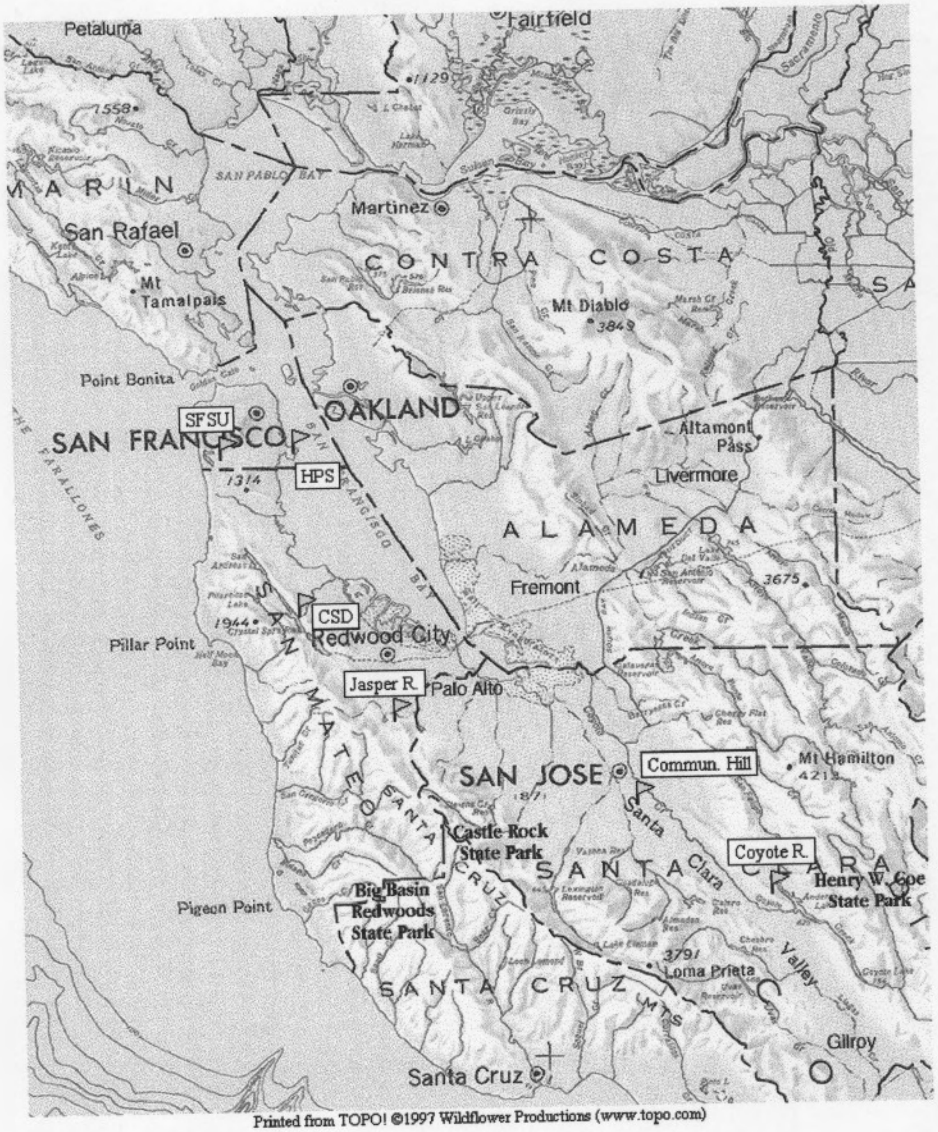
Western Society of Soil Science

field trip

San Francisco, California

June 23, 1999



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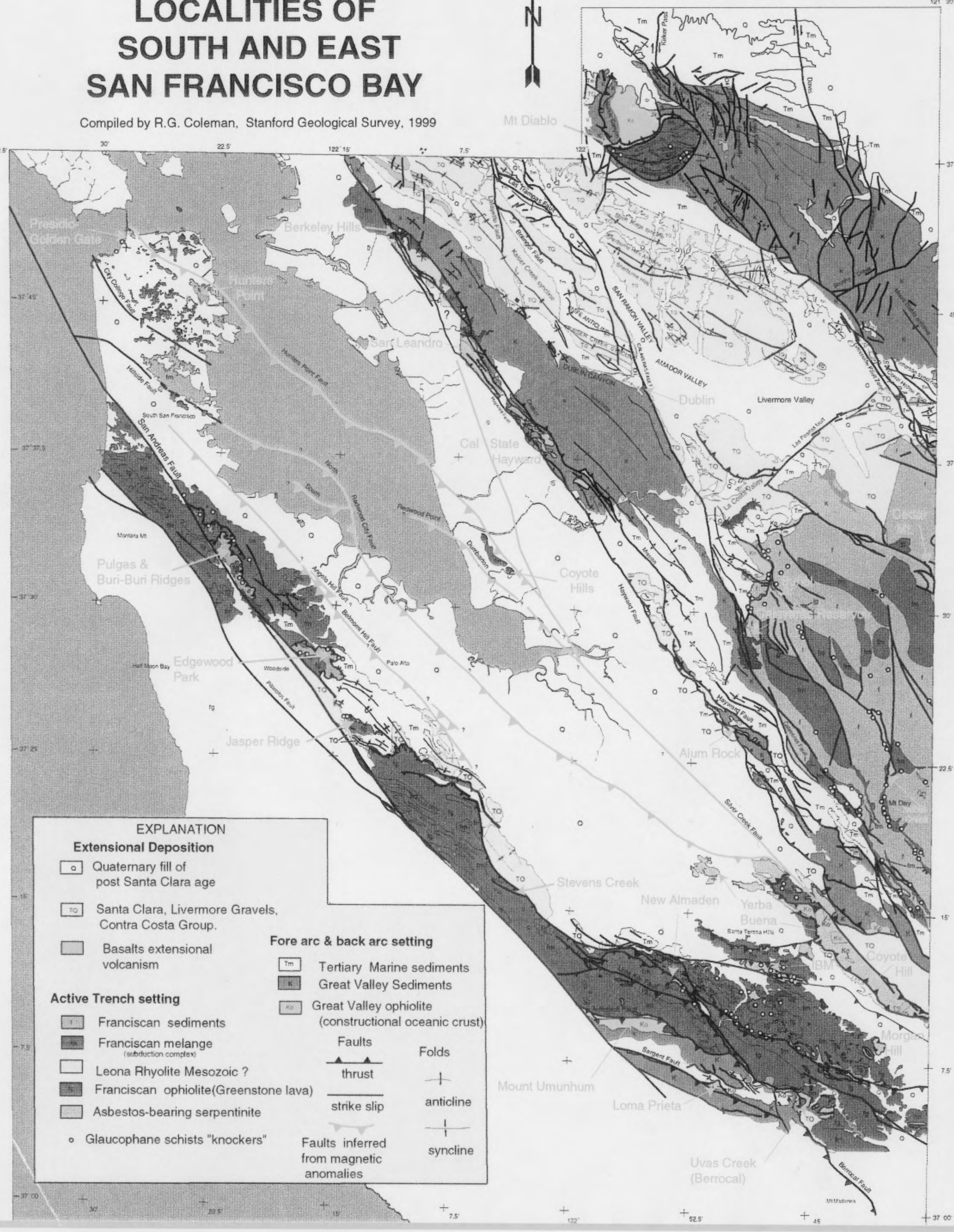
Field Trip Stops and Points of Interest (v) Located on the Map:

0 - SFSU, San Francisco State University
1 - HPS, Hunters Point Shipyard
v - Communication Hill
2 - Coyote Ridge, at Kirby Canyon Recycling and Disposal Facility
3 - Jasper Ridge, at Jasper Ridge Biological Preserve
v - CSD, Crystal Springs Dam

SERPENTINITE LOCALITIES OF SOUTH AND EAST SAN FRANCISCO BAY

Compiled by R.G. Coleman, Stanford Geological Survey, 1999



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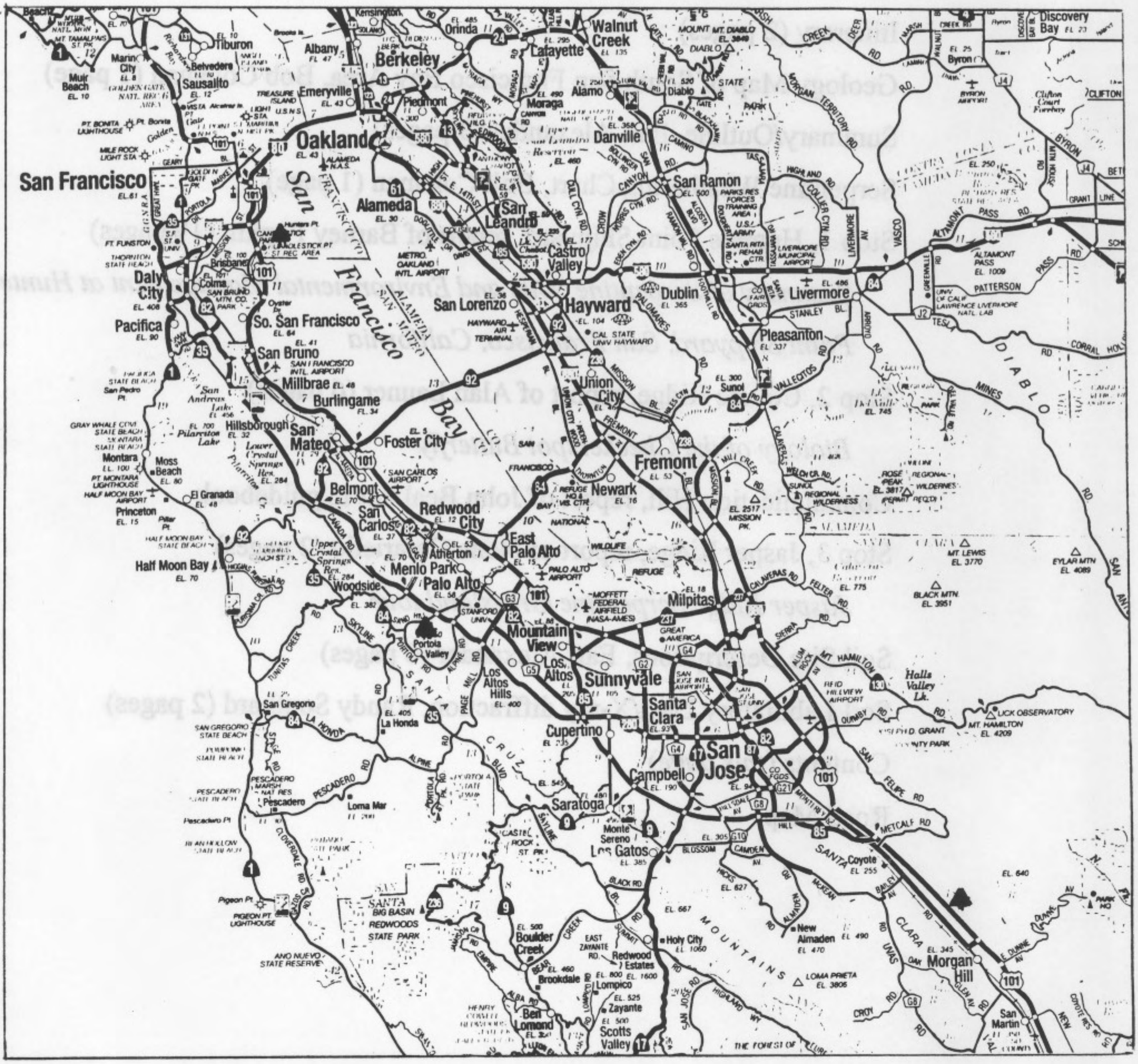

Roads of the San Francisco Bay area.

Serpentine Soils Field Trip
Western Society of Soil Science, June 23, 1999

8 am San Francisco State University to Hunters Point Shipyard (HPS) - 9 mi. (1/2 hr.)

- 0 mi. SFSU campus - from Holloway Avenue turn right onto 19th Ave. (hwy. 1)
  stay right on highway 1 over Brotherhood Way and loop back onto it
  stay in left lane on Brotherhood and Alemany Blvd. to enter I280
- 7 mi. exit I280 onto Army St. (Caesar Chavez), turn right
  from Army St. turn right on Third St. and left on Evans Ave.
  Evans leads via Hunters Point Blvd. to Innes Ave. and main gate of HPS
  HPS Stop 1 - Barney Popkin, on an overlook of the HPS, presents landfill history, its contamination, hazards, and remediation strategies
  HPS Stop 2 - Bob Coleman, at an exposure of Franciscan melange, explains the dynamics of rock formation in the Coast Ranges around San Francisco

9:30 Hunters Point Shipyard to Coyote Ridge (CR) - 65 miles (1.25 hours)

- 0 mi. HPS, main gate - return via Evans and Third to Army Street
- 2 mi. pass under I280, turn right on Pennsylvania Ave. to enter I280 south
- 3 mi. turn from I280 onto U.S. 101
- 7 mi. San Bruno Mtn. on right
- 13 mi. San Francisco Airport on left is built out onto bay fill
- 38 mi. Moffett Field, large hangers on left
- 53 mi. north end of Coyote Ridge is straight ahead
- 64 mi. turn off U.S. 101 onto Coyote Creek Golf Drive go under freeway and up road
- 65 mi office of Kirby Canyon Recycling and Disposal Facility, check in there
  CR Stop 1 - Alan Launer, from the summit of Coyote Ridge, presents purpose and results of ecological studies there, and Bob Coleman adds some comments about geology of area
  CR Stop 2 - pedons CR1 and CR2, both closed, but can be reopened easily; soil analyses from laboratory of Randy Southard

12 noon - lunch

12:45 Coyote Ridge to Jasper Ridge Biological Preserve (JR) - 39 miles (3/4 hr.)

- 0 mi. check out from Kirby Canyon Recycling and Disposal Facility
- 1 mi. enter U.S. 101 freeway going north
- 6 mi. take right lane over U.S. 101 onto highway 85
- 12 mi. approaching Almaden Expressway, Communication Hill on right;
  John Beal has worked with local authorities on urbanization plans for it
- 25 mi veer right to get off highway 85 onto I280
- 37 mi. go under Sandhill Road and turn off I280 onto it, going west

38 mi. Stanford linear accelerator on left

39 mi. enter Jasper Ridge Biological Preserve, park, and walk to Jasper Ridge

JR Stop 1 - Nona Chiariello presents an overview of decades of ecological research on serpentine soils, including current work by Harold Mooney, Hobbs, and many others

JR Stop 2 - Obispo Series on serpentinite (pedon JR1), description in guidebook

JR Stop 3 - Montara Series on serpentinite (pedon JR2), description in guidebook

4:30 Jasper Ridge Biological Preserve to San Francisco State U. - 30 mi. (1/2 hr.)

0 mi. from JRBS, return to I280 and go north

14 mi. San Mateo Creek and Crystal Springs Dam, which survived the 1906 earthquake on the San Andreas fault, which runs along the depression just west of I280 here

21 mi. San Bruno Mtn. straight ahead, or slightly right, and Mt. Diablo 33 miles away across San Francisco Bay on the far right

29 mi. veer left onto highway 1 and Junipero Serra Blvd.

30 mi. turn left from Junipero Serra onto Holloway and go straight to SFSU

Field Trip Hosts and Contributors of Information

Alexander, Earl B., pedologist, Soils & GeoEcology - ealex@compuserve.com
field trip coordinator, describer and sampler of soils on Coyote and Jasper Ridges

Beal, John, associate director, Guadalupe-Coyote Resource Conservation District
an expert on Communication Hill urbanization issues

Chiariello, Nona, Jasper Ridge Biological Preserve - nona@jasper.stanford.edu
director of the Biological Preserve

Coleman, Robert G., Professor Emeritus, Stanford University - coleman@pangea.stanford.edu
expert on local geology and world authority on geology of serpentinite

Launer, Alan - aelauner@leland.stanford.edu
Center for Conservation Biology, Stanford University

Popkin, Barney P., Tetra Tech EMI - popkinb@ttemi.com
hydrologist currently studying hazardous wastes of Hunters Point Shipyard

Southard, R.J., Professor, University of California, Davis - rjsouthard@ucdavis.edu
obtained laboratory analytical data for soil samples from Coyote and Jasper Ridges

SERPENTINE SOILS
Introduction and Outline

Serpentine soils are recognized for the unique plants and plant communities growing on them. Differences in plant distribution from serpentine to nonserpentine soils are generally so great as to be obvious to even a casual observer.

Serpentine soil is a popular designation for soil derived from ultramafic rocks. Peridotite and serpentinite are the predominant ultramafic rocks. Plant distributions are commonly the same on soils derived from both kinds of rock. Plants do not seem to distinguish chemically between peridotite and serpentinite, although soil physical properties may be sufficiently different that soils on peridotite and on serpentinite support different plant communities in some areas. Plants communities on serpentine soils generally have a more xeric aspect than adjacent communities on nonserpentine soils, even where the differences are unrelated to differences in soil physical properties.

Serpentine soils harbor many endemic species, plant species that grow only on serpentine soils. Because of this and their unique fertility problems, serpentine soils have attracted special interest from botanists. Yet there have been few pedological studies of serpentine soils. Geologists have studied weathering of ultramafic rocks and minerals for their interest in the concentration of Fe, Mn, Cr, Ni, and Co in serpentine soils to commercially extractable quantities. Thus, a thorough survey of serpentine soils must span the disciplines of petrology, mineralogy, pedology, plant taxonomy, plant physiology, and ecology. There are also zoological and health aspects of serpentine soils that have been less thoroughly explored by these disciplines.

Definitions.

Serpentine - a group of **minerals**, $Mg_3Si_2O_5(OH)_4$ polymorphs (antigorite, lizardite, and chrysotile).

Serpentinite - **a rock** dominated by serpentine minerals.

Ultrabasic rock - rock < 45% silica (SiO_2), although an upper limit of 48% silica may be more approriate.

Ultramafic rock - rock > 70% magnesium (ma) and iron (f) silicate minerals, mainly olivine, pyroxene, and serpentine.

Serpentine soil - soil with ultramafic parent material.

Kinds of Ultramafic Rocks

Plutonic rock - peridotite, including dunite and pyroxenite (excluding anorthosite)
Volcanic rock - komatiite (all in Archean greenstone belts, 3 to 4 BaBP, on cratons)
Subvolcanic rock - kimberlites (variable composition and inextensive, in dikes and pipes)
Metamorphic rock - serpentinite - blocky (massive), sheared, and fibrous types
  antigorite (formed under green-schist facies conditions, 220-460°C)
  lizardite (product of hydrothermal alteration, 85-185°C)
  chrysotile (hydrothermal alteration and precipitation at ambient temperatures)

Origin (and a Sample Location) of Peridotite

Layered cumulates, in dikes and sills (Stillwater complex, Montana)
Concentric bodies - peridotite center to gabbro margin (Duke Island complex, Alaska)
Ophiolite suites (Josephine ophiolite, California & Oregon)
Nonophiolitic alpine peridotites (Rhonda peridotite, Spain)

Serpentinization of Peridotite - a process requiring much water, yields
brucite - $Mg(OH)_2$
serpentine - $Mg_3Si_2O_5(OH)_4$ with Fe and Ni substitutuions
magnesite, with addition of CO_2 - $Mg(CO_3)$
talc, produced at temperature > 500°C
magnetite - Fe_3O_4

Ultramafic Rock & Soil Chemistry
very high Mg
relatively high Fe, Cr, Ni, Co, Mn
very low Al, Ca
relatively low K, Mo, P (K may not be low in kimberlites)

Weathering of Olivine with Different Leaching Conditions
rapid Mg removal → goethite, hematite, opal
moderate Mg removal → nontronite, goethite
Mg accumulation → saponite, magnesite
residue (resistant to weathering) - chromite
Orthopyroxene (enstatite) weathering is similar, but talc occurs in early stages of weathering
Serpentine weathering yields more smectite and less Fe-oxyhydroxides, and more Fe_3O_4 residue

Soil Properties (representative properties, not comprehensive)
texture - stony loam surface over stony loam to clayey subsoil
common colors - reddish over yellow (peridotite) or gray (serpentinite) subsoil
consistence - friable surface over slightly sticky (peridotite) to very sticky (serpentinite)
soil pH - initially high (neutral or alkaline), declining with age in drained soils of humid climates

Classes of Soils
serpentine soils are in 9 orders, all except Histisols, Andisols, and Spodosols
Inceptisols, Mollisols, and Alfisols are most common orders in California
Vertisols - more common in serpentinite materials
Oxisols - more common in peridotite materials

Plant Community Characteristics
commonly open, plant density less than on adjacent nonserpentine soils
xerophytic aspect
many endemic species
Ni accumulator (Ni > 0.1%) species, many in mustard family, especially *Alyssum* spp.
Thlaspi montanum (3 varieties) and *Streptanthus polygaloides* in California

Fertility (Plant) Problems
low Ca/Mg ratio (Ca/Mg < 0.7)
probable Ni toxicity
possible Cr and Co toxicities
low K, P, and Mo

Health Concerns

asbestos in air and water

serpentine abestos (chrysotile) is much less toxic than amphibole asbestos

high Fe (and Mn) fix P in soils and reduce plant Cu and Zn availability to animals

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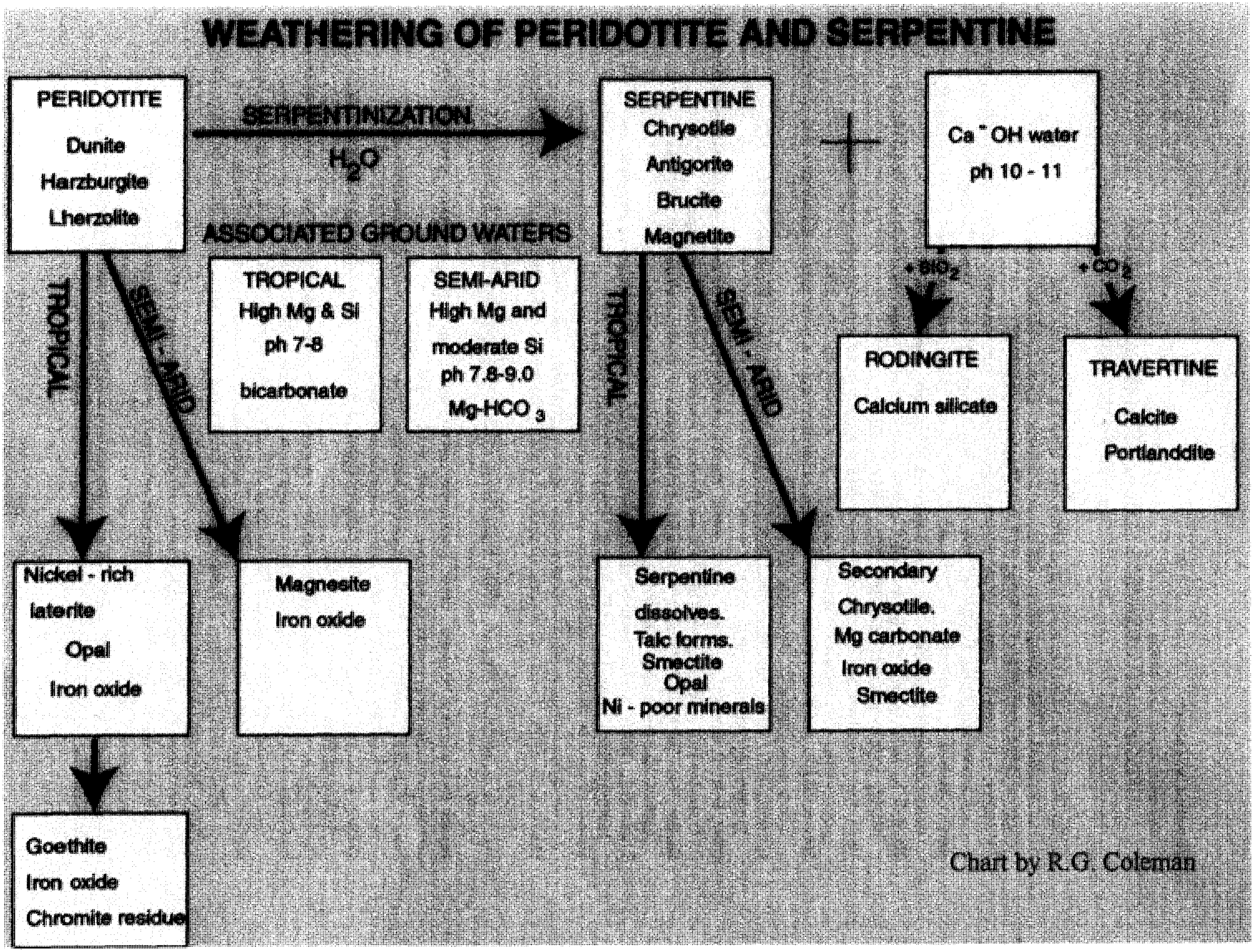

WEATHERING OF PERIDOTITE AND SERPENTINE
PERIDOTITE
Dunite
Harzburgite
Lherzolite
SERPENTINIZATION
H_2O
SERPENTINE
Chrysotile
Antigorite
Brucite
Magnetite
Ca ⁺ OH water
ph 10 - 11
ASSOCIATED GROUND WATERS
TROPICAL
High Mg & Si
ph 7-8
bicarbonate
SEMI-ARID
High Mg and
moderate Si
ph 7.8-9.0
$Mg\text{-}HCO_3$
TROPICAL
SEMI - ARID
TROPICAL
SEMI - ARID
$+SiO_2$
$+CO_2$
RODINGITE
Calcium silicate
TRAVERTINE
Calcite
Portlanddite
Nickel - rich
laterite
Opal
Iron oxide
Magnesite
Iron oxide
Serpentine
dissolves.
Talc forms.
Smectite
Opal
Ni - poor minerals
Secondary
Chrysotile.
Mg carbonate
Iron oxide
Smectite
Goethite
Iron oxide
Chromite residue
Chart by R.G. Coleman

Summary of Serpentinite Soils and Environmental Management at Hunters Point Shipyard, San Francisco, California

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Soils are the dynamic products of the interaction of parent material, climate, water and air, microorganisms, and organic matter over time, as well as land uses and environmental releases. Hunters Point Shipyard (HPS) in San Francisco contains areas to explore the features of soils altered by mechanical and hydraulic filling and the environmental releases associated with U.S. Navy activities. At HPS, the Navy collected and analyzed approximately 9,100 soil samples from 2,100 soil borings, 2,400 groundwater samples from 445 monitoring wells, 235 grab water samples, and 560 sediment samples, under the Navy's Comprehensive Long-Term Environmental Action Navy (CLEAN).

Tetra Tech EM Inc. is conducting soil and groundwater investigations at HPS for the Department of the Navy, Naval Facilities Engineering Command, Engineering Field Activity West, as required by the U.S. Environmental Protection Agency (EPA) and the California Environmental Protection Agency (Cal/EPA). These studies were undertaken under the Navy's CLEAN program to fulfill the requirements of the Navy's Installation Restoration Program. They evaluate the nature and extent of contamination, its potential human health and ecological risk, and the feasibility for remedial actions, if needed, in preparation for transfer of these properties to the City of San Francisco for civilian reuse.

Altered soils features that adversely affect the environment at HPS are:

(1) The Franciscan bedrock source material of primarily serpentinite for fill contains naturally occurring arsenic, beryllium, chromium, and nickel, at concentrations that exceed EPA Preliminary Remediation Goals (PRG).

(2) The source material for fill contributes naturally occurring copper, lead, mercury, nickel, and silver to shallow groundwater at concentrations that are elevated relative to EPA National Ambient Water Quality Criteria (NAWQC) for saltwater life.

(3) The non-engineered, non-compacted and extremely heterogeneous and disordered fill material has permitted leaky storm drains and sanitary sewer lines to sink below the shallow groundwater table and serve as groundwater sinks, inducing baywater flow inward and into the shallow aquifer, and acting as groundwater sink to inadvertently remove onsite groundwater to San Francisco Bay through leaky storm drains or to San Francisco's Southeast Water Pollution Control Plant through leaky sewer lines.

(4) The fill is not currently subject to significant liquefaction, land subsidence, or differential settlement, but may have some lateral spreading potential as shoreline bulkheads degrade.

In addition, land use and releases from Navy and related industrial activities have contributed metals, volatile and semivolatile organic compounds, pesticides and polychlorinated biphenyls (PCB), and petroleum hydrocarbons to soil and groundwater.

This field trip will visit, weather, time, and access permitting, (1) the scenic overview of the facility from the Officers Club (Building 901) and nearby soil erosion and rock slide area in Parcel A, (2) Franciscan Bedrock outcrop, associated bedrock springs, and Pump Station "A" (Building 819) near the Supply Storehouse and Offices (Building 813) in Parcel A, (3) various road cuts and soil types, and (4) soil excavation pits.

Background

HPS is geographically within the southeast corner of City and County of San Francisco. Figure 1 shows the HPS location. Figure 2 shows the HPS environmental cleanup sites. Figure 3 shows the HPS soil distribution map. Figure 4 shows a conceptual A-aquifer groundwater flow model and HPS parcel boundaries.

A de-activated Navy base, HPS consists of 936 acres, with 493 acres of land in the City and 443 acres submerged in San Francisco Bay. The facility contains docks, machine shops, warehouses, and offices with a Navy caretaker staff and 200 small businesses which employ about 1,000 workers. About 40 percent of the buildings at HPS are currently used for general industrial activities, ship decommissioning, and movie set and artists studios.

HPS is divided in to Parcels A through E, and offshore Parcel F, to expedite remedial action and land reuse. Parcel A is an upland that covers about 90 acres, consists of a central area and a connected western area, includes about 63 residences, detached garages, apartments, administrative offices, warehouses, barracks, and other buildings and infrastructure including the hydrologically significant sanitary sewer Pump Station "A" which discharges to the City's Southeast Water Pollution Control Plant. Northeast of Parcel A, Parcel B is a lowland that covers about 63 acres of the northeast lowland and shoreline, and has been used almost exclusively for industrial purposes since the 1940s. South of Parcel B and east of Parcel A, Parcel C is a lowland that covers about 80 acres of the east central lowland and shoreline, contains drydocks and berths, and has been used almost exclusively for industrial purposes since the mid-1800s. Southwest of Parcel C and south of Parcel A, Parcel D is a lowland that covers about 109 acres of the southcentral lowland and shoreline, and was used almost exclusively for industrial purposes since the land was created by in-filling the Bay in the 1940s. South and west of Parcel D, Parcel E is a lowland that covers about 135 acres of the southern and western lowland and shoreline, and has been only partially developed since the land was created by in-filling the Bay during the 1950s through 1970s; Parcel E includes a former industrial landfill area (IR-1/21) and an extensive undeveloped waterfront. Offshore Parcel F was established to address offshore sediment issues.

Hunters Point Shipyard History

In 1987, PCBs, tricholorethene (TCE) and other solvents, pesticides, petroleum hydrocarbons and metals (including lead) were confirmed in fill soils at a number of HPS locations. An HPS Technical Review Committee was formed in 1988 and converted to a Restoration Advisory

Board in 1993 to include community group representatives and local residents as well as local, state, and federal agency representatives. HPS became a federal Superfund site in 1989 under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) because of site contaminants and its proximity to an offsite drinking water source at Albion Springs, which uses artificial tunnels constructed in Bedrock as one of the sources for its water bottling company. The Navy transferred about 39 acres of HPS to the University of California at San Francisco, the City, and a private party as formerly utilized defense sites for civilian use in the late 1970s and early 1980s; the U.S. Army has responsibility for environmental management on these properties.

The Navy started waste site cleanups at HPS in 1984. HPS became a federal Base Realignment and Closure Commission site in July 1991, which slated the shipyard for closure. In January 1992, the Navy, EPA, and Cal/EPA entered into a Federal Facility Site Remediation Agreement to better coordinate environmental investigations and cleanups at HPS. A no-action Record of Decision (ROD) was signed for Parcel A in November 1995 as little contamination was detected on Parcel A, the former military housing portion of the base.

A draft HPS Reuse Plan developed by the San Francisco Mayor's HPS Citizens Advisory Committee was approved by Redevelopment and Planning Commissions and Board of Supervisors in 1995. An HPS Redevelopment Plan was adopted in July 1997. A ROD for Parcel B was signed in October 1997; the selected remedy includes excavation of contaminated soils to 10 feet below ground surface for an unrestricted cleanup level. Excavated soils will be hauled off and disposed offsite. Groundwater will be monitored and a restriction placed on the Parcel B deed prohibiting groundwater uses. Accelerated soil removals at Parcel B began in July 1998.

A Joint Navy and City revised draft Environmental Impact Report/Environmental Impact Study at HPS was released in October 1998. All Parcels are scheduled to reach final remedy decisions by the end of 2000 and upon cleanup be transferred to the City. The estimated facility cleanup costs, as estimated by the Navy, vary from about $300 to $437 million. The Navy awarded $200 million to IT Technology Corporation for environmental remediation action to provide for soil excavation, disposal, and backfill, removal of steam and fuel pipelines, storm drain system rehabilitation, and post construction groundwater monitoring at HPS, to be completed in March 2000. According to the California Governor's Office of Planning and Research, "the Defense Environmental Response Program Report for Fiscal Year [FY] 1996 shows that [HPS] cleanup should be completed by the year 2011 for a total cost of $614 million. As of FY 1996, about $115 million has been spent, 19 percent of the total required. In 1994, the Navy estimated clean-up costs [at HPS] to be $356 million with $79 million having been spent through FY 94. At that time, cleanup completion date was estimated to be August 2001."

The Navy is re-evaluating its remediation strategy at HPS. Previously, the remediation strategy was to accommodate agency and community desires, which exceeded the legal requirements under CERCLA and the reuse requirements under the City's approved reuse plan. A recent Center for Naval Affairs audit of naval facilities established that HPS was slated to be the most expensive of naval facility cleanups nationwide because of its accommodation of these externalities. It may be possible to remediate HPS for somewhat less than $200 million if only legal requirements and approved reuse plans are addressed.

Substantial public improvements will be needed to promote and accommodate redevelopment of HPS. Most of the needed work is related to the utility improvements, and demolition of existing buildings. According to the Cal/OPR, the "total [capital] infrastructure costs [to rehabilitate HPS for civilian use] are estimated to be $142.8 million. Public roads are $20.4 million, private roads $31.6 million, $49.7 [million for] sanitary sewers, water $4.1 million, and $37 million for fire department services and park costs." In addition, "design work for a $100 million infrastructure backbone for wet and dry utilities began in January 1997 [and] construction will begin whenever a major tenant locates at [HPS]." Moreover, according to Cal/ORP, "in 1990, PG&E [Pacific Gas and Electric Company] acquired the gas and electric system at [HPS]. PG&E upgraded the system to California Public Utilities System code, and the Navy guaranteed a specific revenue stream ($129,000) for ten years to support PG&E's investment. The gas system was abandoned." However, rough estimates range from less than $50 million for upgrading utility lines where needed to $250 million for replacing the entire utility system.

Climate at Hunters Point Shipyard

San Francisco has a maritime climate with cool moist winters and cool, foggy summers. Summer temperatures are influenced by low fog in the mornings and a steady flow of marine air from the Pacific Ocean in the afternoon. Because of the marine air flow, extremely hot or cold temperatures are rare. As the marine influence diminishes southward along San Francisco Bay and east of the Coast Range, summers become slighter warmer and winters slightly cooler. San Francisco has an annual frost-free period of 300 to 330 days. The mean annual evaporation is 48 inches, with the greatest evaporation in July.

The HPS climate is characterized by partly cloudy, cool summers with little precipitation and mostly clear, mild winters with rainstorms. Meteorological data from the San Francisco International Airport (SFIA), located about 10 miles south of HPS, indicate that the prevailing wind direction is from the west-northwest. Average daily air temperature in San Francisco ranges from about 51 degrees Fahrenheit (F) in January to 63 degrees F in September, and the average relative humidity averages between 65 to 75 percent in the afternoon. Average annual precipitation at HPS is about 20 inches, with an average monthly rainfall of less than a third of an inch in each month of May through September to over an inch to 4 inches or more in each month from October through April. Historic annual rainfall extremes in San Francisco are a low of 7.42 inches in the 1850 to1851 rainy season and a high of 49.27 inches in the 1861 to 1862 rainy season at San Francisco's Mission Delores, while the 1997 to1998 El Niño season produced 47.22 inches of rain. Average and maximum wind speeds at HPS are about 10 and 20 miles per hour (mph), respectively.

Geomorphology and Topography at Hunters Point Shipyard

HPS is located in California's Coast Range geomorphic province. HPS consists of a small inland, hilly rock upland 70-acre area made up of a bedrock outcrop, up to about 180 feet above mean sea level (MSL), with a larger, adjacent, coastal lowland 423-acre area made up of non-engineered, mechanical deposited, artificial fill material from 0 to 25 feet above MSL. Taken together, the bedrock outcrop and its adjacent, bayward lowlands for an artificial peninsula jetting into the Bay. The steep upland area of HPS is subject to erosion. Cliffward of the HPS Commanding Officer's house at HPS Parcel A, the Navy several decades ago installed a temporary iron sheetpile to help stop or delay an historic slide.

Regional Geology

San Francisco Bay is a tectonically active region along the contact of the North American and Pacific crustal plates. This seismic region is controlled by northwest-southeast trending faults exhibiting primarily right lateral strike-slip movement. The major active faults in the vicinity of HPS are part of the San Andreas fault system. These faults include the Hayward fault (3 miles to the east), the San Andreas fault (9 miles to the west), the San Gregorio-Seal Grove fault (25 miles to the west), and the Calavaras fault (50 miles to the southeast). Basement rocks in the San Francisco Bay area are primarily fractured and sheared rocks of the Late Jurassic to Early Cretaceous Age Franciscan Assemblage. San Francisco Bay is a drowned river valley developed within a southeast-northwest trending structural trough in the Franciscan Assemblage bedrock. Material eroded from the Berkeley/Oakland hills forms the broad, gently sloping coastal plain that borders the eastern shoreline of the Bay.

Extensive areas of fill material are found along the coastal plain that borders the eastern shoreline of the Bay and along the San Francisco Bay western waterfront in San Francisco County. This fill material consists of variable amounts of non-engineered and non-compacted soil, gravel, broken concrete and asphalt, rock, bay muds, alluvial and estuarine sediments, and other solid material. Soil characteristics are highly variable because of the different kinds and amounts of fill material in the profile. Approximately 12.5 percent of San Francisco is composed of artificial fill, not including the fill associated with the SFIA located south of the City in San Mateo County. These fill soils have historically been subject to liquefaction, land surface subsidence, and differential settling. Because of fill history and land use, the City's Maher Ordinance requires that excavated soils of at least 50 cubic yards from areas bayward of the high-tide as indicated on the Historic San Francisco Maps (that is, artificial fill material) be handled as hazardous wastes unless appropriate waste testing is performed on the soils and proves them to be nonhazardous.

Geology of Hunters Point Shipyard

From youngest (shallowest) to oldest (deepest), subsurface materials at HPS are divided into these six geologic units: (1) Artificial Fill of Holocene age, which serves as the A-aquifer; (2) Slope Debris and Ravine Fill of Holocene age; (3) Undifferentiated Upper Sand Deposits of Holocene age, which contributes to the A-aquifer; (4) Bay Mud of Holocene age, which serves as an aquitard; (5) Undifferentiated Sedimentary Deposits of Holocene and Pleistocene age, which serves as the B-aquifer; and (6) Franciscan Bedrock which provides a Bedrock water-bearing zone in fractures and weathered zones. Deposits overlying the Franciscan are of Quaternary age, while the Franciscan Assemblage is of Jurassic to Cretaceous age.

The Artificial Fill at HPS is about 0.5 feet thick near the Parcel A upland to more than 60 feet thick near the shoreline at Parcel B (in IR-24 and IR-60 near Buildings 125, 128, and 159), at Parcel D (in IR-32 at the Regunning Pier, and in IR-39), and in Parcel E (in IR-3 just south of IR-39 near "K" Street, and in IR-12 off "J" Street). The Artificial Fill is composed of extremely heterogeneous non-engineered, non-compacted and generally mechanically deposited: 1) bedrock-derived fill from the Parcel A upland areas; 2) industrial fill consisting of domestic and industrial wastes, including sandblast materials and construction debris; 3) natural fill as dredged materials from the Bay, 4) more recently imported sand and gravel material placed as a cover over Parcel E Site IR-1/21 (36-acre industrial landfill), used for landscaping near Parcel B Dago Mary's Restaurant, and (5) lesser amounts of sand emplaced along utility lines as bedding material with natural low-level radioactivity from Monterey's Colma Formation or Sierra imported fill. The Franciscan Bedrock is a melange of shale matrix with about 80 percent serpentinite, and lesser amounts of sandstone, chert, and shale. Table 1 shows the types, description, estimated volumes and percents of fill material used to construct HPS.

Serpentine/Serpentinite at Hunters Point Shipyard

At HPS, the role of serpentine and serpentinite is very important in understanding soil inorganic chemistry because serpentinite is the major source material for the Artificial Fill and its associated A-aquifer. Serpentine is a mineral group with the general formula $(Mg, Fe)_3Si_2O_5(OH)_4$. It is characterized by fibrous crystals; the group includes the minerals antigorite and the asbestos chrysolite. Serpentinite is a metamorphic rock formed by low-temperature alteration of ultramafic oceanic rocks, commonly associated with the Coast Ranges. It is a rock consisting almost wholly of serpentine minerals derived from the alteration of previously existing olivine and pyroxene. Serpentinite is greasy-feeling, easily deformed, magnetic, green rock. It is the state rock of California. Unlike rocks of the earth's crust, serpentinite contains almost no aluminum. Lacking aluminum, its weathered sediments are unable to form clay, an essential ingredient of fertile soils. The weathering serpentinite does not form insoluble residues that accumulate and transform into fertile soils, but slowly dissolve and run off in both surface and subsurface waters. Rather, serpentinite soils tend to be bare of vegetation and thin between rocky outcrops. To challenge plants trying to live in these soils, serpentinite is almost devoid of potassium, sodium, calcium, and phosphorus - important fertilizers - and is unusually rich in magnesium, chromium, cobalt and other heavy metals which are toxic to most plants. Table 2 shows metals results for bedrock samples at HPS.

Altered Soils of Hunters Point Shipyard

Figure 3 shows the HPS soil distribution map, based on the U.S. Department of Agriculture Soil Conservation Service map. HPS upland soils in Parcel A are classified primarily as "Orthents, cut and fill-Urban land complex" and "Urban land." HPS soils in Parcels B through E are primarily bottom land soils as "Urban land-Orthents, reclaimed complex". The average landsurface slopes at Parcels B, C, D, and E are about 7, 4, 2, and 3, respectively. About 45 percent of the land surface at Parcel A, 80 percent at Parcel B, 90 percent at Parcels C and D, and 40 percent at Parcel E are covered by asphalt, concrete and buildings, or a 72-percent area-weighted average cover on the lowlands of Parcels B through E. The subsurface soils at HPS are extremely heterogeneous and disordered mechanical fill deposits that consist of sandy clays to gravels with poorly graded sands, boulders, and debris deposits. Based on 50 soil samples, the total organic carbon of artificial fill samples ranges from 170 to 80,500 mg/kg, with a median value of 2,565 mg/kg (0.26 percent). A sandblast material sample had a TOC of 0.06 mg/kg.

Ambient Levels of Metals in Soils at Hunters Point Shipyard

Concentrations of metals that are present in soil altered by human activities, as in the case of land made of artificial fill, are referred to as "ambient." Ambient metal concentrations were established for HPS soils to have a basis to assess whether the detection of a chemical constituent indicates site-related contamination or may be attributed to naturally occurring or anthropogenic (human-made) sources. Ambient levels are important because they provide: (1) end points for site characterization, (2) the basis for a background risk assessment and potential points of departure for a risk assessment, and (3) lower threshold to site remediation which may include physical cleanup, treatment, removal, and institutional controls such as deed restrictions and long-term monitoring. The "lower threshold" would be the lowest concentration to drive a remedial action because it would be impractical to remediate below an ambient or natural concentration. Table 3 shows the calculated ambient levels of metals in HPS soils in addition to median and mean metals concentrations in these soils.

Data from over 1,000 HPS soil samples were used to estimate the ambient concentration of 17 metals in soil altered by human activities. Fourteen ambient levels are estimated using the distribution-dependent formulae to find the 95th upper confidence level (UCL) on the 95th percentile (UCL $_{95,95}$) of the soil metals data to establish the Hunters Point Ambient Level (HPAL) for antimony, arsenic, barium, beryllium, cadmium, copper, lead, mercury, molybdenum, selenium, silver, thallium, vanadium, and zinc, as suggested by Cal/EPA with EPA concurrence. Of these serpentinite-derived fill HPALs, arsenic at 11.34 milligrams per kilogram (mg/kg) exceeds the EPA PRG of 0.38 mg/kg and beryllium at 0.75 mg/kg exceeds the PRG of 0.14 mg/kg. Over 200 serpentinite soil samples were used to establish HPALs for serpentinite bedrock; of these, arsenic at 8.16 mg/kg and beryllium at 0.61 mg/kg exceed PRGs. Combining all soil types, including serpentinite fill, serpentinite bedrock, upper undifferentiated sand, Bay Mud, and undifferentiated fill, arsenic at 5.73 mg/kg and beryllium at 0.71 mg/kg exceed PRGs.

Because of the strong correlation between chromium, cobalt, and nickel with magnesium in serpentinite and serpentinite derived fill, three sample-specific regression equations were developed to establish sample-specific HPALs for these three trace metals, with agency concurrence. The average HPAL for chromium, cobalt, and nickel was estimated at 557 mg/kg (PRG of 211 mg/kg) for chromium, 65.3 mg/kg (there is no PRG) for cobalt, and 1,180 mg/kg (PRG of 150) for nickel, based on an average magnesium concentration of 56,600 mg/kg in all HPS soils. The Parcel B ROD used an average HPAL for nickel of 314 mg/kg based on Parcel B soil samples. Where nickel concentrations exceed this HPAL, a new HPAL based on sample-specific regression for nickel as a function of cobalt may be used because this regression is more robust than the magnesium regression as cobalt is less likely than magnesium to leach from weathered serpentinite. A potential HPAL for nickel, based on regression against cobalt, would be about 3,000 mg/kg.

Recently, there has been agency interest over ambient levels of synthetic organic constituents in soils at HPS, such as polycyclic aromatic hydrocarbons (PAH), which typically are related to automobile emissions and petroleum hydrocarbons. In addition, the regulatory agencies have expressed interest in sampling soil and groundwater (1) for analysis of the oxygenate gasoline additive methyl tertiary-butyl ether (MTBE) in the vicinity of USTs, and (2) for analysis of organotins in selected areas of Parcel D.

Additional Anthropogenic Soil Issues of Interest at Hunters Point Shipyard

Because HPS fill material is extremely heterogeneous and disordered as the material varies arbitrarily from clays to boulders with variability in hydraulic conductivity of at least seven orders of magnitude, it is impractical to map and numerically model or quantitatively predict groundwater and contaminant flow, and contaminant attenuation in the A-aquifer. In addition, the hydraulic effects of leaky recharging and discharging storm drains and sewer lines, recharging water pressure lines, pulsating effect of tides, and shoreline materials (including sea walls, concrete walls, and sheetpiles), make it difficult to develop a satisfactory quantitative water budget at HPS. Because the non-engineered and non-compacted artificial fill leads to ground instability, ground settlement, and liquefaction (lateral spreading, flow failure, ground oscillation, loss of bearing strength), especially during earthquake tremors, HPS buildings require pilings, vibroflotation and compaction, and/or thick pads and extensive retrofitting and structural corrective actions, while steep cut slopes require stabilization or sheetpiling.

Fill History at Hunters Point Shipyard

There is a long history of filling at HPS. Some filling of the Bay occurred offshore at HPS prior to 1935 between Drydocks No. 3 and 4 in Parcels B and C. There was extensive filling with non-engineered fill which increased the land area from less than 100 acres prior to 1935 to more than 500 acres from 1935 to1975. Aerial photos show that the most extensive cut-and-fill period occurred during 1935 to1948. Filling was completed in 1975. Rock material from the HPS upland ridge was used for filling in the lowlands and constructing building pads, except in the area of Parcel E Site IR-1/21 (36-acre industrial landfill) which was filled with rock materials mixed with industrial and municipal debris and refuse. The general method of filling the Bay in Parcels C, D, and E at HPS was initially to infill with dredged material to above sea level to make a sand base, then to mechanically place bedrock-derived fill as competent material on the dredged sand base. The denser bedrock-derived fill would then sink into the dredged sand base. About 85 percent of HPS or 423 acres are composed of fill materials, requiring about 27 million cubic yards, based on an average estimated fill thickness of 15 feet in Parcel A, 40 feet in Parcel B, 25 feet in Parcel C, 40 feet in Parcel D, and 35 feet in Parcel E. See Table 1.

Environmental Threats and Contaminants at Hunters Point Shipyard

HPS groundwater, sediments, and soil are contaminated with fuels, pesticides, heavy metals, PCBs, and volatile organic compounds (VOCs). Soil also contains asbestos, some of which is naturally occurring. A small landfill (less than 0.25 acres) located in Parcel E also contains buried radium dials (at IR-2NW). Long-term ingesting or direct contact with contaminated soils, sediments, or groundwater may produce a human health risk. Potential threats may also be presented by off-gas from VOCs, particularly vinyl chloride (which has not been confirmed by soil gas sampling), which is potentially present in hot spots in buried soil and groundwater in Parcels B, C and D/E. Although a literature-based ecological risk assessment was inconclusive, an ongoing ecological risk assessment validation study at HPS is expected to evaluate site-specific ecological risks and potential cleanup levels for open areas in Parcel E.

HPS Soil Contaminant Sources

HPS soil contaminant sources are: (1) PCBs from old electrical transformers, (2) petroleum products, included areas of floating product, from fuels and fuel lines, (3) metals-containing grit from sandblasting, (4) asbestos from insulation, (5) lead in lead-based paints from painted buildings, (6) pesticides from landscaping, (7) solvents from parts cleaning and machining, (8) metals, including chromium, from plating and machining processes, (9) buried radium instrument dials from ship demolition in a small area in Parcel E, and (10) sediment in storm drains and offshore containing metals, VOCs, SVOCs, TPH, PCBs and pesticides. In addition, naturally occurring high levels of metals and asbestos minerals are present in bedrock, and bedrock-derived soils.

HPS Response Action Status

The Navy completed several immediate response actions at HPS. These include removal of abandoned hazardous materials and industrial wastes, including lead-based paints, flammables, corrosives, poisons, and waste oil from PCB-contaminated transformers in 1988 and 1989. During these actions, the Navy removed about 1,500 drums of these materials. The Navy collected, tested, labeled and disposed of PCB-bearing transformers, drums and contaminated soil. In 1990, the Navy removed about 226,000 square feet of ACM from 24 areas. The Navy completely removed PCB-bearing transformers in 1993. The Navy completely removed the equipment from the Parcel D pickling and plate yard and the aboveground storage tanks (AST) and associated soil at the Parcel B tank farm. The Navy completed a treatment program for the 35,000 cubic yards of spent sandblast grit and reused the material for asphalt in 1995. By 1998, the Navy completed removal actions for the Parcel E oil reclamation pond, a portion of the Parcel E industrial landfill, facility-wide storm drain sediments, a portion of drainage tunnel sediments in the Parcel C Drydock No. 4, the Parcel D pickling and plate yard, the Parcel B tank farm, and various discrete contaminated areas.

Currently Contaminated Sites at Hunters Point Shipyard

The remaining soil contaminated areas at HPS are: fuel lines, industrial waste landfill in Parcel E (IR-1/21), oil ponds in Parcel E (IR-3), buried radium dials in Parcel E (IR-2NW), and CERCLA-substances and petroleum hydrocarbons in soils; floating hydrocarbon product on shallow groundwater in Parcels B and E; sediments in buried utility lines containing asbestos, metals, VOCs, SVOCs, PCBs, pesticides, and petroleum hydrocarbons; and about 120,000 to 330,000 cubic yards of offshore sediments containing metals, SVOCs, PCBs, pesticides, tibutylin (TBT), and petroleum hydrocarbons.

Environmental Cleanups at Hunters Point Shipyard

Numerous environmental cleanups have been completed at HPS at the 78 cleanup sites and 35 UST sites. These include: drum removals; PCB-contaminated soil excavation and disposal at IR-8; sandblast grit removal to asphalt recycler; ASTs, 51 USTs and PCB transformers removals along with 160 tons of associated soils, plus Tank S-505 in Parcel E were removed (some USTs were closed in place); Parcel B Tank Farm removal; Parcel A storm drain system sediment cleanup; pesticide-affected soil removal in the Parcel A at a former residential area with disposal to a Class II landfill; removal of chromium- and nickel- affected materials and soils, equipment, sunken baths, aboveground structures and foundations in the Parcel D Pickling and Plate Yard removed in 1996; soil excavation removal action which included treatment of 15,000 cubic yards of contaminated soil and offsite disposal in 1997; and removal of 1,200 cubic yards of contaminated sediments from about 90,000 linear feet of onsite storm drains, 200 cubic yards of contaminated sediments from 850 linear feet of tunnels associated with Drydock 4 (the largest drydock at HPS and only one currently in use), and 2,678 cubic yards of contaminated soil as part of the exploratory excavation removal action in 1997. About 900 linear feet of sheetpile were installed in 1997 as part of two containment remedies to prohibit groundwater contaminated with solvents, metals, oils, pesticides and PCBs from migrating into San Francisco Bay from Parcel E. About 62,400 cubic yards of contaminated soils, steam lines, ACM, and fuel lines were removed in July through December 1998 from Parcel B.

HPS Historical Land Use

Historically, Parcel A at HPS was a non-industrial area for Navy personnel residential facilities. Parcel B contained a restaurant and submarine docks and a drydock. Parcel C contained the large Drydock No. 4. Parcel D was an industrial area that included the pickling and plate yard for ship assembly. Parcels B through D at HPS were used for industrial production along the waterfront with shop facilities for structural machinery, electrical and service groups. These parcels also provided industrial support areas for supply and public works facilities (Parcels B through D). Parcel E was used for recreational areas and to contain the industrial waste landfill, waste oil ponds, and small buried radium dials landfill area.

HPS Future Land Use

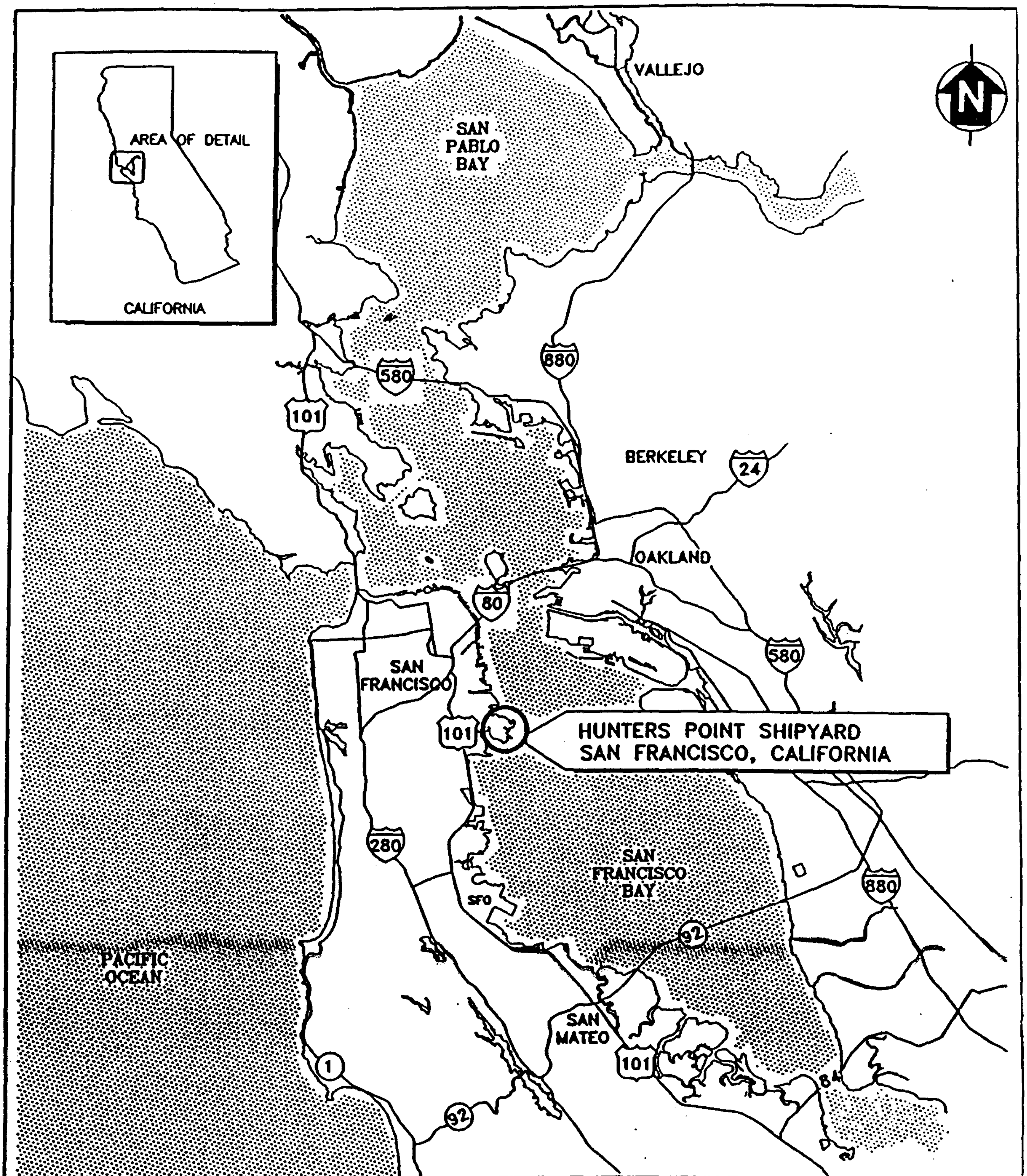
The HPS reuse plan envisions future mixed use at HPS as a new industrial and business park, space for cultural uses as museums and galleries, active recreation areas, and a significant shoreline park accessible to the public - at full build-out to supply 8,300 jobs.

To accommodate infilling of the Bay for the current SFIA expansion, there are plans to create a 15-acre tidal wetland at HPS' Parcel E through a construction funding agreement with the San Francisco Airport Commission for $3.125 million and a 5-acre seasonal freshwater wetland at Parcel B. Wetland construction may be costly if wetlands are constructed in areas containing hazardous wastes which may need to be removed and disposed of to a suitable facility. Construction costs in non-hazardous areas may be as low as $100,000 per acre, as high as $3.3 million to $6.8 million per acre for a tidal wetland in a hazardous waste area, or as high as $91,450 to $180,800 per acre for a seasonal wetland.

Figures

Tables

This summary was prepared on May 5, 1999 for the American Association for the Advancement of Science Pacific Division 80th Annual Meeting, San Francisco State University, San Francisco, California, June 19-23,1999 and WSSS "Serpentine Soils of the San Francisco Bay Area Field Trip" for June 23, 1999. Information in this summary was derived from publicly available documents which were produced through the CLEAN contract and from other sources.



DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

ENGINEERING FIELD ACTIVITY WEST

SAN BRUNO, CALIFORNIA

HUNTERS POINT SHIPYARD — SAN FRANCISCO, CALIFORNIA

FIGURE 1
HUNTERS POINT SHIPYARD
FACILITY LOCATION MAP

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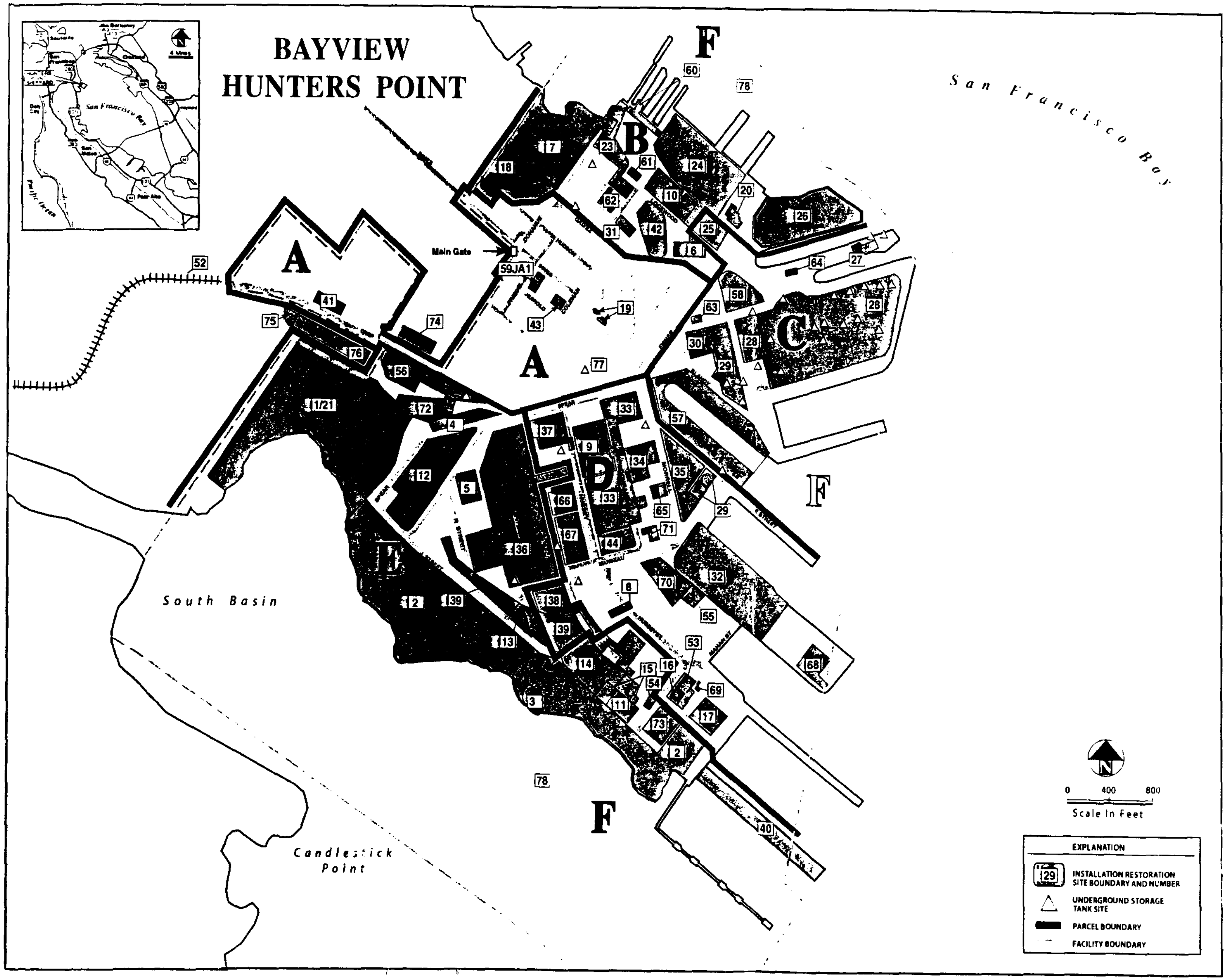


IR SITE No.	REMEDIATION AREA
1	Industrial Landfill (See IR Site 21 also)
2	Bay Fill
3	Oil Reclamation Ponds
4	Scrap Yard
5	Old Transformer Storage Yard
6	Tank Farm
7	Sub-Base Area
8	PCB Spill Area at Former Building 503
9	Pickling and Plate Yard
10	Battery and Electroplating Shop (Building 123)
11	Power Plant Area (Building 521)
12	Disposal Trench Area
13	Old Commissary Area
14	Oily Liquid Waste Disposal Area
15	Oily Waste Ponds and Incineration Tank
16	Container Storage Site
17	Drum Storage and Disposal Site
18	Waste Oil Disposal Area
19	Officers Club (Building 901)
20	Rubber Shop (Building 156)
21	Area Southwest of Building 801 (See IR-1 Site also)
22	Shop Service Buildings 368 and 369
23	Buildings 145, 146, 161, and 162
24	Buildings 124, 125, 128, and 130
25	Machine Shop (Building 134)
26	Nondestructive Testing Lab (Building 157 and Area North of Dry Dock 3)
27	Pump and Compressor Plant (Building 205)
28	Buildings 211/253, 219, 229, 230, 231, 258, 270, 271, 273, and 281
29	Buildings 203, 217, 275, 279, 280, and 282
30	Forge Shop (Building 241)
31	Building 114
32	Regunning Pier and Building 383
33	Buildings 116, 125, 302, 302A, 304, 364, 411, 417, and 418, 424
34	Buildings 351 and 366
35	Buildings 274, 306, 313, 313A, 322, 372 and the area bounded by Manseau, Morrell and E Streets
36	Buildings 371, 400, 404A, 405, 406, 413, 414, 704, 710
37	Buildings 401, 423, 435, 436, and 437
38	Building 500
39	Building 505
40	Building 527 and Pier 2
41	Buildings 816 and 818
42	Buildings 109, 113, and 113A
43	Gardening Tool House (Building 906)
44	Area Near Buildings 408, 409, 410, and 438
45-51	See Listing for Facility Wide Utility Sites
52	Railroad Right-of-Way (Off site west of facility)
53	Building 525 and 530
54	Building 511A
55	Building 307 and Surrounding Area
56	Railroad Yard and Track Southwest of Crisp Avenue
57	Dry Dock 4 Area
58	Scrap Yard North of Building 258
59	Parcel A Groundwater Investigation (Not shown on map)
59JA1	Parcel A Jerrold Avenue Investigation
60	Dry Docks 5, 6, and 7
61	Substation V (Building 122)
62	Submarine Training (Buildings 115 and 116)
63	Former Building 278
64	Substation A (Building 206)
65	Carbon Dioxide Refilling Station (Building 324)
66	Office and Storehouse (Building 407)
67	Sheet Metal Shop (Building 439)
68	Area North of Building 378
69	Buildings 523 and Associated Metal Shed
70	Area Northeast of Building S-308
71	Crane Yard
72	Building 810 Area
73	Asphalt Batch Plant
74	Building 815 (formerly used defense site)
75	Building 820 (formerly used defense site)
76	Area Surrounding Buildings 830 and 831 (formerly used defense site)
77	UST Site S-812 at Building 813
78	Parcel F Subtidal Area

FACILITY WIDE UTILITY SITES NOT SHOWN

45	Steam Lines
46	Fuel Distribution Lines (Tank Farm)
47	Fuel Distribution Lines (Tank S-505)
48	Suspected Steamlines (Building 503)
49	Fuel Distribution Lines (Buildings 203 and 205)
50	Storm Drains and Sanitary Sewers
51	Former Transformer Locations

DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

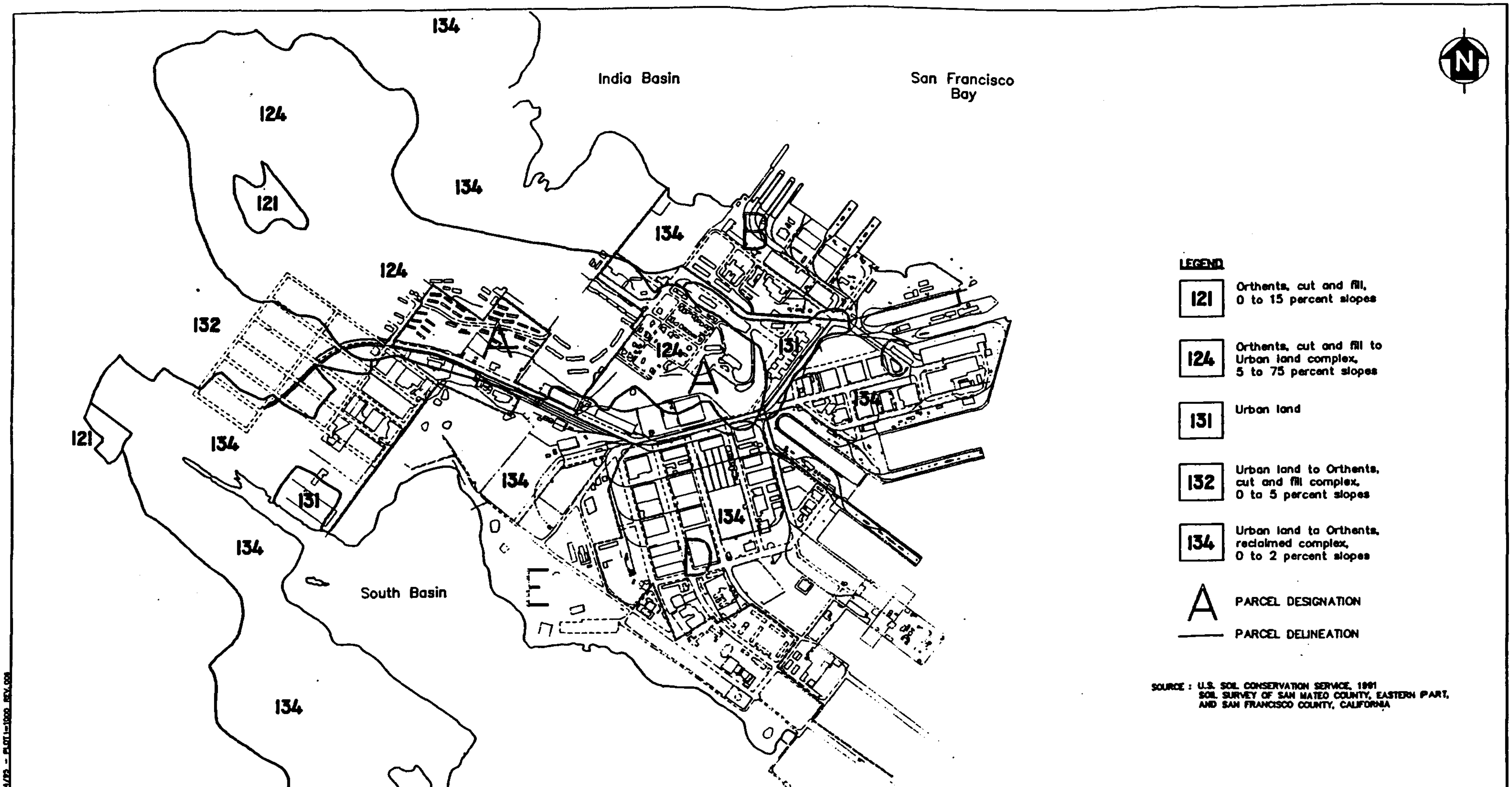
ENGINEERING FIELD ACTIVITY WEST

SAN BRUNO, CALIFORNIA

HUNTERS POINT SHIPYARD — SAN FRANCISCO, CALIFORNIA

ENVIRONMENTAL CLEAN-UP SITES
HUNTERS POINT SHIPYARD

FIGURE 2.



DEPARTMENT OF THE NAVY — NAVAL FACILITIES ENGINEERING COMMAND

ENGINEERING FIELD ACTIVITY WEST

SAN BRUNO, CALIFORNIA

HUNTERS POINT SHIPYARD — SAN FRANCISCO, CALIFORNIA

Figure 3

HPS Soil Distribution Map

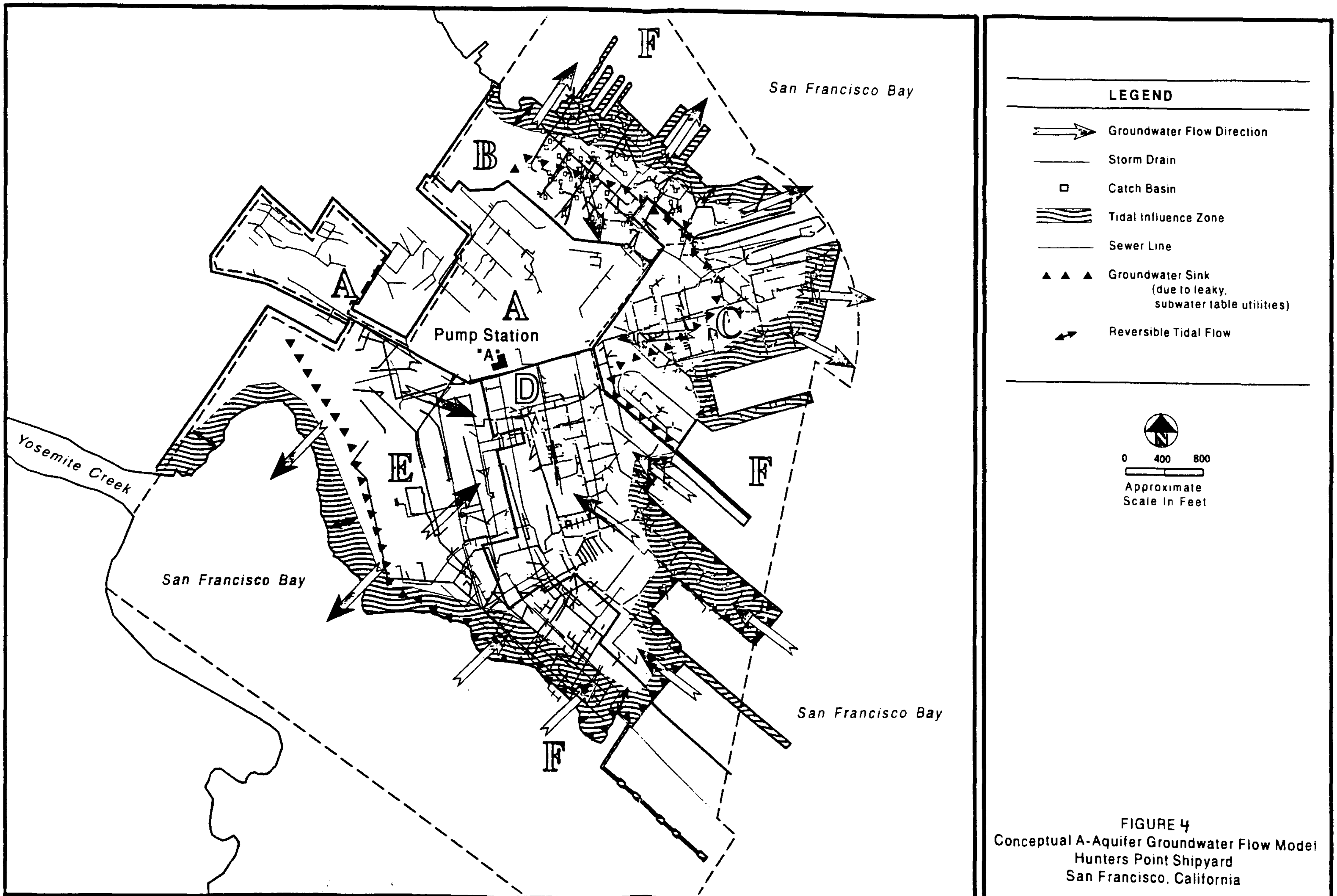


FIGURE 4
Conceptual A-Aquifer Groundwater Flow Model
Hunters Point Shipyard
San Francisco, California

TABLE 1. FILL MATERIALS AT HUNTERS POINT SHIPYARD, SAN FRANCISCO, CALIFORNIA

Fill Material	Description	Estimated Volume, cubic yards	Percent
	Hunters Point Shipyard		
Mechanically deposited bedrock-derived fill from the Parcel A upland, drydock excavations, and Point Avisadero and Shag Rock	Extremely heterogeneous, sandy clays to very fine to very coarse sand, gravel, cobbles, and boulders consisting of weathered and fresh serpentinite with lesser amounts of sandstone, chert, and shale. Covers a large area of 100s of acres; mostly found in top 10 to 30 feet. Boulders are common along the base of the bedrock outcrop in Parcel A, along the seawall shoreline of Parcel B at IR-24 and adjacent to Point Avisadero (off IR-26), behind the Parcel D seawall at IR-28 and Drydocks No. 3 and 4, at Parcel D's IR-70, and along the Parcel E shoreline, and at Parcel E's IR-56 and IR-72. Includes 5 million cubic yards from bedrock excavation of Parcel C's Drydock No. 4, plus bedrock excavations at Point Avisadero (off Parcel E IR-26) and Shag Rock (Parcel E IR-73).	13,250,000	48.40
Mechanically deposited industrial fill	Heterogeneous, sandy clays to very fine to coarse materials, domestic and industrial wastes, sandblast materials, and construction debris including iron iron cables, cars and boxes, spikes, and other metal debris. Includes 263,705 cubic yards of industrial fill at Parcel E IR-1/21 (Industrial Landfill) and IR-2NW (Bay Fill and Disposal Dump Area) debris zone, 1,785 cubic yards of industrial fill at Parcel E IR-3 (Oil Reclamation Pond), plus miscellaneous areas.	325,000	1.19
Natural fill as dredged materials from the Bay	Relatively homogeneous sandy clays to fine to medium sand from the Bay. Covers a large area of 100s of acres, especially along the shoreline of Parcel C at IR-28 and Parcel E at IR-2, and at Parcel E's IR-73. Assumed equal to the volume of bedrock-derived fill	13,250,000	48.40
Miscellaneous mechanically deposited materials	Sand and gravel placed as cover over Parcel E IR-1/21 (40-acre Industrial Landfill and Triple A Sites 1 and 16) and Parcel E IR-3 (10-acre Oil Reclamation Pond); sand for landscaping near Parcel B's Dago Mary's Restaurant (including material with natural low-level radioactivity from Monterey's Colma Formation or Sierra foothills imported fill; sand emplaced along Parcel A utility lines as bedding material; plus miscellaneous areas including Parcel A landscaping.	550,000	2.01
Totals		**27,375,000**	100.00

Table 2. Analyses (total) of Major and Transitional (3d) Elements in Bedrock at Hunters Point.

	Al	Ca	Mg	K	Na	Fe	Mn	Cr	Ni	Co
	g/kg							mg/kg		
Graywacke	36(10)	29(14)	27(11)	0.6(0.5)	0.8(0.9)	50(29)	1.4(1.4)	86(49)	156(111)	29 (7)
Greenstone	23(10)	24(14)	26(28)	1.2(0.6)	0.9(0.6)	35(12)	1.1(1.6)	135(252)	192(346)	26(18)
Serpentinite	21(19)	10(11)	109(75)	1.0(0.7)	1.0(0.9)	41(13)	0.9(1.9)	491(467)	1039(955)	60(42)
Shale	27(10)	13 (8)	29(29)	1.7(0.9)	2.0(1.8)	41(13)	0.8(0.5)	147(108)	182(240)	28(10)

Means of 2 to 335 samples, depending on substrate and element, and standard deviations (σ in parenthesis).

Data extracted from Table 2 of B.P. Popkin, Tetra Tech EMI.

Table 3. Analyses (total) of Minor and Trace Elements in Bedrock and Regolith at Hunters Point.

	Sb	As	Ba	Be	Cd	Cu	Pb
	mg/kg						
Bedrock							
Graywacke	1.7 (0.4)	4.1(5.0)	132 (97)	0.54(0.31)	2.8(2.4)	83(100)	3 (2)
Greenstone	3.3 (4.9)	13.3(23.9)	169(127)	0.42(0.23)	0.4(0.2)	151(450)	28(77)
Serpentinite	9.5(15.9)	5.6(6.1)	178(248)	0.43(0.15)	1.0(0.8)	40 (47)	12(40)
Shale	2.0 (2.2)	6.0(4.9)	137(113)	0.38(0.10)	0.8(0.5)	55 (24)	11(22)
Regolith							
Serpentinite	3.7 (2.5)	3.1(2.8)	152(103)	0.23(0.21)	0.5(0.5)	32 (21)	2 (2)
Serpentinite Fill	4.3 (4.3)	3.0(3.4)	115 (86)	0.26(0.29)	0.7(0.9)	36 (31)	7 (9)
Upper Undif. Sand	2.2 (1.6)	4.3(2.4)	46 (86)	0.24(0.19)	0.4(0.2)	13 (12)	4 (2)
Bay Mud	3.2 (4.3)	7.3(3.6)	47 (34)	0.37(0.22)	0.9(1.2)	29 (14)	8 (4)
Undifferentiated Fill	3.1 (2.5)	2.8(1.8)	177(253)	0.30(0.25)	0.6(0.9)	44 (29)	10(14)
U.S. EPA's PRG	31.	0.38	5300.	0.14	0.9	2800.	130.

	Hg	Mo	Se	Ag	Tl	V	Zn
	mg/kg						
Bedrock							
Graywacke	0.2 (0.2)	—	—	—	—	148(185)	72 (64)
Greenstone	3.8(14.6)	1.0 (0.3)	2.8 (3.8)	—	3.2(4.9)	73 (35)	94(112)
Serpentinite	0.2 (0.2)	5.1(23.2)	24.4(22.0)	1.1(1.0)	2.8(4.4)	81 (57)	62 (53)
Shale	0.1 (0.1)	—	0.8 (0.4)	—	—	51 (91)	96 (86)
Regolith							
Serpentinite	0.9 (0.8)	0.4 (0.3)	0.3 (0.1)	0.2(0.2)	0.3(0.2)	56 (29)	56 (28)
Serpentinite Fill	0.4 (1.6)	0.8 (1.2)	0.7 (2.7)	0.4(0.6)	0.3(0.2)	56 (34)	64(186)
Upper Undif. Sand	0.1 (0.1)	0.6 (0.4)	0.4 (0.2)	0.4(0.4)	0.4(0.3)	40 (25)	33 (19)
Bay Mud	0.1 (0.1)	1.4 (1.6)	0.4 (0.3)	0.4(0.5)	0.3(0.1)	54 (22)	63 (24)
Undifferentiated Fill	0.3 (0.9)	0.7 (1.0)	0.5 (0.7)	0.3(0.4)	0.3(0.3)	70 (36)	65 (34)
U.S. EPA's PRG	23.	380.	380.	380.	5.4	540.	23000.

Means of 69 to 1123 samples, depending on substrate and element, and standard deviations (σ in parenthesis).

Data extracted from Tables 2 (bedrock) and 3 (regolith) of B.P. Popkin, Tetra Tech EMI.

This modified table does not include "ambient levels".

PRG = provisional regulatory goal

TABLE 4. HUNTERS POINT SHIPYARD GROUNDWATER AMBIENT LEVELS (HGAL), SAN FRANCISCO, CALIFORNIA (1 of 2)

Metal	Number of Samples for HGAL	Median Detected at HPS	HGAL (a)	Albion Springs Raw Water (b)	Treated SFWD Water (c)	Treated SFWD Recycled Water (d)	MCL (e)	Tap Water PRG (f)	NAWQC (g)
Concentrations in micrograms per liter									
Antimony	161	9.68	43.26	NA	<5	<60	6	15	500
Arsenic	162	2.10	27.34	NA	<2	<5.0	50	0.045	36
Barium	162	81.10	504.20	NA	14	<10	1,000	2,600	NA
Beryllium	162	0.18	1.40	NA	<1	<2.0	4	0.016	NA
Cadmium	162	0.90	5.08	NA	<1	<2.0	5	18	9.3
Chromium (total)	185	1.25	15.66	NA	<2	<10	50	NA	NA
Cobalt	162	3.50	20.80	NA	NA	NA	NA	NA	NA
Copper	162	1.75	**28.04**	NA	1	10.4	1,000	1,400	2.4
Iron	162	5.80	2,380.00	NA	20	127	300	NA	NA
Lead	162	0.80	**14.44**	1	<1	<3.0	50	4	8.1
Magnesium	162	275,000.00	1,440,000.00	NA	3,400	11,600	NA	NA	NA
Manganese	162	484.00	8,140.00	NA	6	27.0	50.0	180	NA
Mercury	162	0.10	**0.60**	NA	<1	<0.20	2.00	11	0.025
Molybdenum	154	4.13	61.90	NA	NA	NA	NA	180.00	NA
Nickel	182	11.32	**96.48**	NA	<3	<20	100.00	730	8.2
Potassium	162	22,850.00	448,000.00	1,400	530	14,000	NA	NA	NA
Selenium	146	0.37	14.50	1	<5	<5.0	10	180	71
Silver	162	0.75	**7.43**	NA	<1	<10	50	180	0.92
Thallium	136	1.00	12.97	NA	<1	<5.0	2	NA	NA
Vanadium	162	2.15	26.62	NA	NA	NA	NS	260	NA
Zinc	162	6.08	75.68	NA	4	37	5,000	11,000	81

TABLE 4. HUNTERS POINT SHIPYARD GROUNDWATER AMBIENT LEVELS (HGAL), SAN FRANCISCO, CALIFORNIA (2 of 2)

Metal	Number of Samples for HGAL	Median Detected at HPS	HGAL (a)	Albion Springs Raw Water (b)	Treated SFWD Water (c)	Treated SFWD Recycled Water (d)	MCL (e)	Tap Water PRG (f)	NAWQC (g)
Miscellaneous Parameters, in milligrams per liter (except pH)									
Total Dissolved Solids	114	3,670	33,720	402	67	394	500	NA	NA
Aluminum	NA	NA	NA	NA	0.061	<0.2	1	NA	NA
Calcium	NA	NA	NA	72	8.9	15.2	NS	NA	NA
Chloride	102	1,405	16,450	NA	NA	NA	NA	NA	NA
Sodium	NA	NA	9,242.00	20	9.2	110.2	NS	NA	NA
pH	104	7.43	8.58	NA	NA	NA	NA	NA	NA

(a) HGALs for A-aquifer groundwater are the 95th percent upper confidence limit on the 95th percentile of the distribution using a nonparametric formula (Gilbert 1987), to two decimal places.
Bolded HGALs exceed U.S. EPA NAWQC - copper, lead, mercury, nickel, silver.

(b) Albion Water Company, 1994 Water Analysis.

(c) San Francisco Water Department, March 1996, Water Quality Report, Issue No. 1, Vol. 1.

(d) San Francisco Water Department, September 1995, Draft (Updated) Recycled Water Master Plan, Table 4-2.

(e) U.S. EPA or Cal/EPA maximum contaminant level, whichever is lower (U.S. EPA 1994).

(f) U.S. EPA Region IX preliminary remedial goal, February 1995 (U.S. EPA 1995).

(g) U.S. EPA National Ambient Water Quality Criteria for saltwater aquatic life protection, continuous concentrations (4-day average) (RWQCB 1995)

NA Not available

NS No standard

From: PRC Environmental Management, Inc., September 16, 1996. Estimation of Hunters Point Shipyard Groundwater Ambient Levels, Technical Memorandum, Hunters Point Shipyard, San Francisco, California.

BIOLOGY OF THE BAY CHECKERSPOT BUTTERFLY

We've been studying *Euphydryas* butterflies since 1960, when Paul Ehrlich started his work at Jasper Ridge. We started working in the East Hills (aka Kirby Canyon or Coyote Ridge) in the early 1980s, and have spent literally 1000s of person-days on site. Through the course of this work we've done a wide range of studies. I've taken a few summary paragraphs from some of our manuscripts, reports, proposals as background information for the WSSS field trip. **Alan Launer**

Habitat

The Bay checkerspot butterfly is restricted to patches of native California grassland containing a mixture of its larval hostplants (*Plantago erecta*, the primary larval hostplant, and *Orthocarpus densiflorus* or *O. purpurascens*, secondary larval hosts used when *Plantago* becomes senescent) and adult nectar sources (including *Lasthenia chrysostoma*, *Layia platyglossa*, *Allium* species, *Muilla maritima*, *Amsinkia intermedia*, and *Lomatium* species). This mixture of grassland forbs is regularly only found on serpentinitic soils. Serpentinitic rock weathers to form shallow, nutrient poor soils, typically low in nitrogen and calcium, and often high in magnesium, nickel, and chromium. Serpentinitic soils generally dry very rapidly, and as a result are exceedingly harsh environments for most plant species. For these reasons, grasses and forbs from Eurasia, which now dominate California grasslands on other soils, have been unable to do so on serpentinitic soils. As a result, the Bay checkerspot butterfly is currently restricted to remnant patches of native grasslands that are limited in area and isolated from one another.

Natural history

The Bay checkerspot butterfly is univoltine. Adults fly from late February to early May and females lay egg masses of up to 200 eggs at the bases of *Plantago* and *Orthocarpus*. Newly hatched larvae feed gregariously until oviposition plants are defoliated or senesce. Larvae that have not by then reached the appropriate size for diapause (an obligatory dormant period during the summer and autumn months when no food is available) must disperse and find additional hostplants. Only larvae that reach the fourth instar before the onset of the dry season are able to survive diapause. The single greatest source of natural mortality for Bay checkerspot butterflies occurs when larvae are unable to reach the appropriate size before the larval hostplants senesce.

Larvae remain dormant until the following rainy season when *Plantago* germinates. Postdiapause larvae feed from approximately December through February or early March. This is followed by a 10-20 day period as pupae. The precise timing and length of these life cycle stages is dependent upon local weather patterns. During periods of sunny weather, larvae rapidly develop. During cloudy and rainy periods, larvae cannot bask to raise their body temperatures and grow very slowly or not at all. Warm sunny winter weather, therefore, leads to earlier flight seasons than does cool rainy winter weather. The adult flight period may be three to five weeks in length, and can vary in onset from year to year from late-February to late-March. Individual butterflies typically live as adults for one to two weeks.

Variations in the timing of adult flight and hostplant senescence make Bay checkerspot butterfly populations highly prone to weather-induced population fluctuations. Following rainy seasons that favor prediapause larval survival -- many sunny days for postdiapause larval growth, but sufficient rainfall to keep plants growing late into spring -- the number of butterflies in a population may increase by a factor of five or more. During rainy seasons that provide dry conditions in the spring, larval hostplants senesce rapidly, prediapause survival may be extremely low, and the number of butterflies the following year may decrease by an order of magnitude. Not surprisingly, Bay checkerspot butterfly populations either declined or experienced local extinctions during the severe 1975-1977 drought. In addition, long periods of cloudy and rainy weather, such as during El Nino in 1982 and 1983, can delay larval growth and pupal development so that the adult flight season is late, lead to poor "phase relationship" with hostplant senescence. Population sizes decreased by an order of magnitude or more following that El Nino episode.

Topographic effects

The topographic configurations of individual patches of serpentine soil-based grasslands play a critical role in determining the ability of individual patches to sustain viable populations of the Bay checkerspot butterflies through extreme weather years. Variations in aspect and tilt angles across hillslopes provide distinct solar exposure regimes, which in turn create distinct microclimates. For example, south-facing slopes are warmer and drier than north-facing slopes, because south-facing slopes receive much more solar radiation on clear days than do north-facing slopes. This microclimatic variation affects the timing of both larval and hostplant development. Larvae on warm south-facing slopes may develop to adulthood a month (or more) earlier than larvae on cool north-facing slopes. Hostplant senescence is also dependent upon solar exposure; hostplants on south-facing slopes may flower and senesce three or four weeks before those on cooler slopes. The temporal phase relationship between adult flight and hostplant senescence, therefore, varies across the topography of the habitat.

The spatial pattern of prediapause survival across the microclimatic gradient changes from year to year. If the phase relationship between adult flight and hostplant senescence is favorable, prediapause larvae can survive on slopes warmer than those on which the preceding generation developed, and the population will experience a "thermal advance." Population increases are often associated with thermal advances. Conversely, if the phase relationship is poor, then prediapause larvae can only survive on slopes cooler than those on which the preceding generation developed, and the population will experience a "thermal retreat." Population declines are often accompanied by thermal retreats.

These ever-shifting patterns of larval survival emphasize the importance of topographic diversity in maintaining populations of the Bay checkerspot butterfly. Several topographic features contribute to long-term habitat quality. First is the overall range of slope exposures, which determines the overall range of microclimates. Relatively steep, north-facing slopes appear to serve as core habitat, because those slopes provide hostplants that remain edible for the longest period in the spring. Even small areas of cool north-facing slopes will confer to a population resistance to extinction during short or mild periods of drought. However, warmer slopes are also important. The lack of relatively warmer slopes adjacent to cool slopes will tend to retard postdiapause development, resulting in later flight periods and confounding the phase relationship between adult flight and hostplant senescence. A wide variety of microclimates across a patch of habitat assures that at least some survival, timely development, and reproduction can occur under most macroclimatic conditions. Even slopes with the very highest insolation, where the chances of prediapause survival are small, can contribute in some years by providing diverse early season nectar, which increases female fecundity and lifespan, and affects adult movement patterns.

The second topographic factor contributing to long-term habitat quality is the spatial interfacing between distinct microclimates. Areas with high local slope diversity are particularly valuable because postdiapause larvae can readily disperse from cooler to warmer slopes. Such movements can advance the emergence dates of those larvae by a week or more, increasing their chances of reproductive success.

Third, the amount of rainfall actually received by a site is important in determining soil moisture, which in turn determines the timing of hostplant senescence. The amount of rainfall varies widely over short distances in response to local rain shadows and elevation changes. Bay checkerspot butterfly populations residing in serpentine soil-based grasslands in higher rainfall zones are apparently more resistant to droughts, when any extra late season rainfall can make a significant contribution to extending the spring growing season.

Metapopulation dynamics

At the present time, it is thought that the Bay checkerspot butterfly exists in three metapopulations: one located in San Mateo County, one in south-central Santa Clara County, and one in the vicinity of Mt. Diablo. Each of these metapopulations consists of a dynamic mix of occupied and unoccupied habitat patches. Population extinctions and recolonizations are thought to be common occurrences in each metapopulation. While, dispersal between the three metapopulations is minimal, dispersal between close habitat patches within a metapopulation is fairly common. However, dispersal farther than five kilometers is relatively uncommon and 95% of all dispersal events documented through nearly 40 years of research have been less than 500 meters. It should be noted that at least three populations in the Santa Clara County metapopulation frequently consist of more than 250,000 adult butterflies, meaning that at a population level, large numbers of butterflies occasionally disperse comparatively long distances.

Additional and on-going studies

Long-term monitoring and status of regional populations of the Bay checkerspot butterfly. We conduct in depth monitoring of the number and distribution of Bay checkerspot butterflies at several locations and visit virtually all known habitat patches in the area on a rotating basis.

Distribution of plants and moths. We have been working the last five years to determine the spatial distribution of plants and moths at Kirby Canyon. Field data have been entered into our computer databases, analyzed, processed, and graphed back onto our GIS-based landscapes. We also have expanded these studies to other sites in the region.

Impacts of nitrogen deposition on serpentine grasslands. Even though serpentine-based soils act to exclude non-native plant species, this exclusion is far from complete. Throughout Santa Clara County serpentine grasslands that are not either grazed or subject to wildfires are invaded by non-native grasses. These invasions are apparently being made much worse by nitrogen deposition -- with the source of nitrogen being air pollution. Preliminary work by Stu Weiss indicates that this deposition is perhaps a major problem for the local serpentine grasslands (similar air pollution-related deposition has been shown to be a problem in other nutrient-poor systems).

GIS modeling of the serpentine grassland ecosystem. We have constructed a variety of GIS-based models in order to further analyze the serpentine grasslands of the Bay Area. While our primary focus has been on the Coyote Valley region, we have expanded our coverage to include the San Mateo sites as well.

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Note: *Orthocarpus densiflorus* and *O. purpurascens* are now designated *Castlleja densiflora* and *C. exerta* (J.C. Hickman, editor, 1993, *The Jepson Manual*)

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Jasper Ridge Serpentine Grassland tour

Jasper Ridge Biological Preserve of Stanford University is a 489 ha protected area on the extreme western end of campus. The roughly diamond-shaped Preserve is located on the eastern flank of the Santa Cruz Mountains and slightly overlaps the San Andreas Fault zone and several lesser faults. The eponymous ridge extends from the southeast to northwest of JRBP and is obliquely bisected by a jagged, discontinuous band of serpentine grassland totaling about 20 ha, with an additional 5 ha of serpentine chaparral on the western flank of the grassland. On either side of the serpentine grassland are grasslands on different substrates. The serpentine grassland supports a diverse community of native grasses and forbs (roughly 100 species) and generally excludes invasive Eurasian species that have outcompeted native species on other substrates. The area is a refugium both for native plants and for animals that depend on them, such as the threatened *Euphydryas editha bayensis*.

JRBP has been part of Stanford University for more than a century, and is open to researchers from any institution to conduct approved studies. This tour will visit an area of serpentine grassland where various longterm ecological studies have occurred, including studies of the threatened Bay Checkerspot butterfly, the effects of gophers on plant community composition, plant population genetics and ecotypic variation, seed-harvesting ants, responses of grassland to increased atmospheric carbon dioxide, and other studies. Several of these studies are briefly summarized below.

Longterm studies of the Bay Checkerspot butterfly

Studies of *Euphydryas editha bayensis*, or Bay Checkerspot butterfly, were started by Professor Paul Ehrlich in 1960 and have examined many aspects of the ecology and population biology of this butterfly, which was federally listed in 1987 as a "threatened species". Studies have included mark-release-recapture studies of population size and sex ratio; larval feeding ecology; reproductive behavior; isozyme analysis of genetic differentiation; gene flow within the Preserve and between the Preserve and other sites; microclimate effects on mortality; predation; nectaring behavior; protandry; and hilltopping. We will visit the largest of the serpentine grassland "islands" where studies of *Euphydryas editha* have been conducted. In recent years, the butterfly has been extinct in this and a second site, while a third site has had small and declining populations of adults.

Longterm studies of gopher exclusion and rainfall variability

Since 1982, Richard Hobbs (CSIRO, Australia) and Harold Mooney (Stanford University) have monitored experimental plots within the serpentine grassland, some of which have hardware cloth barriers to exclude gophers. They have mapped plant community composition and gopher disturbance annually. During their study they have found that most of the area is disturbed at least once every 3-5 years by gophers. Gopher disturbance level was not related to rainfall (which ranged from 200-1200 mm per year) but the patterning of disturbance was related to soil depth. Following establishment of exclosures, perennial species increased in abundance and then later declined. Data on plant densities on gopher mounds disturbed at different times of year and in different years indicate that local species composition remains distinct for a number of years following disturbance.

Studies of population genetics and ecotypic variation

Several current studies examine differentiation within plant populations occurring on serpentine substrates and as well as differentiation between populations occurring on serpentine and non-serpentine substrates. Prof. Bruce Bohm (Univ. British Columbia) has conducted longterm studies of a common serpentine grassland forb, *Lasthenia californica*. We will visit the sites where he has identified a consistent pattern of distribution of two subpopulations that can be distinguished by pappus shape, isozymes and flavonoid chemistry. Regional studies have found that these types represent geographical races, which apparently co-occur only at Jasper Ridge. Other studies by his group are looking at soil chemistry in the areas occupied by the two races.

Another species, *Linanthus parviflorus*, shows an association between flower color and soil type: flowers are almost always pink on serpentine and predominantly white on sandstone substrates. We will visit field sites where Prof. Douglas Schemske (Univ. Washington) is investigating the genetic basis of this pattern and how it is maintained. He has studied a very similar flower color "polymorphism" in *Linanthus parryae* in the Mojave Desert. Breeding studies with plants grown from Jasper Ridge seed have shown that pink is dominant to white in the determination of flower color. Schemske is also testing whether flower color is linked with other traits that improve survival or reproduction on the different types of soil; in particular he is interested in whether flower color is associated with the more rapid drying of serpentine soils (as compared with sandstone), which might select for earlier flowering and/or ability to tolerate low soil moisture.

Seed harvesting ants

The harvester ant *Messor andrei* is a major seed predator on serpentine grassland, especially for some highly preferred seed species such as *Microseris douglassii*. Seeds of less preferred species, such as the dominant annual species, *Lasthenia californica*, are not foraged until later in the summer when seeds of other species are less abundant. We will visit areas of serpentine grassland where nest densities of *Messor andrei* are roughly 70 per ha, and the ants have a significant effect on plant community structure. Recent studies by Mark Brown (Stanford University) have detailed the foraging behavior and nest re-location dynamics of this species.

Grassland response to global change

A recently completed study directed by Christopher Field (Carnegie Institution) and Harold Mooney (Stanford University) examined the roles of resource availability, species characteristics, and community composition in controlling ecosystem responses to increased CO_2. The serpentine grassland that we will visit, together with adjacent grassland on sandstone soils, provided a comparative system for looking at the response of natural grasslands, differing in productivity, to a doubling of atmospheric CO_2. The study found that most plant responses to CO_2, such as increased plant growth, are consistently greater when nutrients are less limiting. Most of the growth increase under high CO_2 is due to increased water-use-efficiency and soil moisture under elevated CO_2. Improved soil moisture under high CO_2 also tends to extend the growing season, which favors species with longer or flexible lifespans, such as tarweeds.

Pedon CR1, Coyote Ridge

Location: La Laguna Seca land grant, township not surveyed; 37°11'33"N, 121°40'13"W
Date described & sampled: April 16, 1999 by E.B. Alexander
Bedrock & soil parent material: serpentinite, Great Valley sequence
Landform: hill summit
Altitude: 355 meters
Mean temperature: 47°F(8.3°C) January, 69°F(20.6°C) July
Mean annual precipitation: 40 cm (16 inches)
Slope: stony, convex-convex, 7% east (80° azimuth)
Soil drainage class: somewhat excessively well
Rock outcrop < 1%, rock SG = 2.2 (slightly weathered serpentinized peridotite)
Surface stoniness: boulders < 1%, 7% "stones", 7% cobbles, 18% gravel
Soil classification: loamy-skeletal, magnesic, thermic Lithic Argixeroll
Plant community: grass–dwarf plantain

Pedon Description, very shallow Montara taxajunct

A 0 to 3 cm: dark grayish brown (10YR 4/2) gravely loam, very dark grayish brown (10YR 3/2) moist; weak, medium platy to moderate, fine subangular blocky structure, massive where roots are sparse; very hard, friable, sticky, and slightly plastic; common very fine roots; 18 percent gravel, 7% cobbles, 7% "stones", boulders < 1%; slightly acid (pH 6.4); clear smooth boundary.

Bt 3 to 16 (12/21) cm: dark grayish brown (10YR 4/2) very gravely clay loam, very dark grayish brown (10YR 3/2) moist; moderate, medium subangular blocky structure; very hard, firm; very sticky, plastic; many thin and few moderately thick clay coatings on ped faces; few very fine and fine roots; 27 percent gravel, 10 percent cobbles, 5% "stones"; neutral (pH 6.6); abrupt irregular boundary.

R 16 (12/21) to 25 cm: green, highly fractured serpentinized peridotite that appears to be less weathered than indicated by the relatively low density of 2.2 Mg/m^3.

Remarks:

Soil erosion is not evident in the area. Soil cracks, that are evident at the ground surface during summer, have not formed yet. Soil pH with bromthymol blue indicator.

Plant Cover (all listed forbs were in bloom, except soap plant, and heads were developing on ryegrass)

Trees & Shrubs (0%). Herbs (70%): 30% grass, much *Lolium multiflorum*; 30% *Plantago erecta (dwarf plantain); 10% Lasthenia californica* (goldfields); 5% *Chorogalum pomeridianum* (soap plant); 3% *Castilleja densiflora* and *C. exserta* (purple owl's-clover); 1% *Lotus wrangelianus* (Chile trefoil); 1% *Muilla maritima* (common muilla); 1% *Lomatium* sp.; 1% *Layia platyglossa* (tidy-tips); and *Platystemon californicus* (cream cups), *Eschscholzia californica* (California poppy), *Cryptantha* sp., *Astragalus gambelianus* (Gambell's dwarf locoweed), and *Sisyrinchium bellum* (blue-eyed grass) each < 1%. Note: *Castilleja densiflora* and *C. exerta* were formerly designated *Orthocarpus densiflorus* and *O. purpurascens*.

Pedon Site Descriptions

Coyote Ridge
- CR1 - Montara taxajunct
  - loamy-skeletal, magnesic, thermic Lithic Argixerolls
- CR2 - Obispo taxajunct
  - clayey, magnesic, thermic Lithic Haploxerolls

Jasper Ridge
- JR1 - Obispo Series
  - clayey, magnesic, thermic Lithic Haploxerolls
- JR2 - Montara Series
  - loamy, magnesic, thermic Lithic Haploxerolls
- JR3 - very shallow Montara
  - loamy, magnesic, thermic Lithic Haploxerolls

References (terminology and classification)

J.C. Hickman (ed.). 1993. *The Jepson Manual - Higher Plants of California*. University of California Press, Berkeley.

Soil Survey Staff. 1993. *Soil Survey Manual*. USDA Agricultural Handbook No. 18.

Soil Survey Staff. 1998. *Keys to Soil Taxonomy*. USDA Natural Resources Conservation Service.

Pedon JR1, Jasper Ridge

Location: Jasper Ridge Biological Preserve; 37°24'23"N, 122°13'36"W
Date described & sampled: April 21, 1999 by E.B. Alexander and R.G. Coleman
Bedrock & soil parent material: serpentinite, Franciscan formation
Landform: summit of a ridge
Altitude: 174 meters (571 feet)
Mean temperature: 47°F(8.3°C) January, 64°F(17.8°C) July
Mean annual precipitation: 60 cm (24 inches)
Slope: smooth, convex (concave laterally, along contour) 4% southwest (220° azimuth)
Soil drainage class: well-drained
Rock outcrop: none
Surface stoniness: no boulders, "stones" < 1%, 1% cobbles, 12% gravel
Soil classification: clayey, magnesic, thermic Lithic Haploxeroll
Plant community: grass

Pedon Description, **Obispo Series**

A1 0 to 6 cm: dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate, fine subangular blocky structure; extremely hard, firm, very sticky, and very plastic; common very fine roots; 12 percent gravel, 1% cobbles, no "stones"; pebbles 60% serpentinite and 40% chert, subangular; neutral (pH 6.8); clear smooth boundary.

A2 6 to 22 cm: dark grayish brown (10YR 4/2) clay loam, very dark grayish brown (10YR 3/2) moist; moderate, coarse subangular blocky structure; extremely hard, very firm; very sticky, very plastic; few thin clay coatings on ped faces; very few very fine and fine roots; 10 percent gravel, 1 percent cobbles, no "stones"; pebbles 70% serpentinite and 30% chert, subangular; neutral (pH 7.0); clear, wavy boundary.

C 22 to 30 (28/32) cm: light olive brown (2.5Y 5/3) gravely sandy loam, dark grayish brown (2.5YR 4/2) moist; massive, structureless; slightly hard, friable; sticky, slightly plastic; negligible roots; 30 percent gravel, 1 percent cobbles, no "stones"; pebbles all relatively unweathered serpentinite, angular; neutral (pH 7.0); abrupt, irregular boundary.

R 30 (28/40) to 50 cm: green, highly fractured serpentinized peridotite.

Remarks: Soil erosion is not evident in the area. Soil cracks, that are evident at the ground surface during summer, have not formed yet. Soil pH with bromthymol blue indicator. Density of fresh (no visible weathering) pebbles in the C horizon is 2.5 Mg/m^3.

Plant Cover (all listed forbs were in bloom, except soap plant, and heads were developing on ryegrass)

Trees & Shrubs (0%); **Herbs (95%)**: 80% grass, much *Lolium multiflorum*; 10% *Arennaria* sp.; 2% *Lotus humistratus* or *wrangelianus* (Chile trefoil); 5% *Lasthenia californica* (goldfields); 1% *Castilleja densiflora* and *exerta* (purple owl's-clover); 1% *Chorogalum pomeridianum* (soap plant); and sparse *Linanthus parviflorus*, or absent. Bulbs that appear to be *Muilla maritima* are abundant in the A horizon.

Pedon CR2, Coyote Ridge
Location: La Laguna Seca land grant, township not surveyed; 37°11'34"N, 121°40'08"W
Date described & sampled: April 16, 1999 by E.B. Alexander
Bedrock & soil parent material: serpentinite, Great Valley sequence
Landform: ravine sideslope ("backslope")
Altitude: 341 meters (1120 feet)
Mean temperature: 47°F(8.3°C) January, 69°F(20.6°C) July
Mean annual precipitation: 40 cm (16 inches)
Slope: slightly stony, linear-linear 44% northwest (320° azimuth)
Soil drainage class: somewhat excessively well
Rock outcrop: 1%, rock SG = 2.3 (slightly weathered serpentinized peridotite)
Surface stoniness: 1% boulders, 1% "stones", 2% cobbles, 20% gravel
Soil classification: clayey-skeletal, magnesic, thermic Lithic Haploxeroll
Plant community: grass

Pedon Description, Obispo taxajunct

A 0 to 4 cm:, very dark grayish brown (10YR 3/2) gravely clay loam, very dark brown (10YR 2/2) moist; moderate, very fine subangular blocky structure; hard, friable, sticky, and plastic; common very fine roots; 20 percent gravel, 2% cobbles, 1% "stones", 1% boulders; neutral (pH 6.8); clear smooth boundary.

Bt1 4 to 21 cm: very dark grayish brown (10YR 3/2) gravely clay loam, very dark brown (10YR 2/2) moist; moderate, fine subangular blocky structure; very hard, friable; very sticky, plastic; many thin and few moderately thick clay coatings on ped faces; few very fine and common fine roots; 25 percent gravel, 2 percent cobbles, 1% "stones"; neutral (pH 6.9); gradual, smooth boundary.

Bt2 21 to 34 (28/40) cm: very dark grayish brown (10YR 3/2) very gravely clay loam, very dark brown (10YR 2/2) moist; moderate, fine subangular blocky structure; very hard, friable; very sticky, plastic; many thin and few moderately thick clay coatings on ped faces; few fine roots; 30 percent gravel, 10 percent cobbles, 2% "stones"; neutral (pH 7.0); abrupt, irregular boundary.

R 34 (28/40) to 50 cm: green, highly fractured serpentinized peridotite that appears to be less weathered than indicated by the relatively low density of 2.3 Mg/m^3.

Remarks: Soil erosion is not evident in the area, but some disturbance by feral pigs. Soil cracks, that are evident at the ground surface during summer, have not formed yet. Soil pH with bromthymol blue indicator.

Plant Cover (all listed forbs were in bloom, except yarrow, and heads were developing on ryegrass)

Trees & Shrubs (0%); Herbs (95%): 70% grass, much *Lolium multiflorum*; 10% *Plantago erecta (dwarf plantain);* 5% *Lotus wrangelianus* (Chile trefoil); 3% *Lomatium* sp., 2% *Ranunculus californicus* (California buttercup); 2% *Lasthenia californica* (goldfields); 2% *Achillea millefolium* (yarrow); 1% *Platystemon californicus* (cream cups), and *Cryptantha* sp., *Sisyrinchium bellum* (blue-eyed grass), *Trifolium* sp. and *Dodecatheon hendersoni* (Henderson's shooting star) each < 1%.

Pedon JR3, Jasper Ridge

Location: Jasper Ridge Biological Preserve; 37°24'15"N, 122°13'27"W
Date described & sampled: April 21, 1999 by E.B. Alexander and R.G. Coleman
Bedrock & soil parent material: serpentinite, Franciscan formation
Landform: shoulder of a ridge
Altitude: 175 meters (574 feet)
Mean temperature: 47°F(8.3°C) January, 64°F(17.8°C) July
Mean annual precipitation: 60 cm (24 inches)
Slope: smooth, convex (linear laterally, along contour) 6% north (350° azimuth)
Soil drainage class: somewhat excessively well-drained
Rock outcrop: 1%
Surface stoniness: boulders < 1%, 1% "stones", 2% cobbles, 18% gravel
Soil classification: loamy, magnesic, thermic Lithic Haploxeroll
Plant community: leatheroak–chamise chaparral

<u>Pedon Description</u>, very shallow Montara

Oi 2 to 0 cm: loose oak leaves under shrubs, nil in openings between shrubs

A 0 to 6 cm: dark brown (7.5YR 3/2) gravelly sandy clay loam, very dark brown (7.5YR 2/2) moist; moderate, very fine subangular blocky structure; hard, friable, sticky, and slightly plastic; common very fine and fine roots; 18 percent gravel, 2% cobbles, 1% "stones"; pebbles 80% serpentinite and 20% opal, subangular to convoluted surfaces of weathering; neutral (pH 6.8); clear wavy boundary.

Bt 6 to 14 (10/18) cm: brown (7.5Y 4/2) gravely sandy clay loam, dark brown (7.5YR 3/2) moist; moderate, fine subangular blocky structure; hard, friable; sticky, plastic; many thin clay coatings on ped faces; few very fine and fine roots; 25 percent gravel, 5 percent cobbles, "stones" < 1%; pebbles 95% serpentinite and 5% opal, subangular to convoluted surfaces of weathering; neutral (pH 6.9); abrupt, irregular boundary.

R 14 (10/18) to 25 cm: dark green; weathered soft, brownish yellow on surface 1 or 2 mm of soil-bedrock contact; highly fractured serpentinized peridotite.

Remarks: Soil erosion is not evident in the area. Soil cracks, that are evident at the ground surface during summer, have not formed yet. Soil pH with bromthymol blue indicator. Opal in this pedon is secondary silica, precipitated in the soil or its parent rock, whereas chert in pedon JR1 is from primary sedimentary rock of the Franciscan formation.

<u>Plant Cover</u> (canopy or ground area)

Trees (0%); Shrubs (85%): 30% *Quercus durata* (leatheroak); *40% Adenostoma fasciculatum* (chamise); 10% *Rhamnus californica* (coffeyberry); 5% *Heteromeles arbutifolia* (toyon); 1% *Toxicodendron diversilobum* (poison oak); **Herbs (20%)**: 5% grass; 10% *Chorogalum pomeridianum* (soap plant); 3% *Achillea millefolium* (yarrow); 1% *Monardella* sp.; and *Galium* sp. and *Lomatium* sp. each < 1%.

Pedon JR2, Jasper Ridge

Location: Jasper Ridge Biological Preserve; 37°24'15"N, 122°13'27"W
Date described & sampled: April 21, 1999 by E.B. Alexander and R.G. Coleman
Bedrock & soil parent material: serpentinite, Franciscan formation
Landform: shoulder of a ridge
Altitude: 185 meters (607 feet)
Mean temperature: 47°F(8.3°C) January, 64°F(17.8°C) July
Mean annual precipitation: 60 cm (24 inches)
Slope: smooth, convex (linear laterally, along contour) 7% southwest (220° azimuth)
Soil drainage class: somewhat excessively well-drained
Rock outcrop: 1%
Surface stoniness: no boulders, "stones" < 1%, 1% cobbles, 20% gravel
Soil classification: loamy, magnesic, thermic Lithic Haploxeroll
Plant community: grass–dwarf plantain

<u>Pedon Description</u>, **Montana Series**

A 0 to 7 cm: dark brown (7.5YR 3/2) gravelly loam, very dark brown (7.5YR 2/2) moist; moderate, very fine subangular blocky structure; very hard, friable, sticky, and plastic; common very fine roots; 20 percent gravel, 1% cobbles, "stones" < 1%; pebbles 85% serpentinite and 15% opal, subangular to convoluted surfaces of weathering; very slightly acid (pH 6.6); clear smooth boundary.

Bt1 7 to 25 (22/28) cm: dark brown (7.5YR 3/2) gravelly clay loam, very dark brown (7.5YR 2/2) moist; moderate, medium subangular blocky structure; very hard, firm; very sticky, plastic; many thin clay coatings on ped faces; few very fine and fine roots; 18 percent gravel, 1 percent cobbles, "stones" < 1%; pebbles 85% serpentinite and opal < 1%, subangular to convoluted surfaces of weathering; neutral (pH 6.9); abrupt (bedrock) or clear (Bt2 horizon) irregular boundary.

Bt2 25 to 35 cm: brown (7.5Y 4/2) gravely clay loam, dark brown (7.5YR 3/2) moist; moderate, medium subangular blocky structure; very hard, firm; very sticky, plastic; many thin and few moderately thick clay coatings on ped faces; very few fine roots; 25 percent gravel, 1 percent cobbles, "stones" < 1%; all weathered serpentinite pebbles; neutral (pH 7.2); broken (discontinuous horizon) boundary.

R 35 (22/35) to 50 cm: green, highly fractured serpentinized peridotite.

Remarks: Soil erosion is not evident in the area. Soil cracks, that are evident at the ground surface during summer, have not formed yet. Soil pH with bromthymol blue indicator.

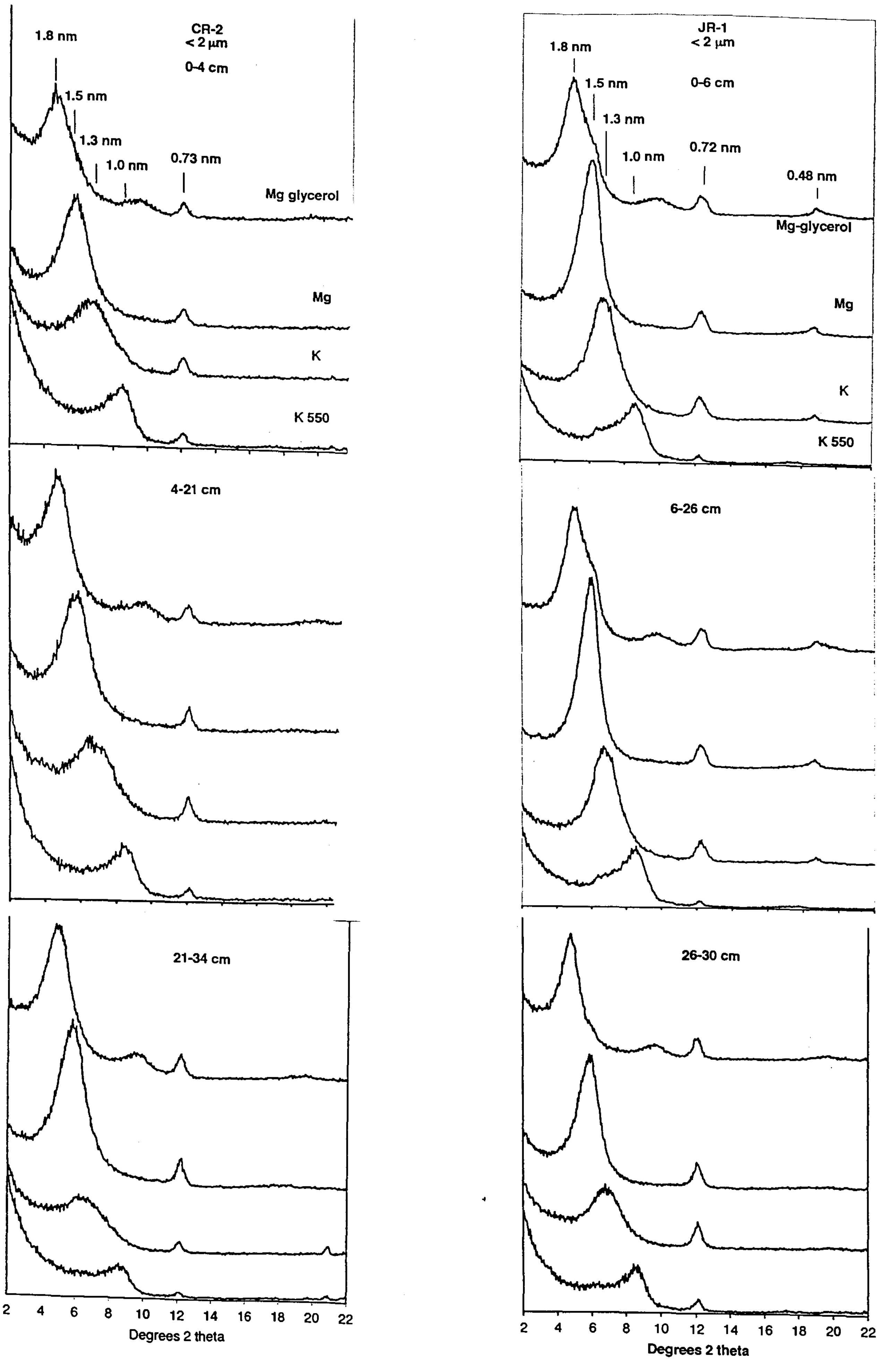
<u>Plant Cover</u> (all listed forbs were in bloom and heads were developing on ryegrass)

Trees & Shrubs (0%); Herbs (80%): 30% grass, much *Lolium multiflorum* and common *Sitanion hystrix* (or *Elymus elymoides*); 30% *Plantago erecta* (dwarf plantain); 5% *Lotus humistratus* or *wrangelianus* (Chile trefoil); 5% *Lasthenia californica* (goldfields); 5% *Castilleja densiflora* or *exerta* (purple owl's-clover); and *Layia platyglossa* (tidy-tips) <1%. Bulbs that appear to be *Muilla maritima* are abundant in the A horizon.

Soil laboratory data from the University of California, Davis – Coyote Ridge and Jasper Ridge pedons.

Horizon	Depth	Particle-Size Sand	Particle-Size Silt	Particle-Size Clay	Org. Matter C	Org. Matter N	Exchangeable Cations Ca	Mg	Na	K	Sum	CEC	pH	CEC/clay
	cm	----------%---------			---%---		--------------cmol(+)/kg--------------							meq/100 g
Pedon CR1														
A	0-3	40	34	26	4.10	0.345	3.4	18.8	0.07	0.61	22.9	23.0	6.2	65
Bt	3-16	37	28	35	1.86	0.176	2.6	26.0	0.07	0.24	28.9	28.8	6.6	74
Pedon CR2														
A	0-4	42	24	34	2.38	0.200	3.1	22.8	0.06	0.48	26.4	25.2	6.7	64
Bt1	4-21	45	22	33	1.92	0.171	2.3	24.9	0.05	0.17	27.4	28.3	6.8	77
Bt2	21-34	38	24	38	1.76	0.149	2.1	28.4	0.06	0.21	30.8	25.9	7.0	61
Pedon JR1														
A1	0-6	41	26	33	1.93	0.156	1.9	23.0	0.06	0.29	25.3	26.8	6.6	72
A2	6-26	36	26	38	0.81	0.076	1.6	27.3	0.06	0.12	29.1	31.1	6.9	79
C	26-30	69	18	13	0.33	0.041	0.7	16.8	0.05	0.05	17.6	18.9	7.1	142
Pedon JR2														
A	0-7	40	35	25	2.31	0.197	2.9	19.8	0.06	0.22	23.0	26.3	6.5	91
Bt	7-25	38	34	28	1.40	0.122	1.7	23.3	0.06	0.10	25.2	30.0	6.8	100
Pedon JR3														
A	0-5	48	23	29	3.04	0.173	5.9	20.5	0.06	0.44	26.9	29.0	6.6	84
Bt	5-14	49	27	(24)	2.17	0.136	4.6	22.1	0.06	0.25	27.0	29.4	6.8	109

Particle-size distribution by hydrometer; C and N by dry combustion; exchangeable cations displacement and CEC by NH_4-acetate; cations by ICP; NH_4^+ displaced with Na^+, and NH_4^+ determined by conductimetric determination; soil pH in 1:1 suspension.
Lab analyses by Shelly Munn, Dig McGahan, Neil Tabor, and Jan Carey.
CEC/clay = 100x(CEC-1.5xC)/clay.


CR-2
< 2 μm
0-4 cm
1.8 nm
1.5 nm
1.3 nm
1.0 nm
0.73 nm
Mg glycerol
Mg
K
K 550
4-21 cm
21-34 cm
2 4 6 8 10 12 14 16 18 20 22
Degrees 2 theta
JR-1
< 2 μm
0-6 cm
1.8 nm
1.5 nm
1.3 nm
1.0 nm
0.72 nm
0.48 nm
Mg-glycerol
Mg
K
K 550
6-26 cm
26-30 cm
2 4 6 8 10 12 14 16 18 20 22
Degrees 2 theta

RECOVERY WORKSHOP SUMMARY

Southern Bay Area Serpentine Plants

San Mateo thornmint *(Acanthomintha duttonii)*
Tiburon Indian paintbrush *(Castilleja affinis* ssp. *neglecta)*
Coyote ceanothus *(Ceanothus ferrisae)*
fountain thistle *(Cirsium fontinale* ssp. *fontinale)*
Santa Clara Valley dudleya *(Dudleya setchellii)*
San Mateo wooly sunflower *(Eriophyllum latilobum)*
Marin dwarf flax *(Hesperolinon congestum)*
white-rayed pentachaeta *(Pentachaeta bellidiflora)*
Metcalf Canyon jewelflower *(Streptanthus albidus* ssp. *albidus)*

April 30, 1997
Palo Alto

The status of known occurrences, information about the species, recovery actions, and corrections to the Natural Diversity Data Base (NDDB) records for the southern Bay Area serpentine plants discussed in the workshop are summarized below. Actions for which participants volunteered are underlined. A list of workshop participants follows the summary.

Acanthomintha duttonii

Biology. Bruce Pavlik reported that *Acanthomintha duttonii* produces a huge number of tiny, dust-like seeds. Diane Steeck observed some, but not much, seed predation. Bruce feels that the seeds may be well-distributed vertically in the soil, since a certain percentage falls into deep cracks in the soil that form in the dry season and subsequently close in the rainy season. Subpopulation 2A of Occ #5 reappeared after not being present for years — probably from the seed bank.

Bruce and Diane Steeck reported that *Acanthomintha duttonii* nutlets germinate readily in the lab, with 90% germination of seeds that were kept in the dark. Bruce noted that when seeds are kept in a cueless environment, they will not germinate until a certain amount of time has passed, as if they had an internal clock.

Bruce stated that once a plant has germinated, it has a 50-60% chance of maturing to set seed. He believes the seeds will survive 7 or 8 years under field conditions without germinating, and that there is a large, persistent seed bank. The environmental cues to germination are unknown.

Niall believes that plants root to a depth of two feet. He also stated that appropriate soils exist at Pulgas Ridge, and that more potential habitat could be identified if a geologist looked for deep fractures filled with alluvium.

After the workshop, Diane Steeck provided the following summary of her research on *Acanthomintha:*

***Acanthomintha ilicifolia*, cont'd**

I studied the reproductive biology of *Acanthomintha duttonii* in 1993 and 1994 at the Edgewood Preserve site, examining flower morphology, conducting hand pollination experiments, caging plants to investigate auto-deposition of pollen, observing pollinators, and examining pollen germination and pollen tube growth. My results suggest that *Acanthomintha duttonii* is self-compatible and capable of self-fertilization in the absence of pollinators, but is not apomictic (able to produce seeds in the absence of any pollen). The number of seeds produced by plants in the four treatments — (1) caged and left alone, (2) hand self-pollinated, (3) hand cross-pollinated and (4) those left open to pollinators — were not significantly different; seedset in all four treatments was high, with over 90% of all ovules developing. Flowers began to self-pollinate and self-fertilize within 2.5 hours of opening. About 1/3 of the sampled flowers had partially self-fertilized within their first 24 hours of opening, suggesting (along with other results) a high degree of inbreeding. Native bees from four families potentially pollinate this species, with two common species of bumblebees, *Bombus vosnesenskii* and *Bombus californicus* providing the most frequent and consistent flower visits during 1993 and 1994.

Occurrences # 2 and 3. These occurrences were confirmed as extirpated, since the sites are completely developed.

Occ #4. Susan Sommers visited this area with Larry Heckard, but couldn't relocate the specific site, although there is undeveloped habitat in the area. Niall McCarten didn't see any habitat that looked right, but Dean Kelch suggested that the area should be surveyed quite thoroughly. It doesn't have extensive clay soils and is more rocky than at Edgewood, but Toni Corelli stated that there is some clay in the area that supports *Fritillaria liliacea,* and Toni, Zoe Chandik and Susan Sommers offered to search the area if they can get permission from San Francisco Water Department (SFWD). NDDB will change the record back to "Presumed Extant."

Occ #5. Bruce Pavlik presented a map of the population reported by Susan Sommers as "2B." (See enclosed map; Occ #5 encompasses Susan's 2A and 2B). Roxanne Bittman will work with Bruce to get a more detailed map of both subpopulations for NDDB.

Bruce stated that this population undergoes fairly regular cycles of growth and decline that don't correlate with temperature, precipitation, or any of the other expected cues. Plant sizes decrease and population densities increase, but not in a way one would expect based on accepted population biology. Growth cycles peaked in 1994 and the population has been declining since then. There are subtle interactions with seeds, seed bank, and soil type. Although the population is declining, Bruce is not concerned, since it is likely a normal part of the population's cycle. NDDB will change the trend field for this occurrence to read "fluctuating."

Most cover is of *Acanthomintha* at this site, where there is little or no competition from non-native species. Subpopulation 2A may have competition from non-native grasses and forbs. There is always evidence of people walking around, although there is little evidence of bikes or vehicles. The population may be being impacted by a change in runoff with the recent construction of houses and a road upslope. Drainage from the developed upslope area now flows down the road and away from the population, although