Public Comments

Item 1 – Submittal of Grant Funding Applications

Written Comments Received By 12pm on 03/28/2024

CITY OF PACIFICA

March 28, 2024

City Council Meeting

From:	William.Leo Leon [redacted]
Sent:	Thursday, March 28, 2024 10:18 AM
To:	Murdock, Christian; _City Council; Woodhouse, Kevin; Coffey, Sarah; Public Comment
Subject:	Letter and Thesis Document, Pacifica Geologic Coastal Study
Attachments:	Summary Report_Living on the Edge, Thesis (with highlight).docx; Thesis_Mussel_Shawn20Rock_Thesis.pdf

Hello Christian,

I am attaching a letter addressed to you with copies to the City Council regarding a Thesis on the History of Mussel Rock. I have also attached a copy of the entire Thesis. The Thesis contains numerous references to Studies of the Topography and Geology of the Mussel Rock Area and the Coastal Bluff formations extending into Pacifica as far south as Laguna Salada.

I encourage everyone concerned with Coastal Erosion and Beach loss to read the attachments.

I approve of Pacific's efforts to seek grants for Coastal Studies and funding. The attached document should be a ready reference for understanding the geological processes at work on Pacifica's coastal areas.

Please share the attached with City Council, Planning Commission.

Best Wishes,

William " Leo" Leon

attachments, Letter and Thesis

William “Leo” Leon
[redacted]

March 28, 2024 - Via Email –

To: Christian Murdock, Director Planning Department; Kevin Woodhouse, City Manager
cc: City Council, Planning Commissioners, City Clerk

Subject: Living on the Edge. Environmental History at Mussel Rock. Thesis, Geological Study, Citations and Exhibits

Dear Christian, I have attached the subject Thesis for your review and as reference in regards to the Beach Boulevard Infrastructure Resiliency Project and our Local Coastal Land Use Plan Update. The Thesis is relevant to current issues affecting Pacifica, such as: Coastal Erosion, Coastal Land Use, Coastal Development and Project Permitting. The Thesis documents and contains Studies that include areas covering Northen Pacifica south to Laguna Salada in Sharp Park. And explains how erosion occurs due to the composition of the underlying soil on our Coastal Bluffs.

Both the summary and the Thesis mentions the increased erosion of Pacifica’s Coastal Bluffs, and seeks further study on the issue of impacts to Pacifica from Coastal armoring at Mussel Rock area. The excerpts and summary of the subject Thesis are on pages 1-6. Excerpts from: Living on the Edge, Environmental History at Mussel Rock, Thesis of Shawn Heiser (2010)**.**

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Figure 13. Marine Terrace South of Mussel Rock to Pacifica. Photo by Shawn Heiser.

CHAPTER 2: Physical Geography of Mussel Rock Seismic Features

The entire area surrounding Mussel Rock lies within the San Andreas Rift Zone, one of many California seismic fault zones designated by the Alquist-Priolo Special Studies Zones Act of 1972. Mussel Rock is part of the San Francisco South Earthquake Fault Zone of California, Central Coast region (State of California Dept. of Conservation 2009). (Heiser P21).

CHAPTER 2 (Cont.) : Physical Geography of Mussel Rock Seismic Features

Merced and Colma Formations:

Since the Merced and Colma Formations consist of weak, poorly consolidated sedimentary mud and sands, the grains do not cement together cohesively, making the rocks soft and vulnerable to erosion processes (Sloan 2006). Coastal bluffs such as these are composed of sandstones and shales where grains of quartz, feldspar, and mica compress into layers of sandstone that crumble easily. **When these formations are wet from precipitation, the shales and siltstones disintegrate, while clays and mudstones soften and liquefy.**

The unconsolidated Merced and Colma Formations underlie the foundations of present-day neighborhoods in the Westlake coastal area, making them prone to landslides**.** The southern Mussel Rock area's present coastal landform is a marine terrace, a wave-cut platform formed thousands of years ago in a nearshore environment, then later uplifted by tectonic activity to its present location. The Mussel Rock marine terrace tilts gently down five kilometers (three miles) into the city of Pacifica (Figure 13). **At Mussel Rock the terrace's elevation is 50 meters (165 feet) above sea level, and then dips down to below sea level at Laguna Salada, on Sharp Park Golf Course in Pacifica (Sloan 2006)(Heiser, P36).**

Geomorphology of the Mussel Rock Landslide

If another major earthquake were to occur near the Mussel Rock area during a particularly wet winter or spring, the area could be dramatically activated, initiating an almost certain local environmental calamity when the reanimated landslide could potentially eject an estimated 765,000 cubic meters (one million cubic yards) of garbage from the buried landfill pits into the Pacific Ocean (Cox-Whitsel 1983).

Erosion Processes and Rates in the Mussel Rock Area. The episodic process of coastal bluff retreat plays a major role in the changing morphology of the Mussel Rock area. Headward erosion of cliff and bluff faces tends to occur here during moderate to strong intensity El Niño Southern Oscillation (ENSO) events where a high storm surge is present. The rate of coastal bluff retreat depends on variables such as the magnitude of wave attack, amount of runoff, and bluff lithology (Griggs 1997; Sloan 2006) (Heiser, P45).

Figure 17 shows coastal erosion processes and human revetment structures at Mussel Rock. Erosion rates can vary widely from year to year, and as such are averaged over the course of several decades in order to establish an expected rate. The degree of erosion in a given place in a given year takes many different variables into account. First is the composition or relative strength of the rocks that comprise the formation of the headland, marine terrace, or coastal bluff. Harder formations made of bedrock such as the Franciscan Complex are more resistant to erosion by ocean waves and rainfall, and therefore will not appear to erode at all over long periods of time. Weaker portions of Franciscan mélange erode faster, creating the arches and sea stacks off shore at Mussel Rock.

Softer materials in the strata, such as the weak sedimentary rocks that make up the Merced and Colma Formations at Mussel Rock are more susceptible to rapid erosion. **The materials of the Merced and Colma Formations are loosely cemented, in some cases with nothing to bind them together. Sometimes other minerals such as quartz or calcite are present, and those minerals seep into spaces between the sand grains and act as a weak cementing agent. In the Merced Formation at Mussel Rock, the empty spaces between sand grains are often filled with water**.

On the one hand, formations with large pore spaces are of great importance to societies for they enable storage of fresh water in aquifers. In the case of the Merced Formation, such aquifers are utilized by municipalities as drinking water supplies. This local aquifer (Heiser,P46) On the one hand, formations with large pore spaces are of great importance to societies for they enable storage of fresh water in aquifers. In the case of the Merced Formation, such aquifers are utilized by municipalities as drinking water supplies. This local aquifer supplies up to half of the drinking water for northern San Mateo County (Sloan 2006**). On the other hand, such a formation is unsound as a foundation for buildings. The water-filled spaces between sand grains are highly susceptible to rapid erosion and landslides, and provide little stability for permanent structures.**

Erosion rates are calculated by averaging cliff and bluff retreat over years through the use of aerial photographs and fixed sensors in the ground. Utilizing these technologies, average erosion rates can be estimated for the last 50 years. Averages provide an overall impression of the rate of erosion, rather than a fixed rate for any given year. According to Johnson and Marcum (2004), evaluation of coastal erosion rates utilizing only aerial photography may be useful only in areas where retreat events are frequent, such as Mussel Rock. But for other coastal areas where retreat is not a significant historical factor, and in settings where coastal bluffs expose weak and fractured rock, annual erosion/ retreat rate studies may be inadequate without data from fixed sensors.

CHAPTER 2 (Cont.) : Physical Geography of Mussel Rock Seismic Features

Geomorphology of the Mussel Rock Landslide

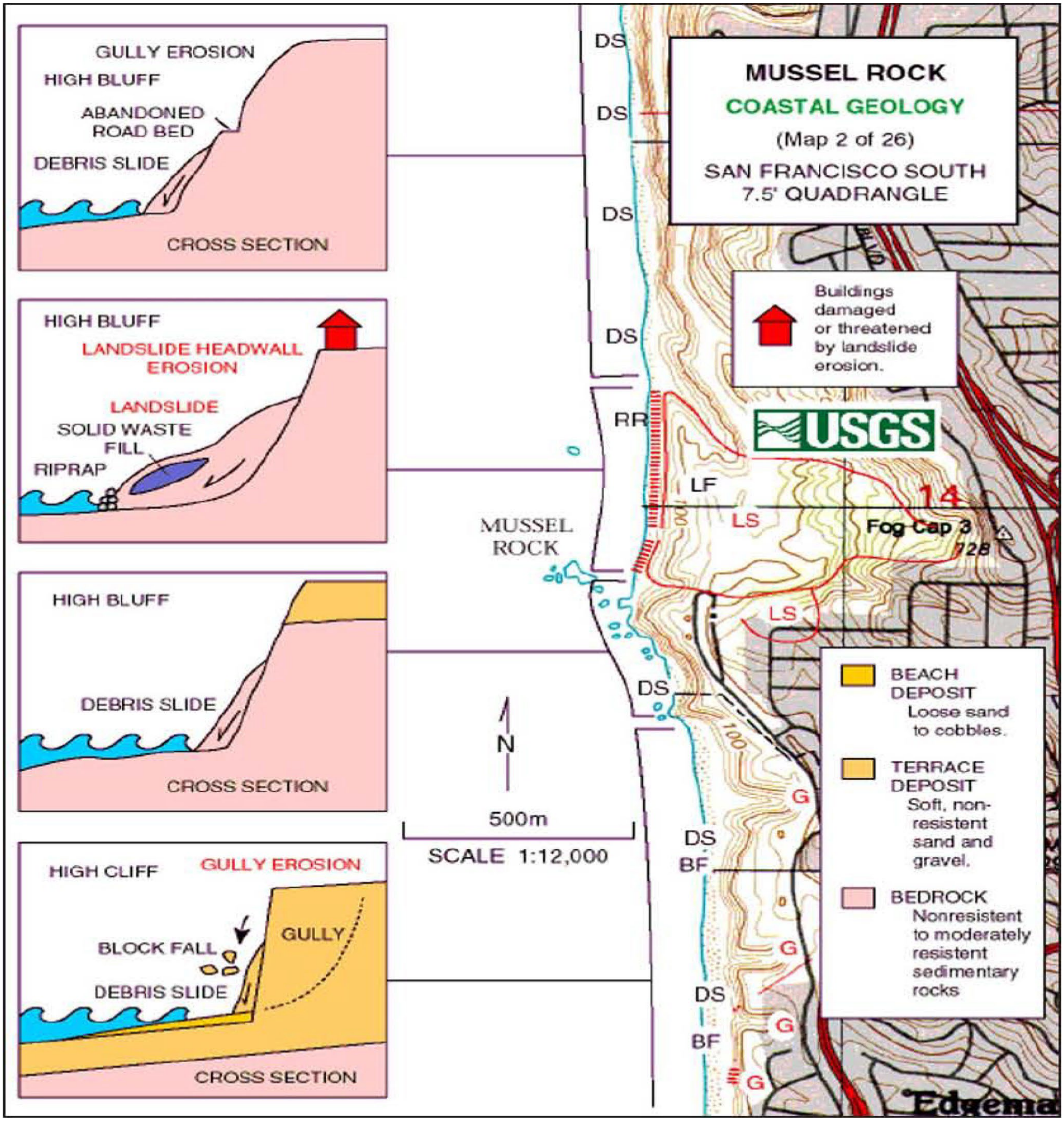

Figure 17. 1982-83 El Niño Coastal Erosion: San Mateo County, California. From Lajoie and Mathieson (1998)

CHAPTER 2 (Cont.) : Physical Geography of Mussel Rock Seismic Features

Erosion Processes and Rates in the Mussel Rock Area

It is well understood that in years when El Niño Southern Oscillation (ENSO) occurs in California, coastal erosion is much higher than in non-El Niño years. When intensified ENSO storms reach the California coast at high tide, rapid and severe erosion occurs on softer rocks such as the Merced and Colma Formations (Hampton and Dingler 1998, Shires 2001).

Since around 1950, three ENSO winters in particular saw dramatic rapid erosion along the San Mateo coast. The first, 1977-1978, re-introduced the ENSO phenomenon to the California coast. The second and largest, 1982-1983, wreaked havoc on numerous coastal areas of California. Major landslides were created or reanimated, causing houses to slide down cliffs and onto beaches, including some in Pacifica a few hundred meters south of Mussel Rock. The third ENSO winter, 1997-1998, caused similar landslides and erosion damage, costing the state millions of dollars in subsequent relocation and revetment projects (Hampton and Dingler 1998; Shires 2001). (Heiser, P48)

All three ENSO periods significantly affected residents living on the coast near Mussel Rock, and several dozen residential structures which suffered foundation damage due to local slumping from oversaturation of the soil. In ENSO years erosion rates for such structures can average up to 0.6-0.9 meters (2-3 feet) per year (Sloan 2005). For non-ENSO years, the average rate of coastal erosion in the area of Mussel Rock is much lower, averaging rates between 0-10 centimeters (0-4 inches), depending on multiple variables. One example of published retreat rates for the area immediately around Mussel Rock for the last 50 years is approximately 25-33 centimeters (10-13 inches) per year (Gilpin 2007).

Other sources of erosion rates for similar strata and geologic units nearby include Hampton and Dingler (1998) whose long-term rates ranged up to 100 centimeters (39 inches) annually. Smelser (1987) provides data from a comparison of measurements made on the eastern crown of the Mussel Rock area in the years between 1979 and 1986. The results of the measurements were alarming for anyone living atop the crown on the eastern scarp: locally, up to six meters (20 feet) of the crown had slumped in the previous seven years, for an average erosion rate of 0.9 meters (three feet) per year. Presently, geologists do not provide average retreat rates locally at Mussel Rock with any consistency or consensus.

Movement along the San Andreas Fault System in the Bay Area breaks up the weakened Merced and Colma Formations, furthering their susceptibility to erosion. Additionally, human activities on marine terraces and cliffs, such as construction can undermine and destabilize the surfaces, encouraging headward erosion of the cliffs (Griggs, Patsch and Savoy 2005) (Heiser, P49).

An example of another erosion process, called passive erosion, or the 'peninsula effect', which could result at Mussel Rock, is the revetment regime in place to prevent the landslide and landfill contents from emptying into the ocean. Protective devices such as seawalls, riprap, terracing, and other revetments at Mussel Rock create the likelihood of passive erosion in the near future, and could be the source of nearby coastal Pacifica's persistent erosion problems. The process by which passive erosion occurs is a result of creating a fixed shoreline position on an otherwise eroding stretch of coastline**. Figure 18 presents average local erosion rates, and illustrates events and action taken to stabilize the coastal area from Lake Merced to Sharp Park, including Mussel Rock (Griggs, Patsch and Savoy 2005).**

Passive erosion occurs when wave action and other erosion takes place around a fixed protective device, which is usually built parallel to the shoreline. The protective structure remains while the shoreline migrates landward over time, eventually creating a peninsula of protected land behind the revetment, while both sides of the protected land are inundated by the landward-advancing shoreline (Griggs, Patsch and Savoy 2005).

One major impact of passive erosion is loss of beach as a result of the protective device, therefore limiting public access to the beach. Because Mussel Rock's beach has been filled in by tons of granite boulders and other weirs and riprap structures, and has a propensity to disappear entirely during winter months, it is not a popular beach for locals except for sport fishing enthusiasts. Perhaps the loss of sand and beach area is not a problem for most local visitors, **but an evolving Peninsula effect, combined with wave refraction, could profoundly impact residents and beach-goers to the south of Mussel Rock in Pacifica (Heiser, P51).**

Erosion Processes and Rates in the Mussel Rock Area

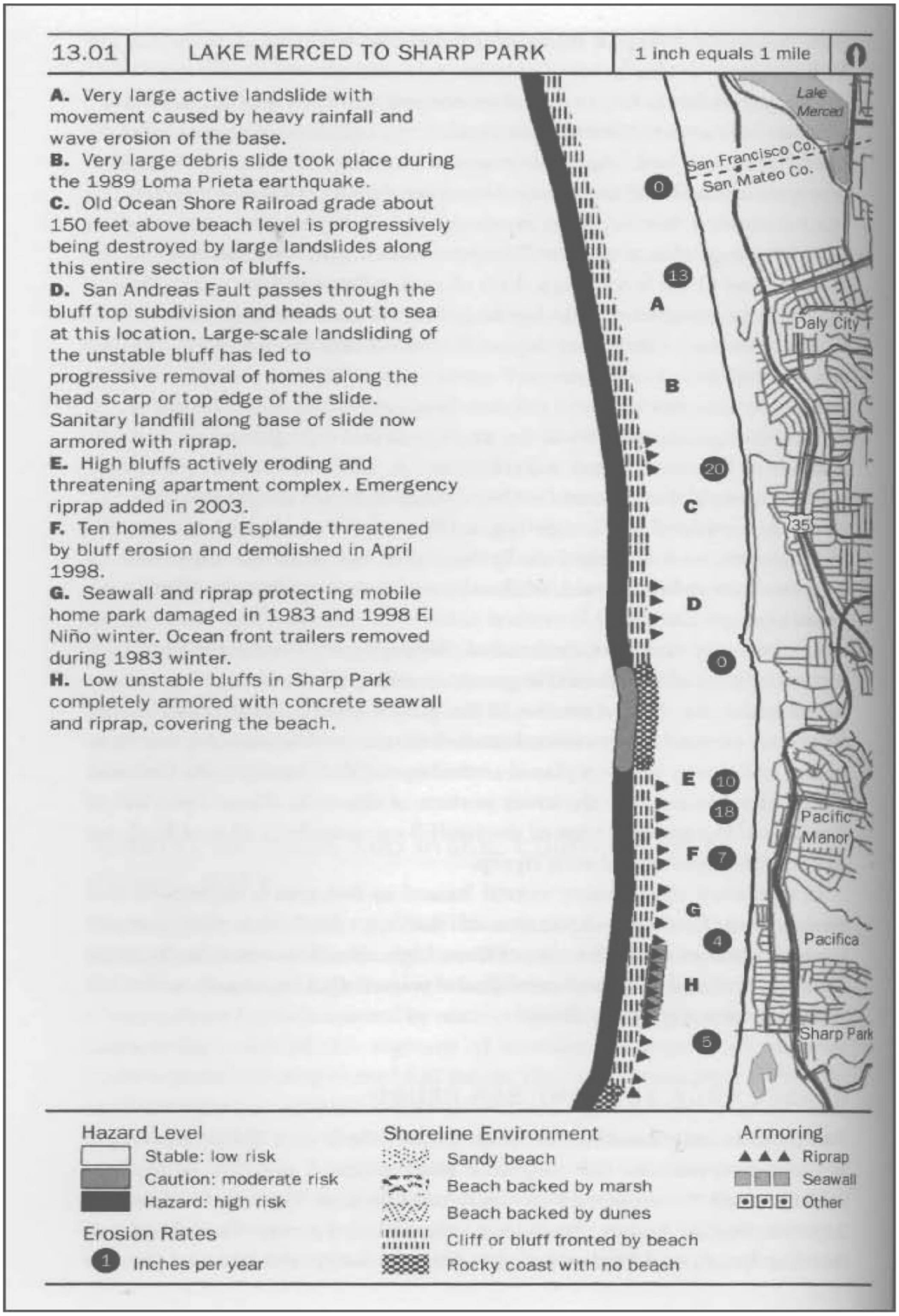

Figure 18. Coastal erosion, hazard, and revetment map showing the area from Lake Merced to Sharp Park. Mussel Rock is located in the center at letter D. From Griggs, Patsch and Savoy (2005).

CHAPTER 2 (Cont.) : Physical Geography of Mussel Rock Seismic Features

Erosion Processes and Rates in the Mussel Rock Area

Coastal Climate at Mussel Rock Coastal fog dominates the climatic regime at Mussel Rock. This local phenomenon acted as a deterrent to settlement and development for centuries. Local weather conditions reflect that of the western San Francisco Peninsula region. Mild and wet winters precede relatively cool and dry (but very foggy) summers. Annual precipitation averages 76 centimeters (30 inches) (Pacifica 2009).

The most rainfall in one month was 46 centimeters (18 inches) in February 1998 and the most rainfall in 24 hours was 13 centimeters (five inches) in December 2004 (Pacifica 2009). The most significant risk to accelerated erosion processes at Mussel Rock is excessive rainfall. El Niño Southern Oscillation (ENSO) winters almost always cause destruction of some human-built structures. This is the physical result of poor decision-making by developers who ambitiously built without consulting engineering geologists (Heiser, P52).

Henry Doelger and Westlake

In 1945 the real estate and construction firm of Henry Doelger purchased 550 hectares (1,350 acres) that stretched east and west of the developed section of Daly City to the ocean and south from Lake Merced to the Pacifica Hills, including the Mussel Rock area (Chandler 1973).

Why were the subdivisions permitted? Simply, the builders did not fully consider either the unstable nature of the underlying bedrock or the long history of land movement near Mussel Rock. At the time of construction no one appears to have challenged the idea, and state and local government regulations protecting home buyers from fault zone construction would not be ratified for another thirty years (Keil 2006).

There were no residential zoning laws and regulations until the Alquist-Priolo Special Studies Zones Act of 1972 (Sullivan, Mustart and Galehouse 1977; Cox-Whitsel 1983; Stoffer 2005). This was the first piece of legislation requiring a minimum amount of fault investigation and approval requirements for all cities and counties in California (Heiser, P91).

A major objective of the Alquist-Priola Act of 1972 was disclosure of this information to potential home buyers. Most learned through friends or neighbors, and some through the administration of the surveys and interviews conducted by college researchers and journalists. Interestingly, very few residents living in the area were aware of the ancient but active Mussel Rock Landslide (Sullivan, Mustart and Galehouse 1977). Ironically, the northern San Mateo County section of the San Andreas is the most densely populated section of the entire 1400-kilometer long fault (Fradkin 1998, Sullivan, Mustart and Galehouse 1977) (Heiser,P113).

This area in northern Pacifica has seen a sharp increase in erosion since the early 1990s (Scott 2009; Griggs, Patsch and Savoy 2005; Shires 2001; Hampton and Dingler 1998). Does Mussel Rock's coastal armoring regime contribute to increased bluff erosion in this area? Is nonlinear hydraulic impact from waves in Pacifica caused by armoring at Mussel Rock? A study should be commissioned that analyzes the potential effects of wave refraction and/or passive erosion taking place locally. If adverse effects are taking place in Pacifica as a result of the armoring regime, then what are potential mitigation measures to address this problem? Another opportunity for additional research at Mussel Rock is an updated risk assessment survey of the residents to see if local knowledge and risk awareness has increased for those living 'on the edge' (Heiser, P124).

Finally, this study's stated intention is to lay the groundwork for future research at Mussel Rock south to Pacifica. For example, additional opportunities for research include a long-term assessment of Mussel Rock's armoring regime and its relationship to recent rapid erosion of the unstable cliffs of the marine terrace immediately down shore into Pacifica.

In my opinion, we also need to track the amounts and locations of coastal armoring that has occurred, and update the amount of Bluff retreat, since the data in the Thesis published. Updating our data will help lead to a better understanding of erosion on Pacific’s Coastal Bluffs and Coastal areas.

Best Regards, William “Leo” Leon

Attachment: Living on the Edge, Thesis of Shawn Heiser (2010)

LIVING ON THE EDGE: ENVIRONMENTAL HISTORY AT MUSSEL ROCK, DALY CITY, CALIFORNIA

A thesis submitted to the faculty of
San Francisco State University
In partial fulfillment of
The Requirements for
The degree

Master of Arts
In
Geography

by

Shawn Christopher Heiser

San Francisco, California

May, 2010

CERTIFICATION OF APPROVAL

I certify that I have read *Living on the Edge: Environmental History at Mussel Rock, Daly City, California* by Shawn Christopher Heiser, and that in my opinion this work meets the criteria for approving a thesis submitted in partial fulfillment of the requirements for the degree: Master of Arts in Geography at San Francisco State University.

Nancy Wilkinson
Professor of Geography

Jerry Davis
Professor of Geography

LIVING ON THE EDGE: ENVIRONMENTAL HISTORY AT MUSSEL ROCK, DALY CITY, CALIFORNIA

Shawn Christopher Heiser
San Francisco, California
2010

This study examines the environmental and land use history of Mussel Rock from Ohlone settlement to the present. Mussel Rock is home to a notoriously unstable garbage landfill, which sits directly on top of the San Andreas Fault Zone and the second largest active landslide on the California Coast. Some people embrace Mussel Rock for its unique geography, history, and beauty, and choose to live here with little regard for the potential calamity resulting from fault movement, landslides, and other erosion processes. Among the geologic and coastal processes that have shaped the geomorphology and ecology of Mussel Rock, the San Andreas Rift Zone and Mussel Rock Landslide are the most significant entities. Yet, at a local level and on a shorter time scale, human alteration and modification of the landscape made a substantial environmental impact. The alteration of the landscape by human activity, including residential subdivisions and a municipal landfill, have placed its residents directly at risk from seismic and landslide hazards. Poor land-use decisions combined with natural processes threaten to push the Mussel Rock area 'over the edge' of the continent.

I certify that the Abstract is a correct representation of the content of this thesis.

_________________________________ ____________________

Chair, Thesis Committee Date

ACKNOWLEDGEMENTS

I would like to express my gratitude to the individuals who helped me in this long journey. To my advisors, Dr. Nancy Wilkinson and Dr. Jerry Davis, who introduced me to the richness and depth of the Geographic Spirit. Your never-ending patience and enthusiasm inspired me countless times during the course of this Graduate Program. Thank you.

Friends, family, colleagues, San Francisco State University Faculty, Staff, and fellow students also provided essential support, assistance and encouragement to me along the way. Although the list of these people is much too lengthy to enumerate in this space, you know who you are. My gratitude to each of you is profound, and I hope to be able to reciprocate the effort for you in the future when I am called upon to do so.

I wish to dedicate this work to the four people closest to me. To Calvin, Raemarie, and Kelly Heiser, who provided for me the foundation for a happy life devoted to love, peace, and compassion. Through your sacrifices and efforts, you instilled in me from a very early age a great passion for travel, adventure, and a fascination with the world around us.
I cannot thank you enough for these virtues.

And finally, to Jeanne Depman, who provides support to me at every turn. Your infectious personality inspires me to maintain the incessant pursuit of knowledge, experience, wisdom, and fun. Thank you so much for your eternal optimism, your generous spirit, for sharing your remarkable editing and creative skill sets, and most of all for your encouragement and love. Now let's see the rest of the world!

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"If there is one place where the catastrophic image of California slipping into the ocean has a measure of validity, it is along the coastal cliffs of suburban Daly City, where the fault comes ashore" (Fradkin 1998, 211).

CHAPTER 1: Introduction

The place known as 'Mussel Rock' embodies contradictions. From the perceived Native American Ohlone period's 'Garden of Eden' to a neglected, stigmatized backwater; from the unconsolidated mélange of the impermanent landforms to a landscape now densely occupied by people and homes. Mussel Rock encompasses active features of geology, seismology, coastal and climatic processes, and represents human agency land-use decisions with long-term complex consequences. Yet today its physical space offers people a refuge in the middle of a metropolis, and this measure of seclusion is valued by many people living in the densely populated San Francisco Bay Area.

Almost every human enterprise that has been attempted at Mussel Rock has resulted in utter failure, whether viewed from a civic planning perspective or with a responsible environmental ethic, from abandoned Ohlone villages to a nursery of toxic invasive Eucalyptus trees; to failed railroads and highways; to the construction of residential subdivisions on unstable sand and mud. Currently occupying the place known as Mussel Rock is a notoriously unstable garbage landfill, which sits directly on top of the San Andreas Fault Zone and the second largest active landslide on the California Coast. Despite these failures, people embrace Mussel Rock for its unique geography, history, and beauty, and choose to live here with little regard for the potential calamity resulting from fault movement, landslides, and other erosion processes.

Among the geologic and coastal processes that have shaped the geomorphology and ecology of Mussel Rock, the San Andreas Rift Zone and Mussel Rock Landslide are the most significant entities. Yet, at a local level and on a shorter time scale, human alteration and modification of the landscape made a substantial environmental impact. The alteration of the landscape by human activity, including residential subdivisions and a municipal landfill, have placed its residents directly at risk from seismic and landslide hazards. Poor land-use decisions combined with natural processes threaten to push the Mussel Rock area 'over the edge' of the continent.

This study examines the environmental and land use history of Mussel Rock from Ohlone settlement to the present. Following a review of the physical geography of the area, human-environmental relationships at Mussel Rock are explored in depth. Extramurality and centrifugal force, spatial concepts of land use, are deconstructed and used to elucidate decision-making of mid-and late-20th century leaders of Daly City. Reasons for rapid development in the 1950s and 1960s, and the ill-conceived landfill at Mussel Rock, are explored in the context of civic and corporate interests on local and regional scales. The physical structure of Mussel Rock is defined in relation to tectonic and coastal forces. Finally, proposals since the early 1980s to convert Mussel Rock to a hybrid coastal park and their resulting failures are examined. The study site has extensive land use history in a complex geological area prone to landslides. The legacy of Mussel Rock's land use history can be summarized best by stating that the effects of geologic and seismic factors were initially uninvestigated, later underestimated, and overall poorly incorporated into urban planning and development of the area. As a result, geologic controls and human development have significantly impacted many of the residents living in the Mussel Rock area. The result of the inability of planners to integrate geologic processes with human development should provide a model for preventing such failures in the future.

Physical Setting

Mussel Rock (N37.666728 W122.494241)

Mussel Rock is not an official park designated by any governing body. Portions of the area are owned and maintained by Daly City, Golden Gate National Recreation Area, and the State of California Parks Department. Mussel Rock is the designation of approximately 100 hectares (250 acres) of coastline near the border between southwestern Daly City and Pacifica in western San Mateo County, California (Figures 1 and 2). The area is occupied a large bowl-shaped depression, the current expression of an active 45 hectare (112 acre) landslide directly above the San Andreas Fault (Figure 2). The landslide depression is fronted by a seawall, a riprap apron, and a narrow beach to the west. To the east, Mussel Rock is a series of steep, eroding 213 meter (700 foot) cliffs. Extensive residential development exists on the top of the bluffs to the east, north, and south of the area.

To the north, the area is bordered by the high, northward-dipping cliffs leading to Fort Funston in San Francisco. To the south, it is bordered by residential and commercial subdivisions sitting atop an ancient marine terrace sloping gently downward into the city of Pacifica. To the east, the area's border is Skyline Drive, built on the high bluffs and winding through the Westlake Heights and Westlake Palisades subdivisions of Daly City. Construction of these housing developments was completed between 1956 and 1959 by the Henry Doelger Construction Company.

Figure 1. Mussel Rock study site. From Hladik and Orlando (2008).

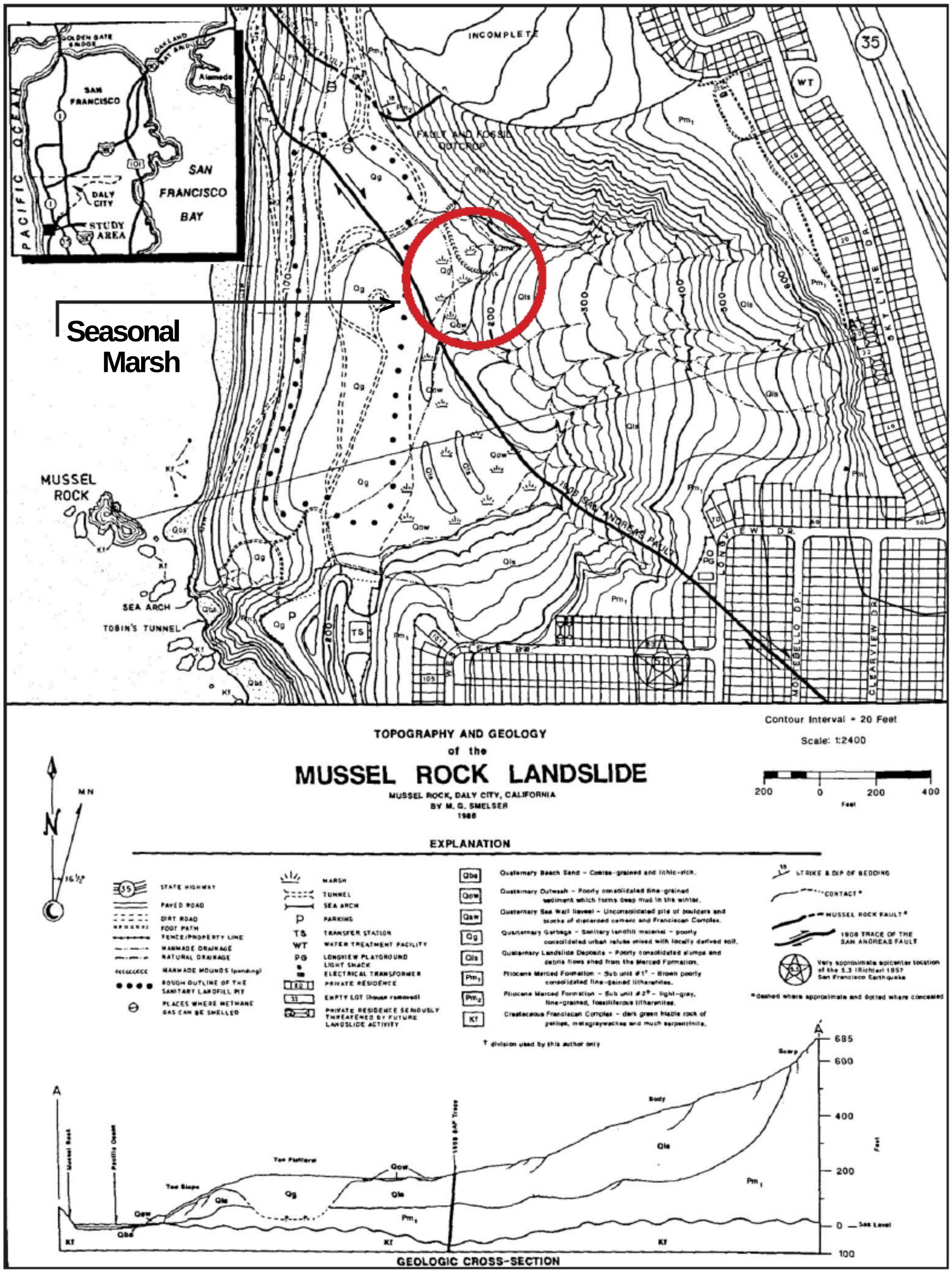

Figure 2. Topography and Geology of the Mussel Rock area. From Smelser (1987).

West of Mussel Rock's border is the Pacific Ocean. Mussel Rock proper (Figure 3) sits approximately 15 meters (49 feet) offshore, and has an elevation of approximately 18 meters (60 feet). Other nearby features include five smaller sea stacks, three eroding arches, and one man-made tunnel. Four hundred meters (1,300 feet) north of Mussel Rock, the San Andreas Fault crosses the shoreline of California, traverses a course northward in the Pacific Ocean and re-crosses land near Point Reyes in Marin County. Figures 4-7 are aerial photographs of the Mussel Rock study area. The sequence of photos begins at the southern end of the study area (Figure 4), and concludes at the northern terminus of the study area near Fort Funston in San Francisco County (Figure 7).

The morphology of today's exposed landforms at Mussel Rock reveals the dynamic changes of sea level over millennia. Most of the exposed rocks tell a larger story of geologic processes such as subduction, uplift, and mechanical and chemical erosion.

A book by journalist John McPhee, *Assembling California*, begins at Mussel Rock. He advocates visits there to contemplate the geologic forces which converge at Mussel Rock. "With regard to the lithosphere, it's a good place to sit and watch the plates move. It is a moment in geography that does your thinking for you" (McPhee 1993, 4).

Figure 3. Mussel Rock proper. Photo by Shawn Heiser.

Figure 4. Southern end of study area, with Transfer Station in center of photo. Mussel Rock proper at bottom left. From Adelman and Adelman (2009).

Figure 5. Main landfill pit and riprap apron fronting beach. From Adelman and Adelman (2009).

Figure 6. Main landfill pit and Upper North Canyon pit at upper left.
From Adelman and Adelman (2009).

Figure 7. Northern terminus of study area, with extensive slope terracing
and drainage regime. From Adelman and Adelman (2009).

Purpose of the Study

In the traditions of land use history, environmental history, and historical geography, this study pays particular attention to patterns and impacts of landscape evolution at Mussel Rock. A major theme is the transformation of the landscape and environment through successive cultures' sequent occupance. How and why have human uses of this area accorded with environmental parameters and constraints over time, and how can inappropriate land uses at Mussel Rock be explained and resolved?

The objectives of Environmental History fit well in Geography, a discipline which trains its practitioners for the task of "considering the totality of phenomena in place" (Williams 1994, 9). While this study is an attempt at a comprehensive understanding of the site's environmental, social, and physical history, postmodernism suggests that achieving totality is not even possible nor often desired (Cronon 1992). Because of the inherent subjectivity of narrative techniques to historicize a landscape, no attempt to claim positivist objectivity is made.

Recent research suggests coastal development conflicts are becoming more common (Griggs, Patsch and Savoy 2005). Early residents along the California coast usually constructed homes and businesses a reasonable distance from bluffs and approaching storm waves and high tides. In recent decades, however, a trend to build as close to the ocean as permits and engineering will allow has emerged. The growth of California's coastal population, and hence development, has led to political and economic pressures around privately-held coastal land. Much of California's coastal development occurred between 1945 and 1976, a period characterized by below-average rainfall and storm frequency, i.e. an absence of El Niño Southern Oscillation (ENSO) presence in the Pacific (Griggs, Patsch and Savoy 2005). By the time ENSO made its return to California in 1977, most coastal property owners were not even aware of the ENSO phenomenon.

Conflict between coastal development and the hazards associated with it is becoming more evident primarily due to four factors: 1) increased migration to coastal communities; 2) progressive erosion of coastal land, causing structures to be undercut or undermined and therefore threatened; 3) human-induced bluff erosion due to cliff-top construction, impervious surface runoff, and landscape watering; and 4) an increase in the frequency of ENSO events beginning in 1977, causing heavier rainfall, elevated sea level, and larger wave action (Griggs, Patsch and Savoy 2005, 3-4). Coastal engineering projects directly or indirectly accelerate erosion rates in adjacent areas by trapping sand and leaving down-coast beaches without sand, furthering erosion in those areas. Additionally, engineered revetment projects such as seawalls and riprap aprons refract oncoming waves away from these objects, thereby increasing their erosion potential down shore from the revetments. This may in fact be happening in Pacifica, California, immediately down shore of Mussel Rock due to its coastal armoring regime. Finally, global climate models indicate a significant rise in sea level in the coming decades, making coastal development issues all the more relevant and pressing.

Because the coastal environment is highly dynamic in terms of wave energy and climatic processes, the land/ocean interface is continually being reshaped, and consequently creates challenges for development. Most of the California coast is eroding relatively rapidly, and all of the above factors play roles in the erosion regime at Mussel Rock. A disconnect between the physical setting, geologic processes and human perceptions of land development converges at Mussel Rock, presenting problematic challenges for residents, developers and civic leaders.

Methodology

My observations of the Mussel Rock area span 15 years, since 1995, when I moved into a house on the eastern crown of the Mussel Rock Landslide. A personal photograph archive of landscape changes along with conversations with locals and Daly City Government employees helped to inspire this study.

Research began with a review of published and unpublished literature and government records relating to Mussel Rock history. Source material was collected from Daly City History Guild, San Francisco Public Library History Center, San Mateo County Historical Museum Archives, United States Geological Survey, Regional Water Quality Control Board, and Daly City Clerk's Office.

An omission of Mussel Rock's Environmental History was apparent among the body of literature, and this omission allowed me to narrow the objective for this study: to tell the story of the historical development of, and changes to, the Mussel Rock landscape by its various occupants throughout its recorded history.

Examination of records at Daly City Clerk's Office uncovered Daly City Council meeting minutes and correspondence between Daly City government officials and Daly City Scavenger Company managers. This material helped to explain why a decision as dubious as siting the Mussel Rock Landfill could occur.

Historical records and literature pertaining to San Mateo County and Daly City history were reviewed at the San Mateo County Historical Museum Archives and Daly City History Guild. Findings include graduate student papers on Ocean Shore Railroad, Ompuromo Village, and Tobin's Tunnel. These papers provided perspectives not yet revealed in Mussel Rock published literature (Darrough 1938, Byers 1946, Drew 1964).

San Mateo County newspaper articles also document local residents' perspectives and experiences on the hazards of living in the San Andreas Rift Zone and on an active landslide.

Geologic literature and aerial photographs reviewed at United States Geological Survey in Menlo Park offered a visual and sequential interpretation of the landscape from above, chronicling the various physical transformations of the landscape at Mussel Rock over the last 100 years.

An extensive collection of material on the Mussel Rock Landfill is located at the archives of the Regional Water Quality Control Board in Oakland. Correspondence between the Water Board and Daly City illustrate the complex and acrimonious relationship of these two bureaucratic entities. These documents reveal the escalating tension between civic and environmental responsibility, as well as the need for infrastructure and development regulations at Mussel Rock.

Throughout the research process an effort was made to use materials that explain why changes in the landscape occurred. The compelling story that follows, as intended by this author, is based on the effects of those changes.

To date, no author has accumulated as voluminous a compendium on Mussel Rock as is found in this project. I believe this will provide a framework by which other studies of the Mussel Rock area can supplement the ongoing environmental history of the place. It will also provide direction for other types of research at the study location and in similar environmental settings elsewhere.

Literature Summary

Following is a summary of the pertinent and tangential literature that influenced this project. Material on the tenets and objectives of Environmental History and Historical Geography informed the theoretical background. Key works include Tuan (1977), Worster (1988), Cronon (1992), Williams (1994), Demeritt (1994), Hughes (2001), and Merchant (2002, 2007). Texts that utilize the historical concept of palimpsests, sequent occupance and landscape alteration include Miller (1971), Clark (1985), Larson (2000), and Baker (2003).

An abundance of literature on the geology and seismic history of the San Mateo coast and Mussel Rock specifically are found in Lawson (1908), Oakeshott (1959), Sullivan (1975), Plafker and Galloway (1989), Pampeyan (1995), Fradkin (1998), Perlman (1999), Stoffer (2004), Sudran (2005), Smookler (2005), and Sloan (2005, 2006).

Coastal erosion processes of California as well as local erosion processes in the Mussel Rock area are found in Griggs (1995), Hampton and Dingler (1998), and Griggs, Patsch and Savoy (2005). A coastal erosion map series by Lajoie and Mathieson (1998) illustrates modifications of the Mussel Rock area through several decades of engineering stability and revetment projects.

There is substantial literature on landslide processes and mitigation measures at Mussel Rock (Daly City Council 1996, Daly City Council 1999, Daly City 2009). There is also tangential literature pertaining to landslides and coastal erosion at susceptible areas nearby Mussel Rock. Shires (2001) and Scott (2009) discuss recent landslides in nearby Pacifica, while Johnson and Marcum (2004) detail the Northridge Bluff Landslide which occurred just north of Mussel Rock. Finally, a key report detailing the Mussel Rock landslide itself is Mark Smelser's Geomorphology of the Mussel Rock Landslide (1987).

Two Master's Theses devoted entirely to Mussel Rock include one that analyzes the contents from the excavations of Ompuromo midden site at Mussel Rock (Clark 1985) and another that details the 20-year history of operations at Mussel Rock Landfill (Cox-Whitsel 1983).

Risk assessment studies, surveys, and interviews that analyze and chronicle the psychological conditions of residents living near Mussel Rock and the San Andreas Rift Zone include Sullivan (1975), Sullivan, Mustart, and Galehouse (1977), Cox-Whitsel (1983), Wilson (1989), Sloan (2005), Sudran (2005) and Scott (2009).

There is a host of tangential and background literature devoted to human and social geography of the region and study area. Rich regional histories of Daly City and Pacifica, two cities whose histories are intertwined with Mussel Rock, have been completed by Chandler (1973), and more recently Gillespie (1986, 2003, 2008). Hunter and Drake (2002) provide a short pictorial history of Pacifica and the Mussel Rock area. Reports on landslides immediately south of Mussel Rock during the El Niño winter of 1997-1998 are detailed in Shires (2001) and Scott (2009). Kiel (2006) provides a detailed history of Henry Doelger and his Westlake subdivisions. For more literature describing historical settlement in San Mateo County and along its coast, see Alexander and Hamm (1916), Cloud (1928), Stanger (1963), Pitt (1970), Brown (1974), Margolin (1978), Hynding (1982), Delgado and Haller (1989), Clarke (1996), and West and Cotchett (2002).

The defining work on Ocean Shore Railroad is Jack Wagner's *The Last Whistle* (1974). Other histories detailing the Ocean Shore Railroad and its planned-community 'paper cities' along the San Mateo Coastline include Darrough (1938), Byers (1946), Brandt (1965), VanderWerf (1992), and Hunter (2004).

Regional Expansion and Development

Mussel Rock's environmental and land use history is closely tied to San Francisco. The growth and development of this 'imperial city' is unique to American development of urban areas in its spatial arrangement, patterns of development, and access to an unprecedented bounty of natural resources to exploit (Brechin 1999, Walker 2001). Unlike many of the metropolitan areas in the United States, the Bay Area did not have a single unified industrial core that decentralized after World War II. Industrial development was more important to Bay Area developers and landowners than residential suburbanization, and this is reflected in the unusual way that the Bay Area industry's decentralized drive outward from San Francisco occurred (Walker 2001). Both extramural and centrifugal forces explain the outward spiraling from San Francisco towards its hinterlands. Centrifugal force owes its tendencies to the spatial constraints of San Francisco's core combined with processes such as the desire and direction of land development projects. New technologies, and natural resource exploitation that pulled industry and development outward from the city, while undesirable land uses were pushed away from the central core usually following social movements or the desire for further development in areas outside the purview of regulatory committees.

Richard Walker (2001) contends that decentralization of industry in the San Francisco Bay Area occurred primarily due to the force of technical and market changes unleashed by accumulation of capital. Rapid changes in industry and technology, coupled with the spatial limitations of San Francisco proper, and episodic outbreaks of new industrial sectors in new places were largely engineered by land-owning banking and industrial magnates. These powerful players and their successors continually pushed to develop real estate parcels they owned further and further outward from the city as new resources and industrial technologies emerged.

This elite group—heavily vested in banking, merchant trades, railroads and mining bonanzas, and more—held reign over an empire stretching from Alaska to Mexico. Each magnate held stakes in dozens of industrial enterprises, and the abundance of cheap labor by means of minority worker exploitation also contributed to the headlong drive toward industrialization in the Bay Area.

Natural events and entities were also factors in the decentralization of industry in San Francisco. The earthquake and fire of 1906, and the subsequent rebuilding of the city, had an unprecedented impact on the outward drive of population and industries, although industry had begun its outward march from the city's core long before the 1906 earthquake (Walker 2001). The spatial presence of San Francisco Bay also helped govern the outward migration of industry initially south towards the Peninsula, and afterward to the East Bay cities of Oakland and Richmond. Transportation improvements gradually helped facilitate industrial expansion throughout the Bay Area. Higher wages and powerful labor organizations in San Francisco contributed to industrial flight outward. Higher wages attracted skilled labor, initiated mass immigration, and led to greater consumption, all of which contributed to innovation and increased regional commercial and industrial expansion.

After gaining statehood in 1849, the city and county of San Francisco originally occupied the entire San Francisco Peninsula, with today's city of Santa Clara being the county's southern terminus. However, in 1856, the second California State Legislature redrew the boundary of the city and county to be exact, thereby creating San Mateo County and spatially restricting the urban core of San Francisco to a "fingernail at the tip of its peninsula" (Brechin 1999, 77). This decision would have enormous implications for all future endeavors regarding local and regional expansion. San Mateo County, six times larger than its neighbor to the north, contained the larger mountains, bigger streams, untapped forests, and warmer weather. As Gray Brechin (1999, 77) asserts, "the city's leaders never accepted the schism imposed at that time: they wanted San Mateo back".

With little prospect of that occurring, they carved up the county to the south and, as landowners, developed it as they desired. These landowners would continue to exploit the natural resources of the peninsula for San Francisco's needs over the next century.

One early example of resource exploitation of the peninsula was in 1862 when Alexis von Schmidt diverted the natural flow of Pilarcitos Creek from its headwaters on Montara Mountain into San Francisco via an aqueduct made from 52 kilometers (32 miles) of red-wood flumes and tunnels, creating the city's long-desired 'permanent' and 'enduring' water supply (Brechin 1999, Righter 2005). The new water supply quickly proved inadequate for the growing city's needs. Extraction of other resources, especially timber and agricultural products from the Peninsula, were exported north to San Francisco, while industry and commerce slowly moved in a reverse direction south into the Peninsula and East Bay. As industry and development pushed outward from San Francisco, commodities flowed into the city from where they were manufactured or extracted outside the city. These push/pull processes were common in nearly all metropolitan areas during the 19th and 20th centuries in the United States (Walker 2001).

The industrial development of South San Francisco at the beginning of the 20th century provides an example of the force of industrial restructuring, property ownership, and political maneuvering of industrial suburbanization on the San Francisco Peninsula (Walker 2001). Industries such as meatpacking, iron, steel, and paint factories, shipyards, and metal shops relocated to San Mateo County and South San Francisco initially, and initiated the rapid development of northern San Mateo County. Other cities in this area quickly followed, providing space for industrial workers as well as undeveloped land for animal grazing and agriculture in the surrounding area. Daly City was among the first of these to develop and the city incorporated on March 18, 1911 by a slim margin of 132-130 in the ballot measure (Chandler 1973).

By the early decades of the 20th century, public pressure resulted in city ordinances forcing relocation of all of San Francisco's slaughterhouses, tanneries, fertilizer plants, and tallow works further away from the downtown area south to the Bay View district at Islais Creek. This action started in motion a gradual but general pattern of relocation of 'undesirable' land use practices southward for the next few decades (Issel and Cherny 1986). Organizational, moral, religious, medical, and hygienic concerns led to extramurality, a socio-spatial process of exclusion, from the city to its fringes. This process later became known as "NIMBYism" (Not in My Backyard), a social discourse that pervades urban planning decisions to this day. The inexorable march south from San Francisco and into San Mateo County was eventually halted by the very interests that continually relocated those industries out from the urban core in the first place. The affluent banking and mining magnates' once-country pleasure homes of Hillsborough and Burlingame were now coming into direct contact with industry. Thus, the industrial expansionists killed industrial proposals near their estates in San Mateo County, and instead shifted their gaze to the East Bay where land values were cheaper and further away from regulatory concerns (Brechin 1999, Walker 2001).

According to Philip Dreyfus (2008, 150), "an overall physical pattern had emerged by the time of the Great Depression in which the most readily observable environmental costs of industrialization had been exported from the metropolitan core. It remains difficult to assess whether this aspect of industrial decentralization had a conscious effect on the way San Francisco residents experienced their own particular urban environment". However difficult, it is clear that these events had an inevitable effect on the residents of the newly industrialized hinterland cities as they developed.

The original extramural expansion southward into San Mateo County exemplified these push/pull processes into and out of the city, and in turn caused the creation of the cities of Daly City, Colma, South San Francisco, and Pacifica immediately south of San Francisco. Creation of these communities was a result of a direct need to occupy the newly created spaces of manufacturing, agriculture, and other social industries including gambling, prostitution, and alcohol consumption. San Francisco's leaders and investors also sought available land for agriculture, cemeteries, and municipal waste collection and storage, since space in the city was occupied by residential and business enterprises.

The extramural process exhibited by San Francisco, resulting in cemeteries, waste yards, manufacturing and industry, gambling halls, saloons, brothels, controversial sporting events (boxing, dog racing) and landfills pushed to areas not occupied by society's elite, helped to shape the identities of those outlying places. Many people perceived these cities as mere traffic corridors between San Francisco and points further south—a landscape of commuter 'bedroom' communities without histories, political identities and geographies unique to their locations (Walker 2001). Such confusion abounded with the rapid urban and suburban expansion following World War II. Thus, the method by which incorporation of such places occurred helped to contribute to the stigmatized perceptions attached to these cities from the beginning, with lingering vestiges still prevalent today. Daly City, located on the border of San Francisco, exemplifies this type of suburb. Daly City's leaders played a significant role in sustaining its stigmatized perception by the decisions made since the city's incorporation. Rapid regional growth in the 20th century threatens to push Daly City "over the edge" due to a failure to heed limitations and anticipate hazards to development along its coast.

CHAPTER 2: Physical Geography of Mussel Rock

Seismic Features

The San Andreas Fault System includes dozens of nearly parallel faults trending northwest in the San Francisco Bay Area, including San Gregorio, Hayward, Rodgers Creek, Calaveras, Serra, San Bruno, Mussel Rock, and other active minor faults. But it is the San Andreas Fault that dominates activity at Mussel Rock. From its origin near the Salton Sea in Southern California, the famed San Andreas traverses northwest through southern and central California before reaching the southern Bay Area. It then continues northwest, bisecting the San Francisco Peninsula on the diagonal until it plunges into the Pacific Ocean 0.4 kilometers (.25 miles) north of Mussel Rock (Figure 2, page 5). The San Andreas Fault then continues north until it meets the continent again at Bolinas Lagoon near Point Reyes in Marin County. The Fault travels northward until it enters the Pacific Ocean again at Cape Mendocino in Humboldt County (Figure 8). The exact place where the 1,400-kilometer (870 miles) long fault ends is subject to controversy, but most geologists believe it terminates in the Pacific Ocean offshore of Shelter Cove south of Eureka in Humboldt County (Alden 2006).

The entire area surrounding Mussel Rock lies within the San Andreas Rift Zone, one of many California seismic fault zones designated by the Alquist-Priolo Special Studies Zones Act of 1972. Mussel Rock is part of the San Francisco South Earthquake Fault Zone of California, Central Coast region (State of California Department of Conservation 2009).

Figure 8. San Andreas Fault. From Clarke (1996).

At Mussel Rock the rift zone, created from the fault, trends northwest, bounded by tall cliffs on the landward east side. Perennial streams once flowed at the surface of the rift canyon towards the Pacific Ocean and fed a seasonal marsh, creating a freshwater habitat for animal and plant species. There are also naturally occurring and fault-created springs and seeps emanating from the cliffs above Mussel Rock. The San Andreas Fault is a major source of groundwater intrusion into the Mussel Rock area. Thus groundwater arrives at the toe of the Mussel Rock Landslide from above, below, and all sides except west, where high wave action threatens to erode the toe of the landslide (Cox-Whitsel 1983; Smelser 1987). The constant maintenance legally required for surface runoff drainage regimes at Mussel Rock constitutes one of the most difficult challenges for the engineers in charge of maintenance and revetment projects (Daly City 2009).

Surface movements on the San Andreas Fault have been predominantly along a vertical plane, with areas southwest of the fault displaced generally towards the northwest. The San Andreas Fault is classified as a right-lateral strike-slip, or right slip fault. The logic behind this term is that when standing on one side of the fault and facing the other, the other side across the fault is moving to the right. The annual average movement rate dating from late Cenozoic times (~23 million years), varies between 0.8-2.0 centimeters (0.3-0.8 inches) depending on location (Pampeyan 1995). This rate of movement is roughly equal to the growth rate of a human fingernail.

The vast majority of movement along the fault is horizontal, but a lesser amount of vertical displacement occurs at and below the surface. There is also a third type of movement called transpression, which is neither horizontal nor vertical, but contains a measure of compression or collision, and accounts for about 10% of the relative motion of the fault (Rademacher 2006). This movement has produced a rapid uplift of the land in certain places, and the heights of the East Bay Hills, Mount Diablo, Mount Tamalpais and the Santa Cruz Mountains were all caused by this 'squeezing' process of transpression.

The fault zone at Mussel Rock is also part of the Loma Prieta portion of the San Andreas Fault. This segment of the fault begins at Mussel Rock and continues south for 130 kilometers (81 miles) to San Juan Bautista. This length of the fault is considered 'doubly charged' due to the fact that this segment contains seismic artifacts from both the 1906 and 1989 earthquakes, the two largest in Northern California in more than 100 years. This section of the San Andreas also contains the densest concentration of inhabitants living on the main branch of the fault in California (Sullivan, Mustart, and Galehouse 1977; Fradkin 1998).

At Mussel Rock the 1906 trace of the fault trends with a bearing of approximately 48 degrees northwest into the ocean. The fault trace is marked by a steep ravine immediately west of Longview Playground, by depressions in the landslide toe platform, and by a ridge line and small gully northwest of the toe platform (Smelser 1987). Extensive leveling and terracing for drainage of the landslide continually obscure the trace of the fault at the surface.

From the rift valley, the second largest landslide on the California coast spreads out and down into the Pacific Ocean for more than 6.5 kilometers (four miles). This 6.9 million cubic-meter (9 million cubic-yard) active landslide, known as the Mussel Rock Land-slide, initially occurred 100,000 years ago, and has been reanimated by large earthquakes in 1836, 1838, 1861, 1868, 1906, 1957, and 1989 (Gilpin 2007). The currently active 45 hectare (112-acre) Mussel Rock Landslide continues to slowly creep down into the ocean, taking with it everything on top and below, including houses, roads, commercial and in-dustrial wastes, revetment structures, and other natural or man-made objects.

Until recently it was widely accepted that the 1906 San Francisco earthquake's epicenter was located in Olema in Marin County. However, recent seismic evidence establishes that the earthquake's epicenter was located about three kilometers (1.9 miles) offshore north of Mussel Rock in the Pacific Ocean (Kim 2004, Sloan 2005). The area around Mussel Rock sustained some of the most intense shaking in the entire Bay Area during this earthquake, according to the Rossi-Forel Scale of intensity distribution (Sullivan 1975). A report by Lawson et al (1908) shows that the Mussel Rock-Thornton Beach-Fort Funston coastal area was severely affected by landslides, slumps, flows, and fissuring. The northern end of the Peninsula segment of the San Andreas Fault showed a right-lateral displacement of about 4 meters (13 feet) after the 1906 earthquake (Stoffer 2005). Fortunately, there was almost no development in the western San Francisco and Mussel Rock areas at the time. The few human developments nearby at the time of the earthquake will be discussed in later chapters.

The cliffs above Mussel Rock slumped considerably in the earthquake, and altered the courses of streams draining the valley. Witnesses of the reanimated landslide at Mussel Rock in 1906 reported a protruding 'tongue' or toe of the landslide measuring 15 meters (49 feet) high and 61 meters (200 feet) wide extending into the Pacific Ocean. The toe persisted at this location until nearly a year later in February 1907, when wave action finally removed the landslide debris (Sullivan 1975).

Subsequent large earthquakes on the Northern branch of the San Andreas have also caused damage around the area of Mussel Rock. On March 22, 1957 a magnitude 5.3 earthquake shook the Bay Area. The epicenter was located 200 meters (650 feet) southeast of Mussel Rock. This earthquake triggered more large slumps and landslides around Mussel Rock, altered the entire area's topography once again, and caused an estimated $1 million in damages (Sullivan, Mustart and Galehouse 1977).

This earthquake also forced the California Board of Transportation to finally abandon the location of the original Ocean Shore Highway, the predecessor to today's California Highway One that ran along the Mussel Rock cliffs over the original Ocean Shore Railroad bed. Landslides on the road were reported to be as large as "a few hundred feet wide and 213 meters (700 feet) measured down the slope of the cliff" (Sullivan 1975).

The magnitude 6.9 Loma Prieta earthquake on October 17, 1989 also caused large landslides between Mussel Rock and Fort Funston, but since 1989 this section of the San Andreas Fault has been classified as locked (not moving or creeping) from Salinas north to its termination northwest of Cape Mendocino, including the rift zone at Mussel Rock (Kious and Tilling 2009). Additionally, an adjacent fault to the San Andreas, appropriately named the Mussel Rock Fault, was claimed to have been discovered in 1999 after a geologist examined layers of uplifted sedimentary rock on the cliffs of the San Andreas Rift Zone at Mussel Rock (Perlman 1999). However, research for this project reveals that geologists have known about and mapped the Mussel Rock Fault for a long time. For example, Geologist Mark Smelser's (1987) article on Mussel Rock Landslide contains maps where the Mussel Rock Fault is clearly labeled (Figure 2, page 5). Regardless of when it was discovered, it is yet to be determined whether the Mussel Rock Fault is still active. Mussel Rock Fault parallels the 1906 trace of the San Andreas Fault, and is recognized by geologists as part of the larger complex network of faults that make up the entire fault block in the San Francisco Bay Area, and on a regional scale as part of the San Andreas Rift Zone. On a local scale the Rift Zone at Mussel Rock is referred to as the Mussel Rock Rift Valley. All of the Mussel Rock study area is located within the San Andreas Rift Zone, estimated to be more than 1.6 kilometers (one mile) wide, and thereby encompassing the residential and commercial structures sitting on the crown of the landslide above the study area. Seismic Engineer Peter Yanev cautions those who live near the fault in Daly City are "gambling the whole investment and perhaps life itself on the slim hope that a large earthquake will not strike again" (Clarke 1996, 213).

Geologic History

Doris Sloan (2005, 1-2) said this about the geological makeup of the Mussel Rock area on the San Mateo County coast: "The steep sandy cliffs from Ocean Beach in San Francisco south to Pacifica are composed of sedimentary rocks so young and weak, geologically speaking, that they hardly qualify as rock…along the coast geological processes can work dramatically in months or years instead of the centuries and millennia of most geologic events. Regardless of the cleverest engineering, the cliffs flow down—taking houses, roads, and backyards with them".

The geologic area around Mussel Rock consists of friable marine sandstones of the low-ermost Merced Formation that nonconformably overlie greenstones of the Franciscan Complex (Figure 2, page 5). A thin layer of Colma Formation overlies Merced Formation beds northeast of the San Andreas Fault. At the surface the fault divides the two major bedrock structures, with Franciscan Complex outcrops west and south of the fault and Merced and Colma Formations to the north and east (Figure 9). Due to the long-term effects of local erosion, slumping, and faulting, the poorly cemented Merced and Colma Formation sediments have been reduced to an active landslide (Smelser 1987).

Faulting and uplift processes have continually reconfigured this collection of rocks, re-sulting in the chaotic assemblages present today. Franciscan Complex landscapes usually consist of gently rolling hills with scattered blocks randomly positioned. This type of topography can be seen in the landscapes of Marin and Sonoma Counties (Sloan 2006). At Mussel Rock, however, no such gentle terrain exists due to the forces of water, wind, human development, and seismic activity.

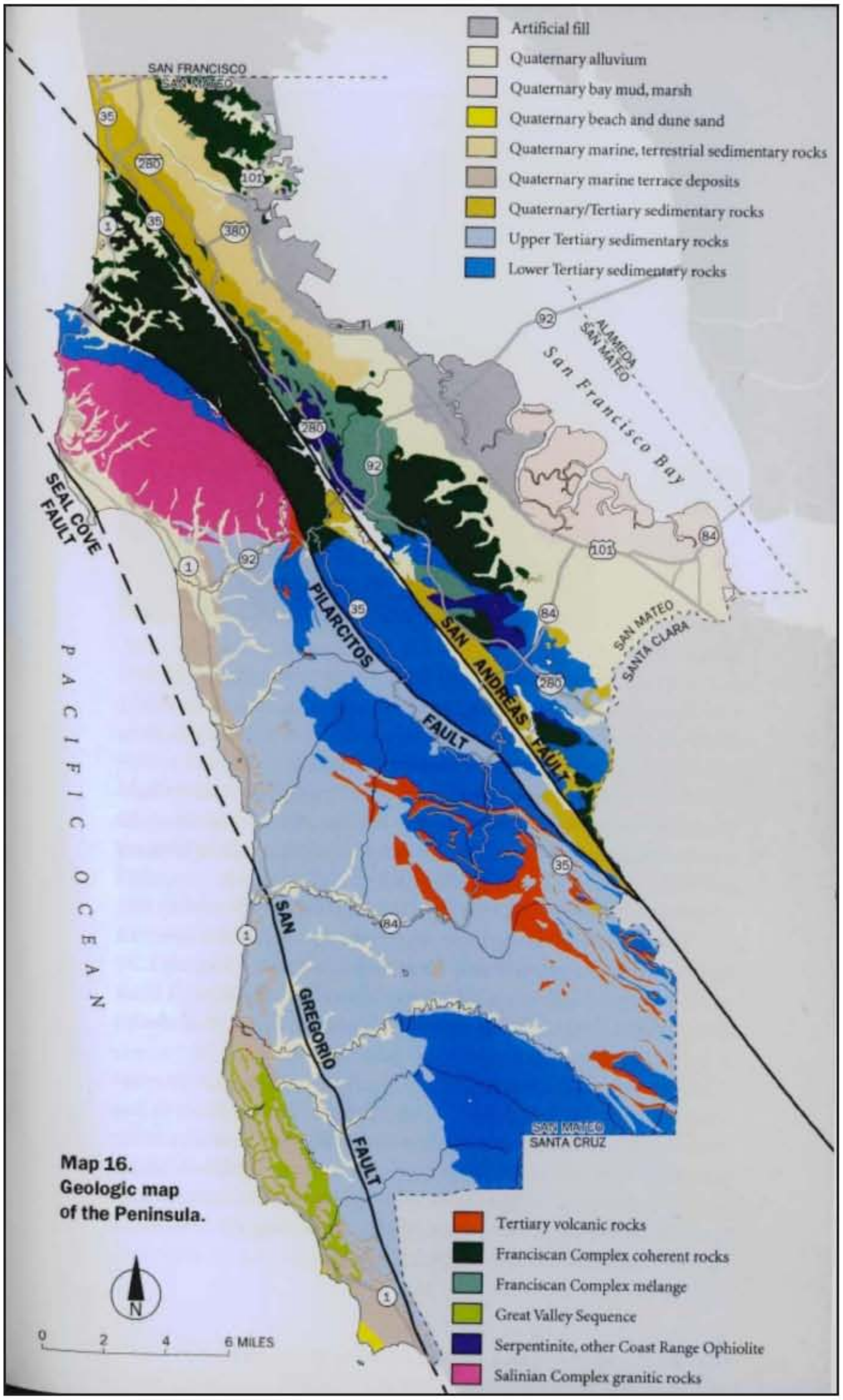

Figure 9. Geologic Map of the Peninsula. From Sloan (2006).

Franciscan Complex

Mussel Rock proper is the remnant of a sea stack, part of a larger Franciscan Complex outcrop west of the San Andreas Fault detached by wave erosion (Figure 3, page 7). Journalist John McPhee (1993) refers to Mussel Rock as a 'horse', a geologic term for a displaced mass of rock that is bounded between the walls of a seismic fault. The Mussel Rock outcrop consists of Cretaceous period greenstone, a component of the Franciscan Complex dating from 80-90 million years ago. Outcrops of the Franciscan Complex at the southwest corner of the Mussel Rock area are about 30 meters (98 feet) thick (Smelser 1987).

The Franciscan Complex greenstone is metamorphosed marine basalt, more resistant to forces of erosion than the overlying Merced Formation east of the San Andreas Fault. Other minerals present in the metamorphosed sedimentary Franciscan Complex include sandstone, pillow basalt, greywacke, shale, radiolarian chert, limestone, and serpentinite (Sloan 2005).

Plate tectonics and uplift are the two main forces behind the geology of this area. Around 145 million years ago, spreading centers in both the Atlantic and Pacific Oceans began to push the North American plate westward, while what eventually became California began to rise from the bottom of the ocean at the Pacific spreading center. Northwesterly movement of the Pacific plate drove the Farallon plate southeastward toward the westward-moving North American plate.

Eventually the Farallon and North American plates collided, and the oceanic crust of the Farallon plate began subducting beneath the much thicker but lower-density continental North American plate. During the subduction process, some of the uppermost rocks were scraped off of the Farallon plate and began to accumulate on the leading edge of the North American plate.

This accreted mélange of deep sea sediments and volcanic materials comprise the Franciscan Complex that is exposed throughout the Bay Area including west of the San Andreas Fault at Mussel Rock (Rademacher 2006). In many locations throughout coastal California (including the Mussel Rock area), the ubiquitous presence of three rock types occurring together in sequences—pillow basalt, radiolarian chert, and greywacke—illustrates that the Franciscan Complex was formed in a deep ocean trench located in a subduction zone (Sloan 2006). The Franciscan Complex is much older than the Merced Formation, which began accumulating around three million years ago during the late Tertiary period (Sullivan, Mustart and Galehouse 1977, Stoffer 2005).

Interestingly, some Franciscan Complex rocks are found on the west side of the San Andreas Fault at Mussel Rock and continuing south to Santa Clara on the Peninsula. This is the only place in the San Francisco Bay Area where Franciscan rocks are located on the west side of the infamous fault (Sloan 2006). This phenomenon is explained by the presence of the Pilarcitos Block, one of four distinct blocks of bedrock (or 'basement' rock) located on the San Francisco Peninsula (Figure 10). Conventional tectonic theory posits that the Pilarcitos Fault represents a former trace of the San Andreas Fault (Andersen, Sarna-Wojcicki, and Sedlock 2001). The Pilarcitos Block consists of the rocks between the San Andreas and Pilarcitos faults in this area. The wedge of Franciscan rocks located in the Pilarcitos Block was accreted to the Pacific plate from the North American plate several million years ago and has been traveling northwest with the Pacific plate ever since.

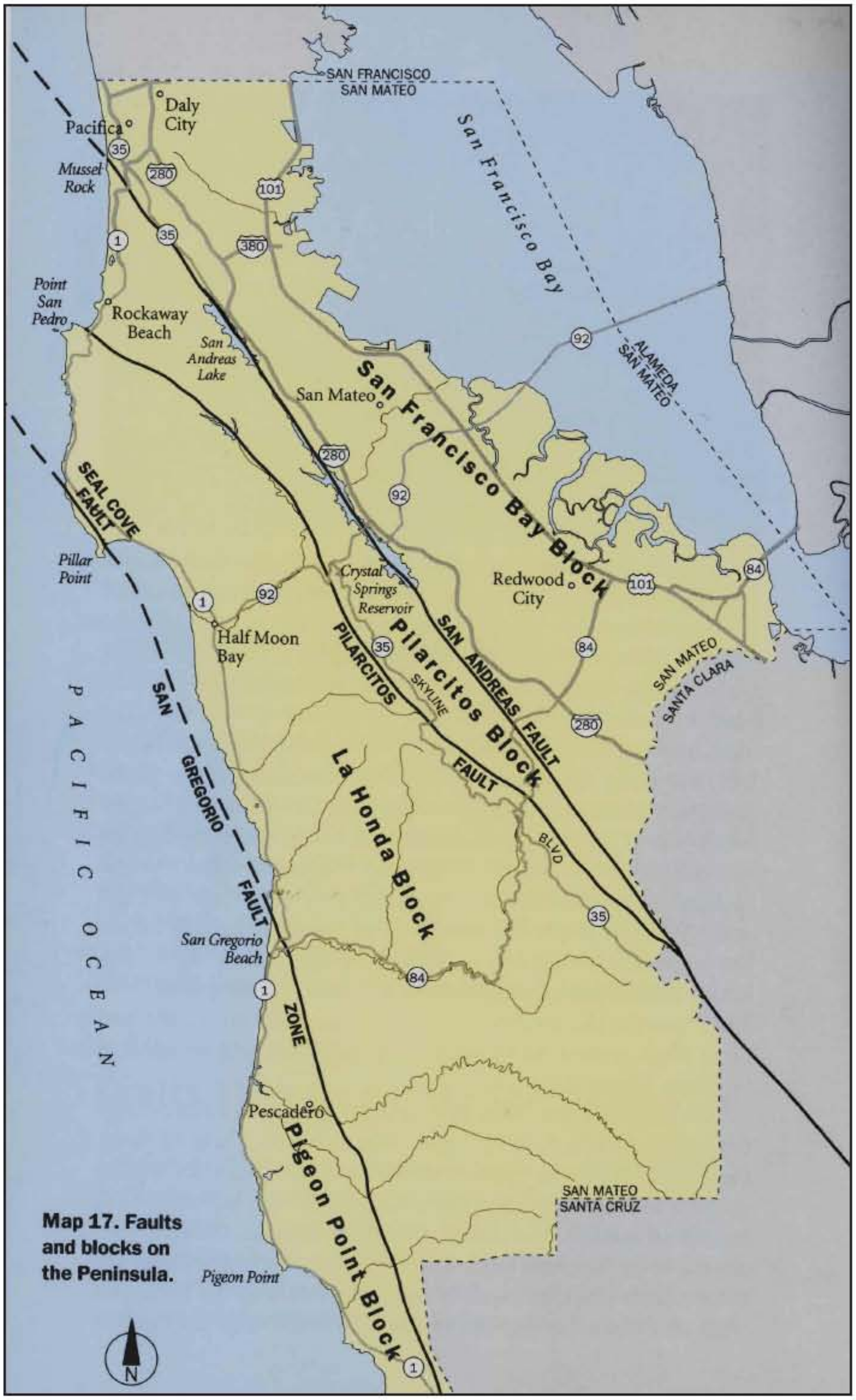

Figure 10. Faults and Blocks on the Peninsula. From Sloan (2006).

Merced and Colma Formations

Sedimentary sand and mud deposits of the Colma Formation overlie shale and sandstone layers of the Merced Formation. Together these deposits form the crown of the Mussel Rock Landslide complex (Figures 4-7, pages 8-9). The Merced Formation constitutes 90 percent of the bedrock structure in this area, and is a visible record of coastal depositional processes (Sloan 2006). Colma Formation deposits—weakly consolidated alluvial soil, sands, and gravels deposited by ancient rivers and streams from the Sierra Nevada—are also of particular importance to this area due to the extensive residential development situated on top of this highly unstable sedimentary deposit (Griggs, Patsch and Savoy 2005). The sediments of the Merced Formation are sedimentary and metamorphic, deposited in a number of marine and non-marine environments over the last three million years.

Eustatic cycles of coastline transgression and regression reflect changes in sea level in response to changes in the amount of water stored in the planet's ice caps. Sedimentary analysis of the Merced Formation indicates that it consists of cyclical successions of depositional facies representing shelf, nearshore, foreshore, backshore, dune, alluvial, freshwater and embayment environments (Clifton and Hunter 1988).

The weakly consolidated sedimentary rocks of the Merced Formation were originally deposited in a 1.6 kilometer (one mile) deep marine basin in horizontal layers. Over time the basin was uplifted and tilted to its current location. The presence of lignite (fossilized plant material) in the Merced strata indicates that the bedding surface became an inland freshwater swamp for a period, before reverting back to seafloor (Sudran 2004).

The Merced Formation and its related units, more than 1500 meters (5000 feet) thick in the Mussel Rock-Fort Funston area, are composed of sediments deposited in a variety of coastal environments. The Merced Formation illustrates a record of short sequences of change in relative sea level at the coast (Sudran 2004).

At the base of these sequences are marine sands deposited offshore during a time when sea level was higher. Shallow marine sand deposits after sea level fell overlie deeper marine sediments (Sloan 2006). Each time sea level continued to fall beach and dune sands formed. These deposits were then buried by pond, swamp, and marsh sediments, forming the mélange that is visibly repeated in the cliffs of the Merced Formation between Mussel Rock and Fort Funston (Figure 11). Although these formations are mostly a reflection of the dynamic changes of sea level through millennia, tectonic processes also undoubtedly played a role in their formation (Sloan 2006).

Colma Formation sands were formed by coastal and fluvial deposition. The Colma Strait was a narrow seaway in existence between 80,000 and 125,000 years ago. The strait's location was just northeast of present day Mussel Rock, extending diagonally across the San Francisco Peninsula and eastward, effectively making what is now San Francisco an island at that time. As sea level fell in the subsequent interglacial period, deposits from the Colma Strait (Figure 12) later formed the Colma Formation that overlies the Merced Formation north of Mussel Rock today (Sloan 2006).

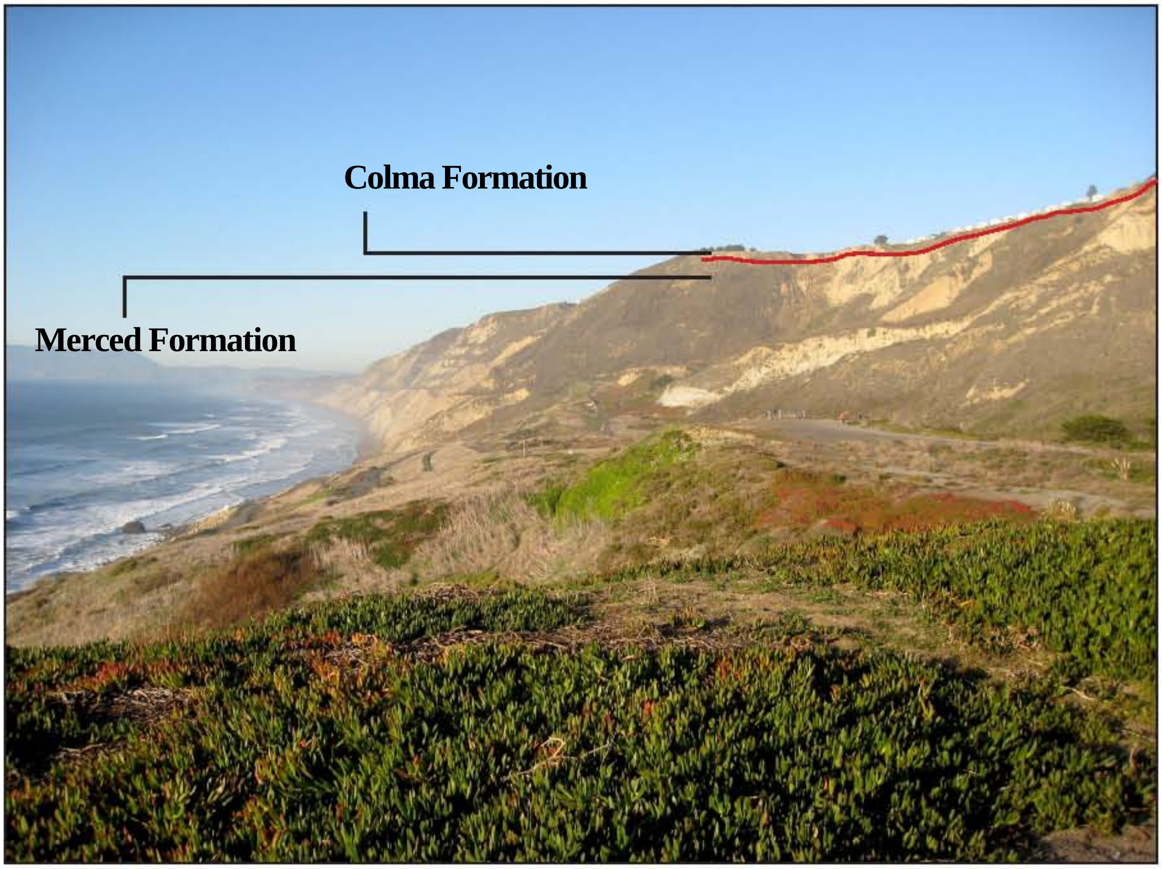

Figure 11. Merced and Colma Deposits North of Mussel Rock to Fort Funston. Photo by Shawn Heiser.

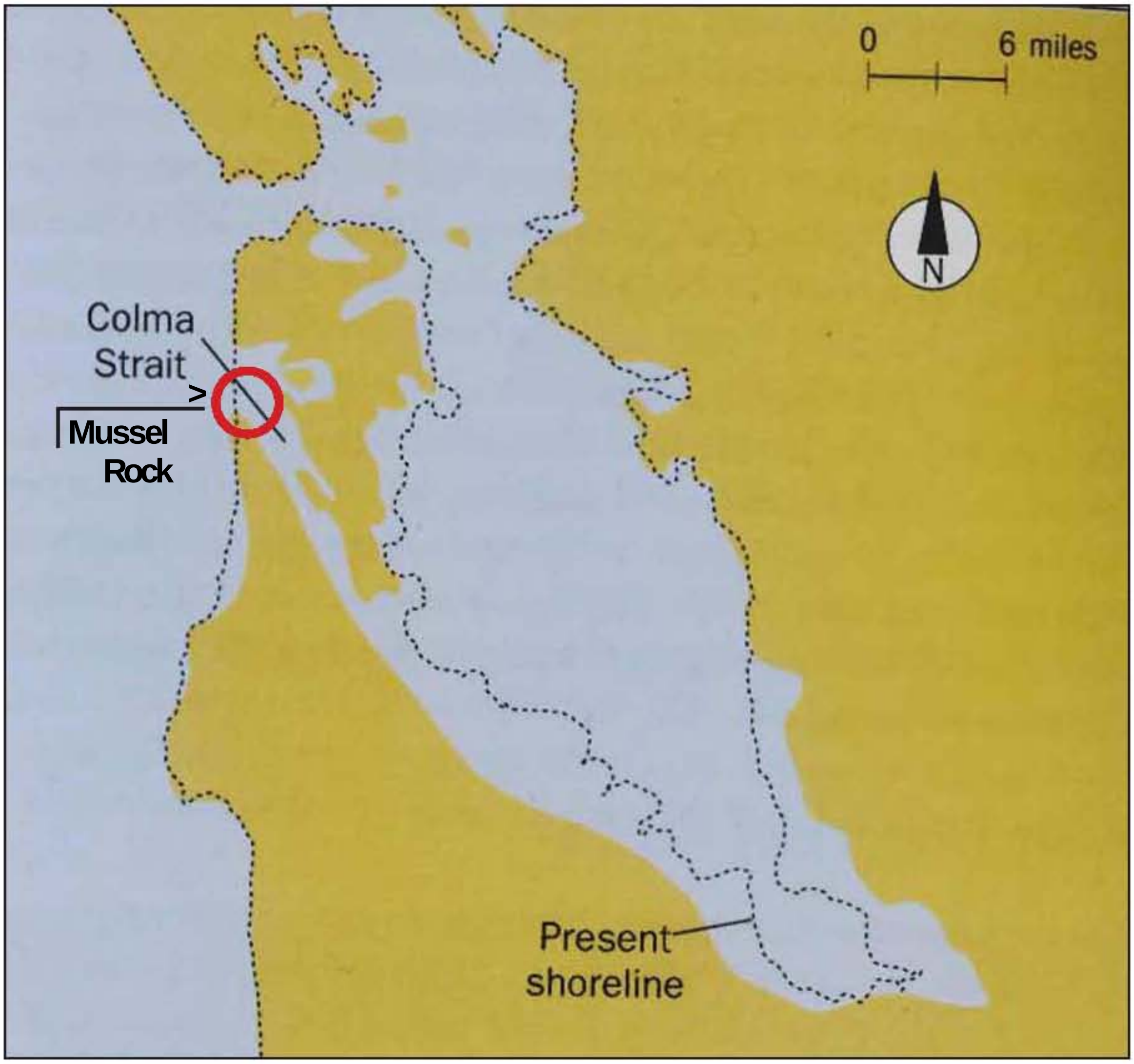

Figure 12. Map of drainage through the Colma Strait during the last Interglacial Period, 125,000 years ago. The strait deposited sands that comprise the Colma Formation at the top of the bluffs above Mussel Rock. From Sloan (2006).

Since the Merced and Colma Formations consist of weak, poorly consolidated sedimentary mud and sands, the grains do not cement together cohesively, making the rocks soft and vulnerable to erosion processes (Sloan 2006). Coastal bluffs such as these are composed of sandstones and shales where grains of quartz, feldspar, and mica compress into layers of sandstone that crumble easily. When these formations are wet from precipitation, the shales and siltstones disintegrate, while clays and mudstones soften and liquefy. The unconsolidated Merced and Colma Formations underlie the foundations of present day neighborhoods in the Westlake coastal area, making them prone to landslides.

The southern Mussel Rock area's present coastal landform is a marine terrace, a wave-cut platform formed thousands of years ago in a nearshore environment, then later uplifted by tectonic activity to its present location. The Mussel Rock marine terrace tilts gently down five kilometers (three miles) into the city of Pacifica (Figure 13). At Mussel Rock the terrace's elevation is 50 meters (165 feet) above sea level, and then dips down to below sea level at Laguna Salada, located on Sharp Park Golf Course in Pacifica (Sloan 2006).

All of the landforms in the area have been altered by climatic and coastal processes such as rainfall and runoff erosion, wind erosion, landslides, slumps, other downslope mass movements, and wave action (Griggs, Patsch, and Savoy 2005).

Landslide deposits in the Mussel Rock depression form a hummocky topography, thickly vegetated and surrounded by the cliffs that form the crown of the landslide. The deposits are poorly consolidated, uncemented slumps and debris flows evidenced by the matrix-supported sedimentology (Smelser 1987). The deposits are dissected by numerous v-shaped drainage channels that funnel fine-grained sediment down the slopes and are deposited on the toe platform as outwash. There are fine outwash sediment deposits in the marsh area near the buried pit of the landfill site (Figure 14). The sediment in the marsh is weakly consolidated uncemented silty clay (Smelser 1987).

Figure 13. Marine Terrace South of Mussel Rock to Pacifica. Photo by Shawn Heiser.

Figure 14. San Andreas Rift Zone and Mussel Rock Landslide, looking southwest. Seasonal marsh at bottom in Spring 2009. Note green space near top of photo where 21 houses have been removed due to landslides. Photo by Shawn Heiser.

Scattered about the deposit are rounded weathered cobbles of gray sandstone and dark gray shale. These sediments make up a small runoff plain between the hummocky landslide deposits and the landfill pit deposits. During the rainy winter season this drainage plain is a marshy area of mud and some standing water, while in summer the plain dries out and mud cracks and a thin white salt crust forms at the surface. The runoff ends up in the Pacific Ocean to the west, being diverted through a large drainage regime designed to avoid percolation into the landfill pit fronting the beach.

To summarize, there are six geologic units in the Mussel Rock area: the Franciscan Complex, the Merced Formation, the Colma Formation, landslide deposits, landslide runoff, and beach sand.

Geomorphology of the Mussel Rock Landslide

Approximately 400 meters (1,300 feet) north of Mussel Rock proper the San Andreas Fault passes through the ancient Mussel Rock Landslide, the most significant threat to the local ecosystem and human habitation in the area. The original landslide likely occurred around 100,000 years ago, and has been reanimated by the 1906, 1957, and 1989 earthquakes, all of which had epicenters near the Loma Prieta portion of the San Andreas Fault (Bonilla 1960; Kious and Tilling 2009).

In 1906, the magnitude 7.8 earthquake sent millions of cubic yards of rock 61 meters (200 feet) wide and 15 meters (49 feet) deep towards and over the beach locally at Mussel Rock (Fradkin 1998, Sloan 2005). In 1957, after extensive development around and on top of the Mussel Rock area, the magnitude 5.3 quake caused numerous smaller slumps and landslides, and extensive damage to Westlake subdivision residences and businesses (Oakeshott 1959).

The geomorphic feature known as the Mussel Rock Landslide—as opposed to the events of the continuing landslides themselves, or the sea stack proper, or the general park-like area—is an enormous entity the size of which is difficult to comprehend looking at it today. The landslide is active, and is slowly but continually moving further into the Pacific Ocean. In fact, most of the landslide's 6.9 million cubic meters (nine million cubic yards) of rock are already submerged beneath the surface of the ocean. It is the second-largest active landslide along the entire California coast, extending 6.5 kilometers (four miles) out to sea (Sloan 2005). Since the early 1900s, sections of the Mussel Rock landslide have been leveled, excavated, and terraced for a variety of utilitarian reasons.

Mussel Rock Landslide is categorized as a major complex rotational slide which most likely began as a slump earthflow (Bonilla 1960). The central portion of the slide consisted of poorly drained, hummocky topography that supported ponding of groundwater and runoff prior to grading by various engineering projects. Material is constantly added to the landslide from the main scarp and flanks by secondary sliding consisting of slumps, erosion gullies, debris slides, outwash and earthflows (Cox-Whitsel 1983; Smelser 1987).

Potential causes of landslides at this location include 1) earthquakes, especially in faulted and weakened rocks; 2) removal of material at the toe of the slide by ocean waves or other excavations; 3) overloading of material at the head of the slide by secondary slides; 4) the pressure of subsurface metamorphic water reducing shear resistance and cohesion of the slide debris; 5) weathering of exposed slide scarps; 6) large quantities of rainfall and intense storms, resulting in surface runoff and percolation into the groundwater; 7) the unstable and unconsolidated nature of the local sediments along with the steep dip of the Merced Formation at Mussel Rock; and 8) human activities including earth fills and cuts (Bonilla 1960; Cox-Whitsel 1983).

Mussel Rock Landslide can be divided into two major segments. The upper body of the landslide consists of larger failing blocks that move slowly downslope. The lower body and toe are composed of landslide debris that flow over the beach and into the ocean. Figure 15 illustrates a generalized block model of the landslide. The steep escarpments, headscarps and flanks above the landslide remnants form the horseshoe-shaped crown of the landslide that wraps around the area, open only to the west (Smelser 1987). The landslide system includes the crown and scarps in the Merced Formation on the north, east and south. The body of the slide is bounded to the north, east and south by the Merced Formation cliffs, and the toe of the landslide is bounded by human-built revetment structures and the Pacific Ocean.

The hummocky pattern of the landslide creates an overall topography of step-like platforms and slopes. These features, along with a variety of slump scarps that average 5.5 meters (18 feet) in height and 9 meters (29 feet) in length, serve as indicators that continuous small-scale slumping is the primary mechanism by which downhill movement of the landslide occurs (Smelser 1987).

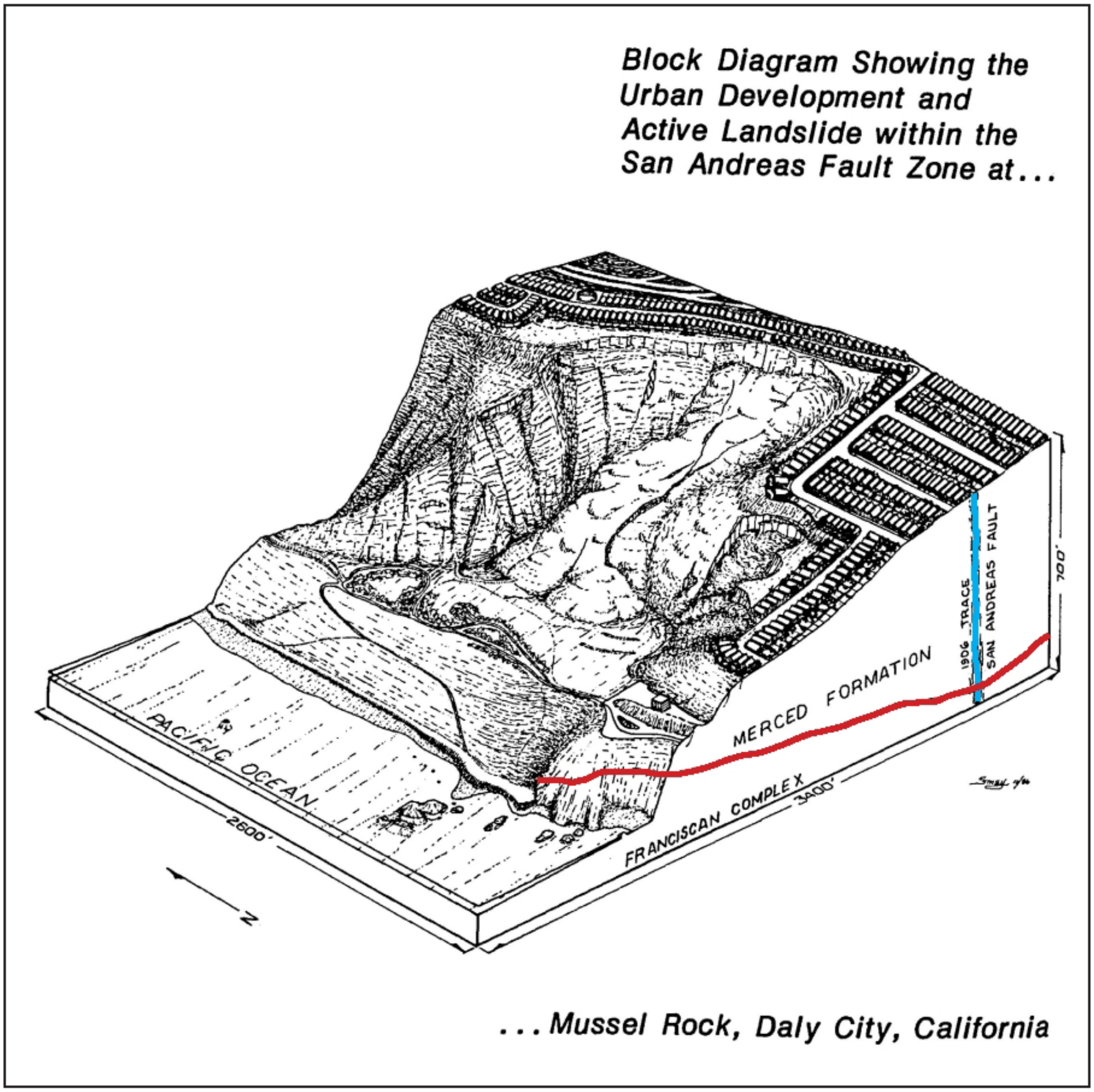

Figure 15. Block diagram of the Mussel Rock Landslide. Note contact between Franciscan Complex and Merced Formations, and San Andreas Fault trace from 1906. From Smelser (1987).

Intermittent, steep-sided v-shaped drainage channels form throughout the landslide deposit from seeps, springs, and runoff. These drainage channels promote further slumping, evidenced by the presence of cracks on the surface of the body of the slide. Urban paving along the crown of the landslide has greatly increased annual runoff into the landslide area (Cox-Whitsel 1983; Griggs, Patsch and Savoy 2005). The drainage systems flow mostly during winter and spring, when marshes, standing water and deep mud deposits also occur on the outwash plain (Figure 14, page 38). As a result most of the downhill movement of the land- slide occurs during the rainy season between the months of November and April.

The eastern scarp of the landslide (and the eastern border of Mussel Rock) is the steepest and least vegetated of the scarps in the area (Figure 16). The eastern scarp measures about 500 meters (1,600 feet) from north to south, and between 1.5 and 40 meters (four and 131 feet) high (Smelser 1987). The scarp slope ranges from approximately 50 degrees west at its most stable portion, to 90 degrees west at the most active part, making the eastern scarp the most unstable and hazardous feature in the Mussel Rock Landslide system (Smelser 1987).

The thickly-vegetated steep northern crown has a sharp ridge containing crevasses measuring 0.9 meters (two feet) wide and 1.1 meters (3.5 feet) deep, and step-like hummocky topography below the ridge that results from slumping. The steep northern scarp, about 425 meters (1,400 feet) from east to west, is comprised of a set of narrow v-shaped, non-vegetated gullies, small vegetated slumps, and 3-6 meter (10-20 feet) scarps above them (Smelser 1987).

Figure 16. Northern and Eastern crown of the Mussel Rock Landslide, with residential homes atop the crown. Photo by Shawn Heiser.

The southern scarp is a series of step-like blocks averaging about 1.8 meters (six feet) in height. This scarp is thickly vegetated and has a shallower slope than its northern and eastern counterparts. The main difference between the southern scarp and the others appears to be that the slump blocks on the southern scarp are much larger than the others. Several underground pipes and cables are periodically exposed on the southern scarp as a result of slumping.

If another major earthquake were to occur near the Mussel Rock area during a particularly wet winter or spring, the area could be dramatically activated, initiating an almost certain local environmental calamity when the reanimated landslide could potentially eject an estimated 765,000 cubic meters (one million cubic yards) of garbage from the buried landfill pits into the Pacific Ocean (Cox-Whitsel 1983).

Erosion Processes and Rates in the Mussel Rock Area

The episodic process of coastal bluff retreat plays a major role in the changing morphology of the Mussel Rock area. Headward erosion of cliff and bluff faces tends to occur here during moderate to strong intensity El Niño Southern Oscillation (ENSO) events where a high storm surge is present. The rate of coastal bluff retreat depends on variables such as the magnitude of wave attack, amount of runoff, and bluff lithology (Griggs 1997; Sloan 2006).

Figure 17 shows coastal erosion processes and human revetment structures at Mussel Rock. Erosion rates can vary widely from year to year, and as such are averaged over the course of several decades in order to establish an expected rate. The degree of erosion in a given place in a given year takes many different variables into account. First is the composition or relative strength of the rocks that comprise the formation of the headland, marine terrace, or coastal bluff. Harder formations made of bedrock such as the Franciscan Complex are more resistant to erosion by ocean waves and rainfall, and therefore will not appear to erode at all over long periods of time. Weaker portions of Franciscan mélange erode faster, creating the arches and sea stacks off shore at Mussel Rock.

Softer materials in the strata, such as the weak sedimentary rocks that make up the Merced and Colma Formations at Mussel Rock are more susceptible to rapid erosion. The materials of the Merced and Colma Formations are loosely cemented, in some cases with nothing to bind them together. Sometimes other minerals such as quartz or calcite are present, and those minerals seep into spaces between the sand grains and act as a weak cementing agent. In the Merced Formation at Mussel Rock, the empty spaces between sand grains are often filled with water.

On the one hand, formations with large pore spaces are of great importance to societies for they enable storage of fresh water in aquifers. In the case of the Merced Formation, such aquifers are utilized by municipalities as drinking water supplies. This local aquifer

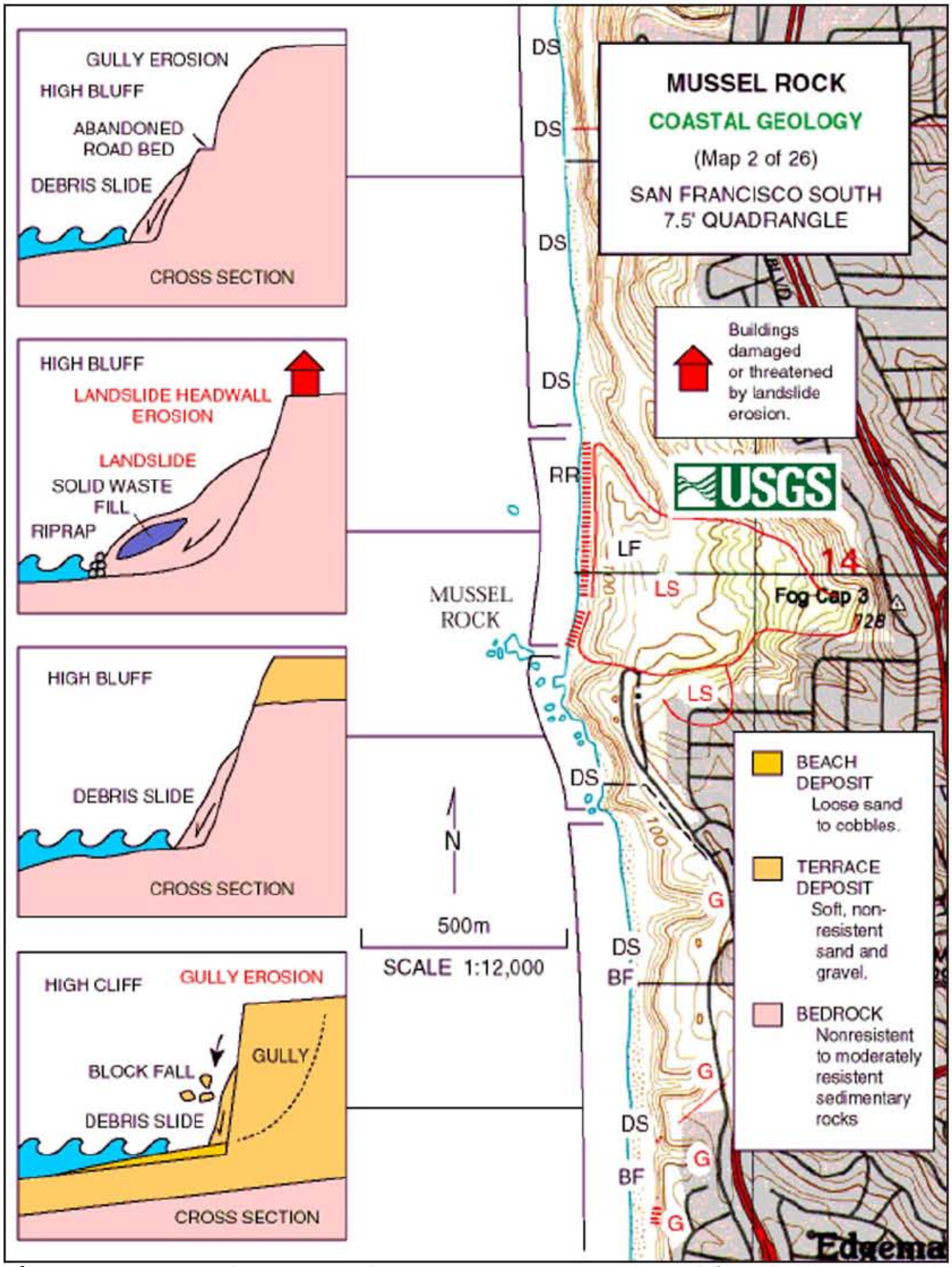

Figure 17. 1982-83 El Niño Coastal Erosion: San Mateo County, California. From Lajoie and Mathieson (1998).

supplies up to half of the drinking water for northern San Mateo County (Sloan 2006). On the other hand, such a formation is unsound as a foundation for buildings. The water-filled spaces between sand grains are highly susceptible to rapid erosion and landslides, and provide little stability for permanent structures.

Erosion rates are calculated by averaging cliff and bluff retreat over years through the use of aerial photographs and fixed sensors in the ground. Utilizing these technologies, average erosion rates can be estimated for the last 50 years. Averages provide an overall impression of the rate of erosion, rather than a fixed rate for any given year.
According to Johnson and Marcum (2004), evaluation of coastal erosion rates utilizing only aerial photography may be useful only in areas where retreat events are frequent, such as Mussel Rock. But for other coastal areas where retreat is not a significant historical factor, and in settings where coastal bluffs expose weak and fractured rock, annual erosion/retreat rate studies may be inadequate without data from fixed sensors.

It is well understood that in years when El Niño Southern Oscillation (ENSO) occurs in California, coastal erosion is much higher than in non-El Niño years. When intensified ENSO storms reach the California coast at high tide, rapid and severe erosion occurs on softer rocks such as the Merced and Colma Formations (Hampton and Dingler 1998, Shires 2001).

Since around 1950, three ENSO winters in particular saw dramatic rapid erosion along the San Mateo coast. The first, 1977-1978, re-introduced the ENSO phenomenon to the California coast. The second and largest, 1982-1983, wreaked havoc on numerous coastal areas of California. Major landslides were created or reanimated, causing houses to slide down cliffs and onto beaches, including some in Pacifica a few hundred meters south of Mussel Rock. The third ENSO winter, 1997-1998, caused similar landslides and erosion damage, costing the state millions of dollars in subsequent relocation and revetment projects (Hampton and Dingler 1998; Shires 2001).

All three ENSO periods significantly affected residents living on the coast near Mussel Rock, and several dozen residential structures which suffered foundation damage due to local slumping from oversaturation of the soil.

In ENSO years erosion rates for such structures can average up to 0.6-0.9 meters (2-3 feet) per year (Sloan 2005). For non-ENSO years, the average rate of coastal erosion in the area of Mussel Rock is much lower, averaging rates between 0-10 centimeters (0-4 inches), depending on multiple variables. One example of published retreat rates for the area immediately around Mussel Rock for the last 50 years is approximately 25-33 centimeters (10-13 inches) per year (Gilpin 2007).

Other sources of erosion rates for similar strata and geologic units nearby include Hampton and Dingler (1998) whose long-term rates ranged up to 100 centimeters (39 inches) annually. Smelser (1987) provides data from a comparison of measurements made on the eastern crown of the Mussel Rock area in the years between 1979 and 1986. The results of the measurements were alarming for anyone living atop the crown on the eastern scarp: locally, up to six meters (20 feet) of the crown had slumped in the previous seven years, for an average erosion rate of 0.9 meters (three feet) per year. Presently, geologists do not provide average retreat rates locally at Mussel Rock with any consistency or consensus. However, Figure 18 presents average local erosion rates, and illustrates events and action taken to stabilize the coastal area from Lake Merced to Sharp Park, including Mussel Rock (Griggs, Patsch and Savoy 2005).

Movement along the San Andreas Fault System in the Bay Area breaks up the weakened Merced and Colma Formations, furthering their susceptibility to erosion. Additionally, human activities on marine terraces and cliffs, such as construction can undermine and destabilize the surfaces, encouraging headward erosion of the cliffs (Griggs, Patsch and Savoy 2005).

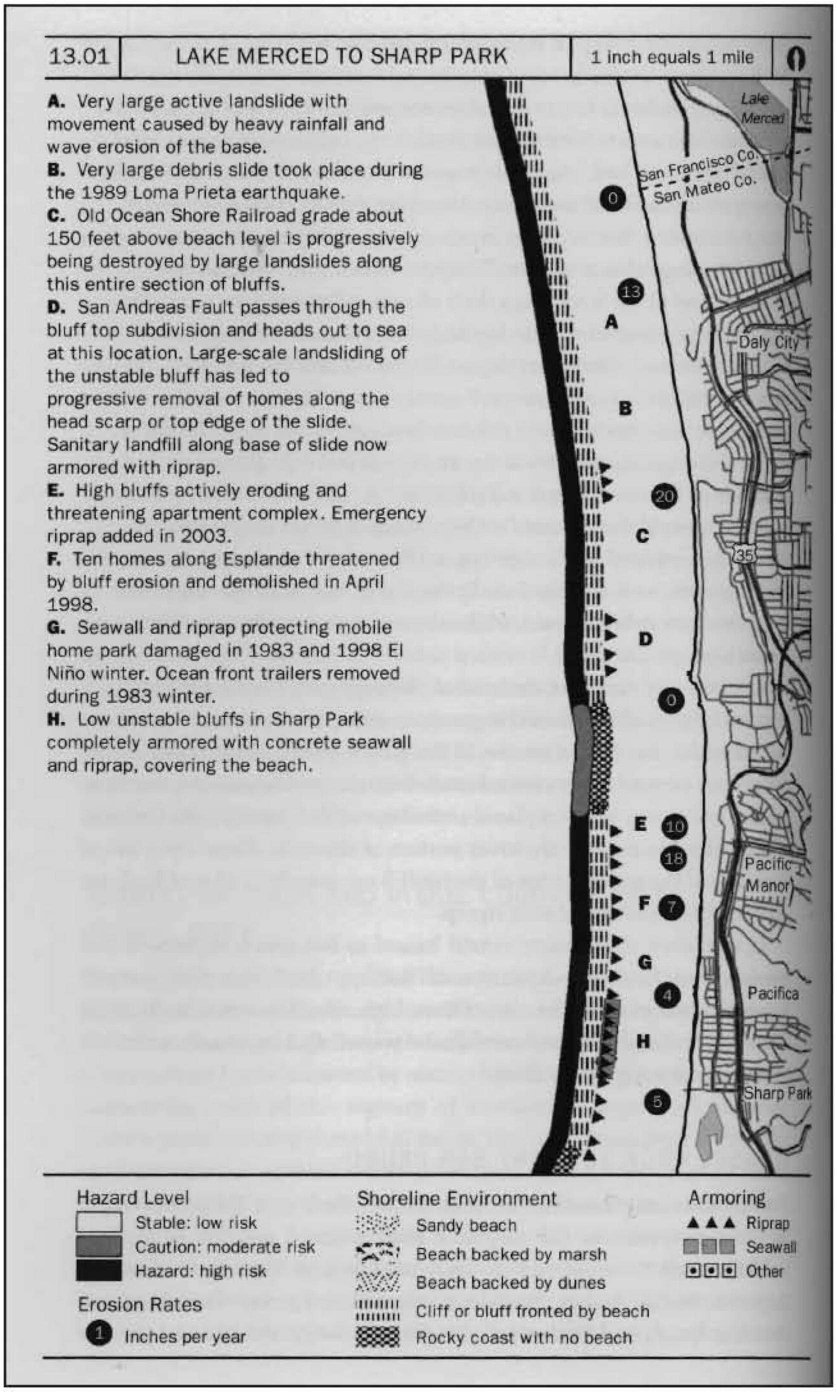

Figure 18. Coastal erosion, hazard, and revetment map showing the area from Lake Merced to Sharp Park. Mussel Rock is located in the center at letter D. From Griggs, Patsch and Savoy (2005).

An example of another erosion process, called passive erosion, or the 'peninsula effect', which could result at Mussel Rock, is the revetment regime in place to prevent the landslide and landfill contents from emptying into the ocean. Protective devices such as seawalls, riprap, terracing, and other revetments at Mussel Rock create the likelihood of passive erosion in the near future, and could be the source of nearby coastal Pacifica's persistent erosion problems. The process by which passive erosion occurs is a result of creating a fixed shoreline position on an otherwise eroding stretch of coastline.

Passive erosion occurs when wave action and other erosion takes place around a fixed protective device, which is usually built parallel to the shoreline. The protective structure remains while the shoreline migrates landward over time, eventually creating a peninsula of protected land behind the revetment, while both sides of the protected land are inundated by the landward-advancing shoreline (Griggs, Patsch and Savoy 2005).

One major impact of passive erosion is loss of beach as a result of the protective device, therefore limiting public access to the beach. Because Mussel Rock's beach has been filled in by tons of granite boulders and other weirs and riprap structures, and has a propensity to disappear entirely during winter months, it is not a popular beach for locals except for sport fishing enthusiasts. Perhaps the loss of sand and beach area is not a problem for most local visitors, but an evolving peninsula effect, combined with wave refraction, could profoundly impact residents and beach-goers to the south of Mussel Rock in Pacifica.

Coastal Climate at Mussel Rock

Coastal fog dominates the climatic regime at Mussel Rock. This local phenomenon acted as a deterrent to settlement and development for centuries. Local weather conditions reflect that of the western San Francisco Peninsula region. Mild and wet winters precede relatively cool and dry (but very foggy) summers. Annual precipitation averages 76 centimeters (30 inches) (Pacifica 2009). The most rainfall in one month was 46 centimeters (18 inches) in February 1998 and the most rainfall in 24 hours was 13 centimeters (five inches) in December 2004 (Pacifica 2009).

The most significant risk to accelerated erosion processes at Mussel Rock is excessive rainfall. El Niño Southern Oscillation (ENSO) winters almost always cause destruction of some human-built structures. This is the physical result of poor decision-making by developers who ambitiously built without consulting engineering geologists.

CHAPTER 3: Environmental and Land Use History at Mussel Rock

The name 'Mussel Rock' has been used for the area since at least 1863. The sea stack itself has been referred to as 'Mussle Shoal Rocks' and 'White Cliff'. However, the latter name may have been a case of either mistaken identity or poor cartographic reference, since the name 'White Cliff' had also been given to what is now Pedro Point in Pacifica (Brown 1974; Wagner 1974). Spanish maritime explorer Juan Manuel de Ayala produced the first map that clearly illustrated Mussel Rock and its rift valley in 1775 (Clark 1985). The following year saw the founding and construction of both Mission Dolores and the Presidio of San Francisco.

Ompuromo: Mussel Rock's First Settlement (~1200-1776)

Based on archaeological evidence, the original inhabitants of the Mussel Rock area were Ohlone tribes, named 'Costanoan' by European settlers. The Ohlone lived in a village they called Ompuromo (ocean-flea place) in the Mussel Rock area for at least several hundred years prior to European arrival in California in 1579. Ohlone cultures on the San Mateo Coast date back at least 5,000 years and perhaps as far back as 15,000 years (Miller 1971; Clark 1985). Ohlone culture at Mussel Rock is evidenced by the archaeological excavations of an Ompuromo midden (shell-mound) site in the area. These excavations at Mussel Rock indicate a permanent or at least seasonal habitation for Ohlone culture for presumably thousands of years until Spanish colonization in 1776 (Clark 1985).

The village of Ompuromo flourished due to its location at a juncture of geographic and seasonal importance. This spatial and cultural crossroads provided the inhabitants with numerous resource zones to exploit. At least six local ecosystems provided a range of food and shelter supplies. These include the sandy beach and dune complex; rocky shoreline and tide pools in the shallows around Mussel Rock proper; the riparian area following the perennial stream out of the rift valley; the freshwater marsh area downstream; the coastal scrub and chaparral environment of the surrounding hills and cliffs; and the offshore open water of the Pacific Ocean (Clark 1985).

The excavated midden site contained large amounts of prehistoric implements, tool manufacturing debris, and faunal remains from food items. Unfortunately for historians and archaeologists, a decision was made in the mid-1970s by Daly City leaders to construct the Mussel Rock Transfer Station, a building where garbage is sorted and transferred elsewhere. The Transfer Station's location was directly on top of the midden mound site, thereby destroying all remaining relics of Ompuromo village. Due to the construction of the Transfer Station in 1978, only 45 cubic meters (1,600 cubic feet) of the much larger site were excavated before funding and time for the project ran out. Subsequent carbon dating from a sample of the recovered materials indicated the items to be from approximately 1500 AD (Clark 1985).

Ompuromo village was located on the cliffs above Mussel Rock, approximately 60 meters (200 feet) above sea level on the southern side of the San Andreas Fault (Figure 19). This site location provided shelter from the prevailing northwest winds. Archaeological evidence indicates that the valley floor of the area was a marsh and wetland system during Ohlone times. Thus, the only places suitable for Ohlone cultural use would have been the beach in front of Mussel Rock and the southern side of the valley. Due to the cold and windy conditions often present at Mussel Rock beach, and the fact that beach deposits can often disappear during intense winter storms, it is understandable why the village of Ompuromo settled on the knoll on the southern boundary of the area. Figure 20 is an idealized painting of what Ompuromo village might have looked like during its many centuries of habitation.

A detailed map from 1853 shows a much more vertical rift valley than that of today, draining the sag ponds and Laguna Alta above and to the north of Mussel Rock (Figure 21). Today we can see the more accurate northwesterly trend of the valley on maps and satellite imagery. A comparison of topographic maps from 1897 and 1980 show that the Mussel Rock rift valley had been widened both to the north and south by the engineered filling of the rift valley for the Mussel Rock landfill. The contours had also been eased by the fill-

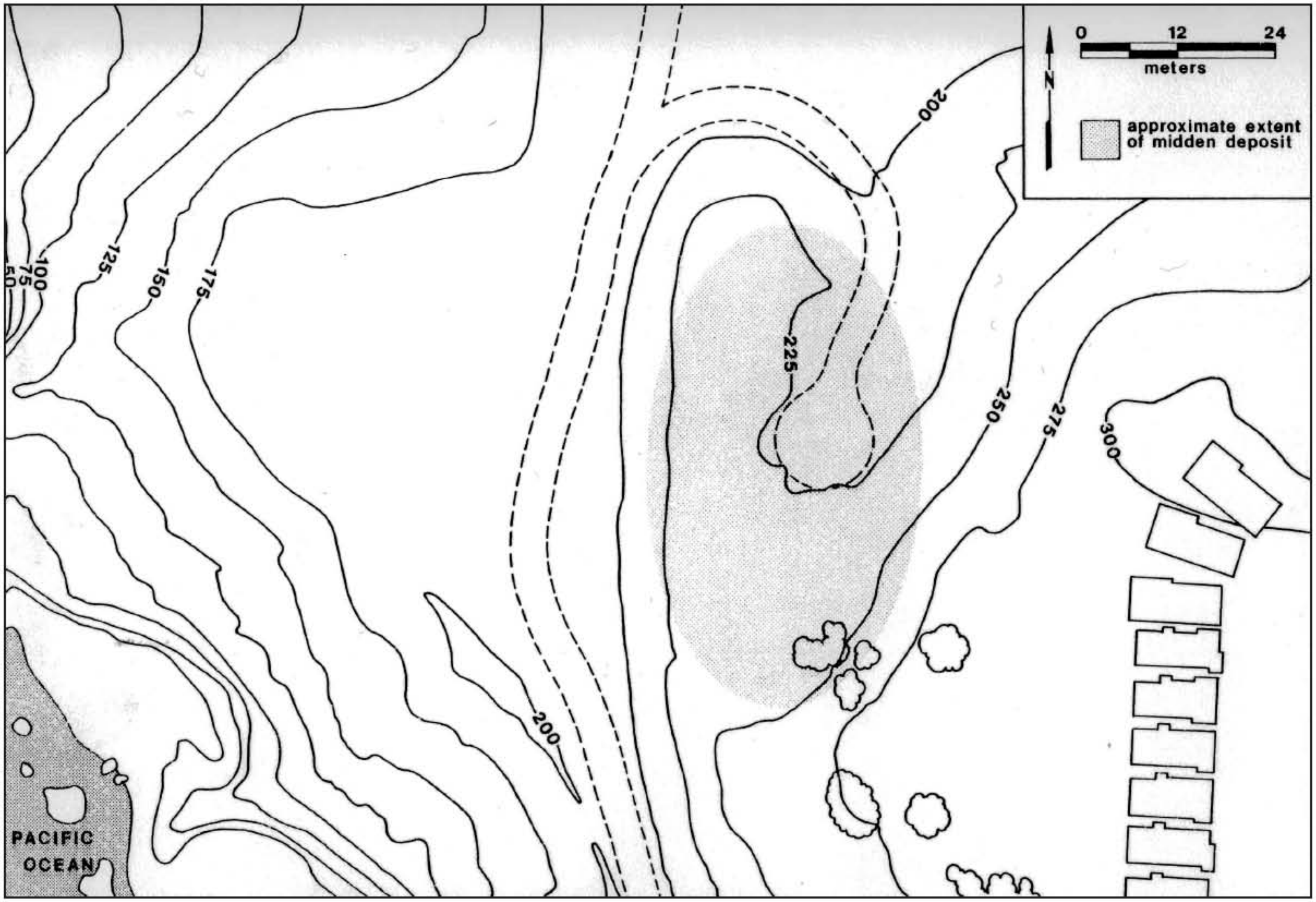

Figure 19. Ompuromo midden site at Mussel Rock in 1977. From Clark (1985).

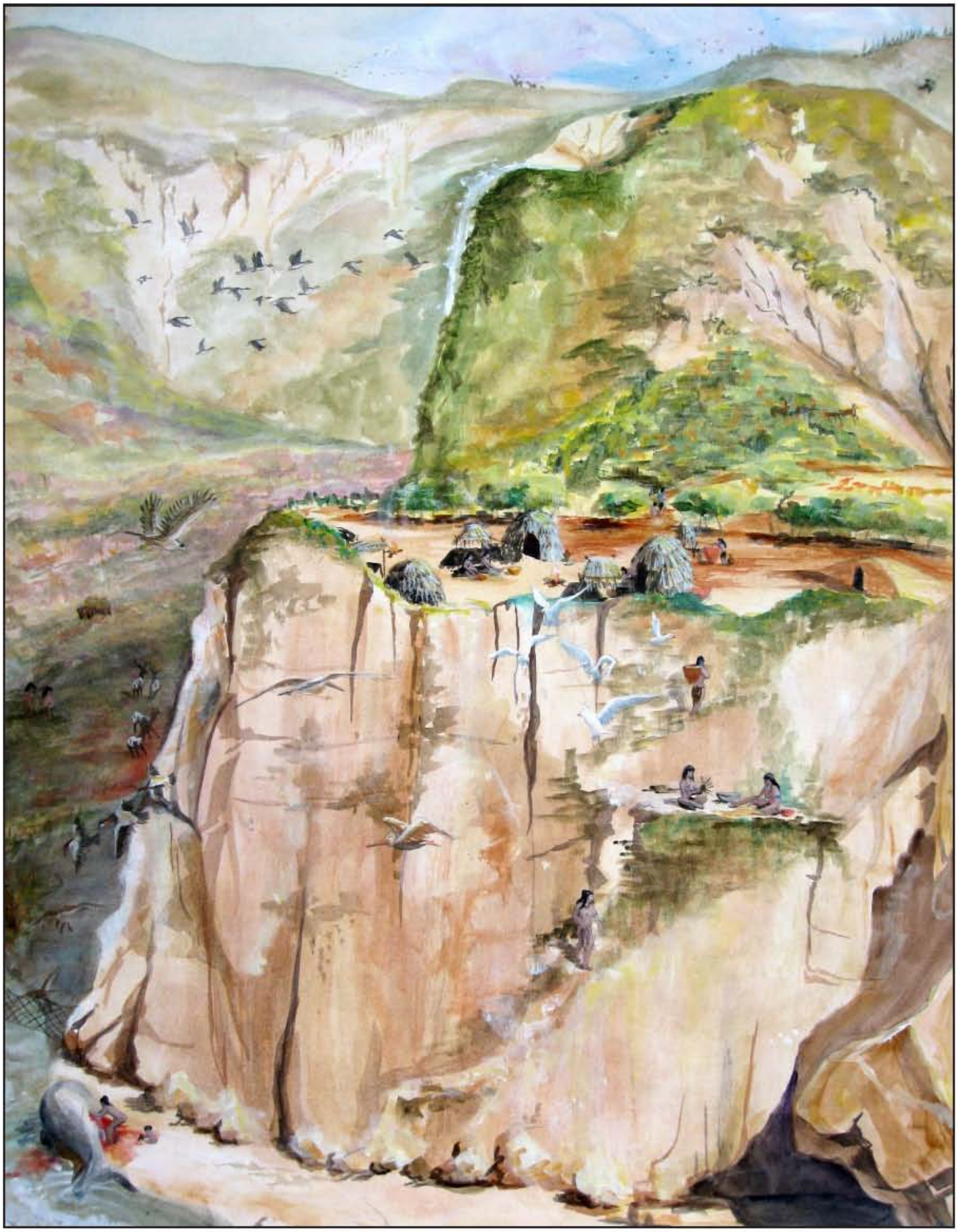

Figure 20. Painting of idealized Ompuromo village at Mussel Rock. From Kooper (date unknown).

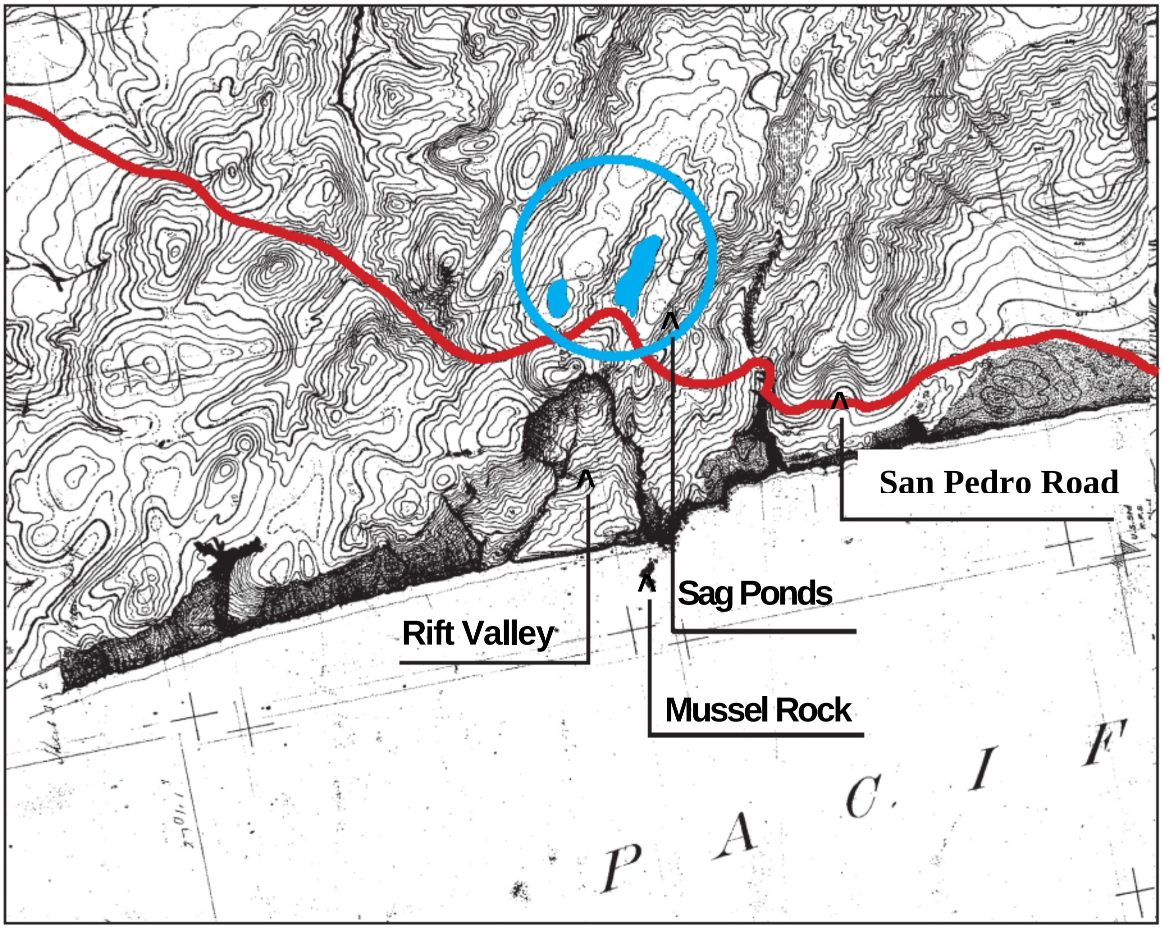

Figure 21. Detail of Mussel Rock area from 1853 Map. Note San Pedro Road, the first coastal route from Mission Dolores to San Pedro Rancho. Also note the drainage channels from sag ponds to the North of Mussel Rock. From Bache (1853).

ing in of the rift valley due to landslides and engineering. During the time of Ompuromo, however, the topography was much more vertical than today. According to Matthew Clark (1985, 19), "there must have been a very good reason why all the sea mammals found in the (shell-mound) site refuse were hauled up a probably near vertical cliff from the beach where they were caught; the best explanation is that the site location was the nearest and easiest location to use".

Natural endemic vegetation regimes at Mussel Rock consisted primarily of beach and dune plants on the western edges of the village. The beach and dune complex would be subject to near constant wind and ocean spray, limiting vegetation in this immediate area to plants adapted to these conditions. With increased distance from the ocean, dune complexes become more stable, and distribution and variety of plants increase. Behind the dunes were coastal prairie and coastal scrub habitats; the former dominated by native perennial bunch grasses, and the latter by coyote brush, poison oak, and small evergreen shrubs.

In the marsh area of the rift valley, riparian species such as willows and cattails flourished. On the uplands to the east and north, oak woodland habitat and grassy plains were dominant (Clark 1985). The Ohlone regularly practiced controlled burning of vegetation to limit shrub growth, facilitate the growth and dispersion of bunch grasses and seed plants, and encourage new growth forage for deer and other animals used by the villagers as food sources.

The estimates of the number and distribution of Ohlone residents in the Mussel Rock area before Spanish colonization differ among historians and archaeologists. Conservatively, some historians claim that as few as three to four families lived in the Mussel Rock coastal area before Spanish arrival in 1769. Other historians and archaeologists posit that while perhaps only one 'triblet' or extended family may have occupied the Mussel Rock area, the triblets usually consisted of 200-300 members of an extended family (Margolin 1978).

Given the size of the area and the bounty of resources available at that time around Mussel Rock, it is reasonable to think that the area was capable of supporting several hundred or more members of an Ohlone triblet on a permanent basis.

Many archaeologists now believe the number of Ohlone in California was much higher than previously acknowledged, as evidenced by various excavations in recent decades at Mussel Rock and Half Moon Bay. At the time of excavation, the recovered Ohlone cultural materials at Mussel Rock were the largest prehistoric faunal resource procurement and processing location yet reported on the ocean side of the San Francisco Peninsula (Clark 1985). In fact, the site turned out to be much larger, deeper and more complex than investigators had originally thought, resulting in the excavation of twice the amount of cultural material originally anticipated, and only a lack of funding caused the cessation of excavation activities. Clark could not confirm whether the Mussel Rock site was utilized as an Ohlone habitation site or a seasonal resource procurement site. Due to the complex set of variables involving seasons, movement of tribes, politics, availability of resources, material needs and other factors, defining any Ohlone settlement as exclusively seasonal or permanent is probably not possible in the context of the San Francisco Peninsula (Margolin 1978).

Mussel Rock had several spring-fed fresh water streams emanating from sag ponds in the San Andreas Rift Valley to the southeast, along with groundwater intrusions accessible at seasonal springs and seeps in the cliffs above the valley. The streams, springs and seeps fed a small freshwater marsh in the depression of the landslide. Willows, cattails, sedges, and various native grasses flourished in the riparian corridor and marsh. Archaeological and geological evidence indicates that the streams were fresh water sources year round. Hence, a reason for permanent habitation at Mussel Rock (Figure 20, page 57).

High concentrations of pelagic birds nested in the cliffs above, and their eggs were often utilized as a food source. Freshwater streams could have supported fresh water and anadromous fish such as salmon and trout until headwaters and the streams' drainage mouths were closed by human alteration beginning in the 20th century. The water bodies were finally filled in as part of the area's extensive residential development in the 1950s. This action represents a great irony between successive cultures' needs and priorities for habitation in the place called Mussel Rock—fresh water.

In Ohlone times, a fresh water source was essential to survival at Ompuromo, and was regarded as a valuable resource. Today, fresh water at the same location is regarded as a burden to be diverted. In order to keep water off the surface of the landslide and prevent it from percolating into the landfill pits and releasing leachates, as well as potentially reactivating the landslide, engineering projects are continual and costly.

It is well known that Central California and the Bay Area were rich with wildlife before European arrival. The abundance of local food sources ensured that, unlike other native populations elsewhere in North America, malnourishment and starvation were unknown to Ohlone tribes (Margolin 1978). As a cultural practice, hunting and gathering rather than agriculture allowed them to exploit food sources available to the tribes in the region. Ohlone village locations were chosen based on the abundance of nearby flora and fauna resources (Margolin 1978). The excavations contained many different animal remains, both terrestrial and aquatic.

If one should have desired items beyond the wealth available at Mussel Rock, within one day's walk was nearly every imaginable habitat that existed at that time in Central California, including San Francisco Bay and even broadleaf and redwood forest environments. These factors illustrate why Mussel Rock proved to be an excellent location that Ohlone tribes utilized for several centuries.

These attractive aspects of Mussel Rock—diversity of resources, temperate weather, and a convenient crossroads for travel networks—remain many of the very same reasons for living here today.

The nearshore environment at Mussel Rock also proved bountiful to the villagers. In the shallow tide pools between the beach and Mussel Rock proper, an almost unlimited amount of shellfish, clams, mussels, abalone, and other snails, fish, octopus and squid could be found any time of year. Although not confirmed by archaeological finds at Mussel Rock, it is assumed that the Ohlone built tule boats to fish and hunt waterfowl in the Pacific Ocean west of Mussel Rock. Made of tule bulrushes, these vessels, propelled by double bladed paddles, would be better categorized as rafts since they were self-floating and not water-displacing crafts (Margolin 1978).

Ohlone cultures sometimes radically altered the landscapes around them. They regularly practiced controlled burning of vegetation to limit plant growth and encourage the expansion of plant and animal species favorable to their diet. Ohlone villages also created their own landfill in the form of a shellmound, which was excavated by American archaeologists centuries later. Originally a large hole in the ground, over decades the midden became a large mound where people would leave their food scraps, tools, jewelry, and other materials no longer useful to them. They would also, on occasion, bury their dead in the shell mounds. Most recently, three Ohlone skeletons were excavated from the Ompuromo village midden in 1977 (Clark 1985). These practices significantly altered the landscape, and represent a palimpsest, or imprint on the landscape of their existence.

The material above is an attempt to provide an informed, albeit detached account of how Ohlone cultures utilized the place of Ompuromo at Mussel Rock, and in what ways they might have made a lasting imprint upon the landscape in the area.

Although they exploited natural resources and altered the landscape as they saw fit, compared with successive cultures the Ohlone lived in a more balanced and harmonious relationship with its natural surroundings. They utilized renewable resources and discouraged excessive consumption, and produced a thriving culture for thousands of years (Margolin 1978; Clark 1985). However, Don Gaspar de Portola's arrival on Sweeney Ridge in Pacifica on November 4, 1769 permanently and irrevocably altered life in California for all Native inhabitants, including the Ohlone and Miwok tribes in the San Francisco Bay Area. From the fateful moment when Portola's party first gazed upon the Golden Gate and San Francisco Bay, European and subsequent American colonization of California proceeded rapidly, and eventually exterminated Ohlone culture.

Spanish Missionary Period (1776-1824)

The arrival of Spanish Missionaries in 1776 brought a quick and brutal end to aboriginal Ohlone culture on the San Francisco Peninsula. Newly introduced European diseases, forced abandonment of villages, and efforts at religious conversion all contributed to the rapid demise of the tribes at the hands of the Missionaries. The history of Spanish, Mexican, and American treatment of native inhabitants in California is well documented (Pitt 1970; Castillo 1978; Clark 1985; Gillespie 1986; West and Cotchett 2002; Merchant 2007).

Ohlone tribes living at or near Mussel Rock at the time of imperial Spanish arrival would have been among the first of the native inhabitants to be collected and forcibly removed to the newly constructed Mission San Francisco de Asis (Dolores). The proximity of Mussel Rock to San Pedro Road, which connected Mission Dolores to the mission outpost at San Pedro Creek in Pacifica, would have virtually ensured capture of any Ohlone living at Mussel Rock by the Missionaries (Figure 21, page 58). By 1801, the entire Peninsula and the coast south to Santa Cruz were completely depopulated of Native Americans (Castillo 1978).

In one of the great genocidal episodes in human history, the Spanish managed to wipe out, in less than thirty years, the entire 'Costanoan' Ohlone culture through brutal assimilation programs and the accidental introduction of diseases to which the native people had no immunity. Between 1776 and 1806, three separate epidemics of influenza and measles swept away the remaining Ohlone that had not been previously captured (Castillo 1978; Clark 1985).

Thus, it is unlikely that many native inhabitants of the Mussel Rock area survived past the late 1700s. Even if a small number managed to avoid capture, rapid changes in the landscape and population of the Peninsula in the subsequent years would have changed their lives irrevocably. The Spanish also made major modifications to local ecosystems. For example, Spaniards replaced the native perennial bunch grasses with introduced annual grasses and weeds to feed other newly introduced animals such as cattle and horses.

Mexican Land Grant Period (1824-1848)

After Mexico gained its independence from Spain in 1821 and became a Republic, California was governed by Mexican grantees who were given large parcels of land previously owned by the Spanish Missions (Figure 22). Some Mexican governors chose to develop their land grants and some chose to sell them to prospectors and ranchers. During this Rancho phase of Northern California under the governance of the Republic of Mexico (1822-1846), three large ranch estates were established in the area surrounding Mussel Rock. In what was then known as Sand Hills (present day Colma, Daly City and Pacifica), Mexican grant recipients established two of the largest Ranchos in Northern California.

The largest ranch, called Buri Buri, covered 6,000 hectares (15,000 acres) in parts of today's peninsula cities of Colma, Burlingame, South San Francisco, San Bruno, and

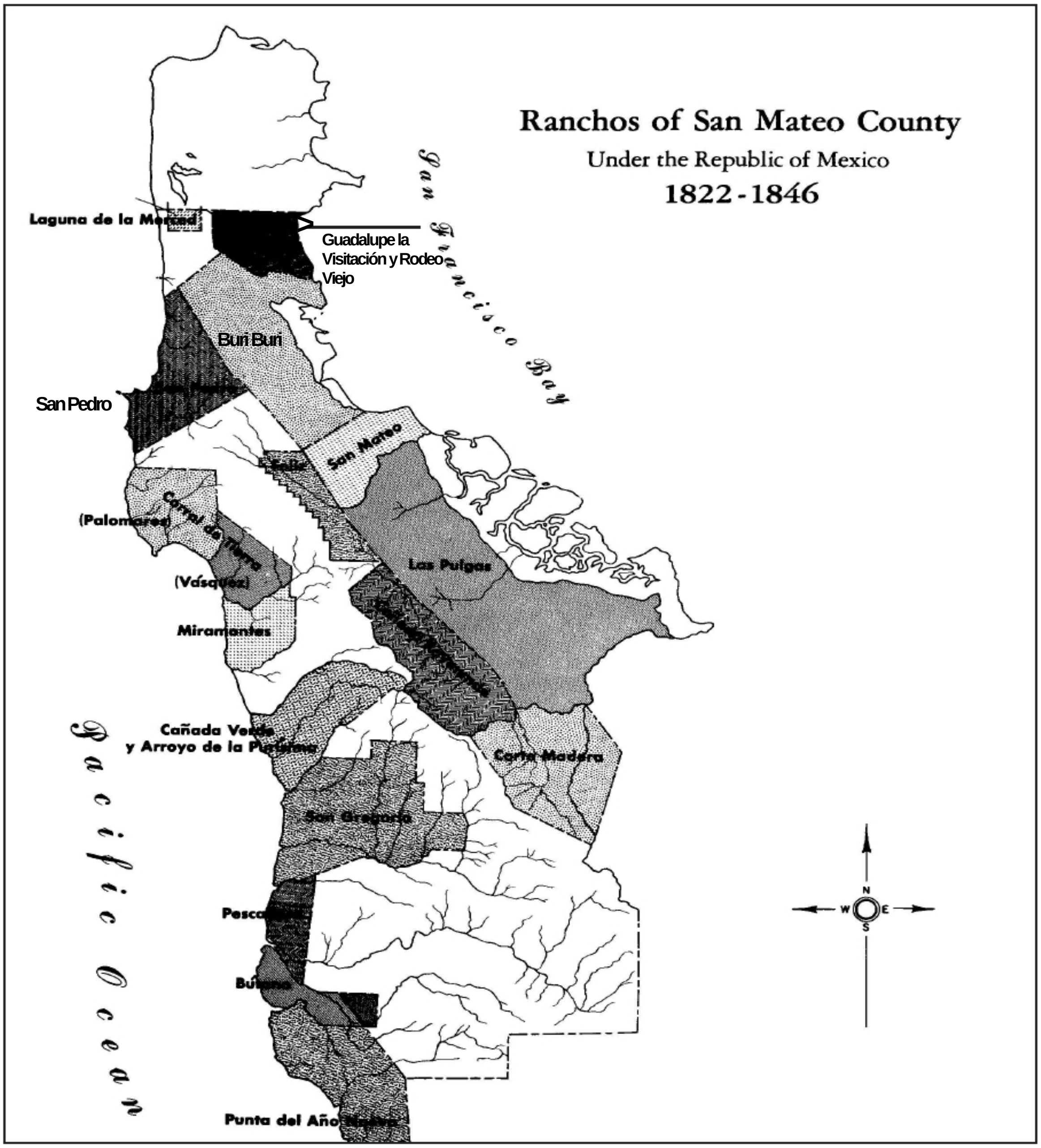

Figure 22. Ranchos of San Mateo County under the Republic of Mexico, 1822-1846. Mussel Rock is near the boundary between San Pedro and Buri Buri Ranchos. Note the perennial streams draining at Mussel Rock on map. From Chandler (1973).

Millbrae. Jose Sanchez originally owned this enormous tract and built an adobe house, used oxen to plow the fields he planted, and operated a grist mill and rodeo ground on various parts of his property (Chandler 1973). The Mussel Rock area was the approximate northern boundary of the second largest land grant on the Peninsula called Rancho San Pedro. Totaling more than 4000 hectares (10,000 acres), Rancho San Pedro extended from Mussel Rock south approximately 26 kilometers (16 miles) to Pedro Point in what is now Pacifica (Clark 1985).

Granted in 1839, Rancho San Pedro was originally owned by Francisco Sanchez. Three years later, Sanchez was appointed Alcalde (Municipal Magistrate, or Mayor) of San Francisco. Sanchez's ranch was used as an Indian village, a mission farm, and a cattle ranch. He is remembered for the home he built on the ranch in 1846, called Sanchez Adobe, now a historical landmark (Hynding 1982). Sanchez also built Hotel San Pedro, a speakeasy known as Adobe House, and an artichoke storage facility. For many years, Rancho San Pedro was the sole provider of food for Mission Dolores in San Francisco, since 50,000 head of cattle had free range of the Peninsula and coast for decades during the Mexican grant period (Chandler 1973; West and Cotchett 2002). The old adobe home on the site is a classic example of Monterey architecture, and is the oldest building in San Mateo County (Hynding 1982). Given the density of Sanchez' cattle herds, it is possible that the Mussel Rock area served as a cattle and horse grazing area during the Rancho San Pedro era.

The nearest ranch to the north of Mussel Rock was Laguna de la Merced, situated near present day Lake Merced in San Francisco. About three kilometers north of Mussel Rock, this ranch was originally granted to Jose Antonio Galindo. Galindo did not develop Laguna de la Merced ranch and eventually sold the property to Francisco de Haro, a son-in-law of Jose Sanchez, owner of the much larger Buri Buri Rancho (Chandler 1973).

Interestingly, in 1839, Galindo was arrested for murder by de Haro, who served at that time as the Alcalde of the area. Galindo was sent to San Jose for incarceration because there was no jail in San Francisco at the time (Chandler 1973). Rancho Laguna de la Merced was later owned by Robert S. Thornton, a noteworthy figure in San Francisco and Daly City history. His ranch south of Lake Merced eventually became part of Henry Doelger's Westlake District residential development in Daly City (Chandler 1973; Hynding 1982). During the Rancho period, it may be assumed that the land around Mussel Rock was utilized by cattle for grazing or for primitive agriculture by land squatters. Whatever its use during this relatively pastoral period, it was not destined to last, as major changes to nearly all aspects of life in California were soon to occur.

The treaty of Guadalupe Hidalgo, a largely American-dictated agreement to secure California's independence from Mexico, and to end the Mexican-American War (1846-1848), was ratified on February 2, 1848. The treaty ended the 24-year reign of Mexico in California. The new Republic was admitted to the United States in 1850. Bolstered by the discovery of gold at Sutter's Creek in 1848, subsequent American colonization on an unprecedented and massive scale began the most expansive and destructive era of human habitation and alteration of California's ecosystems known to history (Brechin 1999). In 1848 the population of San Francisco was 800; by 1851 it had grown to 35,000 (Dreyfus 2008). The Mussel Rock area did not escape the coming American tide as San Francisco's population rapidly exploded. Indeed, the most significant human and environmental impacts in the Mussel Rock area's history were about to fundamentally and irrevocably alter the entire essence of the place once home to several hundred residents who had lived under a very different relationship with the natural world. Upon American settlement neither Ohlone culture nor Mussel Rock would ever be the same.

American Colonization and Development (1848-present)

According to Matthew Clark (1985, 32), "the Hispanic view of the Indians as a resource to be exploited was replaced by the American viewpoint of the natives as a scourge which had to be eradicated". This notion is given credence by the fact that in the years following American occupation and the Gold Rush, and after Yerba Buena was renamed San Francisco in 1847, Indians were often simply shot on sight.

By the 1850s, the inland area immediately surrounding the cliffs above Mussel Rock was known as Sand Hills. After American takeover of California, this aptly named place quickly developed into a farming and dairy district (Figures 23 and 24). It was colonized by mostly Irish farmers who raised cattle and pigs, grew potatoes and grains, and later artichokes, cabbage, flowers, sprouts, carrots, turnips, and beets (Gillespie 1986).

The Sand Hills farming district contained the sag ponds or lakes formed by the San Andreas Fault Zone and the headwaters of the perennial streams that drained into the Mussel Rock valley. Figure 21 (page 58) shows the two most prominent sag ponds, known as Laguna Alta (High Lake) and Laguna de los Terrones (Mudclod Lake) during the Mexican Period, were ultimately graded and filled in the 1950s during the construction of a highway overpass and residential subdivision (Petersen 1958; Sullivan, Mustart and Galehouse 1977; Hynding 1982). This effectively cut off a major source of fresh water for the Mussel Rock valley. The sources that remain at Mussel Rock today are rainfall and groundwater intrusions through springs, seeps, runoff, and the San Andreas Fault, a major supplier of groundwater seepage into the valley.

John Gardner, an Irish immigrant farmer, was the first titleholder of the Mussel Rock area according to the official map of San Mateo County in 1868 (Clark 1985). Figure 23 shows the distribution of land claims in the area circa 1870.

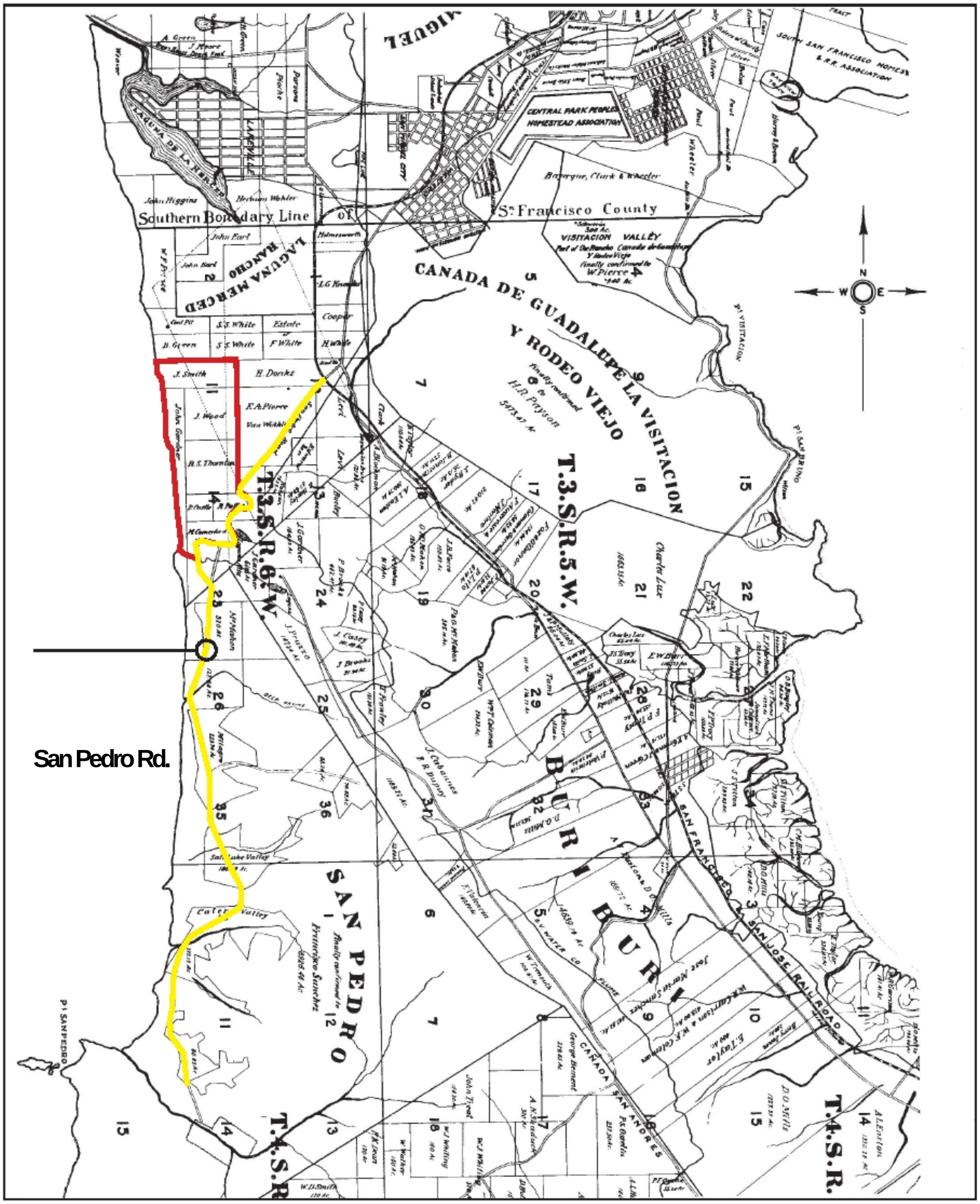

Figure 23. Property Ownership Map of the Gateway Area, 1868. The "Sand Hills" Farming District is located in the middle of the map, east of Laguna Alta and smaller sag ponds. From Chandler (1973).

Figure 24. Aerial photo of the Sand Hills/Mussel Rock area from 1951, looking Southeast. Mussel Rock is at bottom right, below Ocean Shore Highway constructed along former Ocean Shore Railroad bed. Compare with Figure 32 (see page 90) to see subsequent development. From Cox-Whitsel (1983).

Gardner eventually grew weary of the windy and foggy local climate on the western side of the Sand Hills area near Mussel Rock and built a house on the sunnier eastern side of Sand Hills in what is now the Broadmoor neighborhood in Daly City (Chandler 1973). By this time much of northern San Mateo County was devoted to hog farming, and this enterprise opened up more business opportunities for the farming landowners of the area.

In addition to dairying and hog farming, ranch owners in the area that would become Daly City also engaged in other shrewd business ventures such as garbage collecting and recycling. With San Francisco quickly running out of land for landfills, ranchers south of the city readily agreed to take San Francisco's surplus garbage. Once delivered to the ranches, the farmers would sort the trash, recycle what they could, and feed the remainder of the refuse to their pigs. Utilizing this previously unexploited animal food source, the farmers would then cash in on a 'double-profit' when they sold the pork products back to San Francisco businesses and residents. Unbeknownst to them, the pork they consumed was (partially) fortified by their own garbage (Clark 1985).

By 1870, the land east of Mussel Rock had passed into the hands of nurseryman Michael Comerford (sometimes spelled Comenford by historians), who established tree farms and nurseries in this area and to the south in parts of present-day Pacifica (Figure 22, page 65). Beginning around 1871 in the Mussel Rock area, Comerford's Nursery grew seedlings of Blue Gum Eucalyptus that were transplanted by the millions to many other parts of the Bay Area and California (Clark 1985; Gillespie 1986). The nursery also started many of the Monterey Cypress and Monterey Pines that John McLaren planted in his newly-designed Golden Gate Park in San Francisco, and probably many of the trees that now blanket the Presidio of San Francisco. He reportedly sold the seedlings starting at 15 cents apiece (Chandler 1973; Gillespie 1986).

Comerford thought that Eucalyptus trees would be a useful and lucrative species to sell, providing lumber and firewood and serving as windbreaks and boundary markers (Clark 1985). Eucalyptus proved to be inadequate lumber material due to its propensity for cracking and splitting. Despite this, Eucalyptus species became very popular and flourished in the Bay Area and throughout California. Although not known at the time, as with many other introduced invasive species in California, the subsequent dispersion of Blue Gum and other types of eucalyptus trees imported from Australia cause many problems in local environments, including toxification of the soil under the trees so that native species are stunted in the surrounding area.

However successful Comerford's nursery turned out to be, his business ceased operations on April 18, 1906, when the magnitude 7.8 Great San Francisco Earthquake's reanimation of the ancient landslide at Mussel Rock completely buried Comerford's tree farm and nursery. He later sold his parcel at Mussel Rock to Spring Valley Water Company, who later sold it to rancher John MaCready (Daly City Council 1956).

The Oldest Highway Tunnel in California

Before California Highway One and other roads were constructed along the San Mateo coast, traveling from San Francisco to the coast south was a difficult endeavor. Crossing the rugged coastal mountains via San Pedro Road and beyond was challenging, and historical accounts state that it was not uncommon for a trip from San Francisco to Spanishtown (Half Moon Bay) to take more than two days (Miller 1971; Hynding 1982). It was not long before residents of the coastal peninsula began to look for easier routes, such as trains, toll roads, and highways, whether it be over the mountains or over the sand of the beaches at low tide.

Anyone who has spent time walking on the beaches from San Francisco south would have noticed that there is nearly continuous beach along the coast. From the Cliff House on San Francisco's Ocean Beach to Laguna Salada (Sharp Park) in Pacifica, approximately 19 kilometers (12 miles), there is a relatively unbroken stretch of flat beach topography. The only barrier between these two points is the headlands at Mussel Rock. If the obstruction of the headlands could be mitigated, then a simple and scenic road for carriages could solve many of the challenges of travel up and down the coast.

Perhaps the most curious human-made relic at Mussel Rock is a tunnel that was blasted through the Franciscan Complex headlands opposite Mussel Rock proper (Figure 25). For decades the origin of this tunnel remained a mystery. In the early 1950s geologist E.D. Drew suggested the tunnel must be the work of Don Francisco Sanchez, the former owner of Rancho San Pedro during the Mexican land grant period (Drew 1964). Since Sanchez' ranch encompassed most of what is now Pacifica it seemed logical that he had at one time attempted to bore through the headlands at Mussel Rock. Drew lacked empirical data to back up the claim, however.

A few years later, historical investigation clarified the story of the 'oldest highway tunnel in California' at Mussel Rock. Around the turn of the twentieth century, a man named Richard Tobin, one of the founders of Hibernia Bank in San Francisco, acquired parts of the former Rancho San Pedro. He built a ranch house in what is now Pedro Valley which doubled as a family vacation spot. In August 1874 Tobin decided to commission the tunnel project through the headlands at Mussel Rock in order to build a 'highway' along the beach to enjoy scenic carriage rides along the coast. Tobin put up $5,000 and hired a blasting crew to create a series of three tunnels measuring 27.5 meters (90 feet) long, 3 meters (10 feet) high and 3 meters (10 feet) wide (Miller and Sullivan 1975). Reports of interviews with Tobin's children confirmed the tunnel project was their father's enterprise. Completed sometime around January 1875, Tobin's tunnel was used three times by the family before coastal processes ultimately rendered the tunnels unusable (Miller and

Figure 25. Tobin's Tunnel. Photo by Shawn Heiser.

Sullivan 1975). Within several months of the tunnels' excavation a severe winter storm deposited tons of sand into cavities, causing collapse of at least one of the cavities. Tobin must have quickly discovered that in winter months the waves at Mussel Rock remove the sand at the beach, lowering beach level by about six meters (20 feet) (Miller and Sullivan 1975). Without a very long and steep ramp the main tunnel was useless. In summertime the opposite effect occurred, where sand-building could have conceivably filled in the tunnel, thus requiring periodic excavation.

There is also speculation that one or more of the partially-excavated tunnels collapsed during the 1906 earthquake (Miller and Sullivan 1975). If true this would have rendered the entire project a failure, since navigation around the headlands is impossible without the tunnels. Regardless of the causes of the tunnels' degradation and destruction, the intended navigable route is no longer discernable, and the probable course is now sandy beach and rocky shore. Additionally, the former beach at Mussel Rock is now supplemented by tons of riprap revetment on the north side of the headlands. The tall cliffs abutting the tunnel to the north contain spectacular examples of fault gouge, another legacy of the 1906 earth-quake (Figure 26). Zones of crumbled rock powder formed in the cliffs as the sides of the San Andreas Fault ground past each other, pulverizing the Franciscan greenstone basalt like a millstone grinds grain into flour (Sudran 2004).

Now known as 'Tobin's Folly', the tunnel remnant has functioned as a curiosity ever since. It is highly likely that the tunnel was utilized by rumrunners and other merchants to stash illegal contraband during the years of alcohol prohibition (1920-1933). The tunnel would have been a hiding place for cases of Canadian whiskey and wine en route to the many saloons on Mission Street in Daly City, one of the 'wettest' areas in the country during Prohibition (Gillespie 1986). Since then, Tobin's tunnel has provided ample opportunity for the curious to discuss fictitious and legendary uses of the tunnel. Until late 2008 the tunnel was accessible along the paved road leading down to Mussel Rock proper. In the Fall of that year Daly City erected a fence on the perimeter above the beach leading to the tunnel, ostensibly to keep people off of the beach and out of the tunnel, likely for liability concerns (Figure 27). Since installation, several sections of the fence have been cut.

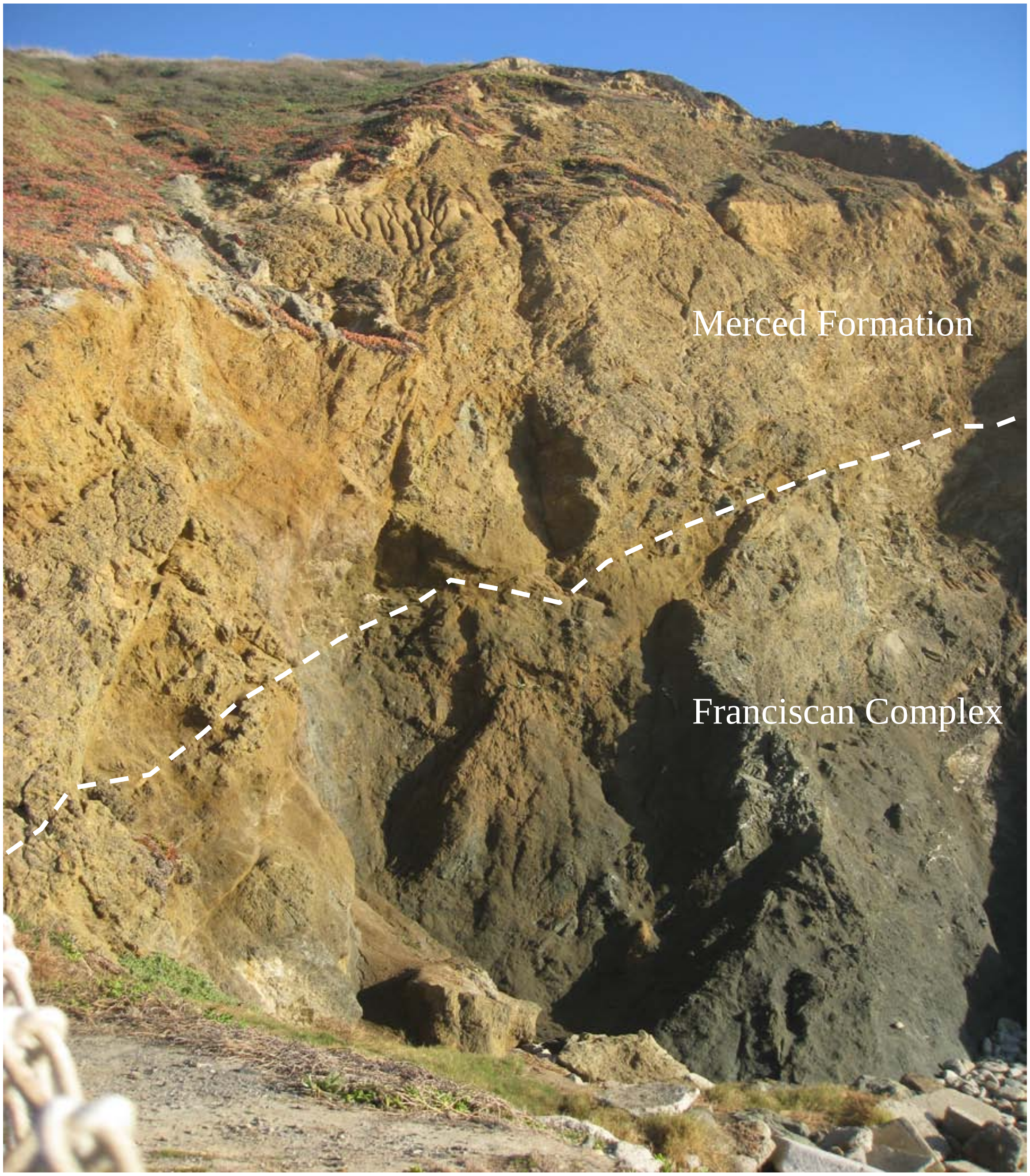

Figure 26. Cliffs immediately north of Mussel Rock, showing contact between Franciscan and Merced Formations, and fault gouge from the 1906 San Francisco Earthquake. Photo by Shawn Heiser.

Figure 27. Fencing installed in 2008 to prevent access to Tobin's Tunnel. Portions of the fence have since been cut. Photo by Shawn Heiser.

Ocean Shore Railroad

In the late 1800s a group of San Francisco entrepreneurs envisioned a transformative and lucrative business venture to the south of San Francisco on the San Mateo County Coast. These enterprising businessmen planned for a new railroad that would connect San Francisco to Santa Cruz, with stops at dozens of destinations along the way. The investors envisioned large tracts of real estate along the railroad's path to be future coastal cities and vacation resorts (Wagner 1974; VanderWerf 1992; Hunter 2004).

The Ocean Shore Railway Company was incorporated on May 18, 1905 for the purpose of constructing and operating a double-track, high-speed electric railroad from San Francisco south to Santa Cruz. With the exceptions of San Francisco and Santa Cruz, most of the Ocean Shore route would be built on privately owned land, much of which the initial investors and their agents quickly acquired with the hopes of luring new residents to purchase housing and business tracts (Wagner 1974; Hunter 2004). In order to attract tourism and weekend excursions, the route was designed to follow as near to the shoreline of the Pacific Ocean as possible, and would cover a distance of 130 kilometers (81 miles). Indeed, one of the major selling points to the investors of Ocean Shore Railroad was the scenic viewscape along its route (Hunter 2004).

By the Fall of 1905 tracks were finished in the southern end of San Francisco and western Daly City. By April 1906, 4,000 men worked on the construction of the line (Wagner 1974; Hunter 2004). With this next stage in construction came the first serious logistical challenge to the builders of Ocean Shore. The ambitious design led the railroad bed and tracks across the tall, precarious 215-meter (700 foot) cliffs between Thornton beach and Mussel Rock. Ocean Shore blueprints indicate that a cut of 46 meters (150 feet) maximum vertical depth was made through the cliff immediately above Mussel Rock (Wagner 1974; Hunter 2004). The cut effectively removed the western margin of the Ohlone's Ompuromo site (Clark 1985).

The Mussel Rock area, although uninhabited at the time, was an important place for the owners and customers of the Ocean Shore, since Mussel Rock was the place where the train first emerged from the bustling city of San Francisco and onto the scenic coastline of San Mateo County. It hugged the dramatic cliffs and provided unparalleled coastal scenery for the train's passengers. The decision to place the railroad track as near to the ocean as possible ultimately led to the railroad's demise.

At 5:12 a.m. on April 18, 1906 the Great San Francisco Earthquake struck. At Mussel Rock, the magnitude 7.8 quake brought down in seconds what had taken the Ocean Shore workers months to erect. The unconsolidated Merced Formation lining the cliffs above Mussel Rock crumbled easily, and over 1,200 meters (4,000 feet) of railroad bed, track, and equipment tumbled into the Pacific Ocean (Lawson et al 1908; Wagner 1974; Sullivan 1975; Hunter 2004). The remaining graded sections south of Mussel Rock were twisted into unusable wreckage. Since the Ocean Shore had not yet seen any revenues, the earthquake proved an enormous setback.

Immediately following the earthquake, however, Ocean Shore began reconstruction of the damaged line and continued construction of the line south. Original plans for a double-track electric line were modified to a single-track steam line (Wagner 1974; Hunter 2004). Passenger trains began in October 1907 with service to Tobin (now Pedro Point in Pacifica). Developers laid out tracts for coastside communities along the route (Wagner 1974; VanderWerf 1992; Hunter 2004). The decision to emphasize coastal views and place the track along many cliffs and mountains next to the coast continued to plague the railroad's financiers, as the cliffs along Mussel Rock, and especially another deep-seated landslide adjacent to Devil's Slide in Pacifica, about 24 kilometers (15 miles) south of Mussel Rock, continued to rapidly erode and fail, requiring near constant maintenance and delays (Darrough 1938; Wagner 1974; Hunter 2004).

A student paper by William Darrough (1938) provides some insight to the high cost of maintaining the track at Mussel Rock. Darrough discusses the bluff-traversing section of track at Mussel Rock as the most expensive section of track to maintain, and that during the years of 1913-1915 the cost of maintaining the two-mile Mussel Rock section of the track alone totaled $35,000 per year. The hemorrhaging coffers of Ocean Shore's backers must have caused them to curse the insistence upon placing the railroad tracks along the cliffs of Mussel Rock and Devil's Slide (Figure 28).

Nonetheless, the Ocean Shore forged on, building stations at 25 stops along the way, including Mussel Rock Station. Built in 1906, the station was located on a small rock just south of Mussel Rock, where presently the parking lot at the end of Westline Drive is located (Clark 1985). Since Mussel Rock was privately owned and real estate development was still several decades from occurring, the Mussel Rock Station was probably the most neglected and least photogenic of all the built stations along the Ocean Shore line. The Station was finally dismantled in the 1930s (Byers 1946).

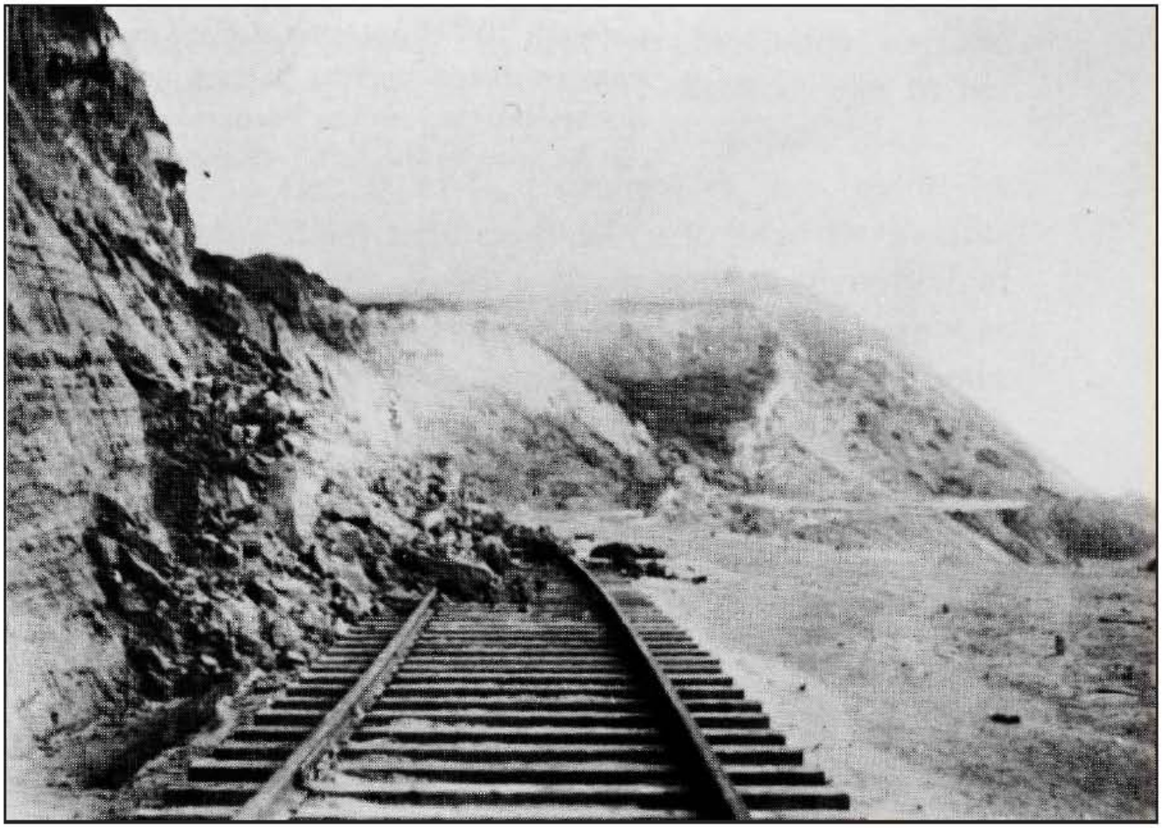

Figure 28. Landslide debris on Ocean Shore Railroad tracks following the 1906 San Francisco earthquake. From Wagner (1974).

Information is limited regarding the Mussel Rock Station. There are no published photographs. The only known source that mentions the Mussel Rock Station is a paper by Mildred Byers, when she was a student at San Mateo Junior College. Byers described the Mussel Rock Station as a passenger shelter "with a shingle roof, rustic walls, and a timber foundation. It was not painted and classed as being in 50% condition". The station's value as of the 1920s was estimated at "a mere $74, the lowest of any of the company's possessions" (Byers 1946, 4). The Ocean Shore Railroad's route map shows Mussel Rock Station among all the planned stations (Figure 29).

In the end, Ocean Shore Railroad, having been resuscitated several times through refinancing, proved to be an abject lesson in overzealous planning. The suburban 'paper cities' of the coastal peninsula did not materialize quickly enough, as much of the real estate was purchased by speculators who never intended on living there (VanderWerf 1992). Because of legal and right-of-way issues, the line was never completed to Santa Cruz, and the railroad never saw steady profits throughout its 20 year existence (Wagner 1974; Hunter 2004). By 1925 the tracks at Mussel Rock had been removed in piecemeal fashion, but the bench cut would soon be utilized to build the original Ocean Shore Highway, the predecessor to today's world famous California Highway One (Sullivan, Mustart and Galehouse 1977; Hunter 2004).

Rumrunners during 1920s Prohibition

Prohibition (1920-1933) provided a boon for alcohol smugglers at Mussel Rock and along the San Mateo Coast. Private 'moonshiners' flourished on the coast, and San Mateo County was estimated to have the largest number of homemade stills in California. Daly City, on the outskirts of San Francisco, developed a reputation as one of the 'wettest' places in the country.

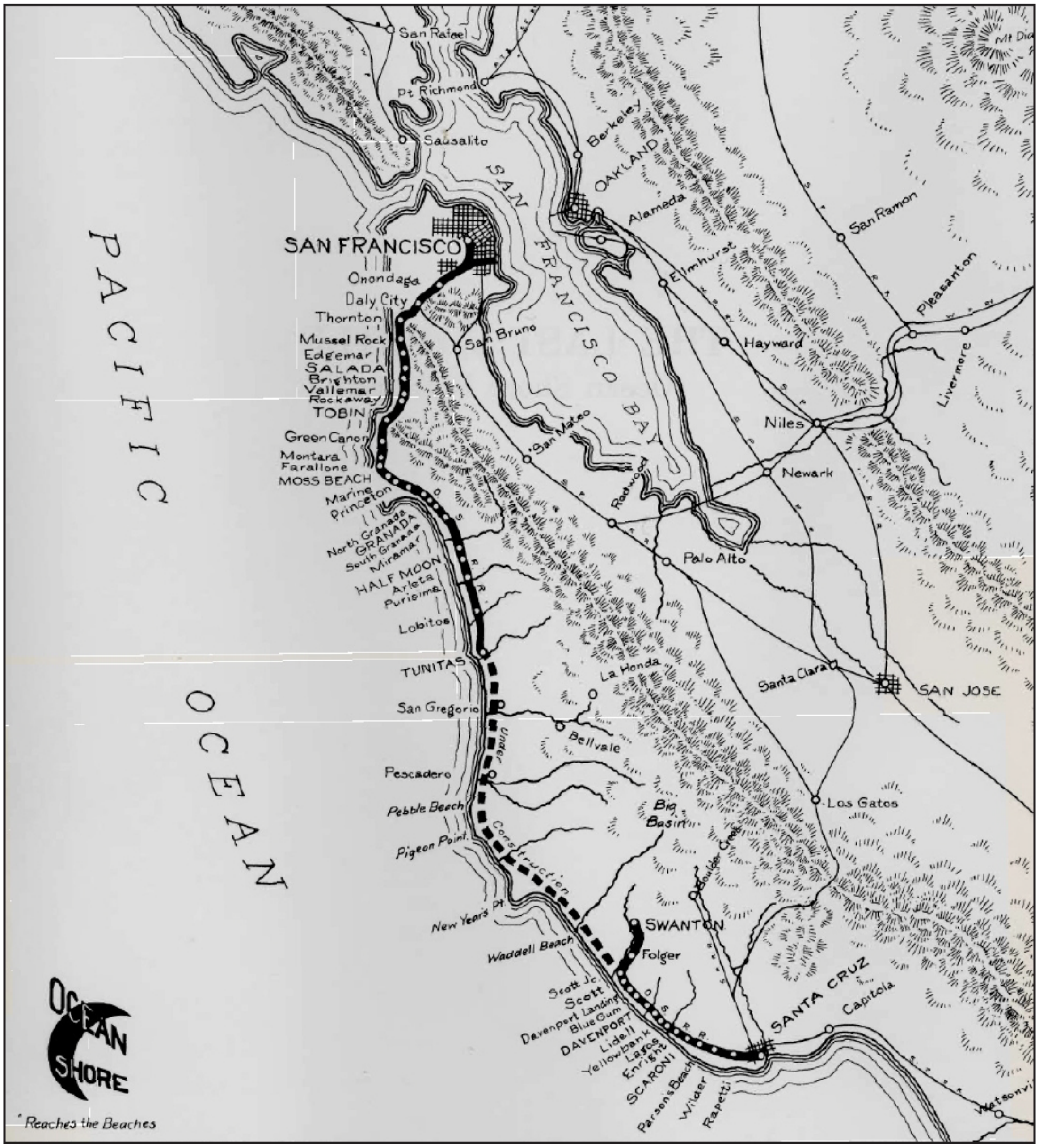

Figure 29. Map of Ocean Shore Railroad route and planned stations, from 1913. From Wagner (1974).

Not subject to the same stringent behavioral laws and regulations as San Francisco, Daly City gained notoriety as a place one could come for any number of illicit activities, such as gambling, drinking, and prostitution. Mission Street in Daly City had, at one time, more than 100 separate drinking establishments (Gillespie 1986).

During the first decade of Prohibition, rumrunners on ships from Canada and elsewhere utilized the foggy and remote San Mateo coastline beaches and tunnels to stash illegal shipments of Canadian whiskey and wine (Hynding 1982). The tunnel built by the Ocean Shore Railroad at Pedro Point in Pacifica was one such site until Federal authorities used dynamite to blast both ends of the tunnel shut (Hynding 1982; Hunter 2004). It is probable that rum and other contraband was also frequently secretly stashed in Tobin's tunnel at Mussel Rock (Figure 25, page 74). For many years rumor swirled that this was the actual and only purpose of this tunnel's construction.

Mussel Rock Wireless Station

In 1926, Captain Robert Dollar, a merchant seaman and owner of President Steamship Lines, built a wireless radio station at Mussel Rock for the purpose of sending and receiving radio transmissions (Figure 30). Located east of Mussel Rock just above the former Salada Beach, the station, dubbed "Dollaradio", was designed to communicate with Dollar's array of steamships in the Pacific. The station's transmitters were located in a small wooden building, while the station's receiving operations were housed in another structure nearby (Calhan 1961; Wagner 1974).

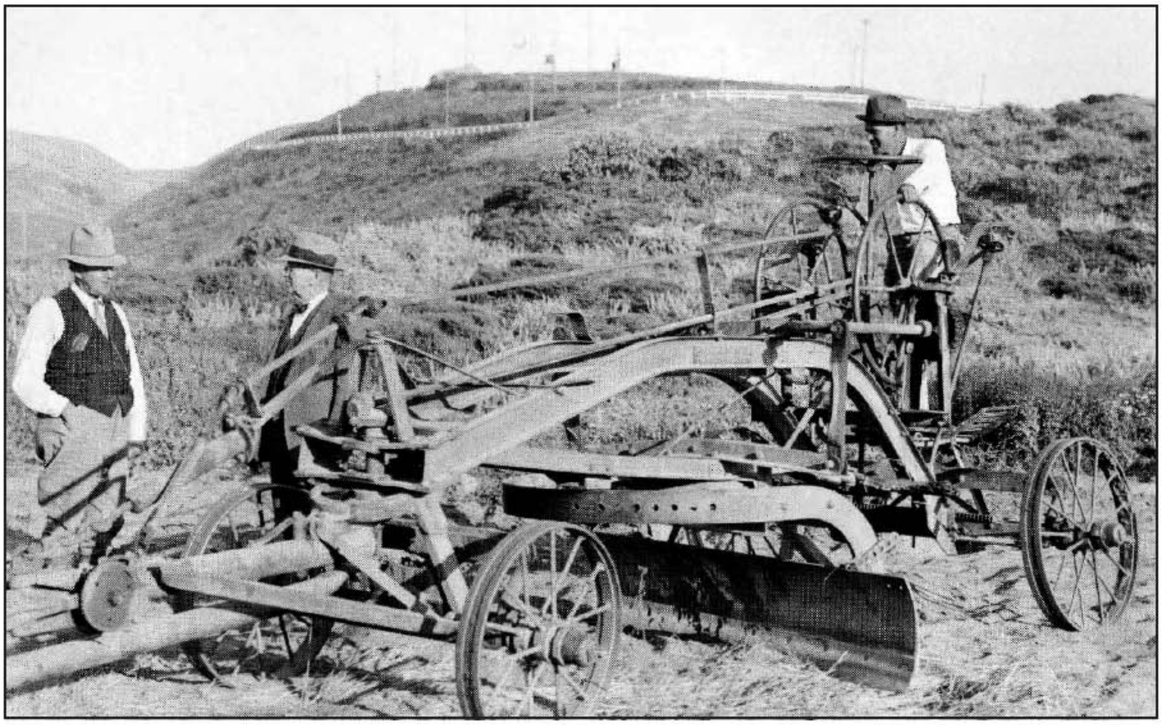

Figure 30. Captain Robert Dollar's Dollaradio Wireless Station at Mussel Rock, shown in the background. From Wagner (1974).

The station received signals from many sources, including distress signals from other ships, which were relayed to the Coast Guard station in Pacifica. As a historical footnote, Dollaradio at Mussel Rock was the place that received historic transmissions from Admiral Robert E. Byrd in Antarctica for some 200 days during his landmark explorations of the South Pole. In late 1934 the name Dollaradio was changed to Globe Wireless Ltd., and the main headquarters was relocated to San Francisco (Calhan 1961). In 1936 the sending station was moved to Palo Alto. The remaining transmission towers were dismantled for the construction of the Highway One bypass above Mussel Rock in 1957 (Petersen 1958).

Ocean Shore Highway

After Ocean Shore Railroad went bankrupt in 1921 the California State Highway Commission saw an opportunity to utilize the old railway bed along the Thornton Beach and Mussel Rock cliffs for a new coastal highway (Figure 24, page 70). In 1936 construction began on the Ocean Shore Highway, modifying the railroad bed into a bench section along the face of the precipitous slopes about 46 meters (150 feet) above the ocean. The highway quickly gained a reputation as one of the most difficult sections of state highway to maintain and keep open (Petersen 1958). Continuous slippage of Merced Formation materials resulting from erosive wave action along the base of the bluffs, coupled with regular slumping and sliding from above the road, made maintenance of the highway progressively more challenging and costly.

During the years between 1950 and 1957, for example, the highway was closed 17 times during the seven winters for a total of 174 days (Sullivan, Mustart, and Galehouse 1977; Cox-Whitsel 1983). The closure periods varied from one hour to 120 days, and detours along small county roads resulted in considerable delays and inconvenience for motorists. The cost of maintaining the highway during this seven year period totaled $425,000, an average of $60,000 per year (Petersen 1958).

It soon became clear that expanding the two-lane highway to a four-lane expressway was not feasible along the Thornton Beach-Mussel Rock section of the Ocean Shore bench. These factors, coupled with the increasing demand for housing in the fast-growing communities of Daly City, Pacifica, and other coastal towns south along the peninsula, compelled the State Highway Commission to abandon the Ocean Shore Highway and design a four-lane divided highway bypassing the Thornton Beach-Mussel Rock cliffs altogether (Figure 32, see page 90). Funding and contractual delays occurred but the bypass section was completed in 1957 (Sullivan, Mustart and Galehouse 1977). The only right-of-way issue to address in the new bypass project was the dismantling and relocation of several of Captain Robert Dollar's "Dollaradio" wireless station located above Mussel Rock.

During construction of the highway bypass, located above and east of Mussel Rock, construction engineers made large cuts and fills of the hills above, including the original sag ponds and hills above them—the headwaters that fed the perennial stream that flowed into Mussel Rock from the Rift Zone. The natural fresh water stream system so crucial to the Ohlone village at Mussel Rock was eliminated, and freshwater availability in the Mussel Rock area became more sporadic.

Military Installation at Mussel Rock

During the World War II era, the strategic geographical location of Mussel Rock led the United States Army to construct two concrete bunkers, comprising approximately 2.5 hectares (six acres), on part of the original landslide complex from the 1906 earthquake (Figure 31; Berry and Sutton 1994). Between 1941 and 1943, three permanent underground concrete structures, consisting of a power plant room and two base end stations were built. Unlike the nearby Fort Funston military complex, which for several decades stored Nike intercontinental ballistic (nuclear) missiles underground, the bunkers at Mussel Rock were used for the purposes of observation and triangulation, one of many such installations along the coast from Fort Bragg to Montara Mountain.

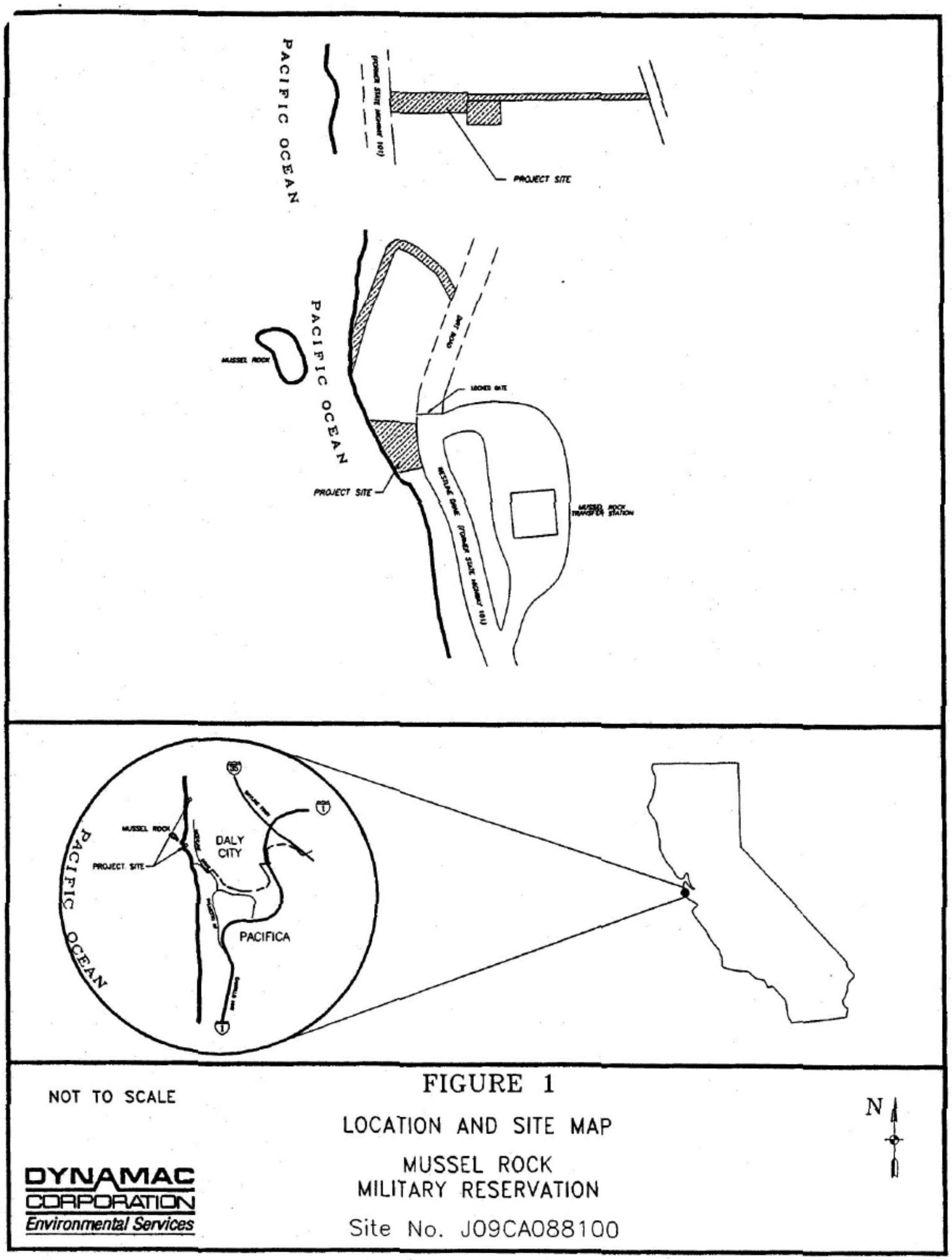

Figure 31. Mussel Rock Military Installation. From Berry and Sutton (1994).

When the specter of war on the Pacific coast diminished after World War II, the army bunker at Mussel Rock was filled in with concrete and buried with topsoil and grasses, and later became a portion of the main landfill pit. Although not visible to the visitor today, these relict army bunkers represent another imprint of human activity at Mussel Rock.

Henry Doelger and Westlake

In 1945 the real estate and construction firm of Henry Doelger purchased 550 hectares (1,350 acres) that stretched east and west of the developed section of Daly City to the ocean and south from Lake Merced to the Pacifica Hills, including the Mussel Rock area (Chandler 1973). The large parcel, used at the time for pig ranches and cabbage and artichoke farming, was purchased from the Spring Valley Water Company, which had acquired the land from the owners of the old Laguna de la Merced Rancho. Doelger drew up plans to build a subdivision called Westlake. He spent the next two decades building thousands of affordable single family homes of a fairly uniform design in a series of subdivisions in western Daly City.

In 1949 Doelger founded the Westlake Subdivision Improvement Association. From this framework he designed and built 32 separate subdivisions, including several hundred homes near Mussel Rock in the Westlake Heights and Westlake Palisades subdivisions (Figure 32). Through the Westlake Subdivision Improvement Association, Doelger's 32 subdivisions had identical sets of by-laws, but each subdivision had a separate set of covenant conditions and restrictions. In an all-too-familiar manifestation of American 1950s racism and xenophobia, the original Westlake by-laws barred non-whites from purchasing property in any Westlake subdivision (Keil 2006). Almost 60 years later, in another ironic twist of fate, today's Daly City is comprised of an overwhelming majority of minority residents. Filipinos represent the majority ethnic group, while Caucasians account for less than 25 percent of the Daly City population (Daly City 2010).

Figure 32. Aerial photo of Mussel Rock from 1969 looking Southeast showing abandoned Ocean Shore Highway, Westlake Heights and Westlake Palisades subdivisions built by Henry Doelger, and the Mussel Rock Landfill. From Cox-Whitsel (1983).

Why were the subdivisions permitted? Simply, the builders did not fully consider either the unstable nature of the underlying bedrock or the long history of land movement near Mussel Rock. At the time of construction no one appears to have challenged the idea, and state and local government regulations protecting home buyers from fault zone construction would not be ratified for another thirty years (Keil 2006). There were no residential zoning laws and regulations until the Alquist-Priolo Special Studies Zones Act of 1972 (Sullivan, Mustart and Galehouse 1977; Cox-Whitsel 1983; Stoffer 2005). This was the first piece of legislation requiring a minimum amount of fault investigation and approval requirements for all cities and counties in California.

By the 50th Anniversary of Daly City's founding, in 1961 home building had become one of its most lucrative industries. Many residents filed complaints about around-the-clock noise from construction crews. Nonetheless, new construction was so vigorously pushed by local governments and developers that by 1958 builders were moving and grading up to 900 kilometers (one million yards) of earth per month, and construction of as many as 80 units began each month in newly platted districts of Daly City and Pacifica such as Westlake, Broadmoor, St. Francis Heights, and Fairmont (Chandler 1973). During the 1960s Daly City's population quadrupled from 15,000 to 60,000 (Hynding 1982). By 1972 over 12,000 people had moved into St. Francis Heights alone. Even high-volume builders such as Doelger, Carl and Fred Gellert, and the Zita Corporation could not keep up with the demand for housing and accompanying civil services.

By the mid-1960s Daly City's new subdivisions drew ridicule on a national level. The housing projects became symbolic of "suburban hell…conformity and America at its worst" (Clarke 1996, 213). William Bronson's *How to Kill a Golden State* (1968, 92) described the Westlake subdivisions as proof California had been "polluted with an aggregation of shoddy construction… best described as schlock—flashy, shabby goods".

This sentiment was most famously expressed by Malvina Reynolds' "Little Boxes", a popular song that lampooned the rows of uniform houses along Highway 35 in Daly City (Keil 2006). As time went on, more significant criticism arose concerning the unstable foundations upon which the subdivisions were built.

Rows of residential housing had been built along the southern crown and scarp of Mussel Rock Landslide as part of Doelger's Westlake Heights development. By 1972, less than 15 years after construction, 11 of these homes had been removed due to active slumping. In 1999, an additional 21 homes on the southern crown (Figure 14, page 38) along Westline Drive were condemned by government agencies and subsequently removed (Linden 2000). Some residents reported being paid a tiny fraction of their homes' previous value in the resulting legal settlements.

Yet, are these homes representative of 'suburban hell' 50 years later? One of Doelger's Architects, Mario Ciampi, won more than a dozen architecture awards for his design of Westlake homes, apartments, and schools (Keil 2006). Many long-time residents claim to love their homes as well as their design. Historian Thurston Clarke reflected on the criticism the Westlake subdivisions endured through the late 20th century in comparison with modern suburban residential development. "What had appeared ticky-tacky in the sixties now looked pretty good compared with what was on offer elsewhere. Perhaps its houses were not much, but it had a good infrastructure of sidewalks and parks. You could walk to elementary schools and churches, and the developers had made a stab at a Main Street of small stores. Try finding these amenities in the newer walled tracts being thrown up around freeway interchanges" (Clarke 1996, 215).

Doelger's Westlake subdivisions did prove to be some of the most affordable homes in the Bay Area for working-class people for most of the 20th century. Those who lost their homes to erosion in past years may disagree, but the majority of residents would probably claim Westlake to be a positive contribution to Daly City.

The same, however, cannot be said about Daly City's other major developmental imprint at Mussel Rock—built contemporaneously with the residential tracts—for it is the most significant risk hazard in the area, as well as another significant source of Daly City's and Mussel Rock's tarnished reputations.

The Dump (Mussel Rock Landfill and Transfer Station)

If civic leaders of late-1950s Daly City could have seen into the future, it can be assured that the most dubious of all human imprints on the landscape of Mussel Rock would never have happened. If the leaders of the city had not made a rash decision based on cost, availability, perceived immediate need, and perceived profit potential, and instead invested in the advice of professional geologists, over $20 million (and counting) could have been saved by the City of Daly City, not to mention decades of legal and regulatory hassles, perpetual capital improvements and continuous environmental degradation. The City could also have been spared its notorious reputation for siting and managing what is generally recognized as the "worst landfill site in California" (Linden 2000, 9).

The Mussel Rock Landfill is at present a closed, unlined Class III landfill located on the active Mussel Rock Landslide and San Andreas Rift Zone. Since its closure on February 15, 1978, Daly City continues to operate a solid waste transfer station at Mussel Rock. This transfer station accepts municipal waste and transports it to the Ox Mountain Sanitary Landfill in Half Moon Bay. The closed Mussel Rock Landfill occupies 11 hectares (29 acres) and lies between steep, unstable slopes below leading to the ocean, and steep slopes above leading to residential areas of Daly City and Highway One (Figure 33). The landfill is composed of two separate excavated 'pits'. The main pit occupies the toe of the landslide, and the secondary pit, called Upper North Canyon, is located about 275 meters (900 feet) to the northwest of the main pit (Figure 34). The total volume of buried waste is

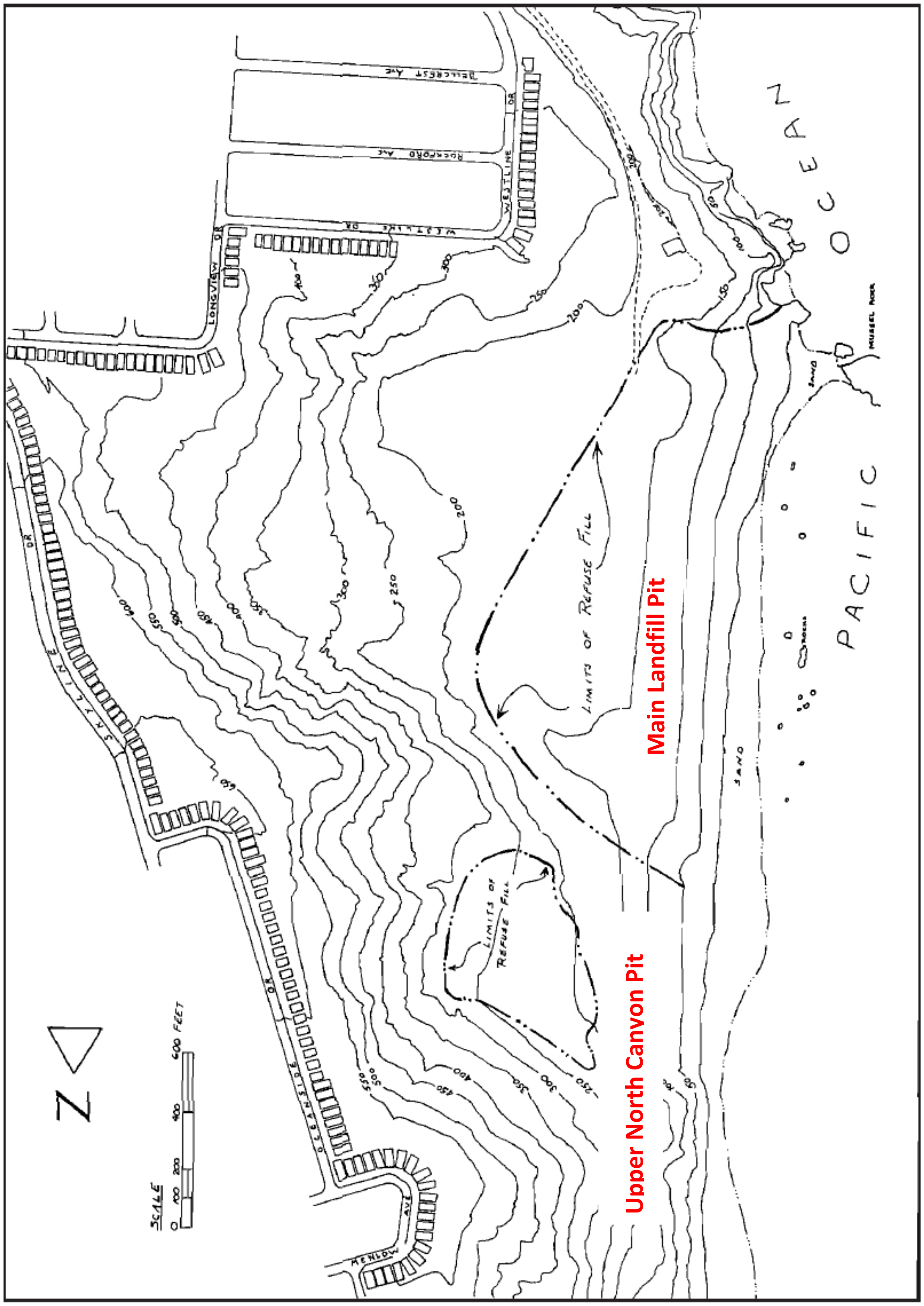

Figure 33. Mussel Rock Landfill limits, showing main landfill pit and Upper North Canyon pit. From Cox-Whitsel (1983).

Figure 34. Upper North Canyon Landfill pit. Photo by Shawn Heiser.

undetermined, but has been estimated at approximately 765,000 cubic meters (one million cubic yards) (Cox-Whitsel 1983).

Daly City Scavenger Company opened the Mussel Rock Landfill in 1957, when it began accepting municipal waste from Daly City residents. Daly City approved the plan for the landfill despite published knowledge of the dynamic geologic nature of the area. The California Department of Transportation had a long history of dealing with the instability of the bluffs at Mussel Rock for Coast Highway One (Petersen 1958; Sullivan, Mustart, and Galehouse 1977; Cox-Whitsel 1983). Additionally, just two months previous to the purchase of Mussel Rock Landfill site, on March 22, 1957, a 5.3 magnitude earthquake centered 200 meters (650 feet) southeast of Mussel Rock had caused extensive damage and landslides along the bluffs and cliffs in the area (Oakeshott 1959).

Daly City claims that it did not have adequate information on the geology of the landfill site at that time, and that prudence and necessity dictated the decision to open the area to a landfill (Cox-Whitsel 1983). The site was already owned by Daly City Scavenger Company, it was conveniently located, and it was immediately available. No other information regarding the suitability of the site was requested by Daly City before approval of the permit for the landfill site. Daly City and the landfill operator signed a franchise agreement in August 1959 that could have prevented further problems had either party decided to take action. Because it stipulated that if the chosen landfill site was deemed to be in any way impractical or inadequate for use as a garbage disposal site, Daly City Scavenger Company would provide an alternative site at the company's expense (Cox-Whitsel 1983). Exercising this option in the early 1960s would have prevented most of the controversial history that followed.

The inadequacies of the Mussel Rock site were clear by 1964, when a Daly City Scavenger Company consultant report identified the presence of the active landslide as well as the presence of the San Andreas Fault at the landfill site (Cox-Whitsel 1983). Two years later a report submitted to the Scavenger Company showed the surface movement of the landslide to be in excess of one meter (3.3 feet) per year with a maximum movement rate of 2.2 meters (7.2 feet) per year (Cox-Whitsel 1983).

The simultaneous construction and population booms of former San Francisco 'hinterlands' of Northern San Mateo County undoubtedly played a large role in The Daly City Planning Commission's hasty and fateful decision in 1958 to approve and develop the Mussel Rock Landfill. By the mid-1950s Daly City's primary landfills in Colma and South San Francisco were nearing capacity from the onslaught of new residents and housing subdivisions (Daly City Council 1956). Pressures on Daly City officials to site a new landfill for the bourgeoning suburb increased with each new month. On November 7, 1955 the City Council of Daly City authorized the retention of an appraiser to assess and report on values in the vicinity of Mussel Rock in contemplation of securing a fill-and-cover site for a municipal landfill. One month later, on December 12, 1955, City Manager Harold Stites recommended to the City Council that an offer of $22,200 be made for the Mussel Rock property (Daly City Council 1956).

Archived documents show alternate landfill sites were available at the time the Mussel Rock site was being considered. They illustrate the urgency on behalf of Daly City to resolve the garbage disposal challenges of the time. It appears Daly City at least initially attempted to avoid siting the landfill at Mussel Rock, preferring instead a proposed site at Linda Mar in Pacifica. Minutes from the City Council meeting on September 11, 1956 reveal that the "Mayor instructed the City Manager to arrange for a meeting with the San Mateo County Board of Supervisors to discuss the garbage disposal problem.

The Mayor also instructed the City Manager to write a letter to the San Mateo County Planning Commission urging them to approve the Linda Mar site for the disposal of Daly City Scavenger Company garbage and impress them that this matter is very vital to Daly City as well as a County problem" (Daly City Council 1956, 4).

Local residents' resistance to the Linda Mar site ultimately led to its rejection as a landfill site, and subsequently placed additional pressure on Daly City to approve the Mussel Rock site for its civic landfill. On December 12, 1955, Daly City Council unanimously passed a resolution instructing the City Manager to enter negotiations for the Mussel Rock Landfill property (Daly City Council 1956). After negotiating a purchase price between the city and its previous owner, John MacReady, on May 14, 1956, Daly City Council instructed the City Attorney to prepare an ordinance for the annexation of the Mussel Rock Landfill site (Daly City Council 1956).

Despite the urgency and need for landfill space, approval of the Mussel Rock site did not come quickly for Daly City. An agenda item from January 28, 1957 authorized yet another appraisal report of the Mussel Rock site, this time with ingress and egress conditions considered. Apparently no consideration or discussion was given to appraise the geologic, seismic, and erosion processes at the site, at a time when such information would have been crucial to the decision making process, and could have potentially saved the city decades of embarrassment and millions of dollars. At the same time, South San Francisco had recently chosen a site for a new landfill, and during the same January 28 City Council meeting the Mayor of South San Francisco, G.J. Rozzi, offered Daly City use of the new South City landfill provided "the scavenger company must undertake the disposal operation through every phase as the City of South San Francisco is unwilling to operate on a flat unit basis" (Daly City Council 1957, 1). However, Daly City leaders thought the South San Francisco option was too expensive, a decision they would later regret.

Why would Daly City choose to site a landfill in one of the most unstable places in California? The answer revolves around a combination of local and regional pressures. Daly City's insistence on believing from the beginning that its municipal landfill could be operated for profit contributed to the desire to utilize space the city already owned. Industry and other undesirable land uses such as landfills were being pushed out of San Francisco with a post-World War II population boom as the Bay Area's population increased by three million people during the course of the war (Chandler 1973; Hynding 1982). This unusually large emigration resulted in Daly City becoming one of the fastest growing cities in the state due in part to large subdivision projects by Henry Doelger, the Gellert Brothers, and Zita Corporation in the 1950s and 1960s (Chandler 1973). This expanded development in turn created a pressing need for infrastructure and civil services to the new residents, and Daly City spent years attempting to find locations outside of Daly City proper for its residential garbage disposal.

As the 1960s approached, City leaders felt obligated to take control of management of its refuse, and eventually chose Mussel Rock as the place to site the municipal landfill. Daly City's rationale included geographical and monetary convenience, perceived immediate need, and desire for profit on the part of City leaders and Daly City Scavenger Company management. Historical records suggest that ties between these two groups were very close-knit, and the strength of these affiliations between the landfill operator and City government suggest that profit was a very strong motivator in this particular land use development decision.

Unfortunately, in order to facilitate approval for the landfill site, Daly City's leaders dismissed, obfuscated, simply ignored, or did not consider the major geologic and seismic instability of the landfill site at Mussel Rock despite the historic precedents established prior to 1957 (Cox-Whitsel 1983).

The earthquake in March of that year—whose epicenter was literally meters away from the landfill site—should have sounded the final warning bell to Daly City's leaders (Oakeshott 1959; Smelser 1987; Sloan 2005). Weeks later, when the California Department of Highways announced the abandonment of the original Coast Highway One through Mussel Rock due to continual landslide problems, Daly City's leaders should have taken note (Petersen 1958; Sullivan, Mustart and Galehouse 1977). Instead they chose not to heed nature's warning signs, and were determined to develop the site as a landfill.

Within a few years, by 1962, the California Regional Water Quality Control Board started receiving reports of garbage falling into the ocean at Mussel Rock (Cox-Whitsel 1983). At that time, even if the Board had wished to order the landfill's closure, it did not possess the authority nor have the proper regulations in place to do so.

Though the evidence suggests that all of Daly City's leaders were united in ignorance regarding the instability of the landfill site, one city employee with engineering and geologic knowledge managed to make his concerns known to the City Council, albeit to no avail (Daly City Council 1963; Chapman 1964). This key figure in the early Mussel Rock Landfill saga is William E. Chapman, who served as City Engineer of Daly City for several years until his resignation in 1964. Primary documents illustrate that Chapman acted as the lone voice of conscience in Daly City politics regarding the potential for disaster at the Mussel Rock site. Chapman was among the first to express doubt towards the stability of the site for a landfill. He also officially acknowledged the presence of the Mussel Rock Landslide as early as 1961, just three years after the landfill opened, despite the city's proclaimed ignorance on the geologic conditions at the site. He expressed frustration to the City Council in 1963 that the city had done nothing in an entire year to construct a seawall and fences at the landfill site, stating that this fact obviously placed the City Council in an embarrassing situation (Daly City Council 1963).

In a letter to the Daly City Clerk on January 17, 1964, Chapman predicted that at Mussel Rock "someday a landslide will occur if remedial measures are not taken and I for one do not want to take the blame" (Chapman 1964).

Chapman also holds the distinction of being the original Mussel Rock 'whistleblower'—the first and only city official to call upon the services of The Regional Water Quality Control Board in order to compel Daly City to build the seawall. Frustrated because he had not been able to get either the city or the landfill operator to construct the seawall, Chapman thought that a letter to the City from "an agency outside of local control would strengthen his position" vis-à-vis the city and its chronic inability to seriously address the instability of the site (Regional Water Quality Control Board 1964).

While Daly City Council officials continued to diminish the geologic challenges to the landfill site, twelve homes adjacent to Mussel Rock were lost due to ground slippage in 1965, while Henry Doelger rushed to complete the Westlake Subdivisions just meters away (Daly City 1984). After leaving his post as City Engineer, William Chapman served as a president of KCA & Associates, an engineering consulting firm that soon after performed surveys and consultant reports for the Mussel Rock site. In the late 1960s he also served on the board of directors for The California Regional Water Quality Control Board, and his experience and expertise as City Engineer during the Mussel Rock Landfill's early days no doubt had influence with the Water Board as an intermediary in its fragmented relationship with Daly City and the Daly City Scavenger Company. Chapman's influence with the City Council and Board of Supervisors likely played a significant role in the decision to eventually comply with the full closure of the landfill ordered by the Regional Water Quality Control Board.

In 1970 Daly City signed an agreement with Pacifica to accept municipal waste from that city into Mussel Rock Landfill on an emergency basis. Originally a one year agreement, the contract with Coastside Scavenger Company was extended for the next five years (Daly City Council 1971). The agreement was cancelled by Daly City in August 1975 when the City Engineer stated that the landfill might only have five to seven years' capacity left, and that priority must be given to Daly City residents (Rowe 1975). The five-year agreement with Pacifica was originally justified by the desire for greater profits for the City and Scavenger Company (Daly City Council 1971).

An increased need for landfill space in the northern peninsula also helped to justify keeping Mussel Rock Landfill in operation, and avoiding the expense of finding an alternate location for a landfill. On March 13, 1972, Daly City Council voted unanimously to extend the original contract with Daly City Scavenger Company to operate the landfill for another twenty years (Daly City Council 1972). Clearly, by this time, despite the headaches and near-constant demands from the Regional Water Quality Control Board, Daly City was resolved to keep its landfill. Less than five years later, after nearly twenty years of incessant struggle to maintain and operate the landfill, as well as numerous citations and cease-and-desist orders from the Regional Water Quality Control Board, Daly City finally relented and made plans for an alternative location for Daly City's garbage. On December 5, 1977 Daly City Council unanimously approved a resolution to construct a transfer station at Mussel Rock as well as a plan dedicating the area as a 'coastside park' (Daly City Council 1977). Shortly thereafter negotiations began on an agreement to transfer all municipal waste to Ox Mountain Landfill in Half Moon Bay. On July 5, 1979 Mussel Rock Transfer Station opened for business, and plans were underway for the permanent closure of the Mussel Rock Landfill.

A number of historic landfills in San Mateo County closed before 1988 (Figure 35). These include Frontierland Park Landfill in Pacifica, Brisbane Landfill, South San Francisco Municipal Dump, Belmont Island Park Landfill, and Half Moon Bay Landfill (California State Water Resources Control Board 2006). Although the regional alternatives for Daly City were few, the city could have found an alternate site if they had chosen a clean closure at Mussel Rock. Currently, San Mateo County possesses only four open landfills: Burlingame Refuse Disposal Area, City of Burlingame Sludge Ponds, Hillside Class 111 Disposal Site in Colma, and Ox Mountain Sanitary Landfill in Half Moon Bay (San Mateo County Recycleworks 2010).

In 1980 Daly City Scavenger Company paid an engineering firm to cover the 12-hectare (29 acres) landfill pit areas with a thick clay soil in a surface water drainage mitigation attempt (Smelser 1987). The soil fill formed a veneer on the landslide toe slope. When workers filled and graded the landfill pit in 1980, some of the landfill material was pushed over the edge of the pit and covered the toe (Smelser 1987). This veneer is about three meters (10 feet) deep, and was subsequently covered with the thick clay soil fill layer. Since then, the veneer has slumped in many places, indicating unconsolidated, non-compacted landfill material as well as movement along the toe of the landslide.

Riprap and a seawall were then placed at the landslide toe to prevent landfill material from slipping into the ocean. The riprap levee measures about eight meters (26 feet) high by 20 meters (66 feet) wide, with an apron slope of approximately 25 degrees (Figure 36). In total, the levee extends some 830 meters (2,700 feet) north from Mussel Rock to the

Municipal Solid Waste Landfill Sites

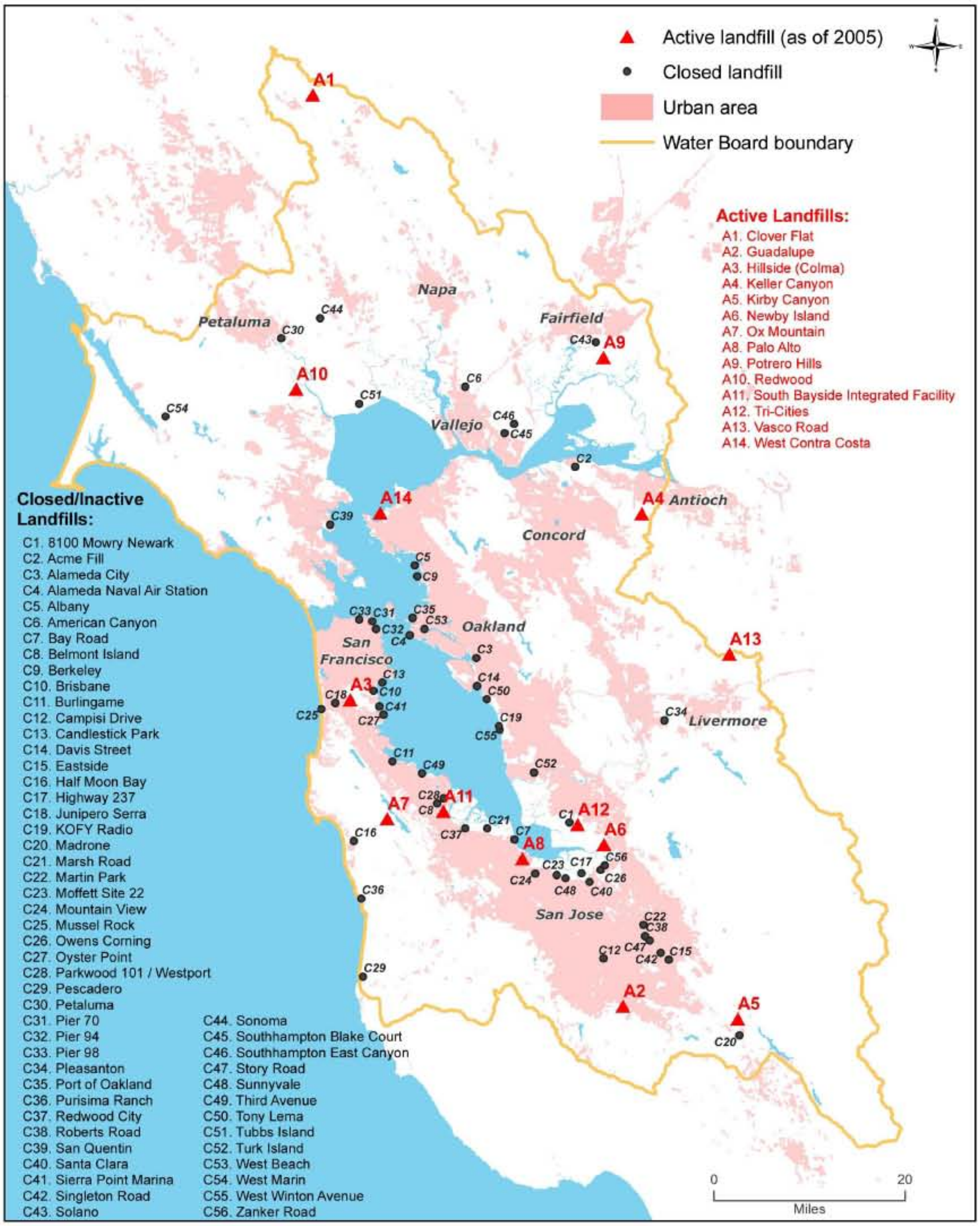

Figure 35. Municipal Solid Waste Landfill Sites of the Bay Area. From California State Water Resources Control Board (2006).

Figure 36. Riprap apron fronting landfill and covering beach, along with rebar and other detritus. Mussel Rock is in the background. Photo by Shawn Heiser.

beginning of Thornton Beach cliffs. The southern end of the riprap is built atop an eroded sea stack of the Franciscan Complex (Smelser 1987). The riprap is composed of different materials, including boulders of granite and Franciscan Complex, blocks of cement and asphalt, and even freeway pilings and street lamp posts (Smelser 1987). Movement and erosion processes have reduced the original and secondary seawall levees, requiring regular maintenance and rebuilding of the revetment structures (Figure 37). Figure 38 shows a partial maintenance plan for the revetment and drainage regime from 1995.

The current seawall is composed of large cobbles and small boulders of mostly granitic materials. The rocks are collected and housed in gabions, or wire cages, stacked on top of one another and tied together with wire. The seawall is approximately 1.5 meters (five feet) high at the surface of the landslide toe. There are eroded relict seawalls as well, such as one built in 1965 (Figure 39). As the photos illustrate, the slumping seawall is clear evidence that the toe of the landslide is currently moving, pushing the landfill pit and materials closer to the ocean despite the ongoing revetment efforts.

Figure 37. Three generations of seawall and riprap in gabions, stacked on top of one another, with slumping from the main landfill pit above. Photo by Shawn Heiser.

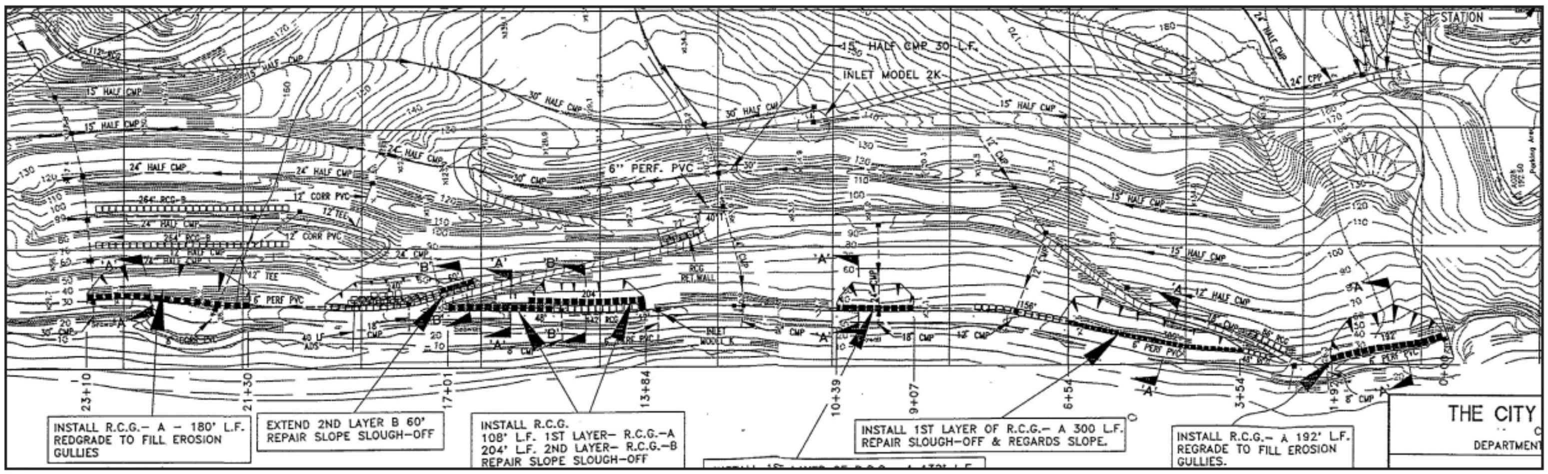

Figure 38. Mussel Rock Park Maintenance plan for 1995. From Daly City Department of Public Works

Figure 39. Relict seawall from 1965, nearly buried by fill and slump material. Photo by Shawn Heiser.

Despite the warnings that were present in the early 1960s before the landfill opened, and after the major problems with the site were identified, Daly City did little to address the problems. After the engineering and geologic reports identified the natural features present at Mussel Rock, Daly City did not require the Scavenger Company to determine the spatial extent of the landslide beneath the landfill, nor the rate of movement along the slide plane in order to determine the long term effects of movement (Cox-Whitsel 1983).

The franchise agreement in the original contract providing for an alternate landfill site by Daly City Scavenger company if Mussel Rock were proved inadequate could have provided Daly City the mechanism by which it could have ordered the closure of the site decades earlier than it was eventually forced to by the California Regional Water Quality Control Board in 1978. If Daly City had chosen to close the site at that opportune time, decades of mitigation, maintenance, and millions of dollars would have been saved. The risk of major environmental damage from an earthquake or landslide would also have been lessened significantly. Additionally, the feasibility of removing the waste from the site would have been much greater at that time. Instead, the City ignored the scientific data and continued to fill the Mussel Rock Landfill with municipal waste for another 15 years, at the cost of thousands of hours of maintenance and mitigation projects, and millions of dollars for drainage and revetment structures.

Since the City and the operators of the landfill began testing, monitoring, and reporting groundwater sampling to the California Regional Water Quality Control Board in 1993, discharges of numerous metals and volatile organic compounds and chemicals have been reported at the Mussel Rock site. Included in groundwater samples are elevated levels of nickel, zinc, copper, lead, and ammonia (Regional Water Quality Control Board 2000; Elias 2005).

Impounding and channeling groundwater and runoff is extremely important in containing the landfill waste and keeping leachates from flowing into the ocean. Since the landfill straddles the San Andreas Fault, keeping groundwater out of the landfill is nearly impossible since the fault channels a significant amount of groundwater flow into the landfill from below.

In 2000 Daly City and Daly City Scavenger Company submitted a study on the feasibility of improving the waste containment at the site (Regional Water Quality Control Board 2000). The study proposed a Non-Action (status quo) plan and three alternative plans. The three alternatives were: 1) an up-gradient well gallery to extract groundwater, followed by an onsite treatment plant; 2) a well field to extract leachates, followed by an onsite treatment plant; and 3) complete removal of all of the waste (also known as a clean closure). Daly City's estimated cost of a clean closure of the Mussel Rock Landfill was $85 million (Regional Water Quality Control Board 2000).

The City and Scavenger Company reviewed these options for their regulatory compliance, public acceptance, ease of implementation, and costs over the next 30 years. The City and Scavenger company chose the easiest, least expensive, and least responsible option of Non-Action, or keeping the status quo (Friedman 1999). This requires maintenance when necessary and minimum amounts of site drainage, grading, and landslide and erosion control and prevention (Regional Water Quality Control Board 2000).

To date, Daly City and Daly City Scavenger Company have paid approximately $15-20 million in maintenance and improvements for the landfill site. This annual cost has increased over the years, as Daly City's fiscal allotment for maintenance of the Mussel Rock Landfill for fiscal year 2008-2009 totaled $955,832 (Daly City 2008). The Daly City Scavenger Company has promised more than $11 million in funding for the projects, which Daly City currently plans to maintain until at least 2022. Obviously, no municipality has $85 million in funding readily available for transportation and relocation of a garbage dump. If the estimate of $85 million is based on an accurate assessment, then Daly City's choice of the non-action alternative becomes more understandable (Friedman 1999). From a purely financial perspective it is easier to comprehend why they chose to keep the landfill material in place and spend an average of $400,000 annually on maintenance, drainage and revetment structures.

The decision to site a landfill in such an unstable and precarious place was not without precedent in the Bay Area. Between the years 1950 and 1970, such practices were commonplace as an estimated 70 municipal landfills ringed San Francisco Bay, some of which are still in operation (Pence 2000). However, none of the other landfills sited on or near the Bay developed such serious potential hazards as Mussel Rock's. In 2000 Wil Bruhns, Senior Engineer on the California Regional Water Quality Control Board, told the San Francisco Chronicle: "(San Francisco) Bay is ringed with old landfills…In the 1950s and '60s, it was fairly common for cities to view the Bay as a swamp to dump garbage in. But there's not one that is in such (a) precarious, geological position as the Mussel Rock Landfill" (Pence 2000).

Surveys of Residents Living in the San Andreas Rift Zone

A number of Risk Assessment surveys conducted in recent decades attempt to evaluate residents' awareness of and attitudes toward the various risks associated with living in a densely populated major seismic rift zone. The most revealing of the surveys comes from Sullivan, Mustart and Galehouse (1977). These geologists from San Francisco State University conducted four sets of surveys in 1970, 1972, 1974, and 1976. Other informal surveys and interviews with Mussel Rock residents in newspapers, journals and books show similar responses to questions of earthquake hazard risk (Wilson 1989; Clarke 1996). Residents liked the affordability of homes in the subdivisions, and frequently cited the clean air and the cliff top and beachside scenery as positive aspects of living there. Most residents were aware of the presence of the San Andreas Fault in the area, but very few of them had been informed about the earthquake hazard by the government or previous occupant (Sullivan, Mustart and Galehouse 1977; Wilson 1989).

A major objective of the Alquist-Priola Act of 1972 was disclosure of this information to potential home buyers. Most learned through friends or neighbors, and some through the administration of the surveys and interviews conducted by college researchers and journalists. Interestingly, very few residents living in the area were aware of the ancient but active Mussel Rock Landslide (Sullivan, Mustart and Galehouse 1977). Ironically, the northern San Mateo County section of the San Andreas is the most densely populated section of the entire 1400-kilometer long fault (Fradkin 1998, Sullivan, Mustart and Galehouse 1977).

CHAPTER 4: Epilogue - The Future of Mussel Rock Park

Philip Fradkin's *Magnitude 8* (1998) argues that Mussel Rock has been utilized as little more than a garbage dump for more than 500 years. In his words, "during that time the residents, be they Ohlone Indians or the latest Asian immigrants" used Mussel Rock as a large refuse pile, and "have watched the high bluffs collapse and slide into the Pacific Ocean when the land shook" (Fradkin 1998, 211). His treatise on living in the San Andreas Fault Zone gives an uneven and rather bleak impression of the local conditions of Mussel Rock at any given point in history.

Unfortunately, Daly City's actions do nothing to dispel such pessimistic assertions. Whenever attempts are made to valorize Mussel Rock and Daly City's place as a seismic hotspot or historic landslide area—which can be of much interest to science and the general public—they are rebuffed by Daly City politicians. It is as if they prefer to keep history and scientific knowledge buried in the landfill pit along with the waste. For example, after Thornton State Beach reopened in 2007, Jim Tanner, a local historian, made a proposal to create a 55-pound bronze information plaque marking the point just offshore from Mussel Rock where the epicenter of the 1906 Great San Francisco Earthquake was thought to have been located. Daly City leaders rejected the proposal based on fear of further stigmatization of Daly City's reputation. Mayor Sal Torres had this response to the proposal: "I don't want people to associate the city with an earthquake that brought a lot of tragedy. We don't need to put a blemish on Daly City's shine. There's no reason for it" (Kim 2004, B-1).

Mussel Rock and its owner, the City of Daly City, endure criticism on a continual basis. The first settlers named their village at Mussel Rock "ocean flea-place". Time has not attenuated the derision of Daly City and its many Mussel Rock failures. Well-worn jokes about 'permafog', cold and wind persist; noisy airplanes overhead are common; Malvina Reynolds' "Little Boxes" ridicules suburban Westlake houses "made of ticky tack…and looking all the same"; and epithets belittle its status as merely another suburb with nothing to do. A time-honored nickname for Mussel Rock among paragliders is simply "The Dump". Despite these critiques the people of Westlake Heights and Westlake Palisades carry on, hoping that another Magnitude 8 does not strike nearby, and hoping to evade another disastrous El Niño season.

Risk assessment surveys conducted at various times in the last 30 years all point to the same conclusions: people live here because it is more affordable than other parts of the Bay Area. As the Ohlone tribes discovered, the place is convenient, in close proximity to travel links and access to transportation interchanges to the greater Bay Area. According to survey responses, most people became aware of the geologic hazards shortly after settling here. Attitudes did not change much with the knowledge gained. A general opinion holds that we're all at risk living here, so why worry more at this location than any other, regardless of distance from a fault? Those who feel this way share a similar philosophy with author John McPhee, who questions the actual statistical hazard risk presented by living on the San Andreas Fault. "In the prodigious roster of earthquakes on the San Andreas Fault, nearly all of them affect no one. The plates drift, the people with them. Fourteen times a year, an earthquake on the order of the 1989 event near Loma Prieta in the Santa Cruz Mountains occurs somewhere in the world. That might seem to thicken the risk. But not much. In California, only seven events have occurred at that level since 1900. So why not move in, spread out, build up, and occupy this incomparable terrain?" (McPhee 2006, 6).

There are additional positives to living at this location. One benefit frequently cited by residents is the scenery (Wilson 1989). Many aspects of topography and geology which make Mussel Rock a risky place to live also offer dramatic scenes of mountains, cliffs and ocean. The area also provides a cool climate for those who dislike warmer summer temperatures, and while the summer 'fog blanket' is a source of derision for some, but for others a unique feature cherished by locals. There is ample room for outdoor recreation of many types along the Daly City coast. The area also offers some of the best air quality in the region thanks to prevailing sea winds, and sunsets are spectacular when not shrouded by thick fog layers.

Daly City has spent the better part of 40 years repairing and maintaining the former dump site at Mussel Rock at a cost of millions of dollars. In recent years some of the maintenance and repair expenses have been reimbursed to Daly City through FEMA funding (Daly City Council 2008). Daly City Scavenger Company continues to add money to the Mussel Rock maintenance budget, even though Daly City bought the landfill from the Scavenger Company in 1995 (Daly City 2009).

Mussel Rock Landfill has required major maintenance projects in nearly every other calendar year since 1962 (Daly City Council 1963; Chapman 1964; Regional Water Quality Control Board 1964; Daly City Council 1971; Daly City Council 1972; Daly City Council 1977; Regional Water Quality Control Board 1986; Daly City Department of Public Works 1995; Daly City Council 1996; Daly City Council 1999; Regional Water Quality Control Board 2000; Regional Water Quality Control Board 2001; Daly City Department of Public Works 2006; Regional Water Quality Control Board 2007; Daly City 2008; Daly City Council 2008; Daly City 2009). The closed landfill and surrounding landscape will require many more years of maintenance and repair, particularly following winters with above average rainfall.

The average annual cost of maintenance and repair now exceeds $400,000 and each of the nine major repair projects since the late-1990s approached or exceeded $1 million (Daly City Council 1999; Daly City Council 2008). This author's estimate of the total amount spent to date on repairs based on City Council records is in the range of $15-20 million.

Meanwhile, a continuous dialog plays out between Daly City and The Regional Water Quality Control Board regarding violations of the closure order agreement. Water Board inspectors survey the site and send the city notice of the various violations; Daly City either denies the violations or claims that they are aware and are working to rectify the problem, but that maintenance projects will take more time and money than anticipated. Daly City also frequently makes the claim that construction and maintenance activities can only be performed during the summer months, when the ground cover at the landfill site is not "saturated with water" (Daly City Department of Public Works 2006). Here, Daly City implicates itself, since the presence of any surface water at the landfill site is a major violation of the closure agreement (Regional Water Quality Control Board 2000).

Therefore, Daly City continually insists it is in complete compliance with all agreements, and yet also insists upon rectifying any problems at the site on the City Council's own terms and allowable budget. While the city does adhere to semi-annual inspection reports on site stability, water quality, and well sampling, they continually request that reports be reduced to one per year, and that some of the testing variables be eliminated entirely from the reports (Elias 2005; Fanelli and Kirby 2006). The Water Board has flatly rejected these requests each year due to the problematic record it has experienced with Daly City (Elias 2005; Giangerelli and Velsy 2009).

To make matters worse, Regional Water Quality Control Board and Coastal Commission employees claim that Daly City officials consistently downplay and diminish the actual amount of money spent on annual maintenance and repair of the landfill site (Friedman 1999; Regional Water Quality Control Board 2007). They believe this ploy helps to diminish the problematic aspects of the decision to keep and maintain the site, as opposed to justifying the cost of a clean closure when the opportunity presented itself.

To whatever extent San Francisco's extramural and centrifugal processes shaped Daly City's identity, Daly City's government is guilty of maintaining the stigmatization through its non-complicit posturing and deplorable actions. This aspect of the Mussel Rock story is the most disturbing and disappointing discovery about Daly City's attitude towards the place itself. Consistent de-emphasis creates and sustains disdain, and perpetuates and further justifies feelings of aloofness. This attitude has filtered down from the city's leaders into the general population, which helps to explain Mussel Rock's relatively hidden and sometimes notorious reputation.

Samuel Chandler's (1973) official history of Daly City gives much consideration to the mid-20th century era of 'home building' and the subsequent drama of providing civic infrastructure for these new districts. The ensuing 'great battles' over the location of roads and highways, schools, churches, and retail districts are considered by Chandler to be a significant part of Daly City's history. Ironically, Chandler's 'official' history of Daly City does not mention Mussel Rock. It is surprising that the city's most dubious decision is insignificant to an author recording the 'official' Daly City history—during the same time period Chandler describes as a 'Golden Age' in the history of the city. Perhaps Chandler's omission was intentional. Many people wish to forget Mussel Rock's complex environmental and land-use history.

Although today Mussel Rock 'Park' is a large open area containing many positive elements of a natural area, currently it is not officially designated a park. This may be a result of Daly City's reluctance to draw large numbers of visitors to the place due to the natural and human-induced hazards in the area, but a general disdain for the place itself by city leaders likely underlies its rhetoric. Daly City's Park and Recreation Director shares a similar attitude as reflected in his reference to Mussel Rock's official status as a mere 'overlook'. Regardless of its history and reputation, many people would disagree with this simplified assessment.

The lifespan of the Mussel Rock Landfill was miscalculated by Daly City officials. Most of the 765,000 cubic meters (1 million cubic yards) of garbage in the former dumpsite are still present and have not decomposed at the rate originally calculated by the city. According to the Regional Water Quality Control Board (2007), the garbage in the landfill could remain for at least another century before decomposition has made an impact on the site. The cost of maintaining and repairing the site due to erosion and movement will remain a large part of Daly City's budget for the foreseeable future.

According to Daly City's Mussel Rock Annual Program, started in 1992 by order of the Regional Water Quality Control Board, maintenance and repair projects will continue until 2022, with an allocated budget of $10,950,000 at present (Daly City 2009). Based on past maintenance project costs, this is likely an insufficient amount. Alternative options for long-term use have been put forth by Daly City. Such attempts in various ways sought to either develop the area further or to shift the financial burden to other parties.

For several years in the mid-1990s Daly City debated proposals from private developers to turn Mussel Rock into a golf course (Daly City Council 1997). Other proposals from private developers include a BMX racing track and a Frisbee golf course. All of the proposals were rejected due to local residents' resistance or defeat by vote of the City Council.

Daly City also attempted to push the Mussel Rock nuisance onto other government offices. Golden Gate National Recreation Area encompasses 95 kilometers (60 miles) of coast-line from Mount Tamalpais in Marin County south to Half Moon Bay State Beach in San Mateo County. Between San Francisco and Half Moon Bay, Mussel Rock is one of the only remaining sections of coastline not federally or state protected (Figure 1, page 4). On separate occasions in the 1980s and 1990s, Daly City tried to sell, and failing that effort, give away its Mussel Rock parcels to the National Park Service's Golden Gate National Recreation Area (GGNRA), only to be rejected twice due to NPS reluctance to assume the cost of maintaining the landfill site (Madden 1984). The Regional Water Quality Control Board was an advocate of full disclosure, as reflected in an internal memo between employees—"We need to make GGNRA clearly aware of this situation. It would bother me to see incredible local idiocy made into a Federal problem" (Regional Water Quality Control Board 1986).

What then is the solution for the long-term future of Mussel Rock? Can its tarnished reputation be redeemed? This author believes so. Even if a clean closure of the former landfill cannot be financially feasible and the refuse must stay in place, Mussel Rock can still be turned into a positive resource for Daly City. However, the first action must be a transformation in city leaders' perception of the place. This transformation would require viewing the place through the lenses of renewed responsibility and respect for natural processes. Positive ways to utilize the landscape and honor the history of human imprint requires acknowledgment of two unique qualities tied to Mussel Rock's history: its unique geologic significance and the historic presence of Ohlone Native Americans.

The idea for a managed San Andreas Fault Zone/Historic Ohlone Cultural Center at Mussel Rock Park was first proposed in the mid 1980s, but was rejected by Daly City. In 1984, the city proposed to develop Mussel Rock Park in a way that embraced and celebrated its history as part of its required Long-Term Coastal Plan. "A San Andreas Fault Visitor's Center and a facsimile Ohlone Indian Village should be considered for inclusion in the Mussel Rock Coastal Park development plan" (Daly City 1984, 38). The Local Coastal Plan, when finally realized, would "convert an isolated shoreline into a regional resource….the 'Gateway to the Peninsula' will be especially true when the beach is fully accessible" (Daly City 1984, 16). To date this Coastal Plan has not been realized, and the reasons for its failure are not revealed in the primary sources or literature. In fact, the entire 1984 Local Coastal Plan provided little information around stakeholders, public comments, pro/con arguments, and the decision-making process. It is as if the entire plan disappeared into the ether.

However, the plan did result in establishing a park-like environment at Mussel Rock with marginally improved public access to the coast, but with no infrastructure or management outside of the landfill and transfer station activities. Daly City only went halfway in their efforts. Calling Mussel Rock a coastal park, covering the landfill, and making it 'park-like' served to decrease the overall risk perception of the place, and slightly lessen its stigma, but ultimately made it no safer or better prepared for visitors than before.

Seeking a grant from the Coastal Conservancy, in 1998 another proposal to re-create the Ohlone Village of Ompuromo and to construct a Mussel Rock Park Interpretive Trail was submitted by Pacifica Land Trust, Daly City's Department of Water and Wastewater Resources, and Daly City's Parks and Recreation. The proposal called for capital improvements including an accessible pedestrian entrance structure, interpretive signage, and beach access.

The project was designed to encourage a community effort, utilizing volunteers in the environmental and historical communities to create "an educational exhibit of the rich cultural history and other interesting features that exist at Mussel Rock" (Daly City Council 1998, 1). Unfortunately, the proposal did not win the Coastal Conservancy's grant money, and was similarly dismissed as potential funding dried up.

Another significant reason to preserve Mussel Rock has recently emerged: to provide protected habitat for the endangered San Francisco Garter Snake, a species endemic to San Mateo County which appears to thrive at Mussel Rock. In recent years, numerous efforts have been made to protect San Francisco Garter Snake habitat areas near Mussel Rock, such as San Bruno Mountain and Sharp Park in Pacifica. Perhaps this aspect of a Mussel Rock Park proposal provides a unifying variable that may be easier for the general public to understand than protecting a park in the name of cultural-archaeological, and geologic, seismic, and development hazard interests.

If a Mussel Rock Park plan of this nature were to be proposed again in the future, an initial roadblock would likely be development financing, considering the current political and economic climate. As envisioned in 1998, minimal capital investments would be needed for signage, construction materials, picnic tables and trail improvement expenditures. Financing could be arranged by an agreement between the three governing levels of ownership and operation of the park. Perhaps a joint venture between The National Park Service, California State Parks, San Mateo County, and Daly City could be organized. Daly City should be expected to continue to fund most of the maintenance and repair work on the landfill site, but money for park development, infrastructure, and maintenance could be paid by Federal, State, and County funds. Alternative sources of money could result from environmental and preservationist organizations, local fundraising efforts, and private donations.

Whatever the reasons for previous rejection of the idea of a hybrid coastal park at Mussel Rock, the plan remains the most far-reaching and redemptive idea for the long-term utilization of the space. The potential benefits offered by this type of park are substantial, and the proposal process should begin anew. The cultural-historical site could include a re-creation of the village, or take the form of commissioned dioramas, signs, plaques, and educational displays. Such an exhibit celebrating the area's Ohlone inhabitants could potentially be unique in California, and thus a significant tourist attraction.

A San Andreas Fault Zone History Center at Mussel Rock would also be among the first of its kind. Its value as a tourist attraction could be considerable. The center would highlight the rich history of geologic and seismic features in the area, such as earthquakes, plate tectonics, landslide and other coastal erosion processes, faults and coastal terraces. Another display would discuss the controversial history of the Mussel Rock Landfill. Locally-employed landslide and fault monitoring instruments and equipment would be on public display. In this way, a forthright approach to reconcile the disconnect between geologic and coastal forces and land-use decisions around development and municipal garbage disposal could take shape in front of the public.

While the potential for increased erosion, landslides, and environmental disaster at Mussel Rock will not diminish for many decades, the opportunity would offer a credible potential solution as to how the park should be responsibly managed in the future. Logic dictates that the social and environmental benefits to this plan would be numerous, multifaceted and proactive. The most elementary benefit is to reverse the historic perception of Mussel Rock by utilizing responsible stewardship to create a positive use of space out of what is currently perceived as a source of shame and disdain caused by poor civic planning and management.

It is clear from statements in proposals that Daly City has interest in positively enhancing its coastal holdings, especially Mussel Rock. However, circumstances such as funding shortages or lack of leadership have caused dismissal of the plans. Ultimately, the realization of such an endeavor would raise the profile of Mussel Rock, its nearby residents of Daly City and Pacifica, and the local government leadership. Open, straightforward, responsible action such as this may ease lingering negative perceptions of Mussel Rock's land uses, and give Daly City a much-needed boost of pride. To fully embrace the fleeting fortune of "living on the edge"—complete with all of its inherent joys and risks—in a responsible manner would be a very good start.

Finally, this study's intention is to lay the groundwork for future research at Mussel Rock Park. For example, additional opportunities for research include a long-term assessment of Mussel Rock's armoring regime and its relationship to recent rapid erosion of the unstable cliffs of the marine terrace immediately down shore. This area in northern Pacifica has seen a sharp increase in erosion since the early 1990s (Scott 2009; Griggs, Patsch and Savoy 2005; Shires 2001; Hampton and Dingler 1998). Does Mussel Rock's coastal armoring regime contribute to increased bluff erosion in this area? Is nonlinear hydraulic impact from waves in Pacifica caused by armoring at Mussel Rock? A study should be commissioned that analyzes the potential effects of wave refraction and/or passive erosion taking place locally. If adverse effects are taking place in Pacifica as a result of the armoring regime, then what are potential mitigation measures to address this problem? Another opportunity for additional research at Mussel Rock is an updated risk assessment survey of the residents to see if local knowledge and risk awareness has increased for those living 'on the edge'.

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