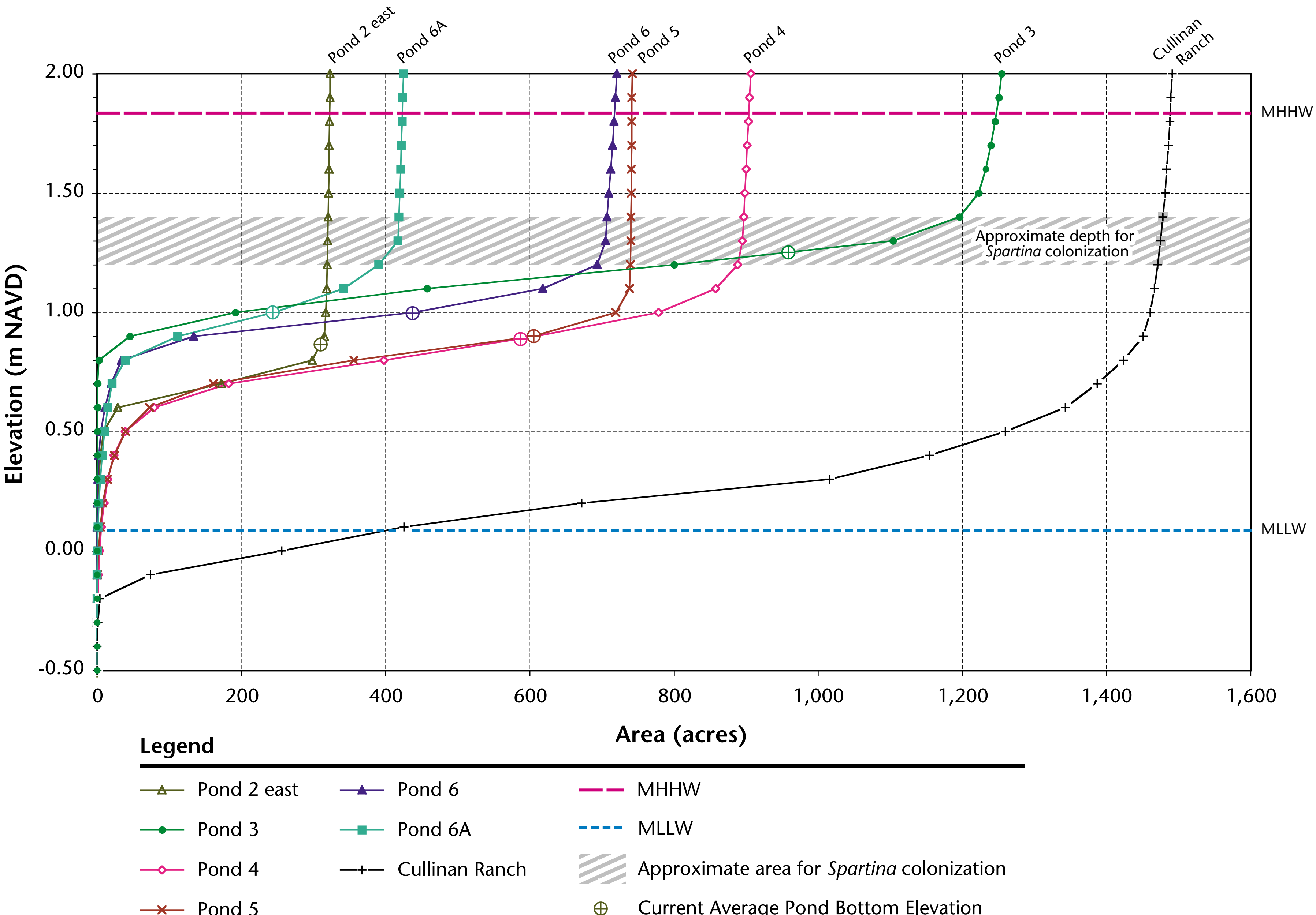
Figure 2-14
Initial Elevations and Years to Vegetation Establishment



Source: Philip Williams and Associates 2002

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Figure 2-15
Plant Colonization as a Function of Elevation by Pond

Sedimentation is also affected by wind/wave action and by neighboring projects. Waves generated in the ponds by wind could reduce the sedimentation rates by either resuspending recently deposited muds or keeping suspended sediments from depositing. Cullinan Ranch, located between SR 37 and the project area, is owned by USFWS as part of the San Pablo Bay National Wildlife Refuge and is slated for restoration to tidal marsh in 20047 at the earliest. Once levees are breached, the demand for sediment in the Napa River Unit will increase, reducing the amount available to the breached ponds.

Design features can be used to speed marsh evolution and to nurture the evolution of marsh components. Faster marsh evolution would reduce potential impacts associated with fringing marsh habitat loss that would occur as a result of scouring of the existing slough channels (once ponds are breached and the tidal prism is increased). The following design features are being considered for the Napa River Unit:

- blocking the borrow ditches between the levee breaches with sediment to keep them from capturing tidal circulation;
- regrading a portion of the levees to an elevation of MHHW by sloping them into the ponds;
- excavating starter channels, and using the excavated sediment to create berms; and
- placing limited amounts of fill to speed initial vegetative colonization and offset short-term decreases in marsh habitat.

These design features are described below. The specific design features applicable to each habitat restoration feature are described under each of the habitat restoration options.

Ditch Blocks. A *ditch block* is simply an area of earth fill that crosses an existing borrow ditch or other channel to inhibit flow. *Borrow ditches* are humanmade drainage channels located adjacent to levees. The purpose of the ditch block is to inhibit existing borrow ditches from capturing the tidal supply and impeding reestablishment of the natural historic channels. Ditch blocks would be constructed based on a consideration of natural marsh morphology. Ditch blocks will be placed between levee breaches to avoid fish entrainment at low tide.

The levees adjacent to the proposed ditch block locations would be lowered to provide fill. Levees would be lowered close to MHHW to maximize generation of relatively dry earth, while maintaining a weight-bearing surface for construction equipment. The ditch blocks would be approximately 100 feet long and 40 feet wide at the top. They would have a finished grade of about MHHW with an average height of 4 feet, and 5:1 side slopes.

Levee Lowering. Levee lowering would consist of excavating the upper portion of an existing levee, and partially filling an adjacent borrow ditch or pond with the excavated material. Borrow ditches would not be filled completely; they would allow continued movement of aquatic species. Levee lowering as referred to here would be in addition to that accompanying the construction of ditch blocks.

Levees would be lowered for several reasons. Levees are human-made features, and can provide access and habitat for predators that compromise the ecological objectives of restoration. Levees can also act as barriers to species migration by creating discontinuous habitat. The lowering of levees near large patches of fringing marsh to elevations consistent with upper marsh vegetation, particularly gumplant *(Grindelia stricta)*, can provide high-tide refugia for marsh species, reducing the risk of predation during high winter tides. The lowering of levees to elevations consistent with marsh vegetation where smaller sections of fringing marsh along slough channels are expected to erode can maintain connectivity between larger patches of fringing marshes, so that marsh species traveling between marshes are less subject to predation. Each habitat restoration option includes a total number of feet of levee that would be lowered, but the exact locations for levee lowering would be determined in consultation with resource agencies, in order to best serve marsh species. The figures for each habitat restoration option only show the initial work to identify sections of levees to lower; these figures are subject to change.

The crest elevation of certain sections of levees would be lowered to an elevation consistent with marsh vegetation and habitat. Levee lowering would consist of moving earth from the upper part of the levee sideways onto the back slope and into the adjacent borrow ditch, if appropriate.

Starter Channels and Berms. A *starter channel* is an excavated channel extending from a breach into a pond. Starter channels would benefit habitat restoration by facilitating more rapid channel and marsh development, and may increase the eventual density of channel drainage. Starter channels would help establish a desired channel pattern, typically similar to the historic pattern, which is likely to result in maximum habitat benefits. Starter channels would provide habitat for fish soon after construction, and would promote the more rapid formation of smaller channels that may ultimately become habitat for rails and other wildlife. The starter channels would also improve site drainage, which may enhance the rates of sedimentation and vegetation establishment.

A starter channel would typically follow a semisinuous path consistent with the historic channel path. The constructed cross section would be roughly trapezoidal. The optimal channel size is the estimated equilibrium channel size. However, actual channel dimensions may be smaller, depending on construction practicality and costs. For example, a much smaller channel can still provide benefit and a much larger channel can be constructed without adversely affecting the restoration. Starter channels could be excavated at some or all of the levee breaches.

Sediment excavated from the starter channels would be placed into berms. ~~on one or both sides of the starter channel.~~ A berm would likely be constructed on only one side of the channel, but berms could be constructed on both sides. The berms would be discontinuous so that side-channels are not obstructed. A *berm* is an embankment of earth fill located within a pond. Berms would directly facilitate rapid development of a diversity of marsh habitat by providing ground elevations conducive to vegetation establishment. Berms would also facilitate marsh establishment by serving as dissipaters of wave energy, creating more sheltered conditions conducive to sedimentation and vegetation colonization.

The proposed berms would be located parallel to the starter channels. The berm crest elevation would vary around MHHW. The intent would be to create an irregular, wide, low-height mound with flat slopes and a sinuous shape roughly paralleling the starter channels. ~~A berm would likely be constructed on only one side of the channel, but berms could be constructed on both sides.~~

Fill Placement. This design feature would consist of placing up to 100 acres of earthen fill (sediment) into the southern portion of Pond 4, or a similar location with low historic channel density. The purpose of this fill would be to accelerate evolution to a vegetated marsh. The sediment would be placed no higher than 1 foot below MHHW elevation, to facilitate channel development on the new marsh. The fill could be placed by bucket or hydraulic means. Fill would be placed carefully to avoid creating undrained sections of the borrow ditch that could trap fish at low tide. Sediment would either be imported from a north bay source, or would be generated by dredging existing slough channels to deepen them. Any sediment used in this fill would be wetland cover quality.

Project Goals for Tidal Wetland Restoration

The goal of the project is to provide a mosaic of wetland habitats within the Napa River Unit, including tidal habitats and managed ponds. This mix of habitats would benefit a diversity of wildlife, including special-status species, migratory waterfowl and shorebirds, anadromous and resident fish, and other aquatic animals. All of the habitat restoration alternatives provide for a mix of tidal marsh and managed ponds, but vary in the extent of managed ponds restored to full tidal exchange.

Goals for tidal habitat restoration, which would include middle marsh, lower marsh, intertidal mudflat, and subtidal areas, are as follows:

- In a phased approach, restore large patches of tidal marsh that support a wide variety of fish, wildlife, and plants, including special status species.
- Create connections between the patches of tidal marsh (in the project site and with adjacent sites) to enable the movement of small mammals, marsh-dependent birds, and fish and aquatic species.
- Restore tidal marsh in a band along the Napa River to maximize benefits for fish and other aquatic animals.

The approach to tidal restoration for ponds opened to tidal action is to enhance tidal circulation and sediment deposition to enable natural processes to gradually regenerate a self-sustaining marsh ecosystem. As noted earlier, a high-quality marsh is well drained, has an extensive channel network, and has other wetland types nearby. Thus, the creation of a high-quality marsh ensures that other tidal habitats are also created.

Subtidal and mudflat habitat are the preliminary stages of tidal marsh restoration and also provide significant habitat values for invertebrates, birds, and fish.

Overview of Managed Pond Habitat and Pond Management

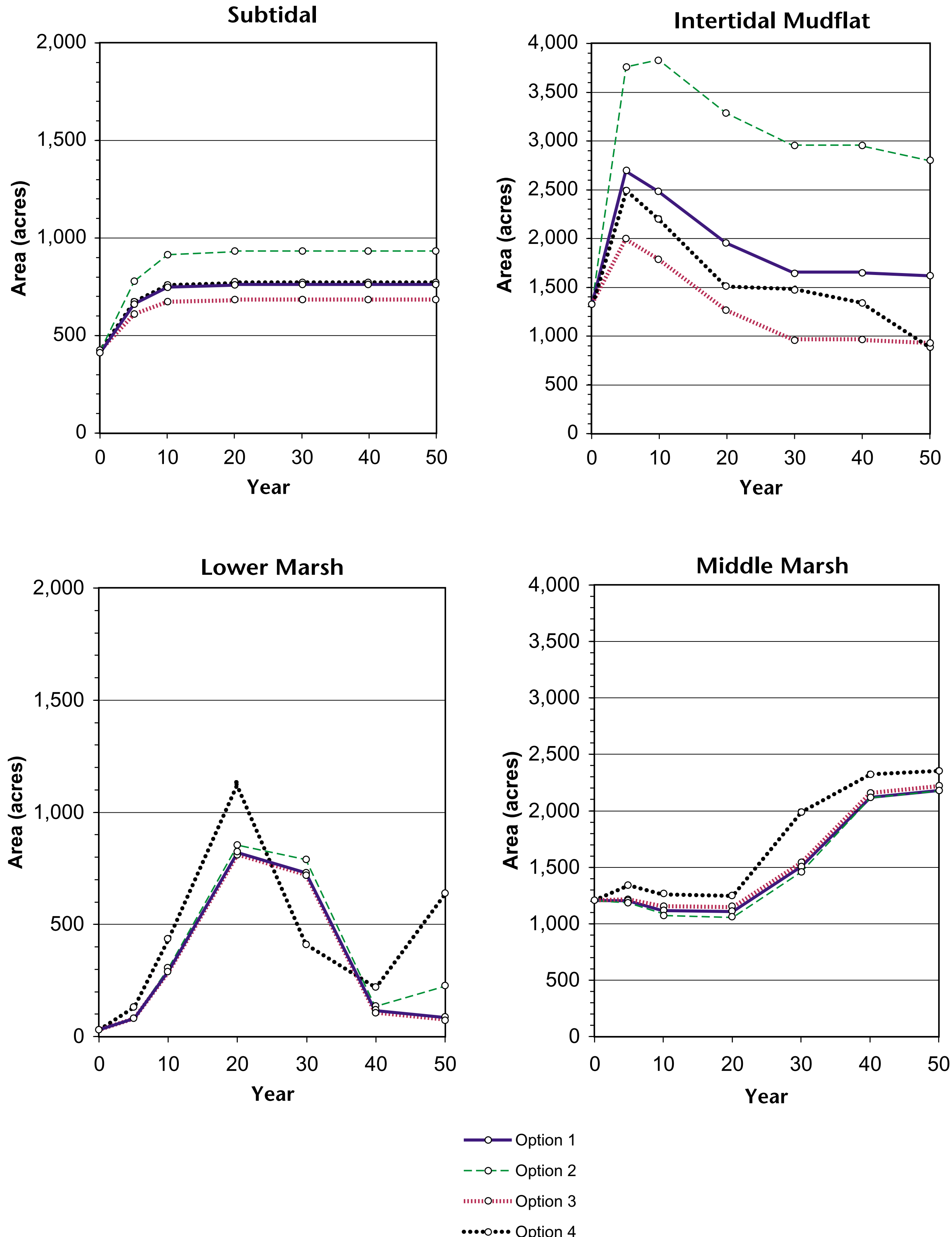
More than 7,000 acres of the Napa River Unit consist of inactive salt ponds that were used for salt production through the solar evaporation of bay water. These ponds, both historically and currently, serve as habitat for phytoplankton, invertebrates, fish, waterfowl, and shorebirds.

The habitat restoration options each provide for the continued management of at least five of the 12 ponds as ponds. Project goals for pond habitat are to enable DFG to better and more efficiently control water depth and salinity for the benefit of shorebirds and waterfowl. Waterfowl and shorebird use of the ponds is influenced by the water depth, salinity, and size of each pond. DFG will write a management plan for the Napa River Unit that will provide for pond management in the long term.

Levees and water control structures for all the ponds that would be preserved as ponds would need to be repaired or replaced so that salinity could be reduced in the short term and the water supply could be managed in the long term. The goal would be to maintain both the depth and salinity for a given pond within a specified range. The range would reflect the needs of different bird species likely to be present in the project area throughout the year, as well as seasonal variations. For example, it is likely that the managed ponds would have higher water levels and lower salinities in the winter (wet season) than in the summer (dry season). Water from the Napa River or Napa Slough would be added to ensure that the ponds do not drop below a certain critical depth, but the salinity of the water would increase during the dry season. Modeling suggests that the high evaporation rates during the dry season coupled with the increase in salinity in the intake water result in increases in salinity even when the water intake and discharge structures are left open to maximize tidal exchange. Recycled water could also be used to help maintain the levels in the ponds but would only be used until salinity is reduced in the upper ponds. Potential eutrophication concerns would have to be addressed if this approach is chosen.

Habitat Evolution

The various habitat restoration options would evolve over different periods of time (Figure 2-16) and achieve different mixes of habitats (Table 2-2). These habitat estimates are based on detailed modeling by Philip Williams and Associates (PWA) (Philip Williams and Associates 2002a) and provide a reasonable estimation of future site conditions given the habitat restoration



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Source: Philip Williams Associates 2002

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Figure 2-16
Habitat Evolution by Alternative

Table 2-2. Habitat Mix Associated with Each Habitat Restoration Option (Acres)

	Year 10					Year 50			
	Present	Option 1	Option 2	Option 3	Option 4	Option 1	Option 2	Option 3	Option 4
Pond Interiors									
Subtidal	0	140	220	110	140	150	220	110	150
Intertidal mudflat	0	2,410	3,760	1,720	2,130	1,550	2,730	860	820
Lower marsh	0	260	280	260	400	50	190	50	610
Middle marsh	0	100	140	90	240	1,170	1,250	1,160	1,340
Managed ponds	6,460	3,550	2,080	4,290	3,550	3,550[a]	2,080	4,290	3,550[a]
Upland/transition	200	190	190	200	190	190	190	200	190
SUBTOTAL	6,660	6,660	6,660	6,660	6,660	6,660	6,660	6,660	6,660
Sloughs									
Subtidal	430	620	700	570	620	630	710	580	630
Intertidal mudflat	80	80	80	80	80	80	80	80	80
Lower marsh	30	30	30	30	30	30	30	30	30
Middle marsh (aka. Fringing marsh)	1,210	1,020	940	1,070	1,020	1,010	920	1,060	1,010
SUBTOTAL	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750	1,750
Ponds & Sloughs									
Subtidal	430	760	920	680	760	770	930	680	770
Intertidal mudflat	80	2,490	3,840	1,790	2,210	1,620	2,800	930	900
Lower marsh	30	300	310	290	440	90	230	80	640
Middle marsh	1,210	1,120	1,080	1,160	1,260	2,190	2,180	2,220	2,360
Managed ponds	6,460	3,550	2,080	4,290	3,550	3,550[a]	2,080	4,290	3,550[a]
Upland/transition	200	190	190	200	190	190	190	200	190
SUBTOTAL	8,410	8,410	8,410	8,410	8,410	8,410	8,410	8,410	8,410
OTHER[b]	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050	1,050
PROJECT TOTAL	9,460	9,460	9,460	9,460	9,460	9,460	9,460	9,460	9,460

[a] If Ponds 6 and 6A are also restored to tidal marsh after 10–20 years, the total area of managed ponds at year 50 would be 2,404 acres.

[b] “Other” category includes nonevolving marsh (the remaining fringing marsh and Pond 2A) and sloughs and upland habitat areas.

Note: The estimate assumes ~~Assumes~~ suspended sediment concentration ~~SSC~~ is 125 mg/l for Pond 3 and 75 mg/l for Ponds 4, 5, 6, 6A, and 2 East; also assumes a fill area of 100 acres for Option 4. Slough erosion occurs over 20 years with 50% by Year 5 and 80% by Year 10. Calculations do not include opening Ponds 6/6A to tidal action. Totals may not add up because of rounding.

Table 2-3. Approximate Dimensions of Design Elements

Design Element	Top Width (feet)	Key Elevations	Typical Side Slope[a] (H:V)	Length (feet)	Potential Middle Marsh Area Created
Breach	Approx. 100[b]	Invert 3–5 feet below MLLW	5:1	NA	NA
Pilot channel	~50	Minimum invert at least several feet below the marshplain	5:1	Varies	NA
Starter channel[c]	50–100	Longitudinal slope deepest near the breach (3–5 feet below MLLW) and shallower in the pond interior (1 foot above to 1 foot below MLLW)	5:1	Varies by option	NA
Berm[d]	Approx. 10	~MLHW to MHW at crest; no higher than +0.5 foot above MHHW	7:1	Varies by option	0.2 acre/1,000 feet
Ditch block[e]	40	~MHHW at crest	5:1	100	0.12 acre/block
Levee lowered to construct ditch block	30	~MHHW at crest	NA	330	0.23 acre/block
Additional levee lowering for high marsh restoration[f]	46	~MHHW at crest	NA	Varies by option	1.1 acre/1,000 feet
Fill placement	NA	~1 foot below MHHW	NA	NA	100 acres assumed, may be less

[a] Side slopes would vary, depending on constructability.
[b] Width at mean higher high water.
[c] Starter channels could be narrower and shallower, depending on cost and constructability constraints.
[d] The width of the lowered levee would be 30 feet. Material from levee lowering would be used to fill a 16-foot width of borrow ditch, giving an effective width of 46 feet for potential marsh habitat
[e] The width of the berm for Habitat Restoration Option 4 would be sized to allow the berm to serve as an effective wave break and may be larger than the width shown here.
[f] Three hundred thirty feet of levee would be lowered to provide material to construct a ditch block.

Source: Philip Williams and Associates 2002c.

approaches pursued under each habitat restoration option. The approximate dimensions of the design elements are provided in Table 2-3 and the number and length of the design elements, including middle marsh habitat created by option, are provided in Table 2-4. All habitat restoration options are assumed to begin after salinity reduction occurs for a specific pond/area.

The habitat restoration options and methods for implementing these options are described in greater detail in the following pages. The habitat restoration approaches include four options:

- Habitat Restoration Option 1: Mixture of Tidal Marsh and Managed Ponds;
- Habitat Restoration Option 2: Tidal Marsh Emphasis;
- Habitat Restoration Option 3: Pond Emphasis; and
- Habitat Restoration Option 4: Accelerated Restoration.

Table 2-4. Number and Length of Design Elements and Middle Marsh Habitat Created, by Option

	Option 1	Option 2	Option 3	Option 4
Number and Length of Design Elements				
Breaches (number)	23	31	19	23
Ditch blocks (number)	22	236	16	22[a]
Lowered levees[b] (ft)	22,200	34,600	14,600	22,200
Berms[c] (ft)	27,500	40,600	19,600	55,300
Starter channels[c] (ft)	27,500	40,600	19,600	55,300
Middle Marsh Area Created by Design Feature (ac)				
Ditch blocks	3	3	2	3
Lowered levees[d]	21	34	13	21
Berms	6	9	4	13
Area fill	-	-	-	100
Total	30	46	20	136

[a] Fewer ditch blocks may be needed, depending on the location of the fill placement.
[b] Less levee lowering than indicated may occur. Includes 330 ft. for each ditch block.
[c] Fewer linear feet of starter channel and berms may be constructed, particularly for Pond 3.
[d] Includes area of partial borrow ditch fill, except when that fill is a ditch block.

Source: Philip Williams and Associates 2002c.

Figure 2-16 and Table 2-2 indicate that Habitat Restoration Option 2 would result in the greatest increase in subtidal and intertidal mudflat habitats, and that Habitat Restoration Option 4 would result in the greatest increase in lower and middle marsh habitats. Habitat Restoration Option 3 would contain the largest area of managed ponds. For areas restored within Habitat Restoration Options 1, 2, and 3 these restoration efforts follow similar trends in the evolution of lower and middle marsh habitats, and are within 100 acres of one another until 40 years after restoration begins and more lower marsh evolves under Habitat Restoration Option 2.

Habitat Evolution in Ponds 3, 4, and 5

Habitat evolution in the project area is dependent on a variety of opportunities and constraints (Philip Williams and Associates 2002c). The opportunities that lend themselves to restoration of the site include:

- hydrologic connection to tidal waters,
- suspended sediment supply,
- natural vegetative process and local seed sources,
- existence of historical antecedent channels,
- site elevations conducive to marsh vegetation establishment, and

- connectivity with existing marsh.

The site constraints that could affect habitat evolution in the ponds include:

- subsided ground elevations below vegetation colonization elevations,
- availability of sediment as a limiting factor,
- loss of existing habitat,
- limitations to natural channel formation such as borrow ditches or hardened pond bottoms,
- flooding and infrastructure,
- levee stability,
- construction access,
- pond and tidal channel sediment characteristics,
- project size, and
- proposed Cullinan Ranch restoration.

Detailed information on each opportunity and constraint was developed and used for the restoration design process in an effort to estimate future conditions. It is predicted that the ponds will contain a full range of subtidal, microtidal, and tidal habitats depending on local elevations, tidal exchange, sediment deposition, grading, vegetation colonization, and other factors.

Modeling Methods and Assumptions

The methods and assumptions behind the analysis of the evolution of restored tidal wetland habitat are provided in *Napa River Salt Marsh Restoration Habitat Restoration Preliminary Design Phase 2 Stage 2 of the Hydrology and Geomorphology Assessment in Support of the Feasibility Report* (Philip Williams and Associates 2002c). The analysis was conducted for both pond interiors and major slough channels and consisted of a series of spreadsheet models that accounted for initial pond elevations, sedimentation, and vegetation colonization rates. The assumptions for pond interior restoration, specifically the sedimentation and vegetation colonization rates, were made following an extensive literature review, input from restoration planners, lessons from other restoration projects, and an analysis of the accuracy of the model predictions (i.e., a sensitivity analysis). The assumptions for the evolution of major slough channels focused on fringe marsh loss by slough channel erosion and rates of channel scour; these assumptions were made based on similar review of literature, consultation with experts, and lessons from other restoration projects. The Napa Sonoma Marsh Restoration Group and the Restoration Technical Advisory Group (RTAG) were involved in reviewing and approving the methods and assumptions.

Modeling Sensitivity and Habitat Variation

The modeling effort represents predicted future habitat evolution given many variables. PWA conducted a sensitivity analysis on variables such as tidal damping, suspended sediment, wind-wave agitation, and channel erosion to determine the extent that these variables would lead to faster or slower marsh evolution. This analysis revealed that the proposed project tends to be optimistic in predicting marsh evolution, but that substantial areas of marsh will evolve even under conservative assumptions. Based on the sensitivity analysis, it is clear that the habitat mix associated with each habitat restoration option provides an estimate of the future conditions, but precise habitat acreage cannot be calculated. This is primarily because the restoration of natural marsh habitat relies on complex (i.e., multi-variate and non-linear) physical and biological processes that are inherently difficult to model and quantify with accuracy (Philip Williams and Associates 2002c).

Ecological Benefits

Irrespective of the exact number of acres of each habitat type that evolves, all habitat types will provide substantial ecological benefits. Subtidal and intertidal habitats will provide substantial benefits for invertebrate, fish, and some water birds. Lower marsh and middle marsh will also provide benefits for tidal marsh species, including birds and small mammals. There remains some uncertainty about the exact species composition and densities that will use the site; however, long-term monitoring will help resolve these questions. Furthermore, the project is designed to allow restoration of the site with a minimum of constructed features, allowing natural ecological processes to drive future site evolution.

2.5.4.2 Habitat Restoration Option 1: Mixture of Tidal Marsh and Managed Ponds

Introduction

Habitat Restoration Option 1 provides for a mosaic of tidal habitats and managed ponds. Under this option, the existing ponds would be restored as follows:

- Ponds 1, 1A, 2, and 2A would be maintained as they are, with levee repair and water control improvements as needed.
- Ponds 3 and 4/5 would be opened to the tidal prism in an orderly manner. Levee breaches would depend on accretion rates and sediment budget (Figure 2-17).
- Pond 6/6A would be maintained as a managed pond during the initial restoration of Ponds 3 and 4/5, an estimated 10–20 years. Adaptive management of the project would determine whether Pond 6/6A is converted to tidal marsh or retained as a pond in the long term. The decision is dependent upon success of tidal marsh development in Ponds 3 and 4/5, availability of other waterfowl and shorebird habitat, and funds available for O&M.
- Ponds 7, 7A, and 8 would be managed as ponds after their salinity has been reduced to ambient or near-ambient levels. Levees would be repaired and water control improvements would be made as needed.

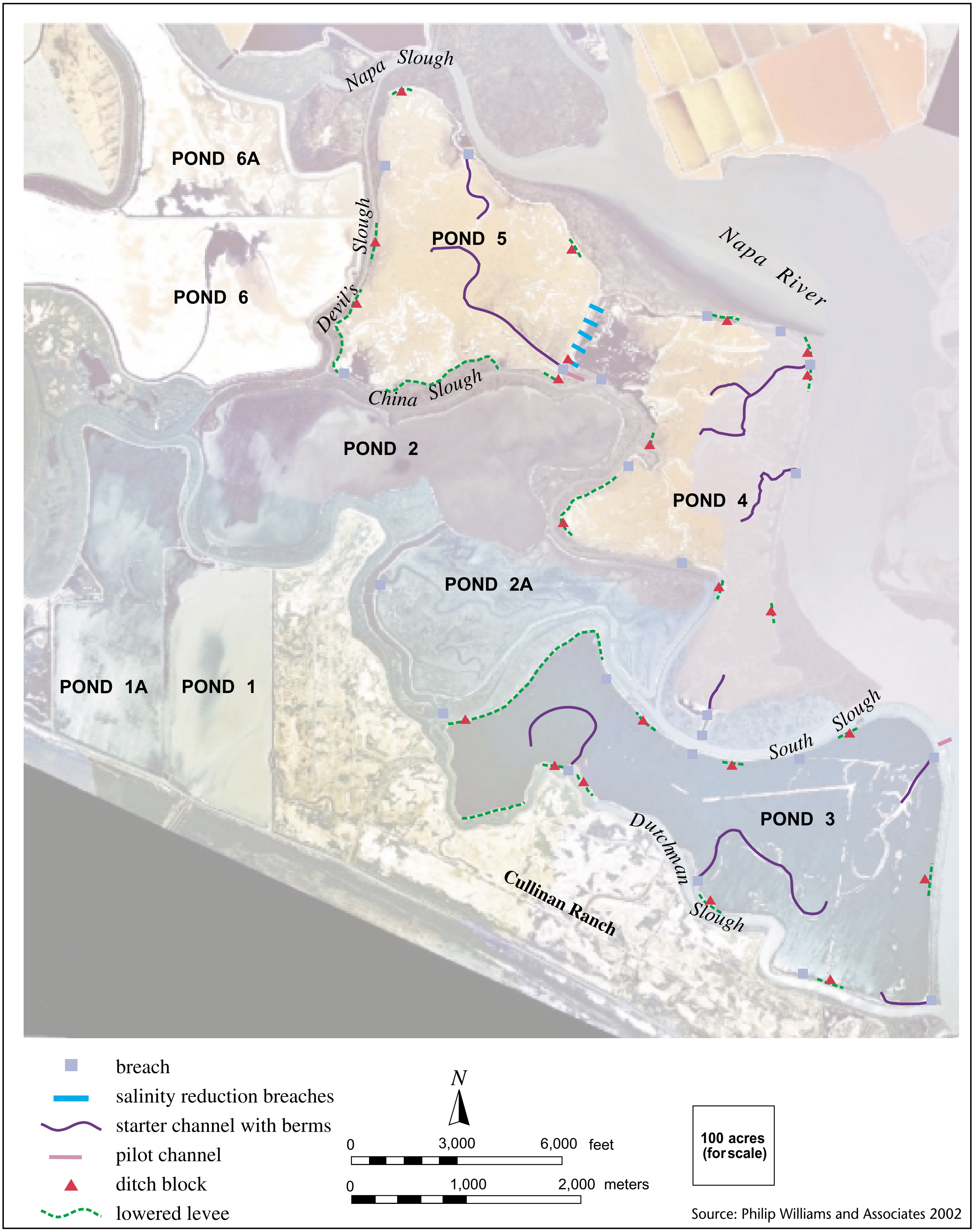

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Figure 2-17
Habitat Restoration Option 1:
Mixture of Ponds and Tidal Marsh

Habitat Restoration Option 1 would lead to the following habitat distribution when the project has matured (Figure 2-18):

- Ponds 1, 1A, 2, 7, 7A, and 8: managed pond;
- Pond 2A and other existing tidal marsh and slough habitat;
- Ponds 3, 4, and 5: new tidal marsh, mudflat, slough, and open water;
- Ponds 6 and 6A:
  - short term—managed ponds;
  - long term—adaptive management approach (Option 1A, new tidal marsh, mudflat, slough, open water; or Option 1B, managed pond).

The evolution of habitat types is illustrated in Figure 2-19.

Ponds 1, 1A, 2, 7, 7A, and 8 (Managed Ponds)

Construction

Facilities. Water control structures would be repaired or replaced as needed. In particular, the siphon between Pond 1 and 2 would be refurbished or replaced with two 54-inch-diameter siphons, and the existing intakes and outlets at Pond 2 would be replaced with new culverts and pipes. (The siphon would have been refurbished and at least 1 siphon would have been installed as part of salinity reduction efforts, if Salinity Reduction Option 2 is implemented.) A 48-inch wide, 200-foot long culvert would be constructed from the donut to South Slough. DFG would also replace the existing 24-inch structure from the donut to Pond 1 and add a new 36-inch structure from the donut to Pond 1A. To further improve water quality, DFG would construct 5 100-foot long levee breaches between Pond 1and 1A. 2,000 feet of the All American Canal, near Pond 2, would also be lowered and breached in 4 locations. Breaches would be approximately 100 feet long. Some of the valves and related equipment on Ponds 7, 7A, and 8 may require replacement when these ponds are converted to managed ponds. Initial levee repairs for all of these ponds would have been completed as part of the salinity reduction effort.

Equipment. The estimated annual equipment required to complete maintenance, repair, and replacement activities for Ponds 1, 1A, 2, 7, 7A, and 8, including replacement of water control structures, is one or two barges, two long-reach excavators, a small bulldozer, refueling tanks, a diesel generator, and a small boat for transportation to and from the project site.

Timing and Duration. Construction activities are expected to be completed within 1 year.

Operations and Maintenance

Facilities. Ponds 1 and 1A would continue to be managed as ponds, and Pond 2 would continue to be managed as a deepwater pond. Ponds 7, 7A, and 8 would be variable-depth, managed ponds after the desalination process. Salinity and depth would be managed by DFG in Ponds 7, 7A, and 8 to provide habitat for migratory waterfowl.

Water control structures for all six ponds would require ongoing maintenance and possibly replacement in the long term (as long as these ponds are managed as ponds).

Equipment. See "Equipment" under the discussion of construction for ~~Habitat Restoration Option 1~~ Ponds 1, 1A, 2, 7, 7A, and 8 above.

Timing and Duration. Long-term maintenance and replacement of the water control structures would require several months of construction each year. Levee maintenance would consist of repairing approximately 5% of the levees each year.

Ponds 3, 4, 5, 6, and 6A (Tidal Habitat)

Construction

Facilities. Tidal habitat restoration activities for Ponds 3 and 4/5, and possibly Ponds 6 and 6A would be designed to facilitate evolution of the site to mature marsh. Activities for Ponds 3, 4, and 5 would include

- removing intake and outfall structures,
- constructing breaches that provide for optimal tidal exchange (23 breaches),
- breaching levees in areas with minimal existing marsh and near historical channels to minimize loss of fringing marsh and encourage the scouring of remnant slough channels,
- creating ditch blocks with associated levee lowering (22 blocks),
- ~~regrading~~ lowering additional levees in various areas ~~where habitat continuity could be disrupted during the restoration period~~ (22,200 linear feet), and
- installing starter channels and berms in the ponds (27,500 linear feet).

Habitat Restoration Option 1 relies on natural sediment processes for the majority of the restoration area, and on natural colonization by marsh vegetation.

Under this option, levees would first be breached to open Pond 3 to full tidal influence. The exterior levees on Ponds 4 and 5 would subsequently be breached. Ponds 4 and 5 are already connected to each other via a breach~~es~~ along the interior levee; ~~these~~ additional levee breaches would be ~~increased~~ installed as part of the salinity reduction effort (see "Salinity Reduction Options" above).

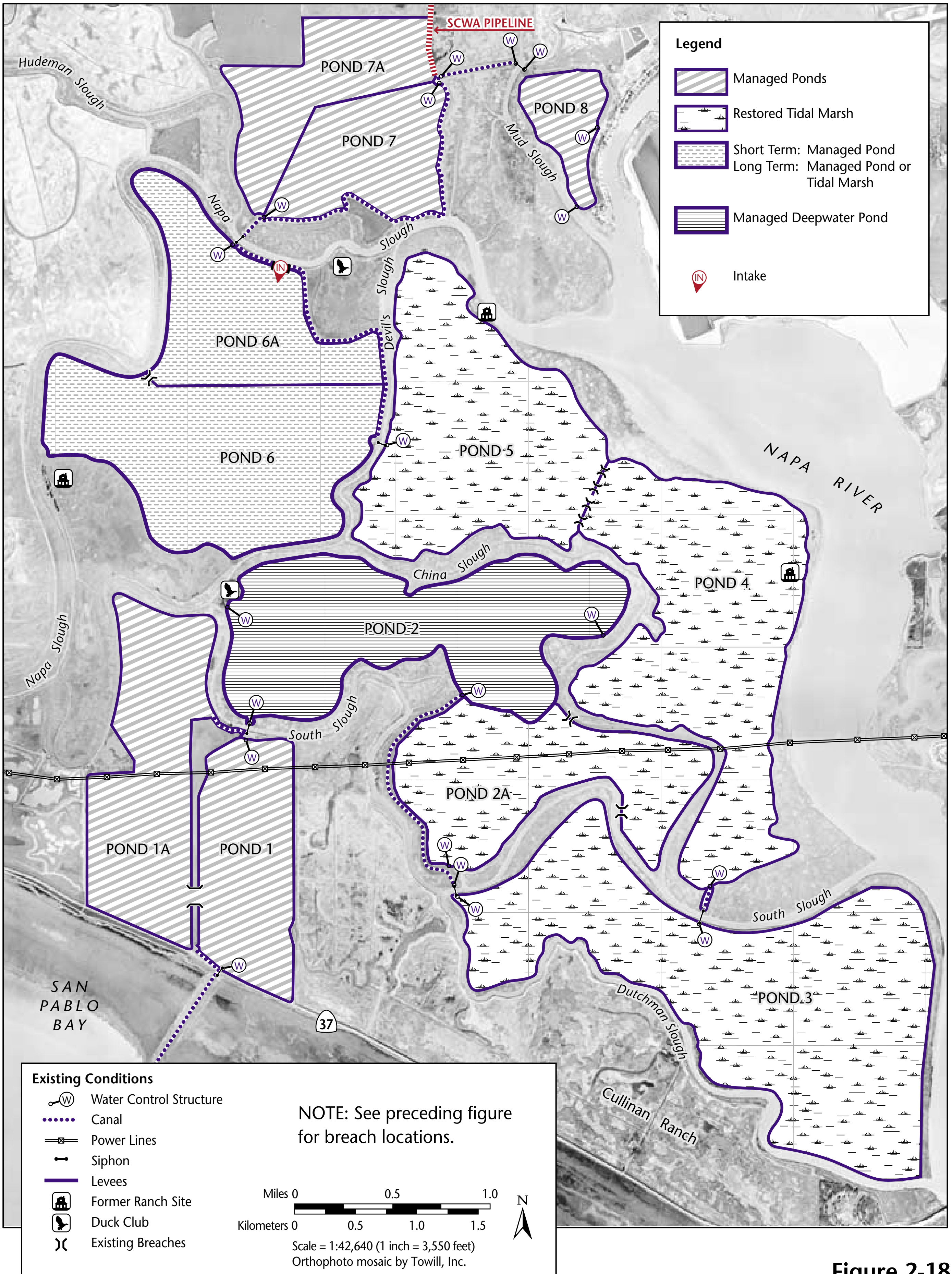

Figure 2-18
Habitat Restoration Option 1:
Habitat Endpoints

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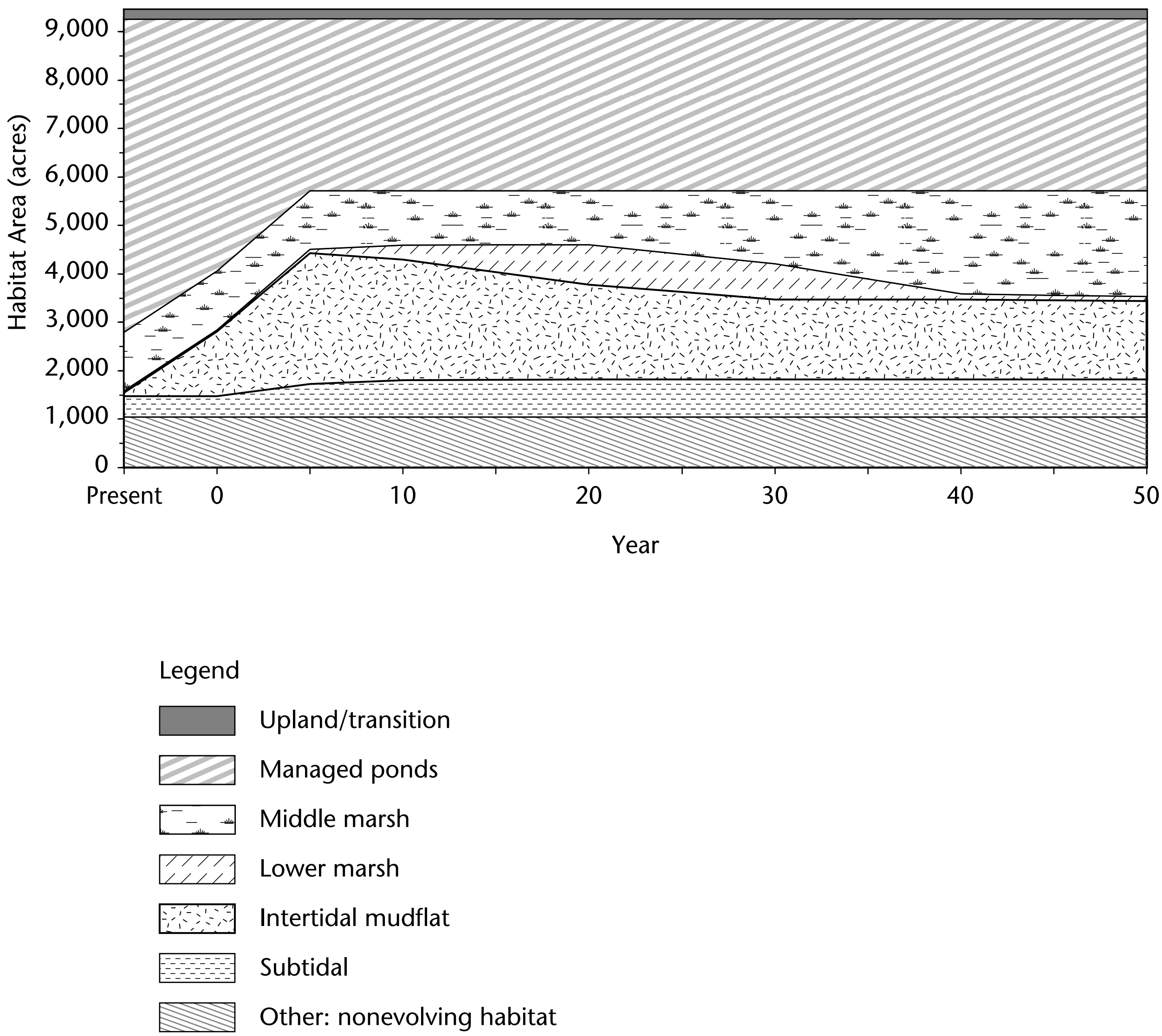

Source: Philip Williams and Associates 2002

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Figure 2-19
Habitat Areas – Habitat Restoration Option 1

Equipment. Equipment used to create the habitat restoration features would be of the same types and quantities as those used during the salinity reduction process and would be delivered to the site in the same manner (via barge at high tide). Construction activities to restore Ponds 3, 4, and 5 to tidal action would consist of excavating or placing explosives to breach levees where needed, and using heavy equipment to remove intake and outfall structures, block the borrow ditches, reslope the levees near the breaches, lower levees, and excavate starter channels and construct berms.

Timing and Duration. Habitat restoration would begin upon the reduction of salinity in the ponds and would start with the breaching of the Pond 3 levees, likely proceeding as follows:

- The evolution of Pond 3 to vegetated lower marsh habitat is expected to happen within 10 years because its elevation is higher than those of Ponds 4 and 5.
- Within no more than 5 years after Pond 3 is opened to the tide (depending on the evolution of Pond 3 and the continued availability of sediment), the exterior levees on Ponds 4 and 5 would be breached.
- A decision regarding the long-term habitat at Ponds 6 and 6A would be made no later than 20 years after the start of the project. If these two ponds are opened to tidal action, it is likely that they would require a longer time to accrete to tidal marsh than the ponds located along the Napa River.

Operations and Maintenance

Facilities. Maintenance of Ponds 4 and 5 in the short term (until Pond 3 is sufficiently restored that they can be breached) would require ongoing operation and maintenance of the water control structures. Maintenance of Ponds 6 and 6A as ponds in the short term, and possibly in the long term, would require the repair of levees and ongoing maintenance and operation of water control structures. Ponds 6 and 6A would be managed as ponds for approximately 10–20 years, and would then either be restored to tidal marsh or continue to be managed as ponds, based on

- the availability of sufficient, high-quality waterfowl and shorebird habitat, including open-water habitat (Ponds 1, 1A, 2, 7, 7A, and 8), in the Napa River Unit and at nearby existing or restored sites;
- the success of tidal marsh restoration in Ponds 3 and 4/5 (success would be determined by percentage of marsh vegetation cover);
- the availability of funding for the operation and maintenance of Ponds 6 and 6A as managed ponds. Funds would be needed to maintain levees and water control structures and to operate the water control structures; and,
- the physical feasibility of operating these large, shallow ponds within the desired water level and salinity ranges.

~~Maintenance of Ponds 4 and 5 in the short term (until Pond 3 is sufficiently restored that they can be breached) would require ongoing operation and~~

~~maintenance of the water control structures. Maintenance of Ponds 6 and 6A as ponds in the short term, and possibly in the long term, would require the repair of levees and ongoing maintenance and operation of water control structures. Additional water control structures for Pond 6/6A, which would be required if Salinity Reduction Option 2 is implemented, would be constructed in the same manner as described for Salinity Reduction Option 1.~~

Equipment. Significant maintenance on or replacement of the water control structures and levee maintenance at Ponds 6 and 6A would be accomplished using heavy equipment delivered to the construction area by barge at high tide. The estimated equipment required to complete ongoing maintenance, repair, and replacement activities for Ponds 6 and 6A is one or two barges, two long-reach excavators, a small bulldozer, refueling tanks, a diesel generator, and a small boat for transportation to and from the project site.

Timing and Duration. Long-term maintenance would require several months of construction each year.

2.5.4.3 Habitat Restoration Option 2: Tidal Marsh Emphasis

Introduction

Habitat Restoration Option 2 provides for a mosaic of tidal habitats and managed ponds with an emphasis on tidal habitats. Under this option, the existing ponds would be managed as follows:

- Ponds 1 and 1A, the western half of Pond 2 (Pond 2W), and Pond 2A would be maintained as they are, with levee repair and water control improvements as needed. A new levee would be built down the middle of Pond 2 (Figure 2-20).
- Ponds 3, 4, 5, 6, and 6A, and the eastern half of Pond 2 (Pond 2E) would be opened to the tidal prism with levee breaches, in an orderly manner depending on accretion rates and sediment budget. Design features would be used as needed for improved accretion rates and habitat evolution. Pond 3 would be opened to tidal action first, followed by Ponds 4 and 5, then Ponds 6 and 6A and Pond 2E. Ponds 2E and 6/6A would be maintained as ponds, with levee repair and water control improvements as needed, until significant habitat development occurs in Ponds 3, 4, and 5.
- Ponds 7, 7A, and 8 would be managed as ponds after their salinity has been reduced to ambient or near-ambient levels, with levee repair and water control improvements as needed.

Habitat Restoration Option 2 would lead to the following habitat distribution when the project has matured (Figure 2-21):