Bothin Marsh Geomorphology, Ecology, And Conservation Options

Chapter 3: Environmental History of Intertidal Habitats in Richardson Bay with Emphasis on Bothin Marsh

Produced by:

Laurel M. Collins
Watershed Sciences
8038 Mary Avenue NW Seattle WA 98117
laurelgene@comcast.net
(510) 384 - 2371

On behalf of

Marin County Open Space District

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Chapter 3: Environmental History of Intertidal Habitat in Richardson Bay

3.0 Introduction

This chapter summarizes the environmental history of Richardson Bay (herein referred to as “the Bay”) with a generally focus upstream or northwestward of the State Highway 101 bridge, with special regard for the study area encompassing the Bothin Marsh Complex (Figure 3.1). See the overall Introduction to this report for a more complete description of the setting.

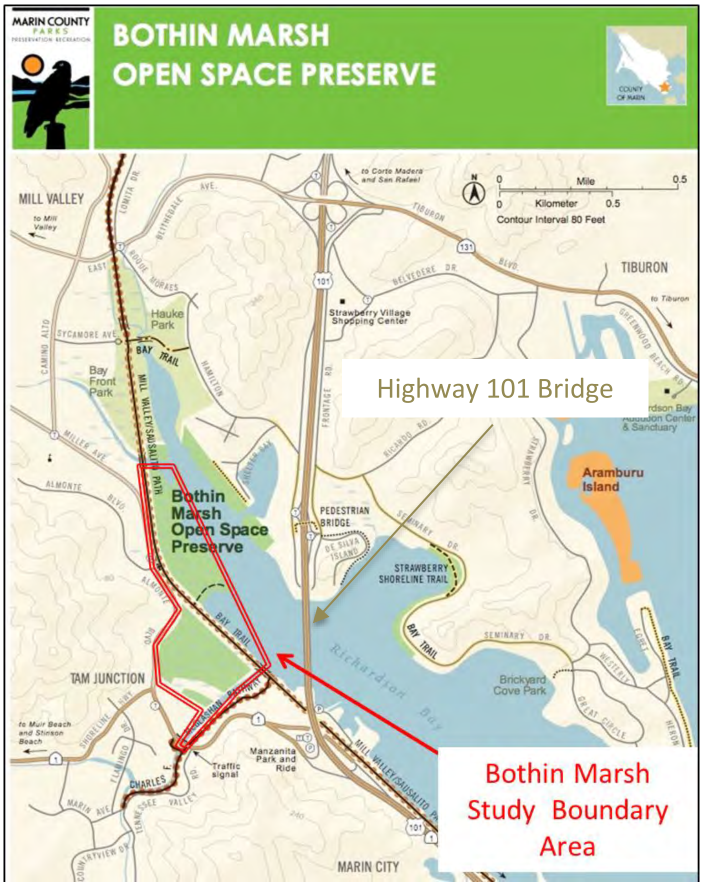


Figure 3.1. Location of Bothin Marsh Complex Study Area in upper Richardson Bay. Map courtesy of Marin County Open Space District.

This historical analysis documents changes in the distribution, abundance and general condition of intertidal habitat types, including their conversion from one type to another, due to natural processes and human intervention. This analysis is supported by the understanding of physical and ecological processes conveyed in Chapters 1 and 2, and draws on that understanding to infer the causes of documented environmental change.

3.1 Summary of Findings

The Bay and its marshes are still adjusting to major environmental changes caused by people since the late 1700s. These alterations of the landscape of the upper Bay have been ongoing and overlapping. The tidal marshes are sensitive to these changes. The marshes have never had a chance to adjust to one set of changes before another begins. They are still adjusting to changes that happened more than a century ago. Many changes have happened since then.

The timeline of environmental change in Richardson Bay (Section 3.4) can be separated into three approximate phases. Phase 1 ended in the 1950s. It was mostly about adding and expanding old world land use around the Bay, such as logging and grazing and residential development. These land uses increased erosion in the local watersheds and flooding along the bayshore. Phase 2 ended in the mid-1970s. It was mostly about dredging, diking, and filling the shallow subtidal and intertidal areas of the Bay, especially tidal marshes, to create marketable lands. Phase 3 is ending now. It’s been about working with nature to manage the Bay for many competing objectives, including flood control, shoreline protection, recreation, and wildlife protection, in the context of modern environmental policies and regulations. The next phase will use the lessons of the past phases to address the challenges of climate change, especially sea level rise.

The following lessons have been synthesized from the accompanying detailed study of the environmental history of upper Richardson Bay.

- Altering one part of the Bay effects what happens elsewhere in the Bay. Ignoring this fact causes the alterations to have unexpected consequences and sometimes to fail expensively. Failed efforts to exploit the Bay for commercial or social interests are evident as eroded reclamation levees, piles of rubble, chronic flooding, damaged habitats, unwanted sedimentation, and a dependence on dredging.
- Major enterprises have come and gone, but their physical and ecological effects on the Bay persist in numerous ways. Logging and ranching forever changed the nature of vegetation and its effects on runoff and erosion in the watersheds around the Bay. Railroading and highway construction has left levees and berms and bridges that dissect the Bay and its marshes, forever changing how winds and waves and tidal waters move throughout the Bay and along its shores. Urbanization has altered the amount and chemistry of runoff entering the Bay. Dredging has rearranged the ancient and more recently deposited sediments of the Bay, while changing the way the Bay fills and drains. These alterations have created a mosaic of fragmented and damaged habitats, left remnants of historical habitats isolated from each other, and created opportunities for biological invasion, while threatening populations of native plants and animals.

- Early reclamation of tidelands during Phase 1 of the Richardson Bay Timeline of Environmental Change (Timeline) had the overall unintentional effect of moving the marshlands bayward. Reclamation of the historical Coyote Creek marshes in the 1870s, coupled with railroading across the Coyote Creek open embayment in the 1880s, initiated the process of turning marsh into land and the embayment into marsh. The railroad levee became the new foreshore. The construction of a reclamation levee along the historical foreshore of Almonte Marsh in the 1920s forced the sediment of the Arroyo Corte Madera del Presidio to bypass the marsh and be deposited in subtidal areas and new mudflats. Storm waves and flood tides moved some of the sediment from the flats to new marshland bayward of the levee. This fringe of new marshland was subsequently reclaimed with another levee in the 1930s. Marshland bayward of this new levee has continued to be nurtured with sediment from the Bay. Throughout this period, in the valleys and embayments of Coyote Creek and Arroyo Corte Madera del Presidio, marsh became land and the Bay became marsh, because of reclamation.

- Upper Richardson Bay is much smaller than it was at the time of Euro-American contact. Its extent has decreased by about 50%, due to reclamation of tidal marshes and flats, and artificial filling of shallow subtidal areas. Much of the reduction in size can be attributed to railroading during the late 1800s. It isolated marshland of Coyote Creek and Arroyo Corte Madera del Presidio from the Bay, especially as trestles were replaced with levees. But, the isolation accelerated after WWII, during phase 2 of the timeline, with aggressive reclamation of tidelands and shallow subtidal areas bayward of the railroad. The decrease in extent of the Bay is reflected in a decreased tidal prism. Although there are no data to calculate the historical loss in prism, it's evidenced by rapid in-filling of dredged areas and chronic shoaling elsewhere. There has been inadequate prism to scour the accumulated sediment to the historical water depths. The average depth of the upper Bay relative to high tide has decreased markedly since the first navigational charts of the mid-1800s.

- Alterations of the Bay have rearranged and redistributed the supplies of sediment from the local watersheds. Very little of the sediment has been exported from the Bay. It has been dredged to improve navigation, to build levees, and to turn the margins of the Bay into land. These major rearrangements of sediment have mostly ignored their net negative, long-term effects on flood control, navigation, and ecology.

- The disconnection of the tidal marshlands from their watersheds has been a very significant change in the overall mechanics of the upper Bay. The marshes owe their existence in large part to the supplies of fine sediment provided by their watersheds. Dikes and levees have increased the distance sediment must travel from the creek mouths to the marshes, which in turn has increased the likelihood that sediment will be delivered elsewhere, including subtidal sediment sinks created by dredging. Of all watersheds of Richardson Bay, the Arroyo Corte Madera del Presidio matters the most as a sediment source. It is by far the largest watershed with the greatest potential for erosion, given its geology, steepness, and rainfall. Its sediment supply is essential for the conservation of tidal flats and marshes of Richardson Bay.

- Alterations vary in their reversibility. Some historical alterations have been monumented by their incorporation into modern land uses. For example, marshlands reclaimed from the 1880s to the 1970s support commercial and residential development that will be difficult to protect from sea level rise. The railroad levee has become the very popular Bay Trail. It can be raised or realigned, but at considerable expense. In contrast, some historical levees are deteriorating on their own and some portions of these levees support popular foot trails or serve as high marsh refuge for wildlife, and therefore might deserve conservation. In-Bay dredged canals are filling with sediment, and in-bay spoil piles are eroding. The need for maintenance dredging in the Bay is decreasing, because deep draft boats are not using the upper Bay. If future flood control plans reroute Coyote Creek to accommodate sea level rise, the need for the Coyote Creek Canal may be nullified. The Canal could then remain as subtidal, or be converted to tidal flats or marsh.

- Sudden extreme events, natural or not, can have lasting environmental significance. Tidal habitats represent a rather sensitive balance between sediment supplies and tidal hydrology. A sudden change in one or the other can trigger major changes in habitat abundance and condition. For example, major storms can trigger landslides that produce large pulses of terrigenous sediment (Collins *et al*. 2001), which in turn can create deltas across diked baylands and tidal marshes (Ellen *et al.* 1988, Watson 2011). Overtopping of levees or their intentional breaching can suddenly transform diked baylands to subtidal or intertidal habitats. Conversely, the completion of a containment levee, the installation of a tide gate, or the creation of other restrictions on tidal flows can suddenly convert tidal habitat into non-tidal habitat, at a large scale. Decisions to accommodate sea level rise rather than contain it may be triggered by one or a series of catastrophic floods. Such events punctuate the environmental history of upper Richardson Bay

- The natural processes of tidal flat and marsh evolution and maintenance are ongoing. Where they have been allowed to operate long enough without disruption, tidal flats and marshes are evolving. This is evident in formerly diked areas that have been opened to the tides, such as North Bothin Marsh, and on the bayward sides of levees that are not directly attacked by wind-generated waves. Varieties of methods exist to enhance or even accelerate marsh evolution, by nurturing processes that govern conditions in upper Richardson Bay, as well as in the marshes.

3.2 Methods

This study of change in upper Richardson Bay followed a proven procedure to discover and compile historical environmental information. The procedure begins with a clear definition of its geographic focus, while recognizing that information from surrounding areas will be useful.

In general, the amount and diversity of information sources increases from the past to the present. The start of a timeline of environmental change is often fixed by the oldest available reputable sources of information that pertains the study area. For Richardson Bay, these sources are the accounts of ranching and timber harvest conducted during the early years of the Presidio de San Francisco and early mission period of the late 1700s and early 1800s. Written accounts about the earliest settlers in the region dating to the first part of the nineteenth century are readily available.

Environmental history is place-based, and therefore reputable maps are always informative. All maps are incomplete or factually wrong in some regards; however, so knowing the purpose of a map and the motivations and qualifications of its author and producer is important. In general, federal and state maps are the most reliable and best documented. Regional and local agency maps can be helpful but tend to be less well documented. Maps produced for commercial purposes, such as real-estate maps, tend to be very selective and somewhat biased in content and design. The accuracy of a map can vary among the features it shows. For example, many bayshore maps produced by regional and local interests to depict the built environment share a common map of the Bay and its marshlands as context, even if the contextual map is wrong. With the advent of automobiles, travel times decreased, and map scales decreased, such that maps of a given physical size showed more area in less detail.

For Richardson Bay, and for most of the California coast, the earliest reputable maps of tidal marshes and related environs are the Topographic Sheets and Hydrologic Sheets of the first Coast Survey. The Coast Survey was a federal program initiated in San Francis Bay in the mid-1800s to maps the waters and immediately adjoining lands for informing federal and state planning and management of coastal resources, especially with regard to navigation. The T-sheets and H-sheets serve as a proven foundation for assessing historical changes in near-coastal environments.

Aerial photography first became locally available in the early 1930s, and has increased in quality and abundance since then. Intervals of time covered by aerial imagery have decreased steadily. The advent of digital imagery has greatly increased the acuity and resolution of landscape images. New high-quality imagery of the entire focus area has become available every few years since the 1990s.

Written accounts by early settlers, local and regional published histories of places within the focus area, diaries and letters describing landscape condition, and landscape paintings of known origin and vintage can provide clues about changing local and regional conditions, and about the land uses affecting the changes. For example, reports on dairy and ranching operations, the amount of lumber removed from watersheds, records of local commerce can shed light on industries utilizing and changing the landscape.

Throughout the Bay Area, and certainly in Richardson Bay, early railroading had profound and lasting impact on tidelands because it often skirted or crossed them with levees that interrupted the flow of tidal waters. The railroads also spurred growth in industries and municipalities along the railways, and hence along the bayshore. Plans for railways and related constructions are often very well documented with reports and detailed maps of conditions along right-of-ways, including as-built conditions for engineered crossings of tidal sloughs and embayments.

As the Bay became more densely populated, and cities were incorporated, the amount of governmental planning of land use increased. Engineering reports on shoreline infrastructure and development became commonplace and dependable. With the advent of federal and state environmental policies and laws in the 1960-70s, the number of expert studies of past and present conditions increased. The number and breadth of academic studies of the Bay also increased, due in part to the needs of government agencies for science support, and to large number of nearby state colleges, major universities, and federal centers for environmental research. Many of the studies focusing on Richardson Bay include environmental histories, which can accelerate any new efforts to understand historical environmental change.

All of these kinds of sources of historical information were utilized in this study of the changes in tidelands and related environments of the Study Area and its environs in upper Richardson Bay. The sources were cross-referenced along a timeline extending from the late 1700s to the present. A weight-of-evidence approach was used to determine the location, timing, and characteristics of likely or known change. Changes are only recorded if they are well supported by multiple lines of evidence. The resulting Timeline of environmental change for upper Richardson Bay, including especially the tidal marshlands, is produced as a matrix that follows Tables 3.1-3.3, and the citations for this chapter. All measurements of area were made using Google Earth, and in some cases involved overlaying historical photographs and maps on Google Earth imagery.

3.3 Quantified Marshland Change

Tables 3.1 is a key to the abbreviations of place names referenced in Tables 3.2 and 3.3, as well as to the Timeline that follows these tables. Table 3.2 reports the amount of change in acres since 1851 for each component marsh of the Bothin Marsh Complex. Table 3.2 focuses on the conversion of mudflat to marsh in South Bothin Marsh. The changes at South Bothin Marsh illustrate how tidal habitats respond to changes in sediment supply, as affected by climate, weather, and land use. Measures of marsh area only include vegetated marsh plains and pannes between the foreshores and backshores. Tidal channels wide enough to be depicted by two banks on the historical maps (rather than by a single line) and areas of levees above tidal influence were excluded from the measurements.

Key to Abbreviations for Tables 3.2 and 3.3	
AA	Almonte Marsh
NBM	North Bothin Marsh
SBM	South Bothin Marsh
EBM	East Bothin Marsh
NMM	North Manzanita Marsh
HCCM	Historical Coyote Creek Marsh
CCE	Coyote Creek Embayment
CC	Coyote Creek
CCC	Coyote Creek Canal
RR	Railroad

Table 3.1. Key to abbreviations of place names. The key pertains to Table 3.2 and Table 3.3 (see immediately below), and to the following Timeline.

Table 3.2. Changes in area of tidal marsh of the Bothin Marsh Complex. Note the gain of about 3 acres of new marsh in South Bothin Marsh (SBM) during the 3-year period 1924-27. This may be alluvial fill that was mapped as marsh, but it nevertheless indicates the possibility of rapid change due to extreme events. The increase in acreage is mainly due to formation of the Coyote Creek alluvial fan in SBM after the severe storms of 1925 (See Timeline).

Year	AM (includes Tam Marsh) (ac)	NBM (includes Rectangle Marsh) (ac)	SBM (ac)	EBM (east of RR) (ac)	NMM (ac)	HCCM (west of SR 1) (ac)	HCCM (east of SR 1) (ac)	CC Embayment (ac)	Total tidal marsh (ac)
1851	49.6	0	0	0	15.8	76.1	(No SR 1)	open	141.5
1870	49.6	0	0	0		65.5	(No SR 1)	open	
1872	49.6	0	0	0	16.6	64.2	3.7	open	134.1
1883	49.6	0	0	0			3.7	47.6	
1889	50.0	0	2.5	0			3.7		
1899	51.7	0	17	0.1	7.3	28.6	3.7	40.5	108.4
1924	45.9	0	27.8	0.20	10.6	32.3	3.0	29.9	119.8
1927	41.6	0	33.4	0.20	13.2	37.6	3.1	21.6	129.1
1946	40.1	0	33.8	0.25	10.9	33.4	2.8	16.6	121.25
1950		0				30.2	2.2		
1952	38.7	0	35.4	0.9	6.0	0	2.2	12	83.2
1960	21.4	0.4	28.0	1.3	1.2	0	0.3	10	52.6
1965	17.5	2.9	26.1	0.8	2.1	0	0	9.5	49.4
1973	18.8	14.3	28.8	0.6	2.1	0	0	5.2	64.6
1976	18.8	14.1	28.0	0.7	2.2			5.0	63.8
1978	18.8	14.0	28.1	0.8	2.1			5.0	63.8
1987	18.4	15.6	28.1	0.9	2.4)			6.1	65.4
8/ 2005	18.2	15.4	29.6	0.9	2.2			3.5	66.3
8/ 2016	18.0	15.3	30.4	0.8	2.2			3.1	66.7

Table 3.3. Evolution of tidal marsh from mudflat at Coyote Creek Embayment (CCE). Since the embayment was created by construction of the railroad in 1883, 47.6 acres of mudflat has evolved into 44.5 acres of tidal marsh, which is presently mostly low marsh, at an overall rate of 0.67 ac/yr.

Significant Event	Year	CCE Mudflat (ac)	% Initial Mudflat	Period of Change (yrs)	Mudflat Change (ac)	Rate of Marsh Evolution (ac/yr)

First Coast Survey	1851	No RR Levee	NA	NA	NA	NA
Sierran hydraulic mining begins	1853	No RR Levee	NA	NA	NA	NA
1300’ RR trestle constructed	1883	47.6 (time zero)	100	NA	NA	NA

Table 3.3 continued

Significant Event	Year	CCE Mudflat (ac)	% Initial Mudflat	Period of Change (yrs)	Mudflat Change (ac)	Rate of Marsh Evolution (ac/yr)
Sierran hydraulic mining ends	1884					
RR trestle shortened to 120’ with more levee	1894					
None	1899	40.5	85	16	7.1	0.44
None	1924	29.85	63	25	10.6	0.43
Significant 1925 rains and flooding (L. Collins 2011), formation of CC delta	1927	21.6	45	3	8.25	2.75
None	1946	16.6	35	19	5.0	0.26
Upstream grading and channelization of HCCM	1952	12	25	6	4.6	0.77
Flooding	1955-6					
CC channelized upstream of Flamingo Rd	1959					
HCCM mostly gone; 5% SBM filled	1960	10.0	21	8	2	0.25
CC diverted from SBM; flap gate added to SBM inlet	1965	9.5	20	5	0.5	0.10
Seasonal desiccation and standing water changes distribution of plants colonization of SBM mudflat	1973	5.2	11	8	4.3	0.54
CCC dredged above SR 1	1974					
None	1976	5.0	10	3	0.2	0.07
None	1978	5.0	10	2	0	0
SBM flap gate removed; undersized inlet armored; bridge #2 installed over 26-ft inlet	1980-1?					
Extreme flooding with sediment pulse	1982					
Some post flap gate marsh converts to mudflat	1987	6.1	13	9	-1.1	-1.20
Flooding with sediment pulse	1998					

None	2005	3.5	7	18	2.6	0.14
Tides overtop CCC levee to and from SBM	2005-17					
None	2017	3.1	6	11	0.4	0.04
Totals	2017	3.1	6	66	44.5	0.67

3.4 Timeline of Environmental change

The Timeline covers the period between the early 1800s and the present. Both the amount of change and its abundant documentation are remarkable. However, the interval between noted years of information is generally much shorter after WWII. This reflects two factors: the relatively slow rate of change before WWII, and the relative paucity of information about that change. Nearly annual accounts of change are available in modern times. While there are gaps in documentation for some early causes of change, such as early reclamation and dredging, most of the changes caused by human intervention have redundant documentation from alternative perspectives. As stated in section 3.2 above, changes are only recorded in the Timeline if they are well supported by multiple lines of evidence. The dates of change are usually inexact, however, unless the changes were rapid and authoritatively documented, either in writing or through imagery.

3.4.1. How to Use the Timeline

The Timeline is constructed as a matrix in four columns as diagrammed below. The Timeline is accompanied by a set of numbered images and figures illustrating the changes noted in the Timeline. Column 1 designates the time period or year. Column 2 references the number(s) of the relevant supporting illustrations that follow the Timeline. The illustration number is typically noted on the lower left corner of the actual image. The third column is a quick reference to any key changes for the corresponding year or time period. The last column provides detailed notes from the sources of historical information, including citations. For convenience, the key to abbreviations (Table 3.1) is reproduced below.

Column 1	**Column**	**Column 3**	**Column 4**
Time Period or Year	Image Ref #	Key Changes	Notes Relevant to Geomorphic Conditions and Landscape Change

Key to Abbreviations for Tables 1 and 2	
AA	Almonte Marsh
NBM	North Bothin Marsh
SBM	South Bothin Marsh
EBM	East Bothin Marsh
NMM	North Manzanita Marsh
HCCM	Historical Coyote Creek Marsh
CCE	Coyote Creek Embayment
CC	Coyote Creek
CCC	Coyote Creek Canal
RR	Railroad

Table 3.1. Key to abbreviations of place names (reproduced from above for convenient use with the Timeline below).

Richardson Bay Timeline of Environmental Change			
Time Period	**Image Ref #**	**Key Changes**	**Notes Relevant to Geomorphic Conditions and Landscape Change**
Pre 1775	None	Landscape was managed by indigenous people	There were more than 5000 years of Coast Miwok settlement in Marin County prior to first European contact at Richardson Bay. The lands were managed in part by intentional small fires of varying frequency. (https://geog.sfsu.edu/sites/default/files/thesis/Peri2005-ArroyoCorteMaderaHabitatAssess.pdf). It is likely that the intentional fires did little to increase soil erosion and sediment supply to the Bay because the fires were not hot enough to create significant water repellency (hydrophobicity) in the soils as has been documented to occur in modern times in some regions of the Bay Area following intense wildfire (Booker, Dietrich & Collins 1993; Collins and Ketcham 2001). Native people were using the natural resources of the historical Coyote Creek Marsh. Nelson (1906) mapped shellmounds very near Almonte Marsh, in small alcoves at the base of hillsides west of present-day Tamalpais High School (Tam High), upstream of the tidal reach of Coyote Creek and of Tennessee Creek, and near the backshore of Manzanita Marsh. Sediment supply to the Richardson Bay from all sources, including the attending creeks, was probably low. Supply was less from the Coyote Creek watershed than from the Arroyo Corte Madera del Presidio watershed, because of its much less steep topography and smaller size. Arroyo Corte Madera might have had occasional punctuated periods of high supply associated with natural debris slides in steep headwater streams of Mount Tamalpais.
1775	3	European contact begins in Richardson Bay	The first European known to visit the present-day location of Sausalito was Don José de Cañizares, on August 5, 1775 (https://en.wikipedia.org/wiki/Sausalito, California). **Image Ref #3** shows a map of the San Francisco Bay produced by Cañizares during 1781. The map might portray the Coyote Creek Embayment at the head of Richardson Bay.
1776-1839	None	Cattle and sheep replace deer and elk as herbivores	During the Mission Period from 1776-1839, The missions in San Rafael (1817) introduced free ranging cattle in eastern and southern Marin County that may have entered the lands around Richardson Bay (http://www.cityofmillvalley.org/community/about/history.htm). The Mission also introduced horses and sheep. Coastal prairies were considered prime pasturage for cattle and sheep ranching because of their productive and nutritious perennial grasses (Burcham 1957: fort and Hayes 2007, Howard 1998). The change from deep-rooted perennial

		Euro-American land uses increase land erosion	grasses to the annual grasses with shallow roots that decompose during the wet season increases the potential for surface erosion and shallow landsliding (Prosser and Dietrich, 1995). The European settlers hunted the abundant mule deer and tule elk that were reported by Richardson to be in great abundance along Richardson Bay. In time, the introduced livestock replaced the native elk and deer as the dominant herbivores.
1792-1848	None	Europeans suppress use of fire as a landscape management tool	The use of controlled fires by Coast Miwoks was discontinued in favor of fire suppression by Euro-Americans who believed fire interfered with the needs for ranching cattle (http://web.sonoma.edu/cei/prairie/history/recent_history.html). This contributed to the dominance of annual grasses, and allowed the accumulation of fuels, which in some areas led to more intense fires, and potential increased water repellency and surface erosion. Reduced interception of rainfall from grazing and fire influences would have led to increased runoff and downstream impacts to channels, causing higher than previous rates of sediment supply to the Bay from bank erosion and streambed incision.
1816	None	Logging begins to contribute to local sediment supplies	Commercial logging began on Mt Tamalpais (https://geog.sfsu.edu/sites/default/files/thesis/Peri2005-ArroyoCorteMaderaHabitatAssess.pdf). This would have significantly increased sediment supply to local streams and increased runoff, especially from the steep headwater streams on Mount Tamalpais. Mechanical soil disturbance would have decreased soil strength, increased shallow landsliding and bank slumping along channels, and reduced interception of rain by the forest canopy. Increased runoff would have initiated chronic channel incision as another added source of sediment. Abundant literature on studies of channel width, depth, and velocity (hydraulic geometry) show that many of the channels throughout the Bay Area have incised their channels since European settlement.
1822	None		The development of the Richardson Bay began with the arrival of William A. Richardson in 1822, shortly after Mexico had won its independence from Spain. Richardson submitted a petition to the California Governor for a rancho across from the Presidio to be located at the headlands of the Golden Gate and to be called “Rancho Saucelito.” “Saucelito” is a misnomer for the California (Osio 1996) term “Sausalito” which refers to a small stand of willows. The presence of a sausal indicates the presence of a spring or small creek. Richardson founded the town of Sausalito by first establishing it as a fresh watering station for the many vessels and schooners entering the Golden Gate (https://en.wikipedia.org/wiki/Sausalito, California).

			Richardson Bay was also used as a relatively quiet anchorage in the lee of the Marin Headlands
1830	None		In 1918, the *Call Bulletin* published a personal description by Stephen Richardson, son of William Richardson, of the late-1830s Richardson Bay that was later excerpted by Annie Sutter for a 1987-88 publication of the *Marin Scope*: “My early life in Sausalito was perhaps the happiest time of my life. A horse trail ran from San Rafael to Sausalito, very much the same as the main highway goes today. The country was entirely untouched by man, and the wild oats grew shoulder high, in spite of the great herds of wild animals browsing in the fields. On an ordinary jaunt from Sausalito to San Rafael I would see enough elk, deer, bear and antelope to fill a good-sized railroad train. I never grew tired of riding through wonderful forest land and over ridges overlooking the sea.” The land grant, which Richardson received in 1838 (“Rancho Saucelito”), totaled over 19,000 acres and extended from Richardson Bay to the sea. “The bay as my father knew it was a fairyland of enchantments . . . the waters had not been fouled by tailings from the mines, and were still crystal clear so that a pebble could easily be seen at a depth of 30 feet. The timber reached in many places down to the shore. The stillness was unbroken save for the shrill piping of the myriad shorebirds, and elk with huge branching horns, graceful antlered stags, and huge grizzly bears stood statuesque on the hillsides.” As stated by Sutter: ”Richardson’s daughter wrote that she saw bands of elk, hundreds in a band, swimming from Angel Island to the shores, and remembers fields of yellow poppies stretching as far as the eye could see. However, all was not Paradise, as attested to by one visiting sailor who, in 1837, ‘sailed for Whaler’s cove . . . remained an hour or two . . . shot a rabbit and got most confoundedly poisoned by what is here called ‘yedra’ - (poison ivy).’” http://www.sausalitohistoricalsociety.com/marin-scope-columns/2013/5/6/early-life-in-sausalito.html The reference to the 30 feet of water clarity in Richardson Bay is remarkable, but not surprising for at least two reasons: (1) suspended sediment in Richardson Bay is more strongly influenced by supplies from local watershed and wind generated waves on the mudflats, particularly at the head of the Bay, than by the larger circulation currents moving in and out of the Golden Gate and the greater San Francisco Bay that carry sediments from Sierran

			sources as well as other adjacent Bay Area watersheds; and, (2) the late 1830s (the period referenced in Richardson's description) probably preceded in major changes in sediment supply caused by European land sues. According to Van Geen *et al.* (1999), significant erosional disturbances dating after 1830, but well before 1890, are evident in sediment cores taken from the mouth of Richardson Bay. Van Geen *et al.* suggest that both hydraulic mining debris and erosion in local watersheds contributed to increased sediment supply well before the turn of the last century. They suggest that after this early erosional disturbance occurred, sediment was distributed more evenly around the Richardson Bay, whereas prior to the disturbance, most of the sediment, particularly at the head of the Bay, was related to local watershed supplies. Local sediment supplies available for marsh building not only involved direct delivery of terrigenous sediment by the streams but would have also involved tidal supplies through and re-suspension of the sediment temporarily stored in the mudflats. During the summer, wind action affects circulation patterns in Richardson Bay, when northwest breezes tend to set up a clockwise circulation current in the Bay (Phillip Williams & Assoc., 1983). The average wind direction for San Francisco Bay is from north to south (http://windhistory.com/map.html#9.00/37.8109/-122.1369). Winds from the north might contribute to substantial intermixing of Arroyo Corte Madera del Presidio sediments with Coyote Creek sediments in the Coyote Creek Embayment. The pattern of sedimentation seen in cores from the mouth of Richardson Bay was considered by Van Geen *et al.* (1990) to be consistent with deforestation and the expansion of agriculture in the watershed of the San Francisco Estuary. Peterson *et al.* (1993), suggest that diking and filling of much of the salt marshes that once surrounded the Estuary resulted in an overall reduction in sediment filtering and trapping and therefore increased the amount of suspended sediment in the Estuary. However, Richardson Bay tended not to receive much of this sediment because of its position perpendicular to the flow of sediment through and around the larger Estuary (Phillip Williams and Associates 1983).
1834	None	Cattle ranching begins and local logging intensifies	Mexican land grants divide Marin County. Cattle and sheep ranching begins for hide and tallow trade and for dairy purposes. John Thomas Reed was granted Rancho Corte Madera del Presidio where wood was cut and transported to the Presidio in 1834. Reed named the City of Mill Valley. He built his sawmill on Cascade Creek (now Old Mill Park) to process the wood in the mid-1830s on land that was

			part of Richardson's Rancho Saucelito. The wilderness of what is now modern Tiburon, Belvedere, Corinthian Island and parts of Corte Madera and Mill Valley became the "Rancho Corte Madera del Presidio" - meaning literally where wood is cut for the Presidio. (http://www.cityofmillvalley.org/community/about/history.htm) To equip his mill, Reed had to trade the resources from his land, 300 elk skins, 20 bearskins and 200 cattle hides with the Russians at Fort Ross for a circular saw, a grist mill flour, guns and ammunition (https://www.mvhistory.org/history-of/history-of-early-mill-valley/).
1845	4	Homesteading begins near marshlands	Homesteading is establishing along the marshes of Richardson Bay. Homesteading practices at the time were associated with practices that disturb soils and make them highly erodible and likely to be carried off the hills and valleys by surficial flow, transporting the fine sediment to the bay. For example, water diversion for farming often required ditching and diversion, as well as small dams for water supply. These activities caused channel adjustments that created more sediment. Farming required plowing fields, and ranching/dairying activities required concentrating animals into small areas. These activities increased rates of local sediment delivery to Richardson Bay.
1848	None		Discovery of gold in the Sierra Nevada prompts the Gold Rush.
1849	None	Significant local creek flooding is likely	Based upon analysis of numerous local historical rainfall records (Goodridge 1996, Collins 2001), 1849 was a year that could have generated flooding in local watersheds.
1850	5	Coyote Creek embayment is entirely open to Richardson Bay	This early map of the Richardson Bay shows that Coyote Creek has an open embayment. However, marshes known to exist in Richardson's Bay were not depicted on this map. Prior to this time, there had been significant upland watershed disturbance in both Coyote Creek and Arroyo Corte Madera del Presidio watersheds. Rhodes suggests that most sedimentation in the Richardson Bay by this time was directly associated with Arroyo Corte Madera del Presidio Creek that poured storm sediments from Mount Tamalpais into the Bay (email communication from P. Rhodes to L. Collins, 3/30/2017). This creek was also known as Widow Reed Creek. The sediments from Arroyo Corte Madera del Presidio contributed to Almonte Marsh, (which was on the south side creek banks near the mouth of the channel to the Bay), but also the much larger marsh system extending up through most of the flats of Mill Valley along the main Arroyo and its tributary tidal sloughs. However, it is suggested that the mudflats within the Coyote Creek Embayment, might have supported a mix of sediments from both Coyote Creek and Arroyo Corte Madera del Presidio that were reworked by waves on the mudflats and then re-deposited on the Historical Coyote Creek Marsh.

1851	6, 7, 8, 9	First detailed coast and geodetic survey map showing HCCM is produced	**Image Ref #6, #7 and #8** show portions of the earliest highly detailed topographic map by US Coast Survey (T-Sheet 00334) of the Coyote Creek area (email communication from Phil Rhodes to L. Collins, 3/30/2017 & 4/21/2017). This map shows tree groves (probably willows) at the downstream ends of Coyote and Tennessee Creeks as they transition into tidal marsh. Both creeks have tidal reaches extending through the tidal marsh to Richardson Bay. The mainstem of Coyote Creek flowed into the landward or upstream boundary of a tree grove (sausal) before transitioning to the marsh. It is not clear that the creek passed through the grove as a single channel or a network of distributaries. It is expected that the grove existed on an alluvial fan of sediment deposited by the creek. A similar configuration is evident for Tennessee Creek. It also flowed into a tree grove while transitioning to the head of the marsh. The same western tributary of Tennessee Creek makes an abrupt eastward turn that might follow the subtle boundary of a transitional alluvial fan. Within the marsh, both Coyote and Tennessee tidal sloughs are highly sinuous. The 1851 map (**Image Ref #7**) shows the intertidal marshes extended upstream and downstream of the confluence of Coyote Creek and Tennessee Creek. Numerous tidal marsh pannes are evident along the foreshore of Almonte Marsh, as indicated in **Image Ref #7**. These pannes are indicative of a poorly drained area of marsh along the backside of an overwash berm. Summaries of historical wind speed and direction data available for the Sausalito Boat Harbor (https://www.meteoblue.com/en/weather/archive/windrose/sausalito_united-states-of-america_5393611) indicate that the foreshore of Almonte Marsh is perpendicular to winds from the southeast, which have a fetch extending the length of Richardson Bay. Although this is not the predominant wind direction, it tends to occur during the onset of Pacific storms. Storm waves and the surge generated by winds along this fetch create the largest waves at Almonte Marsh, and the overwash from these waves very likely explains the formation of this berm. The foreshores of other marshes along Richardson Bay are parallel to this fetch and do not show evidence of overwash berms. The MLLW contour, which marks the bayward margin of tidal flats, is also shown on **Image Ref #7,** and it indicates that flats extended from the south and western sides of Richardson Bay to the mouth of Arroyo Corte Madera del Presidio. Tidal flats extended 1800 feet bayward of the mouth of Coyote Creek, entirely filling the Coyote Creek Embayment.

			There were 35 years of logging on Mt Tamalpais and 17 years of cattle grazing in the vicinity prior to creation of the 1851 map (**Image #7**). Conditions in **Image #7** probably reflect a period of increased sedimentation at the head of Richardson Bay. The watersheds of Coyote Creek and Arroyo Corte Madera del Presidio account for 57% of the drainage area of the Bay. The Arroyo Corte Madera del Presidio accounts for 36%, is much steeper, has a maximum elevation of 2,536 ft, and contained most of the logging activity. It is therefore likely to have been the dominant source of terrigenous sediment. In contrast, maximum elevation of Coyote Creek is 1041 ft. **Image Ref #8** shows the combined drainage area of Coyote Creek and Tennessee Creek. Historical Coyote Creek Marsh (HCCM) had a drainage area of 3.40 square miles. As will be discussed further through the timeline, the modern drainage area of South Bothin Marsh (SBM) became significantly smaller after it was disconnected from Coyote Creek for the construction of the Coyote Creek Canal. The modern Coyote Creek Canal (CCC) marsh has a drainage area of 3.56 square miles, and modern South Bothin Marsh has a drainage area of 018 square miles. **Image #9** shows the historical marshland boundaries projected onto the 2017 Google Earth Imagery. **The historical** Coyote Creek Marsh covers ~76 ac, excluding the tidal channels that were large enough on the maps to depict both banks (as opposed to a single line). If these larger channels are included the aerial extent of marsh was ~92 ac. Unless otherwise noted, marsh area determinations did not include the area within channels that had both banks mapped. The portion of historical Almonte Marsh (AM) relevant to this study covered about 50 ac, and North Manzanita Marsh (NMM) (north segment that is subject to influences within the larger Coyote Creek Embayment and therefore relevant to this study) covered about 16 ac.
1852	None	Commercial logging in Mill Valley ends Probable local creek flooding	Commercial logging in Mill Valley ends (https://geog.sfsu.edu/sites/default/files/thesis/Peri2005-ArroyoCorteMaderaHabitatAssess.pdf). Although logging ends, the geomorphic impacts of related erosion and high sediment delivery to Richardson Bay will continue for years. Based upon analysis of numerous local Bay Area rainfall records (Collins 2001; Gilbert 1917), storms in 1852 could have generated flooding in local watersheds and caused large amounts of

			sediment to be delivered to Richardson Bay, particularly from Arroyo Corte Madera, because it contained most of the logging and is steeper that the other watershed.
1853	None	Hydraulic mining begins in Sierra Nevada.	Hydraulic mining for gold begins in the central Sierra Nevada watersheds draining to the San Francisco Estuary (https://www.sierracollege.edu/ejournals/jsnhb/v2n1/miningtechniques.html). Fine sediment from mining debris led to an increased rate of sedimentation and rapid marsh expansion into parts of Suisun Bay, San Pablo Bay, Central San Francisco Bay and South Bay (https://pubs.usgs.gov/pp/0105/report.pdf). However, the peak of hydraulic mining sediment delivery to these areas did not occur until after the 1880s (Gilbert, 1917). Although much of the San Francisco Estuary was affected by the delivery of hydraulic mining debris, the tidal circulation patterns near the Golden Gate prevented the sediment from entering Richardson Bay, except perhaps near its mouth (Gilbert 1917, Philip Williams and Associates 1983).
1856	10	Extensive Shallowing of Richardson Bay has occurred.	The position of the MLLW contour changes significantly between 1851 and 1856. The change indicates a large-scale shallowing of Richardson Bay during a 5-year period. This might reflect increased sediment supply from erosional land use activities in local watersheds exacerbated by the storms of 1852. As discussed earlier, inputs of sediment from hydraulic mining into the eastern, northern, and central areas of the San Francisco Estuary probably did not have a large impact on Richardson Bay, especially in its upper reaches. The shallowing was likely due to ongoing logging, grazing, road-building, and other land use practices associated with increased homesteading. The tidal marshes changed little between 1851 and 1856, except that Coyote Creek might have migrated or been physically moved to the southern edge of the willow grove at its transition to the tidal marsh. Other details of the tidal marsh channel system evident in the 1851 map (**Image Ref #6**) are missing in the 1856 map (**Image Ref # 10**).
1859	11		**Image Ref #11** for 1859 shows the same bathymetry as mapped in 1856 (**Image Ref # 10**) and similar channel and marsh conditions.
1860	None		Elk were completely eliminated from Marin County by this time (http://web.sonoma.edu/cei/prairie/history/recent_history.html) and had been replaced by cattle, which augmented the conversion of perennial grasslands to nonnative annual grasslands. As a result, the production of sediment from grasslands has been permanently higher than historical rates from both soil erosion and shallow landsliding (Collins *et al*. 2001).

1861	None	Probable local creek flooding	Based upon analysis of numerous local historical rainfall records (Goodridge 1996, Collins 2001; Gilbert 1917), the total rainfall for the winter of 1861-62 was the greatest of any year of record until perhaps the winter of 1982-83.
1867	None	Probable local creek flooding	Based upon analysis of numerous local historical rainfall records (Goodridge 1996, Collins 2001; Gilbert 1917), 1867 was a year that could have generated flooding in local watersheds.
1868	12	San Rafael road on marsh perimeter	The 1868 Detail of Sausalito Land and Ferry Company map (**Image Ref # 12**) is an early parcel map for the sale of tidelands to support developing Richardson Bay by extending large amount of fill from its perimeter. It shows San Rafael Road existing along the perimeter of the historical Coyote Creek Marsh. Although it shows significant changes in the channel planform, the channel and marsh mapping shown her is considered unreliable because the marsh shoreline and topographic mapping along the north and northwestern edges does not conform well with earlier and later maps. It is possible that this map is more diagrammatic than geographically accurate,
1870	13, 14, 15, 16, 17, 18	San Rafael Road exists along backshore of HCCM ~10.5 ac of 1851 Historical Coyote Creek Marsh eliminated at head of Coyote Creek (representing about 49% of original marsh).	Unlike the earlier 1868 map (**Image Ref # 12**), the 1870 No. 7 Salt Marsh and Tide Lands map (**Image Ref #13 and #14**) shows the proposed Coyote and "Saucelito" (sic) Canals and the proposed route of the North Pacific Railroad. Tidelands are divided into parcels and mapped for future sale. Canals are designed to access the reclaimed tidelands and drain Coyote Creek and Arroyo Corte Madera del Presidio. Interestingly, the middle portion of the proposed Coyote Creek Canal (CCC) aligns well with the existing Army Corps project constructed in 1965. The proposed railroad route does not align with the existing route of the Bay Trail, which is on a later railroad levee that formed the modern Coyote Creek Embayment. The State Lands Commission tidelands map (**Image Ref #15)** produced detailed soundings of upper Richardson Bay (email communication from Phil Rhodes to Laurel Collins, 3/30/2017). The map seems to verify the shallowing trend for Richardson Bay evident by comparing the 1851 map (**Image Ref # 6**) and the 1856 map **(Image Ref # 10**). This verification is indicated by the much narrower areas between the MLLW contours on opposing sides of the Bay, and that the MLLW contour extends only to an embayment south of Silva Island. The 1870 bathymetry of Richardson's Bay (**Image Ref #15, #16, and #17**) changed slightly since 1856. The 1870 MLLW boundary extends farther northward toward the head of Richardson's Bay, slightly past Silva Island.

			The 1870 map (**Image Ref #15, #16, and #17**) indicates that ~10.5 acres of marsh at the upstream end near the transition of Coyote Creek into the marsh was eliminated and that the San Rafael Road generally followed the perimeter of the marsh except for cutting off a landward portion of the marsh. This would have reduced tidal prism in the Coyote Creek Marsh, which would have initiated narrowing of the tidal marsh channels. Tidal prism is the volume of tidal flow moving in and out of a bay or tidal channel. A reduction in the tidal prism of a marsh causes its tidal channels to shoal and narrow because they have less volume of tide flow to convey. A shoaling or narrowing of tidal channels is therefore evidence of reductions in tidal prism. The road crossing at Tennessee and Coyote Creeks probably influenced the ability of the creeks to convey their sediment loads downstream. Whether these were bridges or fords are unknown. This map is considered to be a more reliable depiction of the upland MHHW boundary than the 1868 tidelands map, particularly since it indicates survey points along the marsh perimeter. However, the reliability of the depictions of Coyote and Tennessee Creeks above their confluence is uncertain. The map shows that houses existed upstream of the southwest corner of the Coyote Creek Marsh along Tennessee Creek and at the north hillslope between Coyote Creek and Almonte Marshes. Cattle ranching and/or crop farming were likely causing increases in sediment supply to the marshes, which supports the indications of increased sedimentation in Richardson's Bay. The tidal reach of Coyote Creek downstream of its confluence with Tennessee Creek shows substantial decrease in width, since early 1850s. The same is true of Arroyo Corte Madera del Presidio along northern edge of Almonte Marsh. For example, at the site equivalent to where Flamingo Road currently crossed Coyote Creek, the channel width in 1851 was roughly 125 ft. The 1870 map indicates that it narrowed to roughly 80 ft. These changes in channel width reflect the reduction in tidal prism due to marsh reclamation and road crossings. Similar changes in channel width are evident for the Arroyo Corte Madera del Presidio watershed. The 1870 map indicates a significant difference in the planform of tidal reaches of both Coyote and Tennessee creeks upstream of their confluence. **Image Ref #16** shows a detail of Tennessee and Coyote Creeks. **Image Ref #17 and #18** show comparisons of channel position during and prior to 1870**.** By 1870, the Coyote Creek channel had been truncated where the 10.5 ac of marsh had been reclaimed. The cause of this reclamation is not known. It may have involved diking, filling, or a combination of both. The San Rafael Road was likely on an elevated berm but it is upstream of the truncated marsh.

			The sinuosity of the middle portion of tidal reach of Tennessee Creek upstream of its confluence with Coyote Creek had been significantly altered, yet its uppermost tidal reach remained the same.
1872	19, 20	SR 1 on levee across HCCM exists near shoreline	The 1872 US Coast and Geodetic Survey T-5929 **(Image Ref #19 and #20)** used the previous 1851 map information for the depiction of topography, channels, MLLW, and marsh. The only apparent updates are to the roads and agricultural activities. Interestingly, the homesteaders often located their crops on small alluvial fans at the base of tributaries rather than the main valley floors. Under natural conditions, the direction of flow down a fan is variable over time. Streams moving back and forth over the fan depositing their bedload build alluvial fans. When bedload supply is particularly high, many distributaries channels can form that effectively dispersing the sediment and building the areal extend of the fan and its elevation. When a stream has a limited supply of bedload, the flow may become confined to a single-thread channel that cuts into the fan and then re-disperses the stored sediment farther downstream. To tame the channel and to reduce the amount of flooded or saturated soils, farmers often diverted creeks into a single ditch along the middle or more commonly to one side of the fan or to the edge of the valley flat, often connecting the channel to another ditch that diverted the mainstem of the creek from the middle of its valley to the side. This maximized the area for crops and minimized the need for stream crossings. Diverting the flow into straight ditches increased flow velocity, which caused the beds and banks of the ditches to erode. The deeper ditches confined larger flows, which increased the bed erosion. This channel incision undoubtedly increased sediment supplies downstream to the remaining Coyote Creek Marsh and to Richardson's Bay. Such channel incision was likely also occurring in other local watersheds. **Image Ref #19** shows the new presence of Shoreline Road that crosses the eastern portion of historical Coyote Creek Marsh. During the 1870s, the San Rafael Road was the main wagon road between Sausalito and San Rafael (email communication from Phil Rhodes to Laurel Collins, 3/30/2017). The newly constructed State Route 1 (SR 1) along the marsh foreshore was most likely on an elevated levee or berm with a bridge crossing the mouth of Coyote Creek. It might have eliminated about 1.3 ac of the marsh, but was very likely the beginning of significant reductions in tidal prism landward of SR 1.

			The amount of historical Coyote Creek Marsh (1851) that became sandwiched between SR 1 and the marsh foreshore was ~3.7 ac.

1873	21, 22, 23	4000-foot-long RR trestle construction across Richardson's Bay from Strawberry Point to Sausalito.	Based on AB Dickinson (1967) as explained by personal email from P. Rhodes ((4/21/2017): • North Pacific Coast Railroad (NPRR) was the first railroad in Richardson Bay and existed from 1871 to 1902; • The NPRR was incorporated in December 1871. • Ground-breaking at Sausalito for the NPRR was 12 April 1973; • The Daily Alta California Newspaper, 23 August 1873, reported that construction was to begin on 4,000-foot long Richardson Bay trestle; • The Daily Alta California Newspaper 15 November 1873 reported that construction of the trestle was nearing completion. This bridge would have been the first major construction to impact wind fetch, wave generation, and local tidal circulation currents in Richardson Bay. The extent of these impacts is unknown and their effects on sedimentation within the Bay are unknown. However, it seems possible that the trestle might have interrupted wind fetch, and reduced propagation of large waves and re-suspension of mudflat sediment in the upper Bay. The 1873 Map T-01302 (**Image Ref #21**) uses information from 1851 T-sheet (**Image Ref #6 and #7**) and does not show any obvious differences in channel planform, MLLW contour, or marsh features. The marsh pannes, however, are not depicted. This is likely an artifact of the map rather than a change in actual conditions. The Arroyo Corte Madera Creek del Presidio shown in the Almonte Marsh detail, **Image Ref #21,** shows roads and agricultural activities that would likely have been influencing upland runoff and tidal processes, including changes in water and sediment supply. The 1873 T-01302 Marin County Map (**Image Ref #22**) shows the same SR 1 crossing at the mouth of Coyote Creek Marsh as the 1872 T-5929 map (**Image Ref #19**). The new SR 1 bypassed the older road that followed the shoreline above high tide near the head of the marsh. **Image Ref #22** also shows the proposed railroad from Strawberry Point to Sausalito and **Image Ref #23** shows the first trestle that crossed Richardson Bay from Strawberry Point to Sausalito, well southwest of Coyote Creek.
1875	24		According to Dickinson (1967) NPRR service started from Sausalito to Tomales, 11 January 1875, using the 4,000-ft trestle extending from Sausalito to Strawberry Peninsula. This 1875

			map (**Image Ref # 24**) does not show a railroad across Coyote Creek Marsh and does not show sufficient detail to describe any marsh or channel changes since previous years.
1883	25	1310-foot-long trestle of NPRR crosses Coyote Creek Embayment, influencing ~47.5 ac of shallow mudflat RR levee across Almonte Marsh mutes the tides across 42.5% of Almonte Marsh	The NPRR constructed a new main rail line from Sausalito to Corte Madera includes trestle across the southern shallows of Richardson Bay, just bayward of the historical Coyote Creek Marsh (P. Rhodes personal communication). Construction began on the new railroad line on 28 April 1883 (Dickinson 1967). Based on subsequent maps (see **Image Refs #40 and #41**), the length of the original trestle was about 1,310 ft and spanned about 2,160-ft of the Bay. At its western side, it had ~47.6 ac of shallow mudflat of the Coyote Creek Embayment. The trestle was anchored at either end by a new levee totally about 850 ft in length. These berms essentially reduced the opening of the embayment by 850 ft. This effectively narrowed the western side of the embayment by about 61%. The trestle had closely spaced piers. It and the adjoining levees would have caused wave heights to be reduced on the landward side and may have also affected tidal circulation, which in turn would have promoted entrapment of sediments delivered by Coyote Creek, plus sedimentation of tidal sediments within the embayment landward of the trestle. These factors would have caused the quiet embayment landward of the trestle to shoal as tidal flat, and initiate the bayward expansion of the existing tidal marsh. The new rail line extended on a new levee across the eastern portion of Almonte Marsh, cutting off ~22.5 ac (~42.5 %) of the marsh from direct access to tidal flows from Richardson's Bay. The marshland removed from direct tidal access can experience muted tidal action, meaning the high tides are lower and the tidal flow velocities are reduced, relative to other nearby marshland with direct tidal access. Marshland can experience tidal muting because its source of tidal water, such as the mouth of a tidal channel, becomes restricted, or because a levee or berm increases the distance between the marshland at its source of tidal water. The location of the levee across Almonte Marsh can be seen on **Image Ref #40 and #41**. **Image Ref #25** does not show the changes occurring in the marshes, but it does show a major road along the perimeter of the historical Coyote Creek Marsh, and an unimproved road leading upstream along Tennessee Creek to Tennessee Valley, located across the Tennessee Creek watershed divide. Road construction could have caused an increase in sediment supply to the creeks and thus to the quiet embayment caused by the new trestle.

1884	26, 27	Hydraulic mining in Sierra Nevada ends	Hydraulic mining is halted in the Sierra Nevada (https://calisphere.org/exhibitions/14/environmental-impact-in-the-gold-rush-era/). Service started on the new rail line between Sausalito and Corte Madera constructed in 1883 on 28 April 1884 (email from P. Rhodes 4/21/2017). **Image Ref #26** shows extensive wetlands still exist west of the railroad and SR 1 but does not show the railroad trestle. **Image Ref #27 shows the** fill for the railroad levee along the southern alignment near North Manzanita Marsh, but not along the northern alignment near Almonte Marsh.
1889		Mill Valley branch of RR caused tidal prism to be muted over 50% of original (1851) AM.	The Mill Valley Branch rail line that went to the lumber mill near downtown Mill Valley was completed 13 October 1889 (Dickinson 1967). As a result, an additional ~4 ac of Almonte Marsh sandwiched between the Mill Valley and San Rafael Branch lines became subjected to muted tides. Total aces of tidal marsh influenced by muted tidal action equaled ~ 26.5 ac. This represents about 50% of the original (1851) Almonte Marsh area.
1890s	28, 29, 30	Probable local creek flooding	**Image Ref #28, #29, and #30** show photographs of conditions near historical Coyote Creek and Almonte Marshes during the 1890s. Service on Mill Valley rail line started 17 March 1890. Based upon analysis of numerous local historical rainfall records (Goodridge 1995, Collins 2001; Gilbert 1917), 1890 was a year that could have caused local flooding and therefore generated pulses of sediment to Richardson's Bay from local watersheds.
1892	31, 32, 33	Tennessee and Coyote Creeks appear ditched to sides of their valleys	The 1892 Map by Dodge (**Ref Slide #31**) appears to use much of the same mapping information shown in the 1873 Marin County map (**Image Ref #22**) for the depiction of historical Coyote Creek and Almonte Marshes. It incorporates the No. 7 Salt Marsh and Tidelands Sales Map (**Image Ref #15),** to show potential bayland parcels. It therefore cannot be used for assessing mars, and channel change. It does show new information pertaining to the alignment of railroad and its branches to Mill Valley and San Rafael. The 1892 Tamalpais Land and Water Co. Map (**Image Ref #32 & #33**) show changes in the alignments of Coyote Creek and Tennessee Creek, but cannot be used for assessing changes in their width. The map shows that Tennessee and Coyote Creeks rerouted into ditches at the sides of their valleys. In addition, the 1892 map shows a new northward bend in Coyote Creek just upstream of the mouth of the tidal reach of the creek. There is no clear explanation for

			this new bend but one possibility is that it was associated with constriction that might have happened upstream of the SR 1 bridge. The Mill Valley Lumber Company was founded by Captain Robert Dollar to provide lumber for a booming steamship business. The lumber company became a focal point for growth for San Francisco after the 1906 quake and fire (http://www.marinij.com/article/ZZ/20060402/NEWS/604029992). It is unclear if this meant that logging activities resumed on Mount Tamalpais. It seems that the lumber company relied on the railroad to transport products to market rather than commercial navigation of Richardson Bay.
1894	34, 35	RR trestle made smaller, reducing size of inlet of Coyote Creek embayment to 125 ft Probable local creek flooding	Based upon analysis of numerous local historical rainfall records (Goodridge 1995, Collins 2001; Gilbert 1917), 1894 was a year that could have generated flooding in local watersheds and pulses of sediment to Richardson Bay. **Image Ref #34** is a 1913 geologic map that relies on Coast Survey mapping done in 1894-95 to depict marshlands. It shows very broad tidal channels through the interior historical Coyote Creek Marsh. It also shows the confluence of Tennessee and Coyote Creeks to be in a similar location as shown in **Image Ref #33 (**from 1892**)**. The map indicates that the railroad across the Coyote Creek Embayment has a double track south of the Mill Valley Junction by this year. The rail line changed ownership and became the Northwest Pacific Railroad (NPR). The older railroad levees that anchored the railroad were widened to accommodate two lines, and they were lengthened, which shortened 1310-ft trestle to 125 ft in total length. The rail line was converted from narrow gage to standard gage (5/30/2017 verbal communication NWPRR Historical Society). Picture 1 in **Image Ref #35** shows the resized railroad levee in Sausalito. Detailed mapping of the upgraded railroad levee and trestle at the Coyote Creek Embayment is shown in T-Sheet 5929 (**Image Ref #64**). The much shorter trestle and much longer levee substantially altered the hydrological connection between Richardson's Bay and both the Coyote Creek Embayment and its watershed. The 1894 restricted inlet to the Coyote Creek Embayment likely caused: 1) a reduction in tidal prism to the embayment; 2) near elimination of wind-generated waves within the embayment; and 3) a greater potential for flooding upstream of SR 1 when high tides coincided with large rain storms and flood flows from Coyote Creek. These factors would tend to increase sedimentation within the embayment.

			Picture 2 of **Image Ref #35** shows the junction of the Mill Valley and San Rafael rail lines along Almonte Marsh. The marsh along the west side of the Mill Valley branch appears dryer, perhaps due to the muted tides caused by the Railroad levee constructed along the eastern foreshore of the marsh in 1883.
1898	36, 37		The Mill Valley Branch of the rail line pictured in **Image Ref #36** was taken in 1898 and shows sparse development in the background hills. It seems likely that the previous undated picture 2 photo of **Image Ref #35** post-dates **Image Ref #36** because it shows much more hillside development. The Mill Valley branch further dissected Almonte Marsh, restricting tidal flow to the marshlands on the western side of the tracks to small culverts beneath the railroad levee. This further reduction in tidal prism and resulting poor drainage caused the former channels on the west side of the tracks to become pannes or potholes. Much of the marsh vegetation in the backshores of Almonte Marsh during this time appears to be dominated by pickleweed or other low-growing, salt-tolerant vegetation. **Image Ref #37** shows what appears to be a narrow channel in the mudflats connected to the inlet to the Coyote Creek Embayment at the recently shortened trestle. This image also shows an area of light shading at the flatlands between Coyote Creek and Tennessee Creek. The shading is consistent with reflection off standing water. The area may be ponded due to flooding or irrigation. The tides are low in this image, suggesting that any flooding upstream is not tidal. The abandoned 4000-ft-long railroad trestle across Richardson's Bay between Strawberry Point and Sausalito can be seen very faintly in the background of **Image Ref #37**.
1899	38, 39, 40, 41	~32 ac of tidal marsh above the confluence of Coyote and Tennessee Creeks is eliminated The total loss of marsh by 1899 is 42% of the original 1851 HCCM acreage	The 1899 UC Coast and Geodetic Survey Map T-02485 (**Image Ref #38)** shows that the tidal marshland within the lower reaches of the Coyote and Tennessee Creek valleys had been reclaimed. The tidal channel of Coyote Creek upstream of its confluence with Tennessee Creek appears to have been rerouted into a ditch at the north side of its valley. Tennessee Creek still exhibits naturalistic meanders for a short distance upstream of its confluence with Coyote Creek, but farther upstream it appears to have been routed into a ditch running down the middle of its valley. These are substantial changes in the plan form of the creeks since 1892. It is likely that the channels were undergoing continuous change. For example, sedimentation might cause them to abandon their ditches and reoccupy older channel courses, and then again be subjected to ditching.

		South Bothin Marsh begins to evolve within the Coyote Creek Embayment	The width of Tennessee Creek at the present-day crossing of Flamingo Road decreased in width from about 80 feet in 1870 to about 23 feet by 1899. The channel is in a slightly different position than previously mapped in 1892. This 1899 map shows Tennessee and Coyote Creeks mapped as a single line upstream of their confluence with each other. Previously they were mapped as double lines. This indicates that channel narrowing continued and was primarily due to reduced tidal prism and possibly to a lesser degree, increased upstream sediment supply. Marsh is not depicted upstream of the confluence of Tennessee and Coyote Creeks. There is no map evidence of natural or artificial filing of the valley above the confluence with sediment. one possibility is that either the construction of SR1 elevated levee plus the increasingly narrower Coyote Creek channel and the smaller inlet created by the shorter railroad trestle across the Coyote Creek embayment caused the tides to be more muted, so much so that the tides could not reach upstream beyond the confluence. Alternatively, a levee might have been placed along the lower meander of Tennessee Creek that extended to the Coyote Creek confluence. In either scenario, ~33 acres of the historical Coyote Creek Marsh were eliminated. By 1899, only about 32 acres (42%) of HCCM remained. Between 1856 and 1899, Coyote Creek Marsh expanded into the Coyote Creek Embayment. About 7 ac of mudflat evolved into tidal marsh. This was the beginning of what is now referred to as South Bothin Marsh. The railroad also reconfigured the marshlands. About 10.5 ac of the North Manzanita Marsh were enclosed by the railroad and thus became part of the Coyote Creek Embayment. About 6.5 ac of the North Manzanita Marsh remained open to Richardson's Bay. As of 1899, South Bothin Marsh totals ~17 ac, including the ~6.5 ac of newly formed marsh plus the addition of ~10.5 ac of the North Manzanita Marsh. In total, ~49 ac of tidal marsh existed in the Coyote Watershed upstream (west) of the railroad tracks. Almonte marsh slightly increased in area to ~52 ac by expanding northward into the Arroyo Corte Madera del Presidio, as the channel narrowed and migrated northward. The east side of Almonte Marsh and North Manzanita Marsh were the only remaining segments of marsh with full access to tidal waters unimpeded by the railroad or other infrastructure. In other words, it had a fully functioning tidal prism.

1900	42, 43		The 1900 photo in **Image Ref #42** shows the double rail system and its levee that replaced the 1300-ft-long trestle along the Coyote Creek Embayment. This supports the proposed date of 1894 as stated by historians at the NWPRR historical Society (5/30/2017 verbal communication to L. Collins). The Tam Valley Sale map (**Image Ref #43**) shows the layout of the former Coyote Creek marshlands upstream of the Tennessee Creek confluence. The rendering seems to indicate a levee or wall that might be associated with the 1870 loss of ~10.5 acres of marsh (see **Image Ref #16 and #17**). The image also shows a break in slope near Spruce Street, which probably represented the toe of an older alluvial fan built by Coyote Creek. The tidal transition zone, where the sausal had been located, was between Poplar (previously Oak) and Spruce Streets. Based on the 1851 map (**Image Ref # 6**), the head of tide within the creek was just slightly upstream of Poplar Street Field observations from 2017 indicate that the present-day head of tide might be only slightly further downstream, near Laurel Way (previously Main Street). This is based upon cursory reconnaissance observation. The correspondence between historical (1851) and present-date head of tide suggests that the historical muting of the tide has been relieved by the construction of the Coyote Creek Canal and upstream flood control channel.
1901	44	Increased subtidal area	The 1901 Nautical Chart (**Image Ref #44**) shows that the subtidal area of Richardson Bay (i.e., the area below the MLLW contour) has slightly expanded westward along the centerline of the Bay and northward since 1870. These subtidal areas evidently deepened. It reasonable to speculate that the tidal prism of the Bay as a whole was adequate to remove the sediments that had accumulated along the Bay bottom during the period of intensive logging, grazing, and other forms of agriculture.

1902-03 1903	45	Narrow gage RR converted to standard gage Electric train third rail system begins	Service ends for the 4000-ft railroad trestle spanning Richardson Bay between Strawberry Point and Sausalito. It is not clear when the trestle was removed. As the wooden railroad trestles across tidal flats and marshes deteriorated they were largely replaced with levees fill. Tidal flow was not initially impeded as much as it was later when levees replaced the trestles. This conversion is not always dated but some of it might have been done when the Richardson Bay line was electrified in 1902-03 with a “third rail” system of the North Shore Railroad which took over the rail line some tie in 1902 (Phil Rhodes email to L. Collins 4/21/2017). Road Map of Marin County (**Image Ref # 45**) indicates that the watershed south of Tennessee Creek was called Elk Valley (now called Tennessee Valley) and that Coyote Creek Valley was called Coyote Hollow. A “Milk Ranch” was located near the former backshore of historical Coyote Creek Marsh.
1904	None	Probable local flooding	Based upon analysis of numerous local historical rainfall records (Goodridge 1995, Collins 2001, Gilbert 1917), 1904 was a year that could have generated flooding in local watersheds and pulses of eroded sediment into Richardson Bay.
1905	46		This 1905 Map of the San Francisco Entrance (**Image Ref #46**) shows the same channel and marsh features as the 1899 T-sheet 0214785 (**Image Ref #38).**
1906	47		A 1906 photo of Richardson Bay looking eastward shows the sparse development of the land around the Bay (**Image Ref #47**). On December 18, 1906, voters decided to create a new high school called Tamalpais (Tam High). About 2.8 acres were purchased for $2,800, plus an additional ~5 acres of marshland for $509. The railroad soon added a special stop on its line to service the school.
1907?	None		Northwestern Pacific Railroad was incorporated 7 January 1907 as an amalgamation of several railroads including the North Shore. Initially it was owned by Southern Pacific (SP) and Santa Fe railroads. Santa Fe later sold their interest to SP (Dickinson 1967).
1908	48, 49, 50		First building at Tam High was Wood Hall, constructed in 1908 (**Image Ref #48 & 50**). http://thetamnews.org/lifestyles/tamalpais-high-school-an-architectural-history/ These photos also show the railroad levee that restricted the flow of tidal waters to and from the marshes west of the tracks, which likely resulted in reduced marsh surface sedimentation, greater desiccation, and probable subsidence of the marsh surface.

			The Marin County Water Map (**Image Ref #49**) does not show changes in marsh or tidal channels. It does however depict the 1870 loss of ~10.5 ac marsh in the Coyote Creek drainage.
c. 1910	51		The c. 1910 photo (**Image Ref #51)** shows that the marshes along the various embayments of the Sausalito shoreline have not been filled landward of the railroad levee. They were all filled at later times.
1915	52, 53, 54		The 1915 USGS topographic map of San Francisco and Vicinity (**Image Ref #52)** cannot be used to assess channel and marsh change since it has a range of mapping dates from 1894 to 1913. It shows the same channels that were indicated on the 1894-1895 US Coast Survey map shown in **Image Ref #34**. The 1915 photo of Tam High (**Image Ref #53**) shows a portion of Almonte Marsh that documents the muted tidal conditions created by the railroad levee of the Mill Valley branch line. The photo shows a former 1851 tidal slough along its landward bend that used to be at least 45 ft wide, but by 1915 had substantially narrowed and shoaled. The 1915 San Francisco Entrance map (**Image Ref #54**) cannot be used to assess tidal channel or marsh change because it shows the conditions based on the 1899 mapping and bathymetry.
1916	55		The NPR map shows a portion of Arroyo Corte Madera del Presidio tidal channel that was influenced by the railroad levee. This is the same channel bend that can be seen in **Image Ref #57**. In 1851 the channel was at least 220 ft wide in this vicinity, but the bridge over it in this 1915 map is only 106 ft long. The 1851 channel demonstrated a fairly consistent width upstream and downstream of the bridge location. The Mill Valley branch of the railroad had been constructed in 1889, but the San Rafael branch was constructed in 1883. If it is assumed that the Arroyo Corte Madera del Presidio bridge was reconstructed in 1894, while the single rail track was converted to double, the channel must have lost 114 ft of its width between 1895 and 1851 (43 years). This represents an average rate of narrowing (or infilling of the marsh) of about 2.6 ft/yr. Undoubtedly the railroad levee of the San Rafael branch muted the tidal flows in this reach of the Almonte Marsh. The tides were even more severely muted in the marshes west of the Mill Valley branch line, where tidal access was only through a 10 in x 12 in x 35 ft box culvert (**Image Ref 55)**.

			The train depot on the Mill Valley Branch at Tam High was called High School, while the depot on the San Rafael-Sausalito line, south of Tam High was called Almonte.
1917	None		"… contractors completing the portion of road between Manzanita street, near Waldo station, and Coyote Creek bridge is one of the problems that is occupying the attention of the state highway engineers (03/31/1917). https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SN19170331.2.5&srpos=9&e=-------en--20--1--txt-txIN-Coyote+Creek%2c+Mill+valley-------1 Note that Waldo station is near Manzanita Marsh, as shown in **Ref Image 61**.
Early 1920s	56	c. early 1920s artificial levee for power poles in AM and HCCM	Levee construction started to appear west of the Mill Valley railroad branch in Almonte Marsh. Based on 1923 photos and 1924 Coast Survey maps (**Image Ref #56 and #62**), it appears that an artificial levee was constructed during this time in Almonte Marsh and Coyote Creek Marsh to protect a power line corridor. It is not clear exactly when the power poles were placed in the marsh but it is estimated that it was around the mid 1920s. The power poles are indicated on a US Coast and Geodetic map dated 1927 (**Image Ref #64**).
1923	57	Only 50% of Almonte Marsh remains west of the RR	Sports fields, buildings, and artificial fill have been constructed on the west side of the Mill Valley railroad branch on Almonte Marsh by the end of 1923. The Garcia Associates letter of 12/16/16 states that the railroad tracks across Bothin shoreline might have changed from trestle to berm between 1923 and 1949. The evidence presented in this 2018 Watershed Sciences report indicates otherwise, that it happened long before in 1883 in South Bothin Marsh and Almonte Marsh. The photo shows that new marshland has in-filled the original 1851 channel of Arroyo Corte Madera del Presidio. It also shows about 6 ac of marsh had been eliminated near Tam High School. Maps indicate that it is likely that an additional 2 ac of Almonte Marsh had been eliminated west of the San Rafael Road (presently Homestead Blvd).
1924	58, 59, 60	Total area of AM ~35.5 ac and ~99 ac of marsh forms bayward of a c. 1920 levee	Using combined information from the 1924 map (**Image Ref #58**) and the 1923 photos that show development of Tams High School in the former Almonte Marshlands (**Image Refs #56 & #57**), it appears that by 1924 at least 19.5 ac of Almonte Marsh west of the San Rafael branch line tracks had been eliminated by placement of berms and artificial fill.

		Area of shallow mudflats in Coyote Creek Embayment is 63% of original size.	**Image Ref #58** shows a possible cable crossing or pier to deep water at the southern edge of the railroad levee at Manzanita Marsh. **Image Ref #59** shows ~10 ac remaining of Almonte Marsh west of the railroad tracks. This remnant likely had very muted tides because tidal access was only through small culverts beneath the tracks. About 36 ac of marsh existed east of the San Rafael branch rail, of which ~12 ac were relatively new marsh, having formed new shoreline since 1899. The approximate estimates for eliminated and remaining Almonte Marsh include the 1851 tidal channels that were previously wide enough to be mapped as double lines rather than single. The amount of shallow mudflats in the Coyote Creek Embayment west of the railroad tracks decreased to ~30 ac from ~40.5 ac in 1899, representing 63% of its original extent (~47.5 ac). In the 1924 map (**Image Ref #58**), an artificial levee c. 1920 is shown along the entire bayward shoreline of both Almonte Marsh and the newly forming South Bothin Marsh. In Almonte Marsh the levee would have reduced direct tidal access to the marsh from the Bay. Tides would have accessed the marsh from the banks of Arroyo Corte Madera del Presidio. This would have reduced the potential for the reformation of the natural overwash berm that characterized the 1851 foreshore of Almonte Marsh. By 1924, Arroyo Corte Madera del Presidio, near its railroad crossing, as seen previously in **Image Ref #55,** had narrowed to about 65 ft from its original (1851) width of 230 ft. In South Bothin Marsh (**Image Ref # 60**), the c. 1920 levee closely followed the perimeter of Shoreline Highway. Only a small portion of the original HCCM had its foreshore open to the tides. Tides west of SR 1 probably had become severely muted as indicated by the increasing narrowness of the remaining tidal marsh channels. It is not clear how much the SR 1 Bridge might have affected the upstream tidal prism because accurate maps of channel features for this time period were not found. East of SR 1, ~12 ac of new South Bothin Marsh evolved into the embayment between 1899 and 1924. Coyote Creek extended its tidal channel about 650 ft eastward within newly built marshland.

			By 1924, the total amount of tidal marsh west of the railroad levee in the Coyote Creek drainage was about 58 ac. This included ~12 ac of newly forming South Bothin Marsh, ~10.5 ac of the former North Manzanita Marsh, ~32 ac of the historic Coyote Creek Marsh west and ~3.5 ac east of the SR 1. The ~43.8 ac of marsh that had been eliminated from the HCCM were likely used for dairy and agricultural purposes. These are land uses that tend to generate considerable amounts of eroded sediment. It has not been determined if the head of Richardson Bay was dredged this early. It seems the only dredging conducted by this time was to build levees for marsh reclamation. There is no apparent map evidence at this time that commercial or other kinds of ship travel was impeded by shoaling of the Bay or that there was a need for commercial marine transportation at the head of the bay. Access to the railroad and SR 1 reduced the need for commercial maritime navigation. It is assumed that the primary need for maintaining navigability was for access by dredges that were busy creating levees to convert marshlands to future developments.
1925	61		The hiking map of Marin (**Image Ref # 61**) shows that hiking trails led from both Coyote Creek and Tennessee Creek to the Pacific Ocean. The trail along Tennessee Creek was already a road through the length of Tennessee Valley and half way into Elk Valley (presently Tennessee Valley), leading to and from Tennessee Cove. Construction of this road would have increased sediment supply into Tennessee Creek and thus into the Coyote Creek Embayment.
1926	62, 63		The 1926 Coast Survey Chart (**Image Ref #62**) does not show relevant information to assess and landscape change. The photo (**Image Ref #63**) shows an aerial view of Almonte Marsh and the once greater extent of the Mill Valley marshland.
1927	64, 65, 66, 67	Area of shallow mudflats in Coyote Creek Embayment is 45% of original size Coyote Creek delta/alluvial fan forms in Coyote Creek embayment	Almonte Marsh continued to expand northward into Arroyo Corte Madera del Presidio as the channel narrowed and migrated westward, eroding some of the pre-existing 1924 shoreline, including a portion of the c. 1920 levee along the creek mouth. **Image Ref #64** shows the “bulb” of Almonte Marsh that comprises the inside of a large meander bend of the Arroyo Corte Madera del Presidio at its north end. The bulb can also be seen clearly in the previous photo, **Image Ref #63.** The c. 1920 levee might not have been high enough to prevent overtopping by waves at high tide. It was probably only built high enough to potentially facilitate construction of the power line corridor. Small tidal channels extended through the levee as the marsh prograded eastward.

		East Bothin Marsh starts to form North Manzanita Marsh expands	**Image Ref #65** shows the total area of Almonte Marsh east of the tracks. In 1927, it covered ~38 ac, only a couple of acres less than it covered in 1924. The small muted tidal area west of the tracks also decreased in size by ~1 ac for development. This small remnant of muted marsh is here referred to as Tam Marsh, which for the purposes of this study is considered part of Almonte Marsh. A remnant piece still exists today but is not property of Marin County Parks. This remaining marsh segment was not indicated on the 1927 map (**Image Ref #64**). This 1927 map (**Image Ref #64**) is the first to indicate the power line corridor and location of the power poles that extend through Almonte and North Bothin Marsh. It is assumed that a boardwalk was constructed contemporaneously, although it might have been constructed somewhat earlier in the 1920s because the levee that was placed to facilitate construction appears on a 1924 map (**Image Ref #58**). Based upon the differences in the 1923 and the 1927 maps, the Coyote Creek Embayment seems to have experienced rapid conversion from mudflat to marsh, while the width of Coyote Creek within the embayment narrowed substantially (**Images Ref #66 and #67**). **Image Ref #66** shows the amount of mudflats in the Coyote Creek Embayment west of the railroad tracks had decreased from ~30 ac in 1923 to ~21.5 ac in 1927, representing 45% of its original 1851 extent, which was ~47.5 ac. By 1927, the sharp bend in the Coyote Creek tidal channel upstream of the SR 1 Bridge had been straightened, and ~2 ac of marsh had been eliminated along the southern bank of the bend. About 150 ft upstream of the bridge the channel abruptly changed in width from about 73 ft to about 23 ft. Near the present-day Flamingo Road crossing, the channel was mapped as a single line rather than a 25-foot-wide channel. The remaining historical Coyote Creek Marsh was ~40 ac, but had muted tides and might have been a mixture of muted tidal and non-tidal seasonal wetlands. By 1927, the tidal channel of Coyote Creek had built a fan along the backshore of South Bothin Marsh and thus extended its mouth northeastward almost 700 ft relative to its 1924 position. The width of the channel South Bothin Marsh before its northward extension narrowed to about an average of 40 ft where previously it had been more than 160 ft wide. By 1927 South Bothin Marsh had growth to ~33.5 ac. Historical Coyote Creek Marsh, was now

			comprised of ~3 ac east of SR 1 and ~37.5 ac west of SR 1. The total amount of tidal wetland in the Coyote Creek watershed west of the railroad levee was therefore ~74 ac. To the east of the railroad tracks, East Bothin Marsh developed ~0.2 ac of fringing marsh along the outboard toe of the railroad levee. North Manzanita Marsh expanded northward ~13 ac. At some point perhaps around 1927, the original San Rafael Road that roughly traced the backshore of the historical Coyote Creek Marsh became Tennessee Road on the east side of the marsh, Marin Ave to south, SR 1 to the west, and Almonte Blvd north of SR 1 (**Image Ref #67**).
1929	68	Sediment supply to Bay likely increases from post-fire erosion caused by Tamalpais/Mill Valley Fire	It is reasonable to assume that the 1929 Mount Tamalpais fire significantly increased the supply of sediment to Arroyo Corte Madera del Presidio and thus to upper Richardson Bay, in the vicinity of Almonte Marsh. The fire burned 2,500 ac of the creek's watershed over a three-day period, July 4-6, in an area prone to fire-induced erosion (Spittler 1988).
1931	69, 70, 71	Redwood Bridge over Richardson Bay opens Period of filling of Richardson Bay begins	The first Richardson Bay vehicle bridge was originally constructed of redwood and called the Redwood Bridge and opened in November 1931 (**Image Ref #69**). The drawbridge section near the northern edge of the bridge provided a 40-foot wide channel to access the head of Richardson Bay during high tide. It was seldom used during low tide. A view of the bridge construction at low tide can be seen in **Image Ref #70**, with South Bothin Marsh in the background. During the 18-year period from 1931-1949, the drawbridge opened only six times (Information sign of Marin County Parks at Bothin Marsh). The northern anchor and ramp of the bridge required extensive filling of the Bay north of De Silva Island (see **Image Ref #68**). This marked the beginning of ongoing and extensive filling of the Richardson Bay for decades, both upstream and downstream of the Redwood Bridge, including many parts of the Sausalito shoreline. A remnant of the c.1920 artificial levee associated with the power transmission corridor along the foreshore of Almonte Marsh is evident in **Image Ref #71.** Toward its southern shore the levee appears to be breached or eroded away and water can be seen to the base of the power pole nearest to the railroad levee.

1932?	72, 73	Fill placed in the northern upper Richardson Bay Additional levee construction AM	**Image Ref #72** shows the sinuosity of Coyote Creek in its embayment and that the creek transported sufficient sediment from its watershed to continue building an alluvial fan/delta and contributing to the formation of mudflat and tidal marsh. Two levees of different age can be seen that parallel the long North-South axis of Almonte Marsh, c. 1920 and c. 1930. Several other levees of the same possible vintage can be seen in the historical Coyote Creek Marsh and South Bothin Marsh. One is inboard of the foreshore and the others are on the west side of SR 1. These levees are mapped in yellow on a 1946 photo (**Image Ref #73)**. Very minor commercial development had occurred by 1932 along SR 1, mostly at the northern edge of South Bothin Marsh. Extensive artificial fill had been placed for the northern span of Hwy 101 beyond the Redwood Bridge. It can also be seen that sediment had started to accumulate at the southern piers of the bridge downstream of the mudflat channel leading from the opening to the Coyote Creek Embayment. This sediment is likely derived from Coyote Creek Marsh; the sediment transported from Arroyo Corte Madera del Presidio is more likely upstream and in the deep channel beneath the drawbridge.
1936	None	Impact of shoaling on navigation noted for upper Richardson Bay	This narrative was extracted from the Sausalito News (No. 3, 17 January 1936): "The story of a once useful waterway gone to waste by becoming more shallow with the passing years and how it can be converted into a useful harbor that will spell prosperity for this end of Marin was told to U. S. Army engineers at War Department hearing in the City Hall on Wednesday afternoon. And, there was revived the plan studied 25 years ago [1911] or so to cut a ship canal through a gap in the hills to the Pacific Ocean at Tennessee Cove, a scheme that sounds almost fantastic at first blush but which, upon careful study, appears quite feasible and at the same time would offer a means of scouring a channel through the sixty to eighty feet of mud that fills Richardson Bay except for the shallow covering of water at high tide." file:///Users/laurelco/LAUREL03/Bothin%20Marsh/Bothin%20Literature/Sausalito%20News%2017%20January%201936%20%E2%80%94%20California%20Digital%20Newspaper%20Collection.html In this excerpt referencing 60 to 80 feet of mud, it is assumed to be referring to the total amount of bay mud above underlying bedrock in Richardson Bay. The idea of cutting a new opening to the bay through Tennessee Valley was presumably not further pursued. This proposal clearly was not carried forth but it is interesting to note that it was initially proposed in 1911.

1937	None	Golden Gate Bridge built	Completion of the Golden Gate Bridge (it was started in 1933) initiates a building boom that leads to the need for additional highway construction in Sausalito and Mill Valley. The increased development in the Coyote Creek and Arroyo Corte Madera del Presidio undoubtedly increased the local sediment supplies to upper Richardson Bay.
1940	None	Electric rail service ends and freight service begins	Electric rail and passenger service to Mill Valley ends 1 October 1940 (P. Rhodes 4/21/2017 email). The rail line begins to support freight service in 1940's(P. Rhodes 4/21/2017 email). Richardson Bay Cleanup Set: Sept 14, 1940: " Richardson Bay is going to be cleaned up. All the old windjammers and discarded steamer hulks that have been reposing quietly in the shallow bay graveyard will soon be pulled forth and destroyed completely. Notice was given yesterday by the United States Army engineers that on next Tuesday, bids will be received for the removal of the hulks. "The wrecks which it is proposed to do away with include the former steam schooner Helene and the remains of the barkentine Echo, which last year was burned to the water's edge by the Richardson Bay Yacht Club and which since that time has given the Coast Guard boys several uncomfortable hours chasing its drifting carcass down . . ." (Newspaper clipping at California Room, Marin Civic Center Library).
1942	None	Artificial fill increases in Richardson Bay	Wartime ship construction began in Sausalito at what was then known as Marinship. An estimated 838,763 cubic yards of earth and rock were excavated from Pine Point, Waldo Point and nearby areas. The resulting fill was spread using heavy equipment across the shoreline and tidal mudflats at Sausalito to create new land on which the various buildings of the shipyard were rapidly constructed (https://en.wikipedia.org/wiki/Marinship).
1945	None		The Sausalito News (No 30, 26 July 1945) reported that: "Richardson Bay Dredging Urged by State Chamber. A region-wide program for the early development of six north coast harbors to stimulate postwar expansion of commerce, industry, fishing, lumber shipments and other activities that will increase the wealth of this region has received the backing of the North Coast Council of the California State Chamber of Commerce. Proper maintenance and dredging of the channel in Richardson Bay as far as the Marinship yards is the council's goal for Sausalito, it was stated. This channel is rapidly filling, It was reported to the council by President Harry Braun, and Director J. Herbert Madden of the Sausalito Chamber of Commerce, who requested the state body to aid in helping to alleviate the local condition." Sausalito News (March 1, 1945) reported: "For the third time in recent years the Richardson Bay drawbridge was raised to allow passage of the dredge Liberty to dig out the yacht harbor

			Marvel Mar and to begin work piling up land behind the cottages to make more land available for development. The dredge was expected to operate for two weeks (included in 4/21/2017 email from P. Rhodes). This article refers to previous dredging in Richardson Bay but documentation of it has not been found.
1946	73, 74, 75	Sediment deposition continues at southwestern piers of Redwood Bridge	The 1946 aerial photo (**Image Ref # 73**) further reveals the extent of additional levees that might have been constructed c. 1920s and 1930s in the historical Coyote Creek and South Bothin Marshes and during the 1930's in the Altamonte Marsh. Artificial filling had continued in the Coyote Creek watershed, particularly along SR 1. **Image Ref #74** shows that by 1946 Almonte Marsh was about 1.5 ac smaller than it was in 1927. This is due to marsh erosion along the inside bend of the large downstream meander of the Arroyo Corte Madera del Presidio. A portion of the c. 1920 levee was eroded away at the channel bend as well as at the southern end of the marsh, where the c. 1930s levee and the c. 1920s levee converged. The Tam Marsh diminished in size by 1 ac due to artificial fill. **Image Ref #75** shows that by 1945, the historical Coyote Creek Marsh had decreased to about 33.5 ac on the west side of the road and on the east side it decreased to about 3 ac. Given the number of levees and distance from the tidal source, and narrowness of the remaining tidal channel of Coyote Creek, it is likely that much of the Historical Coyote Creek Marsh west of SR 1 was converting to a mixed brackish tidal/seasonal marsh due to the diminished tidal prism. The tidal flats of Coyote Creek Embayment decreased in size to ~16.5 ac (35% of its original 1851 acreage). The size of the South Bothin Marsh increased its size from ~33 ac in 1927 to ~34 ac. The total amount of tidal marsh in the Coyote Creek watershed west of the railroad levee totaled ~70.0 ac. It is apparent in these images that sediment accumulated downstream of the subtidal channel of Coyote Creek at the Redwood Bridge. The evidence is the sizable sediment bar at the southwest pilings. It seems likely that, as Coyote Creek extended itself eastward and then northward within the Coyote Creek Embayment, sediment transport from the creek into the bay via the subtidal channels accelerated. East Bothin Marsh had slightly increased in size from ~0.2 ac in 1927 to ~0.25 ac in 1946.
1949	76	Redwood Bridge decommissioned.	Redwood Bridge over Richardson Bay was decommissioned in 1949 (information sign along Bothin Marsh, Marin County Parks). A cable crossing is shown to cross Richardson Bay to

		New concrete bridge built for Hwy 101	either side of the Redwood Highway 101 Bridge and portions of Manzanita and South Bothin Marshes (**Image Ref # 76**).
1950	77, 78, 79	ACMdP straightened upstream of railroad bridge	Increased artificial fill along SR 1 is evident in **Image Ref #77**. The fill reduces the Historical Coyote Creek Marsh to ~30 ac on the west side of SR 1 and to ~2 ac on the east side. South Bothin Marsh had ~4 ac of artificial fill but it also continued to prograde toward the railroad levee within the Coyote Creek Embayment resulting in only a slight increase in total tidal marsh acreage to ~33.5 ac. **Image Ref #78 and #79** shows increasing fill near the Tam Marsh and the area of marsh between the Mill Valley and San Rafael branches of the railroad at Almonte Marsh. **Image Ref # 79** provides unobstructed detail of Almonte Marsh, revealing a new straight canal cut through a former meander in Arroyo Corte Madera del Presidio upstream of its railroad bridge.
1952	80, 81	Less than 3% HCCM remains east of SR1 as land development accelerates Only 54% of former marshland west of SR1 remains	**Image Ref #80** shows the conditions of the study area in 1952 and **Image Ref #81** shows polygons that indicate change in marsh acreage since the mid to late 1940s. Almonte Marsh increased to ~39 ac following 1946. About 37 ac were east of the RR levee. This was probably mostly due to the extension of the northern bulb at the bend in Arroyo Corte Madera del Presidio. The muted tidal marsh south of Tam High decreased in size from ~3 ac to ~1 ac. It is worth noting that the material dredged during the straightening of Arroyo Corte Madera del Presidio west of the railroad bridge was spread discontinuously to either side of the new channel, without blocking tributary tidal marsh channels, rather than being used to construct containment levees. Less than 3% of the historical (1851) Coyote Creek Marsh existed in 1952, represented by the ~3 ac marsh remnant just east of SR 1. Development had begun to spread across the remaining Historical Coyote Creek Marsh west of SR 1. Coyote Creek and Tennessee Creeks in the historical marsh upstream of SR 1 become completely ditched. These activities surely increased sediment supply to Coyote Creek, South Bothin Marsh, the enclosed embayment, and Richardson Bay. The reduced tidal prism caused by upstream marsh reclamation decreased the power of the ebb tidal flows to move sediment through the tidal channels to Richardson Bay. This coupled to the increase in sediment delivery promoted sedimentation within the Coyote Creek Embayment.

			A network of gullies is apparent in the steep, small tributaries of the northern hillsides in the Coyote Creek watershed. The existence of these gullies supports the contention that earlier heavy grazing led to increased runoff and erosion that augmented the terrigenous sediment supply to the Bay. **Image Ref #80** shows colonies of cordgrass moving out onto the mudflats of the embayment. Total acreage of marshland west of the railroad levee (South Bothin Marsh plus historical Coyote Creek Marsh) was reduced to ~37.5 ac, about 54% of its size in 1946. Marsh expansion in the Coyote Creek Embayment caused a reduction in the total acres of mudflat from ~16.5 ac in 1946 to ~12 ac in 1952. North Manzanita Marsh and East Bothin Marsh had merged by 1952 in area of marshland covering ~7 ac, but individually they had ~6.0 ac and ~0.9 ac, respectively. The North Manzanita Marsh portion of this marshland became smaller as levee building and artificial filling proceeded at is southern edge.
05/28/ 1953	None	Dredging operations resume in Richardson Bay	The Sausalito News, #22, 28 May 1953 reported that: "Richardson Bay Bridge [Redwood Bridge] was closed last night at 10 o'clock and traffic was rerouted for about 40 minutes . The bridge was closed to allow a dredge to pass through to the Zaro Yacht Harbor, where dredging operations are being resumed." https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SN19530528.2.6&srpos=6&e=-------en--20--1--txt-txIN-dredging+richardson+Bay-------.
10/01/ 1954	None	Dredging continues in upper Richardson Bay	Sausalito News, #39, 1 October 1954) reported "dredging operations were started this week north of the Richardson Bay bridge to accommodate the equipment, which will be used for construction of the new Richardson Bay bridge. Construction of the new span is expected to start within the next week or two." https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SN19541001.2.5&srpos=1&e=-------en--20--1--txt-txIN-dredging+richardson+Bay-------1.
Dec 1955	82 83	Significant flooding throughout the Bay Area due to intense rain	Flood at Arroyo Corte Madera del Presidio was caused by 9 inches of rainfall over the watershed that resulted in a peak discharge of 1400 cfs at the Camino Alto Bridge (USACE 1968). Flooding was widespread and ultimately led to the start of many flood control projects that straightened and diverted channels throughout Marin County.

			Specific areas of flooding can be seen in Tam Valley in **Image Ref #82 and #83**. (Madrone Assoc. 1975).
1956	84	Concrete Hwy 101 bridge construction begins Containment levee started east of AM shoreline	A new concrete Richardson Bay Bridge was under construction during 1956. This may have permanently isolated and diminished portions of North Manzanita Marsh. **Image Ref #84** shows that a new levee was constructed of dredge spoils well over 600 feet offshore of the Almonte Marsh. It is presumed that this levee was being constructed to contain dredge spoils and thus reclaim an area of mudflat and shallow bay for development. It would have substantially reduced tidal prism in the upper Richardson Bay, interfered with the generation of wind-generated waves along the fetch of the Bay, and ironically would have led to a greater need for maintenance dredging in the boating channel. The inset photo in **Image Ref #84** shows the kind of junk materials that were used for constructing many of the levees and artificial berms in the Bay. Materials similar to these can be found in South Bothin Marsh today, although the date(s) of their placement is uncertain. The photo also shows the amount of filling that has begun and was being planned for the Bay waterfront in Sausalito.
1957	85, 86, 87	Increased shoaling of Richardson Bay due to continued losses in tidal prism and likely increases in local sediment supply	The Independent Journal (1/2 6/1957) published a map of the planned dredging and development of Richardson Bay (**Image Ref #85**). It shows a canal cutting through the northern bulb of Almonte Marsh and another canal cutting through South Bothin Marsh. It also shows the area of a cable crossing that extends farther west of the alignment of the Redwood Bridge that was shown in the 1949 bathymetric map (**Image Ref #86**). The significance of this difference is not known. **Image Ref #86** shows that upper Richardson Bay had shoaled since1949. The tidal flats had extended southward, as indicated by the southward migration of the MLLW contour, toward the Richardson Bay Bridge. This shallowing was likely caused by a multitude of factors including reduced tidal prism due to marsh reclamation and artificial filling of the Bay, increased sediment supply from the 1955 flooding, and from ongoing local land use disturbance. **Image Ref #87** shows changes in the position of the MLLW contour between 1851 and 1956. Two principal periods of shallowing of the upper Bay were 1851-1856 and 1901-1956. Shorter episodes or even brief pulses of terrigenous sediment due to especially wet winters,

			major storms, wildfires, and bursts of land development may have punctuated both periods. However, sediment supply during the first period was due mainly to land uses, such as grazing and logging, in the local watersheds. The latter period was dominated by the interference with tidal processes, such as construction of levees, channelization of tidal channels, and dredging that decreased the tidal prism of the upper Bay and thereby increased the tendency of the tidal flats and marginal marshlands to expand. The earlier period of increased sediment supply might have been followed by a period of near recovery to pre-existing depths in upper Richardson Bay, if the tidal prism had been maintained. The chronic shoaling that resulted from the loss of tidal prism might only be reversed by maintenance dredging or long-term sea level rise.
1959	None	Coyote Creek concrete channel constructed upstream of Flamingo Road	To protect the housing developments on the historical tidal marshlands of the original Coyote Creek Marsh, which evidently had only been slightly raised by fill and might also have been influenced by subsequent subsidence, the USACE devised a flood control plan that involved an engineering project along the lower 7,100 feet of the Coyote Creek channel (USACE 1959). The project entailed installing a concrete-lined channel for approximately 3,000 feet upstream of Flamingo Road, and dredging the downstream 4,200 feet of earthen channel (ESA-PWA 2012). The project was motivated in part by the historic flooding of 1955. However, the alignment of lower portion of the project, called for the Coyote Creek Canal, which agrees closely with development plans dating back to 1892 (see **Image Ref #31**).
1960	88, 89	Fill provided for Shelter Cove Near elimination of North Manzanita Marsh Channelization of ACMdP through Almonte Marsh Near constant dredging of Richardson Bay	Richardson Bay Master Plan was adopted (Independent Journal ref from 7/15/1969). **Image Ref #88** shows that new fill had been place at the head of Richardson Bay for the Shelter Cove development, northwest of the fill that had been placed earlier for the north span of the Highway 101 at Richardson Bay Bridge. New dredge spoil deposits can be seen along the south edge of the 1956 containment levee. Marin News (10/29/1960) reported that the U. S. Army Dredge Hardin' "has finished its week - long 24-hours-per-day churning around Richardson Bay and the Sausalito side of San Francisco Bay. Object was the cleaning and dredging of ship channels in Richardson Bay, which the Harding affected on schedule. The non-stop shift started Monday morning, Oct. 17, and was concluded Monday morning, Oct. 24. According to Army Engineer in Sausalito the Harding steamed off for Mare Island on Tuesday." (https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SN19601029.2.36&srpos=5&e=-------en--20--1--txt-txIN-dredging+richardson+Bay-------1

		Exterior containment levee constructed. Appearance of North Bothin Marsh	By 1960, Almonte Marsh had decreased in size to ~21.5 ac, 62% of its size in 1952, or 41% of its maximum size in 1899. About 20 ac were east of the railroad levee. This was due to continued flood control canal construction in Arroyo Corte Madera del Presidio that extended a diversion canal through Almonte Marsh, isolating the northern bulb of the marsh. The bulb, as defined by the large eastern bend in the channel, had been a natural feature of the channel that naturally expanded northward as the channel migrated. The larger southeast migrating bends in the lower tidal reaches of Arroyo Corte Madera del Presidio, at least historically included sand bars and beaches exposed at low tide, and natural levees along the banks. They increased the overall ecological diversity in the tidal landscape. They were mapped in the 1851 Coast and Geodetic Survey map (**Image Ref #7 and #9**). The flood control canal for the Arroyo Corte Madera del Presidio was much narrower and straighter than the original natural channel. It lacked the capacity to convey the tidal prism of the original tidal marsh landscape. Its straightness increased the delivery of terrigenous sediment to the shallow subtidal areas of the Bay, bypassing the remnant marshlands. The tidal flow and sediment distribution of upper Richardson Bay were completely and permanently altered in a way that would tend to increase its modern tendency to shallow. **Image Ref #89** shows the extent of filling by 1960 as evidenced in **Image Ref #88** and the other aerial images shown. About 1 ac of new marshland can be seen inside the southern corner of an incomplete containment levee. It was located just south of the main canal dredged for navigation, just east of the c. 1920 levee on Almonte Marsh, and it had at least three openings to allow dredges and barges to enter and exit from different directions. The new marshland forming along the interior (landward or western) margin of the incomplete containment levee is here referred to as North Bothin Marsh. The effects of this incomplete levee on tidal circulation and sedimentation in upper Richardson Bay are unknown. It is likely to have diminished the heights of wind-generated waves trained on the foreshore of Almonte Marsh. It may have reduced the exposure of the foreshore sediment delivered to the upper Bay from the Arroyo Corte Madera del Presidio. The deepened areas of the Bay from which the dredged materials were removed to build the levee served as sediment sinks, reducing the availability of sediment to sustain tidal flats and marshes.

			Image Ref #88 also shows further filling and grading of North Manzanita Marsh and South Bothin Marsh. **Image Ref #89** shows that North Manzanita Marsh has ~1 ac of marsh remaining that is part of the Bothin Marsh complex. About 2 ac of the marsh have become isolated to the south. Less than ~0.5 ac of Manzanita Marsh remaining to the north had started merging with East Bothin Marsh. About 1.0 ac was excavated as a deep pond, possibly to capture road runoff. East Bothin Marsh had grown only slightly, from ~1 ac to ~1.3 ac. South Bothin Marsh had been graded and filled just west of the historical 1851 foreshore, and along the southern bank of the lower tidal reach of Coyote Creek, near its mouth in the Coyote Creek Embayment. New containment levees were being constructed for additional reclamation farther into the marsh. About 9.0 ac of South Bothin Marsh was lost to artificial filling. The marsh also continued to prograde into the Coyote Creek Embayment, gaining ~2.0 ac. Overall, South Bothin Marsh decreased in size to ~28.0 ac, about 79% of its 1952 size. The tidal flats of the Coyote Creek Embayment were furthered reduced by conversion to tidal marsh. Since 1952, the embayment decreased in size from ~12 ac to ~10 ac, which was about 19% of its maximum size. The fan of the Coyote Creek tidal channel within the Coyote Creek embayment appears to have been straightened or ditched, perhaps to increase its capacity to convey floodwaters from upstream, and to promote expansion of its fan. Grading for suburban development on the historical tidal marshlands west of SR 1 appears to have been completed. Additional grading and artificial fill are evident east of SR 1, leaving a small remnant (~0.3 ac) of tidal marsh at the north edge of the original (1851) foreshore. By 1960, construction of the concrete flood control channel of Coyote Creek upstream of Flamingo Road is apparently complete.
1963	90	Elimination of the northern bulb of AM begins	Dredging activity had started to remove the remaining northern bulb of Almonte Marsh. **Image Ref #88** shows a dredge in the process of excavating the marsh bulb. The spoil material may have been used as fill for the Shelter Cove development to the immediate east.
1964	91	Construction of the CCC for flood control begins in SBM	Sausalito News published this report (21 October 1964): “Demolition of the Poplar Street Bridge, which crosses Coyote Creek in Mill Valley, continued last week despite protests from merchants who were nearly cut off from their customers, and the attempt of Tamalpais Fire Chief Herbert Owen to prevent the bridge's destruction. The operation is part of the Coyote

			Creek Flood Control project." (https://cdnc.ucr.edu/cgi-bin/cdnc?a=d&d=SN19641021.2.68&srpos=1&e=-------en--20--1--txt-txIN-Coyote+Creek%2c+Mill+valley-------1). By 1964, lower Coyote Creek downstream of SR 1 was relocated to its current, straightened alignment as the Coyote Creek Canal. Dredged material was placed on the marshes to the north of this canal, severing the tidal connections between South Bothin Marsh and Coyote Creek except during extreme high tidal or flood conditions (ESA and PWA 2012). A flap-gate had been installed under the railroad levee at the inlet to the Coyote Creek Embayment and operated from 1964 to 1980 (ESA-PWA 2012). The flap gate allowed overflow waters from the creek and local runoff to exit the embayment into Richardson Bay during low tide, but prevented tidal waters from entering the embayment. Isolation from the tides and from the creek allowed the embayment to desiccate during the dry season. The desiccation would have caused the organic faction of the sediments to oxidize, reducing their bulk density and thus lowering the elevation of the land through subsidence. **Image Ref #91** shows areas of likely artificial fill placed on South Bothin Marsh along the alignment of the future Coyote Creek Canal. The purpose of this fill is uncertain, however it seems possible that it was placed to backfill areas along the levees of the future flood control canal. Containment levees for reclaiming Richardson bay just south and east of the Richardson Bay Bridge are visible at the bottom-center of **Image Ref #91**.
1965	92, 93	CCC constructed Rubble and debris piles placed in SBM Tidal flap gate placed at SBM limits tides to the embayment	**Image Ref #92 shows that c**onstruction of the Coyote Creek flood control project had begun. It extended into South Bothin Marsh and into the developing East Bothin Marsh to straighten tidal reach of Coyote Creek channel into a trapezoidal canal with levees on its banks extending to the railroad levee. The north bank appears to have had a continuous levee, while the south bank might have only had a levee on its lower half and a short distance downstream of the SR 1 bridge. A new 105-foot-long railroad bridge was constructed over the new Coyote Creek Canal. The drainage area of South Bothin Marsh was now only ~0.18 ac due to the canal isolating the marsh from the Coyote Creek watershed. A maintenance plan was developed for continued dredging of the channel. The design capacity of the canal was to carry a 20-year storm from the watershed. The discharge of a 20-

		Interior containment levee constructed at AM Early development of North Bothin Marsh bayward of Almonte Marsh	yr storm was reported to be 1,075 cfs in 1959 (USACE 1959) and 1,952 cfs in 2005 (PWA 2005). The base height of the Coyote Creek Canal was below MLLW and the Canal was excavated straight through the adjoining mudflats beyond the railroad levee to the subtidal Sausalito Canal on the east side of the Richardson Bay Bridge. This was done to connect the subtidal Coyote Creek Canal to the main northwest trending deeper dredged Sausalito Canal. This configuration promoted the transport of sediment from the Coyote Creek Watershed to the ebb flows of the Sausalito Canal that could carry the sediment toward San Francisco Bay. However, the net direction of fine sediment transport is more likely toward upper Richardson Bay, due to dominant direction of flood tide and wind-generated waves, typical of such estuaries with small fluvial discharges. The connection of the two Canals seems to have increased the need for dredging the Sausalito Canal, while isolating South Bothin Marsh from its terrestrial sediment supply provided from the Coyote Creek watershed. **Image Ref #93** shows that the former outlet of the Coyote Creek Embayment was made smaller, further limiting the tidal prism, and hence its sediment supply to South Bothin Marsh. It appears that the inlet involved a new approximately 26 ft-long bridge with an accompanying tidal flap gate of unknown dimension. This new bridge and flap gate replaced the 125 ft-long trestle. The flap gate eliminated tides from entering Coyote Creek Embayment. It only allowed floodwaters that overflowed the Coyote Creek Canal and other runoff from local urban drains to exit the embayment at low tide. The aerial photos indicate that the mudflat channel leading away from the east side of the opening became very narrower. It was not dredged and its small size was evidence of very reduced and discontinuous flow from the embayment. This elimination of tidal action within the embayment also eliminated tidal sedimentation, except during extreme flood events that overtopped the railroad or Canal levees. South Bothin Marsh became sediment-starved with no sufficient mechanism to gain elevation. Coyote Creek was unable to continue building its fan within the embayment. The conversion of the embayment into a floodwater storage basin would have caused seasonal changes in salinity from nearly fresh to brackish during winter to saline or hypersaline in late summer, due to the basin's desiccation. Repeated wetting and drying would have oxidized the organic faction of the sediments, causing the basin to lose some height, while increasing the acidity of the sediments, and thus causing some metals,

			such as iron, to mobilize. The wetting and drying can also cause elemental mercury to transform into the biologically active and toxic methylmercury (Yee *et al*. 2008). The Coyote Creek Embayment, including the abandoned truncated segment of the former Coyote Creek channel, was slightly reduced in size from an estimated ~10 ac in 1960 to ~9.5 ac by 1965, representing about a 20% reduction from its original 1883 size. By 1965, ~4 ac were eliminated in South Bothin Marsh mostly due to the excavation of previously vegetated marshland to create the Coyote Creek Canal, reducing the total acreage of the marsh to ~26 ac. Concrete rubble and other urban debris was placed on the South Bothin Marsh in and around the abandoned former Coyote Creek channel near its mouth and alluvial fan, and along the northwest backside of the northern flood control levee. This might have been done to fill former Coyote Creek channel of the diked marsh to buttress the backside of the new canal levee and to prevent headward erosion into its backside from the former truncated Coyote Creek; or, it was simply the disposal of unwanted materials, reflecting a general regard for diked marshes as disposal areas. A new interior containment levee was constructed on the Richardson Bay mudflats between the Almonte Marsh foreshore and the more eastern 1960 containment levee. North Bothin Marsh would form within this new interior containment levee. Almonte Marsh had changed in size very little since 1960. About 1 ac had developed near the north end of the new interior containment levee. It had minor erosion near at its north foreshore and minor expansion of its eastern foreshore, before the construction of the interior containment levee. It covered ~19 ac, of which ~1.5 ac was Tam Marsh, and ~17.5 ac was east of the railroad levee. About 3 ac of the new North Bothin Marsh formed at the northwestern area of the intersection of the 1960 exterior containment levee and the railroad levee. East Bothin Marsh expanded bayward very slightly. The area that had been merging with North Manzanita Marsh became isolated from the rest of East Bothin Marsh by the Coyote Creek Canal and hereafter is considered part of the North Manzanita Marsh. The total size of east Bothin Marsh therefore decreased by ~1 ac.

			North Manzanita Marsh covered ~2 ac due to the addition of a small portion of East Bothin Marsh, and construction of pond that might have functioned as storm runoff retention for the highway.
1966	94, 95, 96, 97	Continued formation of North Bothin Marsh Filling of San Francisco Bay curtailed by passage of the state McAteer-Petris Act and formation of the San Francisco Bay and Conservation and Development Commission	**Image Ref #94** shows that recent dredging and filling was widespread throughout upper Richardson Bay during the 1960s. The photo shows that the Coyote Creek Canal was not yet fully complete. Its banks appear wavy, not yet straight or parallel to each other. A vehicle trail leading to the areas of rubble disposal and in the diked South Bothin Marsh can be seen along the north bank of the Canal. The excavated runoff retention pond can also be seen along the remnant shoreline of North Manzanita Marsh. An earlier image (see **Image Ref #92)** shows dredge material being placed within the cell of the interior containment levee. Marshes forming within this cell and along either side of its levee are referred to as North Bothin Marsh. The containment cell was partially filled with material dredged from Shelter Bay and the subtidal channel of Arroyo Corte Madera del Presidio. **Image Ref #95 shows** canals that had been dredged and containment levees that had been constructed for the disposal of dredged sediment, the formation of the bar near the southern piers of the Redwood Bridge. The upper part of Richardson Bay had become completely altered. The historical navigational Chart 5532 (**Image Ref #96**) fails to show many of these changes. However, it does show a narrower MLLW boundary than the previous 1957 chart (**Image Ref #86**) and it only extends to south side of the Richardson Bay Bridge rather than slightly upstream as it did previously. Dredging is required to maintain these areas. Sediment supply from the CCC can actually be seen in the picture (**Image Ref #95**) as murkier water traveling to the Sausalito Canal. **Image Ref #97** shows some of the additional artificial filling that was occurring south of the Richardson Bay Bridge. These changes in the upper Bay have reduced its tidal prism, which in turn has affected the distribution and extent of mudflats and the power of wind-generated waves, which in turn has affected sediment delivery to the Bothin Marsh complex. By 1966, a trend toward net shoaling of the Bay is clearly evident.

			It should be noted that essentially no sediments have been exported from the upper Bay. Sediment provided from the local watersheds have been accumulating in local subtidal and lower intertidal areas. Dredging in these area has been used to construct local levees to contain other locally dredged sediment. These containment cells would later be breached. The increasing sediment pile within the upper Bay has been naturally and artificially redistributed within the Bay. A reasonable inference is that, in the absence of interference, the shoaling of the Bay would have generated new tidal flats and new tidal marsh, and would have supported the evolution of high marsh from low marsh.
Post 1966	98		**Image Ref #98** was taken sometime after 1966 as indicated by the development of more marshland and filling within the small Rectangle Marsh (considered part of North Bothin Marsh) south of Almonte Marsh but within the north side of the exterior containment levee. The new interior containment levee can be seen just beyond Rectangle Marsh. Levee construction was eliminating portions of SBM on its southeast corner.
1967	None	Coyote Creek Canal completed	Flood Control work was fully completed for Coyote Creek in 1967. The Coyote Creek Canal requires regular maintenance dredging to retain its design capacity. About 14,000 cubic yards of sediment were removed in 1965, and an unknown amount was removed in the fall of 1974 (Madrone Associates 1975).
1968	99	Hotel constructed on artificial fill [;aced on former NMM	**Image Ref #99** coarsely shows marsh and land development around upper Richardson bay since 1952 and 1968. Some of the larger changes depicted include the dredged areas of the Bay, Arroyo Corte Madera del Presidio, and Coyote Creek Canal. The developed areas are shown as a purple tint and purple stippled areas indicate excavations from dredging of the Bay and loss of marshland such as at Manzanita Marsh. Although urbanization has surely increased the amount of runoff with the creeks, the tidal channels are all much smaller than their historical counterparts, demonstrating the former importance of tidal prism, not upland streamflow, to support the wider and deeper channel of the historical marshes. Construction of a Howard Johnson Hotel was completed on artificial fill that had been placed on a former area of North Manzanita Marsh.
1969	None	Extension of Sausalito Canal proposed and the Richardson Bay	The Independent Journal (03/07/1969) reports a measure on the voter ballot endorsed by the Marin Conservation League would extend the Sausalito Canal 2.5 miles from the Army Corps of Engineers turning basin to the Mill Valley small craft harbor, which was under construction, with costs shared by the City of Mill Valley and property owners along the Canal, who had

		Channel Dredging District formed	formed the Richardson Bay Channel Dredging District to assess themselves for the project. Independent Journal (07/15/1969) reports a proposal to develop Richardson Bay's "cluttered" waterfront at Manzanita and Waldo Point were presented to Planning Commissions
1970	100	Rail line converted to a pedestrian path sometime after 1970s (?)	**Image Ref #100** shows that the clearance for boat and ship traffic below the San Rafael Bridge at high tide is 56 ft wide by 39 ft high. It also shows the existence of the CCC but seems to rely upon and show the same bathymetry as from 1966. According to Garcia Associates' letter of 12/16/16, after the railroad was fully decommissioned sometime after the 1970s, it was converted to a pedestrian path (CMDPW, 2016: 2). It is not known if this reference is to an earlier trail predating the 1981 Bay Trail.
1971	None		Rail line across Bothin Marshes begins freight service (P. Rhodes verbal communication and 4/21/2017 email Phil Rhodes).
1973	101, 102, 103	Early breaches occur through NBM interior containment levee Advent of the US Clean Water Act regulating the dredging and discharge of fill into waters of the US including Richardson Bay and its tidal marshes Interior dredge spoils observed in NBM	**Image Ref #101** shows that some colonies of vegetation appear to have coalesced in South Bothin Marsh as compared to the aerial photo of 1952 (**Image Ref #80**). By this time the marsh had been disconnected from the Coyote Creek watershed for 9 years. The photo shows that the Coyote Creek Embayment is able to drain at low tide, but the fully diked Almonte Marsh has abundant standing water. Only the highest areas of dredge spoils and the levees appear above water surface. The fringing tidal marsh along the foreshore of Almonte Marsh has expanded bayward. The higher areas of disposed dredged sediment in Almonte Marsh appear to support vegetation except in areas where sediment disposal is very new. The seasonal wetting and drying of this basin would have caused seasonal changes in salinity from nearly fresh during winter to saline or hypersaline in late summer. Repeated wetting and drying would have oxidized the organic faction of the sediments, causing the basin to lose some elevation, while increasing the acidity of the sediments, and thus causing some metals, such as iron, to mobilize, causing to transformation of elemental mercury to toxic methylmercury (Yee *et al*. 2008). These conditions were unfavorable to vegetation, and caused much of the basin to remain barren. Other notable changes by 1973 include further hotel development on the portion of South Bothin Marsh that had been leveed in 1966, and new levee construction to reclaim areas landward of the commercial district along SR 1. The exterior containment levee had been excavated by a dredge digging a borrow ditch for building the new interior containment levee. Maintenance dredging was conducted in the upper portion of the Coyote Creek Canal one year after this photo was taken.

			According to ESA-PWA & WRA (2012) the containment cell "at the north end of Bothin Marsh (referred to in this report as Almonte Marsh) was not reconnected to the tides until sometime in the 1970s or 1980s, when a number of breaches opened up in the north side of the berm to allow tidal access". **Image Ref #102** shows the same area as **Image Ref #101** but 3 days later. The more recent image shows a possible breach of the interior containment levee in about the middle of the Almonte Marsh foreshore. It is not known if this happened naturally or purposely. *T*he breach occurred where the mudflats were deepest within the containment cell. It appears that water has drained somewhat from the marsh. The former foreshore of the historical Almonte Marsh is also evident. A very high area of dredge spoils is evident along the western edge of the marsh that might be much older than the other dredging spoils. Based on field investigations for this report, these older spoils contain abundant broken shell of subtidal mollusk infauna mixed with silts and clays, and were placed on the historical tidal marsh rather than on dredged sediment. The material is not from an Indian shellmound. These spoils are evident in earlier images (see **Image Ref #73** from 1946). It seems likely that they were dredged from the Coyote Creek Embayment during the construction or reconstruction of a railroad trestle and possibly deposited for a possible staging area for trestle construction. **Image Ref #103** shows polygons representing the areas of components of the Bothin Marsh complex. The areal extent of Almonte Marsh, including Tam Marsh, decreased slightly to ~19 ac. East of the railroad levee, ~13.5 ac of marsh were subjected to cyclic wetting and drying. Tam Marsh decreased slightly in size, as did the north end of Almonte Marsh, as a result of levee construction. North Bothin Marsh increased in size to ~14.5 ac from dredge spoils developing wetland vegetation, some growth on fringing marsh of the levees, and ~0.5 ac Rectangle Marsh expansion, although the northeast corner of the marsh had started to erode. East Bothin Marsh slightly decreased to ~0.5 ac. The size of North Manzanita Marsh did not change. Although many levees had been constructed to contain dredge sediment and thus reclaim much of upper Richardson Bay, the required dredging and disposal of sediment into the areas bounded by the levees had not been completed due to challenges under the 1965 McAteer-

			Petris Act and the 1972 federal policies and laws regulating and generally preventing such activities.
1974	104, 105	Maintenance dredging CCC Small breach at NE corner of NBM	Madrone Associates (1975) reported that maintenance dredging of Coyote Creek was conducted in December of 1974 to remove cordgrass, pickleweed and salt grass that was expected to gradually reestablish. The emergent plants were acting as silt traps, accelerating siltation of the canal and reduction of flood control capacity. The mode of dredging was the dragline, which typically scrapes off a layer of mud and plant material, including most roots, and disposes it in waiting trucks. The project design called for a 4:1 sloping shoreline (Madrone Assoc., 1975). **Image Ref #104** shows the 1973 breach and an additional breach at the northeast corner of the interior containment levee of North Bothin Marsh. Standing water appears high in Almonte Marsh perhaps from relatively recent rainfall. It is not sediment-laden because features beneath the water column can be seen such as the remnant channels. Conversely, Coyote Creek Canal has turbid water that has formed a plume at its outlet and is intermixing with water in Richardson Bay. It appears that there is a moderate flood tide moving up the Bay because the turbid water from Coyote Creek is being pushed up the bay toward Bridge 2 of South Bothin Marsh. This photo shows evidence that Coyote Creek has ample suspended sediment supply that gets transported to Richardson Bay. It also indicates that there is a mechanism for sediment distribution into South Bothin Marsh during flood tides if the flap gate was not present. It is presumed that if the design capacity guidelines are maintained, a greater than 20-year recurrence interval terrestrial uplands flood would be required to deposit sediment on South Bothin Marsh unless it coincides with an exceptionally high tide. In South Bothin Marsh there is a general zone of numerous large patches of mudflat and colonies of sparse vegetation. Its upper boundary is the shoreline that predated the flood control project (1965) that is pickleweed-dominated and its lower boundary is a more densely vegetated area of cordgrass that colonized the mudflats of the embayment. A new small breach at the northeast corner of North Bothin Marsh can be seen on the interior containment levee that brings tides to the small section of marsh near the power pole, which borders Arroyo Corte Madera del Presidio and has levees on 3 other sides.

			In **Image Ref #105,** the tide looks relatively high in Richardson Bay but Almonte Marsh looks dry, or at least has a lower water level, which indicates its limited tidal connection. The water level in the Coyote Creek Embayment appears to be the same level as the tides, which indicates that either there was sufficient rainfall and urban runoff to the embayment it fill it and keep it from draining at high tide or that tidal waters had overtopped the Coyote Creek Canal levees or that the flap gate was not fully functioning. In South Bothin Marsh the image shows a transitional zone with numerous large patches of mudflat and sparse vegetation. Its upper boundary probably defines the lower boundary of the shoreline of the older pickleweed-dominated marsh that predated changes caused by the flood control project in 1965. Its lower boundary is established by the greater abundance of cordgrass and darker colored vegetation in the photography. The eroding northeastern corner of Rectangle Marsh can also be seen in this image. It is likely that the deep dredging for the borrow ditch reduced the amount of toe support at the foot of the levee, subsidence and insufficient fill height of the levee contributed to its erosion.
1975	106	Bothin Marsh area purchased for conservation	The Trust for Public Land purchased the Bothin Marsh area in 1975 from the railroad (https://www.savesfbay.org/bothin-marsh). The navigational chart of **Image Ref #106** does not show any shift in the position of the MLLW contour downstream of Richardson Bridge from the previous 1970 version of the chart (**Image Ref #98**). It does however depict the MLLW contour (boundary of the mudflats) and the Sausalito Canal to the head of Richardson Bay and Arroyo Corte Madera del Presidio. The inner containment levee was also mapped and a note was added about the Richmond Bridge being under construction.
1976	107, 108	Formation of large bar at mouth of ACMdP	It is a low tide in the 1976 photo shown in **Image Ref #107**. Yet standing water can be seen in the deeper mudflat area that has become a small embayment in North Bothin Marsh. A large depositional bar at the mouth of Arroyo Corte Madera del Presidio has formed at the ebb lee of the abandoned exterior containment levee. The levee contributes to shallowing the middle of Richardson Bay while the Sausalito Canal through its continued dredging helps transport the sand-sized bedload of Arroyo Corte Madera del Presidio farther down the bay. The borrow ditch on the west margin of the Bay, without continued dredging, functions as a sediment trap. A plume of turbid water can be seen emanating from the lower Richardson

			Bay moving upstream into the deeply dredged segments of Shelter Cove and the north side of Rectangle Marsh. **Image Ref #108** shows polygons representing the areal extent of the different marsh units. Almonte Marsh maintained its total size of ~19 ac with ~13.5 ac subject to desiccation, and ~4.0 ac that were covered with vegetation. The vegetated portion of the marsh had been reduced to small isolated fragments of higher marsh that had developed on the older dredge spoils near the railroad levee near the southern edge of the historical Almonte Marsh shoreline. The marsh channels in Almonte Marsh were too far from the tidal inlet in North Bothin Marsh to be influenced by tidal prism. North Bothin Marsh had a very minor decrease in total marsh area (~14.0 ac) due to a small amount of erosion of Rectangle Marsh. The area subject to seasonal desiccation in NBM developed a ~2.5-ac inner bay, while ~4 ac was still subject to desiccation. Vegetation expanded on the dredge spoils to ~4.5 ac and fringing marsh was ~1.0 ac. The width of the small breach in the inner containment levee that appears in 1973 was now about 16 ft. Its 1973 width appeared to be about the same but it might not have been very deep, perhaps it was more a surficial channel that developed on a low spot by water overtopping the levee. East Bothin Marsh and North Manzanita Marsh had very small increases in size, ~1.0 ac and ~2.0 ac respectively. South Bothin Marsh and the Coyote Creek Embayment both decreased slightly in size, 28.0 ac and 5.0 ac respectively. South Bothin decreased due to additional fill in its southeast corner and the embayment decreased due to slight expansion of vegetation from South Bothin Marsh.
1978	109		Changes in size of the different marsh segments, shown in **Image Ref #108**, were relatively minor although there was a general tendency of vegetated marsh expansion along the dredge spoils in Almonte and North Bothin Marsh and shrinking of the desiccated areas. The North Bothin Marsh embayment decreased in size to ~1.5 ac. The c. 1930 levee dividing Almonte and North Bothin Marshes had a breach that connected tidal flow between them. The breach in the inner containment levee of North Bothin Marsh widened, allowing a greater amount of tidal prism into North Bothin Marsh. The width of the

			breach widened to ~26 ft. It is not known if the breach in the c. 1930s levee happened naturally or if it was man-made. The channel in Almonte Marsh widened and eroded headward since it had more tidal flow. The overall size of Almonte Marsh stayed the same but the vegetation on the dredge spoils expanded to ~4.5 ac and the desiccated area decreased to ~13.0 ac. The size of South Bothin Marsh stayed the same but because there was different reflectance of vegetation and mudflats in the 1978 photo, it was possible to map a transition zone between the embayment and the slightly higher, predominantly vegetated marsh. The latter was ~19.0 ac. The transition ecotone was ~9.0 ac. It was characterized by numerous low areas subject to ponding interspersed with mudflats that were subject to long periods of desiccation. The mudflats were interspersed with patches of sparse vegetation, most likely cordgrass.
1981	None	MCOSD acquires Bothin Marsh Bay Trail & bridges built with grade control at Bridge 2 Tidal flap gate possibly removed creating a 26 ft span of the inlet to the Coyote Creek embayment Bridge 1 rebuilt	Marin County Parks and Open Space District formally acquires the marsh and easement across the old railroad tracks (https://www.savesfbay.org/bothin-marsh). The Mill Valley-Sausalito multi-use path, here called the Bay Trail, has an approved 20-foot improvement width that consisted of a 10-ft wide asphalt concrete path with 5-ft wide earthen shoulders on each side. ESA-PWA and WRA (2012) report that around 1980 improvements were made to the railroad line to incorporate the Bay Trail. At this time the flap gate at Bridge 2 outlet of Coyote Creek Embayment was replaced with an approximate 26-foot span footbridge, returning a limited amount of tidal prism to South Bothin Marsh. Based upon following images of 1982 and 1983 (**Image Ref # 110 and #111**) the Bay trail appears to have been constructed between 1981 and 1982. After the trail was completed, the inlet of South Bothin Marsh at Bridge 2 had a rock-armored base for grade control. This feature remains today and limits daily tidal connection to the Coyote Creek Embayment and South Basin Marsh. Bridge 1 over the Coyote Creek Canal was partially rebuilt, having a span of about 105 feet.
1982	110	Probable local flooding and high sediment loads from local landsliding	The two basins of Almonte Marsh and North Bothin Marsh are both flooded in **Image Ref #110** but they can still be distinguished by the slightly higher elevation c. 1930s levee that is covered by vegetation. The small breach of the inner containment levee shows the small channel that connects tides of North Bothin Marsh to Almonte Marsh. At the north end of

		associated with intense and prolonged rainfall	Almonte Marsh, sediment rich water of Arroyo Corte Madera del Presidio Canal can be seen entering the head of the Bay. In this same image, sediment laden-water can be seen moving out of Coyote Creek Canal, mixing with the flood tide of the bay and then moving toward the inlet of the Coyote Creek Embayment at Bridge #2. This exemplifies how locally derived sediment supply is redistributed on the marsh. If the creek were connected directly to South Bothin Marsh it would be functioning more naturally as a delta of its local watershed. Based upon analysis of numerous local historical rainfall records (Collins 2001; Gilbert 1917), the storms of the 1st week of January 1982 generated flooding in local watersheds throughout Marin County (Blodgett and Chin, 1989) and stream discharges were accompanied by very high sediment loading due to the initiation of numerous landslides and high rates of stream erosion throughout Marin County. Many streams had record flooding in the County. The photograph in **Image Ref #110** was taken January 7th.
1983	111	Paths along Coyote Creek Canal	The photograph in **Image Ref #110** shows conditions at either flood tide, or shortly after, when Arroyo Corte Madera del Presidio is the predominant sediment source in the head of Richardson Bay compared to the relatively clear waters of Coyote Creek Canal and the Bay itself. Sediment-rich water can be seen in a plume emanating from the Arroyo Corte Madera del Presidio that flows toward the inlet of North Bothin Marsh toward the levee breach of the inner containment levee. This is likely an important supply of suspended sediment to the marsh. The bar that has grown at the north side of the remaining exterior containment levee appears larger and emerges above the water level. It clearly captures and stores a significant amount of fine-grained bedload from Arroyo Corte Madera del Presidio. The Bay Trail appears to be fully constructed on the railroad levee and two pathways appear to be improved along the banks of the Coyote Creek Canal. Although a boardwalk already existed along the south bank of the canal it is not clear if there was an additional one along the north bank or just a pathway. The sediment supply from the Arroyo also contributes to growth of the fringing marsh along the outboard side inner containment levee. The dredged borrow pit that parallels its base, however, prevents it from prograding along a gentle uniform gradient that might eventually form if dredging of the bay bottom in this area is not renewed.

08/15/ 1984	None	Houseboats required to have sewage hookups in the Bay	Key step was taken in regulating sewage outfall from houseboats in Sausalito. Sewage hook-ups to be required in the future. Source: Independent Journal article at California Room, Marin Civic Center Library. This indicates that local water quality and its influence on wildlife might have improved following the mid 1980s.
1987	112	Effects of Bridge 2 flap gate removal evident	By 1987 the effects of removal of the flap gate could be seen in the landscape of South Bothin Marsh. Depicted in **Image Ref #112** are polygons representing the different marsh segments relative to the 1987 conditions. In the Coyote Creek Embayment the water elevation once again changed daily with the tides and the adjacent mudflats were no longer seasonally desiccated. The transition zone that was shown in **Image Ref #109** that was comprised of patchy mudflats and sparse vegetation was narrower than in 1976 but its upper boundary was still at the same location. The transition zone filled with more vegetation (probably cordgrass) along its lower boundary. The lower boundary was able to trap sediment more effectively where vegetation was more dense and closer to the source of sediment as it moved inland through the inlet. This filtering mechanism essentially cleans the water as it moves toward the higher elevations of the marsh that still remained sediment depleted because of the muted tidal prism moving through the small inlet of Bridge 2. Its 26-foot-wide opening and shallow depth limit the amount of tides and length of time that tides can reach the slightly higher, backshore areas of the South Bothin Marsh. Hence, the areas of pickleweed and their foreshore that predated the flap gate have a lower rate of sedimentation than the areas near the embayment that support cordgrass. The Coyote Creek Embayment increased over 1 acre in size becoming ~6.0 ac and the South Bothin Marsh totaled ~27 ac. Along the north bank of the Coyote Creek Canal path, the location where there was a pathway seems to have become compacted, depressing its elevation where it subsequently started to hold water, resembling a ditch. North Manzanita Marsh and East Bothin Marsh increased very slightly and were ~2.5 ac and ~1.0 ac respectively. In North Bothin Marsh the width of the tidal inlet increased to 32 feet from its 26-foot width in 1978 when it first started forming. Such an increase in width indicates a substantial increase in the amount of tidal prism reaching both North Bothin and Almonte marshes since they interconnect through two small channels by this time. The small embayment within North Bothin Marsh had a very slight decrease in size and was ~1.5 ac as surrounding land became more vegetated. It is very likely that the embayment became increasingly shallower

			from the sediment supply that was associated with intermixing of the tides with sediment from the adjacent watersheds. The fringing marsh of North Bothin and the rectangle Marsh both prograded increasing their size to ~1.5 ac and ~2.5 ac respectively. The vegetated area increased and was ~10.0 ac. In total North Bothin Marsh was ~15.5 ac. Since North Bothin Marsh was bringing more tidal prism to Almonte Marsh, the formerly desiccated mudflats in Almonte Marsh started re-establishing vegetation. Almonte Marsh was a total of about 18.5 acres, including the ~1.5 ac of Tam Marsh and ~17.0 ac of marsh east of the Bay Trail. Some very minor marsh erosion occurred along the bank of Arroyo Corte Madera del Presidio. A very small channel breach appeared in the containment levee at the northern portion of Almonte Marsh. Its channel leads to a small area of high dredge spoils rather than to the larger marsh.
1995	113	Upper Richardson Bay above 101 Bridge named Pickleweed Inlet by USGS Mudflat expansion near ACMdP	The navigational Chart 5532 shows the MLLW boundary from the 1975 Chart 5532 (**Image Ref #106**) projected onto the 1995 chart. A comparison of the 1975 and 1995 boundaries indicates that the Sausalito Canal MLLW boundary widened slightly south of Richardson Bay Bridge where it also developed a more uniformly shallow depth of about 1 foot above MLLW. Upstream of the bridge, where it was now named Pickleweed Inlet, the MLLW boundary narrowed by 1995. This indicates continued sedimentation of the headwaters of Richardson Bay and much of it is likely associated with the high sediment supplies of the 1982 flood event that had high sediment loading from Arroyo Corte Madera del Presidio. No new dredging seems to have occurred between 1975 and 1995.
1996	None	101 Bridge retrofitted	Richardson Bay Bridge had extensive retrofitting at this time (illustrative sign along Bothin Marsh Bay Trail, Marin County Parks). It is not clear how this may have affected conditions in Richardson Bay near the bridge.
1998	None	Probable local flooding	Based upon analysis of numerous local historical rainfall records (Collins 2001; Gilbert 1917), 1998 was a year that could have generated flooding in local watersheds.
1999	114	Urbanization along much of head of bayshore Area of mudflat equals area of subtidal in upper Bay	The topographic map of **Image Ref #114** shows the intensive increase in urban development at the head of Richardson Bay. The map demonstrates that the only large remaining marshes north of Richardson Bridge are those along the western shoreline and are associated with Arroyo Corte Madera del Presidio, Almonte, and South Bothin Marshes. Upstream of the Richardson Bridge the amount of open water is practically equal to the amount of remaining marsh, roughly 0.17 square miles, whereas in 1851, the amount of marsh was larger, roughly 0.53 square miles, compared to the amount of open water, which was ~0.38 square miles. In the absence of dredging most of the Richardson Bay would be above MLLW.

			Urban development abuts remaining marsh and bay shoreline. The urban area has changed the way runoff from the uplands is routed to the lowlands through pipes and canals, along roads and structures, and where it picks up, transports and deposits sediment. In general, the urban changes provide more runoff more quickly, which exacerbates the amount and speed at which flooding occurs downstream. These problems will be exacerbated with rising sea level because there is negligible space for terrestrial stream flow to spread onto a floodplain as it meets the future rising tides at increasingly higher elevations farther back into the valley.
2005	115	Significant sedimentation in subtidal area bayward of mouth of ACMdP	The size of the different marsh units by August 2005 are shown in **Image Ref #115**.l Almonte Marsh filled with more vegetation and the channel that was connected to the breach in inner containment levee of North Bothin Marsh enlarged, bringing slightly more tidal prism to Almonte Marsh. Total acreage was slightly smaller in Almonte Marsh, ~17.9 ac, due to marsh erosion at the north end along Arroyo Corte Madera del Presidio and widening of the channel. North Bothin Marsh stayed nearly the same size, ~15.5 ac, loosing a bit of its fringing marsh on the outside on the containment levee, which slightly decreased (~1.3 ac). The inner bay got smaller, decreasing in size to ~0.5 ac, while the vegetated marsh on the interior of the containment levee expanded. It was ~11.0 ac. The width of the breach in the containment levee increased to about 42 ft. Since the 2005 image was taken during low tide, it is possible to see the changes along the bottom of Richardson Bay. North of the channel breach of the inner containment levee, the borrow ditch appears to have shallowed from sedimentation, while south of the breach the borrow ditch is maintaining more depth due to the ebb tides that flow from Almonte and North Bothin Marsh through the breach. The large bar that formed at the outlet of Arroyo Corte Madera del Presidio started to show some erosion along both its east and west sides as flow diverges during the ebbing tide and flows to either side over the bar. On a rising tide it appears to flow southeastward over the bar. The sediment on the bar is being reworked and redistributed, with some amount likely moving upstream and reaching portions of Almonte Marsh. The deeply dredged area of the turning basin (for the dredge) just north of Rectangle Marsh also appears to have shallowed.

			The channel exiting the Coyote Creek Embayment of South Bothin Marsh shows some change where it has created a small shoal and a subtle delta fan at the outlet of Bridge 2. This indicates that there is some sediment being removed from the embayment during ebb tides and it seems to be from the channel network that appears to be deepening while the marsh surface gains in elevation from sediment deposition. The grade control at the bridge outlet also causes a steep drop to the bay during low tides, which exacerbates the formation of a plunge pool at the end of the grade control of the inlet, which might eventually lead to undermining and destabilization. If the bed at the inlet incised, the lower elevation tides would start to influence South Bothin Marsh and drainage velocities might increase. As it stands, such a sudden change in slope from the grade control structure is a fairly unnatural feature in mudflats. At South Bothin Marsh, the transition zone of patchy areas of mudflat and sparse vegetation seemed to expand to ~7.0 ac with an increasing amount of mudflat broken up by corridors of vegetation following the slightly higher banks along some of the larger channels in the marsh. In general, the density of channels leading to the Coyote Creek Embayment has been very high during all years, with channels too numerous to map in South Bothin Marsh. The marsh vegetation continued to expand toward the Coyote Creek Embayment reaching ~22.8 ac. The total amount of marsh and patchy mudflats was ~29.6 ac, which was more than 3 acres larger than in 1987. This embayment lost ~2.6 acres to vegetation during the same time period. On the south bank of the Coyote Creek Canal a ditch-like feature appeared parallel to the channel banks. There are three possible hypotheses about the origin of the ditch. One is that there used to be a paved pathway that was removed, leaving a low area (communication from Veronica Pearson, Marin County Parks). Another hypothesis is that there was a pathway that became compacted, and a third hypothesis is that is that there was an earlier because vegetation did not grow beneath the former alignment of the boardwalk that inhibited vegetation growth beneath it and that it was moved that was moved prior to 2005. East Bothin Marsh stayed the same size (~1.0 ac) and North Manzanita Marsh eroded slightly, decreasing its size and was ~2.0 ac.
2013	116, 117. 118. 119	Net historical decrease in the area of Richardson Bay	A comparison of the historical 1851 head of Richardson Bay marshes to modern conditions of 2013 is provided in **Image Ref #116**. Separate analyses are done for the whole Bay and its smaller southern arm that extends between Sausalito and Strawberry Point to Mill Valley. The Bay as a whole has 80% less marshland. It has 14% less mudflat and subtidal area. It’s 27%

		study area as a whole is 27% Net decrease in the southern arm of Richardson Bay with the Bothin Marsh Complex 50% AM eastern breach continues to widen	smaller overall. The Mill Valley arm has 74% less marsh, 30% less mudflat and subtidal area, and is 50% smaller. This means there is greater loss of total area in the southern arm that includes the Bothin Marsh Complex. The reduced size of the southern arm of Richardson Bay plus its shoaling means that its has lost tidal prism, at least in the upper area near the Bothin marshes. Since there are no historical measure of tidal range or velocity, the loss in tidal prism is unknown, However, large-scale restoration of tidal marsh would increase the prism and reduce any need for dredging. A storm drain map created by the Marin County Geographic Information Systems Department in **Image Ref # 117** shows the drainage network that leads to South Bothin and Almonte Marsh. The accuracy of the GIS map relative to the characterization of artificial paths, pipelines, and ditches does not seem to be fully depicted or relative to the Map Key, however, the map does seem to show a complex network of channels and drains and indicates whether they are perennial, intermittent or ephemeral. The 3-dimensional projection **in Image Ref # 117** of the stream network provides a perspective of the two different drainage areas of Coyote Creek Canal and South Bothin Marsh, which prior to 1965 was connected to the Coyote Creek watershed. The Coyote Creek Canal has a drainage area of ~3.6 square mile. The drainage area of South Bothin Marsh (unless the creek has a large flood coinciding with high tide) has been reduced to ~0.18 square mile due to the levees along the Canal. The numerous small headward tributaries drain open space lands that still have natural processes that provide sediment to the channels of the valley bottoms that are highly altered. Generally, the lower valley bottom channels are highly confined, either within pipes, between concrete walls, or between buildings that inhibit natural channel features such as meanders, sediment bars, and floodplains. The lower valley main channels essentially function as water and sediment chutes to the Canal where dredging is required to maintain flood protection of the valley bottom. Tidal water extends over 3,600 ft up-valley from SR 1 bridge. Based upon previous analyses by USACE (1959) the properties on the low lying parts of the valley floor are only protected from flooding of Coyote Creek when it has discharges of less than a 20-year recurrence interval and this is under the sea level conditions that existed in the mid-1960s. The projected sea level rise of 55 to 65 in (4.5 to 5.5 ft) by 2100.

			Image Ref #118 shows a parcel map of the Bothin Marsh Complex and surrounding areas, possibly representing ownership in 2013. Most of South Bothin Marsh, north of the north bank of Coyote Creek Canal and a portion of Richardson Bay extending to the Sausalito Canal is owned by the Marin County Open Space District. There is a small inholding near the southwestern boundary that belongs to CalTrans. The Bay Trail, a small section of marsh along the south bank of the Coyote Creek Canal, and the Sausalito Canal appear to be managed or owned by the County. The portion of Almonte Marsh, referred to as Tam Marsh, and the area of North Manzanita Marsh are not owned or managed by the County. **Image Ref #119** shows a 2013 LiDAR digital elevation model referenced to NAVD 88 that was provided by the Marin County Department of Public Works. The levees of dredge spoils that were initially placed on mudflats along the northeastern bank of Coyote Creek Canal have subsided. As a result, there is an increasing connection of tides between the lower Coyote Creek Canal and Coyote Creek Embayment. The map elevations indicate that the Bay Trail is generally between +7 and +7.5 ft NAVD 88. It is therefore subject to annual flooding from King Tides over some segments of the Bay Trail each year. When these high tides flow over the Bay Trail the large volume of water at the start of the ebb tide flows from the Coyote Embayment over the subsided levee of the north bank of Coyote Creek Canal, which is lower than the Bay Trail, and then into the Canal. At the start of ebb tide, since the Canal drains faster than the Embayment, water flows from the Embayment to the Canal. The outlet of the embayment at Bridge 2 is too small to drain at the same rate as the Canal at Bridge 1. At the upper northwest bank of the Canal, a small channel coveys flood tides into a shallow basin bounded by the old alluvial fan and artificial fill that separates the basin from the rest of the backshore of South Bothin Marsh. During the highest tides and terrestrial flood flow conditions, most of South Bothin Marsh and Coyote Creek Canal would merge together as open water, leaving a few of the artificial fill areas of demolition debris as isolated high points that may function as refugia for wildlife. The LiDAR map also shows the very low elevation of Rectangle Marsh and the areas near the embayment of North Bothin Marsh. It also demonstrates the lack of channel network in Almonte Marsh that would benefit from increased tidal connection to supply sediment to the

			backshore. The breach in the levee at north Bothin Marsh is twice the width of the South Bothin Marsh inlet at Bridge 2. Width of the breach of the inner containment berm at North Bothin Marsh measures to be about 50 feet compared to its 2005 width of 42 feet. If it continues to widen it will bring more tidal sediment into the backshores of sediment-starved Almonte Marsh. The LiDAR map also show the low elevation of land along the commercial district of SR 1. Much of the Coyote Creek valley floor toward the western boundaries of the Historical Coyote Creek Marsh have been affected by subsidence of the fill and marshlands on which they were developed, which increases the threat of flooding from projected sea level rise.
2016	120, 121, 122	Incipient breaches at north bank of CCC have slightly enlarged	The areas of marshland for 2016 are shown in **Ref Image #120**. In general there has been relatively little measureable change since 2005. South Bothin Marsh increased very slightly to ~13.4 ac as vegetation colonized more of the Coyote Creek Embayment and fringing marsh of Coyote Creek Canal. Two small channels have enlarged slightly on the north bank levee of Coyote Creek Canal. One is very close to the railroad levee, and the other is about half way up the canal. These channels help drain the high overflow tides that move from Coyote Creek Embayment into the canal. Coyote Creek Embayment decreased to a ~3.0 ac. East Bothin Marsh decreased very slightly and had about 1.0 ac and North Manzanita stayed the same at ~2.0 ac. Almonte Marsh has decreased slightly to 18.0 ac, primarily due to erosion of its north side. North Bothin Marsh decreased very slightly and had ~15.3 ac, due mostly to erosion of the fringing marsh of Rectangle Marsh along the outside of the south side of the inner containment levee, and along the south side of Rectangle Marsh. A geomorphic map of the South Bothin Marsh in **Ref Image #121** highlights some key features of the vegetated marsh, adjacent surroundings, and the unvegetated intertidal ecosystems pannes, tidal channels, mudflats, and bay. The map primarily depicts a time sequence of marsh growth as influenced by the activities of artificial filling within the former Coyote Creek embayment and reclamation of the former Historical Coyote Creek Marsh. Although the colored polygons represent the extent of marsh over different time periods, they also represent the actual amount of existing vegetation at the time of the 8/2016 base map image. Thus it is important to emphasize that the pattern does not represent the age of the existing vegetation on the marsh but the temporal pattern of marsh migration. Therefore, the

			coverage of vegetation during the historical time periods might also have been more dense within the different bands of color, but appear to be diminished due to increases in size of pannes and channels during 8/2016. A single white line represents the 1851 shoreline. Light grey areas are essentially the unvegetated intertidal areas. Artificial fill that was placed in front of the 1851 shoreline is shown as dark grey and has a mix of vegetated land and commercial development. Artificial levees, dredge spoils, and a combination of the two are shown as various shades of pink, while red polygons represent demolition debris and concrete rubble. Colored polygons (other than light and dark grey polygons) represent areas with vegetation. The Bay Trail, shown as a light pink polygon, is a partial exception since some portions of the levee are paved, bare ground, or rocky slope. Dark green polygons represent transitional high marsh vegetation to artificial fill that is above MHHW. Its distribution represents a mix of time periods. Most of the other polygons are linked to a time period over which vegetation colonized the mudflats in Coyote Creek embayment as it adapted to various perturbations such as changes in the size of the tidal inlet, diversion of Coyote Creek, installation and subsequent removal of a tidal flap gate, and rising sea level. Bright green polygons represent the extent of marsh by 1899. The dark blue polygons represent the position of the Historical Coyote Creek in 1960 before it was diverted a few years later. The surrounding polygons of yellow (1978), blue-green (1946), and dark purple (1952), and light purple (1960) show the migrating extent of marsh along its delta/alluvial fan and quieter perimeter waters of the embayment. After the construction of the flood control canal and installation of the tidal flap gate, the areal extent of marsh colonization diminished and progressively slowed between 1965 and 1978. The time intervals are represented by olive-green (1965), olive-brown (1973), light-green (1976) and yellow-green (1978) polygons. The olive-green and olive-brown areas might approximate the areas that were most subject to seasonal periods of standing water and desiccation while the flap gate was in place. It might have been removed during 1981 and the areal coverage of vegetation became smaller for a short time due to drowning . Polygons colored green (1987), burgundy (2005), and rusty orange (8/2016) represent marsh colonization after the 26-foot wide inlet was opened to the Coyote Creek embayment. The amount of vegetation colonization within the embayment appears to be decreasing, and the

			channel network and panne density (amount of channel per unit area) appears to be slightly increasing during the last decade. This likely reflects the influence of increased submergence from rising sea level and insufficient sediment supply. Rectangle Marsh and East Bothin Marsh do not reflect any notable marsh colonization since 1987. **Ref Image #122** shows a geomorphic map of the North Bothin and Almonte Marsh marsh complex using the same legend key for polygons representing intertidal vegetation and significant adjacent vegetated levee features above MLLW. Unlike South Bothin Marsh, it does not have a high density of channels and pannes. Almonte Marsh and North Bothin Marsh are separated by the c. 1930s levee (rosy pink polygon) shown as a narrow band near the power line boardwalk (red line). The pattern of Marsh colonization of Almonte Marsh shows the progressive bayward migration in from of the 1851 foreshore (white line). The light-blue band reflects the location of the 1851 overwash wave-formed berm at the foreshore. The bright green polygon shows the extent of marsh growth by 1899 and the 1927 marsh extent is represented by the teal color. The exterior levee (medium pink) on Almonte Marsh was placed on the 1946 marsh, about 20-25 ft inland from its foreshore. Some of it was preexisting from 1930s but upgraded and extended in 1965. Dredge spoils, shown as salmon pink polygons, were placed at the north end of Almonte Marsh between 1965 and 1973 but the west dredge spoils might be as old as the original railroad construction of 1883. The levee on North Bothin Marsh constructed in 1965 on mudflats is shown as fuchsia pink. Dredge spoils, were added at the south end sometime between 1965 and 1973. The conversion from small mudflat embayment to marsh with tidal channels within North Bothin Marsh has been fairly rapid since the initial levee breach in 1974. The only notable marsh colonization between 1946 and 1976 was on the outboard side of the levee. The south corner of the marsh near the intersection of the Bay Trail and the exterior levee appears to be loosing vegetation while a relatively newly formed panne increases in size. This is likely reflecting insufficient tidal prism and sediment supply. The geomorphic map clearly shows the low drainage density in 2017 of the North Bothin/Almonte Marsh complex.
2017	123, 124, 125	Evidence of loss of high elevation marsh within SBM	The photograph in **Ref Image #123** show a very high tide where water is pouring out of South Bothin Marsh over the low north bank levee of the Coyote Creek Canal. This represents what will become an increasing condition with sea level rise, and will likely change much of the tidal dynamics of the marsh. This photo shows that if Coyote Creek were at a very large flood

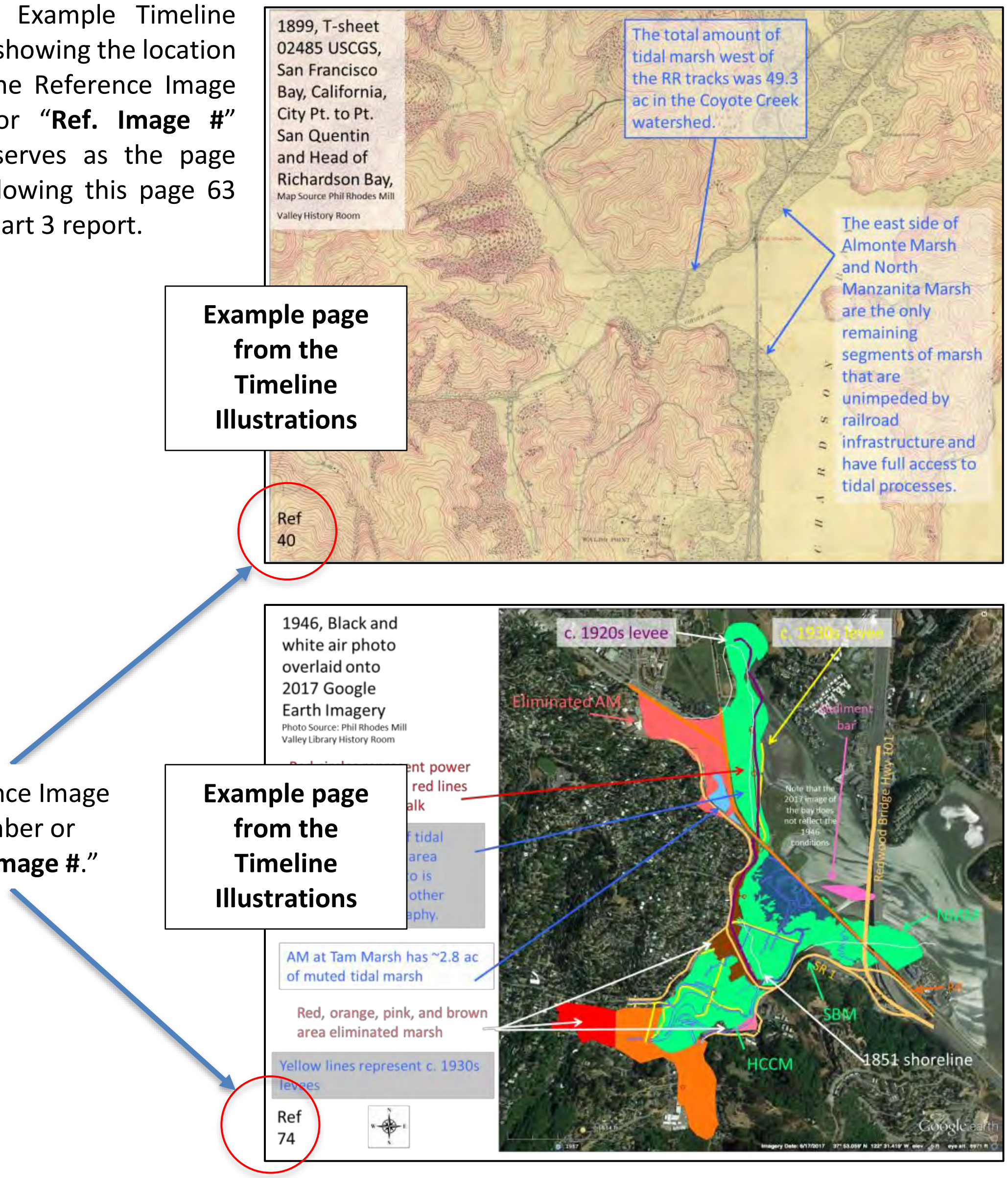
		and due to sea level rise	stage during a similarly high or higher tide, the Bay Trail, the small outlet of Coyote Creek Embayment at Bridge 2 and the structure of Bridge 1 would impede the escape and conveyance of floodwaters to Richardson Bay. The tidal choking of the basin creates a net water surface slope toward Coyote Canal can be seen while South Bothin Marsh drains during the higher stages of extreme high tides. **Ref Image #122** shows several photographs that demonstrate some of the characteristics of South Bothin Marsh including sediment-rich water of Coyote Creek, areas of backshore that still desiccate due to the muted tide caused by the constricted inlet at Bridge 2 inlet, channels deepening and marsh building in the Coyote Creek Embayment, and tidal connection between the Coyote Creek Canal and South Bothin Marsh during a lower tide than the one shown in the previous **Image Ref # 124**. The original rocky railroad levee of the Bay Trail continues to separate South Bothin Marsh from North Bothin Marsh at almost all tidal stages. The undersized, South Bothin Marsh tidal inlet that has armored grade control continues to choke tidal flows, creating muted tides that delay flood/ebb peaks within the tidal basin, relative to the Bay. It establishes visible, turbulent water surface slopes between the tidal basin and the bay at the inlet during ebb tides that creates scour at the outlet **Ref Image #125** shows a comparison of the modern and historical marshes of the Bothin Marsh Complex in the context of each other and their watersheds. Only Almonte Marsh overlaps with the extent of the 1851 historical marsh. The total amount of combined area of all the modern marshes is ~66.7 ac. The original combined extent of historical marshes was 141.5 ac, of which HCCM had 761 ac. ~18 ac of AM exists of its ~50 ac. It is the only historical marsh remaining in the study area. The extent of historical marshes is within the future extent of sea level rise.

3.5 Timeline Illustrations

The following pages contain the graphs and images used to illustrate the Timeline presented above. There is one illustration per page. The second column of the Timeline refers to the images as Reference Image Numbers, or “**Ref. Image #.**” The Reference Image Numbers are also provided in the lower left corners of the illustrations, to facilitate easy cross-referencing between the Timeline and its illustrations. The illustrations are numbered consecutively, such that the “**Ref Image #**” also serves as the page number. This is shown kin Figure 3.2 below.

It should be noted that not every image is used in the Timeline.

Figure 3.2. Example Timeline illustration showing the location of the of the Reference Image Numbers, or “**Ref. Image #**” That also serves as the page number following this page 63 of the this Part 3 report.



Reference Image Number or “**REF Image #.**”

Bothin Marsh Preserve and Project Boundary

Map Source: https://www.marincountyparks.org/~/media/ Images/Departments/PK/Open%20Space/Bothin%20Marsh/ Map%205Bothin073114.pdf

Location of Bothin Marsh Open Space Preserve is shown in green. The double red line shows the project area for modern tidal Bothin Marsh, the focus of this memorandum. The historical analysis extends beyond the boundaries of the project area to understand the context of landscape change

Ref 1


Bothin Modern Marsh
Location Names for Historical
Tracking and Analysis
Map Source: Google Earth Imagery 8/14/2016
Marsh names and abbreviations:
AM = Almonte Marsh (includes Tam Marsh)
EBM = East Bothin Marsh
HCCM = Historical Coyote Creek Marsh (not shown)
NBM = North Bothin Marsh (includes Rectangle
NMM = North Manzanita Marsh
SBM = South Bothin Marsh
Tidal flood control channels:
ACMdP = Arroyo Corte Madera del Presidio Canal
CCC = Coyote Creek Canal
CCr = Coyote Creek
Bridges:
Bridge 1 = ~105-foot-long footbridge over CCC
Bridge 2 = ~27-foot-long footbridge over Coyote Creek Embayment
Shoreline Bridge = Highway 1 Bridge over CCC
Richardson Bay Bridge = Redwood Highway Bridge 101 concrete bridge
Other Features
Hwy 101 = Highway 101
RR = Railroad right-of-way (later becomes Bay Trail Bay)
Bay Trail = Mill Valley Sausalito Path (former RR)
SR 1 = State Route 1
Bay Trail = Mill Valley Sausalito Path, also known as Bike Path
Ref 2
Arroyo Corte Madera del Presidio Canal
Bothin Marsh Study Boundary Area
Almonte Marsh AM
Tam Marsh part of AM
Bay Trail
Richardson Bay
North Bothin Marsh NBM
Richardson Bay Bridge
Rectangle Marsh part of NBM
Coyote Creek Embayment
South Bothin Marsh SBM
East Bothin Marsh EBM
North Manzanita Marsh NMM
Bridge 2
Richardson Bay Bridge along Hwy 101
Bridge 1
Shoreline Bridge along State Route 1 SR1
Coyote Creek Canal CCC
Google

1781, Cañizares Map of San Francisco Bay

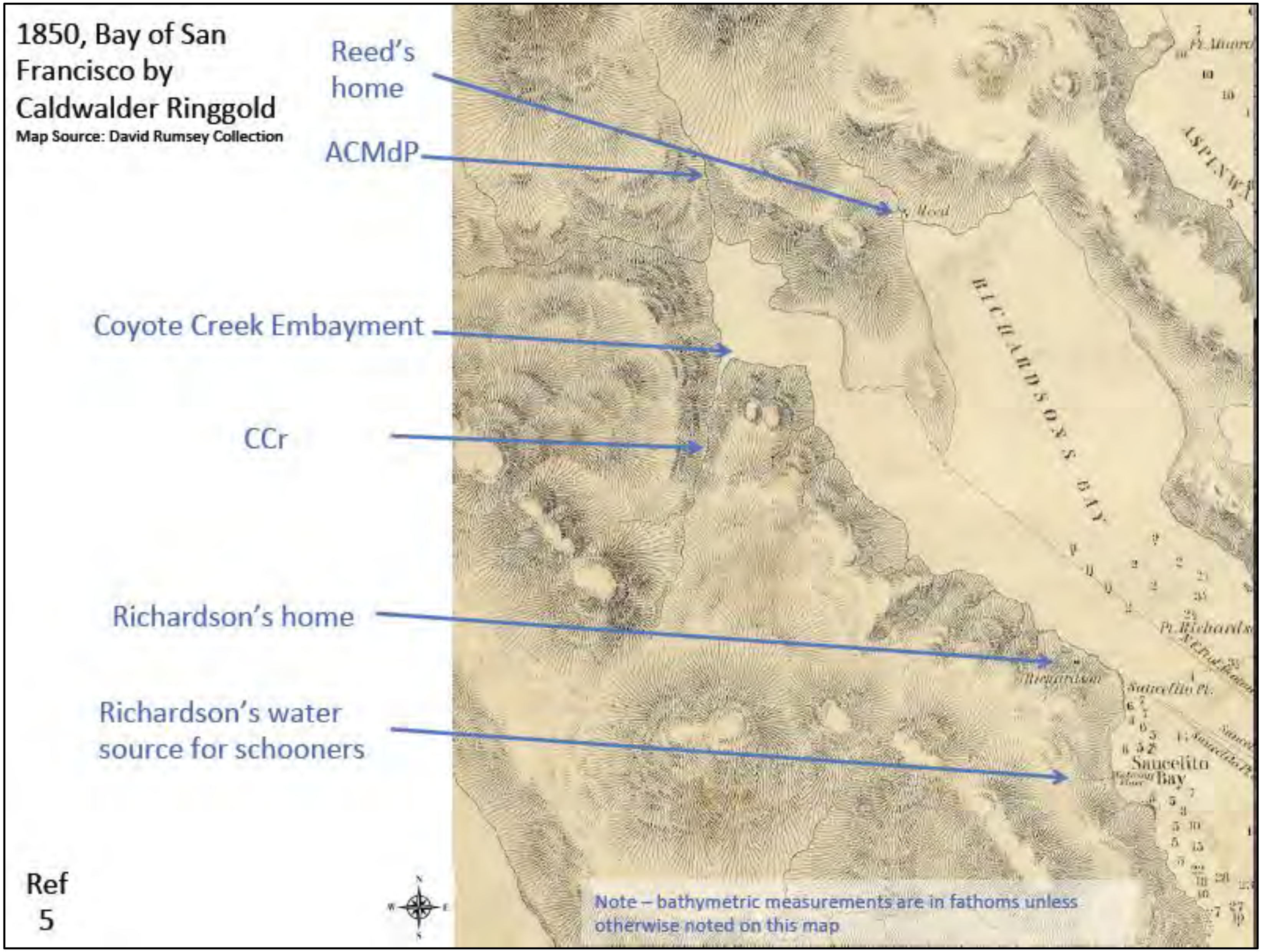
Map Source: https://commons.wikimedia.org/wiki/File: 1781_Ca%C3%B1izares_Map_of_San_Francisco_Bay.pdf

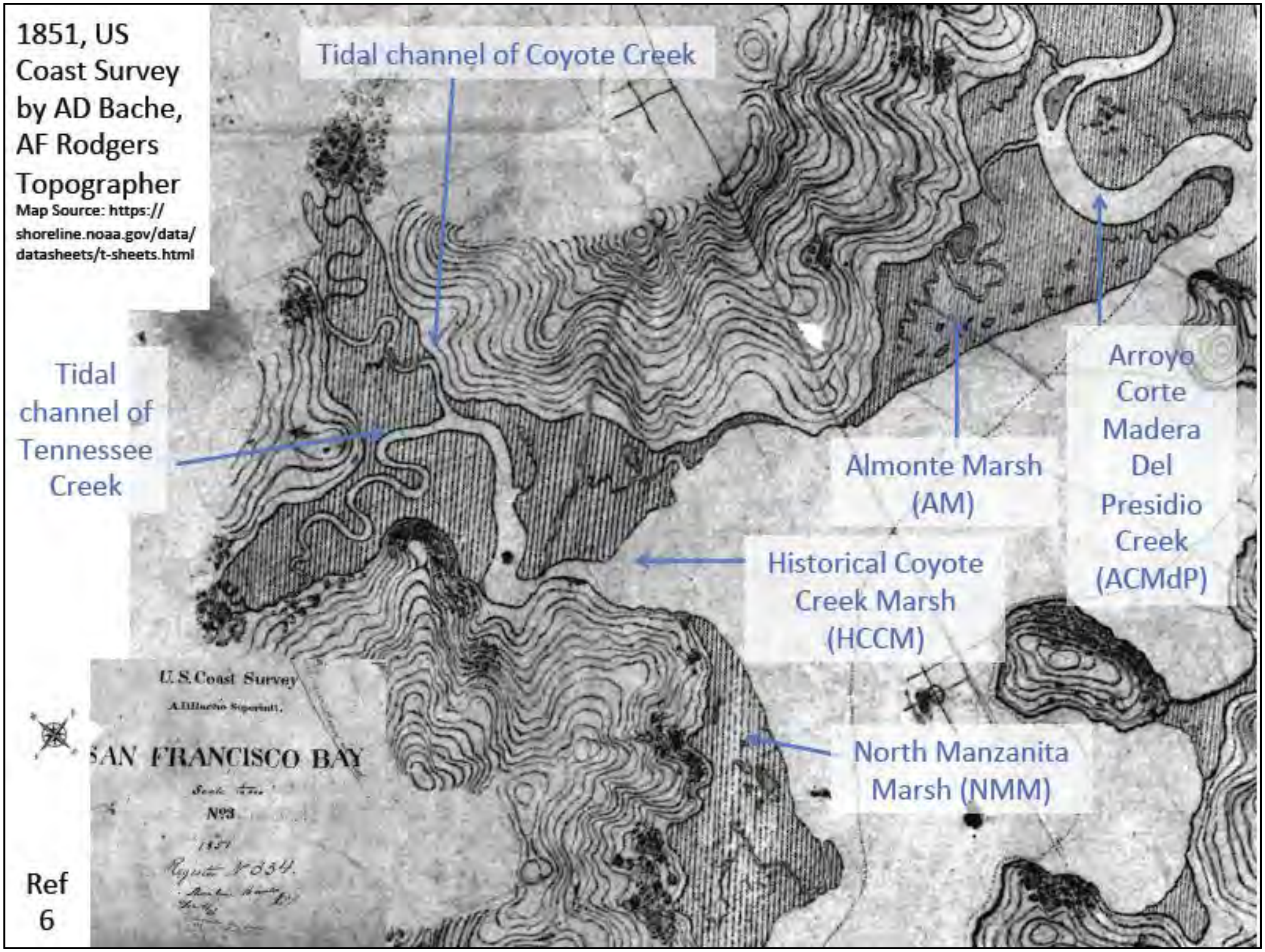
Possible embayment of Coyote Creek can be seen between the E and D symbols on the map.

B. Point Reyes
C. Point Bonita
D. Lime Point
E. Richardson's Bay
F. Belvedere
H. San Pablo Bay
Y. Petaluma Creek
M. San Joaquin river
N. Sacramento river
Q. Oakland, etc.
S. Coyote Point
T. Mission Creek (Channel Street)
V. Presidio
X. Mission Dolores
I. Fort Point
Z. Point Lobos or Pt. of the Guardian Angel
e. Golden Gate
f. Angel Island
g. Alcatraz

Ref 3

This anonymous painting of Wm. Richardson's home c. 1845 is from the Bancroft Library. It appears in Jack Tracy's book, Moments in Time.


1850, Bay of San Francisco by Caldwalder Ringgold
Map Source: David Rumsey Collection
Reed's home
ACMdP
Coyote Creek Embayment
CCr
Richardson's home
Richardson's water source for schooners
Ref 5
Reed
RICHARDSON'S BAY
Richardson
Saucelito Pt.
Saucelito Bay
Note – bathymetric measurements are in fathoms unless otherwise noted on this map

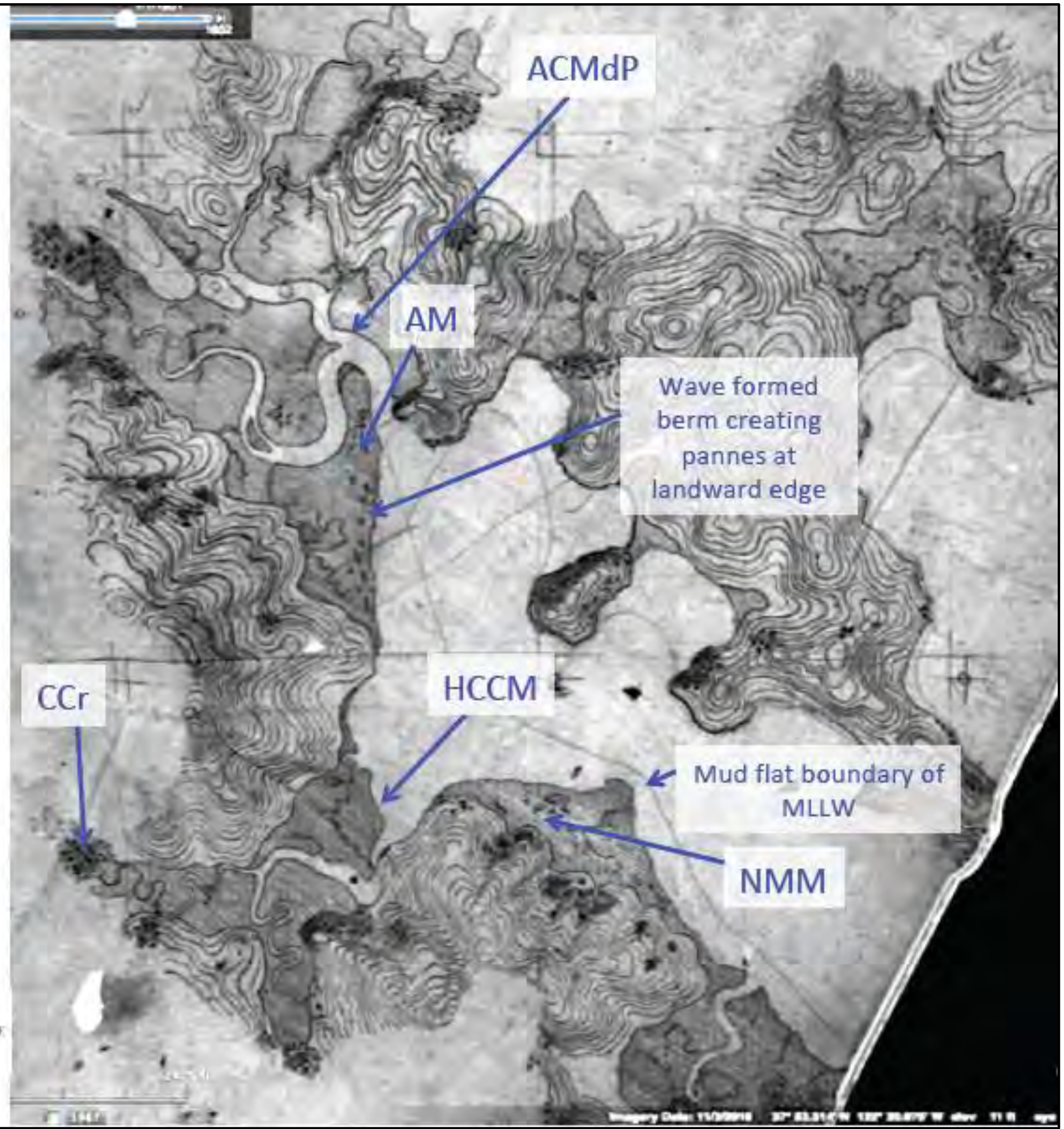

1851, US Coast Survey by AD Bache, AF Rodgers Topographer
Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html
Tidal channel of Coyote Creek
Tidal channel of Tennessee Creek
Almonte Marsh (AM)
Arroyo Corte Madera Del Presidio Creek (ACMdP)
Historical Coyote Creek Marsh (HCCM)
North Manzanita Marsh (NMM)
U.S. Coast Survey
SAN FRANCISCO BAY
Nº3
Ref 6

1851, US Coast Survey by AD Bache, T-00334

Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html

This map has the earliest depiction of the boundary line of Mean Lower Low Water (MLLW) in the head of Richardson Bay. It is possible that Richardson Bay was already exhibiting some level of shallowing and narrowing of the MLLW boundary by the time the map was made because of the land use activities in the upland watersheds that already included significant disturbances from grazing, logging, and conversion from native perennial grasslands to annual.

Ref 7



1851, Drainage Area of US Coast Survey by AD Bache, T-00334 Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html

The dramatic reduction in drainage area to SBM was caused by diversion of Coyote Creek and construction of the CCC for flood control. Modern SBM has been robbed of upland fluvial sediment supply.

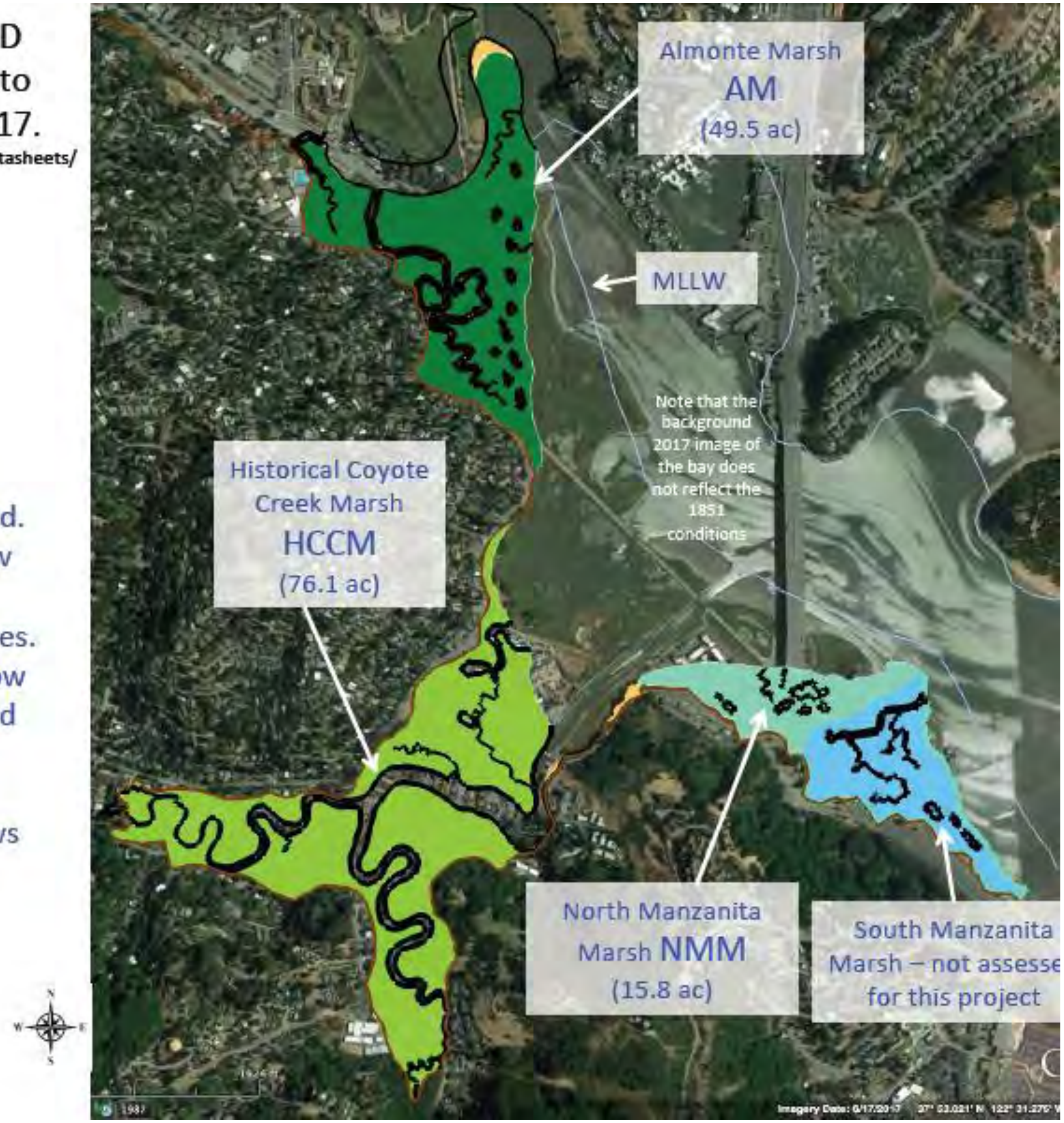
Ref 8

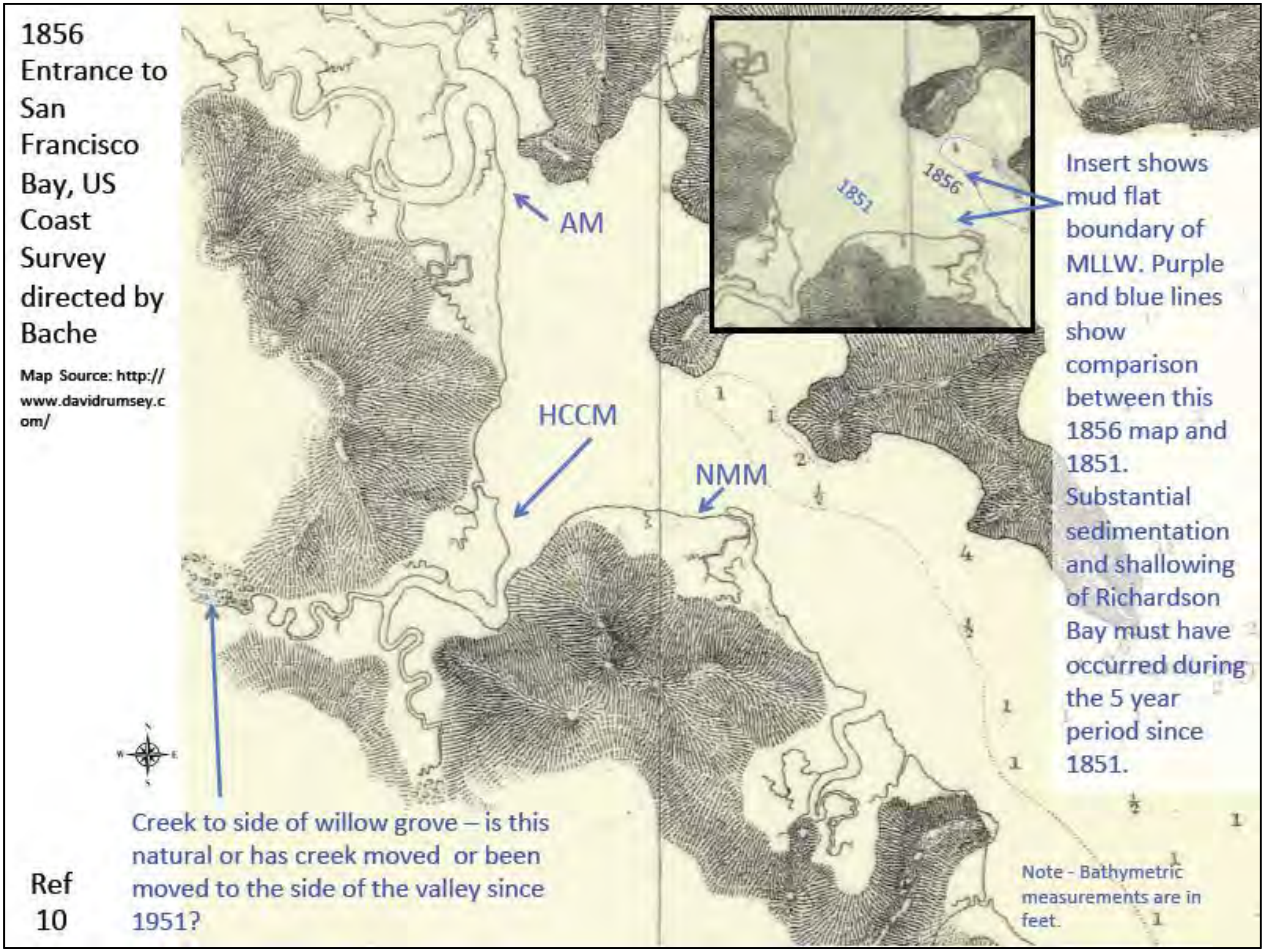
1851, US Coast Survey by AD Bache, T-00334 overlaid onto Google Earth Imagery 6/2017.

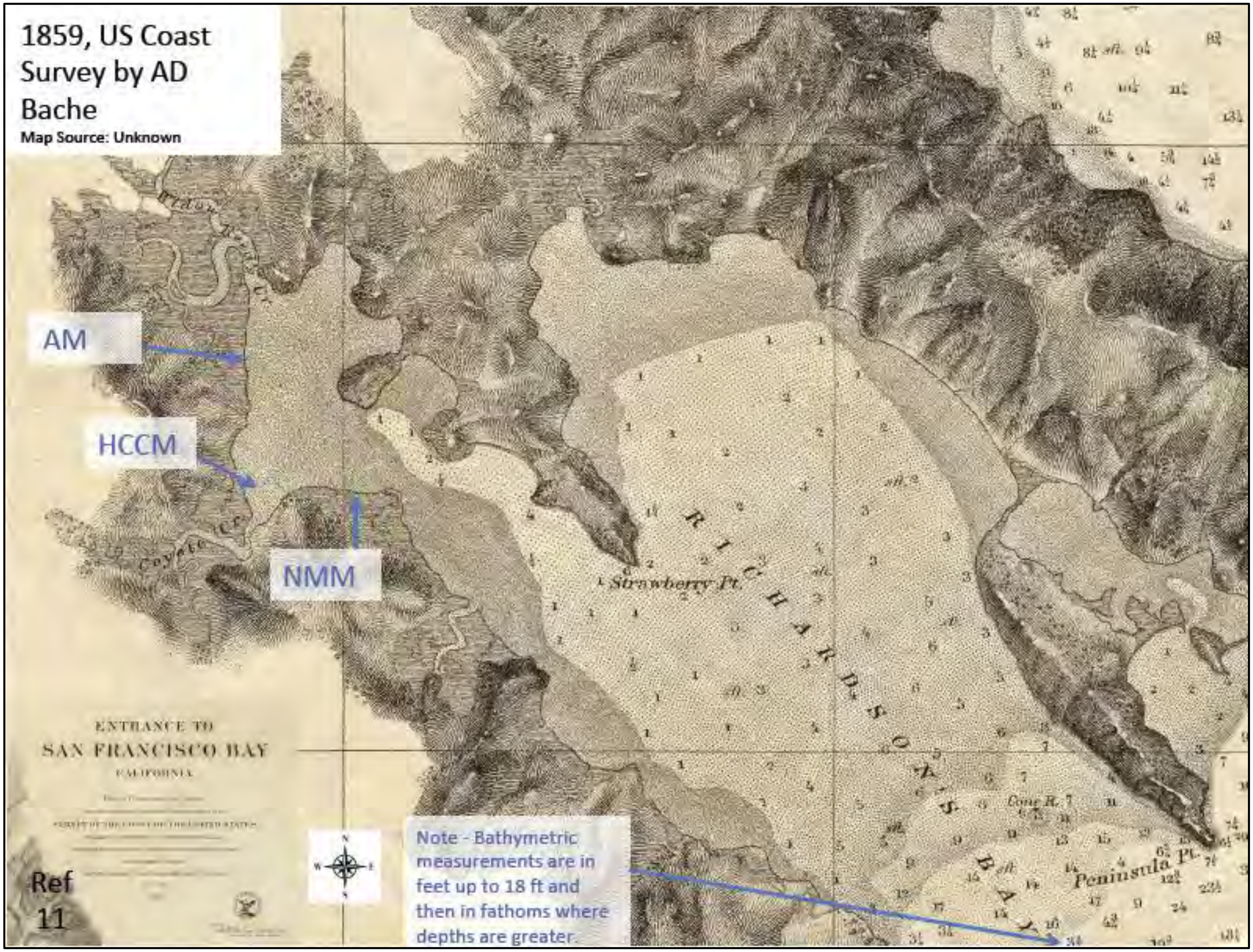
Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html

Relative to the modern landscape, historical 1851 marshes have been highlighted. Green and blue polygons show historical high elevation pickleweed-dominated marshes. Buff colored polygons show low elevation cordgrass-dominated marshes. Black lines show historical tidal channels and ponds. The lavender line shows MLLW.

Ref 9

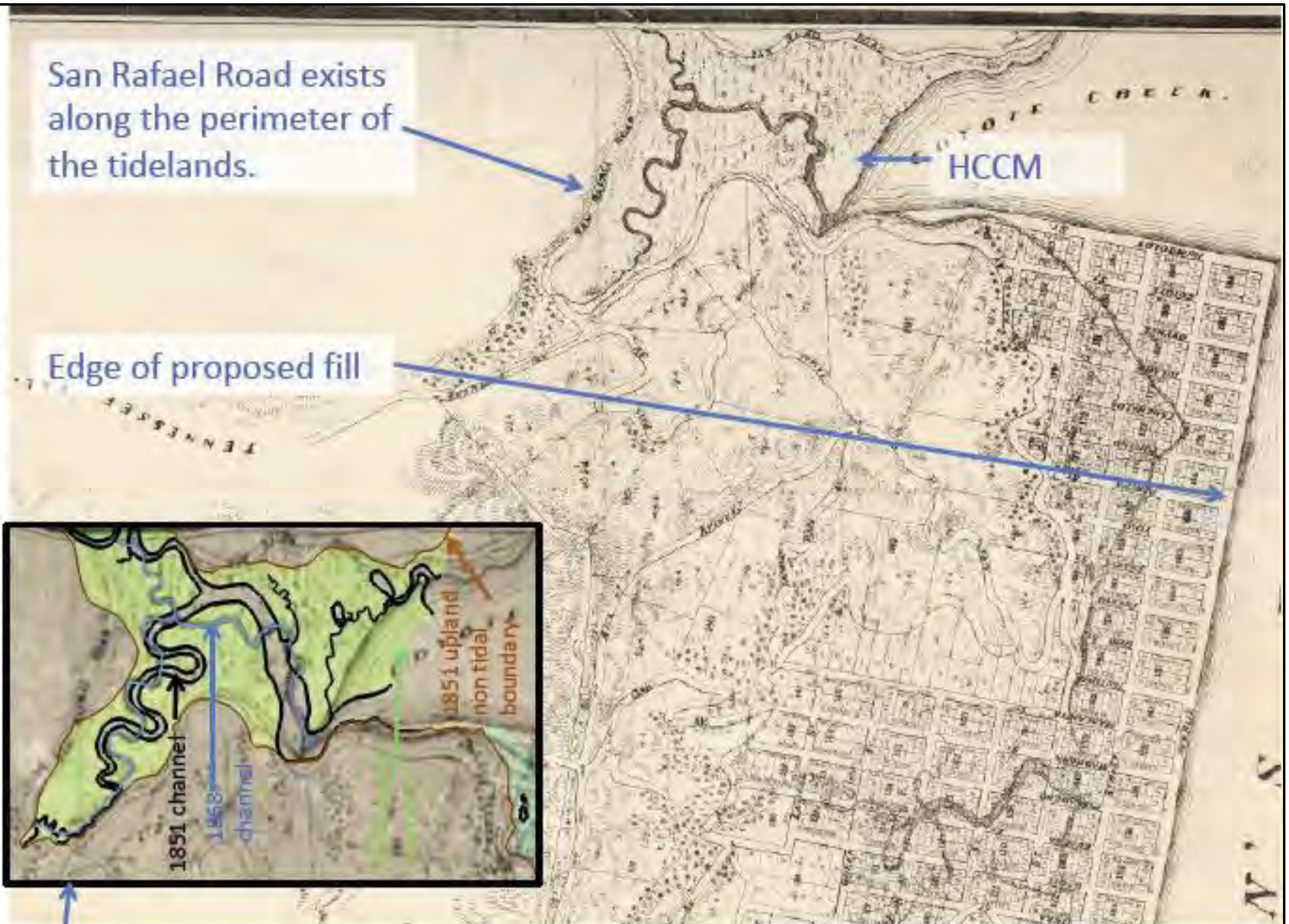



1856 Entrance to San Francisco Bay, US Coast Survey directed by Bache
Map Source: http://www.davidrumsey.com/
AM
HCCM
NMM
1851
1856
Insert shows mud flat boundary of MLLW. Purple and blue lines show comparison between this 1856 map and 1851. Substantial sedimentation and shallowing of Richardson Bay must have occurred during the 5 year period since 1851.
Creek to side of willow grove – is this natural or has creek moved or been moved to the side of the valley since 1951?
Note - Bathymetric measurements are in feet.
Ref 10


1859, US Coast Survey by AD Bache
Map Source: Unknown
AM
HCCM
NMM
Strawberry Pt.
RICHARDSON'S BAY
Peninsula Pt.
ENTRANCE TO
SAN FRANCISCO BAY
CALIFORNIA
Note - Bathymetric measurements are in feet up to 18 ft and then in fathoms where depths are greater.
Ref 11

1868 Detail of Sausalito Land and Ferry Company

Map Source: https://www.google.com/search?q=sausalito+land+and+ferry+company+map&tbm=isch&imgil=g254e1IEcnnaaM%253A%253BkWqyDVbWR_QzRM%253Bhttp%25253A%25252F%25252Fwww.frederickbee.com%252Fsausalitomap.html&source=iu&pf=m&fir=g254e1IEcnnaaM%253A%252CkWqyDVbWR_QzRM%252C_&usg=__TdENRKEyB87VEOzHgl-MbZL9B8A%3D&biw=1620&bih=1319&ved=0ahUKEwj2wMGcwKzTAhUCsFQKHdkeDbcQyjcITA&ei=kzz1WLarGYLg0gLZvbS4Cw#imgdii=vCtljqNZmaHiXM:&imgrc=g254e1IEcnnaaM:



Detail showing comparison of 1868 channel position and sinuosity to 1851. Note the 1868 map appears to be a conceptualized channel and shoreline. A better survey was done in 1870 of the marsh shoreline. The 1851 marsh boundary is shown in green with the brown line representing the upland non-tidal boundary.

Ref 12

1870, Map No. 7 of Salt Marsh and Tidelands Sales map

Map Source: Marin County Recorder's Office

Proposed Coyote Canal was not constructed in the historical marsh but the lower part of this proposed canal closely aligns with the 1965 CCC that was cut through the modern SBM.

Downstream of these points channel mapping seems to follow the 1851 alignment

Ref 13

May 1870, No. 7 Salt Marsh and Tidelands Sales Map,

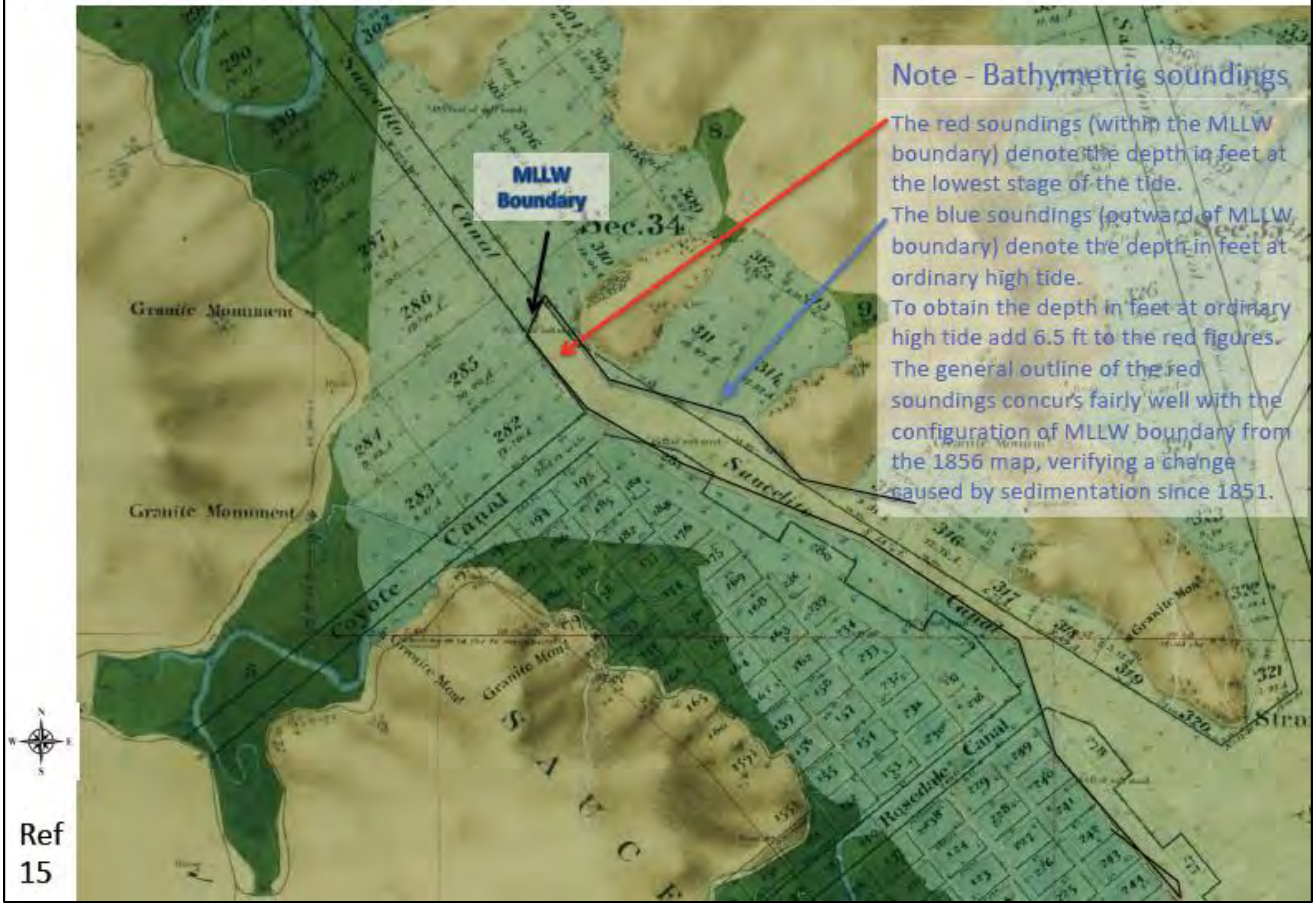
Map Source: Mill Valley Library History Room

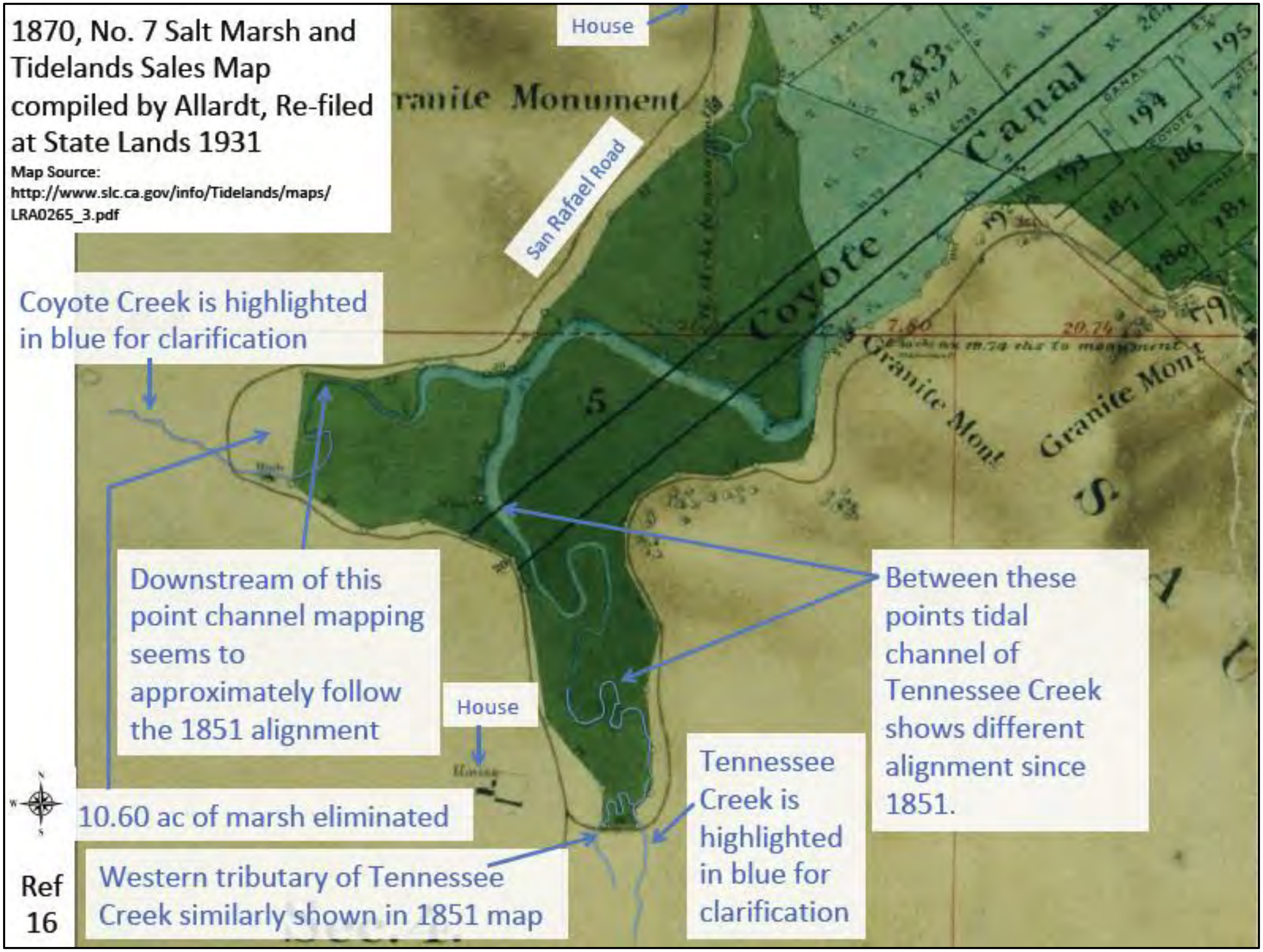
The head of the north fork of the historical marsh has been cut off.

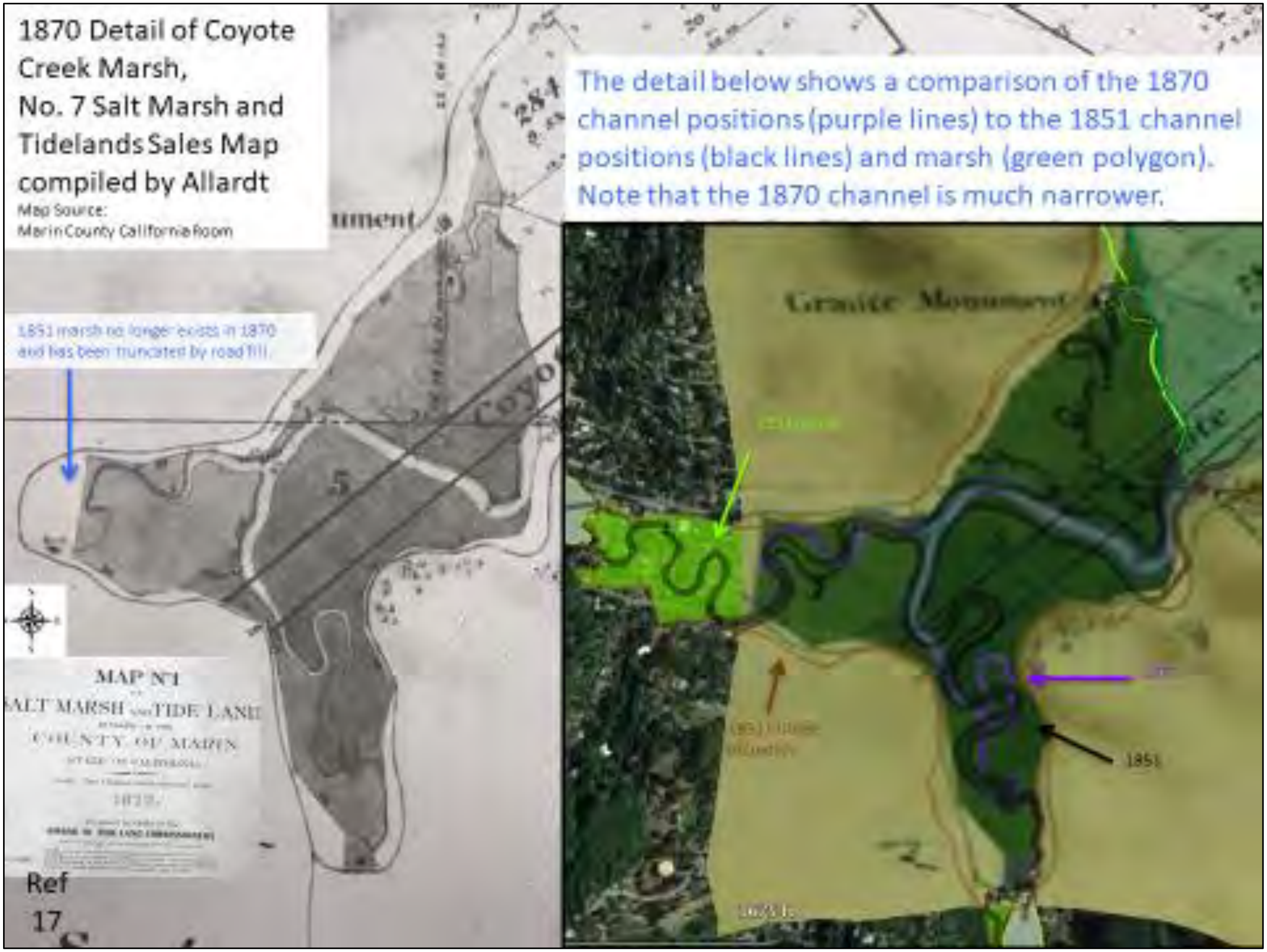
The San Rafael Road otherwise follows the perimeter of the marsh. About 10.6 ac marsh eliminated. Greater creek detail is mapped in other 1870 maps (Image Ref #14, #15 & #16).

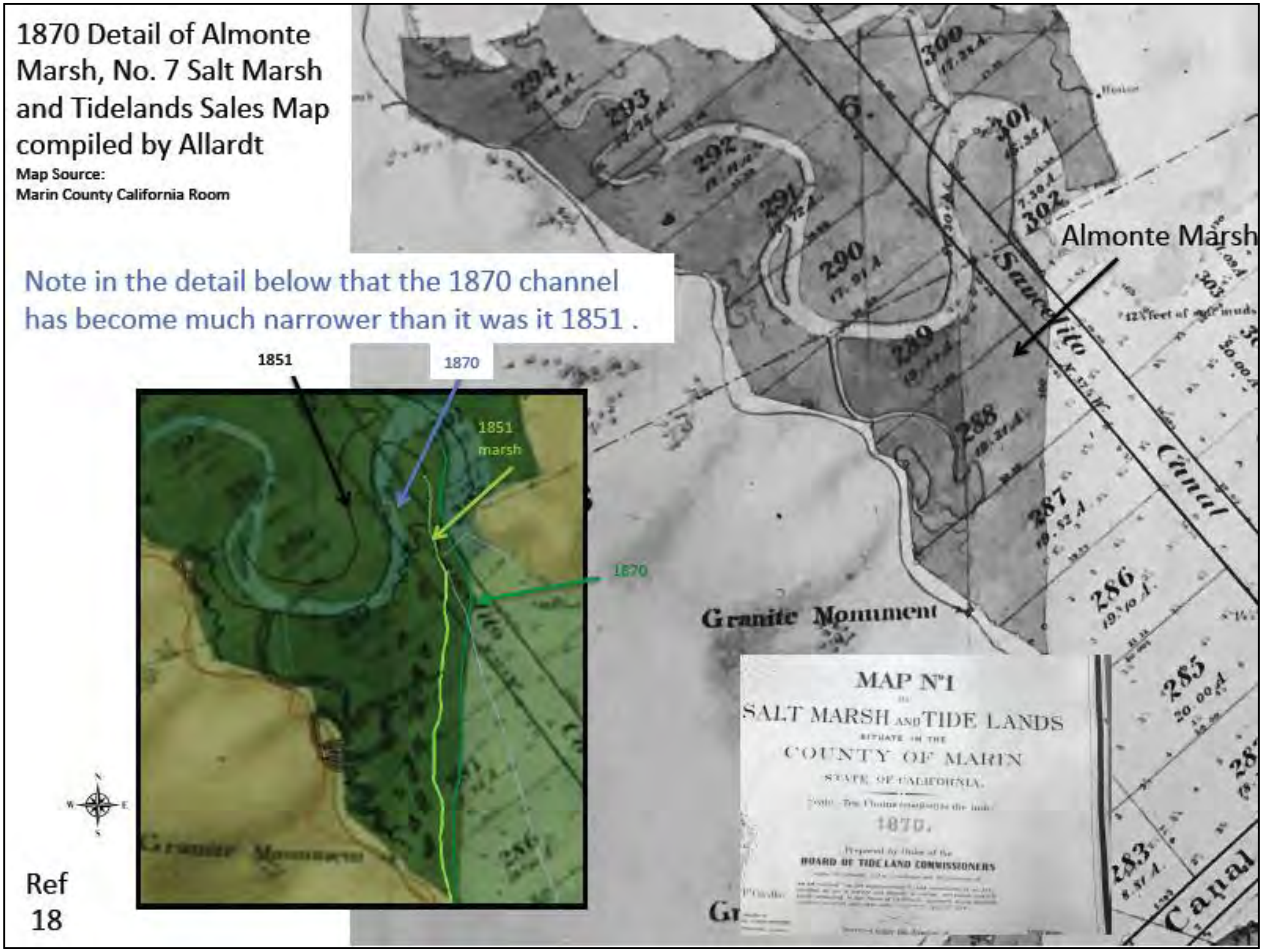
Ref
14

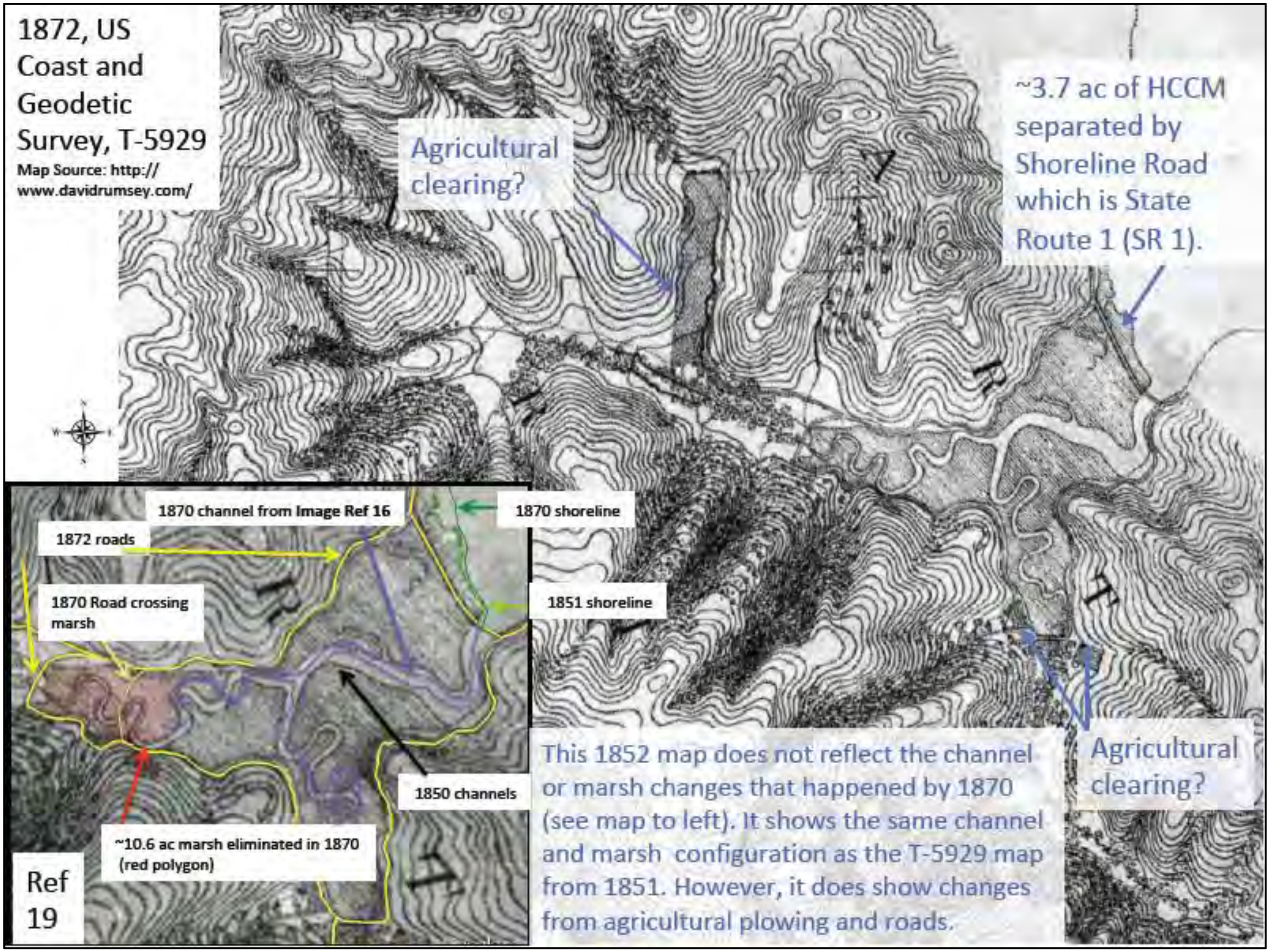
1870, No. 7 Salt Marsh and Tidelands Sales Map compiled by Allardt, Re-filed at State Lands 1931 Map Source:http://www.slc.ca.gov/info/Tidelands/maps/LRA0265_3.pdf

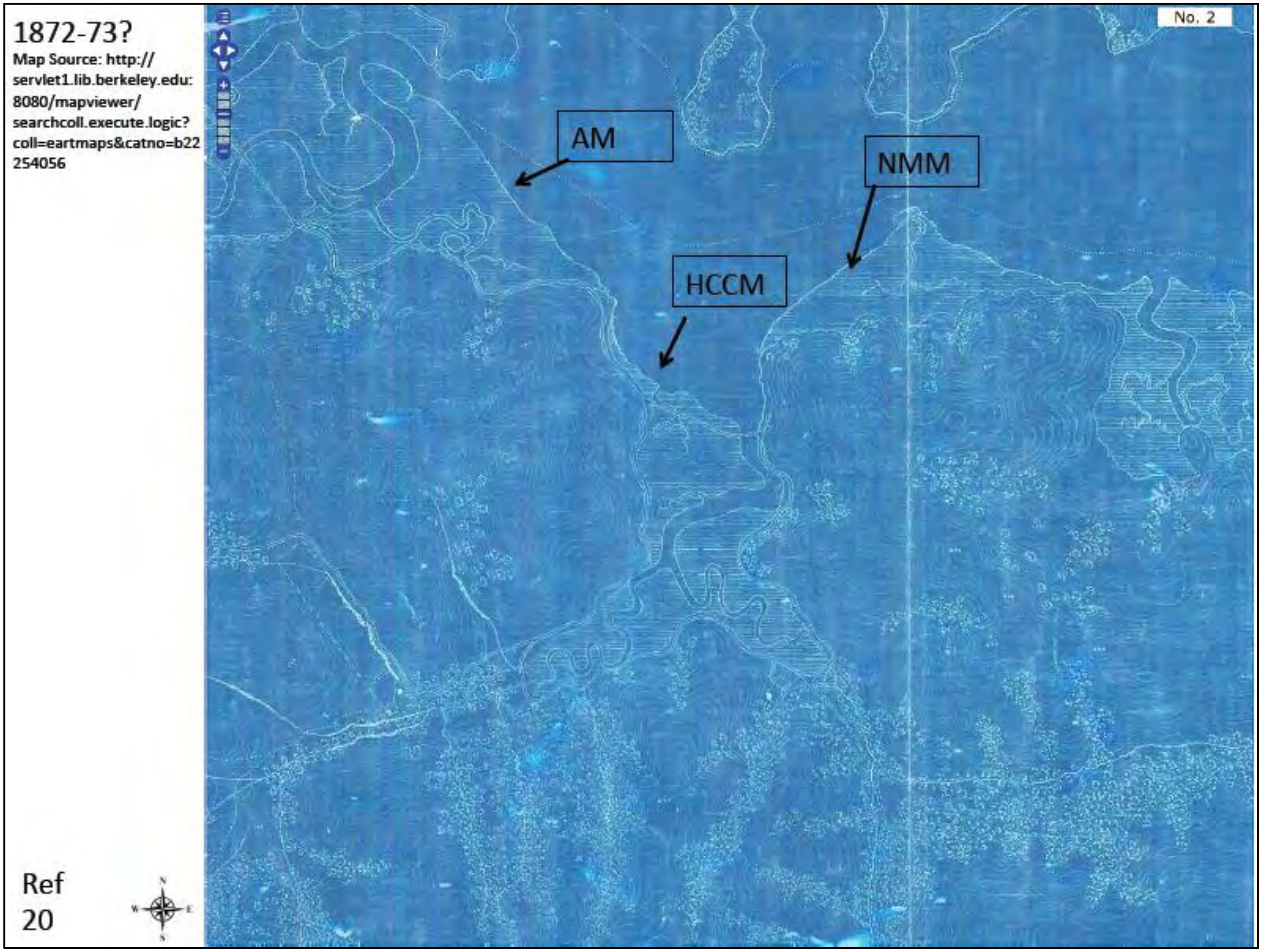


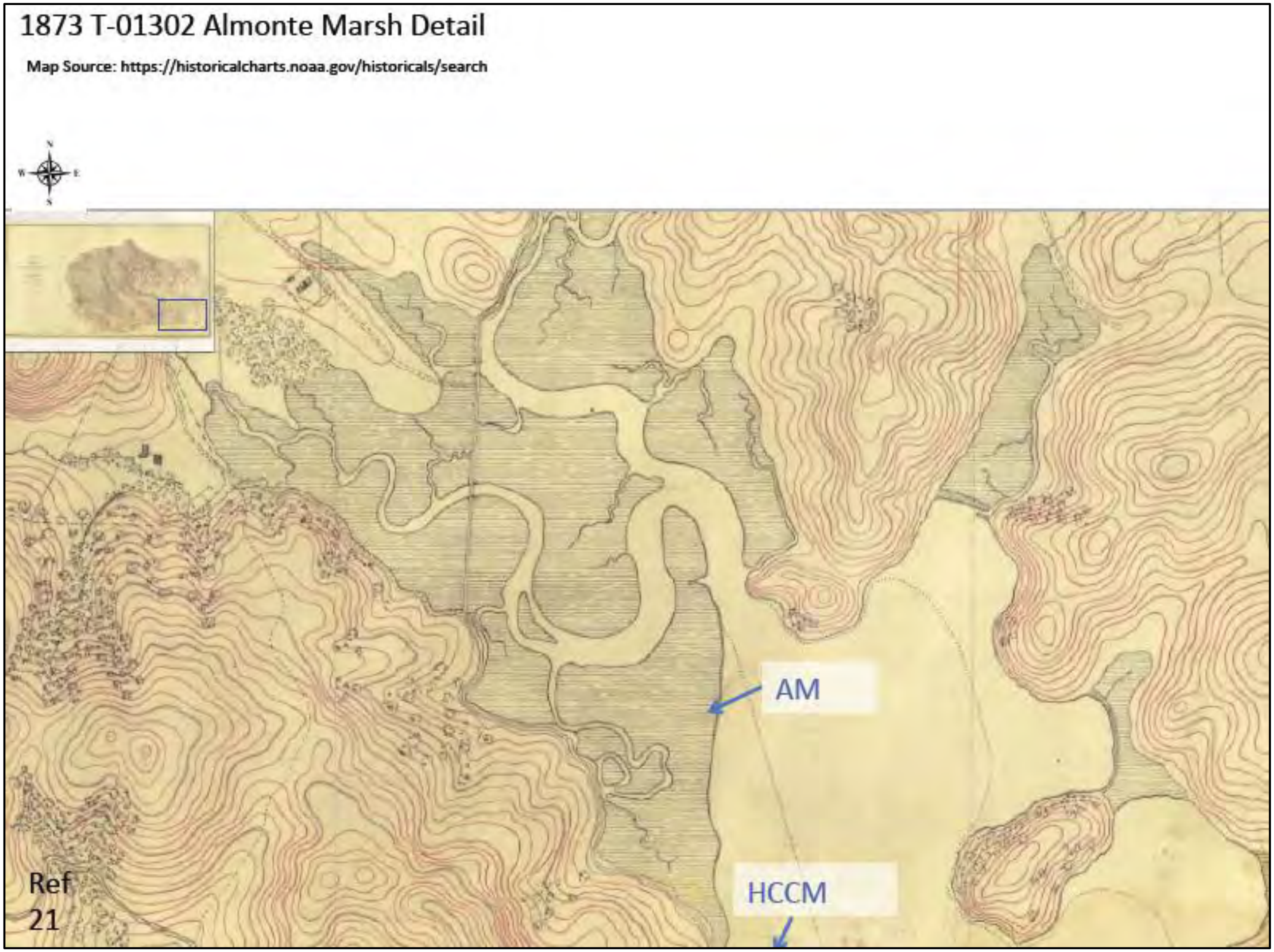

1870, No. 7 Salt Marsh and Tidelands Sales Map compiled by Allardt, Re-filed at State Lands 1931
Map Source: http://www.slc.ca.gov/info/Tidelands/maps/LRA0265_3.pdf
House
San Rafael Road
Granite Monument
Coyote Canal
Coyote Creek is highlighted in blue for clarification
Downstream of this point channel mapping seems to approximately follow the 1851 alignment
House
10.60 ac of marsh eliminated
Western tributary of Tennessee Creek similarly shown in 1851 map
Tennessee Creek is highlighted in blue for clarification
Between these points tidal channel of Tennessee Creek shows different alignment since 1851.
Granite Mont
Granite Mont
Ref 16


1870 Detail of Coyote Creek Marsh,
No. 7 Salt Marsh and Tidelands Sales Map compiled by Allardt
Map Source:
Marin County California Room
1851 marsh no longer exists in 1870 and has been truncated by road fill.
The detail below shows a comparison of the 1870 channel positions (purple lines) to the 1851 channel positions (black lines) and marsh (green polygon).
Note that the 1870 channel is much narrower.
Granite Monument
1851
MAP No 1
SALT MARSH AND TIDE LAND
COUNTY OF MARIN
Ref 17


1870 Detail of Almonte Marsh, No. 7 Salt Marsh and Tidelands Sales Map compiled by Allardt
Map Source:
Marin County California Room
Note in the detail below that the 1870 channel has become much narrower than it was it 1851 .
1851
1870
1851 marsh
1870
Almonte Marsh
Granite Monument
Sausalito
Canal
MAP No. 1
SALT MARSH AND TIDE LANDS
SITUATE IN THE
COUNTY OF MARIN
STATE OF CALIFORNIA.
1870.
BOARD OF TIDE LAND COMMISSIONERS
Ref
18


1872, US Coast and Geodetic Survey, T-5929
Map Source: http://www.davidrumsey.com/
Agricultural clearing?
~3.7 ac of HCCM separated by Shoreline Road which is State Route 1 (SR 1).
1870 channel from Image Ref 16
1870 shoreline
1872 roads
1870 Road crossing marsh
1851 shoreline
1850 channels
~10.6 ac marsh eliminated in 1870 (red polygon)
Ref 19
This 1852 map does not reflect the channel or marsh changes that happened by 1870 (see map to left). It shows the same channel and marsh configuration as the T-5929 map from 1851. However, it does show changes from agricultural plowing and roads.
Agricultural clearing?


1872-73?
Map Source: http://servlet1.lib.berkeley.edu:8080/mapviewer/searchcoll.execute.logic?coll=eartmaps&catno=b22254056
No. 2
AM
NMM
HCCM
Ref 20


1873 T-01302 Almonte Marsh Detail
Map Source: https://historicalcharts.noaa.gov/historicals/search
AM
HCCM
Ref
21

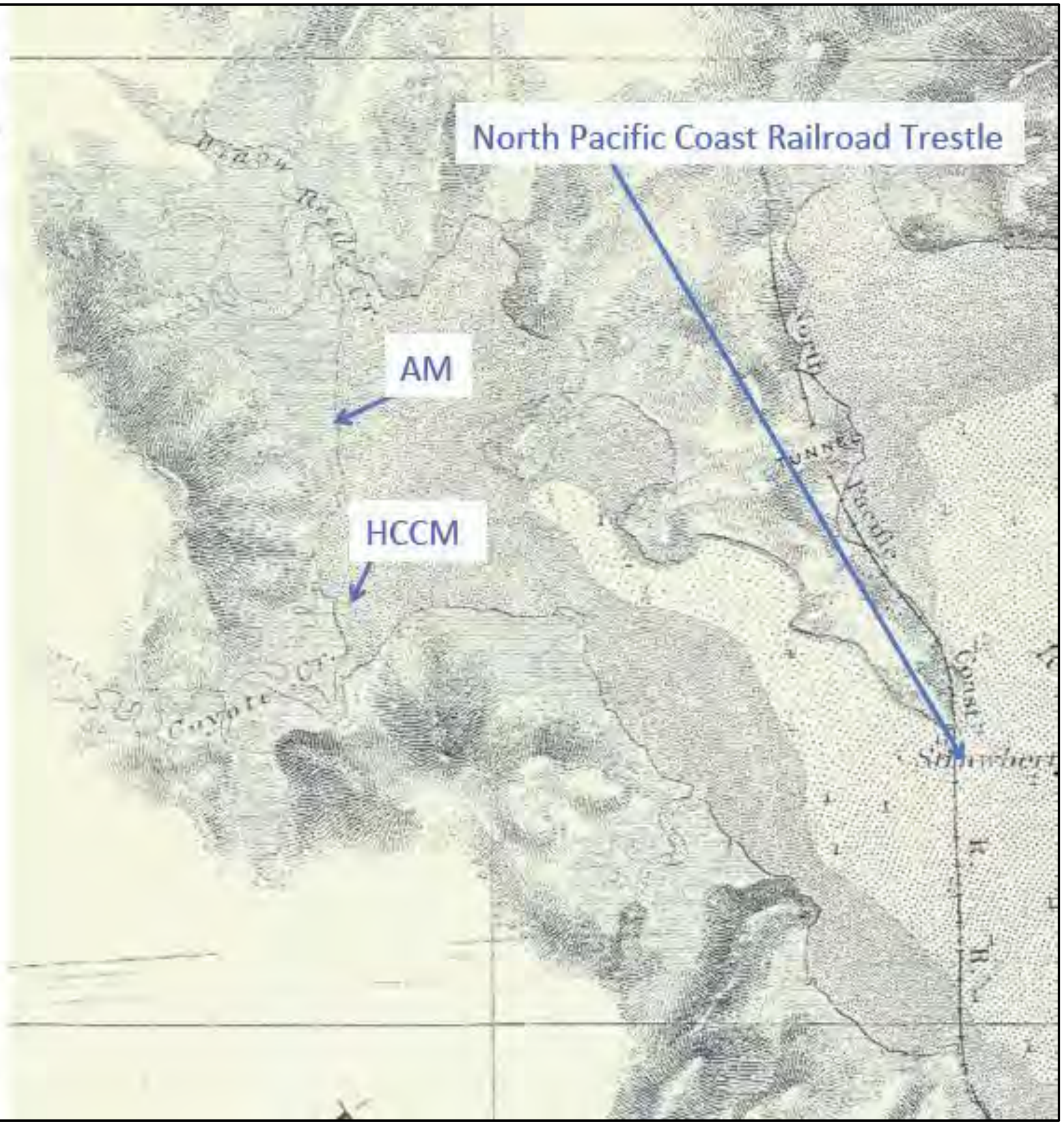
1873 Detail of Map of Marin County Compiled by Austin, drawn by Whitney

Map Source: Marin History Museum

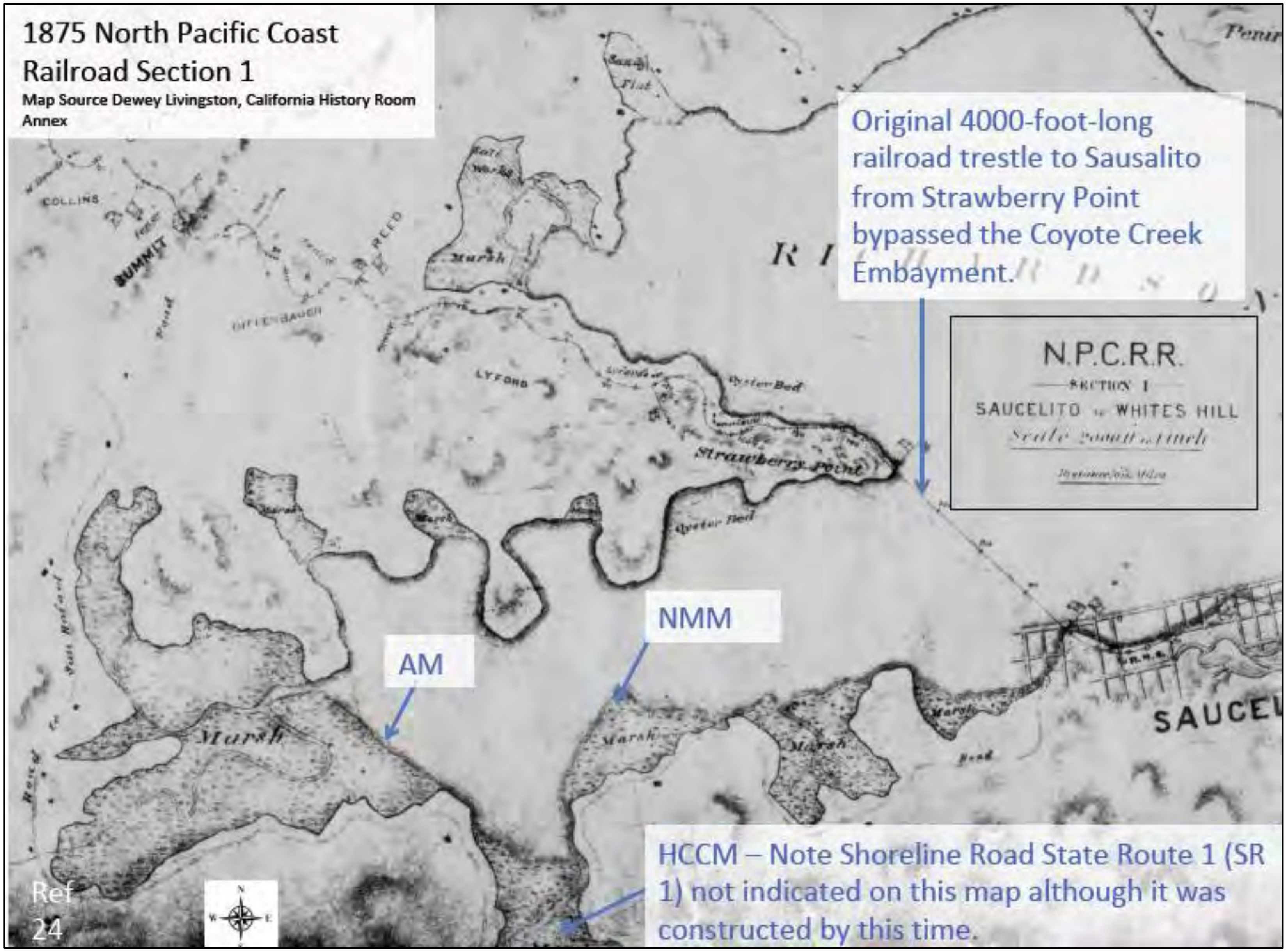
Ref 22

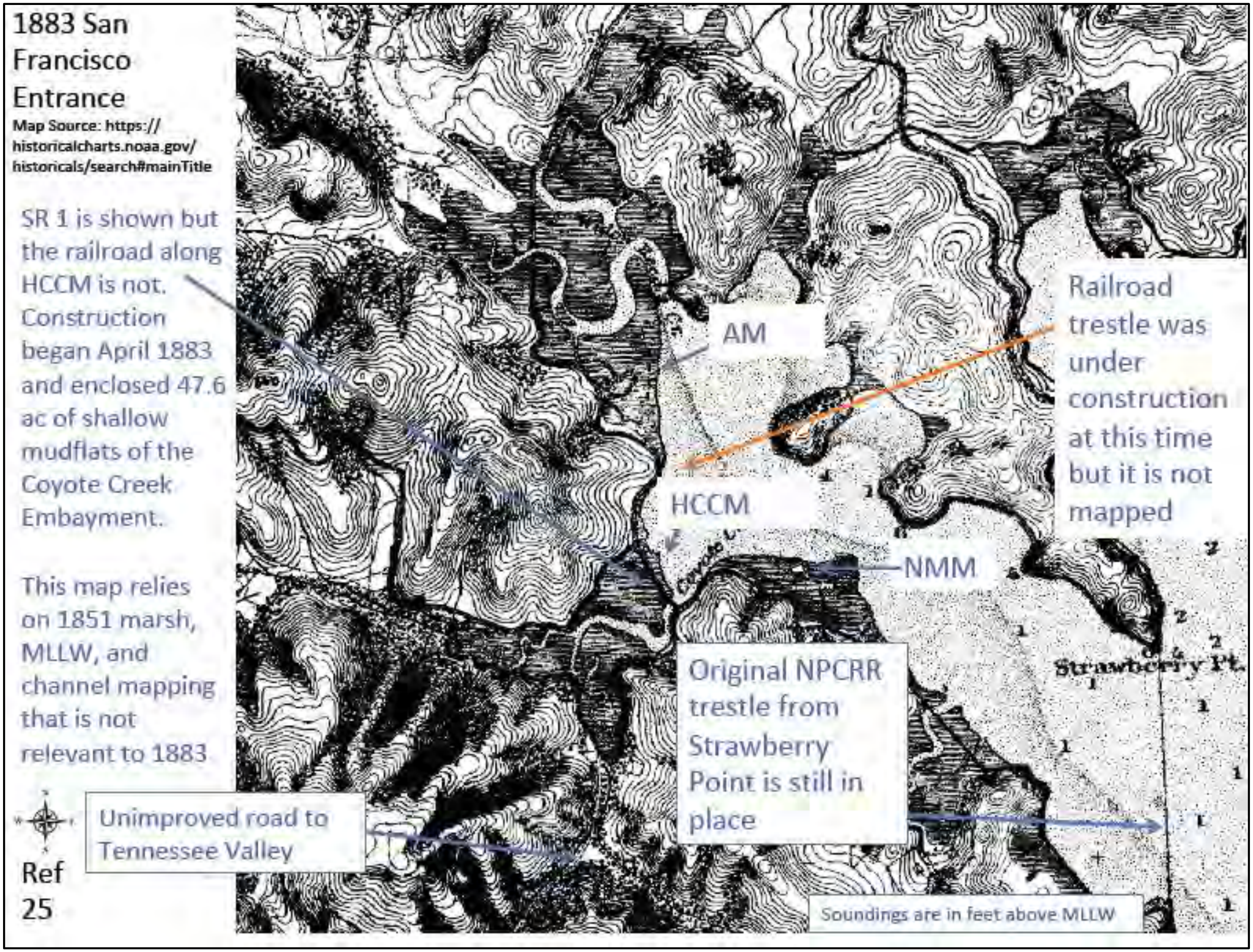
1873 (??) showing earliest North Pacific RR trestle to Sausalito on an earlier map of 1859 Entrance to San Francisco Bay Map by US Coast Survey directed by Bache

Map Source: http://www.davidrumsey.com/



Ref 23


1875 North Pacific Coast
Railroad Section 1
Map Source Dewey Livingston, California History Room Annex
Original 4000-foot-long railroad trestle to Sausalito from Strawberry Point bypassed the Coyote Creek Embayment.
N.P.C.R.R.
SECTION 1
SAUCELITO to WHITES HILL
Strawberry Point
Oyster Bed
Marsh
AM
NMM
HCCM – Note Shoreline Road State Route 1 (SR 1) not indicated on this map although it was constructed by this time.
SAUCEL
Ref 24

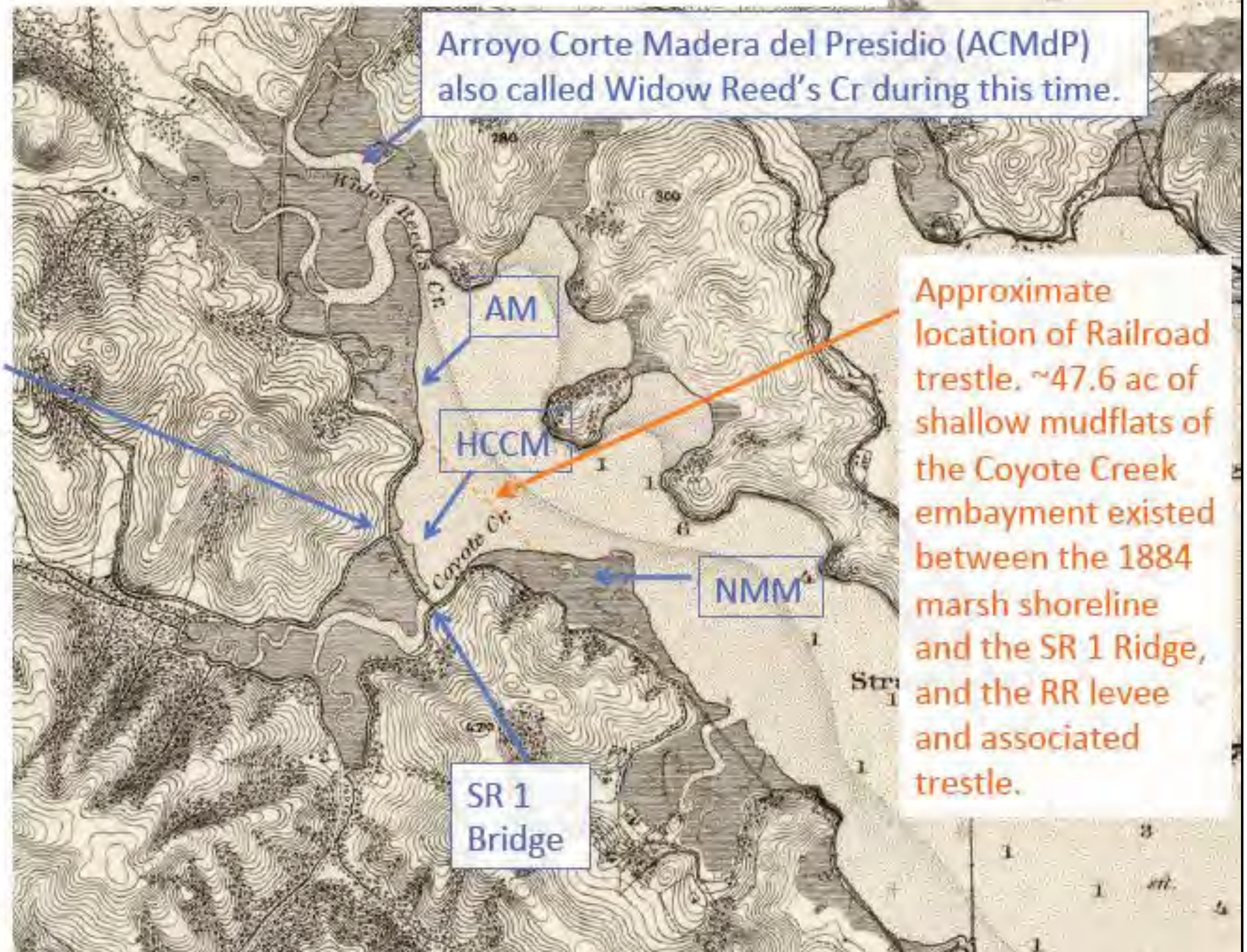

1883 San Francisco Entrance
Map Source: https://historicalcharts.noaa.gov/historicals/search#mainTitle
SR 1 is shown but the railroad along HCCM is not. Construction began April 1883 and enclosed 47.6 ac of shallow mudflats of the Coyote Creek Embayment.
This map relies on 1851 marsh, MLLW, and channel mapping that is not relevant to 1883
Ref 25
Unimproved road to Tennessee Valley
AM
HCCM
NMM
Railroad trestle was under construction at this time but it is not mapped
Original NPCRR trestle from Strawberry Point is still in place
Strawberry Pt.
Soundings are in feet above MLLW

1884 Detail San Francisco Entrance, U.S. Coast Survey.

Map Source: https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~239951~5512086:San-Francisco-entrance,-California-?sort=Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No&qvq=q:COAST%2BSURVEY%2BEntrance%2BSAN%2BFRANCISCO%2BBAY;sort:Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No;lc:RUMSEY~8~1&mi=0&trs=10

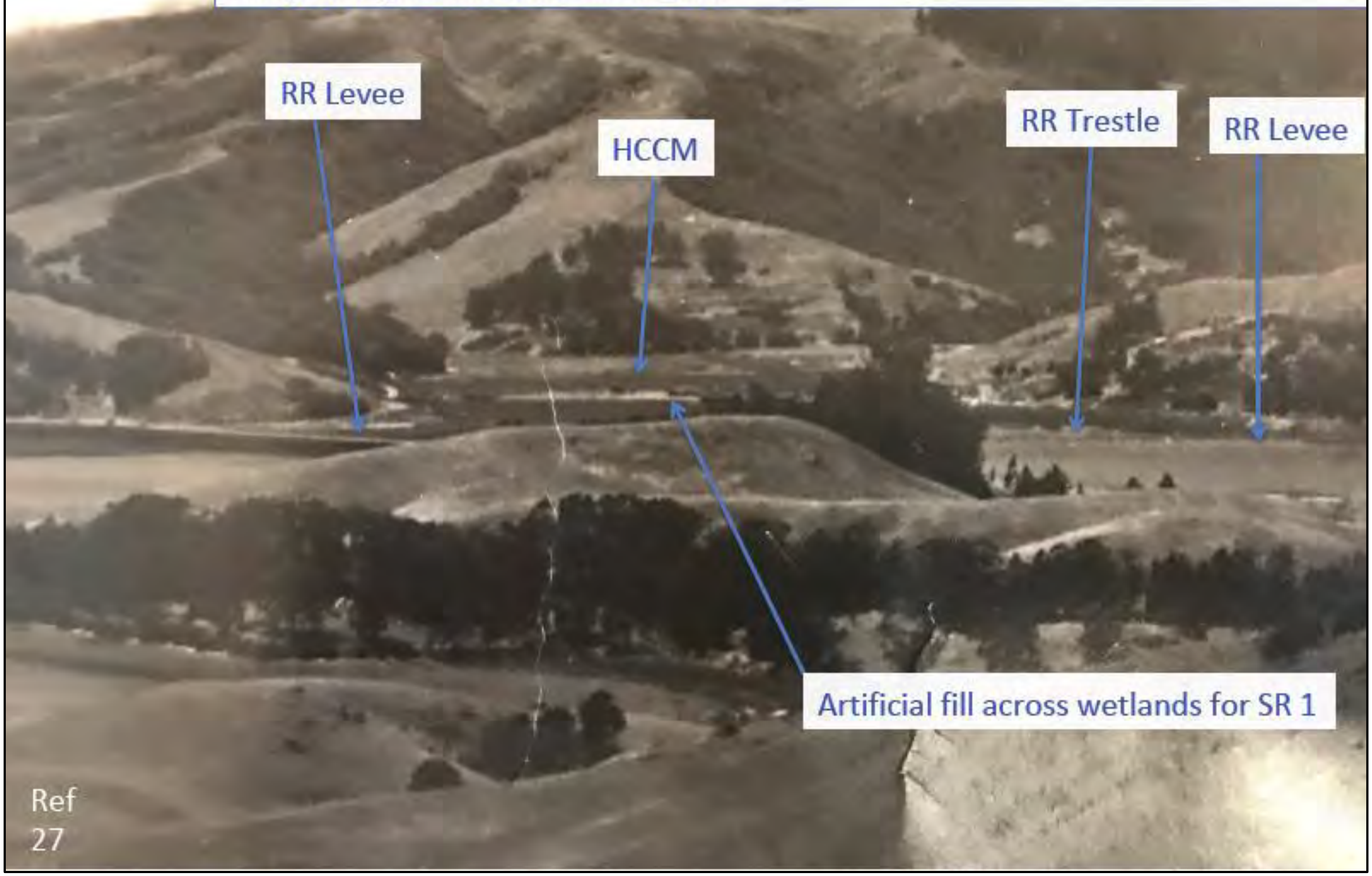
Although the roads appear to be updated, the marsh, channel, and MLLW features appear to rely on the 1851 mapping. The NPCRR across AM and Coyote Creek Embayment was completed by April 1884 but it is not shown on this map.

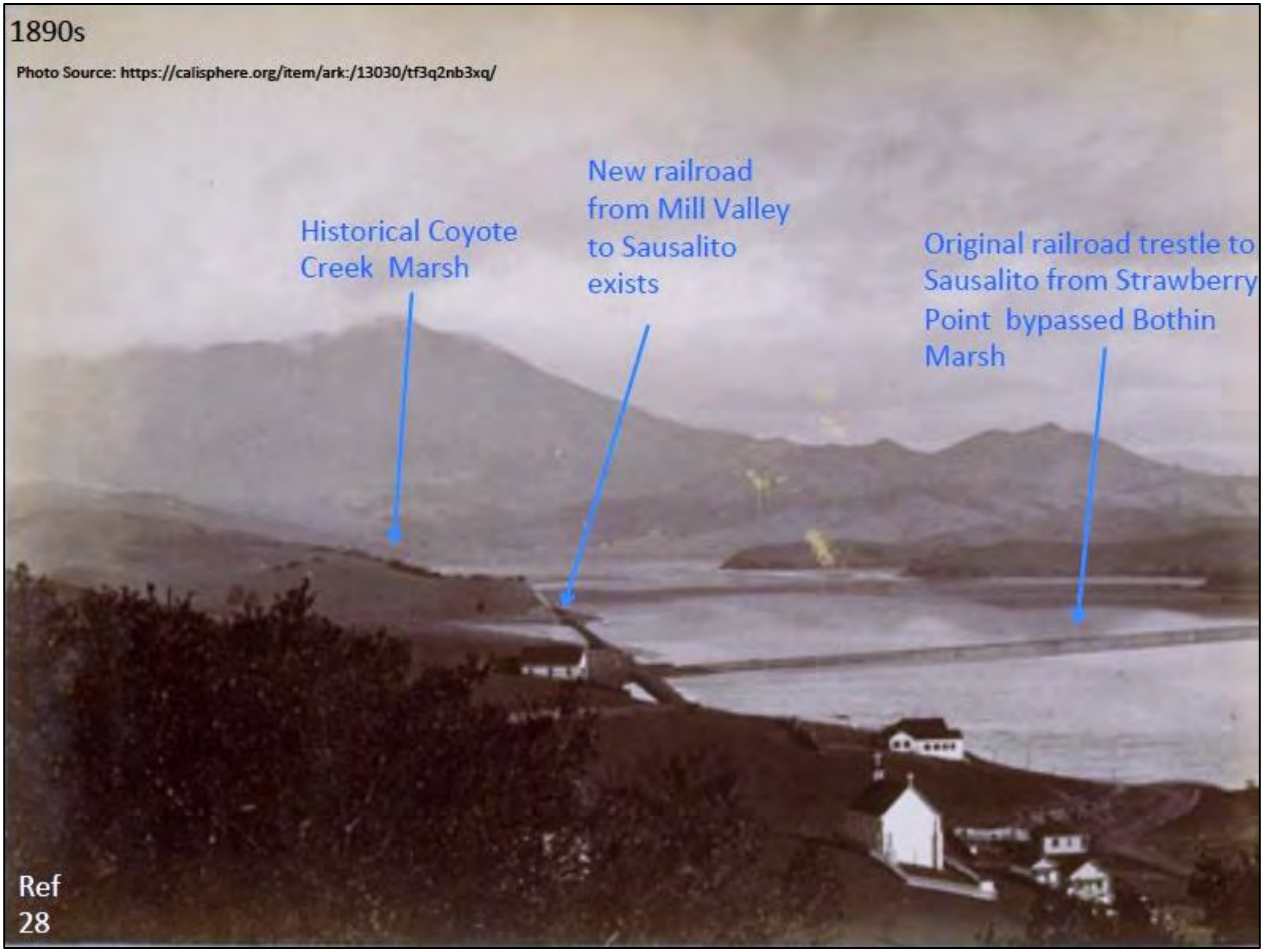
Ref 26



Post 1884?
Photo Source: GIS Dept. Marin County

Looking west toward Historical Coyote Creek Marsh. The railroad trestle can be seen crossing the Coyote Creek Embayment. Construction began on this branch of the NPCRR in April 1983. Service began in April 1984. Extensive wetlands still exist west up the tributary valleys of Coyote and Tennessee Creeks.



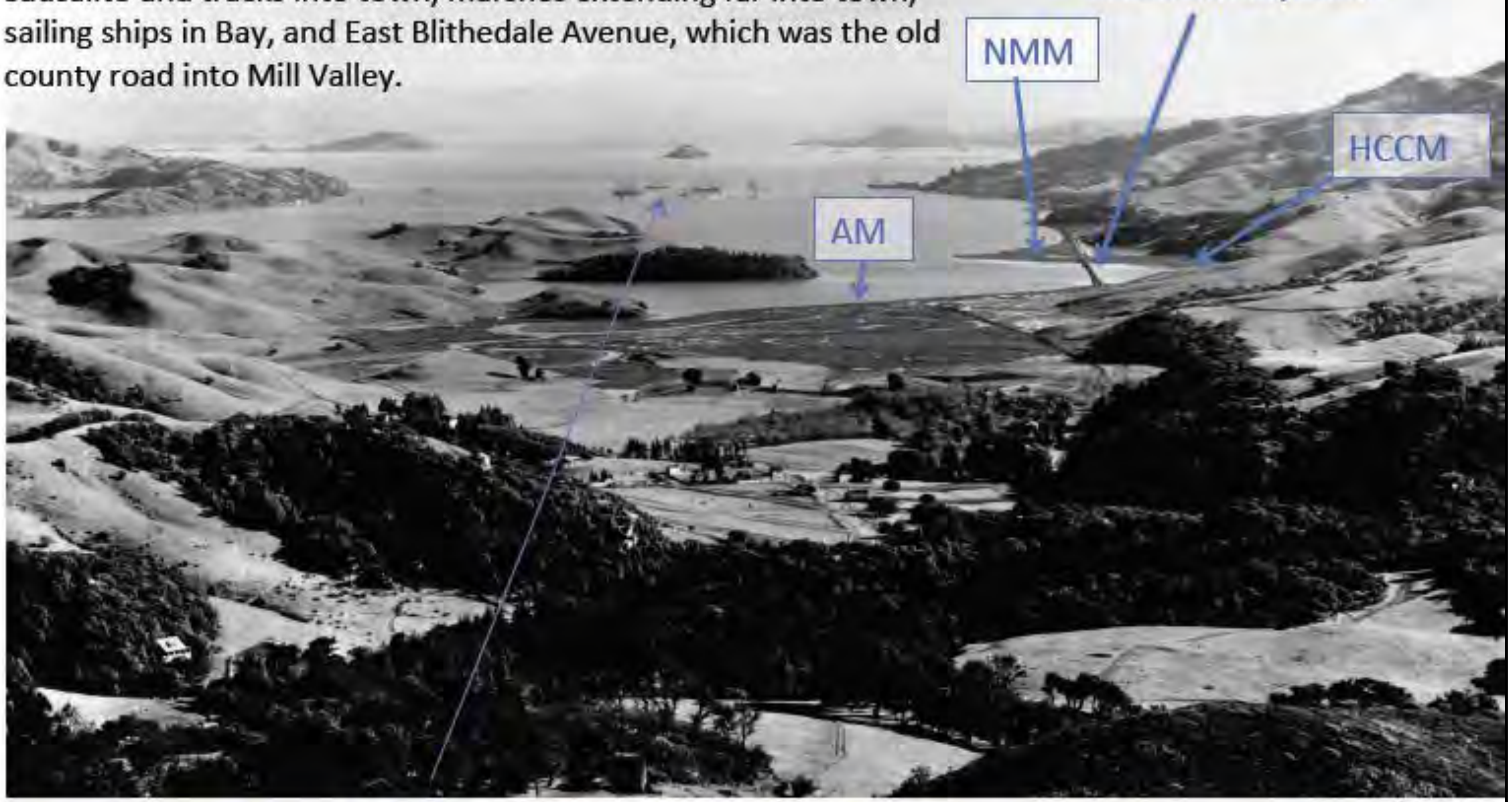

1890s
Photo Source: https://calisphere.org/item/ark:/13030/tf3q2nb3xq/
Historical Coyote Creek Marsh
New railroad from Mill Valley to Sausalito exists
Original railroad trestle to Sausalito from Strawberry Point bypassed Bothin Marsh
Ref 28

Early 1890

Photo Source: Ref #MVN1146v1, History Room, Mill Valley Public Library

Looking down from Summit Avenue in 1890, ten years before the city was incorporated. In this year the first lots were sold at auction by Tamalpais Land and Water Co. Photo shows train trestle from Sausalito and tracks into town, marshes extending far into town, sailing ships in Bay, and East Blithedale Avenue, which was the old county road into Mill Valley.

Note - The 1300 foot-long railroad trestle can still be seen across the Coyote Creek Embayment.

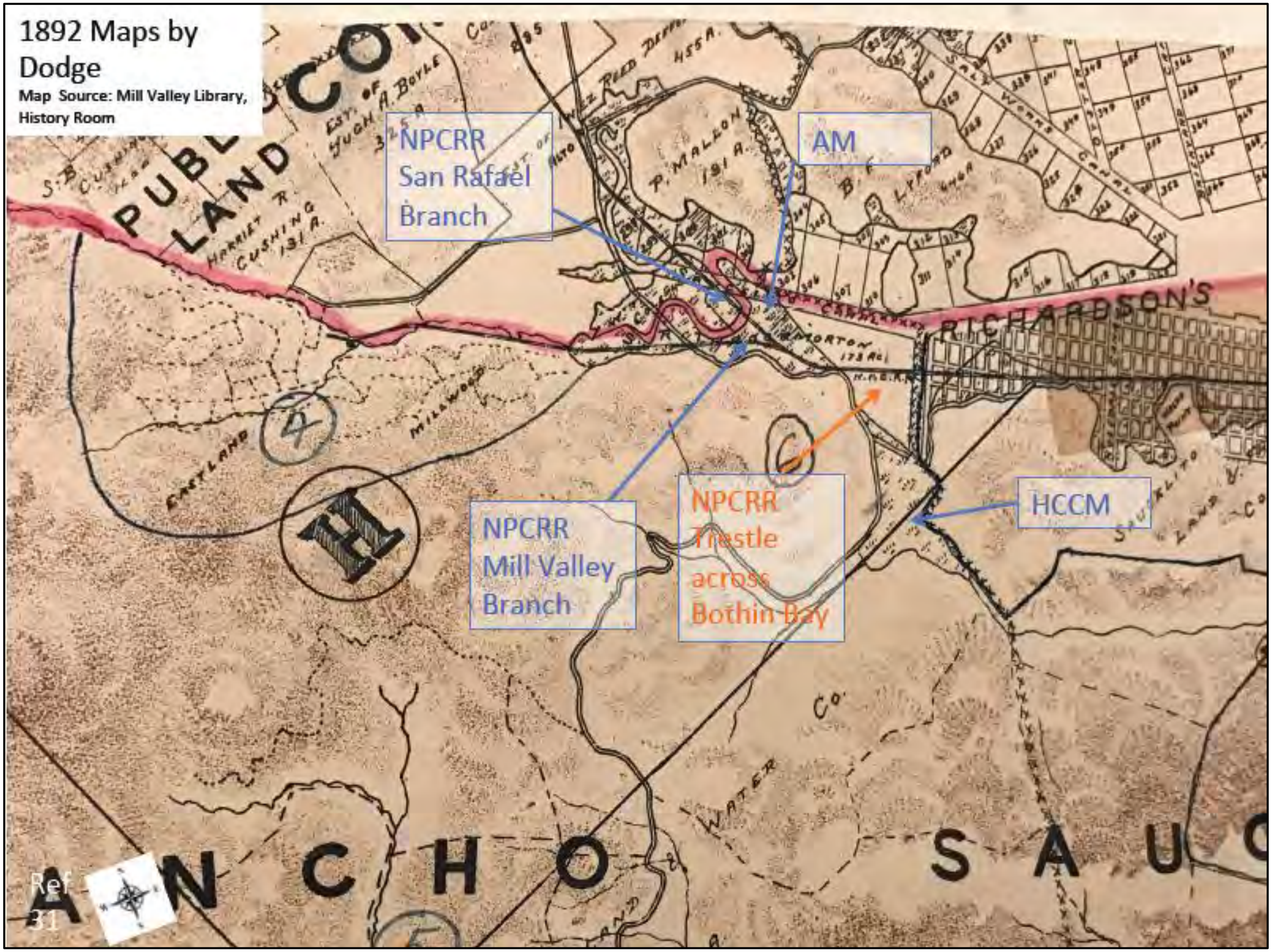


Ref 29 Schooners anchored at the entrance to Richardson Bay rather than within it, possibly because it was too shallow by this time.

Early 1890, Color Enhanced Postcard (same as Image Ref 29)

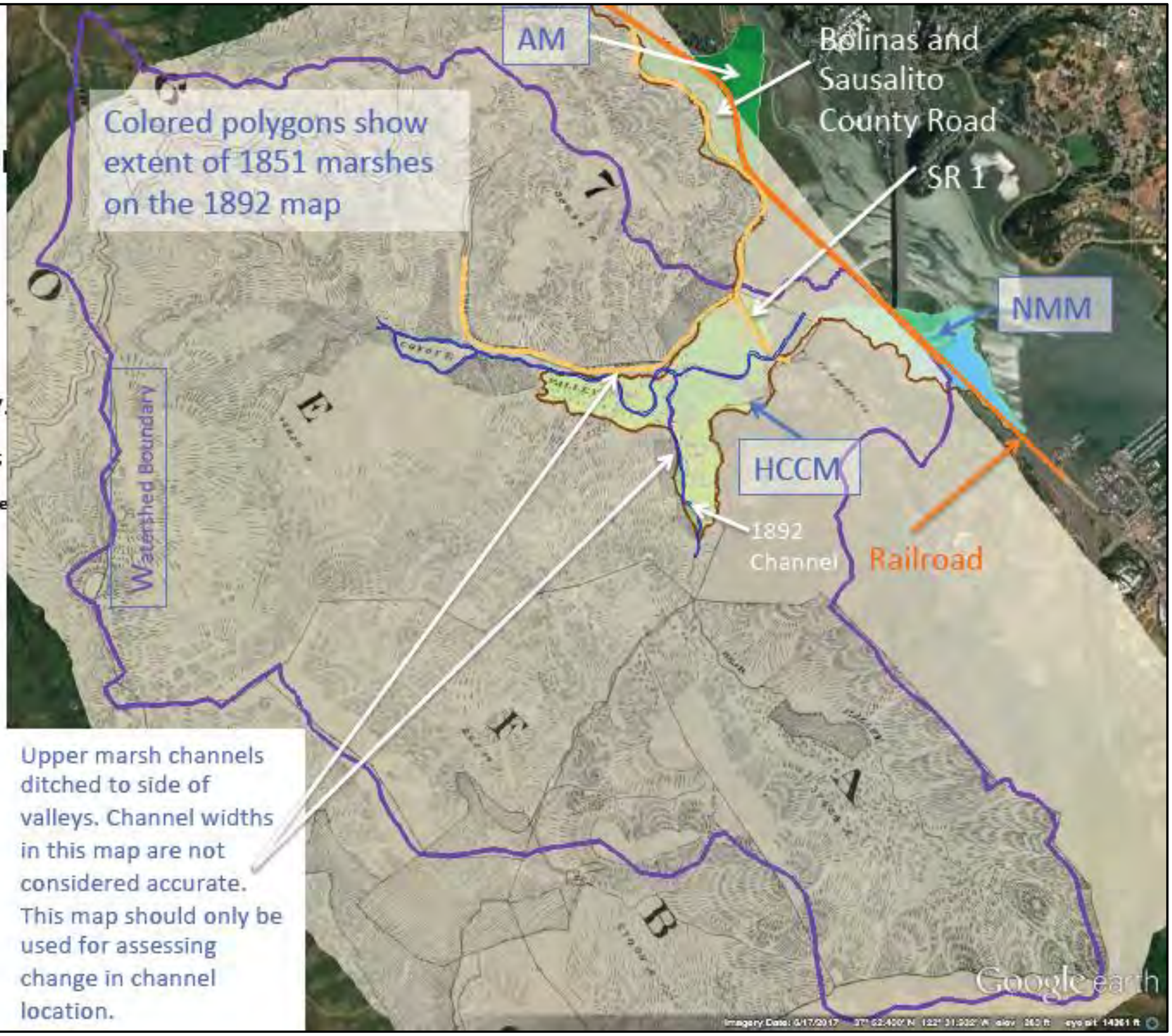
Photo Source: Anne T. Kent California Room, Marin County Free Library

Ref
30

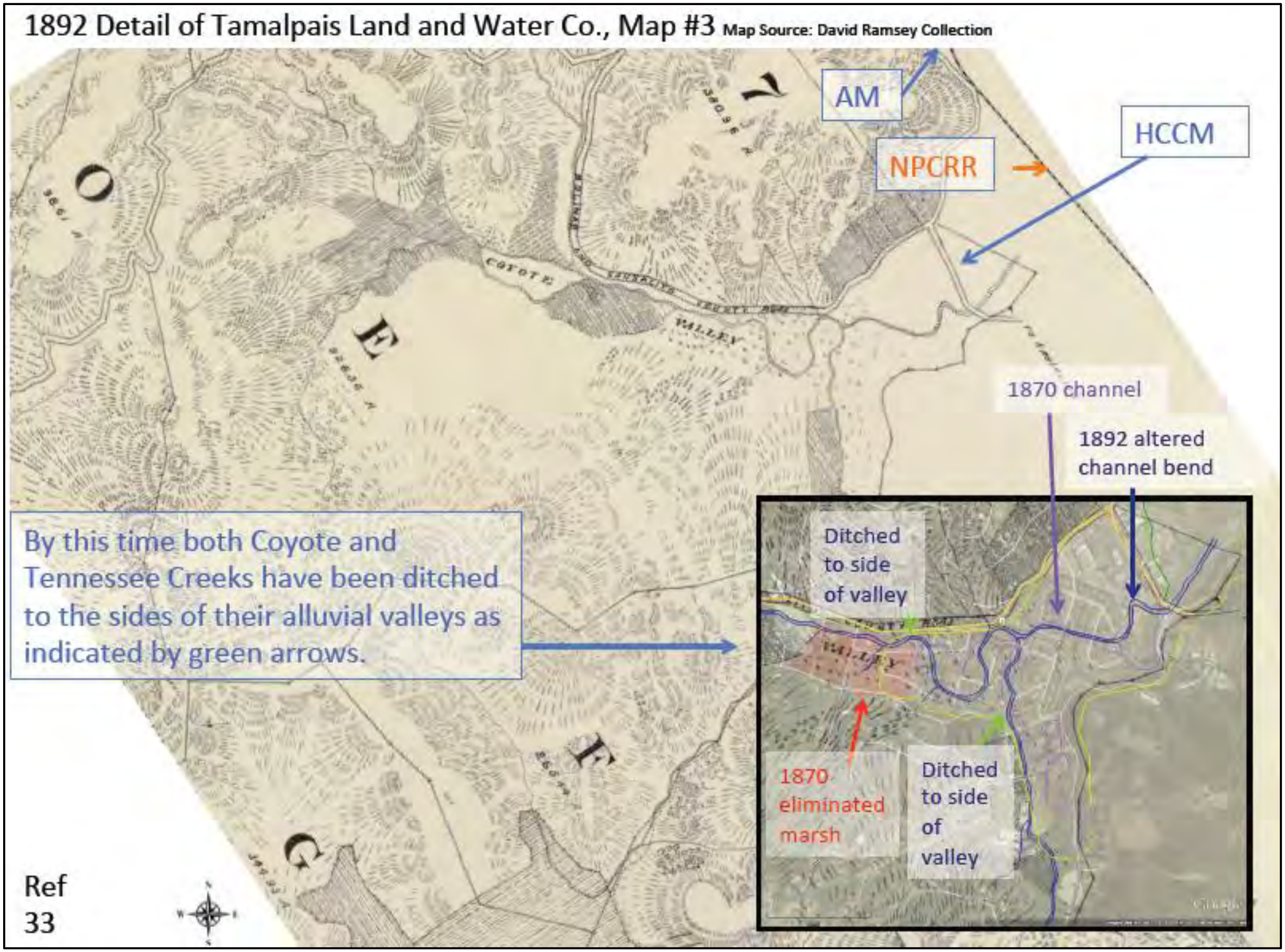

1892 Maps by Dodge
Map Source: Mill Valley Library, History Room
NPCRR San Rafael Branch
AM
NPCRR Mill Valley Branch
NPCRR Trestle across Bothin Bay
HCCM
Ref 31
PUBLIC LAND
RICHARDSON'S
RANCHO
SAUC
WATER
Co.
P. MALLON 191 A.
HARRIET R. CUSHING 131 A.
EASTLAND
MILLWOOD

1892 Tamalpais Land and Water Co. Ma[p] #3 with 1851 tideland polygons projected on 2017 Google Earth Imagery.

Source: 1892 map from David Ramsey Collection; 1851 mapping from US Coast Survey by AD Bache[e] T-00334



Ref 32

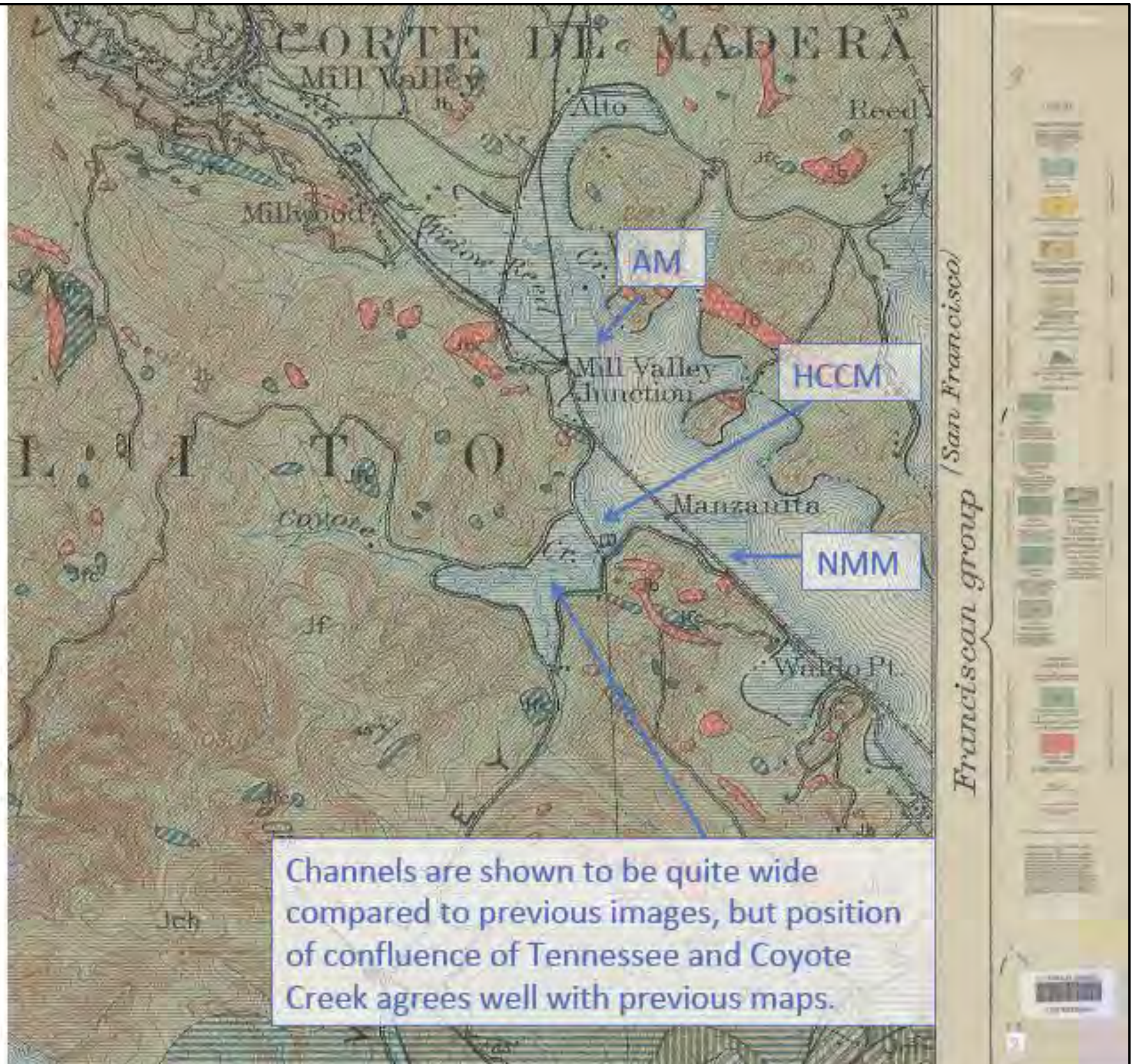

1892 Detail of Tamalpais Land and Water Co., Map #3 Map Source: David Ramsey Collection
AM
NPCRR
HCCM
COYOTE
VALLEY
1870 channel
1892 altered channel bend
By this time both Coyote and Tennessee Creeks have been ditched to the sides of their alluvial valleys as indicated by green arrows.
Ditched to side of valley
1870 eliminated marsh
Ditched to side of valley
Ref 33

1894-1895 US Coast Survey mapping used on a 1913 Areal Geology Map by Andrew Lawson, detail shown

Map Source:
UC Berkeley Library
C039230698

This map does not show changes in marsh or tidal channels relative to the 1908 date since the topographic information is from R.B. Marshall from 1894-1895.

Ref 34



Undated photographs "1 and 2" from Garcia and Associates Letter of 12 December 2016 that misidentifies this area as Coyote Marsh. Source: Garcia Assoc., Memo of 12/16/16

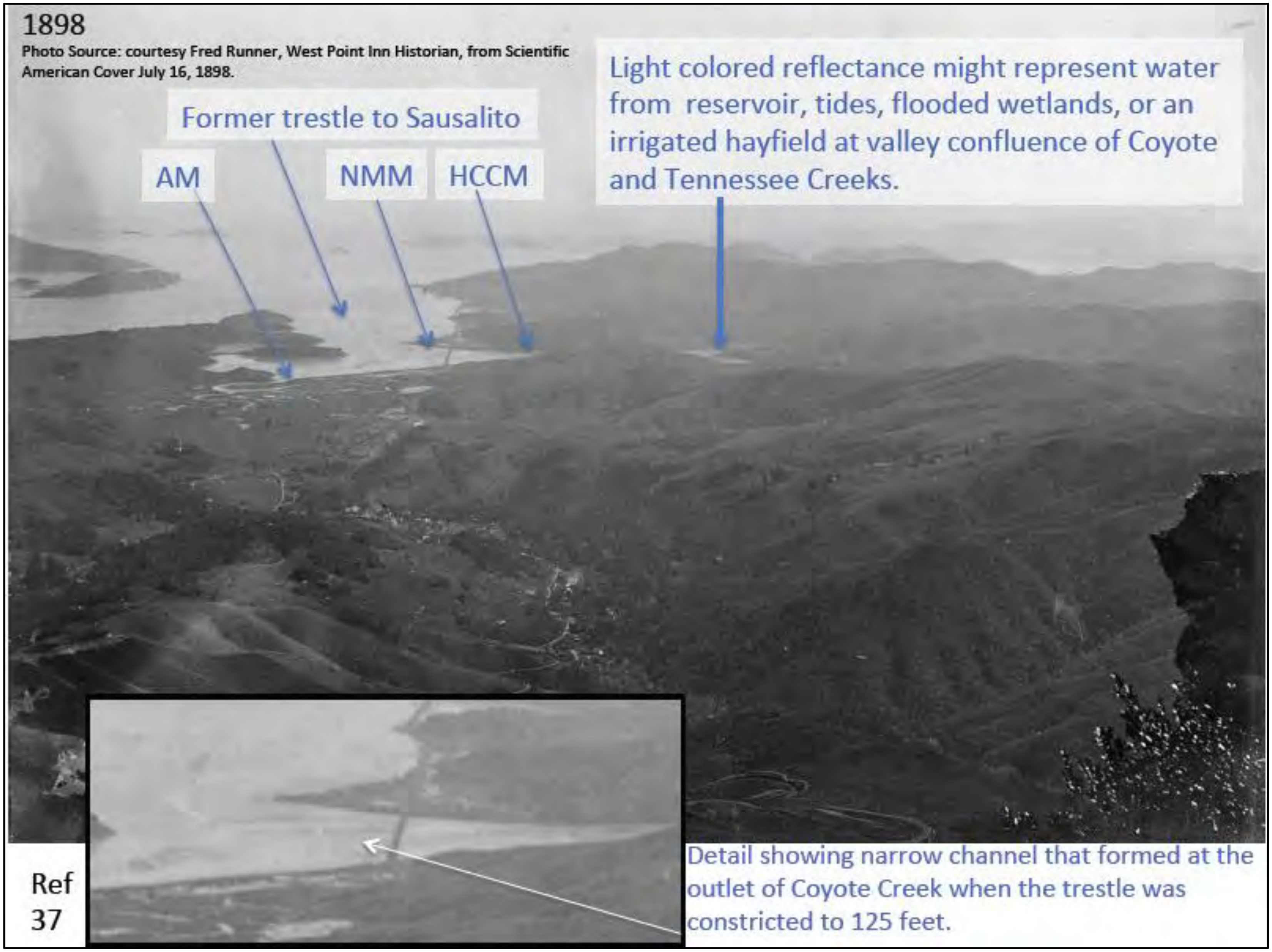
Upper photo is looking northward from Sausalito at a RR levee along Sausalito south of Bothin Marsh. It looks like the drawbridge of the Redwood Bridge of Hwy 1 can be seen in the distant background. Note how high the RR levee is with new fill for the double track. By 2017 in Bothin Marsh sediment has filled substantially to a greater height along both sides of the RR The red arrow is presumed to be pointing at an outlet beneath the tracks.

The lower photo shows Almonte Marsh to either side of the tracks while looking northward where the Mill Valley branch splits from the San Rafael Branch

Ref 35

Circa 1898, looking northward along the Mill Valley branch of the NWPRR just beyond the intersection with the San Rafael branch that veers eastward and future Tam Valley High School location, which would be to the southwest. All portions of the tidal marshlands in this photo are bounded and influenced by an altered tidal prism from the railroad berms.

Photo Source: https://calisphere.org/item/ark:/13030/kt1t1nc8zg/


1898
Photo Source: courtesy Fred Runner, West Point Inn Historian, from Scientific American Cover July 16, 1898.
Former trestle to Sausalito
AM
NMM
HCCM
Light colored reflectance might represent water from reservoir, tides, flooded wetlands, or an irrigated hayfield at valley confluence of Coyote and Tennessee Creeks.
Ref 37
Detail showing narrow channel that formed at the outlet of Coyote Creek when the trestle was constricted to 125 feet.

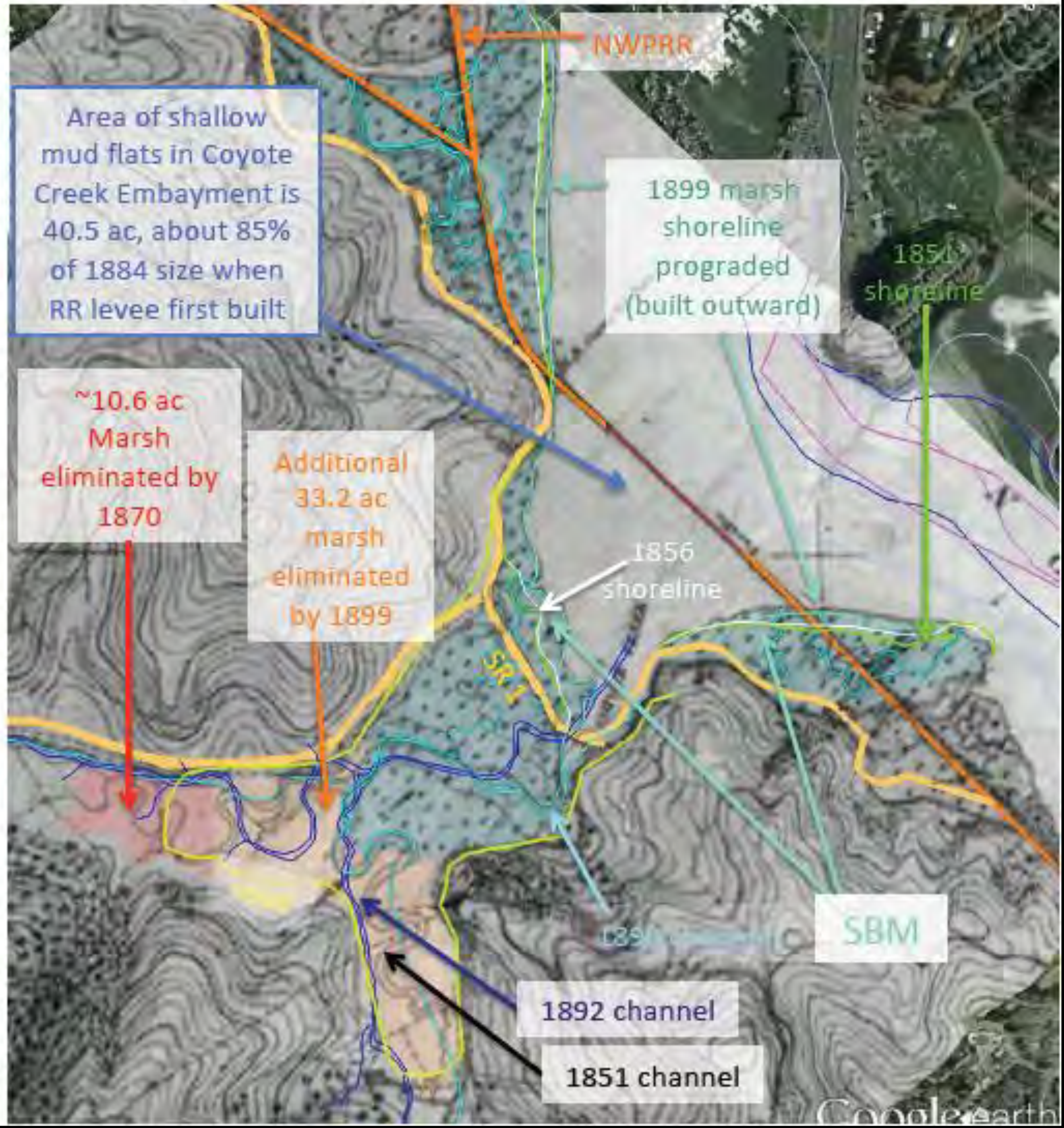
1899, Detail of T-sheet 2485 USCGS, San Francisco Bay, California, City Pt. to Pt. San Quentin and Head of Richardson Bay. Image on left is overlaid onto 2017 Google earth Imagery.

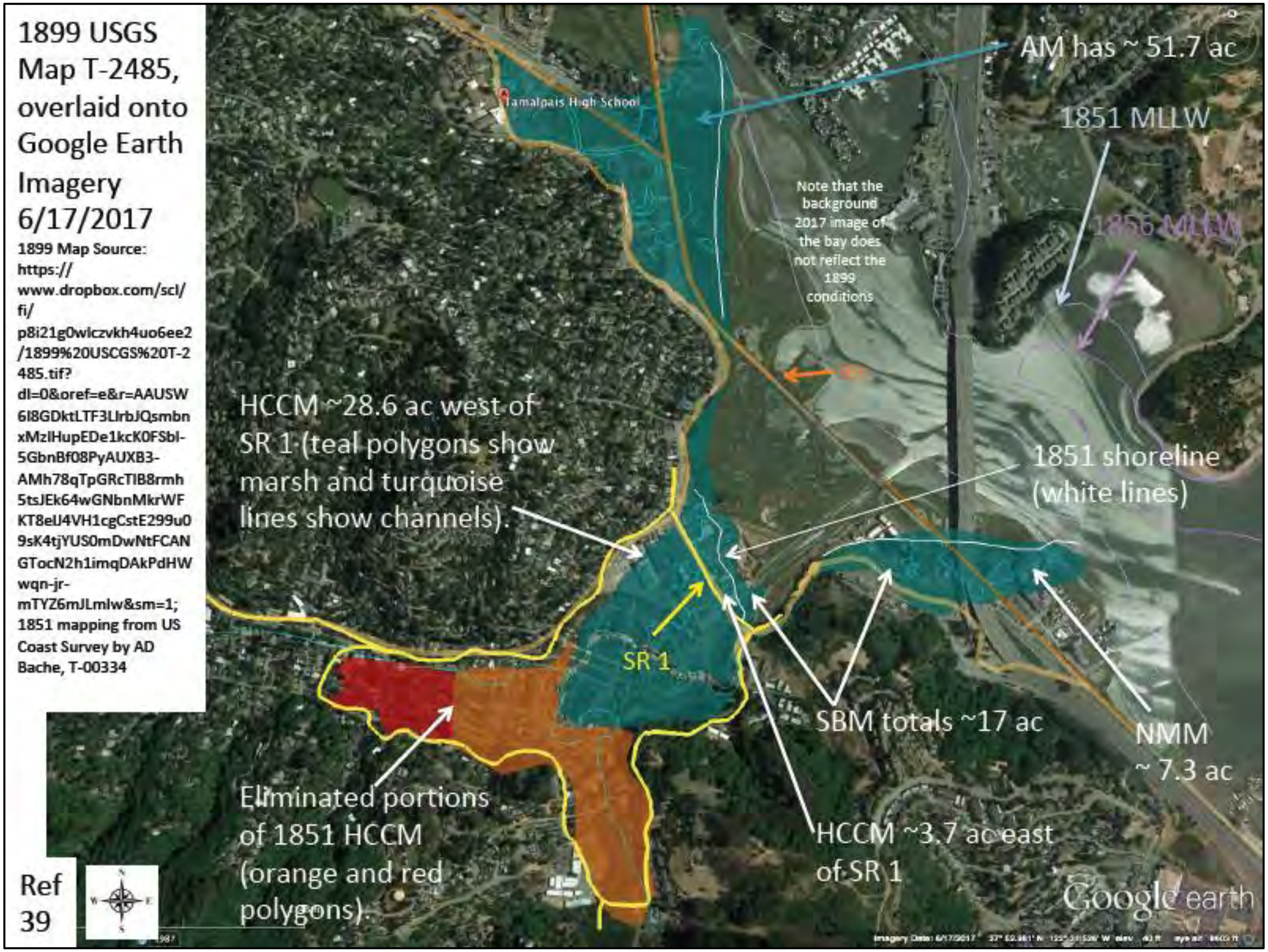
Map Source:
https://www.dropbox.com/scl/fi/p8i21g0wlczvkh4uo6ee2/1899%20USCGS%20T-2485.tifl=0&oref=e&r=AAUSW6I8GDktLTF3LlrbJQsmbnxMzlHupEDe1kcK0FSbI-5GbnBf08PyAUXB3-AMh78qTpGRcTIB8rmh5tsJEk64wGNbnMkrWFKT8eIJ4VH1cgCstE299u09sK4tjYUS0mDwNtFCANGTocN2h1imqDAkPdHWwqn-jr-mTYZ6mJLmlw&sm=1

Note that as of 1899, following RR levee construction, new marsh that prograded into the Coyote Creek Embayment beyond the 1851 shoreline is here referred to as South Bothin Marsh (SBM), which has built ~6.6 ac of new marsh against the 1851 shoreline. An additional ~10.4 ac of NMM was isolated by tracks and it is here counted as part of SBM, causing it to have a combined total of 17 ac.

The total remaining HCCM east and west of SR 1 was 32.3 ac.

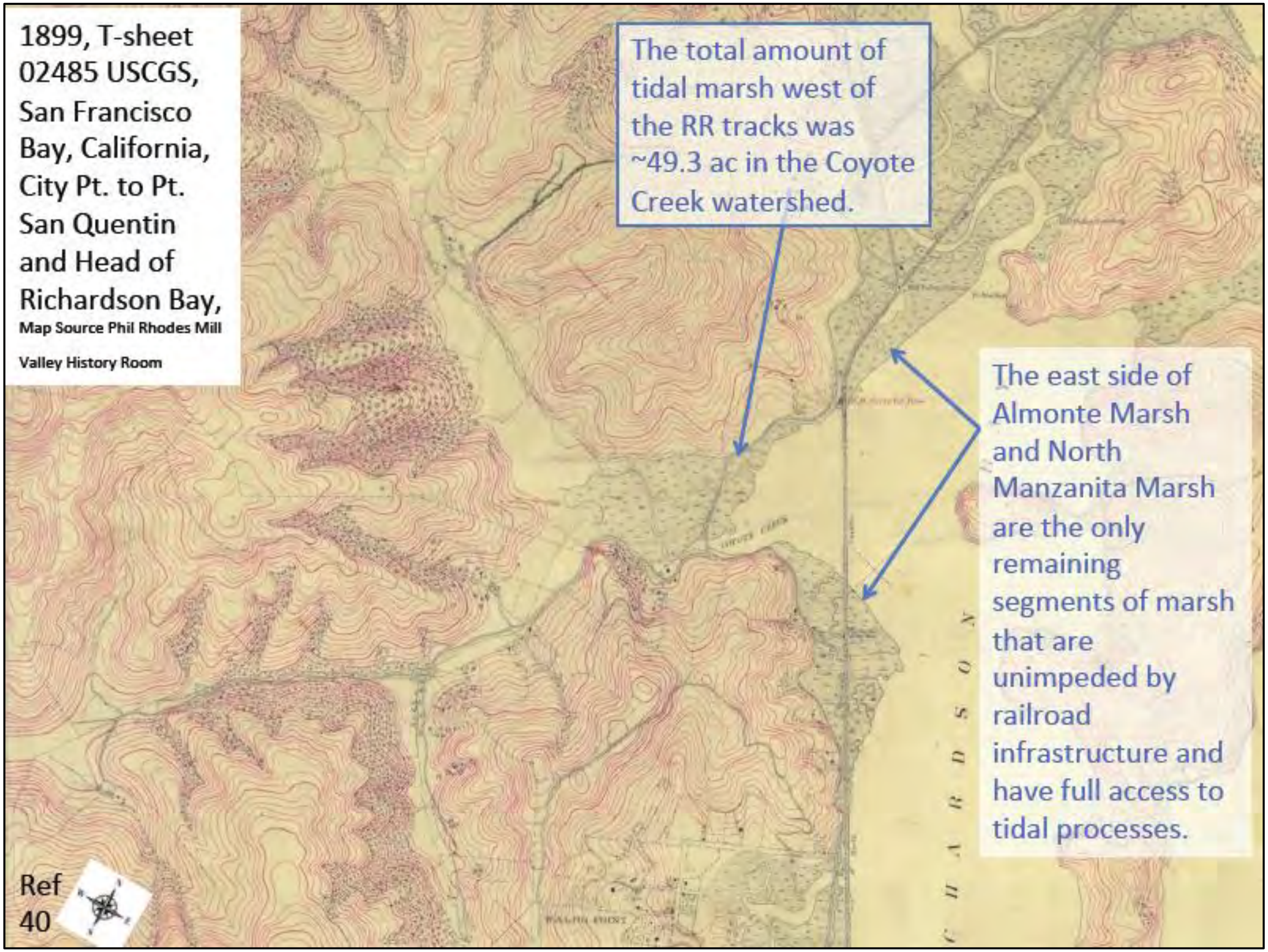
Ref
38





1899 USGS Map T-2485, overlaid onto Google Earth Imagery 6/17/2017

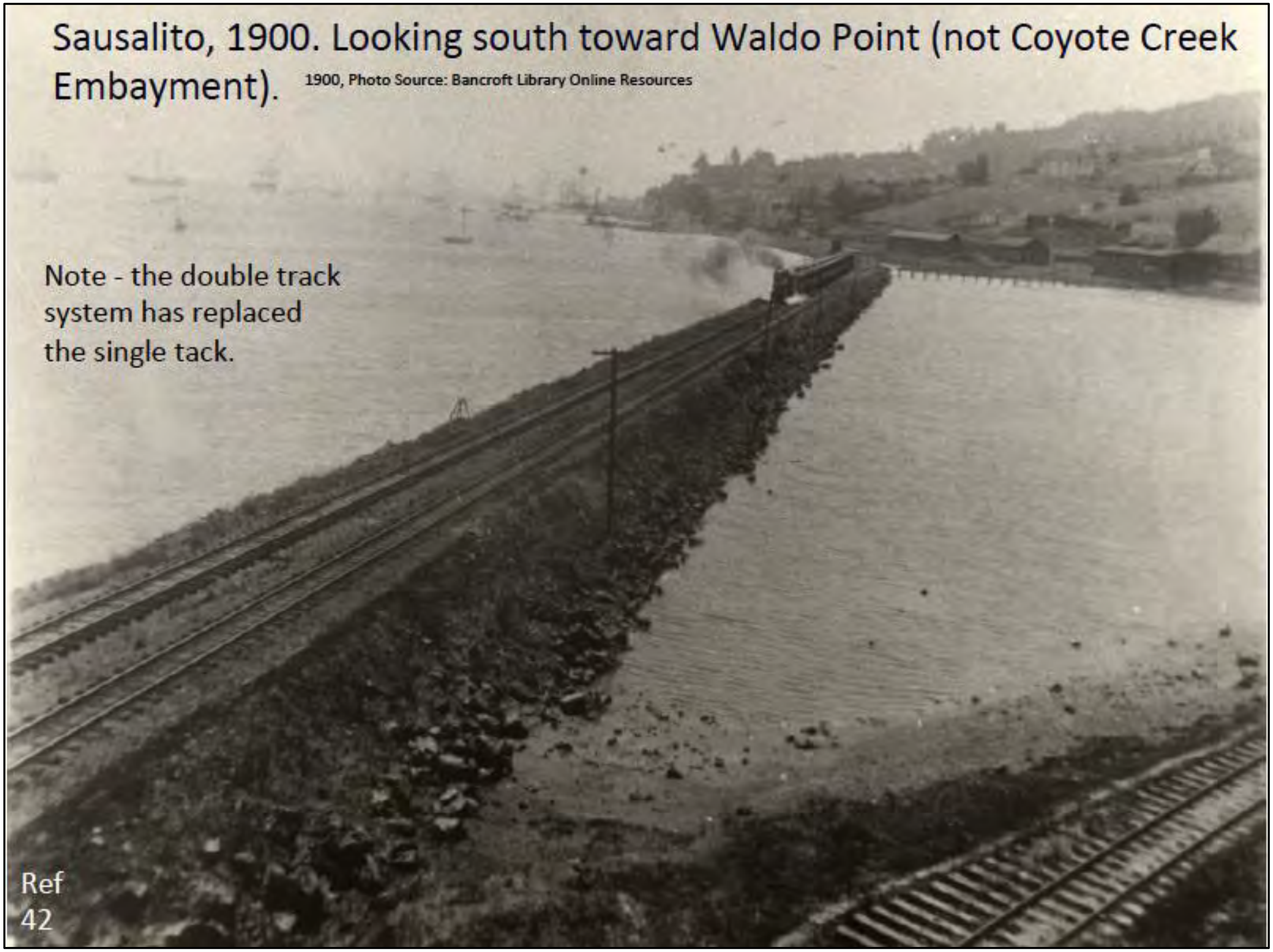
1899 Map Source: https://www.dropbox.com/scl/fi/p8i21g0wlczvkh4uo6ee2/1899%20USCGS%20T-2485.tif?dl=0&oref=e&r=AAUSW6I8GDktLTF3LlrbJQsmbnxMzlHupEDe1kcK0FSbl-5GbnBf08PyAUXB3-AMh78qTpGRcTlB8rmh5tsJEk64wGNbnMkrWFKT8eU4VH1cgCstE299u09sK4tjYUS0mDwNtFCANGTocN2h1imqDAkPdHWwqn-jr-mTYZ6mJLmlw&sm=1; 1851 mapping from US Coast Survey by AD Bache, T-00334


1899, T-sheet 02485 USCGS, San Francisco Bay, California, City Pt. to Pt. San Quentin and Head of Richardson Bay,
Map Source Phil Rhodes Mill Valley History Room
The total amount of tidal marsh west of the RR tracks was ~49.3 ac in the Coyote Creek watershed.
The east side of Almonte Marsh and North Manzanita Marsh are the only remaining segments of marsh that are unimpeded by railroad infrastructure and have full access to tidal processes.
Ref 40

1899, Detail of T-sheet 02485 USCGS, San Francisco Bay, California, City Point to Point San Quentin and Head of Richardson Bay, Map Source Phil Rhodes Mill Valley History Room

Railroad trestle is here depicted in detail. Outside hatch marks typically denote fill. Bridge abutments are denoted with curving outside lines that bend away from the span. These are clearly evident on this map. While there is no certainty this 1899 map is entirely correct in its depiction of the rail line here, Rhodes (Mill Valley Library History Room) considers it unlikely that the surveyor and drafter of this map would have gotten such key details on a waterway wrong. Source: 1899 T-sheet from P. Rhodes, email 4/25/2017. Historians from the NWPRR Society state that the trestle was replaced with a berm in 1894 (verbal communication to L. Collins). This seems consistent with information developed for this report. The length of the original trestle over the Coyote Creek Embayment appears to have been about 1310 feet long while the total amount of berm extending across the bay from the 1899 shoreline to the trestle was about 850 feet.

Ref 41

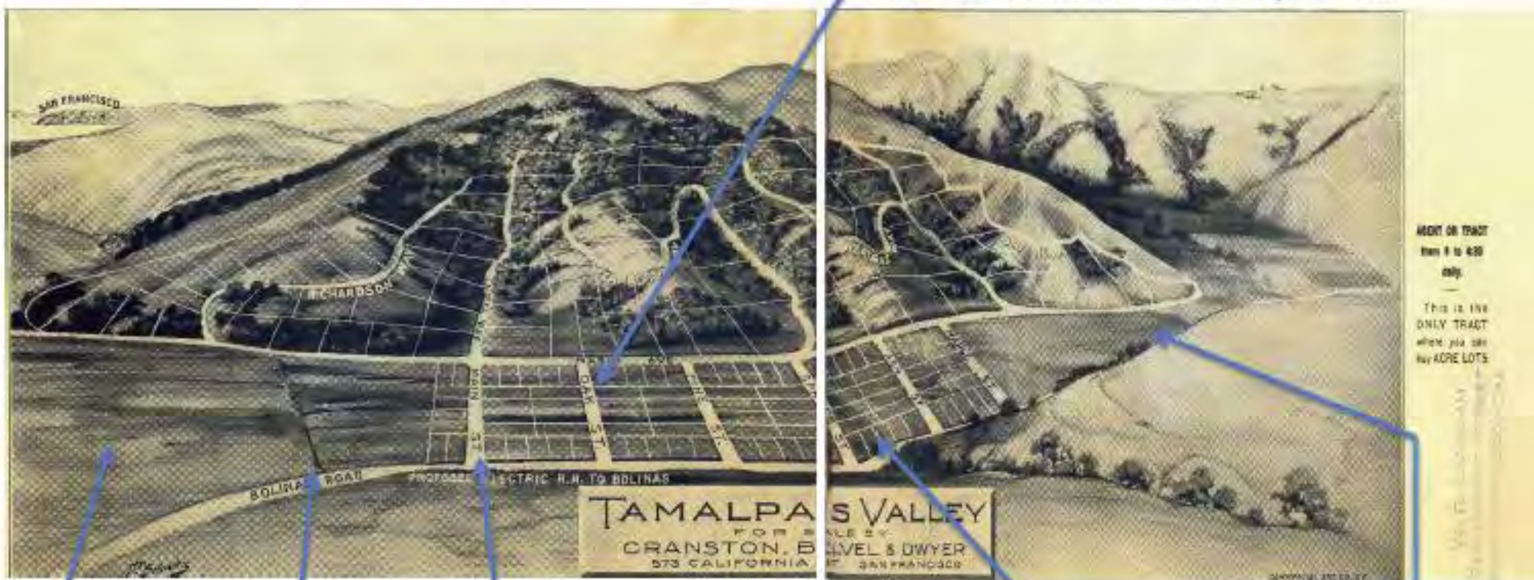


Sausalito, 1900. Looking south toward Waldo Point (not Coyote Creek Embayment). 1900, Photo Source: Bancroft Library Online Resources

1900 Tam Valley for Sale, looking south at former head of tide at Coyote Creek

Map Source: Anne T. Kent California Room, Marin County Free Library

Oak Street now called Poplar St.



Tidal wetlands

Possible levee that might coincide with one that was constructed by 1870 and eliminated 10.6 acres of tidal marsh?

Main Street now called Laurel Way

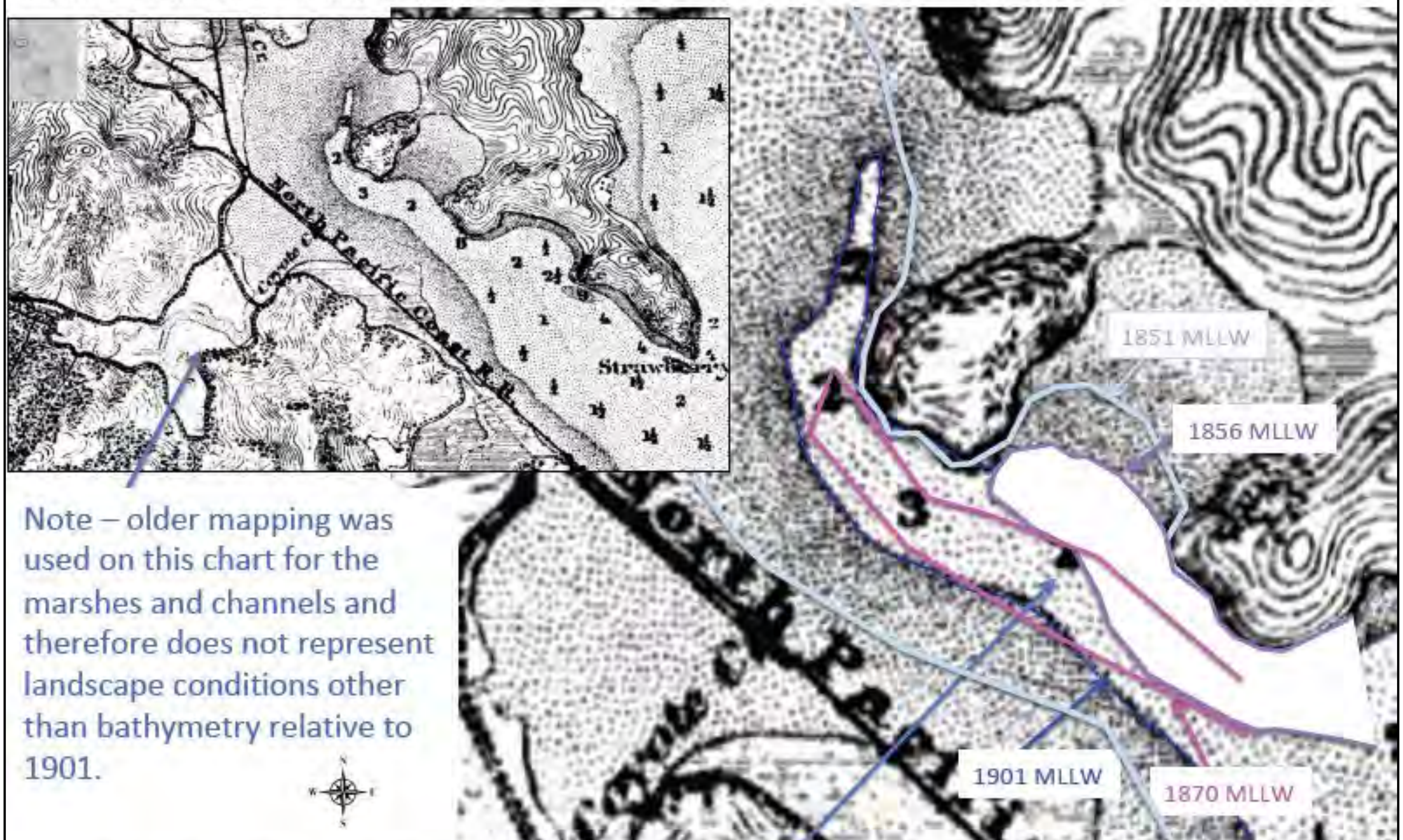
Alluvial valley of Coyote Creek

Historical tidal marsh existed down valley of Spruce Street but it is interesting to see this distinct change in slope in the transition from alluvial stream to tidelands in this rendering

Ref 43

1901, Nautical Chart, Detail of San Francisco Entrance US Coast and Geodetic Survey

Map Source: https://historicalcharts.noaa.gov/historicals/search#mainTitle



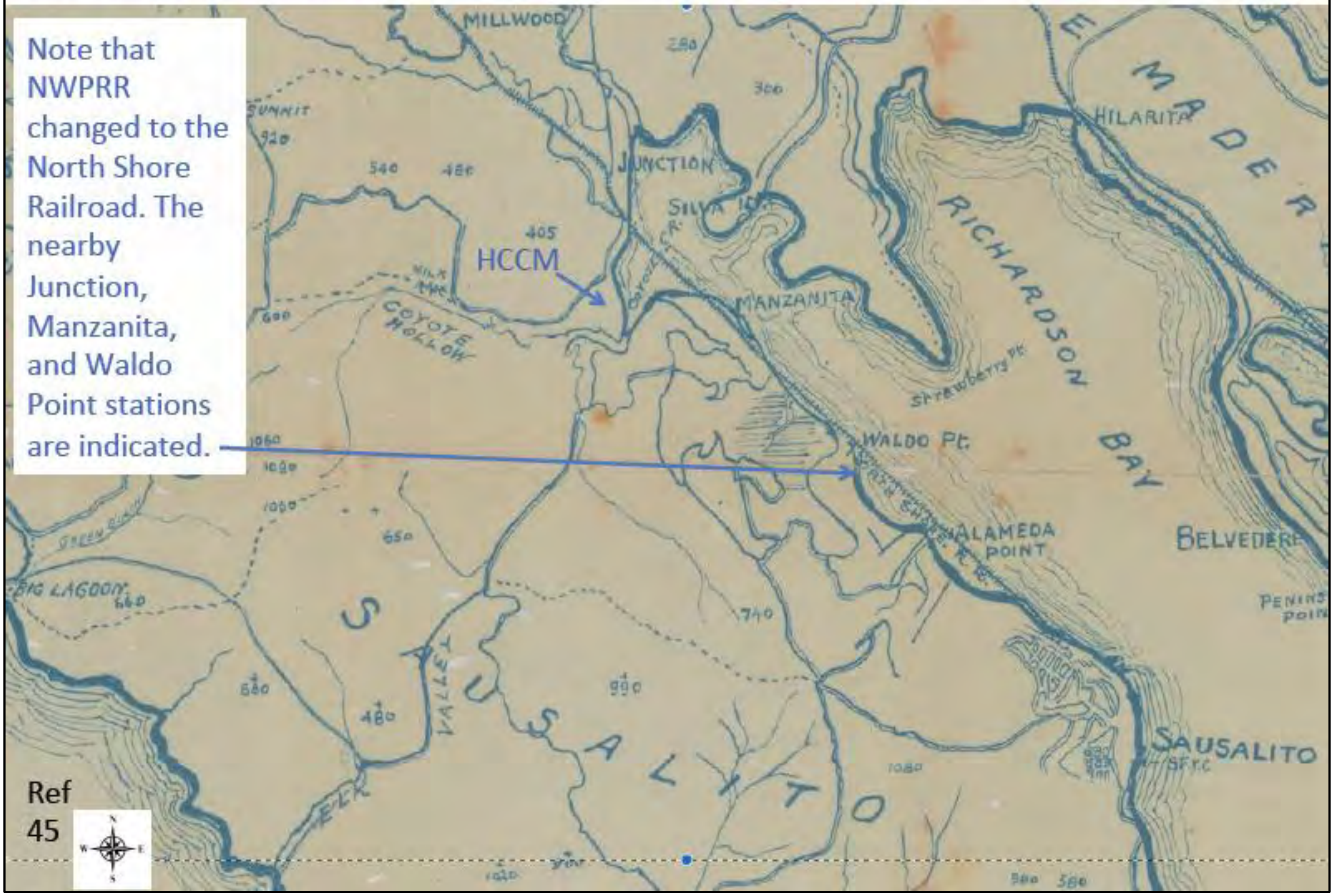
Note – older mapping was used on this chart for the marshes and channels and therefore does not represent landscape conditions other than bathymetry relative to 1901.

Ref 44

Note - Soundings are in feet above MLLW. Shallow mudflats continue to be more extensive than they were in 1851 (light blue line), but following the extensive sedimentation in 1856 (purple line), the MLLW boundary has been progressively expanding and deepening landward since 1870 (pink line).

1903 Road Map of Marin

Map Source: http://servlet1.lib.berkeley.edu:8080/mapviewer/searchcoll.execute.logic?coll=eartmaps&catno=b22254341



1905 San Francisco Entrance, U.S. Coast Survey Chart 5532

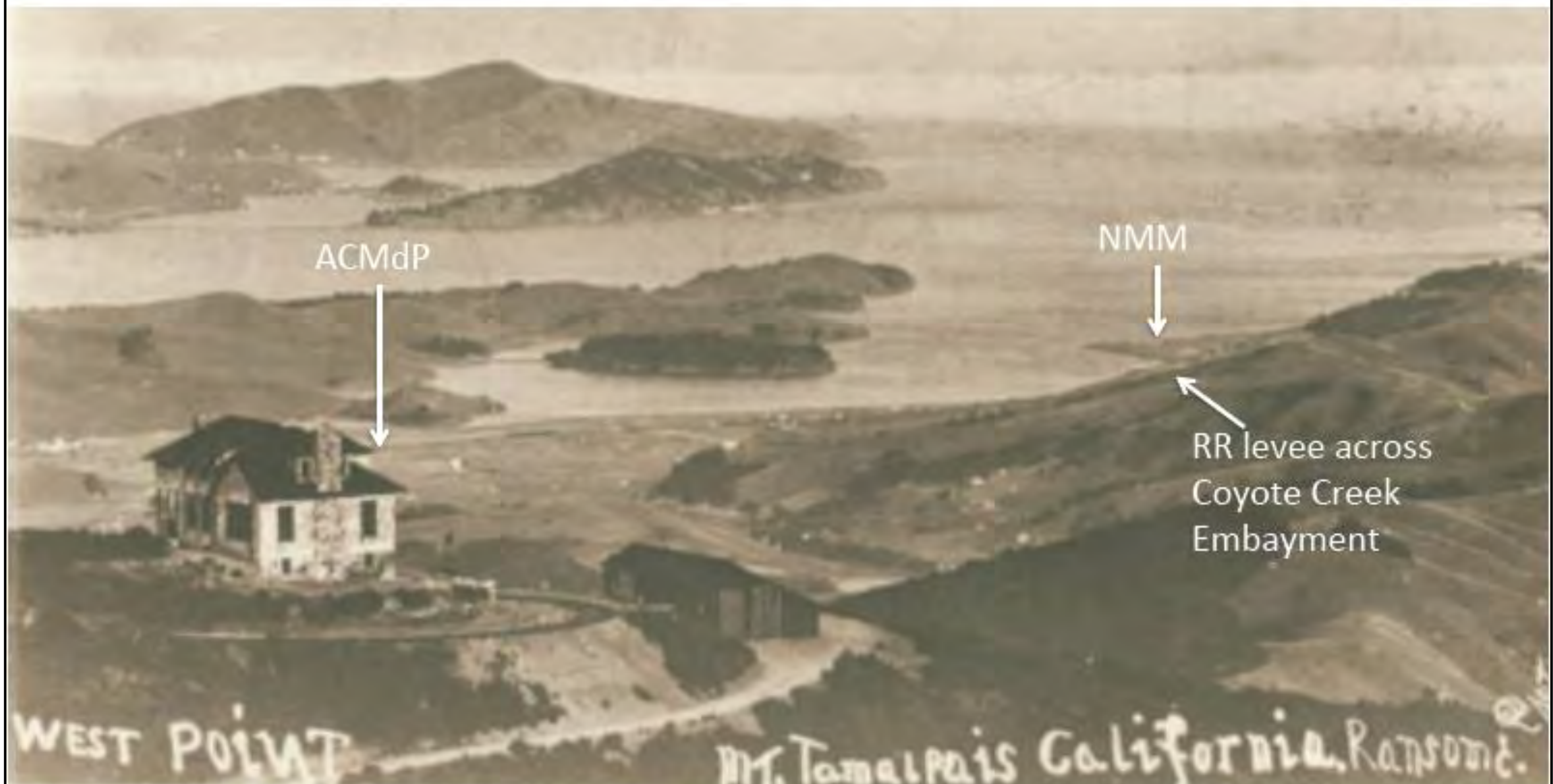
Map Sourcehttps://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~4227~360039:San-Francisco-entrance,-California-?sort=Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No&qvq=q:1905%2BCOAST%2BSURVEY%2BSAN%2BFRANCISCO%2BBAY;sort:Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No;lc:RUMSEY~8~1&mi=1&trs=3

This map used the HCCM channel mapping from 1899 T-02485 and therefore is only used for assessing bathymetric change.

Ref 46

1906 Arroyo Corte Madera del Presidio Marsh,

Photo Source: https://calisphere.org/item/ark:/13030/kt358024j5/



Ref
47

1908

Photo Source: https://mvhistory.org/wp-content/uploads/2014/08/TamTrainStop.jpg

Students waiting for commuter train at the new train stop on the Mill Valley line fronting the high school. November 1908

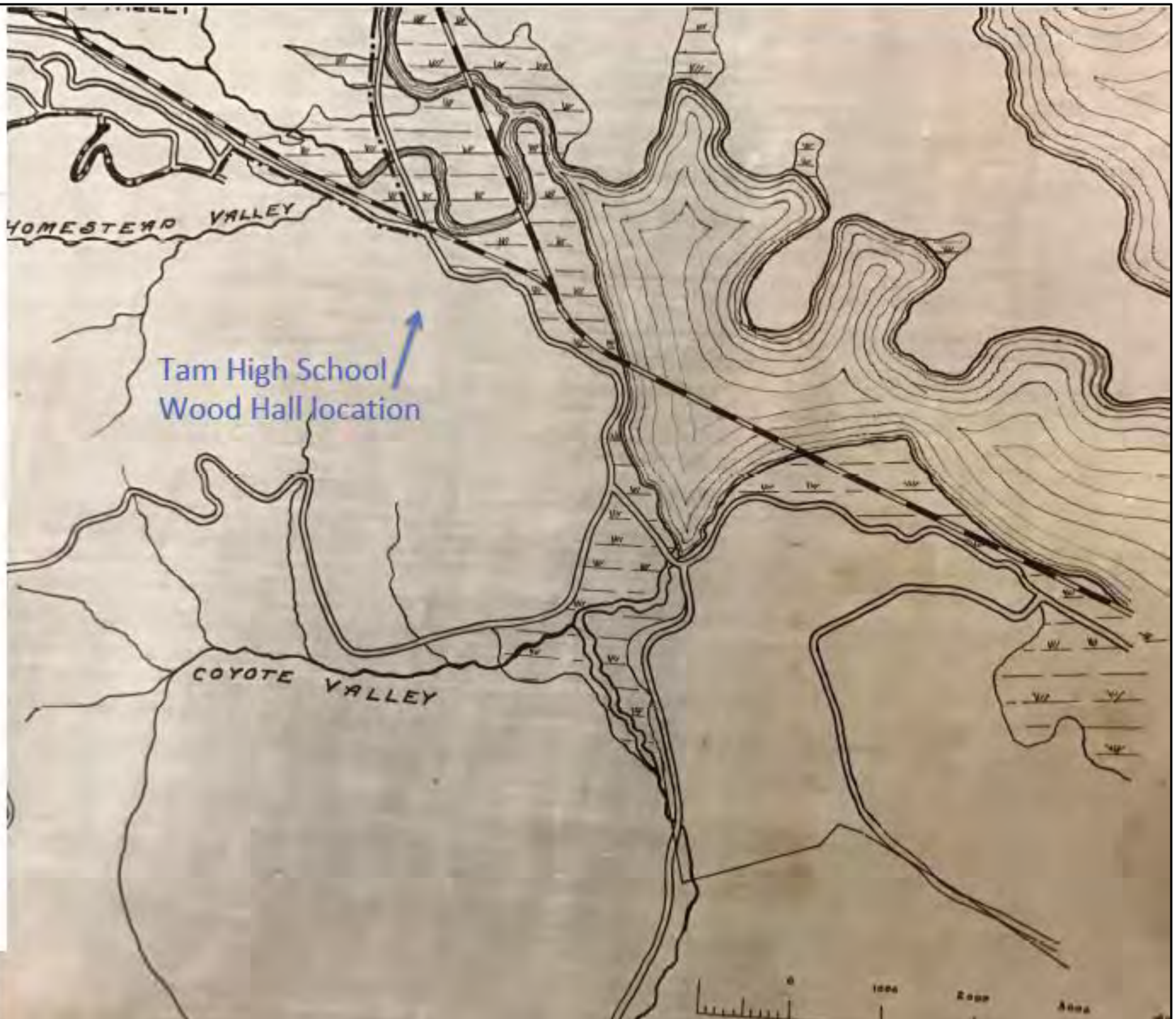
Ref 48

1908 Marin Water Co, Map

Source: Mill Valley Library History Room

This map does not show the changes in marsh or tidal channels relative to actual 1908 conditions. It does reflect the 1870 eliminated ~10.6 acre of marsh in the Coyote Drainage.

Ref 49



Post 1908-09 (?)

Photo Source: https://s-media-cache-ak0.pinimg.com/originals/e8/c0/2e/e8c02e2b816187bf75603fd820c5db41.jpg

Wood Hall, building with tower on right, was built first in 1908. http://thetamnews.org/lifestyles/tamalpais-high-school-an-architectural-history/

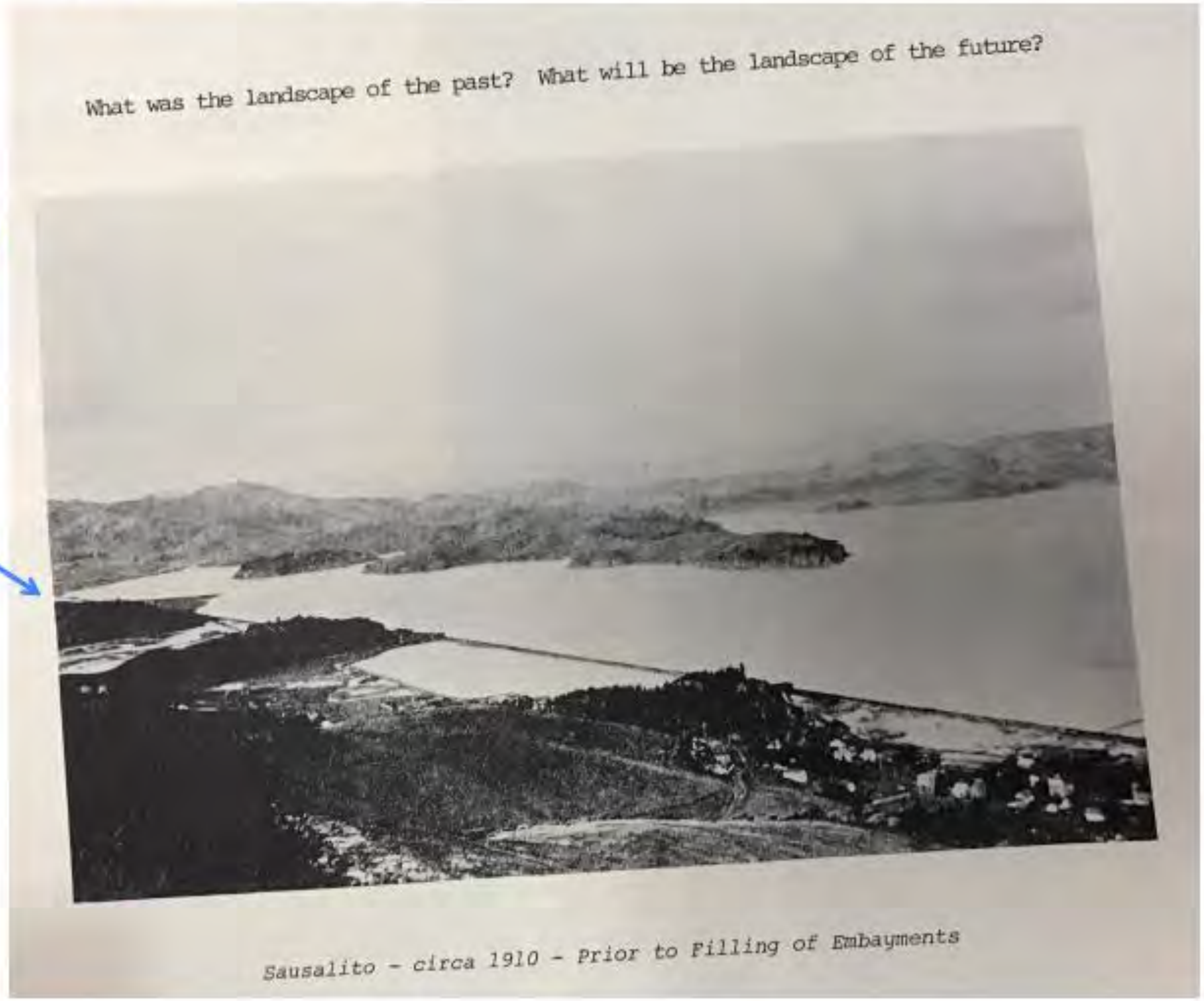
Ref 50

Circa 1910 Richardson Bay in Transition

Photo Source: Anne T. Kent California Room, Marin County Free Library

Note – Embayments in Sausalito are not yet filled landward from the backshore of of the railroad levees.

HCCM



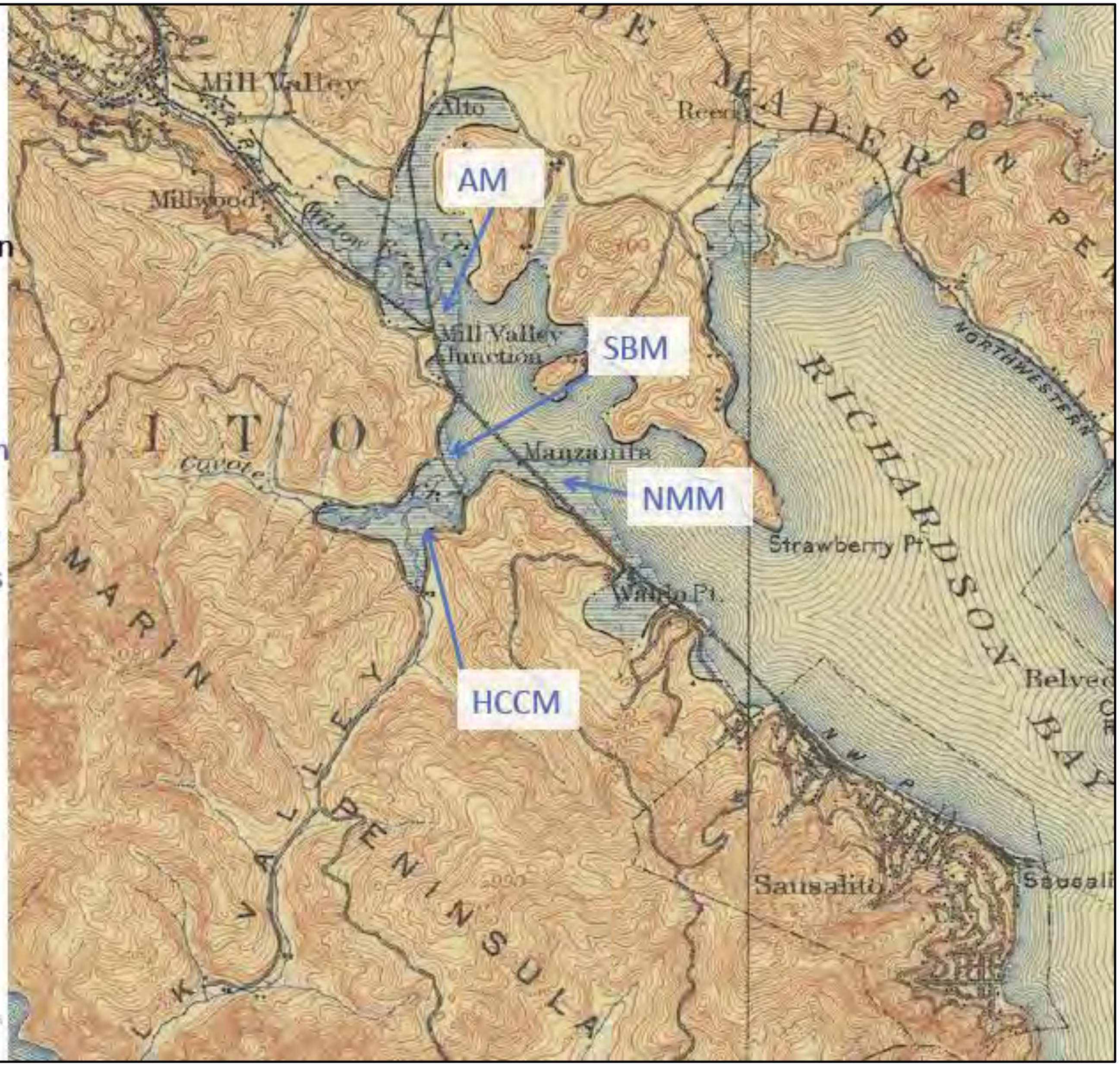
Ref 51

1915 San Francisco and Vicinity Map, Surveyed 1894-1913, 25-ft contour intervals, (detail of Richardson Bay)

Source: USGS

This map does not show the changes in marsh or tidal channels relative to the 1908 conditions and since it has a range of years for survey dates, it cannot be used to asses channel or marsh change for the Coyote Creek Marsh.

Ref 52



1915, Just South of Tamalpais High School

Photo Source: https://calisphere.org/item/ark:/13030/kt5p3025pm/

Ref 53 This remnant 1851 channel bend of a tidal tributary to Arroyo Corte Madera del Presidio used to be at least 40 ft wide.

1915, San Francisco Entrance

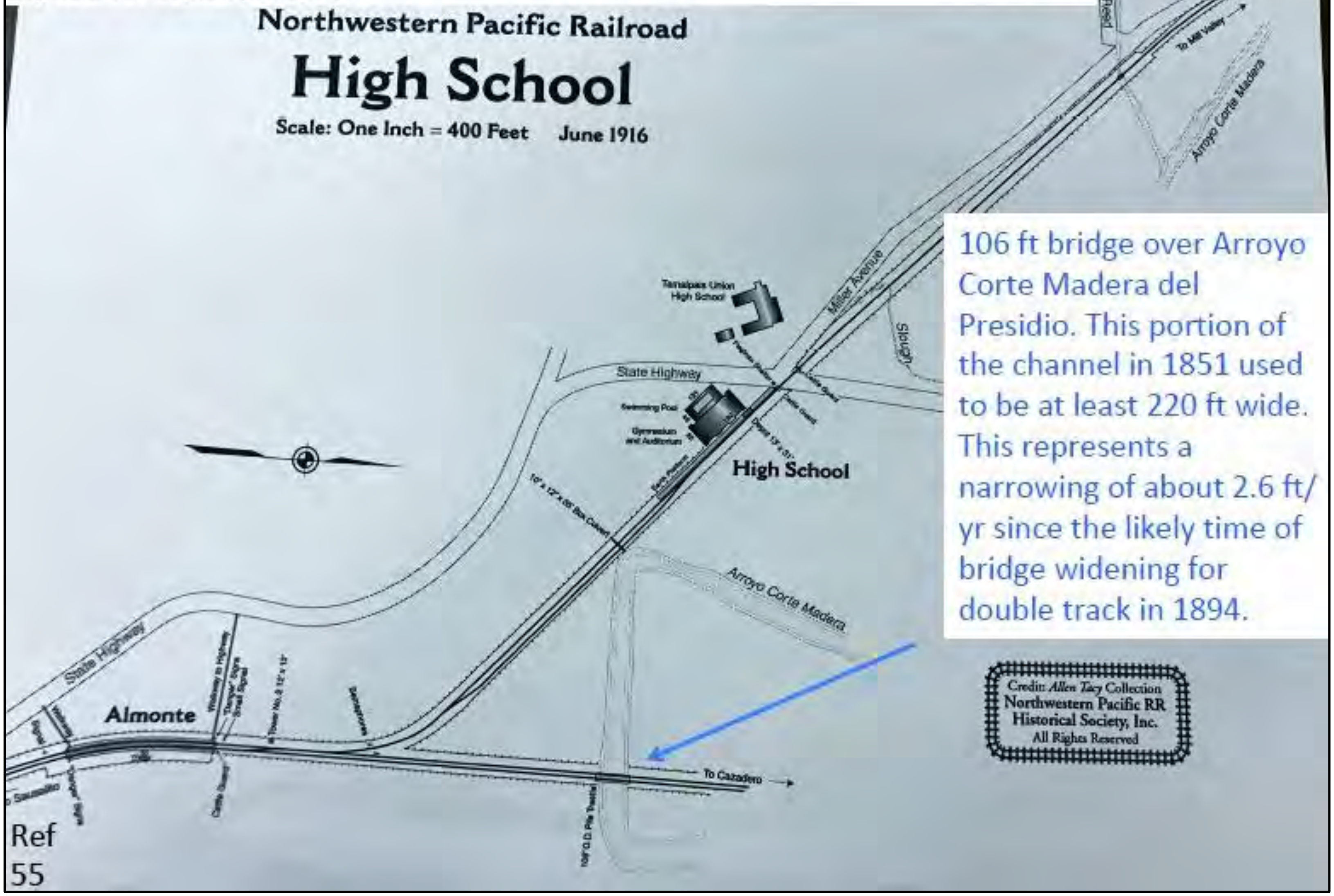
Map source: https://historicalcharts.noaa.gov/historicals/search

This map shows the marsh and tidal channels relative to the 1899 and bathymetry relative to 1905, therefore it cannot be used to assess channel or marsh change during 1915 for the Coyote Creek Marsh.

Ref 54

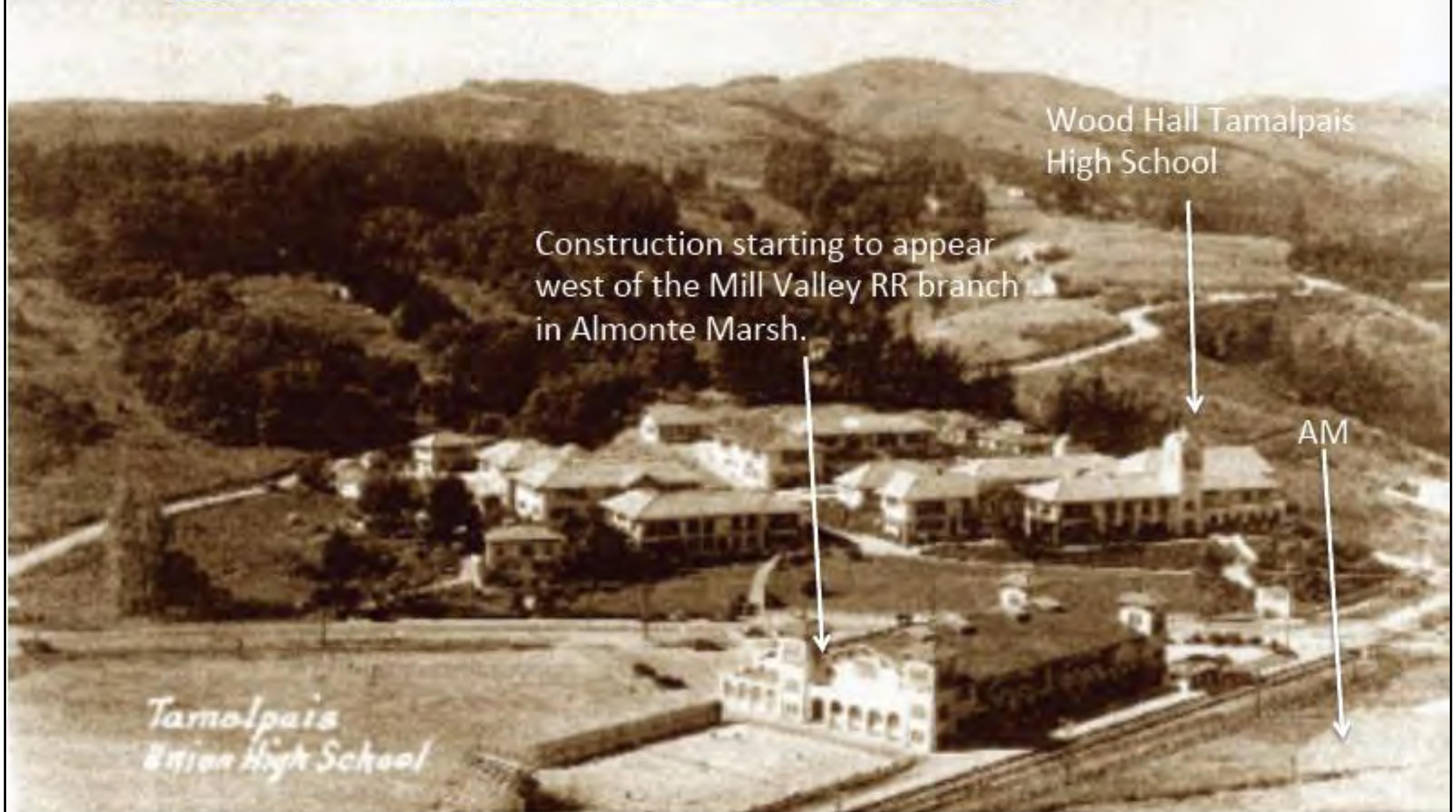
1916, Details showing the junction of Mill Valley and San Rafael branches of the North Western Pacific RR along the Almonte Marsh

Map Source: Mill Valley Library History Room



Post 1920s, Tamalpais High School

Photo Source: https://s-media-cache-ak0.pinimg.com/originals/e3/d1/18/e3d118b13d382772e408c8a0c1e81cd9.jpg



This picture must follow the 1920's because Keyser Hall and Gus Gym were constructed by the 1920s. http://thetamnews.org/lifestyles/tamalpais-high-school-an-architectural-history/

Ref 56

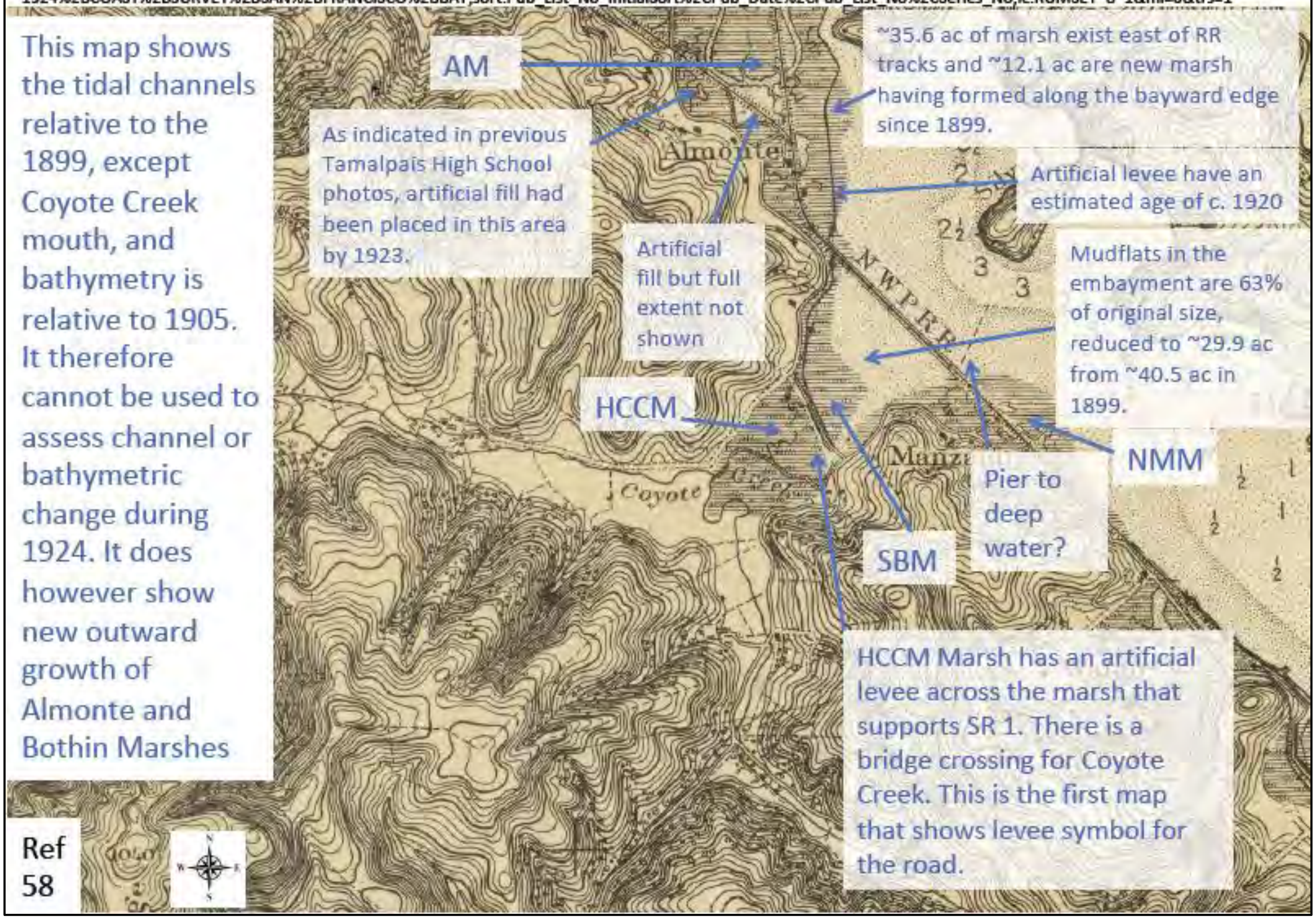
1923, Tamalpais High School. Photo Source: https://mvhistory.org/wp-content/uploads/2014/08/TamHigh1923.jpg

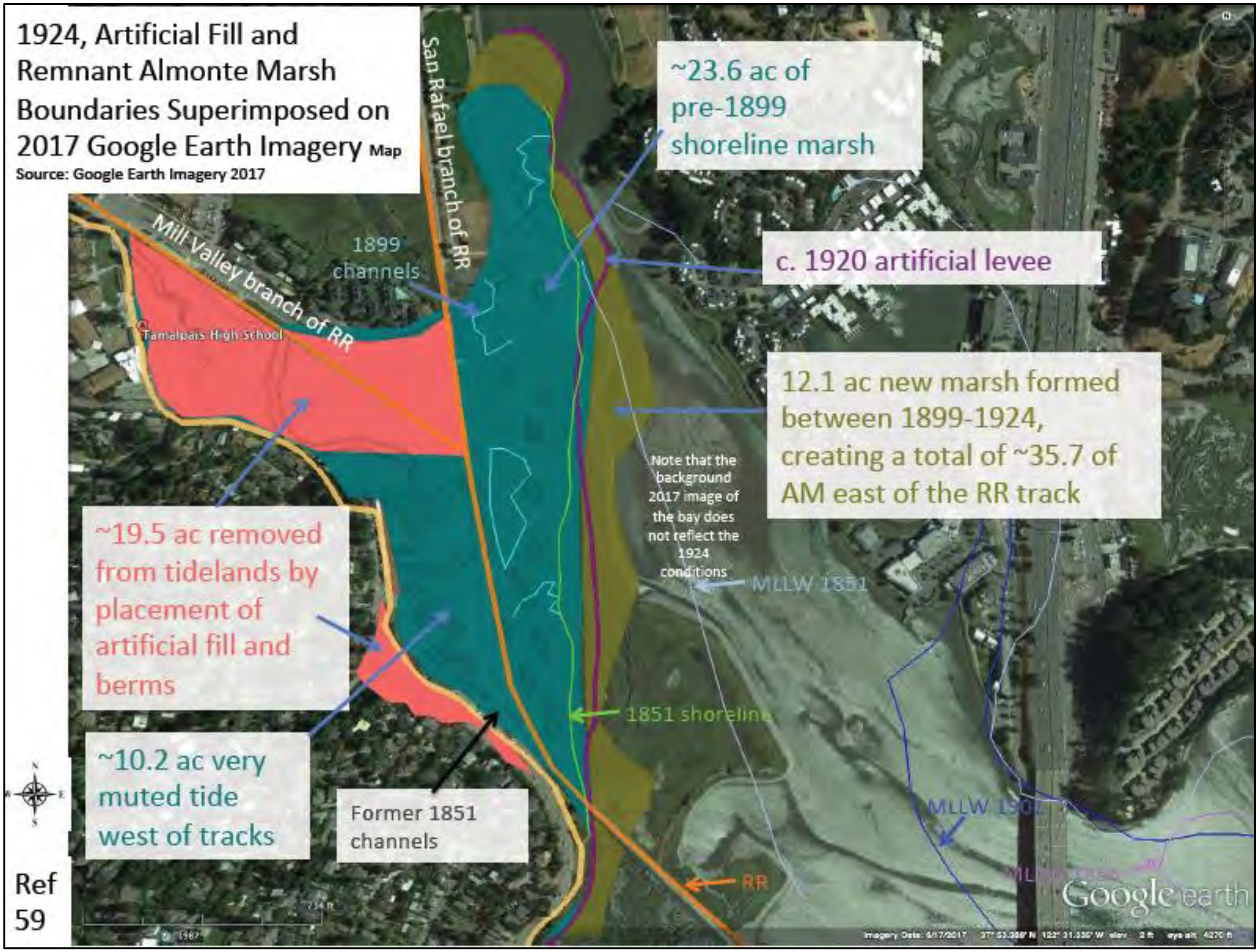
This early 1923 sports field track is the site of the 2017 parking lot. About 5.8 ac of marsh were eliminated at this location and another ~2.0 ac were probably eliminated along the western upland edge of the San Rafael Road, now called Homestead Blvd.

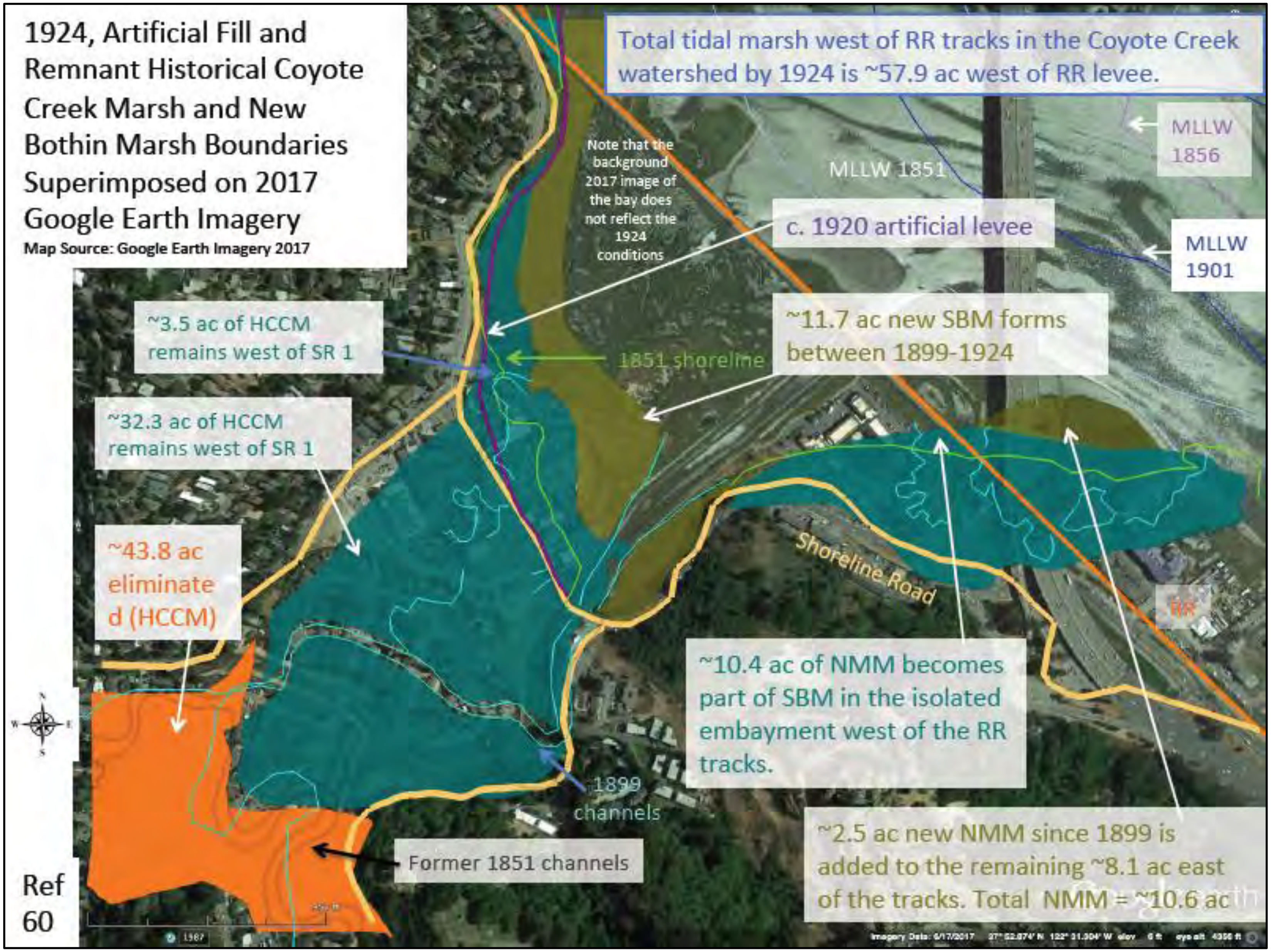
Aerial photo showing the lower portion of Keyser completed and the upper Keyser being built. Note the "Canteen" at Almonte and Camino Alto Ave far left side.

Ref 57

1924, San Francisco Entrance U.S. Coast Survey Chart 5532 Source: https://www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~265460~5524567:United-States--West-coast,-san-Fran?sort=Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No&qvq=q:1924%2BCOAST%2BSURVEY%2BSAN%2BFRANCISCO%2BBAY;sort:Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No;lc:RUMSEY~8~1&mi=0&trs=1




1924, Artificial Fill and Remnant Almonte Marsh Boundaries Superimposed on 2017 Google Earth Imagery Map
Source: Google Earth Imagery 2017
San Rafael branch of RR
Mill Valley branch of RR
Tamalpais High School
1899 channels
~23.6 ac of pre-1899 shoreline marsh
c. 1920 artificial levee
12.1 ac new marsh formed between 1899-1924, creating a total of ~35.7 of AM east of the RR track
Note that the background 2017 image of the bay does not reflect the 1924 conditions
MLLW 1851
~19.5 ac removed from tidelands by placement of artificial fill and berms
1851 shoreline
~10.2 ac very muted tide west of tracks
Former 1851 channels
MLLW 1902
RR
Ref 59
Google earth

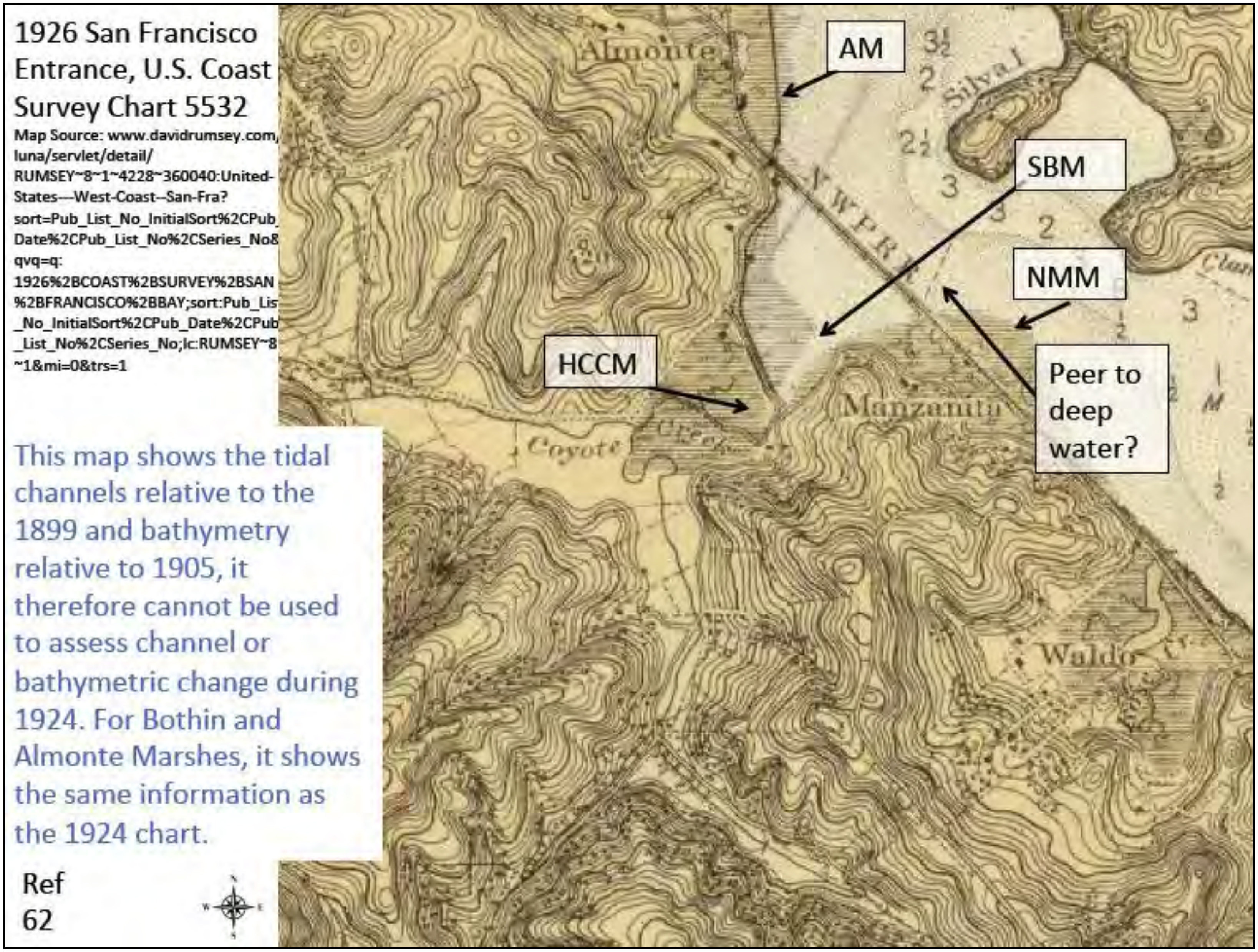

1924, Artificial Fill and Remnant Historical Coyote Creek Marsh and New Bothin Marsh Boundaries Superimposed on 2017 Google Earth Imagery
Map Source: Google Earth Imagery 2017
Total tidal marsh west of RR tracks in the Coyote Creek watershed by 1924 is ~57.9 ac west of RR levee.
Note that the background 2017 image of the bay does not reflect the 1924 conditions
MLLW 1856
MLLW 1851
c. 1920 artificial levee
MLLW 1901
~3.5 ac of HCCM remains west of SR 1
1851 shoreline
~11.7 ac new SBM forms between 1899-1924
~32.3 ac of HCCM remains west of SR 1
~43.8 ac eliminated (HCCM)
Shoreline Road
RR
~10.4 ac of NMM becomes part of SBM in the isolated embayment west of the RR tracks.
1899 channels
Former 1851 channels
~2.5 ac new NMM since 1899 is added to the remaining ~8.1 ac east of the tracks. Total NMM = ~10.6 ac
Ref 60

1925 Hiking Map of Marin by NWPRR

Map Source: California History Room, Library Marin Civic Center

Railroad station names are indicated on this map.

Ref 61


1926 San Francisco Entrance, U.S. Coast Survey Chart 5532
Map Source: www.davidrumsey.com/luna/servlet/detail/RUMSEY~8~1~4228~360040:United-States---West-Coast--San-Fra?sort=Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No&qvq=q:1926%2BCOAST%2BSURVEY%2BSAN%2BFRANCISCO%2BBAY;sort:Pub_List_No_InitialSort%2CPub_Date%2CPub_List_No%2CSeries_No;lc:RUMSEY~8~1&mi=0&trs=1
This map shows the tidal channels relative to the 1899 and bathymetry relative to 1905, it therefore cannot be used to assess channel or bathymetric change during 1924. For Bothin and Almonte Marshes, it shows the same information as the 1924 chart.
Ref 62
AM
SBM
NMM
HCCM
Peer to deep water?
Almonte
Manzanita
Coyote
Waldo

1926, Looking westward at Arroyo Corte Madera del Presidio and Corte Madera Creek

Photo Source: Anne T. Kent California Room, Marin County Free Library

Ref 63

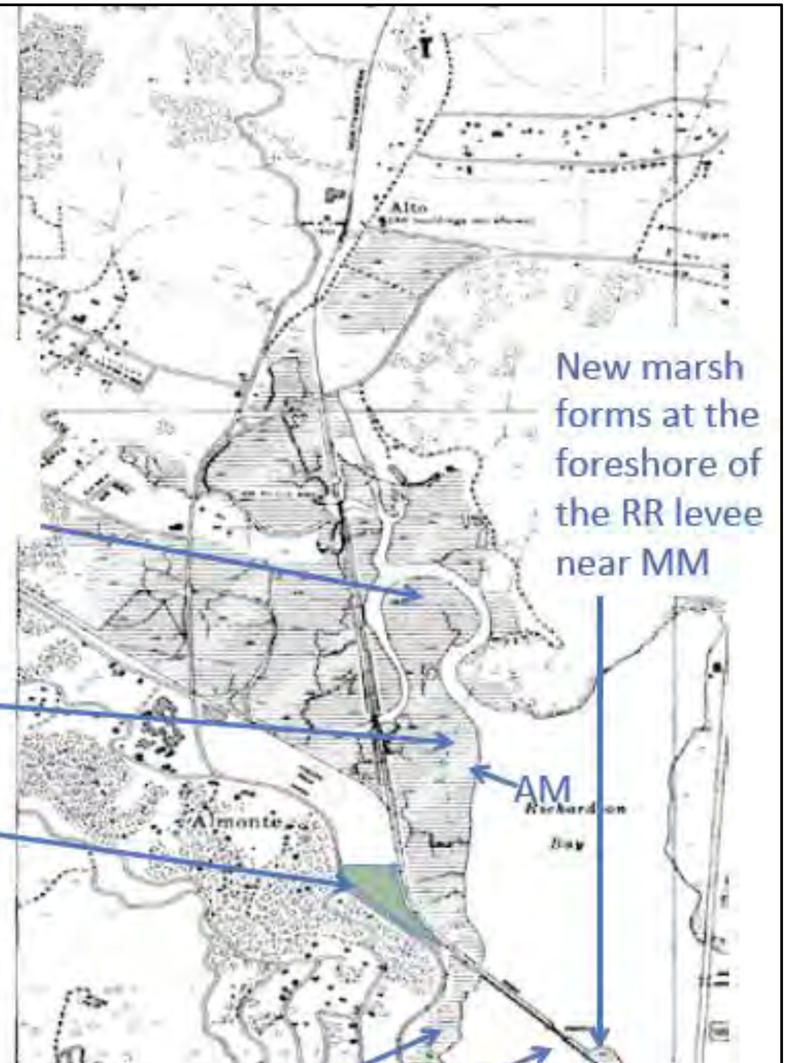
1927, US Coast and Geodetic Survey, Planimetric Map T-sheet 5929 overlaid onto 8/2016 Google Earth Imagery

Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html

Bend along Arroyo Corte Madera, referred to as the "bulb", extended northward creating new marsh and then migrated westward at the last bend before the mouth, thereby eroding parts of AM.

Electrical power line corridor and boardwalk

~3.8 ac of "Tam" marsh, still remained in this section but are not depicted with appropriate symbology on this map. Tam marsh is tallied as part of AM.

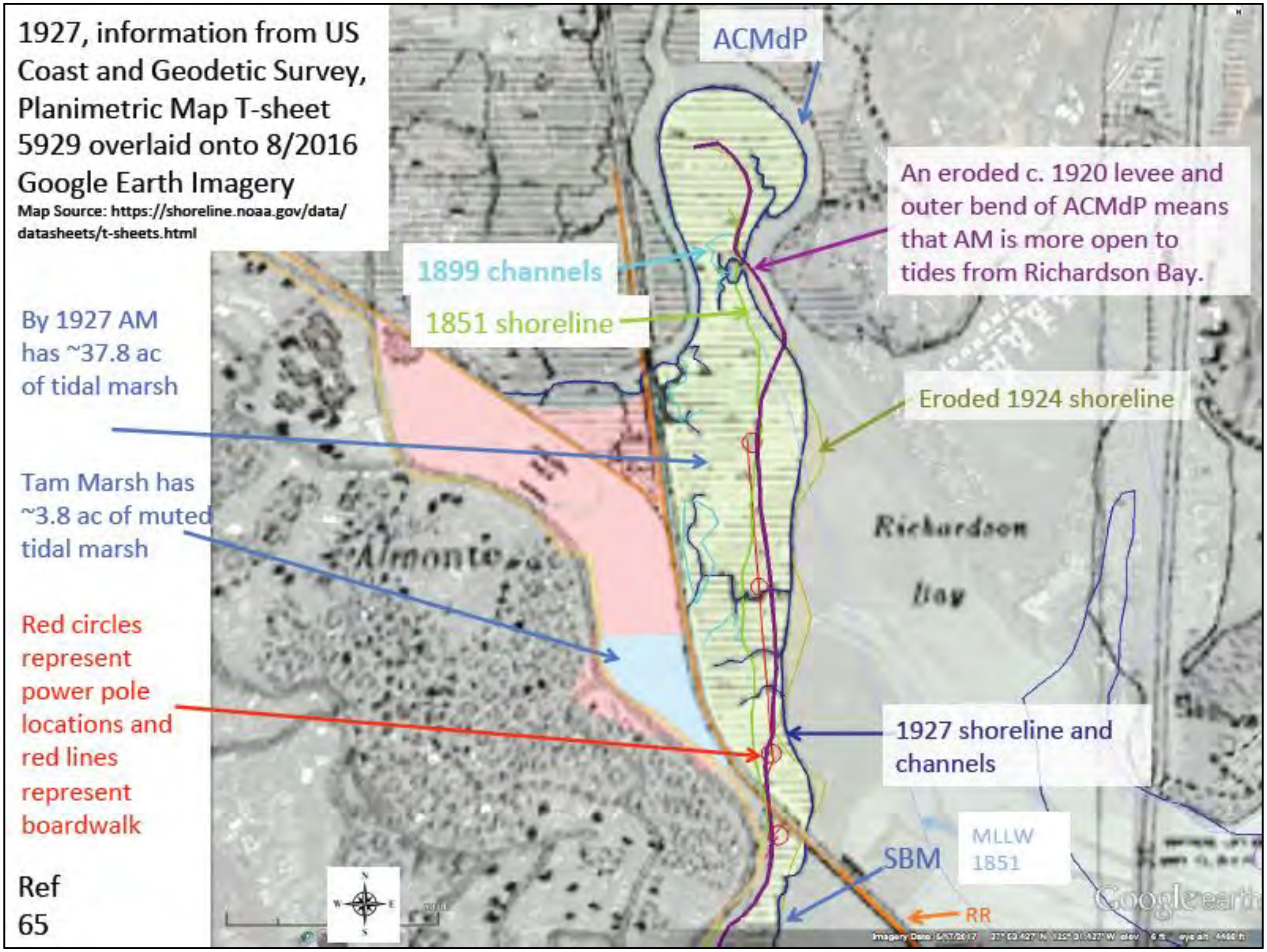


New marsh forms at the foreshore of the RR levee near MM

SBM

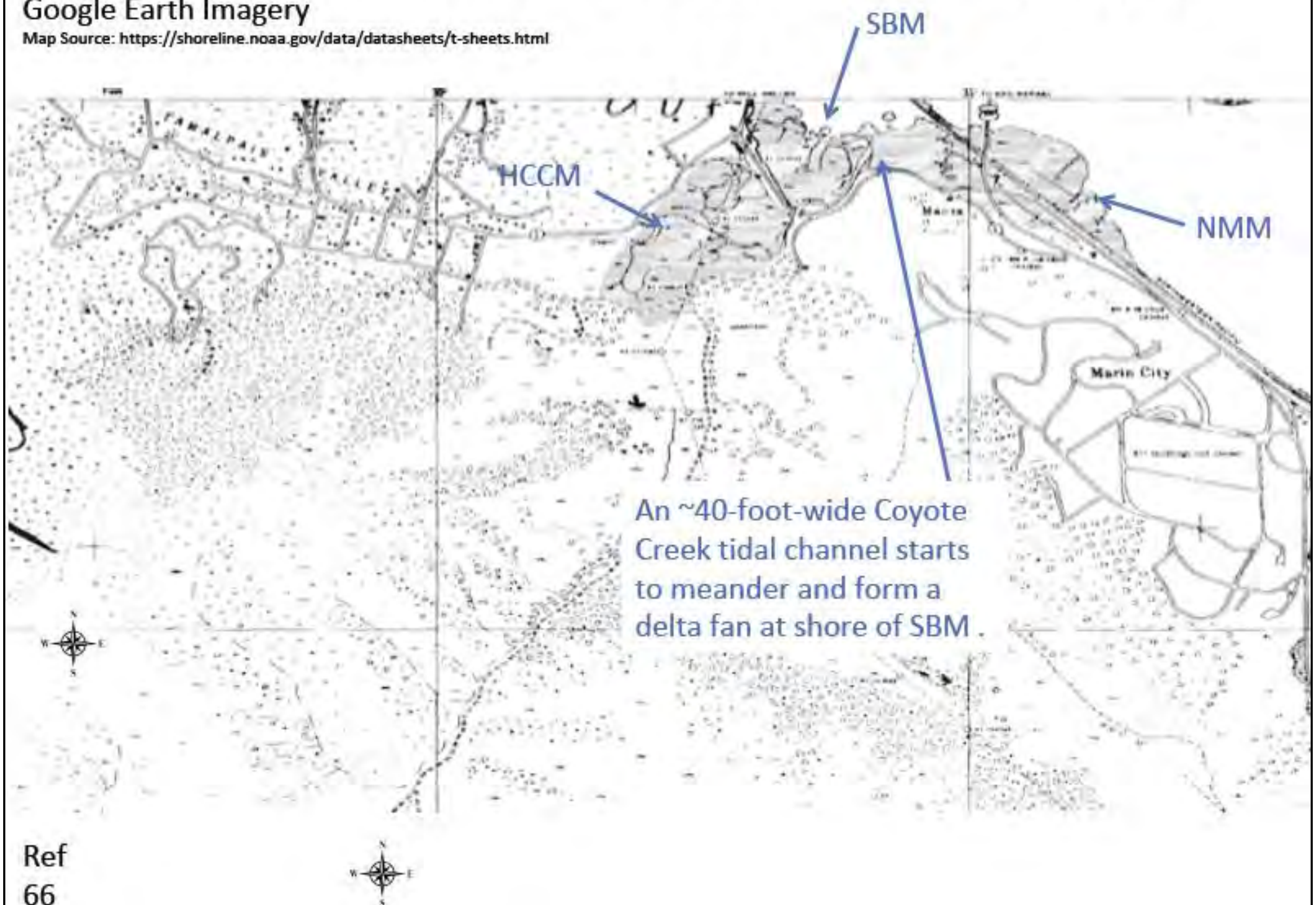
~125 ft-long trestle spans the Coyote Creek embayment

Ref 64


1927, information from US Coast and Geodetic Survey, Planimetric Map T-sheet 5929 overlaid onto 8/2016 Google Earth Imagery
Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html
By 1927 AM has ~37.8 ac of tidal marsh
Tam Marsh has ~3.8 ac of muted tidal marsh
Red circles represent power pole locations and red lines represent boardwalk
Ref 65
ACMdP
1899 channels
1851 shoreline
An eroded c. 1920 levee and outer bend of ACMdP means that AM is more open to tides from Richardson Bay.
Eroded 1924 shoreline
Almonte
Richardson Bay
1927 shoreline and channels
MLLW 1851
SBM
RR
Google earth

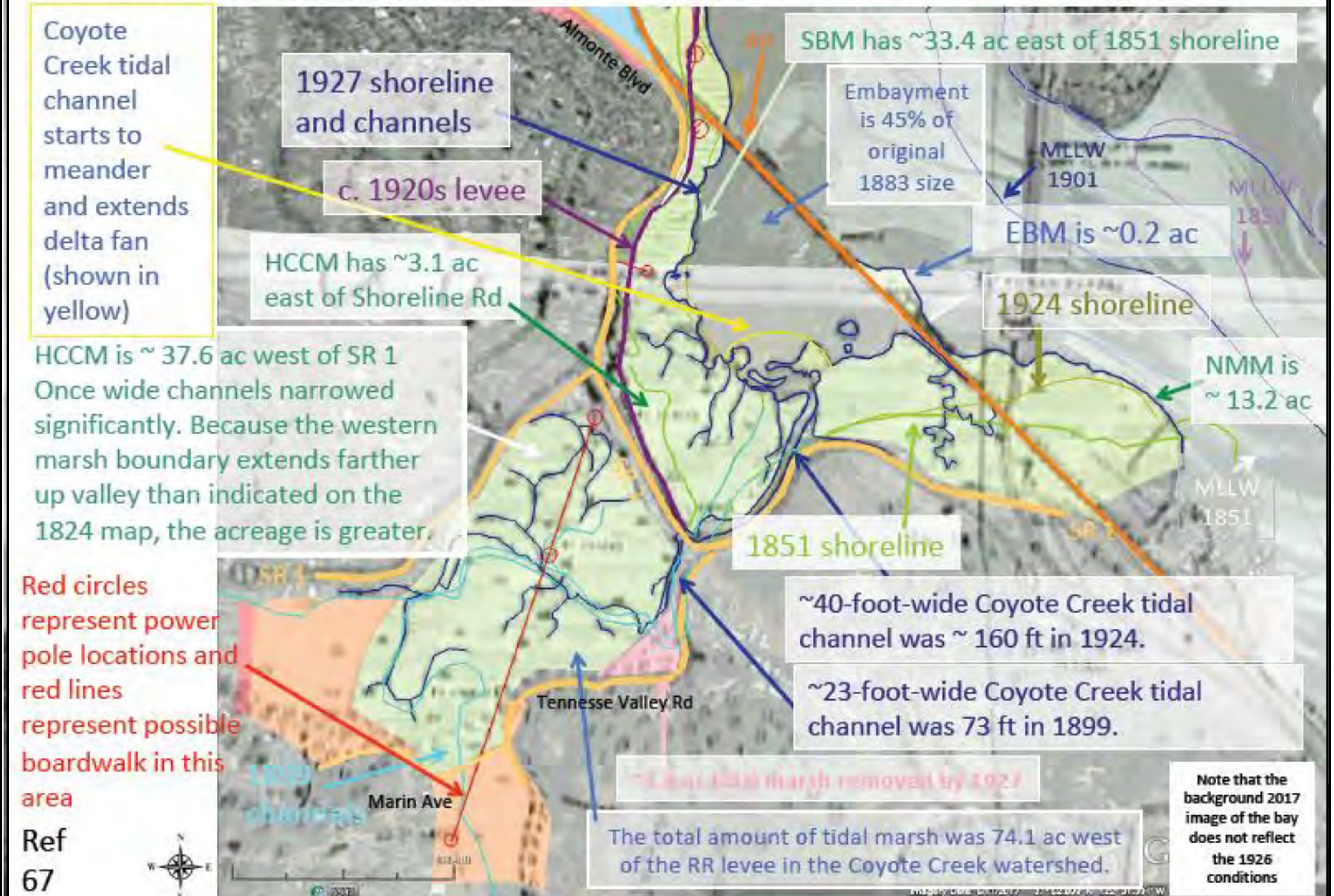
1927, US Coast and Geodetic Survey, Planimetric Map T-sheet 5927 overlaid onto 8/2016 Google Earth Imagery

Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html



Ref 66

1927, US Coast and Geodetic Survey, Planimetric Maps T-sheet 5927 and 5929 overlaid onto 6/2017 Google Earth Imagery Map Source: https://shoreline.noaa.gov/data/datasheets/t-sheets.html



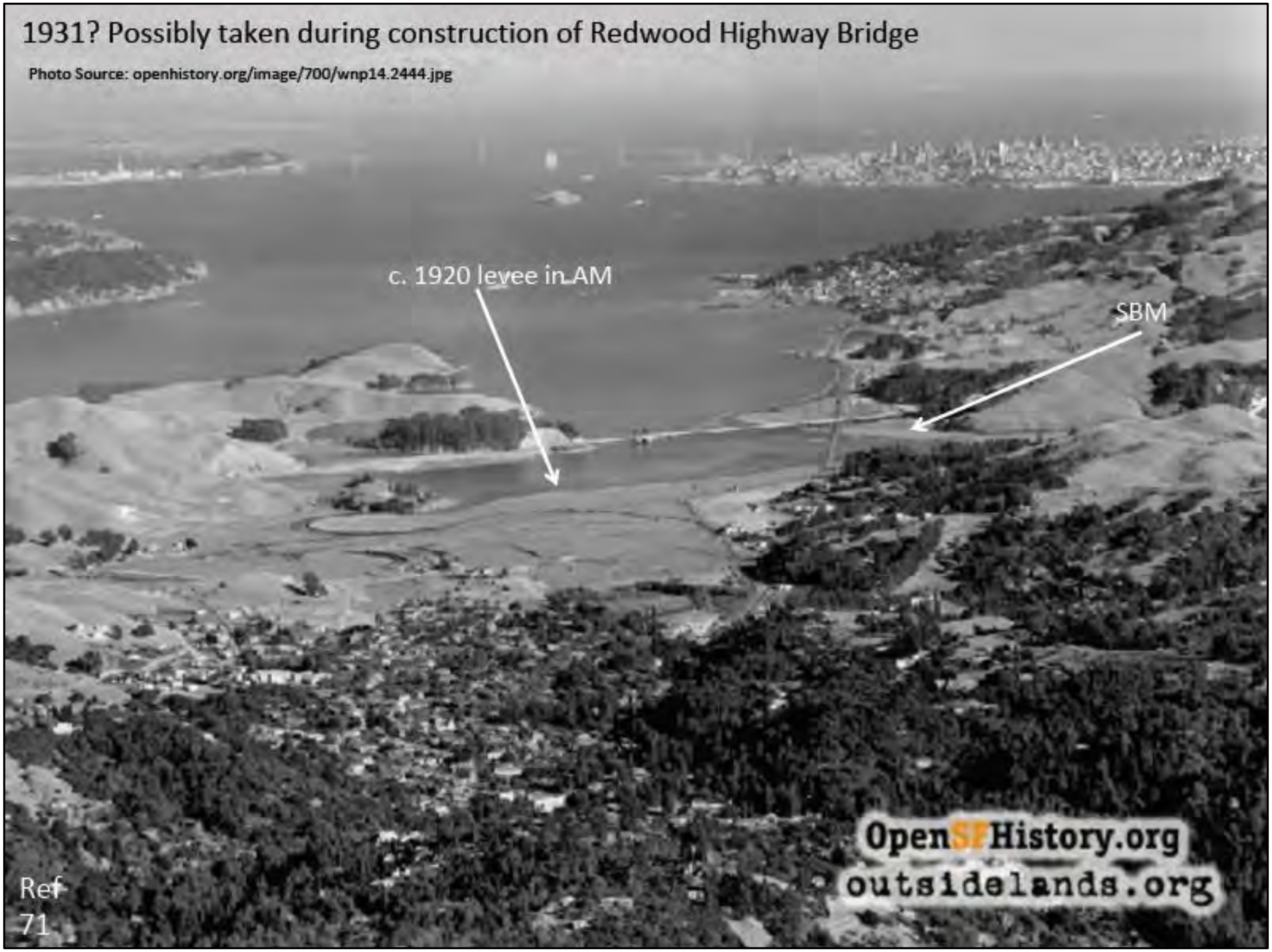
July 1929 Smoke from Mount Tamalpais/Mill Valley Fire

Photo, Source: https://www.marincounty.org/~/media/images/departments/fr/history/1920/1929_fire_5_after_jpg.jpg

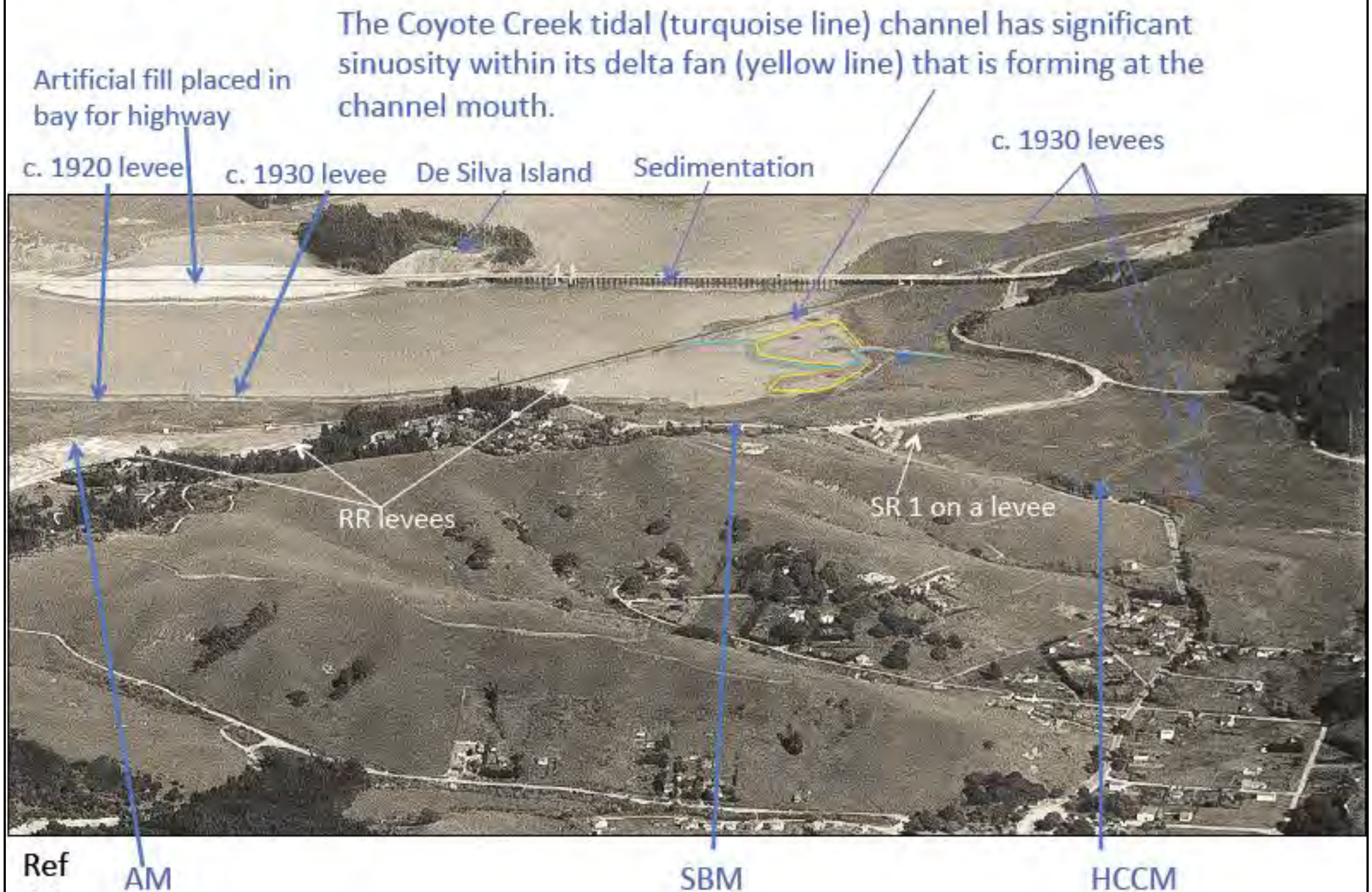
1931, Illustrative sign along Bay Trail in Bothin Marsh Source: Marin County Parks Sign

1931, Construction of the Redwood Highway Bridge, South Bothin Marsh in background.

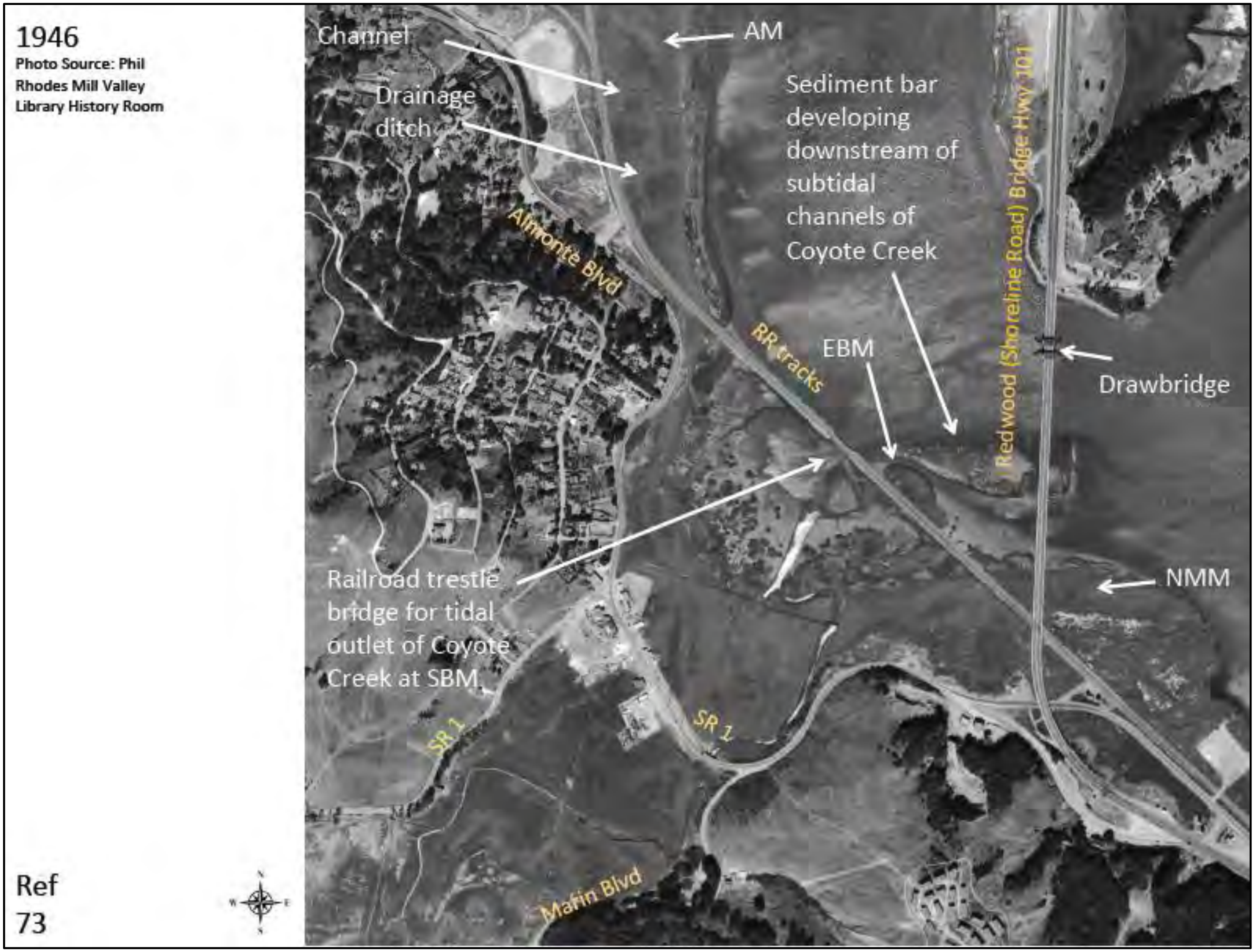
Photo Source: Richard Tourney


1931? Possibly taken during construction of Redwood Highway Bridge
Photo Source: openhistory.org/image/700/wnp14.2444.jpg
c. 1920 levee in AM
SBM
OpenSFHistory.org
outsidelands.org
Ref 71

1932?,
Photo Source: https://mvhistory.org/wp-content/uploads/2015/07/Tam-Valley-24.jpg



Ref
72


1946
Photo Source: Phil Rhodes Mill Valley Library History Room
Channel
AM
Drainage ditch
Sediment bar developing downstream of subtidal channels of Coyote Creek
Redwood (Shoreline Road) Bridge Hwy 101
Almonte Blvd
RR tracks
EBM
Drawbridge
Railroad trestle bridge for tidal outlet of Coyote Creek at SBM
NMM
SR 1
SR 1
Marin Blvd
Ref 73

1946, Black and white air photo overlaid onto 2017 Google Earth Imagery

Photo Source: Phil Rhodes Mill Valley Library History Room

Red circles represent power pole locations and red lines represent boardwalk

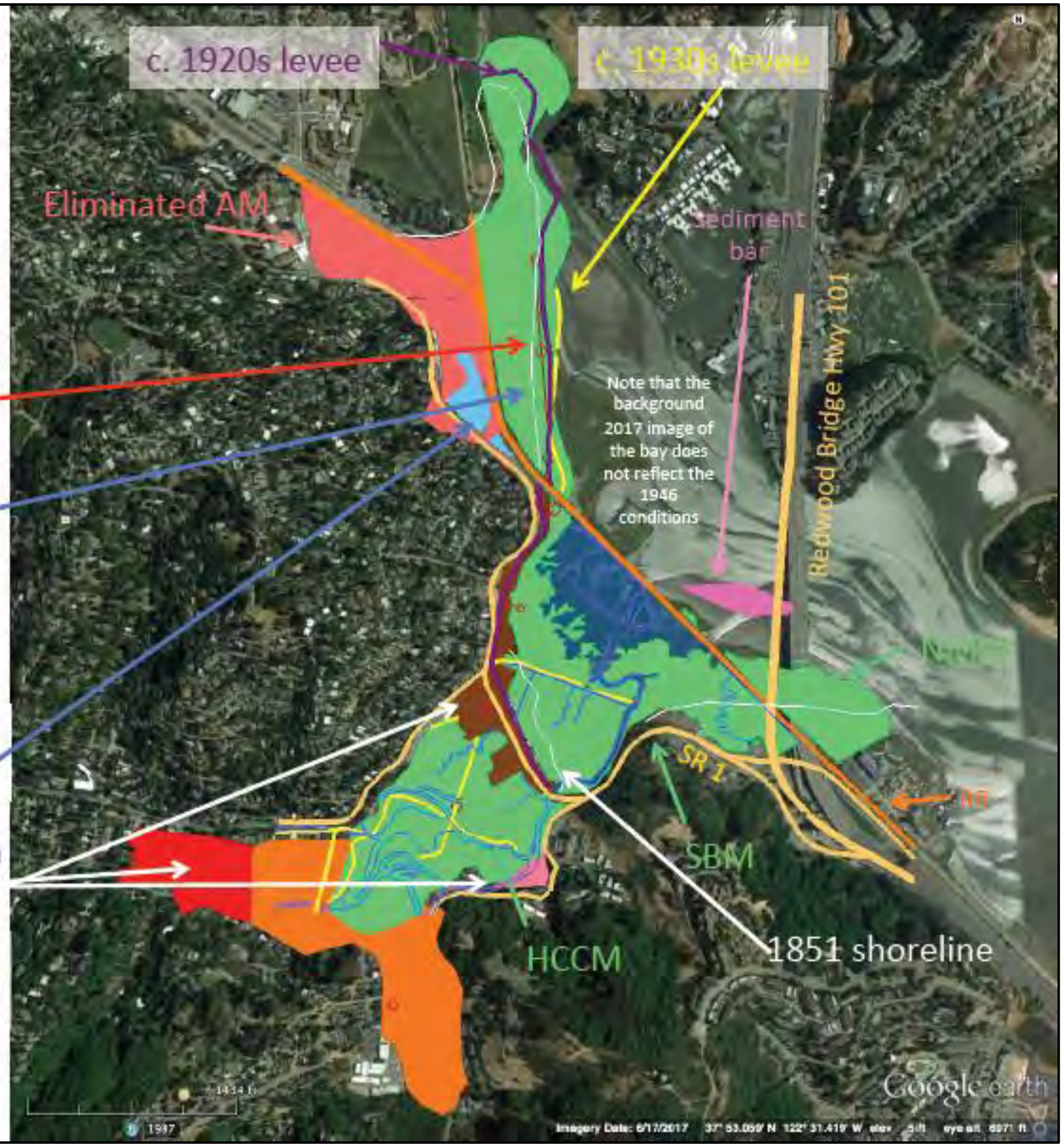
AM has ~37.3 ac of tidal marsh, light green area beyond 1946 photo is extrapolated from other maps and photography.

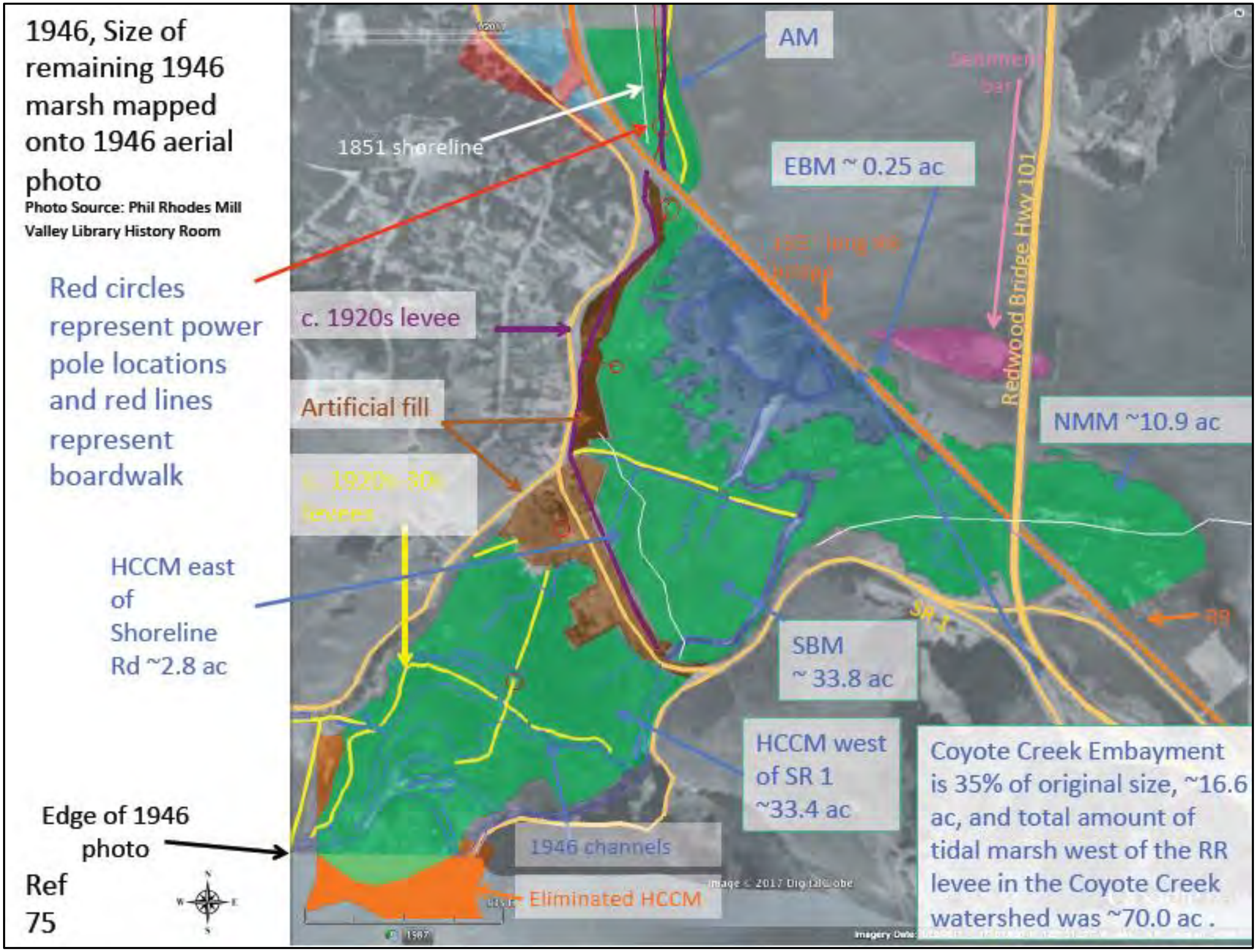
AM at Tam Marsh has ~2.8 ac of muted tidal marsh

Red, orange, pink, and brown area eliminated marsh

Yellow lines represent c. 1930s levees

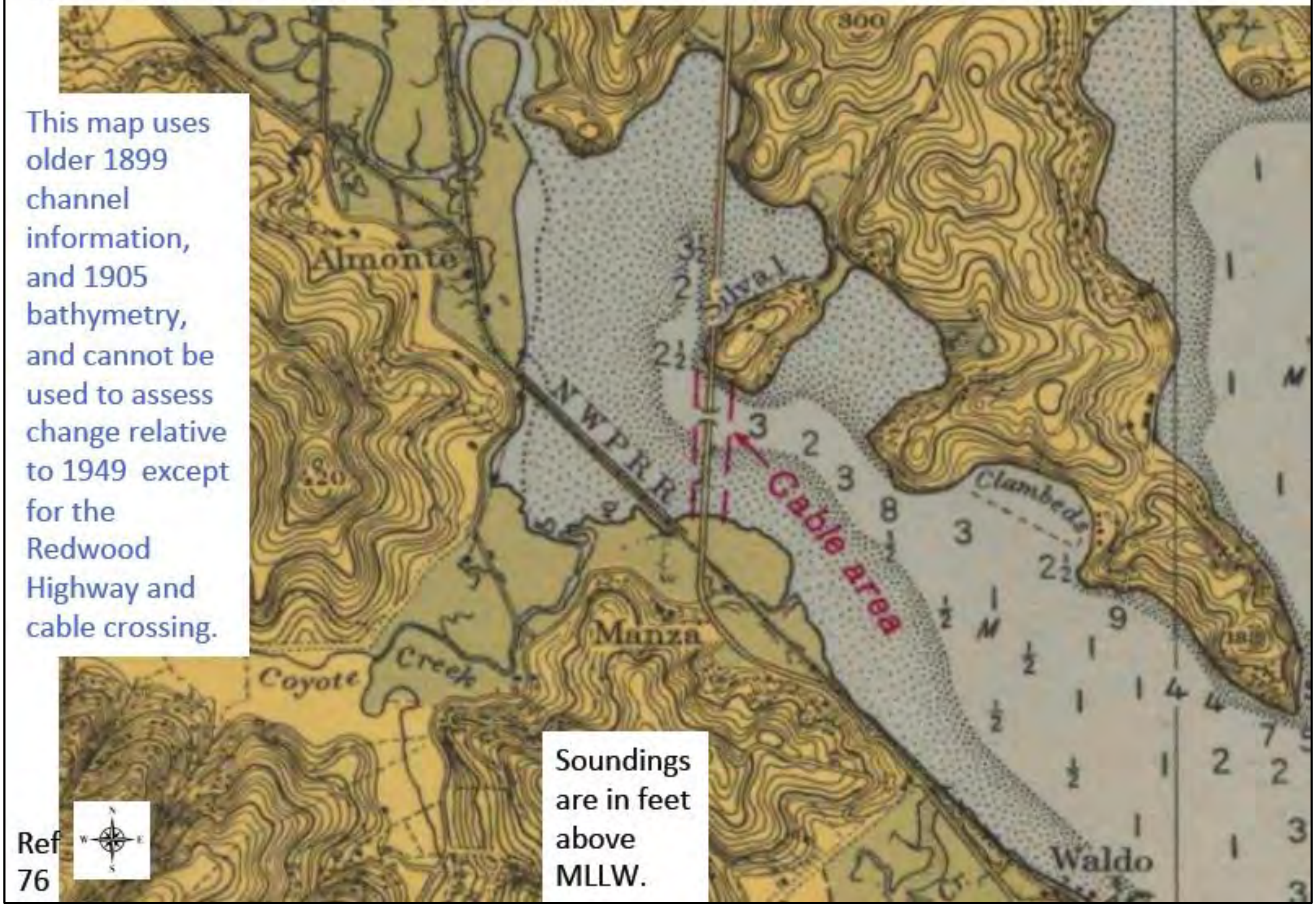
Ref 74




1946, Size of remaining 1946 marsh mapped onto 1946 aerial photo
Photo Source: Phil Rhodes Mill Valley Library History Room
Red circles represent power pole locations and red lines represent boardwalk
HCCM east of Shoreline Rd ~2.8 ac
Edge of 1946 photo
Ref 75
AM
1851 shoreline
EBM ~ 0.25 ac
c. 1920s levee
Artificial fill
Redwood Bridge Hwy 101
NMM ~10.9 ac
SBM ~ 33.8 ac
HCCM west of SR 1 ~33.4 ac
1946 channels
Eliminated HCCM
Coyote Creek Embayment is 35% of original size, ~16.6 ac, and total amount of tidal marsh west of the RR levee in the Coyote Creek watershed was ~70.0 ac .

1949, San Francisco Entrance, U.S. Coast Survey Chart 5532

Map Source: https://historicalcharts.noaa.gov/historicals/search#mainTitle




1950, Photo
Source: Sausalito Historical Society
Artificial fill increases for commercial area along SR 1
Sediment bar still exists downstream of subtidal channels of Coyote Creek
Ref 77

1950, Looking southeastward at Redwood Highway Bridge crossing Richardson Bay

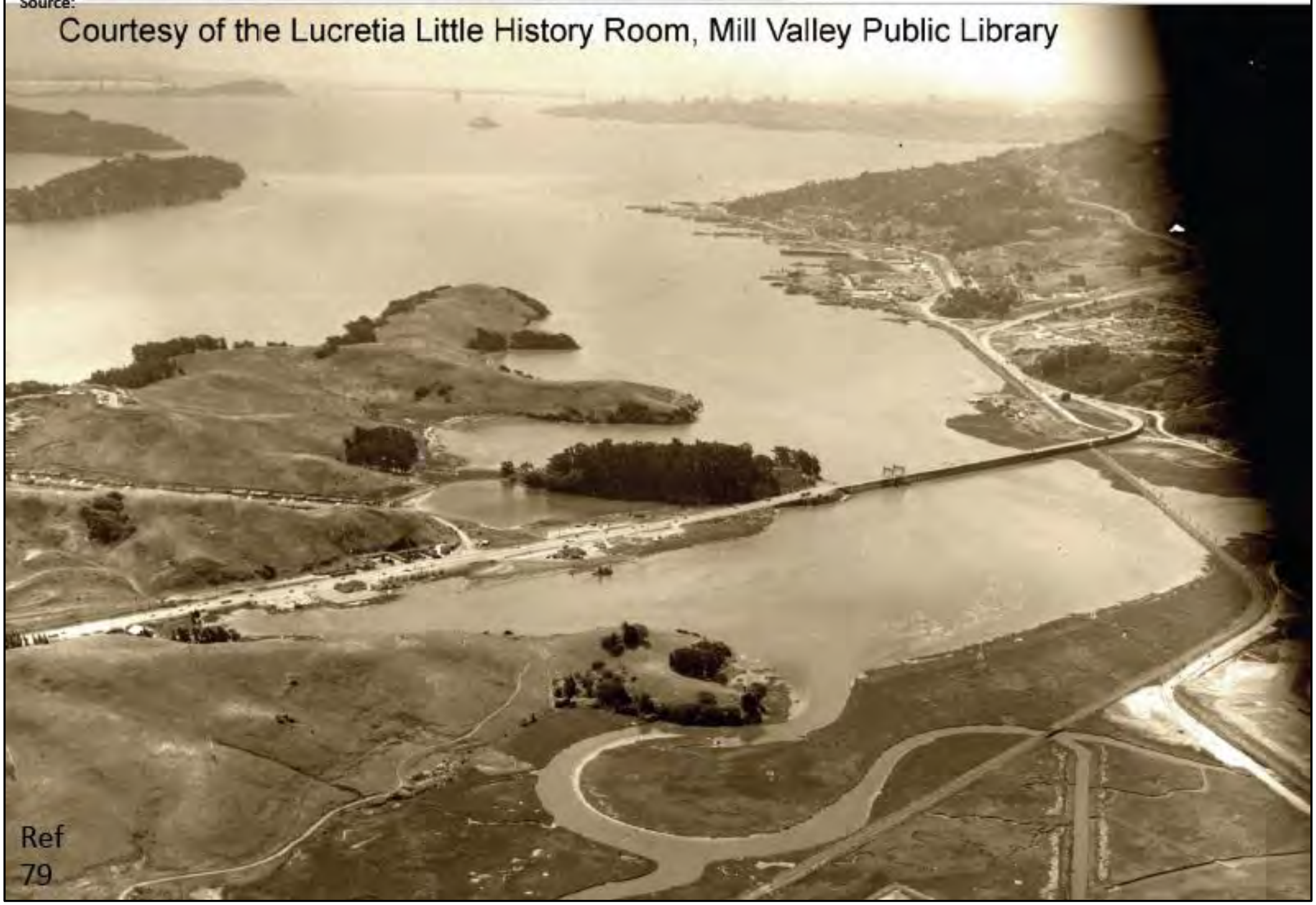
Photo Source: https://mvhistory.org wp-content/uploads/2014/08/ TamHigh1923.jpg

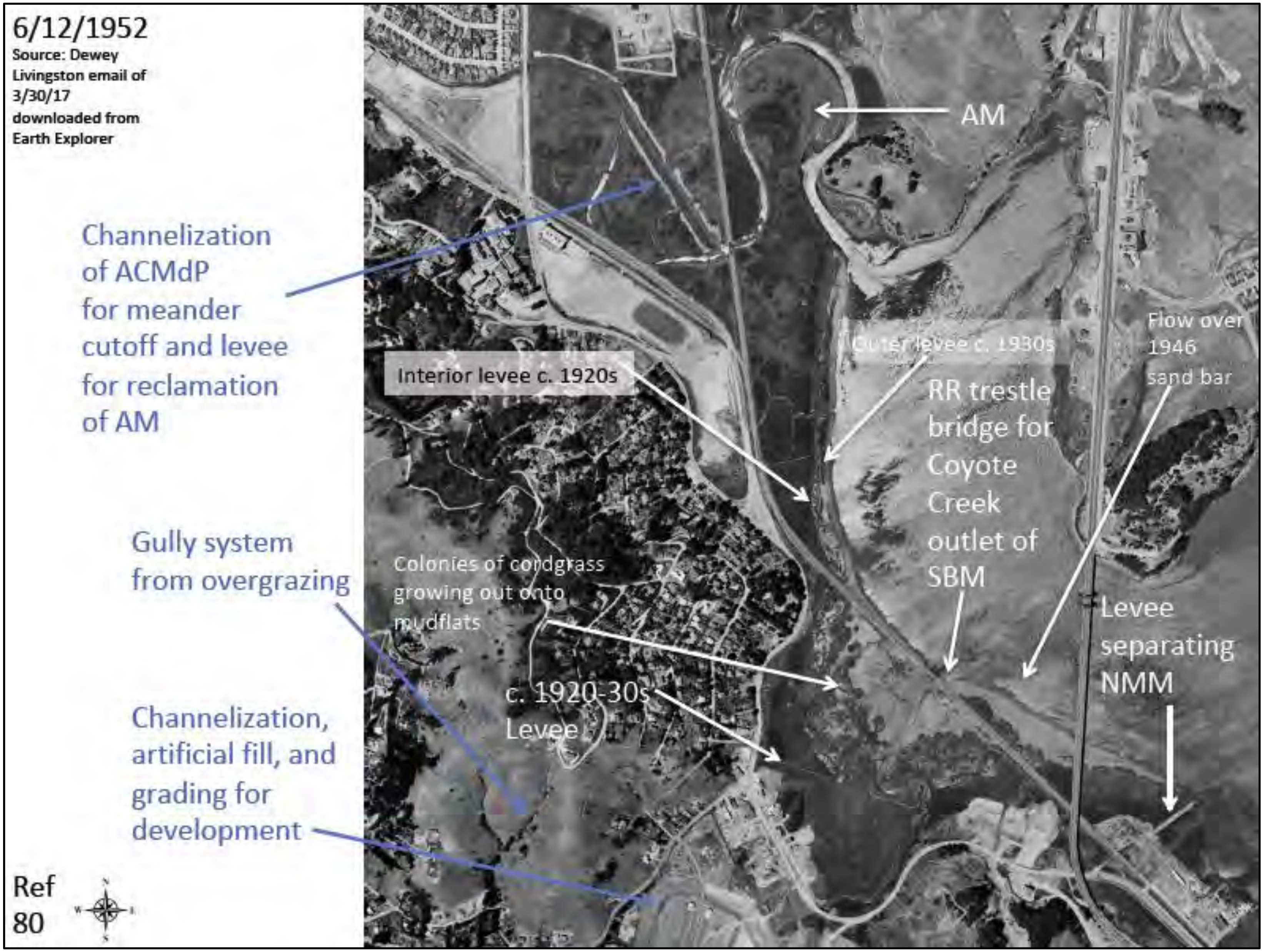
This later c. 1931 sports field is constructed to south of the earlier 1923 track. Artificial fill has been placed over much of the former Almonte Marsh on the west side of Mill Valley RR branch and in the small triangle between the two branches.

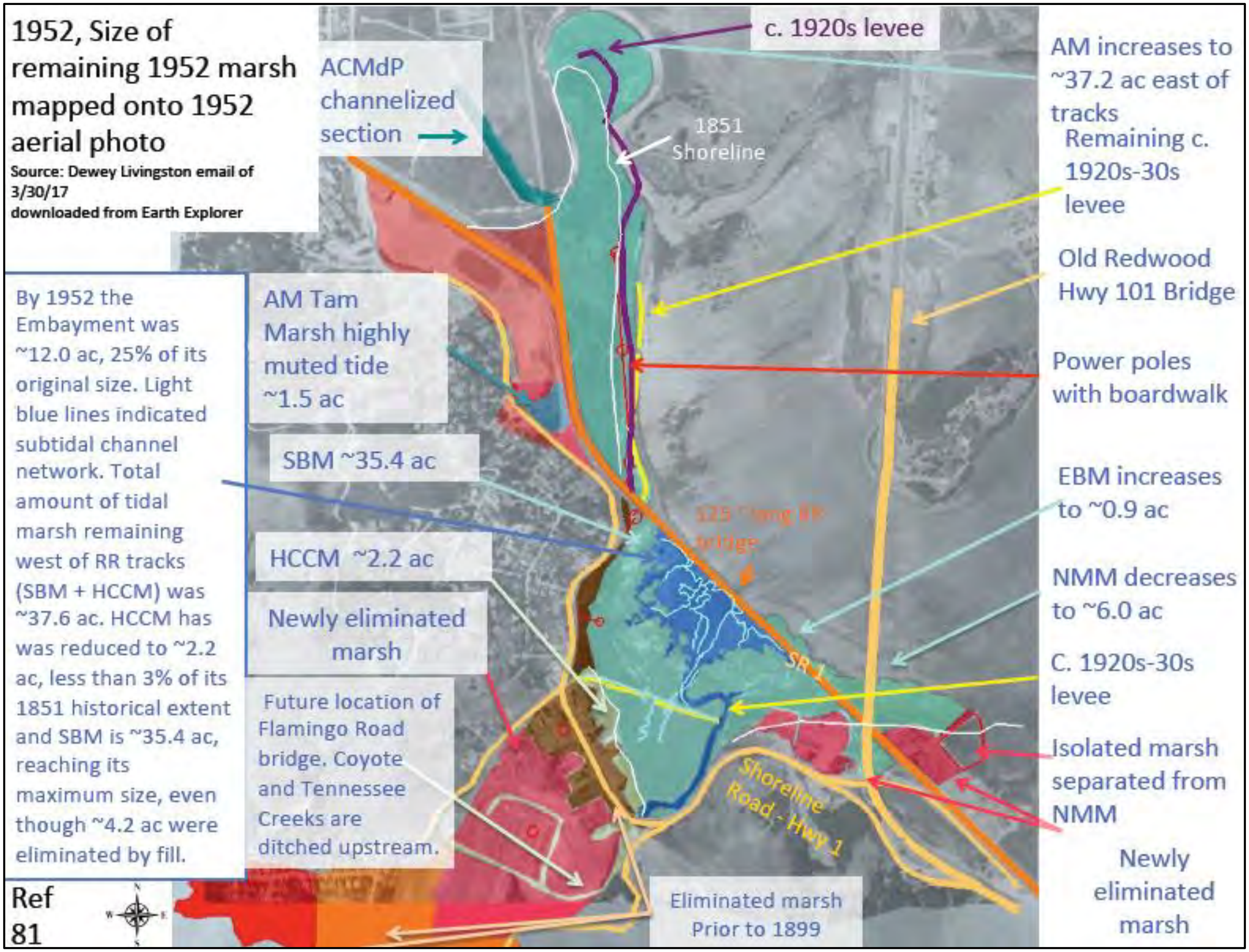
Ref 78

1950, Detail of looking southeastward at Redwood Highway Bridge crossing Richardson Bay

Source: https://mvhistory.org/wp-content/uploads/2015/05/Before-dredging-about-1950.jpg




6/12/1952
Source: Dewey Livingston email of 3/30/17 downloaded from Earth Explorer
Channelization of ACMdP for meander cutoff and levee for reclamation of AM
Gully system from overgrazing
Channelization, artificial fill, and grading for development
Ref 80
AM
Interior levee c. 1920s
Outer levee c. 1930s
RR trestle bridge for Coyote Creek outlet of SBM
Flow over 1946 sand bar
Colonies of cordgrass growing out onto mudflats
c. 1920-30s Levee
Levee separating NMM


1952, Size of remaining 1952 marsh mapped onto 1952 aerial photo
Source: Dewey Livingston email of 3/30/17
downloaded from Earth Explorer
ACMdP channelized section
c. 1920s levee
1851 Shoreline
AM increases to ~37.2 ac east of tracks
Remaining c. 1920s-30s levee
Old Redwood Hwy 101 Bridge
Power poles with boardwalk
By 1952 the Embayment was ~12.0 ac, 25% of its original size. Light blue lines indicated subtidal channel network. Total amount of tidal marsh remaining west of RR tracks (SBM + HCCM) was ~37.6 ac. HCCM has was reduced to ~2.2 ac, less than 3% of its 1851 historical extent and SBM is ~35.4 ac, reaching its maximum size, even though ~4.2 ac were eliminated by fill.
AM Tam Marsh highly muted tide ~1.5 ac
SBM ~35.4 ac
HCCM ~2.2 ac
Newly eliminated marsh
Future location of Flamingo Road bridge. Coyote and Tennessee Creeks are ditched upstream.
EBM increases to ~0.9 ac
NMM decreases to ~6.0 ac
C. 1920s-30s levee
Isolated marsh separated from NMM
Newly eliminated marsh
SR 1
Shoreline Road - Hwy 1
Eliminated marsh Prior to 1899
Ref 81

1956 Flooding

Source: Tamalpais Valley Improvement Club

JANUARY 6. 1956

www.tamvalley.org/images/TheProgressPics/1996TheProgress-Pg7.pdf

MAIN ST. (LAUREL) TOWARDS SHORELINE

SHORELINE BETWEEN PINE & SPRUCE

Ref 82

1956 Flooding

Source: Tamalpais Valley Improvement Club

www.tamvalley.org/images/TheProgressPics/1996TheProgress-Pg7.pdf

Ref 83

SHORELINE BETWEEN POPLAR & PINE ST.

Date 1956?, Richardson Bay looking Northwest

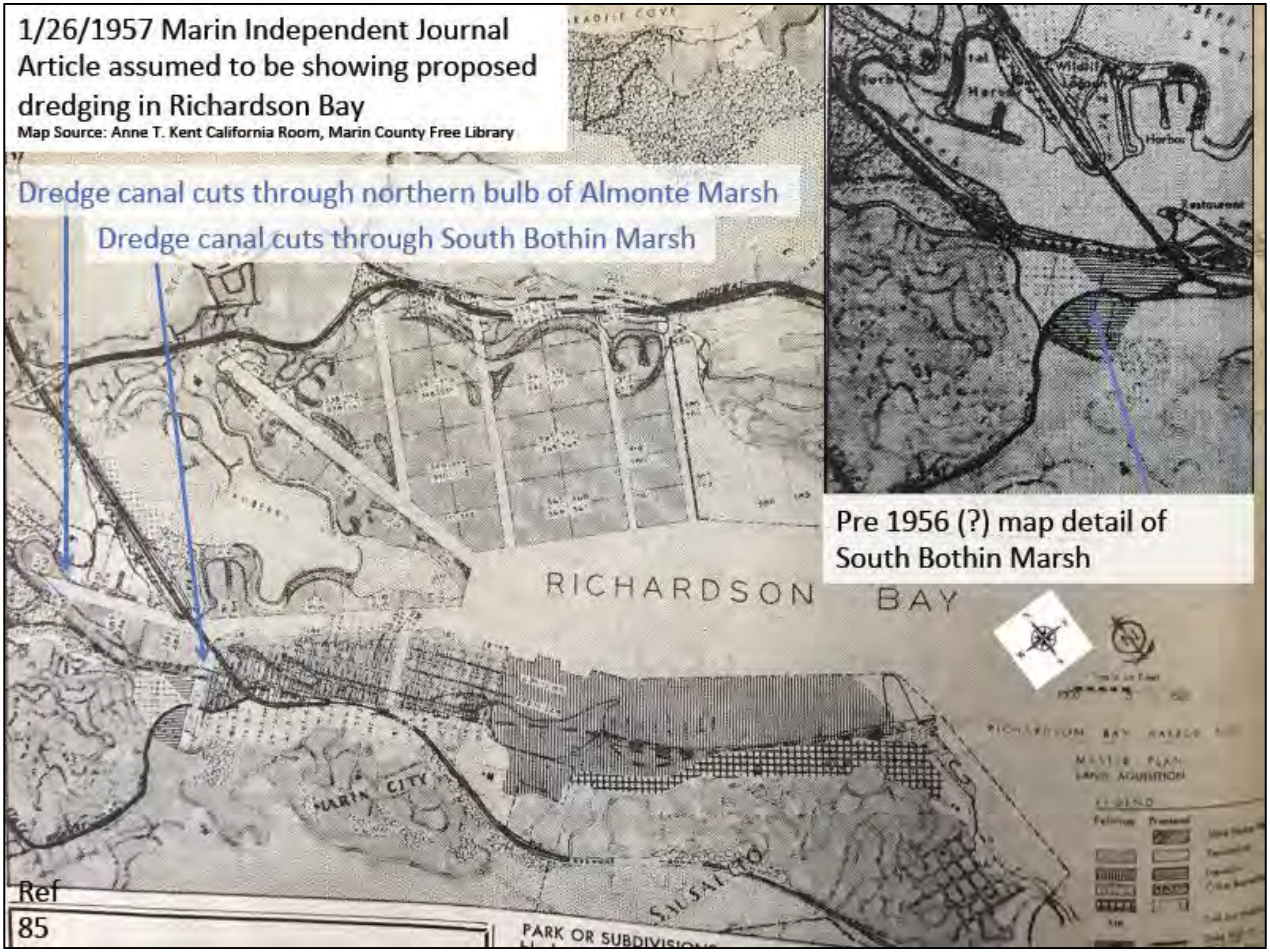
Photo Source: California History Room Marin Civic Center Library

Containment levee had been constructed for placement of dredge spoils to continue to fill the bay in front of Almonte Marsh shoreline.

Construction new concrete bridge for Highway 101 started in 1956

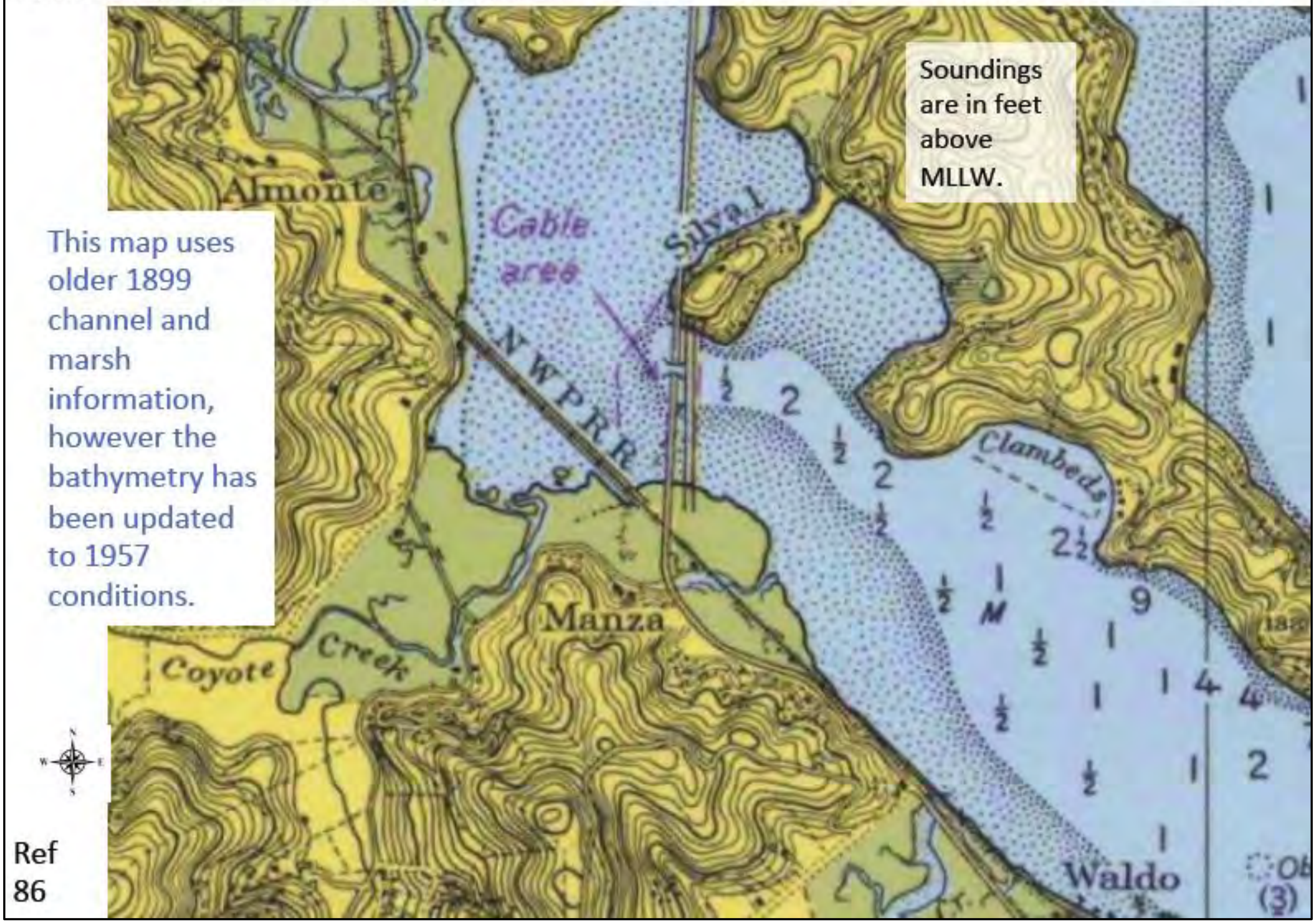
Materials comprising fill in Sausalito.

Ref 84


1/26/1957 Marin Independent Journal
Article assumed to be showing proposed
dredging in Richardson Bay
Map Source: Anne T. Kent California Room, Marin County Free Library
Dredge canal cuts through northern bulb of Almonte Marsh
Dredge canal cuts through South Bothin Marsh
Pre 1956 (?) map detail of
South Bothin Marsh
RICHARDSON BAY
MARIN CITY
SAUSALITO
PARK OR SUBDIVISION
Ref
85

1957, San Francisco Entrance, U.S. Coast Survey Chart 5532

Map Source: https://historicalcharts.noaa.gov/historicals/search#mainTitle



Bathymetric MLLW Boundaries from San Francisco Entrance, U.S. Coast Survey Charts #5532 Projected onto 6/2017 Google Earth Imagery

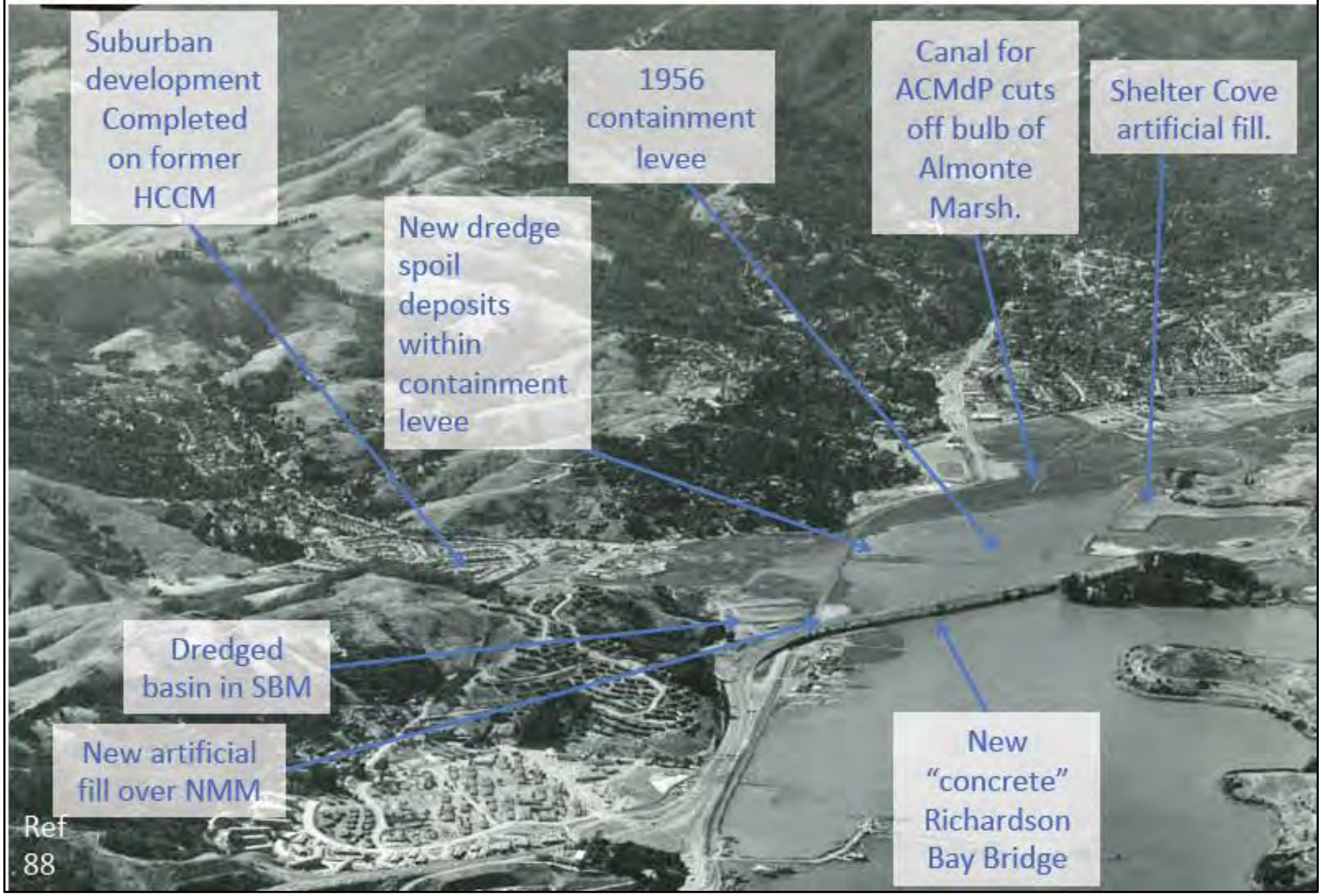
Map Source: https://historicalcharts.noaa.gov/historicals/search#mainTitle

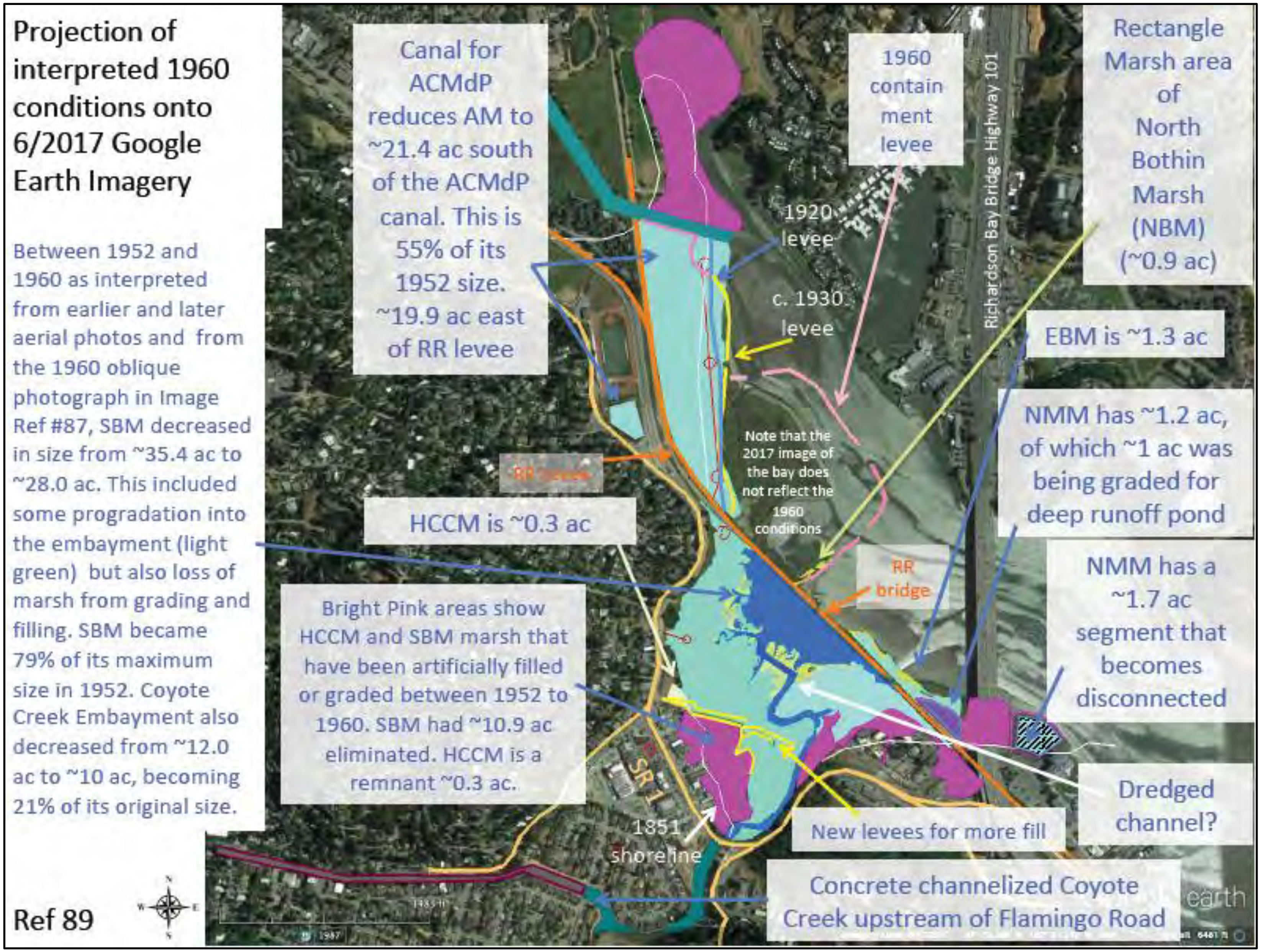
This map shows the changing conditions of the MLLW boundary. It shows that following 1851 (light lavender line) sedimentation in the bay pushed the 1856 boundary significantly southward (violet line). This might have been related to the influx of hydraulic mining sediment from the Sierra and local logging and ranching activities. By 1901 the shallow bay deepens northward (navy blue line), but by 1956 it shallow again, nearly approaching the 1856 boundary of MLLW. The latter period of shallowing might relate to loss of tidal prism from marsh reclamation and bay filling, as well as increased sediment supply from grading for urban development, channel diversion and channelization, and 1956 record flooding.

Ref
87

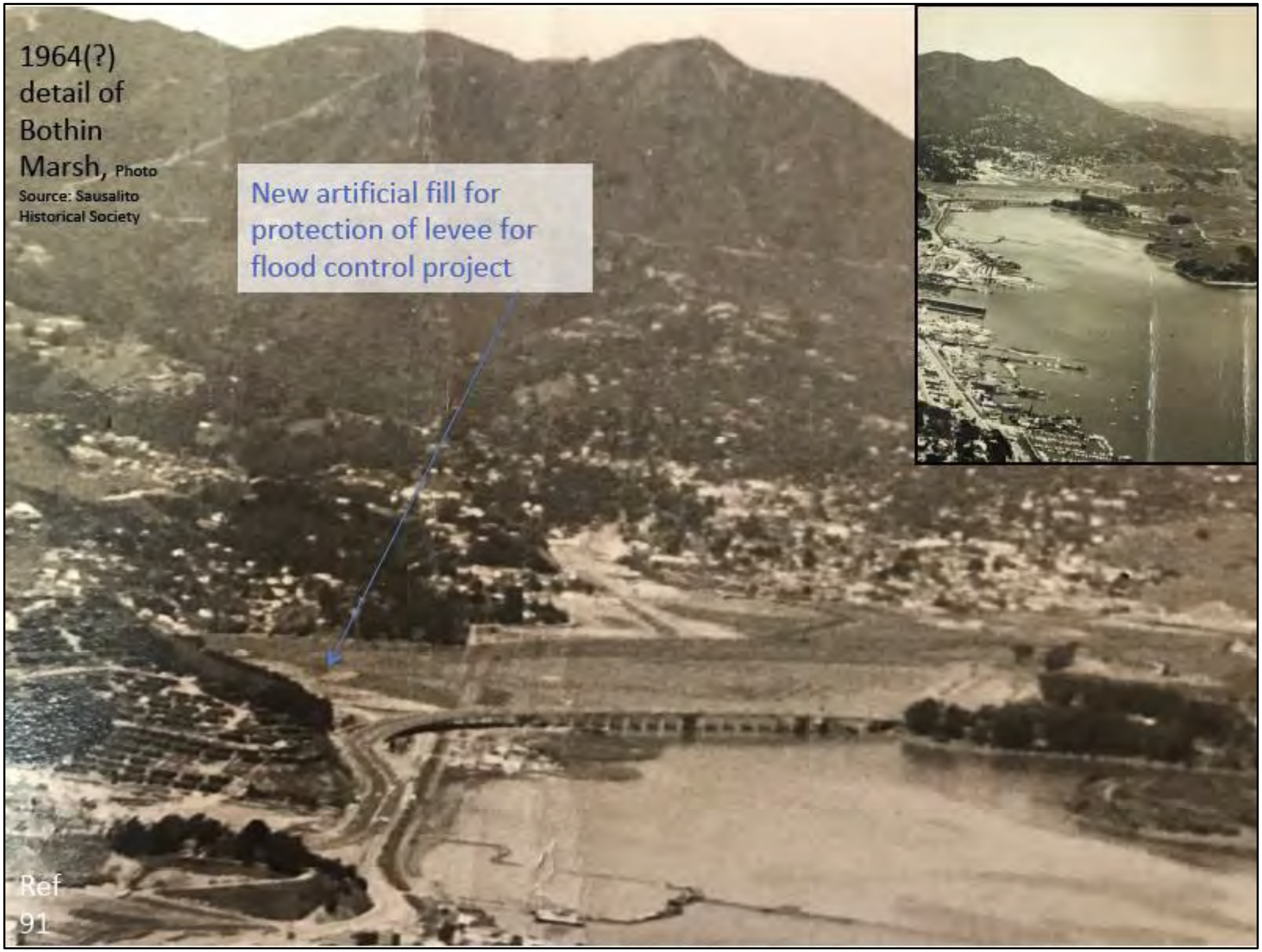
8/2/60 Brady Collection Marin History Museum, detail of photo 6941644175_bbfa0a6966_o

https://www.flickr.com/photos/25539851@N05/6941644175/in/album-72157631793232232/




Projection of interpreted 1960 conditions onto 6/2017 Google Earth Imagery
Between 1952 and 1960 as interpreted from earlier and later aerial photos and from the 1960 oblique photograph in Image Ref #87, SBM decreased in size from ~35.4 ac to ~28.0 ac. This included some progradation into the embayment (light green) but also loss of marsh from grading and filling. SBM became 79% of its maximum size in 1952. Coyote Creek Embayment also decreased from ~12.0 ac to ~10 ac, becoming 21% of its original size.
Ref 89
Canal for ACMdP reduces AM to ~21.4 ac south of the ACMdP canal. This is 55% of its 1952 size. ~19.9 ac east of RR levee
1960 contain ment levee
1920 levee
c. 1930 levee
Richardson Bay Bridge Highway 101
Rectangle Marsh area of North Bothin Marsh (NBM) (~0.9 ac)
EBM is ~1.3 ac
NMM has ~1.2 ac, of which ~1 ac was being graded for deep runoff pond
RR levee
HCCM is ~0.3 ac
Note that the 2017 image of the bay does not reflect the 1960 conditions
RR bridge
NMM has a ~1.7 ac segment that becomes disconnected
Bright Pink areas show HCCM and SBM marsh that have been artificially filled or graded between 1952 to 1960. SBM had ~10.9 ac eliminated. HCCM is a remnant ~0.3 ac.
SR 1
1851 shoreline
New levees for more fill
Dredged channel?
Concrete channelized Coyote Creek upstream of Flamingo Road
earth


1963, Looking Southeast at Richardson Bay
Photo Source: California History Room, Marin Civic Center Library from Richardson Bay in Transition, A land Use Study Sponsored by the Fish and Wildlife Service
Shelter Cove Artificial Fill
containment levee
bridge
ACMdP channelized, NBM boundary defined
Dredge removing AM bulb at bend of ACMdP
Ref 90


1964(?) detail of Bothin Marsh, Photo Source: Sausalito Historical Society
New artificial fill for protection of levee for flood control project
Ref 91

8/27/65 Brady Collection Marin History Museum, detail of photo 6941654707_a01f6f488d_og

Photo Source: https://www.flickr.com/photos/25539851@N05/albums/72157631793232232/page4

Flood Control Project diversion and trapezoidal tidal channel of Coyote Creek eliminates ~4 ac SBM and ~0.25 ac EBM.

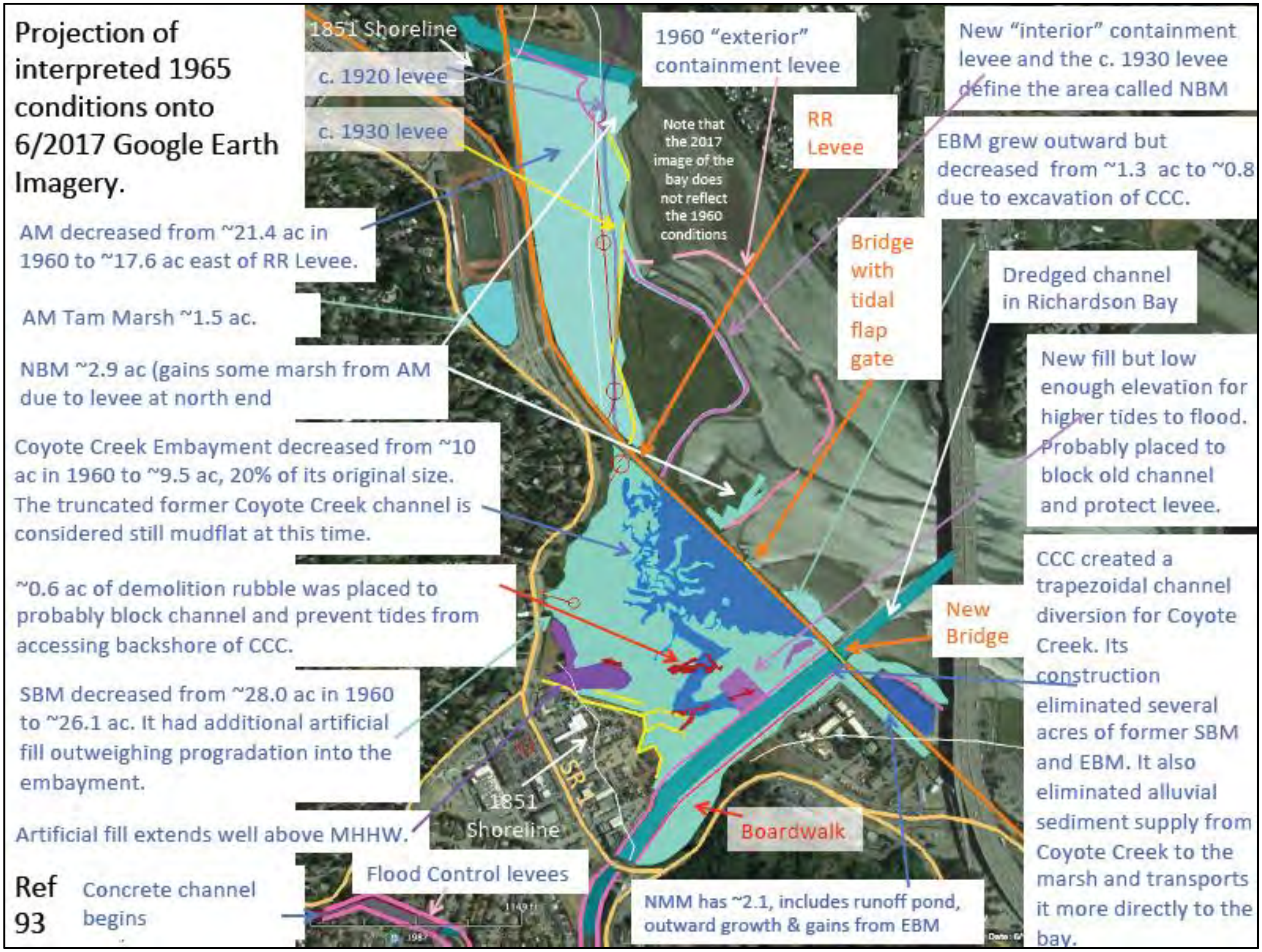
Artificial fill placed for narrowing the opening of Coyote Creek Embayment

New interior containment cell levee under construction (dredge in picture).

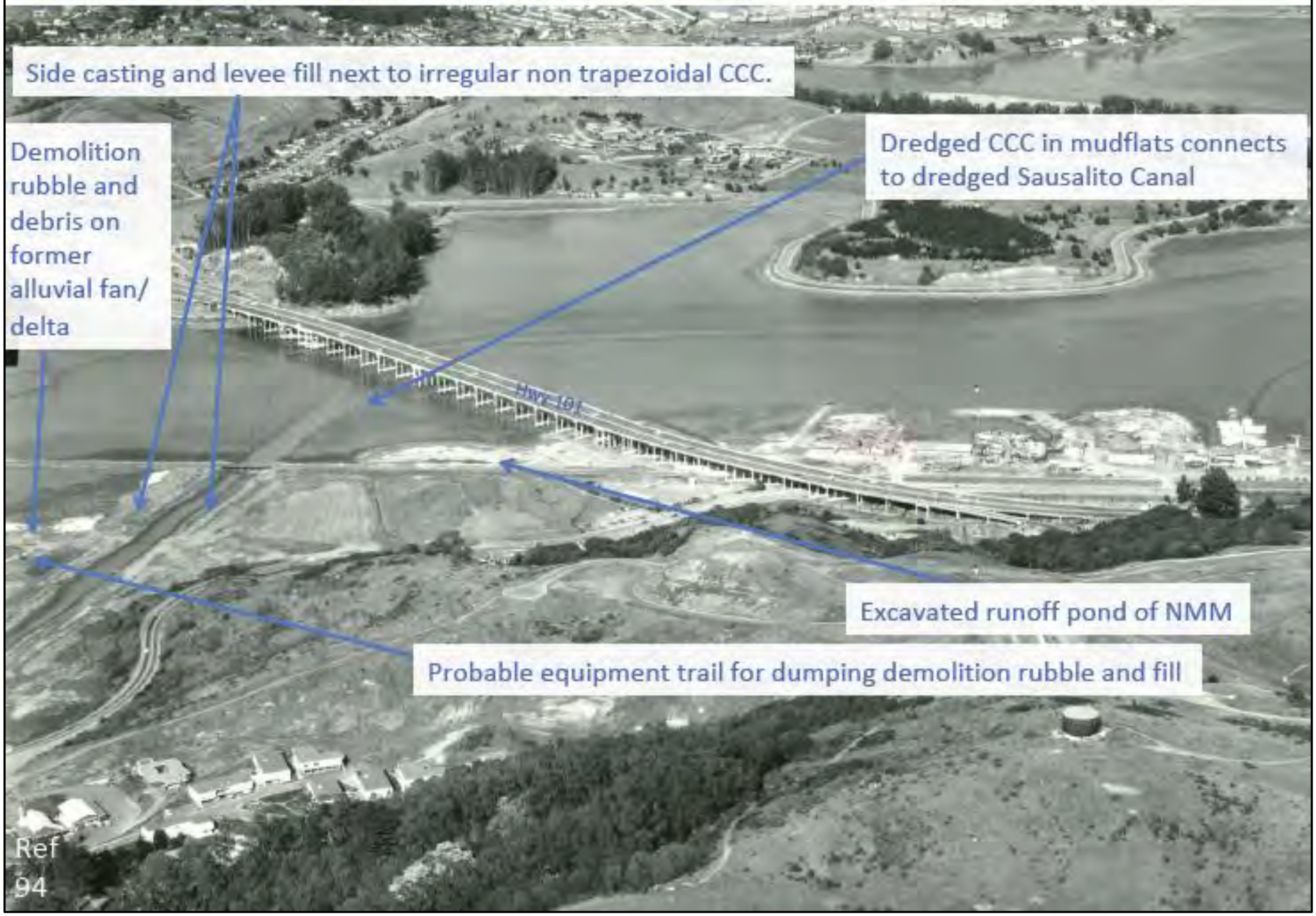
Ref 92

Artificial fill placed c. 1961?

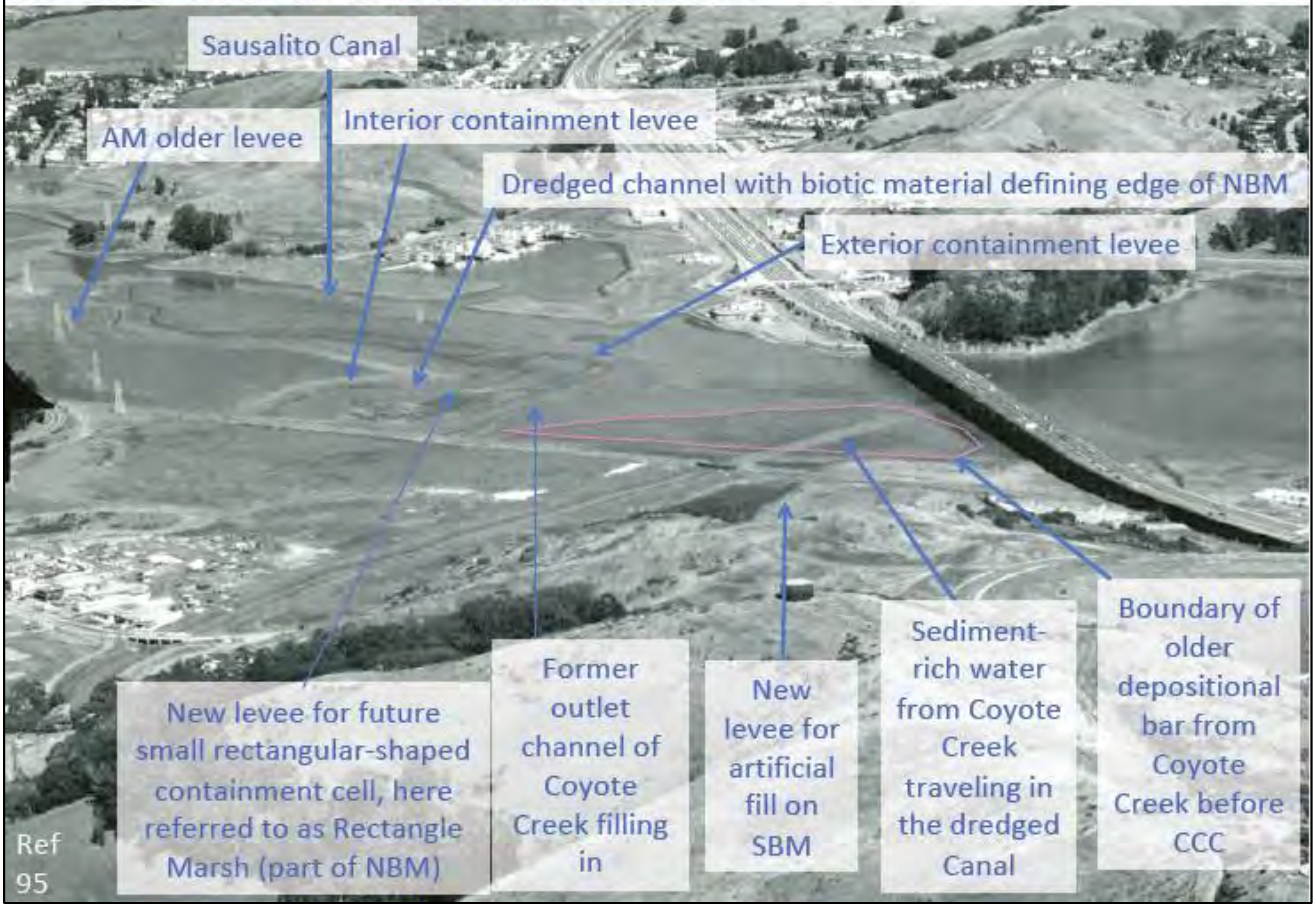
~2.4 ac artificial fill from 1964 (might include much of the demolition rubble and debris that is still present in the marsh. Note path leading to site from the west.


Projection of interpreted 1965 conditions onto 6/2017 Google Earth Imagery.
1851 Shoreline
c. 1920 levee
c. 1930 levee
1960 "exterior" containment levee
New "interior" containment levee and the c. 1930 levee define the area called NBM
RR Levee
Note that the 2017 image of the bay does not reflect the 1960 conditions
EBM grew outward but decreased from ~1.3 ac to ~0.8 due to excavation of CCC.
AM decreased from ~21.4 ac in 1960 to ~17.6 ac east of RR Levee.
Bridge with tidal flap gate
Dredged channel in Richardson Bay
AM Tam Marsh ~1.5 ac.
NBM ~2.9 ac (gains some marsh from AM due to levee at north end
New fill but low enough elevation for higher tides to flood. Probably placed to block old channel and protect levee.
Coyote Creek Embayment decreased from ~10 ac in 1960 to ~9.5 ac, 20% of its original size. The truncated former Coyote Creek channel is considered still mudflat at this time.
~0.6 ac of demolition rubble was placed to probably block channel and prevent tides from accessing backshore of CCC.
New Bridge
CCC created a trapezoidal channel diversion for Coyote Creek. Its construction eliminated several acres of former SBM and EBM. It also eliminated alluvial sediment supply from Coyote Creek to the marsh and transports it more directly to the bay.
SBM decreased from ~28.0 ac in 1960 to ~26.1 ac. It had additional artificial fill outweighing progradation into the embayment.
SR1
1851 Shoreline
Artificial fill extends well above MHHW.
Boardwalk
Flood Control levees
Ref 93
Concrete channel begins
NMM has ~2.1, includes runoff pond, outward growth & gains from EBM

3/17/66 Brady Collection Marin History Museum, detail of photo 6795542488_fbe0d8e619_o
https://www.flickr.com/photos/25539851@N05/6795542488/in/album-72157631793232232/

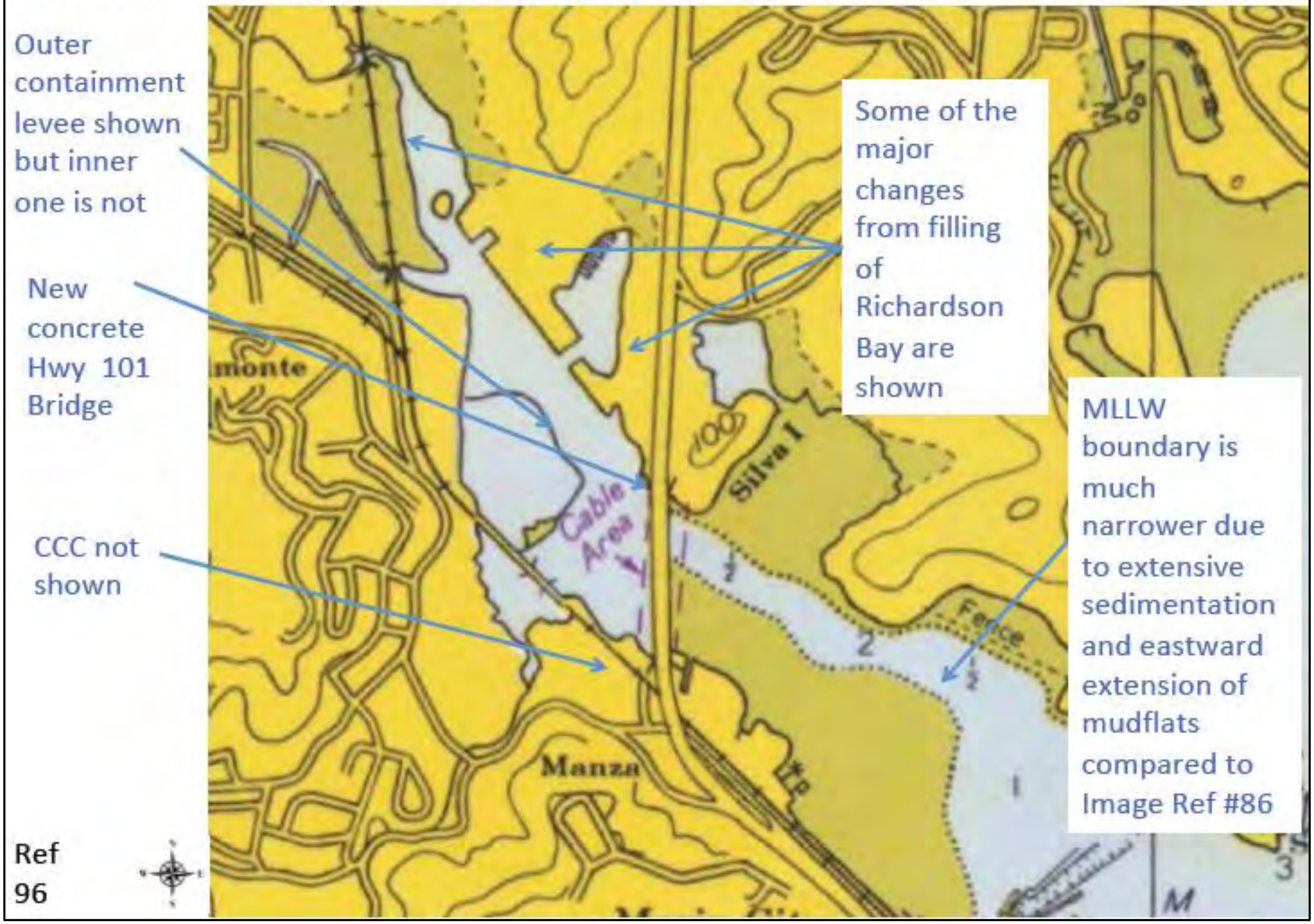


3/28/66 Brady Collection Marin History Museum, detail of photo 6795542182_972fbae8d7_o
https://www.flickr.com/photos/25539851@N05/6795542182/in/album-72157631793232232/



10/1966, San Francisco Entrance, U.S. Coast Survey Chart 5532

Map Source: https://historicalcharts.noaa.gov/historicals/search#searchInput

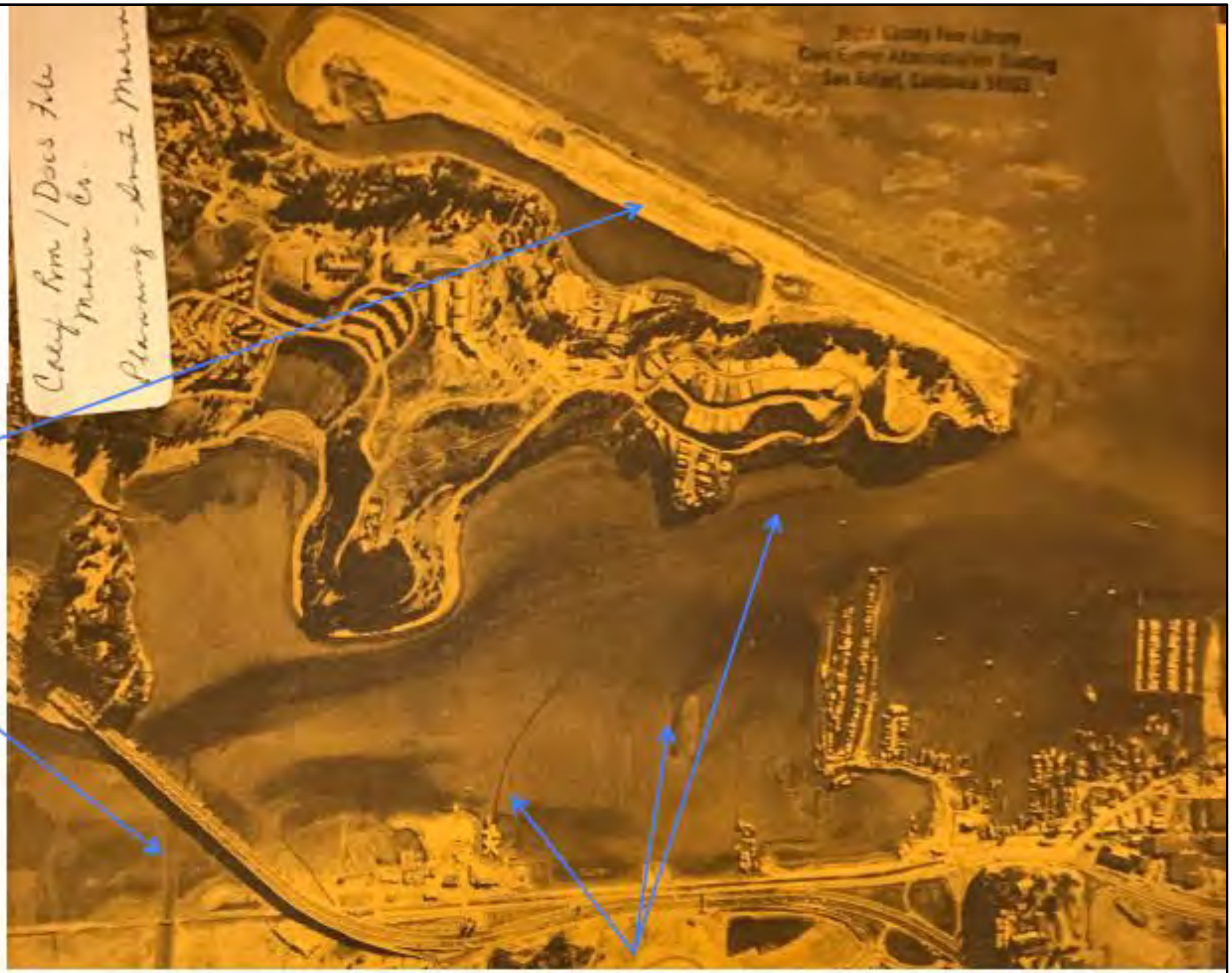


Post 1966, Cover photo of Richardson Bay Specific Plan

Photo Source: California History Room Marin Civic Center Library

Fill for area later known as Aramburu Island

Dredged subtidal channel for CCC



The photo shows abundant evidence of Richardson Bay filling in with artificial fill and sediment deposition of bay bottom, both contributing to need for dredging subtidal channels for navigation.

Ref 97

Date unknown, Post 1966 completion of flood control channel

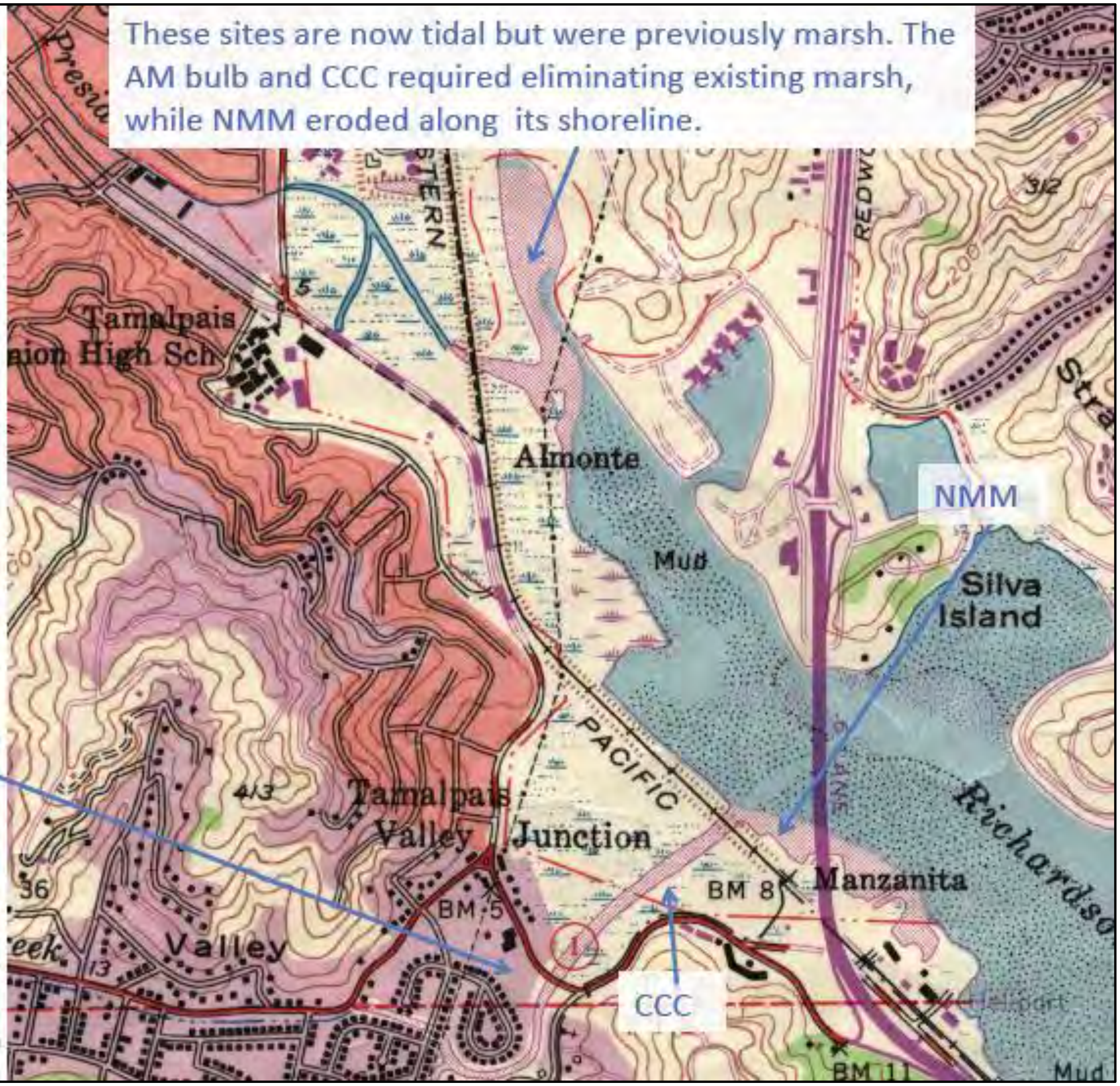
Photo Source: Sausalito Historical Society

1968, USGS San RAFAEL 15' QUADRANGLE

Source: http://servlet1.lib.berkeley.edu:8080/mapviewer/searchcoll.execute.logic?coll=histoposf

Some of the broad scale changes in Richardson Bay can be seen in this map that depicts older information from 1952 and 1968. Topography is from 1952. Urban extension is from 1968 and shown as a purple tint. It does not reflect marsh details of additional containment cells, channels, and levees.

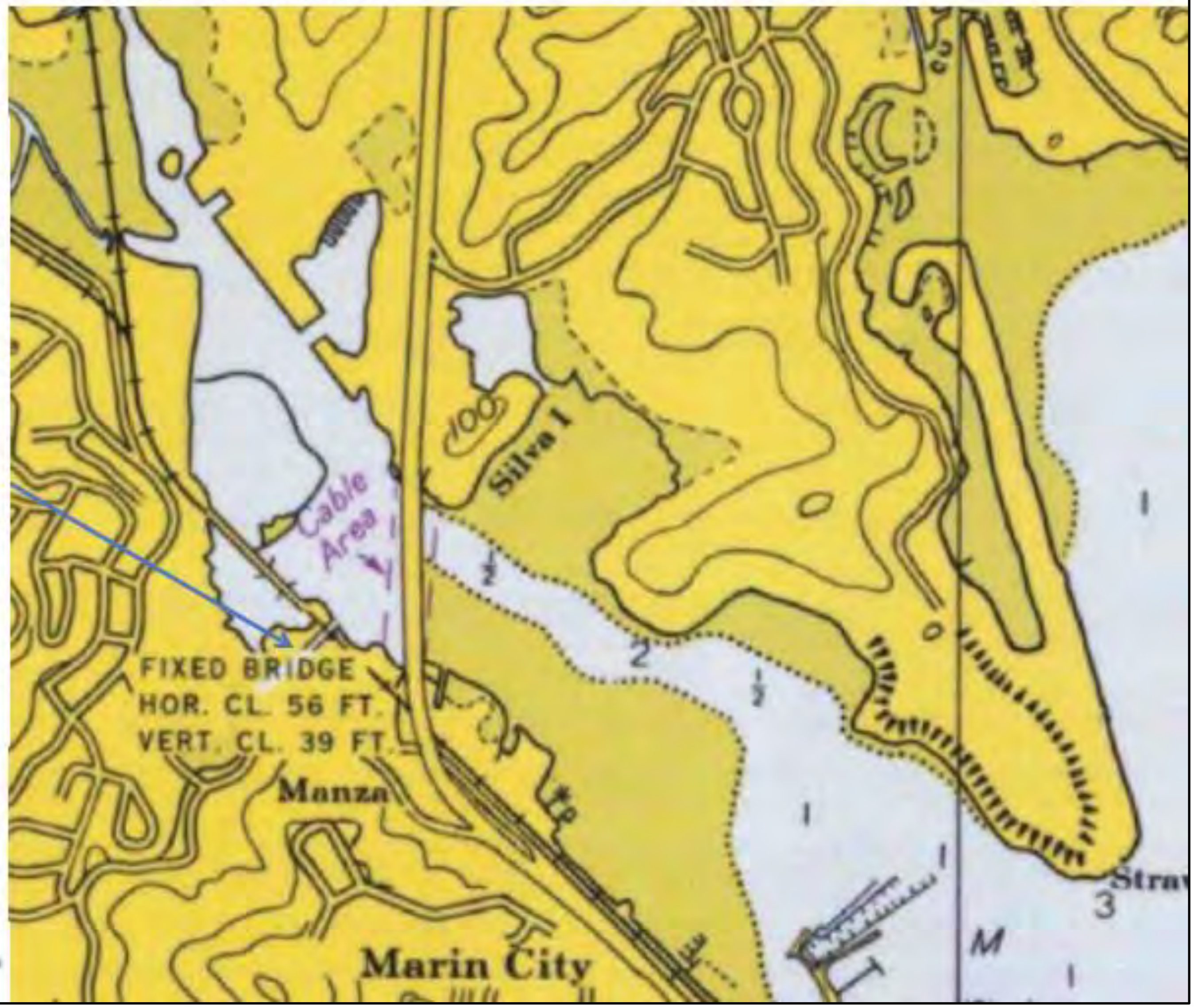
Ref 99



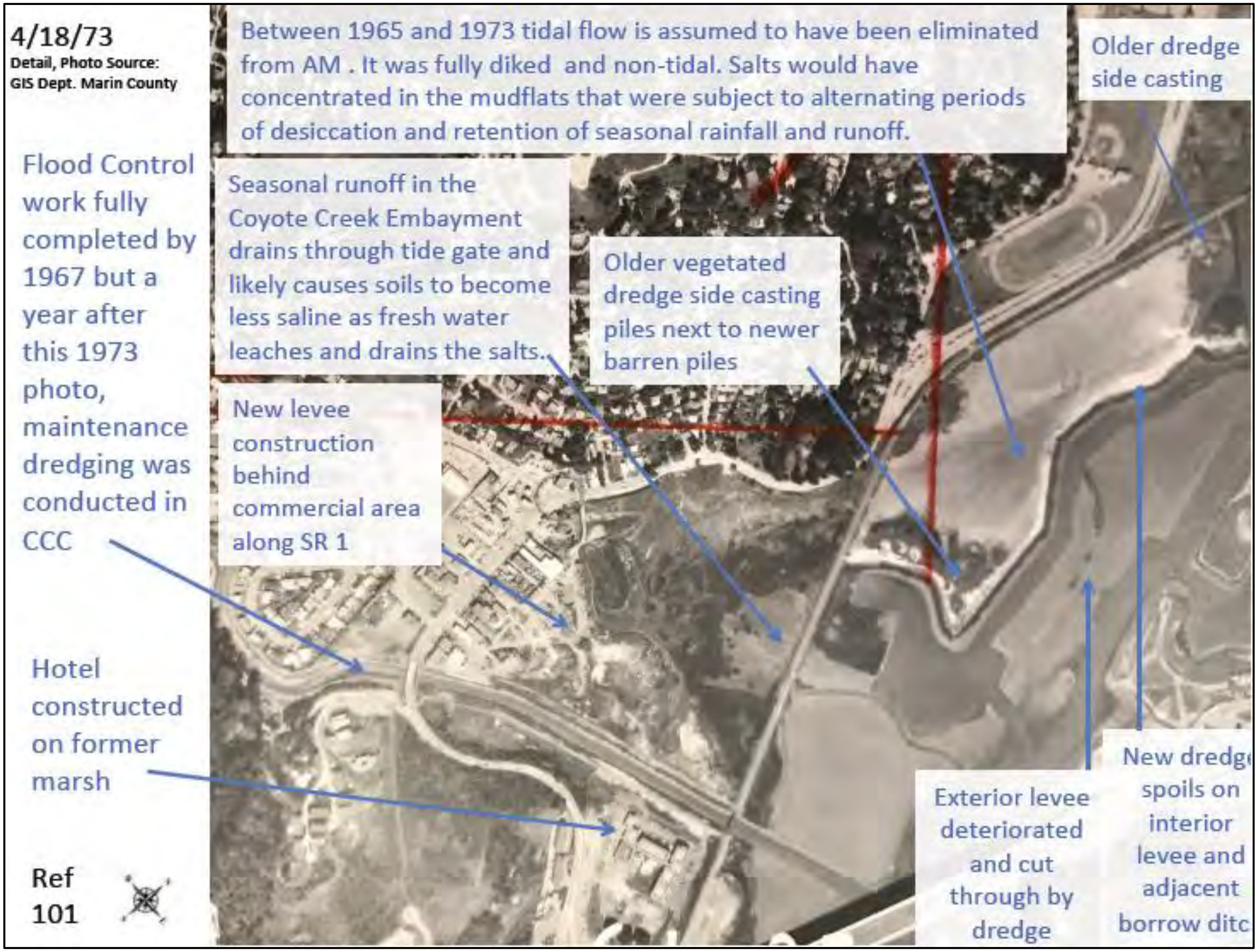
1970, San Francisco Entrance, U.S. Coast Survey Chart 5532

Map Source: https://historicalcharts.noaa.gov/historicals/search#searchInput

This map uses older 1966 bay marsh, and bathymetry information, however CCC and navigation dimensions for Hwy 101 Richardson Bay Bridge are shown at the southwest end of the bridge.



Ref 100


4/18/73
Detail, Photo Source:
GIS Dept. Marin County
Flood Control work fully completed by 1967 but a year after this 1973 photo, maintenance dredging was conducted in CCC
Hotel constructed on former marsh
Ref 101
Between 1965 and 1973 tidal flow is assumed to have been eliminated from AM . It was fully diked and non-tidal. Salts would have concentrated in the mudflats that were subject to alternating periods of desiccation and retention of seasonal rainfall and runoff.
Older dredge side casting
Seasonal runoff in the Coyote Creek Embayment drains through tide gate and likely causes soils to become less saline as fresh water leaches and drains the salts..
Older vegetated dredge side casting piles next to newer barren piles
New levee construction behind commercial area along SR 1
Exterior levee deteriorated and cut through by dredge
New dredg spoils on interior levee and adjacent borrow ditc

4/21/73, Detail of

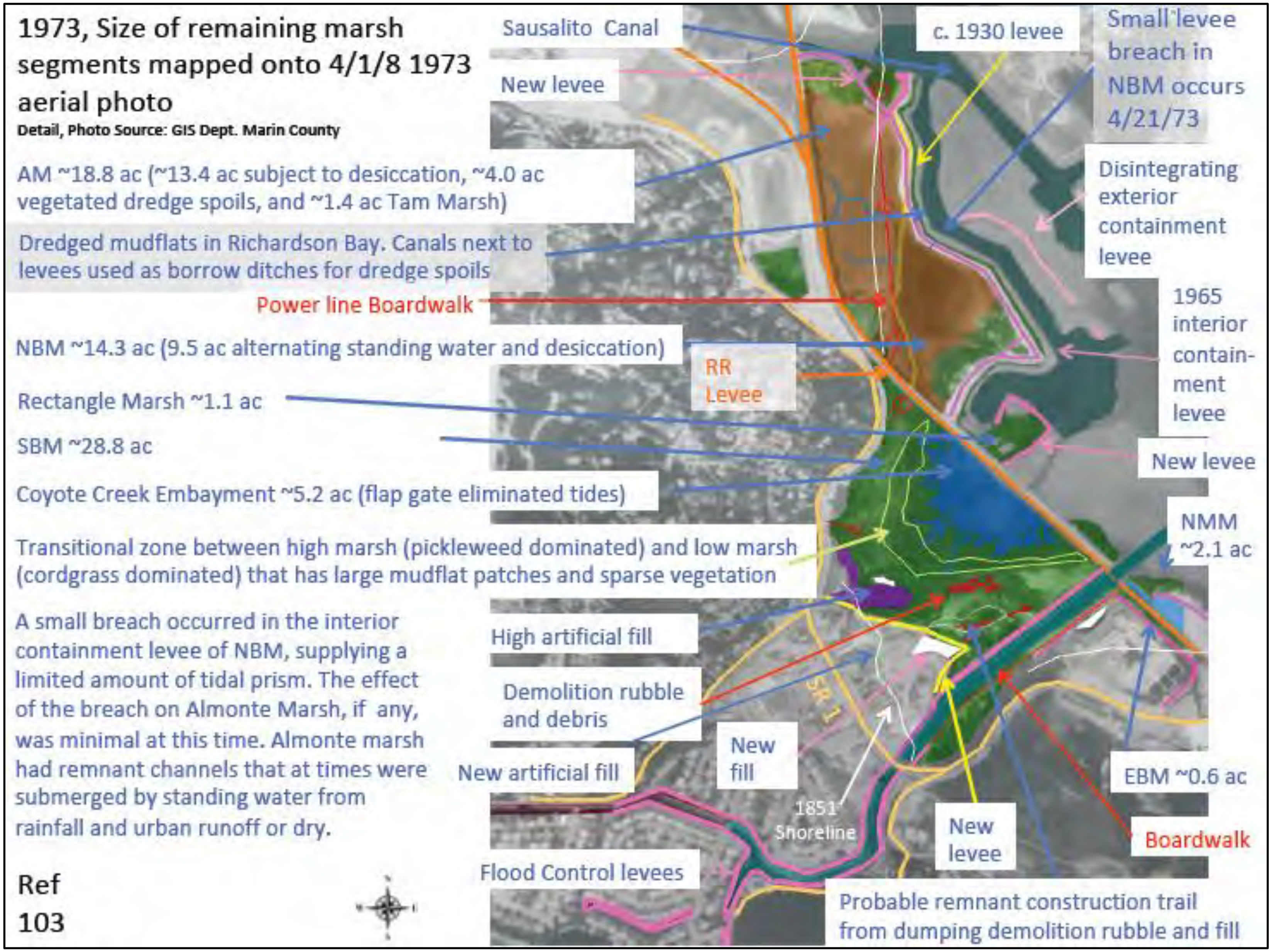
Photo Source: GIS Dept. Marin County

This photo that was taken 4 days after the previous Image Ref #101 and indicates a very small, perhaps shallow breach at the eastern edge of interior containment levee.

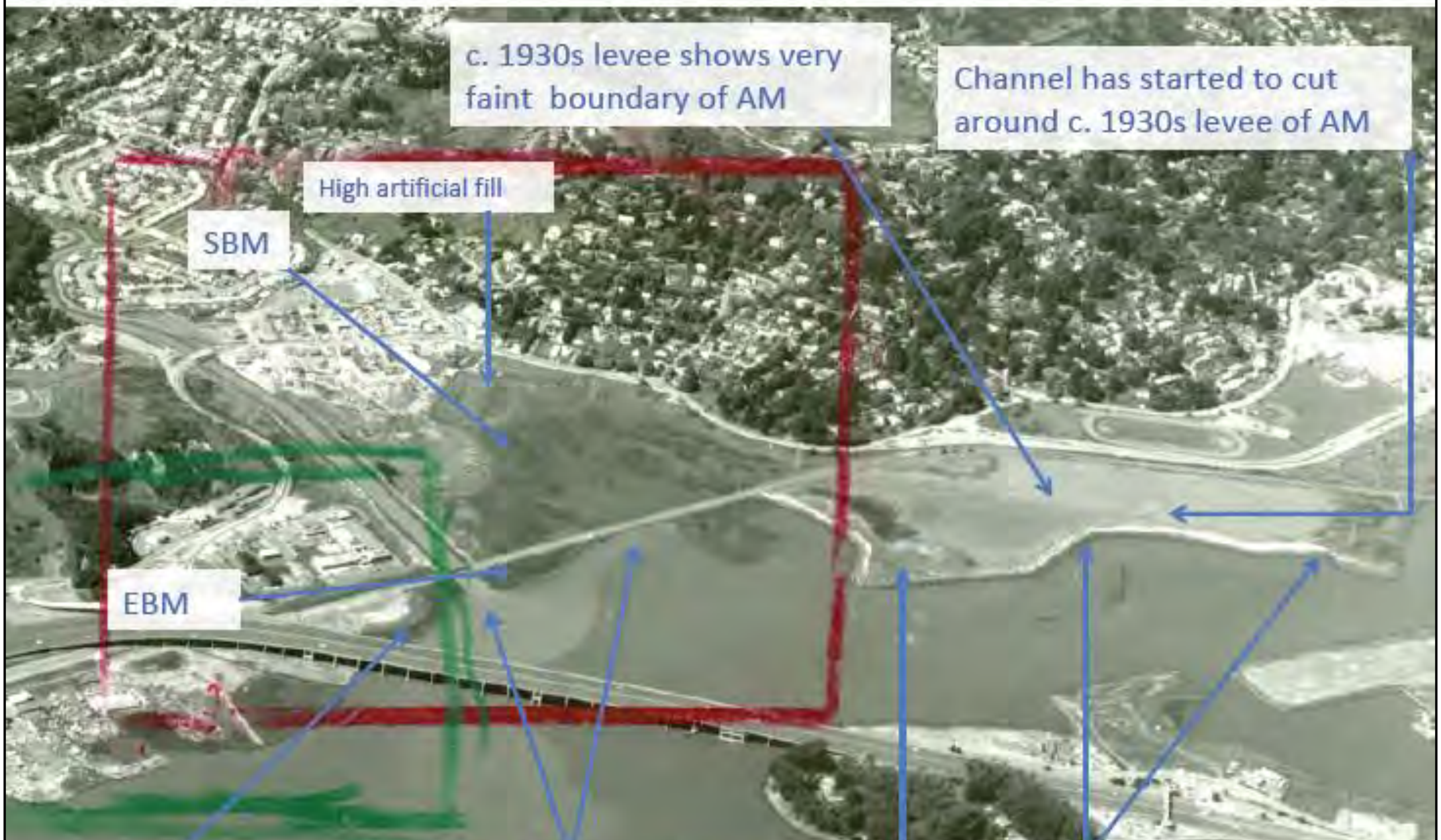
Oldest dredge spoils possibly place during construction of RR levee.

Uniform trapazoidal channel was completed by 1967

Ref 102

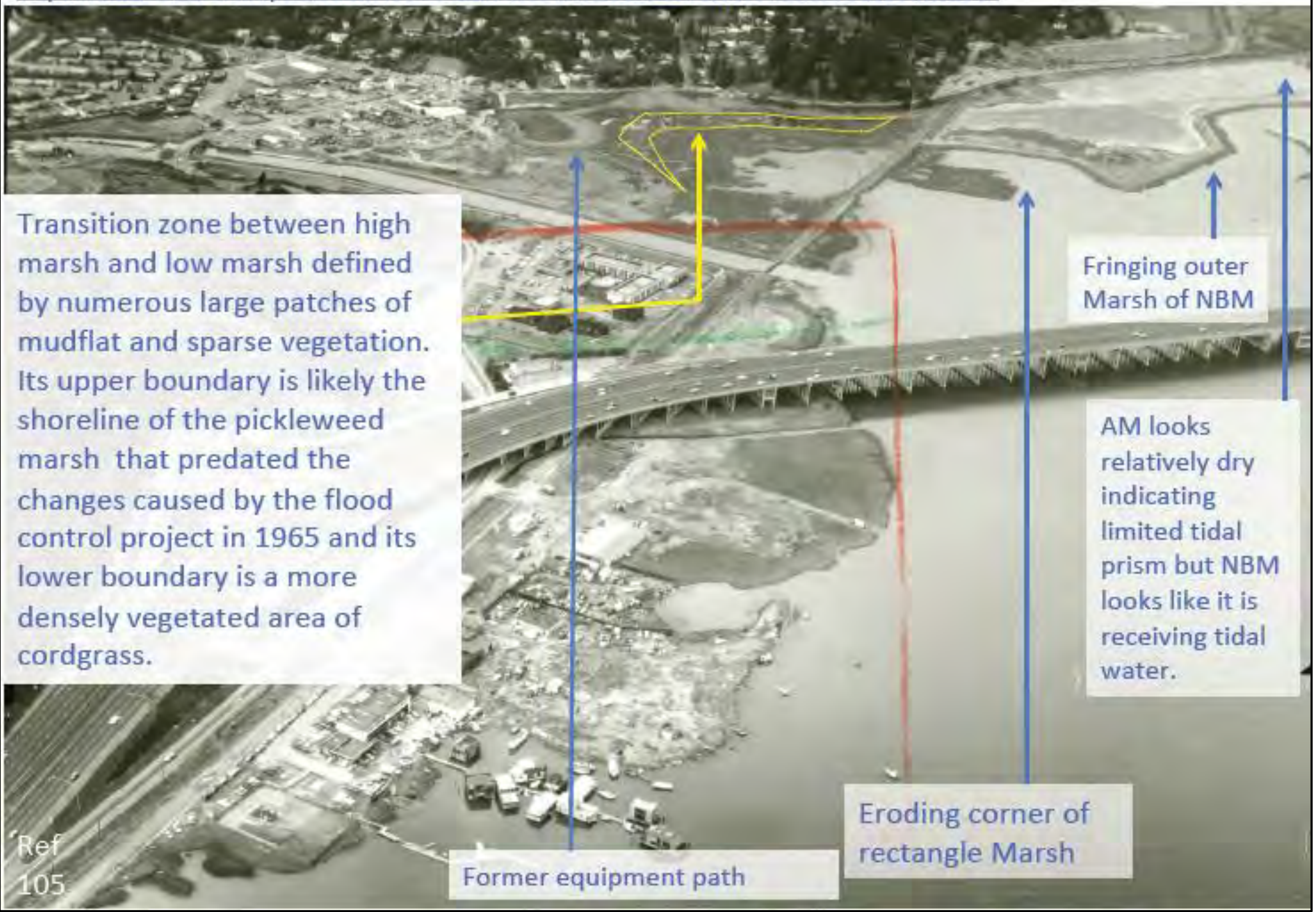

1973, Size of remaining marsh segments mapped onto 4/1/8 1973 aerial photo
Detail, Photo Source: GIS Dept. Marin County
AM ~18.8 ac (~13.4 ac subject to desiccation, ~4.0 ac vegetated dredge spoils, and ~1.4 ac Tam Marsh)
Dredged mudflats in Richardson Bay. Canals next to levees used as borrow ditches for dredge spoils
Power line Boardwalk
NBM ~14.3 ac (9.5 ac alternating standing water and desiccation)
Rectangle Marsh ~1.1 ac
SBM ~28.8 ac
Coyote Creek Embayment ~5.2 ac (flap gate eliminated tides)
Transitional zone between high marsh (pickleweed dominated) and low marsh (cordgrass dominated) that has large mudflat patches and sparse vegetation
A small breach occurred in the interior containment levee of NBM, supplying a limited amount of tidal prism. The effect of the breach on Almonte Marsh, if any, was minimal at this time. Almonte marsh had remnant channels that at times were submerged by standing water from rainfall and urban runoff or dry.
Ref 103
Sausalito Canal
New levee
c. 1930 levee
Small levee breach in NBM occurs 4/21/73
Disintegrating exterior containment levee
1965 interior contain-ment levee
RR Levee
New levee
NMM ~2.1 ac
High artificial fill
Demolition rubble and debris
New fill
New artificial fill
SR 1
1851 Shoreline
New levee
EBM ~0.6 ac
Boardwalk
Flood Control levees
Probable remnant construction trail from dumping demolition rubble and fill

4/3/1974. Brady Collection Marin History Museum, detail of photo 8097543117_4f8658fcca
Photo Source: https://www.flickr.com/photos/25539851@N05/8097543117/in/album-72157631793232232/



Ref 104 NMM Silty water of CCC, some of which recirculates into SBM during flood tide. NBM Breach in interior containment levee of NBM

11/17/1974. Brady Collection Marin History Museum, detail of photo 8097553838_740e449d37_o
https://www.flickr.com/photos/25539851@N05/8097553838/in/album-72157631793232232/



1975, San Francisco Entrance, U.S. Coast Survey Chart 5532

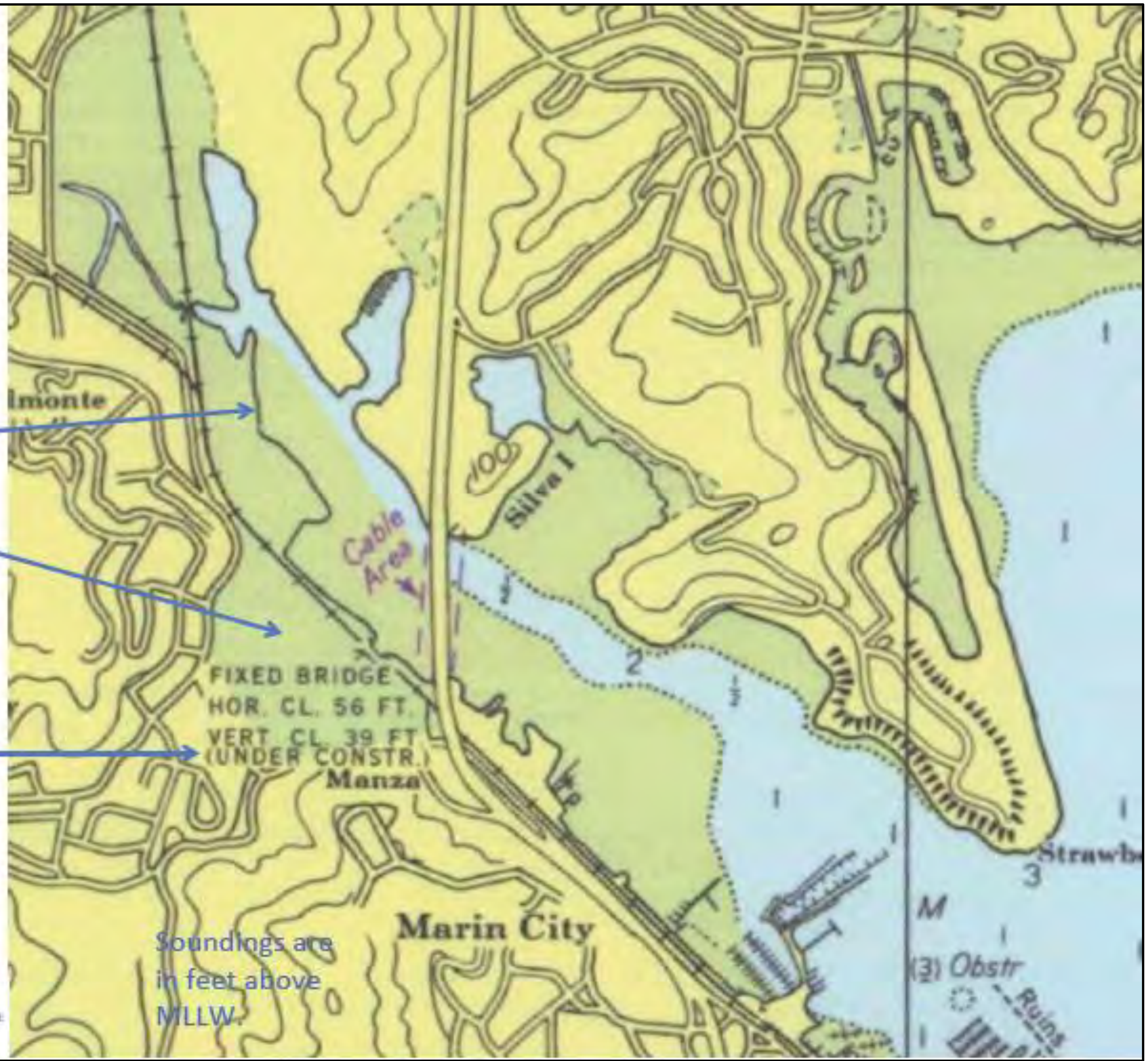
Map Source: https://historicalcharts.noaa.gov/historicals/search#searchInput

Inner containment levee depicted

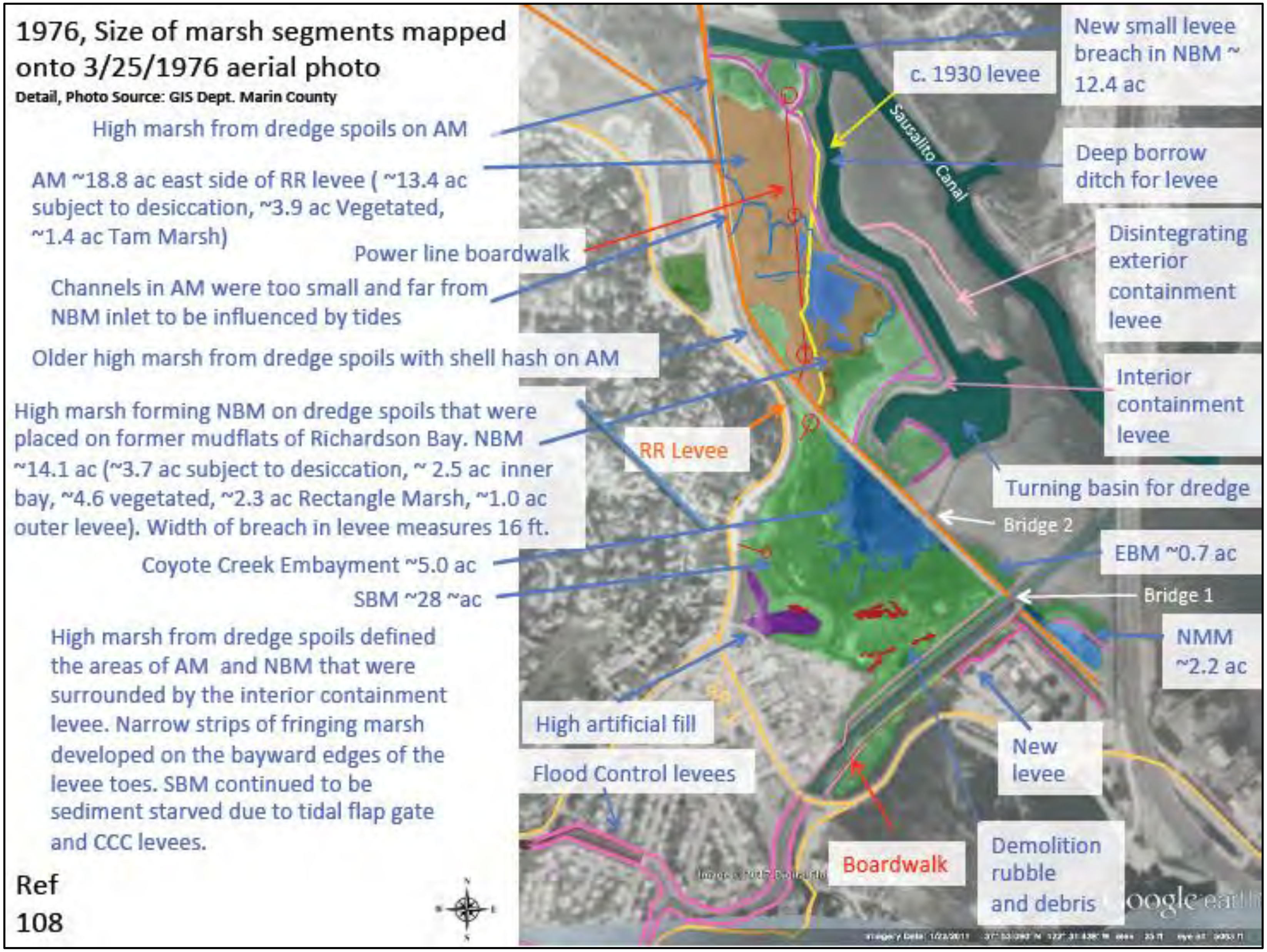
Coyote Creek Embayment not depicted, possibly indicating no tidal connection but CCC is not indicated either.

Richardson Bay Bridge is noted to be under construction

Ref 106




3/25/1976,
Photo Source: GIS
Dept. Marin County
A depositional bar expands at the head of Richardson Bay in the ebb lee of exterior containment levee. Its presence contributes to tidal prism reductions at the head of the Bay
Embayment in NBM
Ref
107


1976, Size of marsh segments mapped onto 3/25/1976 aerial photo
Detail, Photo Source: GIS Dept. Marin County
High marsh from dredge spoils on AM
AM ~18.8 ac east side of RR levee (~13.4 ac subject to desiccation, ~3.9 ac Vegetated, ~1.4 ac Tam Marsh)
Power line boardwalk
Channels in AM were too small and far from NBM inlet to be influenced by tides
Older high marsh from dredge spoils with shell hash on AM
High marsh forming NBM on dredge spoils that were placed on former mudflats of Richardson Bay. NBM ~14.1 ac (~3.7 ac subject to desiccation, ~ 2.5 ac inner bay, ~4.6 vegetated, ~2.3 ac Rectangle Marsh, ~1.0 ac outer levee). Width of breach in levee measures 16 ft.
Coyote Creek Embayment ~5.0 ac
SBM ~28 ~ac
High marsh from dredge spoils defined the areas of AM and NBM that were surrounded by the interior containment levee. Narrow strips of fringing marsh developed on the bayward edges of the levee toes. SBM continued to be sediment starved due to tidal flap gate and CCC levees.
Ref
108
New small levee breach in NBM ~ 12.4 ac
c. 1930 levee
Sausalito Canal
Deep borrow ditch for levee
Disintegrating exterior containment levee
Interior containment levee
RR Levee
Turning basin for dredge
Bridge 2
EBM ~0.7 ac
Bridge 1
NMM ~2.2 ac
High artificial fill
Flood Control levees
New levee
Boardwalk
Demolition rubble and debris
Google earth

1978, Size of marsh segments mapped onto 3/15/1978 aerial photo

Detail, Photo Source: GIS Dept. Marin County

Breaches in c. 1930 levee provide limited access of tides from reconnected channel to AM which had ~4.4 ac of vegetation on dredge spoils and ~13.4 ac alternately desiccated or flooded, and ~1.4 ac were muted tides of Tam Marsh. In total Am was ~18.8 ac.

High marsh forming NBM on dredge spoils that were placed on former mudflats of Richardson Bay. NBM ~14.0 ac (4.4 ac subject to desiccation, ~ 1.7 ac inner bay, ~4.9 vegetated, ~2.1 ac Rectangle Marsh, ~0.9 ac outer levee)

Breach of western edge of the former “inner berm” levee provides tidal connection to NBM but still very limited tidal connection to AM due to c. 1930 levee. A portion of the inner mud flat was deep enough that it maintained an open water embayment whereas much of the area that would previously become desiccated was now subject to diurnal tides.

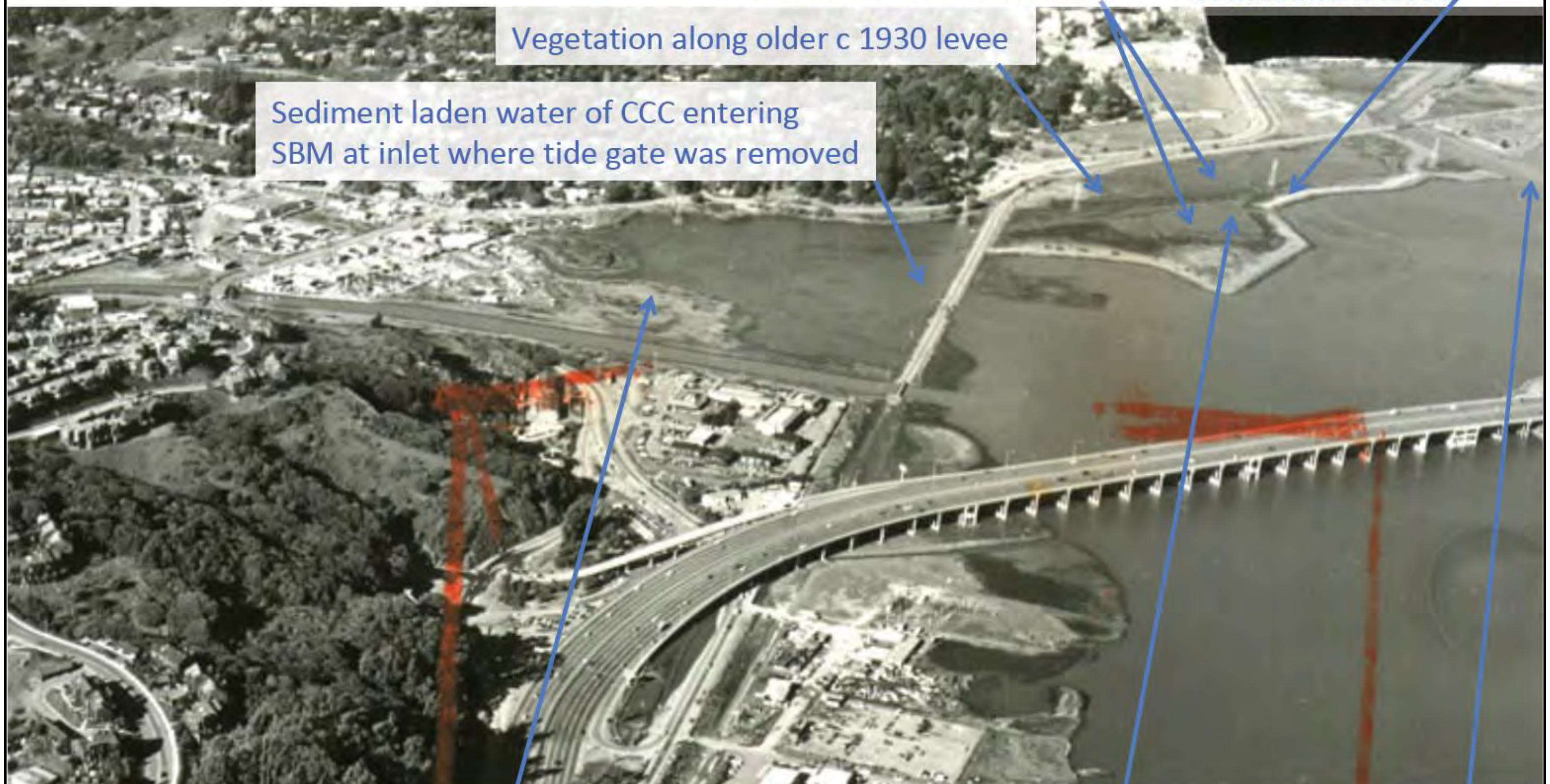
Ref 109

SBM ~28.1 ac It has ~8.9 ac transitional ecotone (buff color) with low areas subject to ponding interspersed with patchy mud flats interspersed with sparse vegetation and that was subject to desiccation. There was ~19.2 ac upper ecotone marsh.

1/7/82 Brady Collection Marin History Museum, detail of photo 9203005392_8a9c940470_o
https://www.flickr.com/photos/25539851@N05/9203005392/in/album-72157631793232232/

Two basins of AM and NBM

Levee breach of Inner containment levee



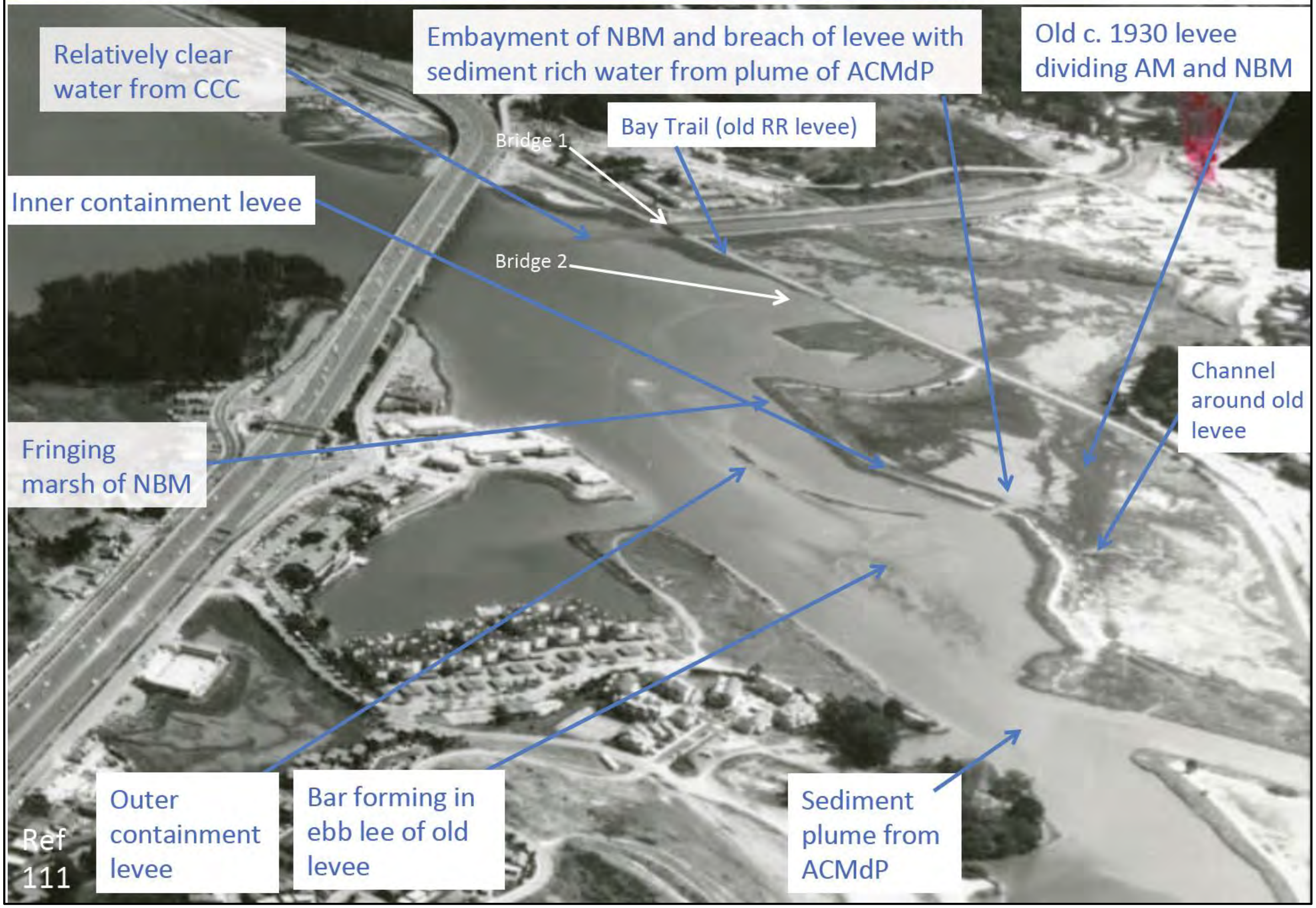
Following the removal of the tidal flap gate, the tide is once again inundating most of South Bothin Marsh. Older alluvial fan and high area of artificial fill are above the flood tide in this photo.

Almonte Marsh and North Bothin Marsh connect after levee breach through a small channel along the c. 1930 levee

Sediment rich water of ACMdP

Ref 110

5/18/83 Brady Collection Marin History Museum, detail of photo 8097553838_740e449d37_o
https://www.flickr.com/photos/25539851@N05/9186712606/in/album-72157631793232232/



1987, Size of remaining marsh segments mapped onto 6/1987 Google Earth Imagery

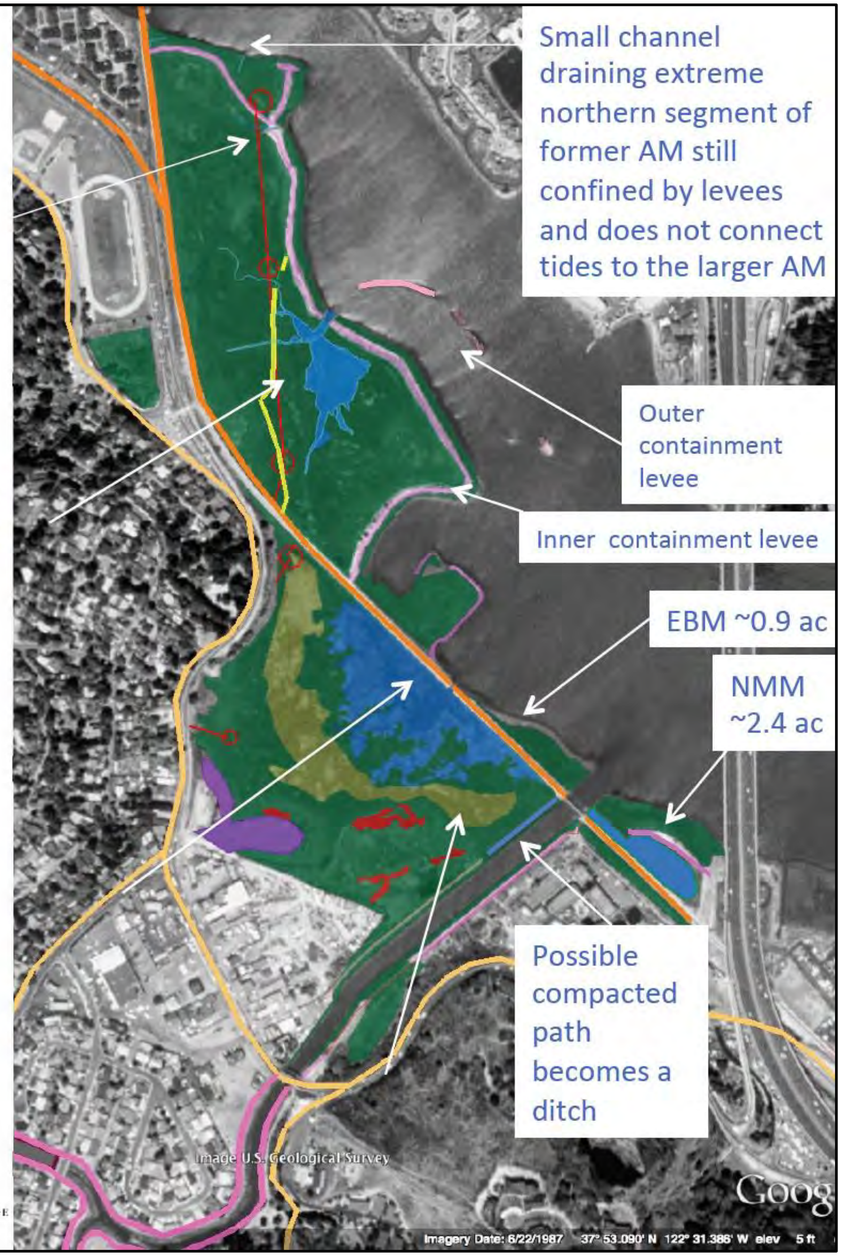
Photo Source: Google Earth

New small channel appears draining the northeastern part of AM, but it has very limited tidal prism and leads into an area surrounded by higher elevation dredge spoils. AM ~18.4 ac (~17.0 ac marsh and ~1.4 ac Tam Marsh)

Daily tides connected AM and NBM through two small channels that emanated from the single levee breach in NBM, which increased in width to 32 ft from its former 20 ft in 1978. The vegetation in NBM marsh increased to ~10.1 ac while the embayment stayed nearly the same in size (~1.6 ac) but probably shallowed. The desiccated area disappeared. The fringe and Rectangle marshes both increased, ~1.5 ac and ~2.4 ac respectively. In total it was ~15.6 ac. The width of the breach increased to 32 ft.

Tide gate had been removed around 1981 when the Bay Trail was constructed and a new 26-foot-wide bridge at the inlet was constructed to drain the Coyote Creek Embayment. SBM maintained its ~28.1 ac and Coyote Creek embayment increased to ~6.1 ac since the water level was now elevated by the tides rather than seasonally desiccated. The transition zone of ~5.7 ac of patchy mudflats and sparse vegetation narrowed as vegetated colonized the lower boundary.

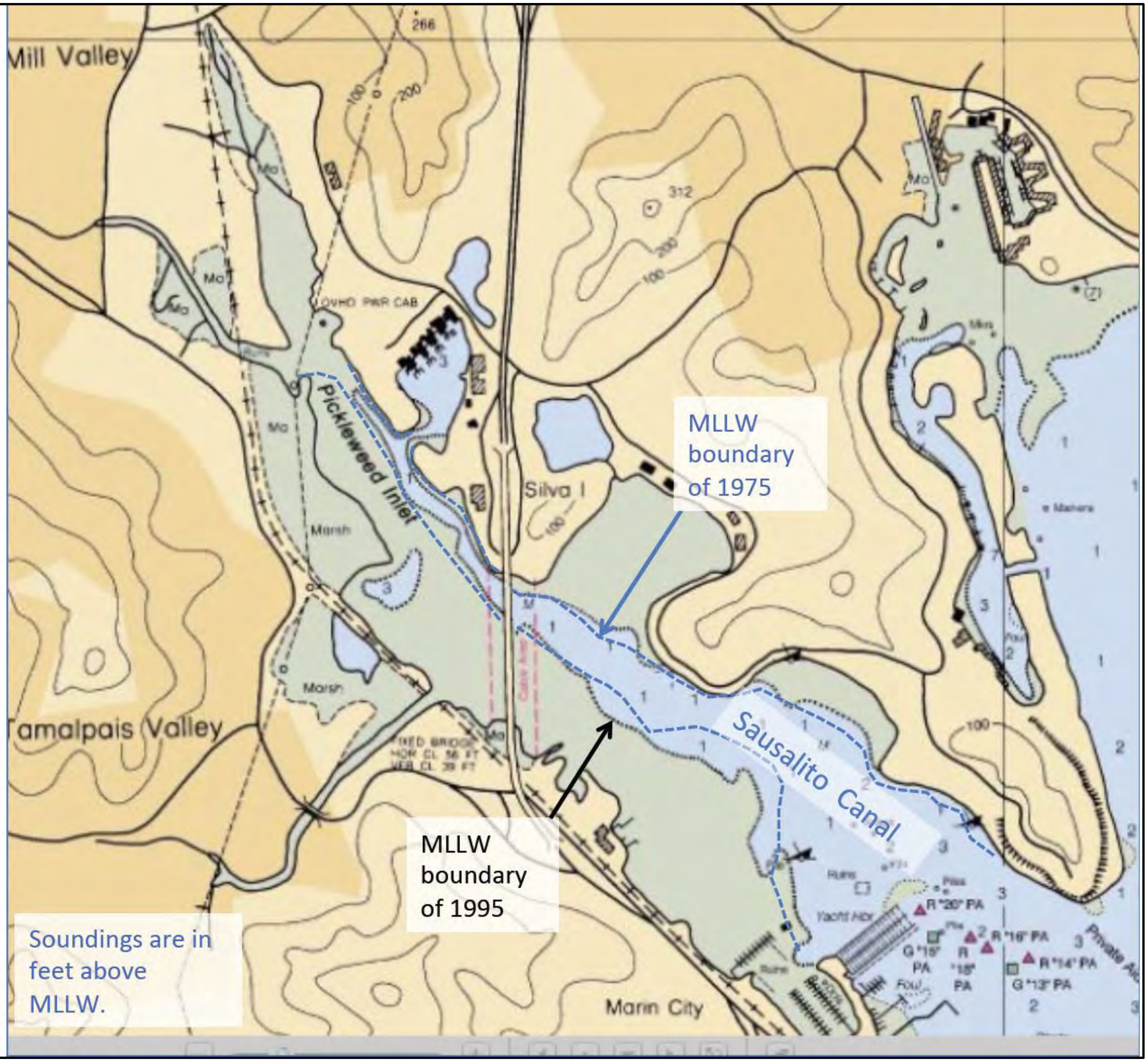
Ref
112



1995, San Francisco Entrance, U.S. Coast Survey Chart 5532 Map Source: https://https://historicalcharts.noaa.gov/historicals/search#mainTitle

The MLLW boundary from the 1975 Chart 5532 (Image Ref #106) was superimposed onto this 1995 chart (blue dashed line). A comparison indicates that the Sausalito Canal MLLW boundary has widened slightly south of Richardson Bridge but narrowed upstream of it where it is now named Pickleweed Inlet. The canal also became more uniformly shallow, eliminating deep areas.

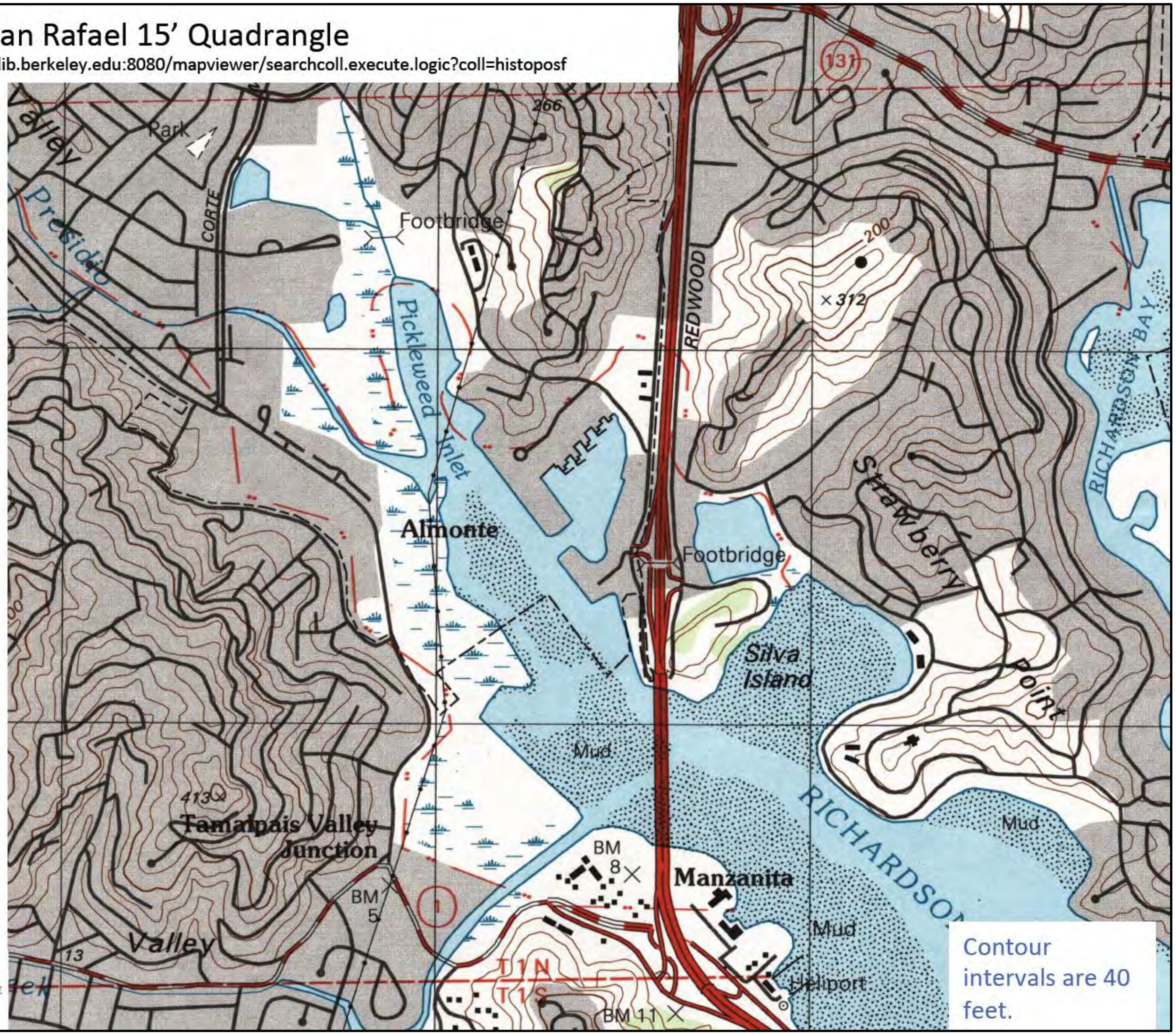
Ref 113



1999, USGS San Rafael 15' Quadrangle

Source: http://servlet1.lib.berkeley.edu:8080/mapviewer/searchcoll.execute.logic?coll=histoposf

The topographic map shows the increased urban development around Richardson Bay (grey areas) and the pattern of dredging and filling that changed its shoreline. The boundary of the mud areas (stippled) versus the deeper water below MLLW do not appear relevant to this date.



Contour intervals are 40 feet.

Ref 114

2005, Size of remaining marsh segments mapped onto 8/2005 Google Earth Imagery

Photo Source: Google Earth

Inner containment levee

AM ~18.2 ac, channel is deepening and widening providing more tidal prism

Borrow ditch shallows

NBM embayment decreased in size to ~0.5 ac as vegetation increased around it to ~11.2 ac. NBM is ~15.4 ac total, had a slight reduction in size of fringe marsh of outer levee ~1.3 ac. Rectangle Marsh maintained its size of ~2.4 ac. Width of the breach increased to 42 ft.

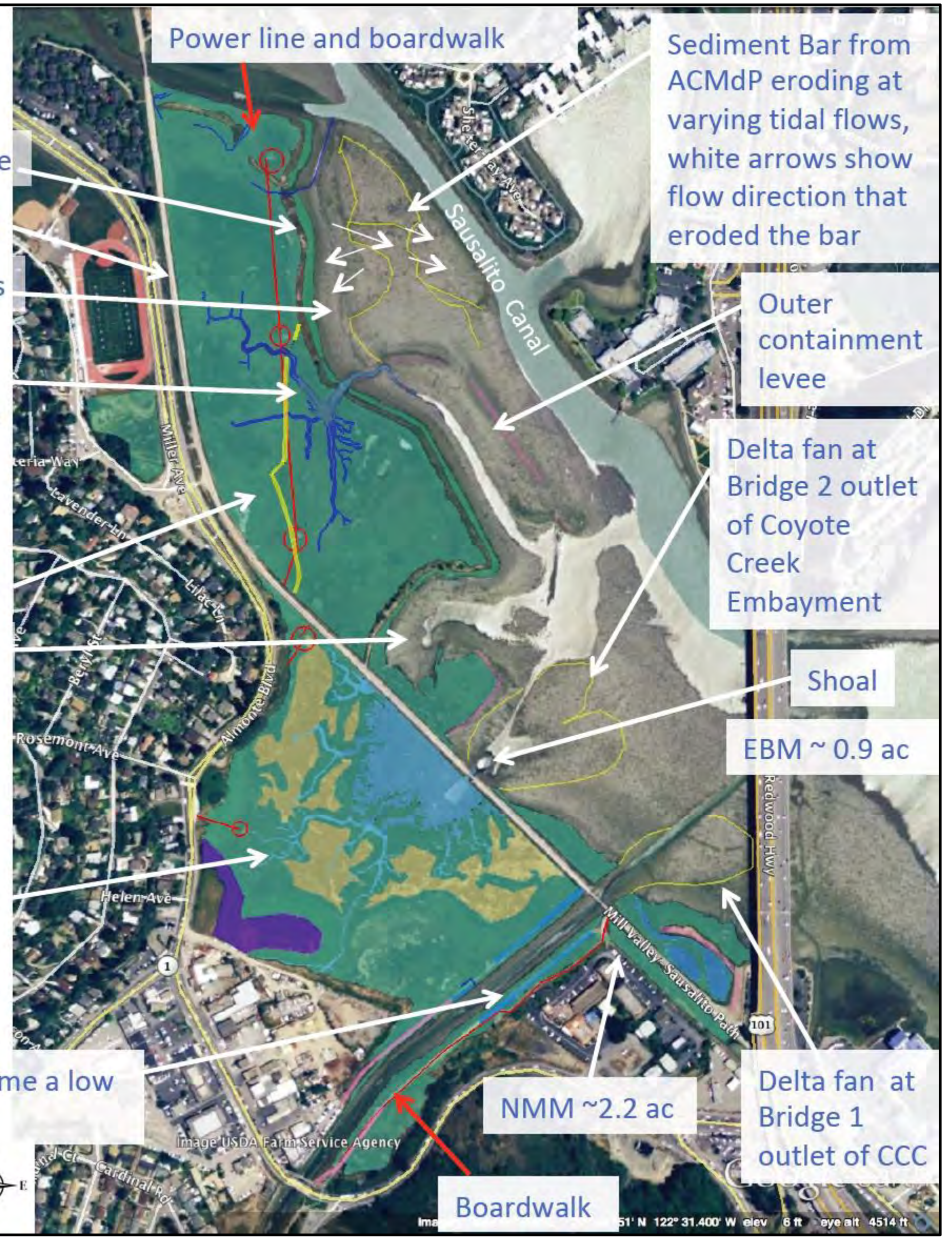
c. 1930 levee that divides AM and NBM

Turning basin for dredge shallows

SBM increased the size of the patchy mudflats transition zone (yellow polygons) to ~6.8 ac but it became divided by some of the larger channels (light blue) that had continuous vegetation along their banks. The acreage of marsh vegetation increased to ~22.8 ac, creating a combined total size of SBM marsh to be ~29.6 ac while the Coyote Creek Embayment (darker blue) decreased to ~3.5 ac.

Former pathway beneath older boardwalk that became a low ditch–like area due to lack of vegetation growth.

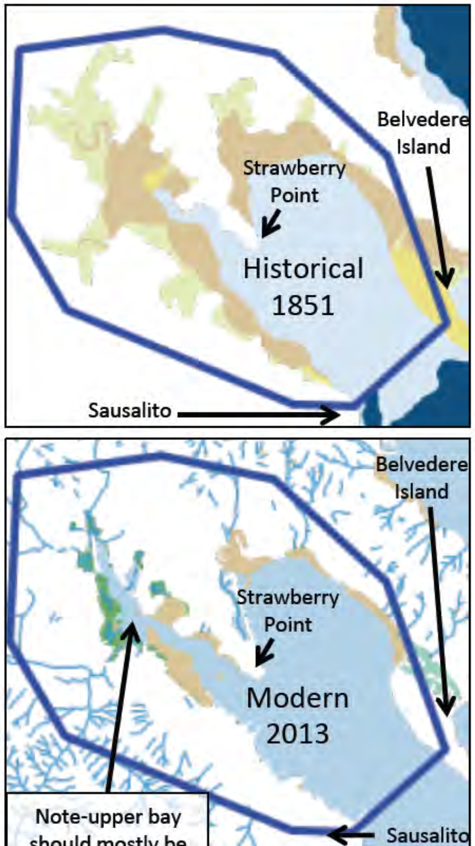
Ref 115



Changes in Modern (2013) and Historical Areas of Marine and Estuarine Wetlands

Map and Data Source: California EcoAtlas San Francisco Estuary Institute, www.ecoatlas .org

Richardson Bay Overall



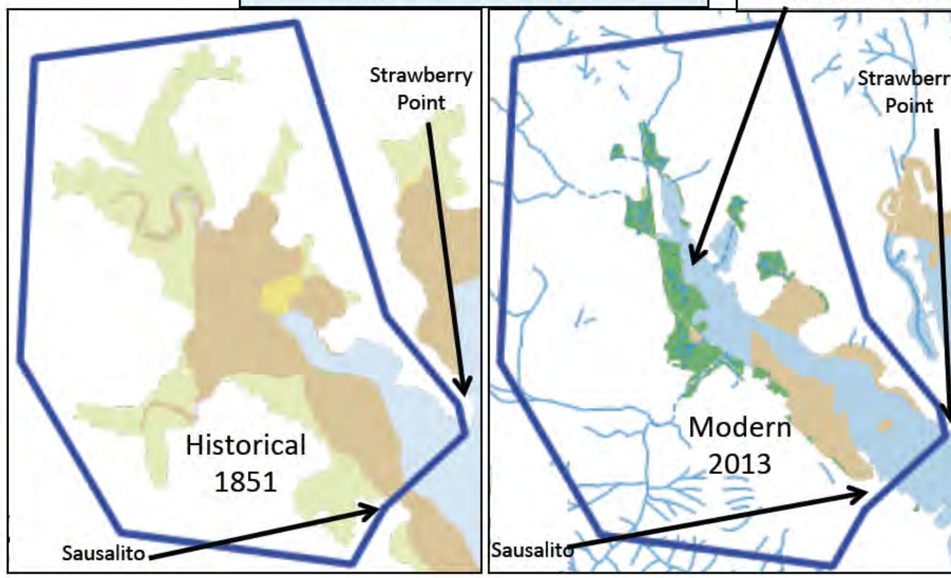
Note-upper bay should mostly be mapped as mud flat not shallow but SFEI map not mapped correct in this area

Marsh
Mudflat
Shallow Bay

Ref 116

Richardson Bay northward of Sausalito and Strawberry Point

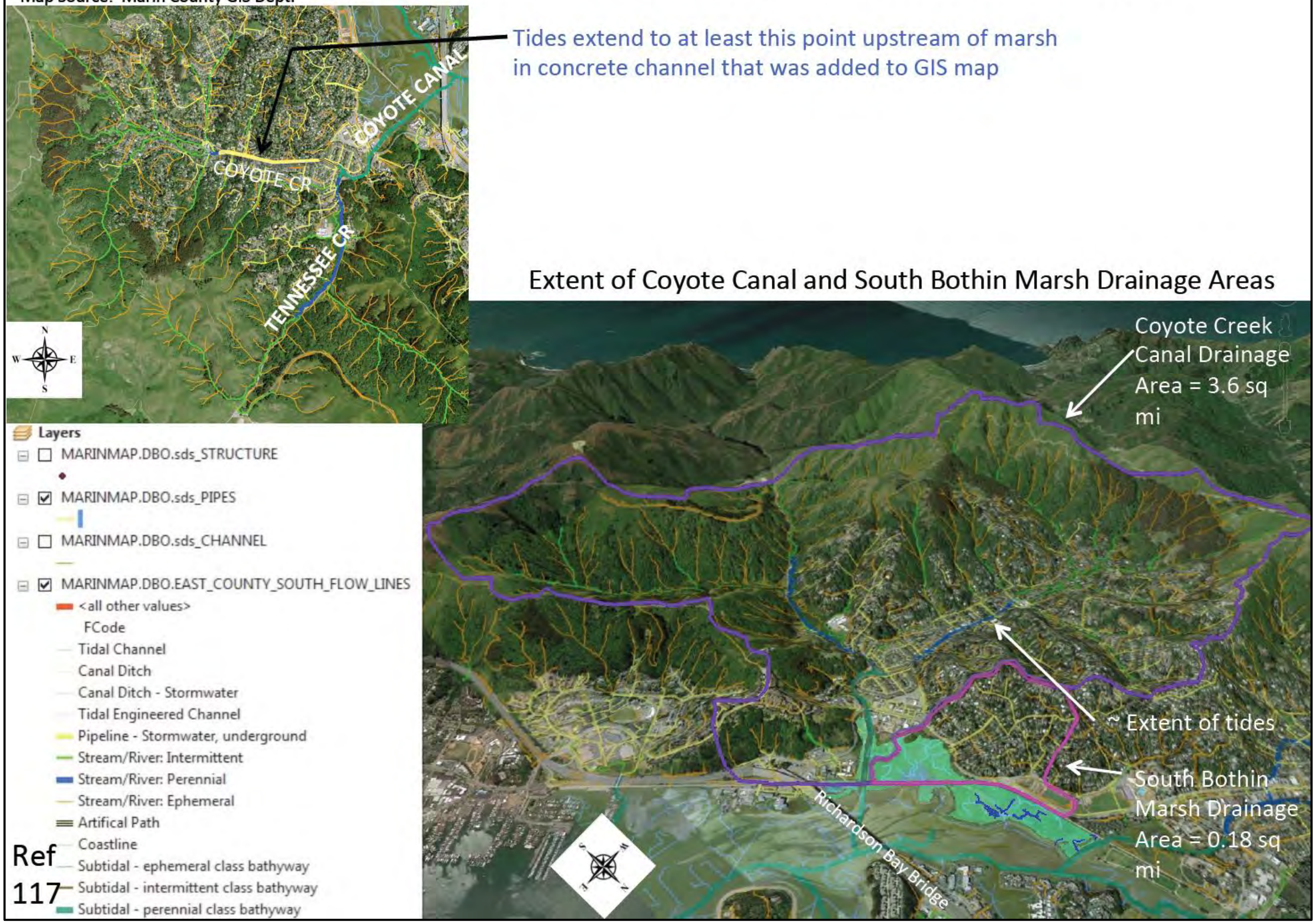
Note- upper bay should mostly be mapped as mud flat not shallow but SFEI map is not correct in this area

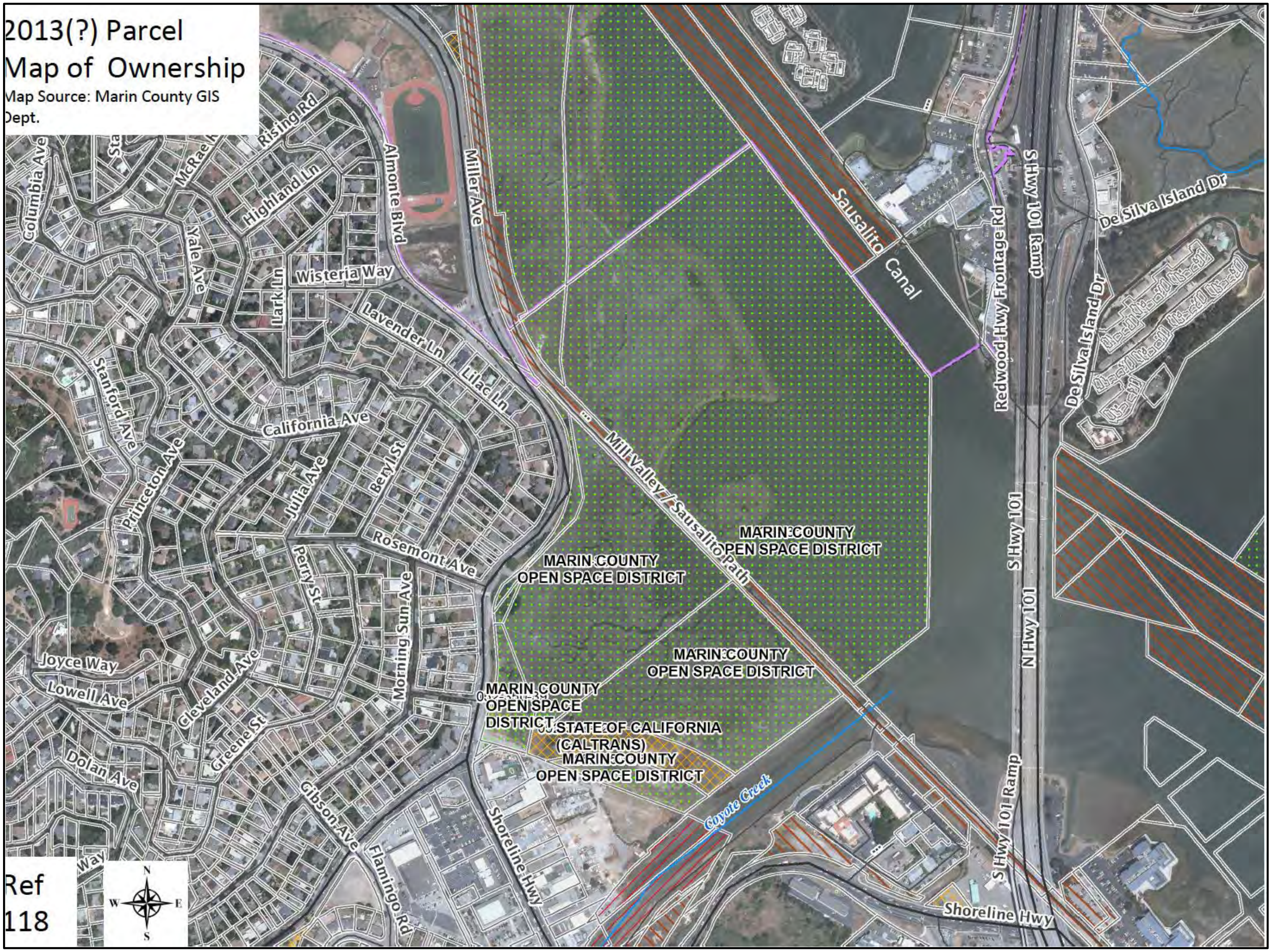


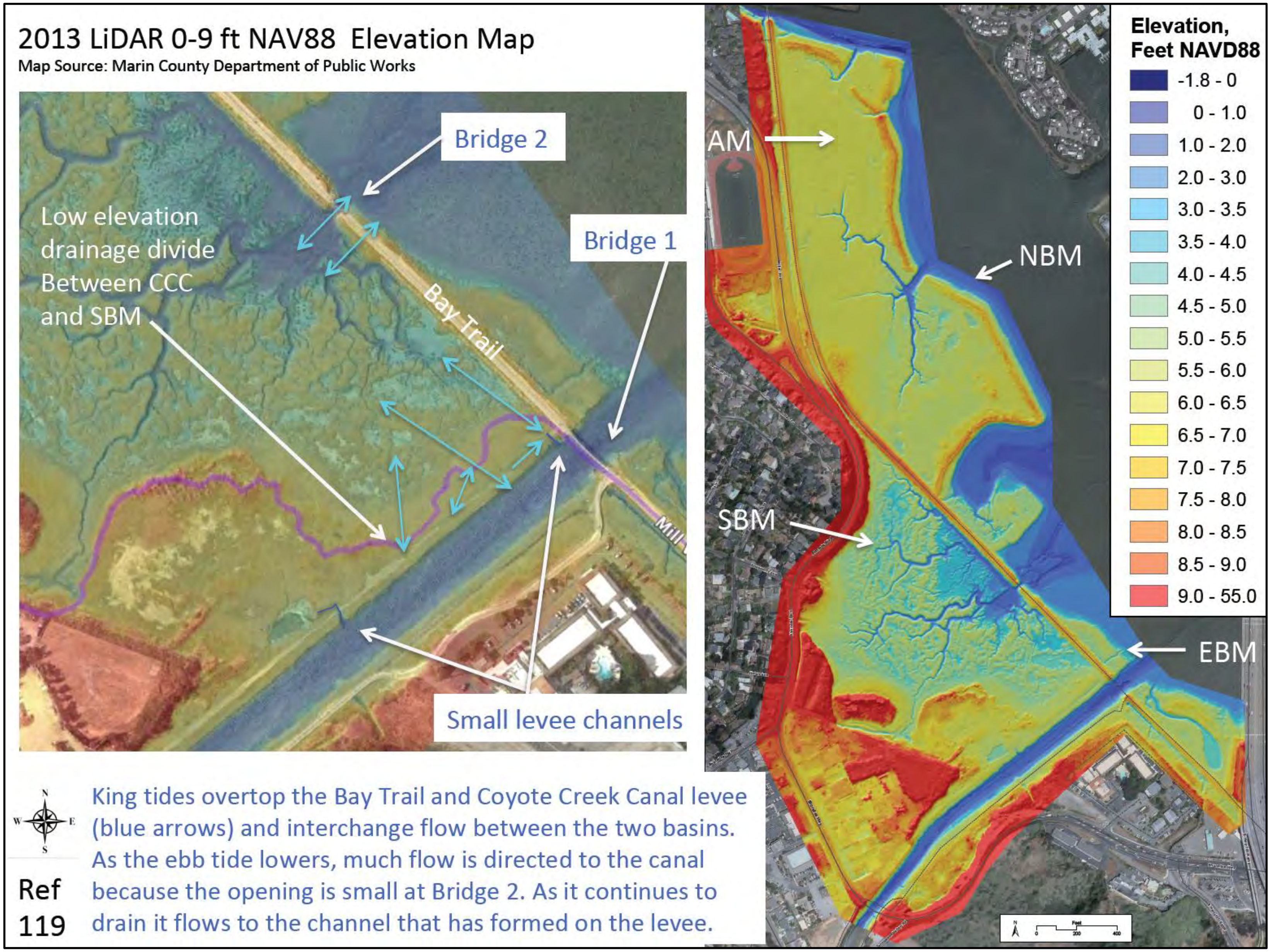
	Modern (acres)	Historical (acres)	Percent Remaining
Richardson Bay Overall			
Marsh	126	620	20
Mudflat & shallow bay	2,455	2,868	86
Total	2,581	3,488	73
Richardson Bay northward of Sausalito and Strawberry Point			
Marsh	124	486	26
Mudflat & shallow bay	431	613	70
Total	555	1,099	50

2013 Storm drain map superimposed on aerial photography and Google Earth Imagery

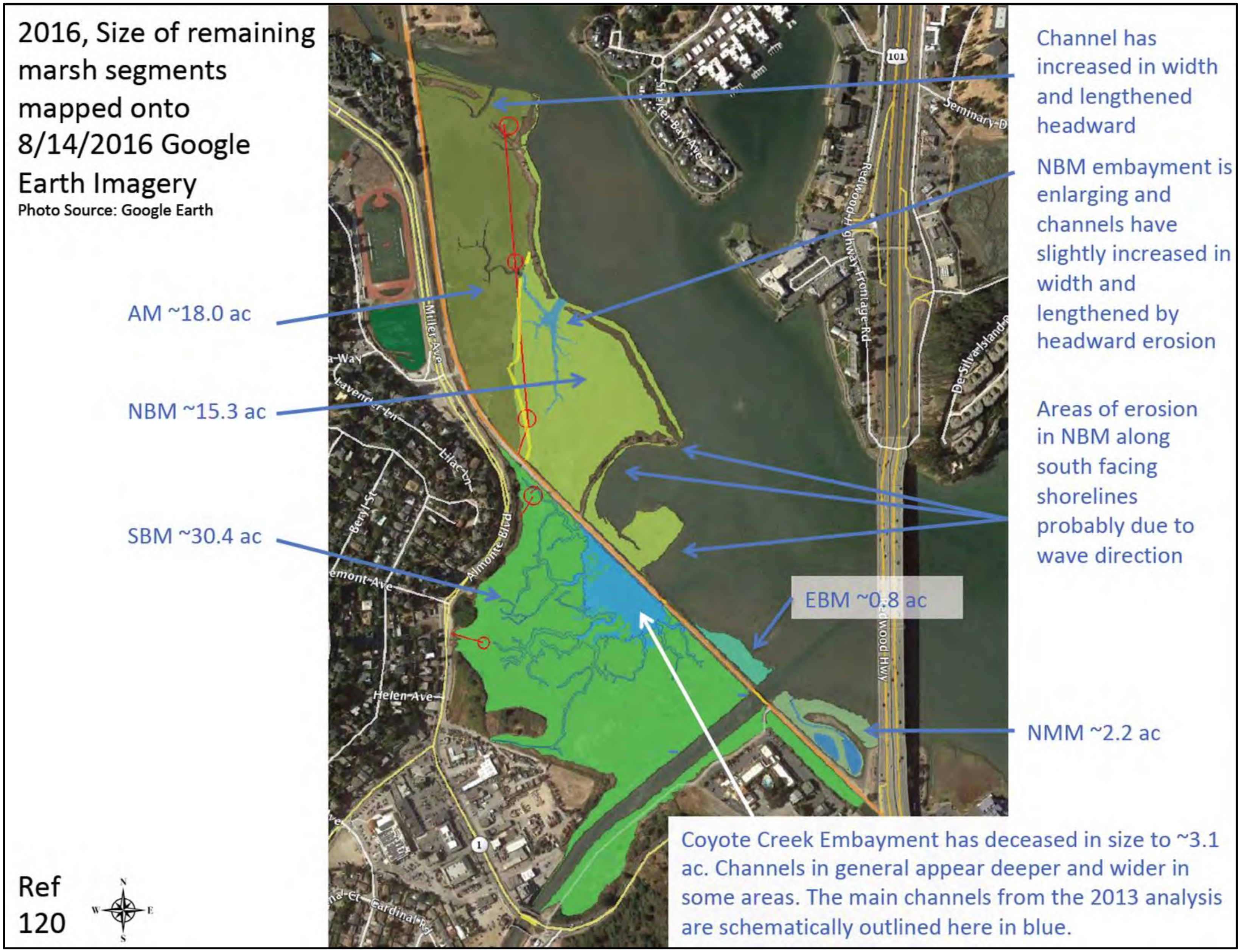
Map Source: Marin County GIS Dept.

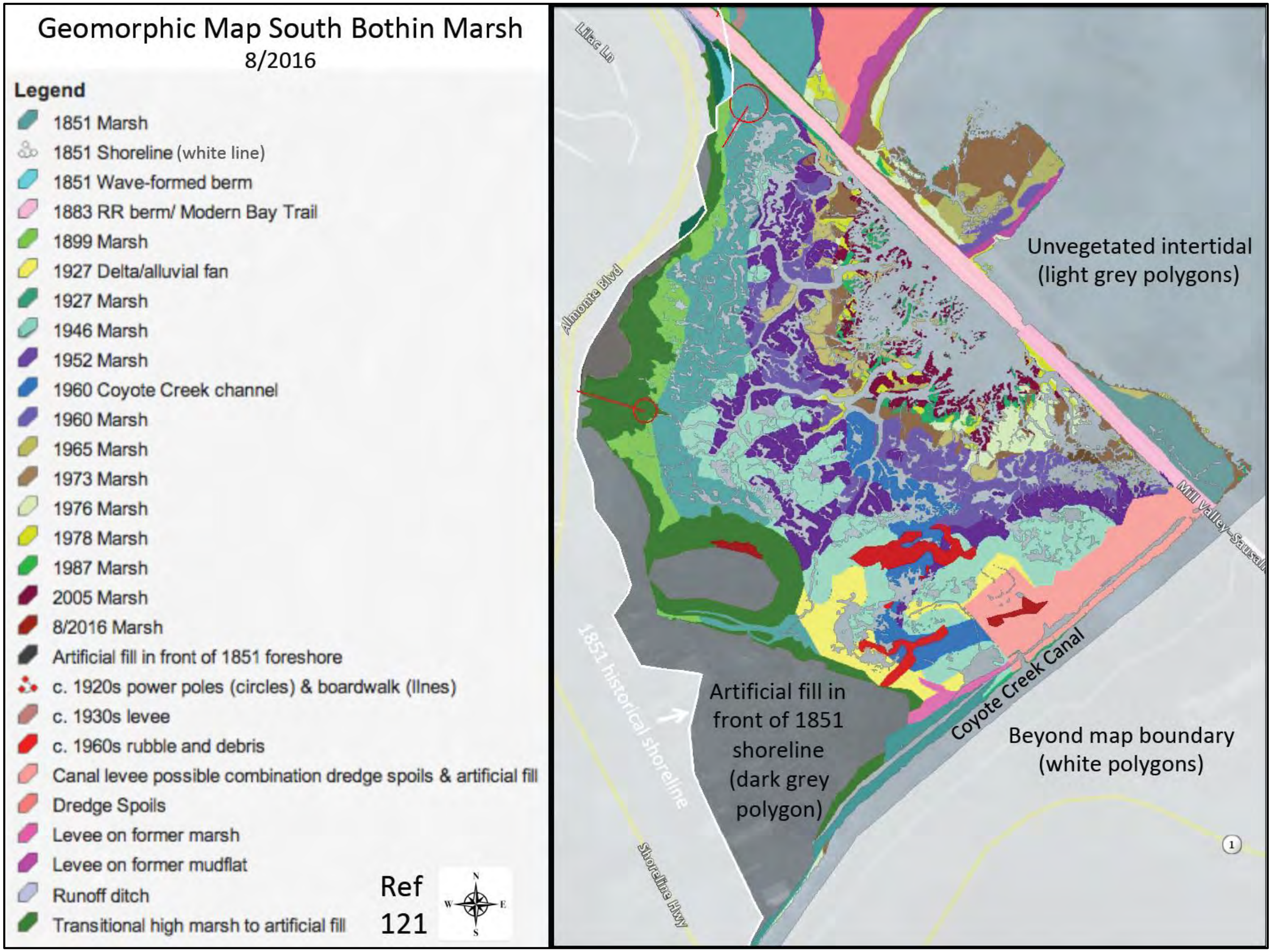


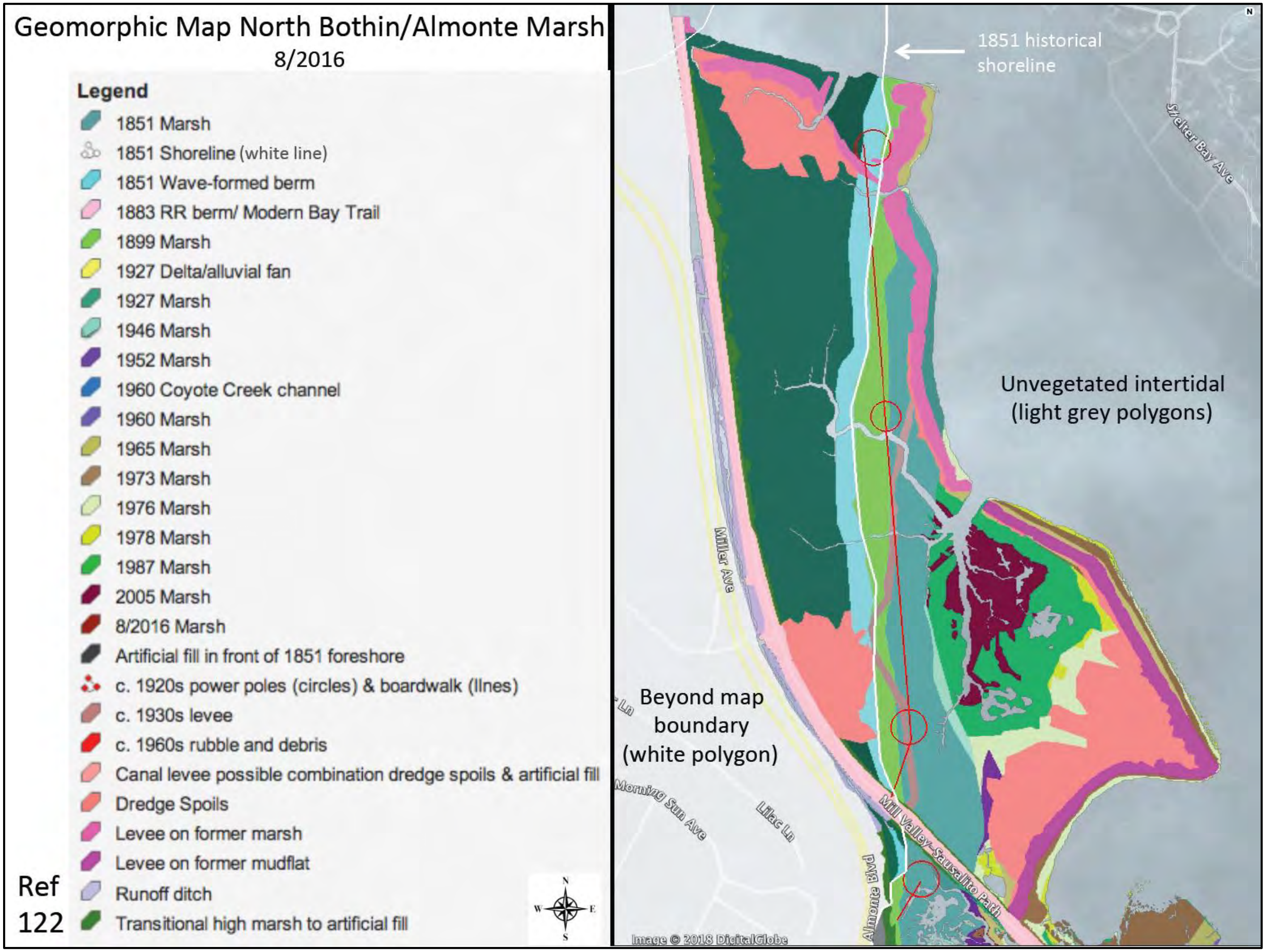

2013(?) Parcel
Map of Ownership
Map Source: Marin County GIS Dept.
Ref
118
N
S
E
W
MARIN COUNTY
OPEN SPACE DISTRICT
MARIN COUNTY
OPEN SPACE DISTRICT
MARIN COUNTY
OPEN SPACE DISTRICT
MARIN COUNTY
OPEN SPACE
DISTRICT
STATE OF CALIFORNIA
(CALTRANS)
MARIN COUNTY
OPEN SPACE DISTRICT
Mill Valley / Sausalito Path
Sausalito
Canal
Coyote Creek
Miller Ave
Almonte Blvd
Rising Rd
Highland Ln
Wisteria Way
Lavender Ln
Lilac Ln
California Ave
Rosemont Ave
Columbia Ave
Yale Ave
Lark Ln
Stanford Ave
Princeton Ave
Julia Ave
Beryl St
Perry St
Morning Sun Ave
Joyce Way
Lowell Ave
Cleveland Ave
Greene St
Dolan Ave
Gibson Ave
Flamingo Rd
Shoreline Hwy
Redwood Hwy Frontage Rd
S Hwy 101 Ramp
S Hwy 101
N Hwy 101
De Silva Island Dr



King tides overtop the Bay Trail and Coyote Creek Canal levee (blue arrows) and interchange flow between the two basins. As the ebb tide lowers, much flow is directed to the canal because the opening is small at Bridge 2. As it continues to drain it flows to the channel that has formed on the levee.


2016, Size of remaining marsh segments mapped onto 8/14/2016 Google Earth Imagery
Photo Source: Google Earth
AM ~18.0 ac
NBM ~15.3 ac
SBM ~30.4 ac
Channel has increased in width and lengthened headward
NBM embayment is enlarging and channels have slightly increased in width and lengthened by headward erosion
Areas of erosion in NBM along south facing shorelines probably due to wave direction
EBM ~0.8 ac
NMM ~2.2 ac
Coyote Creek Embayment has deceased in size to ~3.1 ac. Channels in general appear deeper and wider in some areas. The main channels from the 2013 analysis are schematically outlined here in blue.
Ref 120
Miller-Ave
Almonte Blvd
Redwood Hwy
Redwood Highway Frontage Rd
Shelter Bay Ave
Seminary-Dr
De-Silva-Island-Dr
Lavender-Ln
Lilac-Ln
Beryl-St
Helen-Ave
Cardinal-Rd
101
1


Geomorphic Map South Bothin Marsh
8/2016
Legend
1851 Marsh
1851 Shoreline (white line)
1851 Wave-formed berm
1883 RR berm/ Modern Bay Trail
1899 Marsh
1927 Delta/alluvial fan
1927 Marsh
1946 Marsh
1952 Marsh
1960 Coyote Creek channel
1960 Marsh
1965 Marsh
1973 Marsh
1976 Marsh
1978 Marsh
1987 Marsh
2005 Marsh
8/2016 Marsh
Artificial fill in front of 1851 foreshore
c. 1920s power poles (circles) & boardwalk (lines)
c. 1930s levee
c. 1960s rubble and debris
Canal levee possible combination dredge spoils & artificial fill
Dredge Spoils
Levee on former marsh
Levee on former mudflat
Runoff ditch
Transitional high marsh to artificial fill
Ref
121
N
W
E
S
Lilac Ln
Almonte Blvd
Unvegetated intertidal
(light grey polygons)
Mill Valley-Sausal
Coyote Creek Canal
1851 historical shoreline
Artificial fill in
front of 1851
shoreline
(dark grey
polygon)
Beyond map boundary
(white polygons)
Shoreline Hwy
1


Geomorphic Map North Bothin/Almonte Marsh
8/2016
Legend
1851 Marsh
1851 Shoreline (white line)
1851 Wave-formed berm
1883 RR berm/ Modern Bay Trail
1899 Marsh
1927 Delta/alluvial fan
1927 Marsh
1946 Marsh
1952 Marsh
1960 Coyote Creek channel
1960 Marsh
1965 Marsh
1973 Marsh
1976 Marsh
1978 Marsh
1987 Marsh
2005 Marsh
8/2016 Marsh
Artificial fill in front of 1851 foreshore
c. 1920s power poles (circles) & boardwalk (lines)
c. 1930s levee
c. 1960s rubble and debris
Canal levee possible combination dredge spoils & artificial fill
Dredge Spoils
Levee on former marsh
Levee on former mudflat
Runoff ditch
Transitional high marsh to artificial fill
Ref 122
1851 historical shoreline
Shelter Bay Ave
Unvegetated intertidal (light grey polygons)
Miller Ave
Beyond map boundary (white polygon)
Morning Sun Ave
Lilac Ln
Mill Valley-Sausalito Path
Almonte Blvd
Image © 2018 DigitalGlobe

2017 Photo taken in the field 2017 Source: L. Collins

Ref 123 This photo shows that if Coyote Creek was at a very large flood stage during a similarly high or higher tide, the Bay Trail, the small outlet of Coyote Creek Embayment at Bridge 2, and the structure of Bridge 1 would impede the escape and conveyance of flood waters to Richardson Bay. Looking northward. Bridge 1 alt right side of photo.

2017 Photos taken in the field 2017 Source: L. Collins

Sediment-rich water in Coyote Creek

Desiccated backshore areas affected by muted tides

Channels deepening and erosion in the mudflats of the Coyote Creek Embayment

Ref 124

Looking northwest at high tide flowing from Coyote Creek Canal into the South eastern corner of Coyote Creek Embayment.

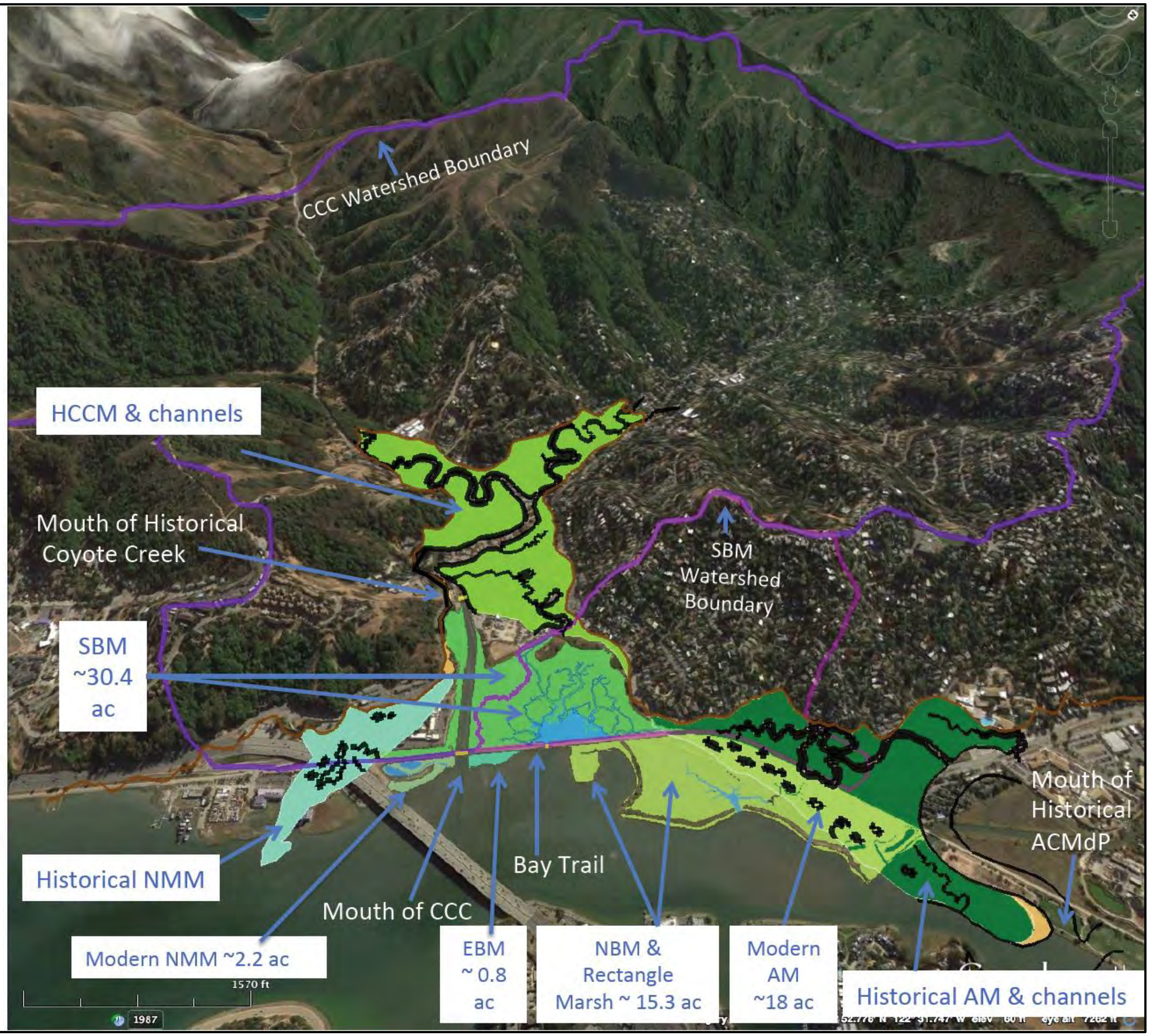
Comparison of 1851 and 2017 Bothin Marsh Complex

Source: 2017 Google Earth Imagery base map

~18 ac of AM exists of its ~50 ac. It is the only historical marsh remaining in the study area.

The total combined area of all the modern marshes is ~66.7 ac. The original combined extent of historical marshes was 141.5 ac, of which HCCM had 761 ac.

The extent of historical marshes is within the future extent of sea level rise.



Ref 125

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Chapter 3 final figure. South-facing view of native brackish tidal marsh vegetation with shallow roots flourishing on the leached sediments at the top of an historical unnatural levee along the southeastern foreshore of North Bothin Marsh, beneath planted shrubbery killed by salt water intrusion into its deeper root zone, due to sea level rise.