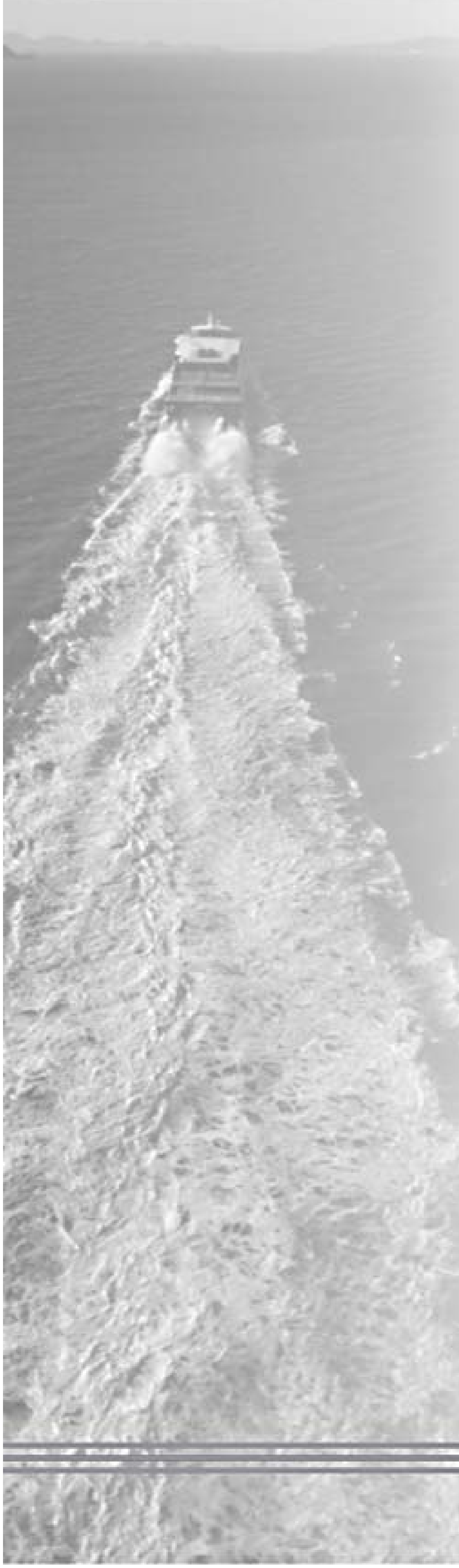

Technical Appendices

Final Program Environmental Impact Report

Expansion of Ferry Transit Service in the San Francisco Bay Area

Prepared by:

URS Corporation

June 2003

Prepared for:

WATER TRANSIT AUTHORITY

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Proposed Project Non-Peak Ferry Times and Distances

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1		Freqency	Travel Time	Distance	AveSpd	Idle Time	Number of	Total Run Time/	Total Idle Time/	Total Distance/
2	Ferry	(min)	(min)	(miles)	(mph)	(min)	Runs/Period	Period (min)	Period (min)	Period (miles)
3	90_ALASF	60	28.8	7.52	18.1	1.2	9.0	259	11	68
4	90_ALASF-	60	28.8	7.52	18.1	1.2	9.0	259	11	68
5	Alcatraz	60	8.4	4.00	12.0	6.6	9.0	76	59	36
6	Alcatraz	60	8.4	4.00	12.0	6.6	9.0	76	59	36
7	90_HBFB	0								
8	90_HBFB-	0								
9	90_OAKFW	60	24.0	8.80	11.7	6.0	9.0	216	54	79
10	90_OAKFW	60	24.0	8.80	11.7	6.0	9.0	216	54	79
11	92_SSLTO	60	20.4	7.66	15.3	9.6	9.0	184	86	69
12	92_SSLTO-	60	20.4	7.66	15.3	9.6	9.0	184	86	69
13	93_TIBFW	60	20.4	5.47	9.4	9.6	9.0	184	86	49
14	93_TIBFW-	60	20.4	5.47	9.4	9.6	9.0	184	86	49
15	95_BERSFMBA	60	20.4	9.05	17.4	9.6	9.0	184	86	81
16	95_BERSFMBA-	60	20.4	9.05	17.4	9.6	9.0	184	86	81
17	95_RDWCSF	60	48.8	24.57	32.0	11.2	9.0	439	101	221
18	95_RDWCSF-	60	48.8	24.57	32.0	11.2	9.0	439	101	221
19	95_RMDFB	60	33.0	9.00	25.0	12.0	9.0	297	108	81
20	95_RMDFB-	60	33.0	9.00	25.0	12.0	9.0	297	108	81
21	95_SSFSF	60	30.0	10.44	32.0	0.0	9.0	270	0	94
22	95_SSFSF-	60	30.0	10.44	32.0	0.0	9.0	270	0	94
23	96_SFTI	30	13.2	2.11	16.0	1.8	18.0	238	32	38
24	96_SFTI-	30	13.2	2.11	16.0	1.8	18.0	238	32	38
25	91_LARKN	60	43.6	12.74	16.0	13.2	9.0	392	119	115
26	91_LARKS	60	43.6	12.74	19.1	13.2	9.0	392	119	115
27	94_VALFB	60	53.8	26.55	29.0	6.2	9.0	484	56	239
28	94_VALFB-	60	53.8	26.55	29.0	6.2	9.0	484	56	239
29	95_HERSF	240	43.6	19.57	26.0	16.4	2.3	98	37	44
30	95_HERSF-	240	43.6	19.57	26.0	16.4	2.3	98	37	44
31	96_PITSF	200	80.7	34.10	26.0	9.3	2.7	218	25	92
32	96_PITSF-	200	80.7	34.10	26.0	9.3	2.7	218	25	92
33									**Total Miles**	**2613**
34										
35	**Small ferry total min.**							**4691**	**1249**	
36	**Small ferry total hrs.**							**78.2**	**20.8**	**Hours**
37	**Large ferry total min.**							**2385**	**473**	
38	**Large ferry total hrs.**							**39.8**	**7.9**	**Hours**

ENRG-A
Proposed Project Peak Ferry Times and Distances

	A	B	C	D	E	F	G	H	I	J
36	91_LARKN	20	43.6	12.74	16.0	13.2	18.0	785	238	229
37	91_LARKS	20	43.6	12.74	19.1	13.2	18.0	785	238	229
38	Deadhead							30		
39	94_VALFB	30	53.8	26.55	29.0	6.2	12.0	646	74	319
40	94_VALFB-	30	53.8	26.55	29.0	6.2	12.0	646	74	319
41	Deadhead							40		
42	95_HERSF	60	43.6	19.57	26.0	16.4	6.0	262	98	117
43	95_HERSF-	60	43.6	19.57	26.0	16.4	6.0	262	98	117
44	Deadhead							60		
45	96_PITSF	60	80.7	34.10	26.0	9.3	6.0	484	56	205
46	96_PITSF-	60	80.7	34.10	26.0	9.3	6.0	484	56	205
47	Deadhead							30		
48									**Total Miles**	**3636**
49										
50	**Small ferry total min.**							**6109**	**1466**	
51	**Small ferry total hrs.**							**101.8**	**24.4**	**Hours**
52	**Large ferry total min.**							**4512**	**932**	
53	**Large ferry total hrs.**							**75.2**	**15.5**	**Hours**

ENRG-A
No Project 2025 Non-Peak Ferry Times and Distances

	A	B	C	D	E	F	G	H	I	J	K
1		**Freqency**	**Time**	**Distance**	**AveSpd**	**Idle Time**	**Number of**	**Total Run Time/**	**Total Idle Time/**	**Total Distance/**	**Running Hours/**
2	**Ferry**	**(min)**	**(min)**	**(miles)**	**(mph)**	**(min)**	**Runs/Period**	**Period (min)**	**Period (min)**	**Period (miles)**	**Route**
3	90_FWALA	90	44	8.8	12	6.6	4.3	191	29	38	3.2
4	Alcatraz	60	10	4.00	17.3	5	6.5	65	33	26	
5	Alcatraz	60	10	4.00	17.3	5	6.5	65	33	26	2.2
6	90_OAKFW	90	45.12	8.8	11.7	6	4.3	196	26	38	3.3
7	91_LARKN	90	47.78	12.74	16	13.2	4.3	207	57	55	
8	91_LARKS	90	40.02	12.74	19.1	13.2	4.3	173	57	55	6.3
9	92_SSFW	99.99	37.31	5.41	8.7	9.6	3.9	146	37	21	
10	92_SSFW-	99.99	37.31	5.41	8.7	9.6	3.9	146	37	21	
11	92_SSLTO	90	30.04	7.66	15.3	9.6	4.3	130	42	33	
12	92_SSLTO-	90	30.04	7.66	15.3	9.6	4.3	130	42	33	9.2
13	93_TIBFW	99.99	34.91	5.47	9.4	9.6	3.9	136	37	21	
14	93_TIBFW-	99.99	34.91	5.47	9.4	9.6	3.9	136	37	21	4.5
15	94_VALFB	90	54.93	26.55	29	6.2	4.3	238	27	115	
16	94_VALFB-	90	54.93	26.55	29	6.2	4.3	238	27	115	7.9
17											
18	**Total Min.**							**2196**	**521**		
19	**Total Hrs.**							**36.6**	**8.7**	**Hours**	

ENRG-A
No Project 2025
Peak Ferry Times and Distances

	A	B	C	D	E	F	G	H	I	J	K
1 2	**Ferry**	**Freqency (min)**	**Time (min)**	**Distance (miles)**	**AveSpd (mph)**	**Idle Time (min)**	**Number of Runs/Period**	**Total Run Time/ Period (min)**	**Total Idle Time/ Period (min)**	**Total Distance/ Period (miles)**	**Running Hours Route**
3	90_FBALA	40	34.94	7.86	13.5	6.6	9.00	314	59	71	
4	Deadhead							15			5.5
5	Alcatraz	60	10	4.00	17.3	5	6.00	60	30	24	
6	Alcatraz	60	10	4.00	17.3	5	6.00	60	30	24	
7	Deadhead							15			2.3
8	90_HBFB	99.99	29.03	9.87	20.4	6	3.60	105	22	36	
9	90_HBFB-	99.99	29.03	9.87	20.4	13.2	3.60	105	48	36	
10	Deadhead							60			4.5
11	90_OAKFB	60	29.42	7.11	14.5	13.2	6.00	177	79	43	
12	Deadhead							60			3.9
13	91_LARKN	60	47.78	12.74	16	13.2	6.00	287	79	76	
14	91_LARKS	30	40.02	12.74	19.1	13.2	12.00	480	159	153	
15	Deadhead							30			13.3
16	92_SSLTO	60	30.04	7.66	15.3	9.6	6.00	180	58	46	
17	92_SSLTO-	60	30.04	7.66	15.3	9.6	6.00	180	58	46	
18	Deadhead							30			6.5
19	93_TIBFB	50	21.79	6.9	19	9.6	7.20	157	69	50	
20	93_TIBFB-	50	21.79	6.9	19	9.6	7.20	157	69	50	
21	Deadhead							30			5.7
22	94_VALFB	60	54.93	26.55	29	6.2	6.00	330	37	159	
23	94_VALFB-	60	54.93	26.55	29	6.2	6.00	330	37	159	
24	Deadhead							30			11.5
25											
26											
27	**Total min.**							**3190**	**834**		
28	**Total hrs.**							**53.2**	**13.9**	**Hours**	
29											

APPENDIX TRAN-A

This information is summarized from the Metropolitan Transit Commission's (MTC's) Bay Area Transit Information web page (www.transitinfo.org), which provides a full description of existing Bay Area transit system routes and schedules, and hosts an interactive web-based personalized transit trip planner.

1.0 SCHEDULED BUS SERVICE

AC Transit

The Alameda-Contra Costa Transit District (AC Transit) serves Western Alameda and Contra Costa Counties, with transbay service to the San Francisco Transbay Terminal.

Altamont Commuter Express

The Altamont Commuter Express (ACE) is a new commuter train service providing two morning and two afternoon trains traveling between Stockton and San Jose, with additional stops in Lathrop/Manteca, Tracy, Livermore, Pleasanton, Fremont and Santa Clara.

American Canyon Transit

Bus service is operated by the City of American Canyon and the Napa County Transportation Planning Agency.

Benicia Transit

Provides local service in the City of Benicia with connecting service to Vallejo, Pleasant Hill BART, and Sun Valley Mall.

Cloverdale Transit

Provides fixed-route and demand-response service in the city of Cloverdale. It also has connections to Sonoma County Transit for intercity trips.

County Connection

This service is maintained by the Central Contra Costa Transit Authority. It serves Central Contra Costa County and provides with connections to Pleasanton and Antioch.

Dumbarton Express

Weekday express bus service across the Dumbarton Bridge, connecting Union City (BART), Fremont, Newark, Menlo Park and Palo Alto. Dumbarton Express service is provided through a consortium of AC Transit, BART, Union City Transit and Santa Clara Valley Transportation Authority.

Fairfield-Suisun Transit

Provides local service in the cities of Fairfield and Suisun City and Cordelia Villages. Provides express service between Fairfield, Vacaville, Davis and the Pleasant Hill BART station. Service between Fairfield, Solano College, Vallejo, and the El Cerrito Del Norte BART station is provided by Vallejo Transit.

Golden Gate Transit

Golden Gate Transit provides daily bus service within Marin, Sonoma, San Francisco and Contra Costa counties.

Greyhound

Greyhound provides inter-city coach service between Bay Area cities and beyond.

Healdsburg In-City Transit

Provides fixed-route service in the city of Healdsburg. It also has connections to Sonoma County Transit for intercity trips.

Lake Transit

Provides fixed-route and demand-responsive bus service in Lake County, with connections from Route 3 to Napa Valley Transit in Calistoga (Lincoln and Napa River and Bothe-Napa State Park).

Mendocino Transit

Provides local and rural service in Mendocino County with connecting service to Santa Rosa via U.S. 101 and S.R. 1. Rural service in Mendocino County is also provided by Mendocino Stage and the California Western Railroad (the famous "Skunk").

Napa Valley Commute Club

Napa Valley Commute Club (NVCC) is a nonprofit organization that has been providing commuters with an alternative to driving to and from San Francisco for over 20 years. NVCC provides bus service into San Francisco each weekday morning and back home each afternoon. Morning stops are at three convenient locations in the City of Napa.

Petaluma Transit

Provides local service in the City of Petaluma and connections to Sonoma County Transit for intercity trips.

SamTrans

SamTrans provides service throughout San Mateo County with connecting service to San Francisco, the Transbay Terminal, and Palo Alto.

San Benito County Transit

Provides shuttle bus service between Hollister, San Juan Bautista, Salinas, and South Santa Clara County, as well as Dial-A-Ride service and Rideshare matching.

San Francisco Muni

Provides bus, streetcar, and cable car service in the City of San Francisco.

San Joaquin Regional Transit (SMART)

SMART operates local and express service in Stockton. Connections can be made to French Camp, Lathrop, Manteca, and Tracy via County Area Transit. SMART also provides interregional commuter routes serving the Bay Area.

Santa Clara VTA

Santa Clara Valley Transportation Authority (VTA) provides bus and light rail service in Santa Clara County. Jointly operates Highway 17 Express with Santa Cruz Metro.

Santa Rosa CityBus

Provides local service in the City of Santa Rosa. Connections to Sonoma County Transit and Golden Gate Transit are available at the Santa Rosa Transit Mall.

Sonoma County Transit

Provides intercity service in Sonoma County and local service in Rohnert Park, Cotati, Guerneville, Sebastopol and Windsor.

St. Helena VINE

Provides local service in the City of St. Helena and to Deer Park at St. Helena Hospital. Connections to VINE at St. Helena City Hall (northbound side) and Main at Pope Streets (southbound side) in downtown St. Helena, and to Lake Transit at St. Helena Hospital.

Tri Delta Transit

Eastern Contra Costa Transit Authority (ECCTA, Tri Delta Transit) provides local service in Shore Acres, Bay Point, Pittsburg, Antioch, Oakley and Brentwood. Connections to BART at Pittsburg/Bay Point BART station. Connection to County Connection Route 930 is at Hillcrest Park and Ride or County East Mall.

Union City Transit

Union City Transit is Union City's own bus system operating within the city limits. Routes are coordinated with BART trains, AC Transit, and the Dumbarton Express to areas outside of the City. Main transfer points are at the Union City BART station and Alvarado and Dyer.

VINE

The VINE is the Napa County region's fixed route bus service along Highway 2, operating seven days a week. VINE service is provided by the Napa County Transportation Planning Agency.

Vacaville City Coach

Provides local service in the City of Vacaville.

Vallejo Transit

Provides local service in the city of Vallejo and express service between Solano County, Vallejo, Hercules and the El Cerrito Del Norte BART station. Vallejo Transit also operates the Vallejo Baylink Ferry between San Francisco, Angel Island, and Vallejo.

VTA

Santa Clara Valley Transportation Authority (VTA) provides bus and light rail service in Santa Clara County. It jointly operates Highway 17 Express with Santa Cruz Metro.

WHEELS (LAVTA)

WHEELS is a service of the Livermore Amador Valley Transit Authority (LAVTA) and serves the communities of Dublin, Livermore, and Pleasanton. WHEELS service is centered around the Dublin/Pleasanton BART station and the Livermore Transit Center.

WestCAT

Provides service in Pinole, Hercules, and neighboring communities. Express service to El Cerrito Del Norte BART station is provided weekdays, weekends and holidays. Local fixed route service operates on weekdays, with some Saturday service.

Yolobus

Yolobus operates local and express bus service 365 days a year in Yolo County and to downtown Sacramento. Yolobus connects with UC Davis Unitrans and Citylink in Davis and with Sacramento Regional Transit District buses and Light Rail in Sacramento.

Yountville Shuttle

Provides local service in the Town of Yountville and the Veterans Home of California. Connections to VINE at Veterans Home and on Washington Street in downtown Yountville.

2.0 SHUTTLES, PARATRANSIT, AND DIAL-A-RIDE SERVICE

Brentwood Dimes-A-Ride

Dimes-A-Ride service is provided in Brentwood by Tri Delta Transit. Fares are partially subsidized by the City of Brentwood.

Broadway Shuttle

The Free Broadway Shuttle provides electric bus service along Broadway in Downtown Oakland between Kaiser Center and Jack London Square.

Calistoga Handy Van

This is the dial-a-ride service for City of Calistoga and provides countywide service for both non-ADA and ADA certified riders. Regional connections can be made to Vallejo Transit and Vallejo Baylink Ferry.

Emery Go-Round

A free shuttle connecting Emeryville's employers and shopping centers with MacArthur BART station. Service is provided on weekdays and Saturdays. The Emery Go-Round is funded by the City of Emeryville and local businesses.

Intercity Van Go

Intercity Van Go is the dial-a-ride service for Napa County, and provides countywide service for both non-ADA and ADA-certified riders. Regional connections can be made to Vallejo Transit and the Vallejo Ferry.

Marguerite Shuttle

This service connects Stanford University campus with various Palo Alto locations.

Menlo Park Midday Shuttle

The Menlo Park Midday Shuttle is a free service connecting points in Menlo Park, the Menlo Park Caltrain Station, Stanford Shopping Center, and Stanford Medical Center, and operates Monday through Friday from 10:00 a.m. to 2:30 p.m. Tuesday through Friday, the route is extended to include the Menlo Park Senior Center, the Belle Haven neighborhood, and the OICW Training Center.

Rio Vista Transit

Rio Vista Transit is a dial-a-ride service for the general public in the city of Rio Vista. Service is also provided to locations in Antioch, Fairfield, and Lodi.

VINE Go

VINE Go is the paratransit/dial-a-ride service for Napa County and provides countywide service for both non-ADA and ADA-certified riders. Regional connections can be made to Vallejo Transit and Vallejo Baylink Ferry.

West Berkeley Shuttle

West Berkeley Shuttle (formerly Berkeley Electric Shuttle Transit, or BEST) connects the Ashby BART Station with West Berkeley employment centers Monday through Friday during peak commute hour. WBS is provided by the Berkeley Gateway Transportation Management Association, the City of Berkeley, the Bayer Corporation, and Wareham Development.

WestCAT

Dial-a-Ride Transportation is available to seniors and to passengers with disabilities Monday through Saturday. General public Dial-a-ride service is available in Rodeo and Crockett weekdays, and throughout the service area on Saturdays

3.0 FERRY SERVICE

Alameda/Oakland Ferry Service

Ferry service between Alameda Main Street, Jack London Square, Oakland, San Francisco Ferry Bldg., San Francisco Pier 39 (Fisherman's Wharf), and Angel Island State Park.

Angel Island - Tiburon Ferry

Ferry service between Tiburon and Angel Island.
Service between San Francisco and locations around the Bay for both commute and pleasure trips. Blue & Gold Fleet also operates the Alameda/Oakland Ferry and the Vallejo Baylink Ferry.

Golden Gate Ferry

Golden Gate Ferry provides daily ferry service between Larkspur or Sausalito (Marin County) and San Francisco.

Harbor Bay Ferry

Ferry service from the Harbor Bay Isle Ferry Landing located at the end of Harbor Bay Parkway on Bay Farm Island (City of Alameda) to the San Francisco Ferry Building. Travel time is approximately 25 minutes.

Red and White Fleet

Since 1892, the Red and White Fleet has been providing service around the bay for both commuter and pleasure trips. Red and White Fleet Ferries operates ferry service to the U.S.S Aircraft Carrier Hornet on Alameda Point. The Richmond Ferry no longer operates.

Vallejo Baylink Ferry

The Vallejo Baylink Ferry provides service between San Francisco and Vallejo with connection service to Marine World. Baylink is operated by Vallejo Transit.

Table 3.12-2 in Section 3.12 of the Program EIR summarizes existing water transit service in San Francisco Bay. Current routes are presented in Figure in Section 2 of the Program EIR.

4.0 RAIL SERVICE

Amtrak California/Capitol Corridor

Amtrak provides intercity passenger rail throughout the country. The Capitol Corridor connects the cities of Auburn, Sacramento, Oakland and San Jose. It provides 18 daily trips between Sacramento and Bay Area stations. Amtrak California, a partnership between Amtrak and Caltrans (the State Department of Transportation), provides additional intercity rail and bus service within California.

ACE

The Altamont Commuter Express (ACE) train serves Stockton, Lathrop/Manteca, Tracy, Livermore, Pleasanton, Fremont, Santa Clara, and San Jose.

BART

The Bay Area Rapid Transit (BART) operates rail service in San Francisco and the East Bay.

Caltrain

Provides commuter rail service along the San Francisco Peninsula, with 26 stations between San Francisco and Gilroy via San Jose. Bus connection is available to Santa Cruz. Passenger service on the Peninsula corridor began in 1863 under the authority of the San Francisco and San Jose Railroad Company. Later, the Department of Transportation, Caltrans assumed responsibility for the line. In 1987 the Peninsula Corridor Joint Powers Board (JPB) was formed with SamTrans as its administrative arm. The JPB assumed operating responsibility for Caltrain in 1992.

Muni

Light rail service along five lines within the City of San Francisco.

VTA Light Rail Service

Service between South San Jose and the Great America Industrial Area of Santa Clara via the San Jose Civic Center.

APPENDIX CUL-A

This appendix contains a shipwreck index and overview of cultural resources in the study area.

1.0 STATE LANDS COMMISSION SHIPWRECK FILE

The following is a list of shipwrecks located in the vicinity of proposed ferry sites.

Location	Longitude	Latitude	Name of Shipwreck
Oakland Wharf	-	122° 22'	Great Western
Government Island, Oakland Estuary	37° 47'	122° 15'	Golden Gate, Edwin May, Alven Besse, James Rolph Jr., Simla, Ruth, and Star of Vancouver
Oakland Wharf	37° 48'	122° 15'	Friedebergh and Herald
Point Richmond	37° 54'	122° 23'	Adele Hobson and Associated Oil #8
Antioch	38° 00'	122° 48'	Forrester
Pittsburg Landing	38° 01'	121° 51'	Leader
Pittsburg	38° 01'	121° 52'	Charles B. Kennedy, Golden Shore
Point Benicia and Martinez	38° 02'	122° 11'	Sacramento
Angel Island	37° 51'	122° 27'	New England
In SF Bay, near Angel Island	37° 51'	122° 27'	Seven Sisters and Benton
Sausalito	37° 51'	122° 28'	Service, Aloha and Caroline
San Rafael Canal	37° 58'	122° 27'	Maryland, Novato and Annie
Clay Street Wharf	37° 46'	122° 23'	Mary Ellen
Presidio Wharf	37° 48'	122° 28'	Golden Rule
Alcatraz	37° 49'	122° 25'	McPherson
Alcatraz	37° 49'	122° 27'	Fernstream
Near Alcatraz	37° 49'	122° 28'	Oliver Cutts
At Half Moon Bay	37° 29'	122° 28'	At least 10 ships located here.

For the locations listed below, refer to Figures 2-1, 2-2, and 2-3 and the discussion of the corresponding project alternatives in Section 2 of the program Environmental Impact Report (EIR). Numerical assignment in parentheses indicates the location of existing and potential new ferry terminals noted on Figures 2-1, 2-2, and 2-3.

Descriptions of known shipwrecks listed in the California State Lands Commission Database (California State Lands Commission n.d.) were examined. One shipwreck is listed in the "Carquinez Straits" (the *Uncle Abe*), and another is listed as "between Benecia and Martinez" (the *Sacramento*). The database does not clarify their locations in relation to the ferry routes or terminals examined in this EIR.

2.0 CULTURAL RESOURCES OVERVIEW

Marin County

Larkspur (1)

- **Location:** Southeast of the intersection of Highway 101 and East Sir Francis Drake Boulevard. This is an existing and functioning ferry terminal.
- **Wharves:** Steamboats and ferries have been functioning in this area since 1850 by way of Corte Madera Creek. This area was also a busy terminal on the Northwest Pacific Railroad. Although it is likely most of the older wharves associated with this use are now gone, portions of wharves or piers may still be extant from this long period of use.
- **Piers:** see Wharves.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Tiburon (2)

- **Location:** Paradise Drive and Main Street. This is an existing and functioning ferry terminal.
- **Wharves:** None recorded.
- **Piers:** Piers were established in this area for the Railroad-Ferry Depot circa 1900. Most have been destroyed, but the area may still contain remains of pier construction.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The Railroad-Ferry Depot (c. 1900) for the railroad-ferry yards and piers at Point Tiburon is the only dual-use terminal to survive west of the Hudson River. The depot is on the National Register of Historic Places. Near the ferry site on Main Street is the McNeil Building, constructed in 1886 and the first structure built on water side of the street. The McNeil building may be considered eligible for the National Register.
- **Other:** None recorded.
- **Prehistoric:** Nelson shellmound No. 41 noted in Belvedere Cove.

Sausalito (3)

- **Location:** Bridgeway at Anchor Street. This is an existing and functioning ferry terminal.
- **Wharves:** Sausalito waterfront was widely known as an anchorage and supply station for whaling vessels and military transportation. The Sausalito Land and Ferry Company built

wharves to transport ferries and people to San Francisco area in the mid-1850s, therefore the wharves and any remains of wharves may be considered historic.

- **Piers:** None recorded.
- **Shipwrecks:** Recorded in the vicinity are the shipwrecks of the *Service*, the *Aloha*, and the *Caroline*.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** A former dry dock cassion is located here but was rendered not eligible to National Register in 1987; however, the dry dock cassion may continue to act as an obstruction in the water.
- **Prehistoric:** Archaeological site at Caledonia and Pine Street, CA-Mrn-3. None recorded.

San Rafael (30)

- **Location:** Location not specifically defined.
- **Wharves:** Yacht Harbor located in San Rafael.
- **Piers:** None recorded.
- **Shipwrecks:** Recorded in the vicinity are the wrecks of the *Maryland,* the *Novaso*, and the *Annie*.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** Nelson shellmounds No. 93, 94, 91, 31, 7 identified.

Angel Island (5)

- **Location:** Ayala Cove on north side of island. This is an existing and functioning ferry terminal.
- **Wharves:** From 1863-1946, Angel Island was used as an Army base, Fort McDowell. The East Garrison station was a major induction station. A quarantine station was built in 1888 at Hospital Cove (Ayala Cove), and Angel Island became a major immigration and public health facility ("Ellis Island of the West") until 1946. During World War II approximately 87,000 troops passed through here on way to Pacific front. Prisoners of war were interned here as well. Wharves, piers, or docks may be extant from this long period of use. Angel Island became a state park in 1955.
- **Piers:** see Wharves.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The Angel Island U.S. Immigration Station is listed on the National Register and is part of the Golden Gate National Recreation Area.
- **Other:** None recorded.

- **Prehistoric:** A report notes a "steeply sloping shell midden on what may have been a natural terrace." Nelson shellmound No. 45 identified in area.

Fort Baker (8)

- **Location:** Horseshoe Bay, just east of the Golden Gate Bridge.
- **Wharves:** Fort Baker has been occupied by the military since 1850. Wharves, piers or docks may be extant from this long period of occupation.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc):** Fort Baker is now part of the Golden Gate National Recreation Area and is listed on the National Register. Many potentially historic houses are located in Fort Baker, in particular many built between 1901 and 1904.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Contra Costa County

Martinez (24)

- **Location:** In the vicinity of the Martinez Yacht Harbor at the end of Court Street.
- **Wharves:** Martinez was a center for wheat shipping until the railroad came through in 1879. It was also the southern terminus for the busy ferries that crossed Carquinez Strait from Benicia until the Benicia-Martinez bridge was opened in 1960. With this long period of use, associated wharves, piers, docks, or their remains may be present and should be considered historic.
- **Piers:** See wharves.
- **Shipwrecks:** Recorded in the vicinity is the shipwreck of the *Sacramento* and *Uncle Abe*.
- **Designations (National Register, National Register eligible, etc.):** Martinez Historic District is centered on Main and Ferry Street.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Pittsburg (26)

- **Location:** At the Pittsburg Marina/Central Harbor, accessed via Marina Boulevard.
- **Wharves:** Railroad and wharves were built in Pittsburg in the early 1860s to facilitate transportation of coal from mines to Pittsburg and New York Landing. The associated wharves, piers, or railways may be extant in area and may be considered a historic resource.

- **Piers:** None recorded.
- **Shipwrecks:** Wreck noted off of electrical transmission substation, recorded wrecks of the *Forester*, the *Charles B. Kennedy*, and the *Golden Shore*.
- **Designations (National Register, National Register eligible, etc.):** Historic District of New York Landing is listed on the National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Crockett (27)

- **Location:** Location not specifically defined.
- **Wharves:** Crockett has served as the company town of California and Hawaiian Sugar Refinery for many years. Historic wharves, piers, or docks associated with this company may still exist near the project location.
- **Piers:** See wharves
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The California and Hawaiian Sugar Refinery may be considered eligible to the National Register.
- **Other:** None recorded.
- **Prehistoric:** One report noted that Crockett was once the site of a Native American village. None recorded.

Hercules/Rodeo (28)

- **Location:** Unspecified location along San Pablo Bay.
- **Wharves:** Hercules began as the California Powder Works company town in 1881. The potent and explosive black powder produced in Hercules was first used in World War I. In 1917, after the U.S. had entered the war, the Hercules plant became the largest producer of TNT in the country. In the 1960s, the plant transitioned to the production of fertilizer. The plant was sold in 1976 and closed permanently in 1977 due to economic factors. It remained idle until 1979 when it was purchased by a group of investors. There may be historic wharves, piers, or docks associated with the California Powder Works and/or the fertilizer plant near the project location.
- **Piers:** see Wharves.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The fertilizer plant may be considered eligible to National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Point Molate (29)

- **Location:** Location not specifically defined.
- **Wharves:** Located at Point Molate was Winehaven (built in 1911), said to be the largest winery in the United States. The area is now known as the U.S. Naval Fuel Supply Depot. Wharves, piers or docks may remain that were associated with Winehaven and/or the U.S. Naval Fuel Supply Depot.
- **Piers:** None recorded.
- **Shipwrecks:** Possible shipwreck right of Point Molate pier; recorded shipwrecks of the *Adele Hobson* and the *Associated Oil #8*.
- **Designations (National Register, National Register eligible, etc.):** In 1978, Winehaven was added to the National Register (also know as Point Molate; Fuel Department; NSCO).
- **Other:** Point Molate Beach is the location of a Chinese shrimp village. Docks or associated building remnants may be located in this area. Point Molate is part of the U.S. Naval Fuel Supply Depot.
- **Prehistoric:** Three archaeological sites are recorded in the area. Nelson shellmound identified at edge of Point Molate.

Antioch (46)

- **Location:** No location specified.
- **Wharves:** Ferry service from Antioch to Sherman Island was established here by the Lauritzen brothers to transport people and later cars throughout the Delta. The ferry service thrived until in 1926 when it was replaced by the Antioch Bridge. Wharves, piers or docks may remain that were associated with the ferry service.
- **Piers:** Piers or docks associated with the ferry service may still be extant.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Richmond (4)

- **Location:** Harbor Way South/Scott Avenue. This is an existing terminal but service has been suspended.
- **Wharves:** In the early 1900s, shipyards grew along Richmond's South Shoreline, and by World War II Kaiser Richmond Shipyards was one of the biggest wartime shipbuilding operations on the West Coast. It closed in 1945, but many buildings and auxiliary structures are still located in the area. To the north of the Inner Harbor Basin is the Richmond Shipyard No. 3 on Harbor Channel. Above the Inner Harbor Basin is the Plate Shop of the Richmond Shipyard No. 2, and to the northeast of the Inner Harbor Basin is the Ship Ways of the

Richmond Shipyard No. 2. Most likely extant wharves, piers and docks are located here that are associated with the extensive shipyard history.

- **Piers:** See wharves.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Four industrial facilities, Plate Shop of Kaiser Shipyard, Prefabrication Plant of Shipyard No. 2, Kaiser Shipyard No. 3, and Ford Motor Company Assembly Plant, were determined eligible for the National Register. The Filice & Perrelli Cannery may be eligible for the National Register as well.
- **Other:** None recorded.
- **Prehistoric:** Three prehistoric sites within Inner Harbor Basin Area. The former site of Ellis Landing is located near the top of Harbor Channel. The Ellis Landing shellmound at foot of Eleventh Street was the site of one largest shellmounds in the Bay Region. Nelson shellmound site No. 295 identified here. Coles and Loud also recorded shellmounds in this area.

Solano County

Vallejo/Mare Island (25)

- **Location:** 495 Mare Island Way in Memorial Park. This is an existing and functioning ferry terminal.
- **Wharves:** Wharves and piers are associated with existing ferry service
- **Piers:** see wharves
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Buildings just north of the project site have been surveyed and determined eligible for the National Register. The ferry site is near Memorial Park. Vallejo served as the state capitol in 1852. Near the existing ferry site is the Vallejo City Hall and County Building Branch at 734 Marin, listed on the National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Benicia (40)

- **Location:** Location not specifically defined but may be at terminus of First Street or Fifth Street.
- **Wharves:** In 1847 the town of Benicia was laid out by Dr. Robert Semple, who in 1849 established a ferry that provided continuous service from Benicia and Martinez for 115 years. Benicia was an important port of entry for many years. It has the advantage of deep water at

the shore where seagoing vessels could discharge their cargoes directly on land. At the water's edge are concretions, scattered old timbers and railroad ties. A wharf existed here in mid to late 1800s.

- **Piers:** Early pier pilings are abundant in several locations in both inland and tidal settings.
- **Shipwrecks:** A shipwreck (the 1843 Boston whaler *Stamboul*) is located northwest of the Benicia Point city wharf. Used as whaler in San Francisco until 1894 and moved to Carquinez Straits Shallows, it was used as a floating work platform until 1918.
- **Designations (National Register, National Register eligible, etc.):** Numerous historic resources within the project vicinity including at the end of First Street are the Lido Tavern, two historical markers, and a railway station. On the north side of the Marina is the Benicia Antique Shop, a historical marker, the "What Not" Shop (1848), Salt Box House (c. 1850), and the Washington House (1850) (Benicia's oldest hotel building), all considered historic sites. At the end of Fifth Street St. Dominic's Church (1854) is located about two blocks northwest of the end of Fifth Street which is also considered a historic resource.
- **Other:** None recorded.
- **Prehistoric:** A report states that exposed historic archaeological deposits are evident in areas near the shoreline. These include glass, ceramic, brick, sawn bone, and wood. Much of the area has been covered in man-made fill material for decades, isolating the cultural deposits and resulting in potential for the presence of significant historic features (foundations, privies, trash deposits). The report also notes the presence of two Native American shell middens. Nelson shellmounds have been identified at end of Fifth Street (No. 238) and near Gull Point (No. 237).

Alameda County

Berkeley/Albany (7)

- **Location:** Along the Berkeley waterfront.
- **Wharves:** The Berkeley Marina is one of the largest and oldest yacht harbors in the East Bay. It was constructed in 1935 and may have wharves associated with recreational boating.
- **Piers:** None recorded. Berkeley Pier nearby.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** The park area near the Berkeley Marina was created by capping a landfill site from the 1900s. None recorded.

Oakland Army Base (32)

- **Location:** Location not specifically defined.

- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Numerous buildings and structures within the Oakland Army Base have been listed on or determined to be eligible to the National Register or the California Register of Historic Resources. Two National Register Historic Districts are located within the Oakland Army Base, the Northeast OARB district and the Northwest OARB district. Both districts were identified and determined eligible for listing on the National Register as a result of the 1990 study for the Cypress structure replacement project by Caltrans. A separate report states that the Southern Pacific Interlocking Tower (built in 1919) is considered eligible to the National Register under Criteria A.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Oakland International Airport/Oakland Coliseum (42)

- **Location:** Unspecified, along east Bay shore.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The North Field of the Oakland International Airport is a local landmark district. A World War II training center, the U.S. Army Air Corps Mechanics Training Detachment may be eligible for listing on the National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Oakland Inner Harbor (47)

- **Location:** No location specified.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** Recorded near the harbor is the shipwreck of the *James Rolph Jr*., the *Simla*, the *Ruth,* and the *Star of Vancouver*.
- **Designations (National Register, National Register eligible, etc.):** A few potentially historic buildings are located along the Lake Merritt Channel, including a few early warehouse structures and Western Pacific Railroad trestles. Lake Merritt Channel Park is located along Lake Merritt Channel.

- **Other:** None recorded.
- **Prehistoric:** None recorded.

Alameda Point (13)

- **Location:** Seaplane Lagoon.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** Possible historic shipwrecks. Also possible that disabled aircraft associated with the operations of Alameda Naval Air Station (NAS) have been ditched within the project area.
- **Designations (National Register, National Register eligible, etc.):** This location is part of Alameda NAS.
- **Other:** Extensively dredged in the 1930s and 1940s for the naval facility. Historic resources are limited to potential submarine features associated with the heavy shipping traffic around the Oakland Harbors and possibly crashed aircraft.
- **Prehistoric:** Low probability of prehistoric resources because of extensive dredging. None recorded.

Alameda/Harbor Bay Isle (14)

- **Location:** Harbor Bay, Parkway and McCartney Rd. This is an existing and functioning ferry location.
- **Wharves:** New construction in project area.
- **Piers:** New construction in project area.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Portions of Harbor Bay Isle/Bay Farm Island were farmed until the 1930s; however, the island has been extensively altered for new residential development. The ferry site is constructed on recent fill.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Alameda-Main Street (15)

- **Location:** Main Street along Oakland estuary.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.

- **Designations (National Register, National Register eligible, etc.):** This location is part of Alameda NAS.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Jack London Square (16)

- **Location:** Foot of Clay Street, two blocks west of Broadway. This is an existing and functioning ferry terminal.
- **Wharves:** All of the development in this area is of recent construction.
- **Piers:** None recorded.
- **Shipwrecks:** Recorded near the wharf are the shipwrecks of the *Great Western*, the *Golden Gate*, the *Besse*, the *Edwin May*, and the *Alven.*
- **Designations (National Register, National Register eligible, etc.):** U.S.S. Potomac, which is on the National Register, sits near the edge of the site. Also on the National Register is the Pacific Gas and Electric (PG&E) Building at 1625 Clay Street. A potentially eligible historic structure is the PG&E substation located at 689 Second Street. Located at 552-592 Second Street is the Oakland Iron Works-United Works and the Remillard Brick Company, which is listed on the National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

San Leandro Marina (17)

- **Location:** Unspecified, but likely at San Leandro Marina.
- **Wharves:** The San Leandro Marina prospered during the 1890s with the oyster industry. Seed oysters were brought around the Horn and implanted in the San Leandro oyster beds. The industry diminished after 1911 because of pollution of San Francisco Bay. Remnants of this industry may still be present in the project area.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded. Nelson shellmounds Nos. 324 and 325 identified north of the Marina.

San Mateo County

San Francisco International Airport (18)

- **Location:** Unspecified location.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** The *Port Costa* was recorded off of South San Francisco; however, potential for additional shipwrecks is high due to the level of maritime activity.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** Aircraft remains may be located in project area due to proximity of airport.
- **Prehistoric:** None recorded.

Oyster Point (19)

- **Location:** End of Oyster Point Boulevard in Oyster Point Marina/Park.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Half Moon Bay (43)

- **Location:** Location unspecified.
- **Wharves:** Although Half Moon Bay has been home to whalers, dairymen and farmers, the location is unspecified, so no cultural resources have been recorded. However, cultural resources association with these industries should be anticipated.
- **Piers:** None recorded.
- **Shipwrecks:** Ten shipwrecks recorded in the vicinity.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** One report states that caches of historic artifacts, trash or privy pits, architectural or foundation remnants may remain. Possible that subsurface resources may exist and/or may be obscured by recent cultural or natural factors.
- **Prehistoric:** None recorded.

Redwood City (21)

- **Location:** Unspecified, Redwood Creek along Harbor Boulevard.
- **Wharves:** A natural shipping point was established where the slough emptied into the Bay. Lumber became an important industry at this locale. Although no resources have been recorded, due to the shipping history, wharves, piers, or docks may exist in this area.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Santa Clara County

Moffett Field (22)

- **Location:** Unspecified, along south Bay shore.
- **Wharves:** None recorded.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Moffett Field is a National Register Historic District under the name U.S. Naval Air Station Sunnyvale, California, Historic District. Near this district is potential to encounter further historic archaeological deposits associated with Old Whelan Farm or other farm structures.
- To the east of Moffett Field is a site in the Bay water that has been designated a San Francisco Bay National Wildlife Refuge.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Coyote Point (35)

- **Location:** Location unspecified.
- **Wharves:** During the latter half of the 19th and first half of the 20th centuries, the western side of the point was home to a series of commercial and recreational piers and wharves. In 1868, a wharf for the Wisnom Lumber Company was constructed on the northwestern side of Coyote Point. By the 1930s, the eastern side of the point was used as a popular small craft anchorage, and the County of San Mateo responded by building a small marina here in the 1940s. During World War II, Coyote Point served as a U.S. Merchant Marine Cadet School. Due to the long period of activity in this area, wharves, piers or docks may be associated with the project area.

- **Piers:** see Wharves.
- **Shipwrecks:** An old Scow wreck of the *Daisy Gadsby*, built in 1911, was placed near the marina to create an artificial breakwater. World War II concrete barges from Richmond Shipyards were moved here and are currently used as fuel docks and offices.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** In 1922 this site became home to the Pacific City Amusement Park, the "Coney Island of the West," which closed the following year due to bankruptcy.
- **Prehistoric:** Evidence of an isolated burial. Many Nelson shellmounds identified in vicinity. Shellmounds documented by Hamilton are also identified in the vicinity including sites C-788, C-787 and C-786.

Foster City (36)

- **Location:** Location unspecified
- **Wharves:** Brewer's Island, upon which Foster City was eventually established, was originally developed for dairy purposes in the early 1900s by Frank M. Brewer. In the late 1950s, the land was owned by the Leslie Salt Company and the Schilling Estate. At this time, the planned community of Foster City was established. It was an engineering challenge to create Foster City from the marshlands of Brewer's Island, but by 1964 the first home was built in Foster City. Therefore, no wharves, piers or docks are considered historic resources, however, the land and environs have had a long period of use.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

East Palo Alto (37)

- **Location:** Location unspecified
- **Wharves**: Ravenswood (later changed to East Palo Alto) Point was unique along the Peninsula in that it offered a dry land port accessible from deep water. A long wharf was built, and the town of Ravenswood began to grow on an economy driven by shipping. In 1863, Lester Cooley purchased the wharf and renamed it Cooley's Landing. Although nothing remains of the wharf, nonvisible underwater portions may be extant.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.

- **Prehistoric:** None recorded.

San Francisco County

Mission Bay (12)

- **Location:** Unspecified, adjacent to the Mission Bay Redevelopment Area.
- **Wharves**: In the 1880s and 1890s, lumber and hay were the predominant cargo brought into Channel Street, which formed the northern boundary of Mission Bay. Steamboat Point had a shipyard and later boatbuilders who constructed steam schooners, square-rigged sailing vessels, and yachts. The boatbuilders eventually moved south as the hay and lumber business boomed. Waterlots were sold and some owners drove 80-foot pilings to create fences on the property. Others sank wooden vessels to become “improvements intended as fill” and validate their ownership claims. Piers and bulkheads reached out to enclose the waterlots, which were filled with log cribbing to hold rocks, sand, and dirt. Pile drivers operated day and night as piers spread into the bay. Millions of cubic yards of fill extended the waterfront farther east. By 1867, a causeway had enclosed two-thirds of Mission Bay. With this extensive period of use and fill, associated wharves, piers, pilings, docks, or their remains may be present and should be considered historic.
- **Piers:** See wharves
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** Del Monte Fruit built the China Basin cannery warehouse in 1925 with railroad spur tracks to unload banana boats that came into the channel directly into railroad freight cars. This area is now under redevelopment by University of California, San Francisco.
- **Prehistoric:** None recorded.

China Basin/Pac Bell Park (11)

- **Location:** South of Pac Bell Park on the Mission Street Channel.
- **Wharves:** The history of the site is similar to Mission Bay; however, much of the area has been altered due to the addition of the new ballpark. With the extensive period of use and fill, associated wharves, piers, pilings, docks, or their remains may be present and should be considered historic.
- **Piers:** see Wharves
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** The China Basin cannery warehouse was built in 1925 by Del Monte Fruit with railroad spur tracks to unload banana boats that docked into the channel and loaded directly into railroad freight cars. This area is now under redevelopment by University of California San Francisco.

- **Prehistoric:** None recorded.

Presidio (10)

- **Location:** Location unspecified.
- **Wharves:** The Presidio has been in military control under the Spanish, Mexican, and U.S. armies for over 200 years. Today, the Presidio is part of the National Park Service. Many historic wharves or piers may be present in this area due to the extensive period of use.
- **Piers:** None recorded.
- **Shipwrecks:** Recorded in the vicinity is the shipwreck of the *Golden Rule*.
- **Designations (National Register, National Register eligible, etc.):** The Presidio is a National Historic Landmark and part of the Golden Gate National Recreation Area.
- **Other:** None recorded.
- **Prehistoric:** An archaeological site of an 1858 dump and a 20th century residential dump near a small pier was noted, along with many other archaeology sites. None recorded.

San Francisco Pier 41/43 (9)

- **Location:** The Embarcadero at the foot of Powell Street. This is an existing and functioning ferry terminal.
- **Wharves:** This area has been an integral part of shipping for the San Francisco area for many decades. Therefore, wharves, piers or docks may be present in the area due to the long period of use.
- **Piers:** Permanently docked on Pier 41 East is the *Balclutha* (Star of Alaska) ship.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The *Balclutha* is on the National Register of Historic Places.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Treasure Island (6)

- **Location:** Unspecified location.
- **Wharves:** Treasure Island is a man-made island constructed in 1939-1940 for the Golden Gate International Exposition. It was later taken over by the U.S. Navy. Wharves, piers, docks, or their remains may still be extant from naval use.
- **Piers:** see Wharves.
- **Shipwrecks:** None recorded.

- **Designations (National Register, National Register eligible, etc.):** Building 3, the aircraft hangar, is potentially eligible to the National Register based on its association with the Golden Gate International Exposition. The building was used as the Palace of Fine and Decorative Arts during the Exposition. Treasure Island is a former Naval Reservation.
- **Other:** None recorded.
- **Prehistoric:** Low probability of prehistoric remains due to dredging for construction of island in the 1930s; however, there are prehistoric sites on adjacent Yerba Buena island. None recorded.

San Francisco Ferry Building (20)

- **Location:** On the Embarcadero at the foot of Market Street. This is an existing and functioning ferry terminal.
- **Wharves:** The Ferry Building has an extensive history of transporting people to and from various areas in the Bay Area. A report states there is no evidence of Gold Rush wharves, buried hulks or trash deposits under or adjacent to the footprint of the Ferry Building. The report does state that possible trash and disassociated artifacts may have been lost or discarded off the far ends of the historic wharves during the Gold Rush or City Building Period, but these would be disassociated materials of limited scientific value. The project area could contain remains of wharves, piers, or docks.
- **Piers:** See Wharves.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** The Ferry Building, built in 1896-1903, is on the National Register of Historic Places. The Ferry Station Post Office Building (also known as the Agricultural Building) is also on the National Register of Historic Places. The Ferry Building rests on the east side of the New Seawall, which may be eligible for nomination to the National Register.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Fort Mason (31)

- **Location:** Location unspecified.
- **Wharves:** Starting in 1797 and lasting through the Spanish and Mexican period, Fort Mason was one of two sites in the Bay that was armed for defense of the harbor. It also served as an important element in the first submarine mining of the Bay, in the Spanish-American War. From the Spanish-American War to the Korean Conflict, Fort Mason's role was the headquarters of the San Francisco Port of Embarkation, which concentrated the various branches of supply operations serving the garrisons of new U.S. possessions in the Pacific. Due to the significant and changing military history, wharves, piers or docks may be extant or underwater, but should be considered historic resources.

- **Piers:** The last Liberty ship from World War II, the *Jeremiah O'Brien*, is moored at one of the Fort Mason Piers.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** Fort Mason Historic District is listed on the National Register. The Old Parade Route and MacArthur Avenue contribute to the listing on the National Register. Fort Mason is the headquarters for the Golden Gate National Recreation Area.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Hunters Point (33)

- **Location:** Unspecified, at Hunters Point Shipyard.
- **Wharves:** The function of shipbuilding and repair had dominated the development of Hunters Point from the 1860s until 1945 when the Navy used the site while preparing to enter into World War II. Most of the flat land was created by cut-and-fill work undertaken by the Navy during World War II. Approximately half of the buildings were constructed during this period as well.
- **Piers:** None recorded.
- **Shipwrecks:** Decaying ships were beached in the shallows off the north side of Hunters Point. In 1930s it was noted that five historic ships sat rotting in the cove west of the point, but Navy filling during World War II may have destroyed these ships. They should be taken into consideration as potential historic resources.
- **Designations (National Register, National Register eligible, etc.):** Hunters Point Commercial Dry Docks Historic District comprises eight buildings and wharves in the area. A 1988 report concluded that three properties meet the criteria for National Register Listing: Dry Dock No. 1, treated as archaeologically sensitive area and potentially contributing element to the historic district, Drydock No. 4; and Building 253, Ordnance and Optical Building. Hunters Point is also a U.S. Naval Reservation.
- **Other:** None recorded.
- **Prehistoric:** A report states that four potentially archaeological sensitive zones including possible prehistoric shellmounds, early settlement and commercial development, industrial resources, Chinese shrimp camps, maritime resources, and 20th century landfills are present in the area. None recorded.

Candlestick Point (34)

- **Location:** Location not specifically defined.
- **Wharves:** None recorded.
- **Piers:** A report states that the Thomas Avenue Pier was located in the area as well as the Carroll Avenue Pier. The Empire Lead Mill Company Pier appears to have been razed or

buried during the 1940s, but remains of the pier may still exist below ground surface. Remains of piers and or wharves may be located in this area and, if found, would be considered a historic resource.

- **Shipwrecks:** Wrecks noted on U.S. Geological Survey map. A report states that the burnt hull of a wooden sailing vessel is exposed in Bay mud and is reasonably well preserved. A different report states that maritime resources in the form of sunken or abandoned late 19th or early 20th century vessels may be found deeply buried below South Basin and Visitation Cove fill. These would consist of Chinese junks, scow schooners, barges, and other small vessels.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** The "powder houses" associated with the Carroll Avenue Pier may exist below several feet of fill.
- **Prehistoric:** None recorded. Two Nelson shellmounds, Nos. 7 and 8, identified in area.

Alcatraz Island (38)

- **Location:** Northeast side of island. This is an existing and functioning ferry terminal.
- **Wharves:** Alcatraz has an extensive history, beginning as a military compound from 1850-1933. From 1934-1963, it was a federal prison and then occupied by Native Americans from 1969 to 1971. Alcatraz is currently a national park. Due to the extensive history, extant or remains of wharves, piers or docks may be considered historic resources.
- **Piers:** None recorded.
- **Shipwrecks:** Recorded in vicinity is the shipwreck of the *Fernstream,* the *McPherson*, and the *Oliver Cutts*.
- **Designations (National Register, National Register eligible, etc.):** Alcatraz is listed on the National Register and is part of the Golden Gate National Recreation Area.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Sonoma County

Gnoss Field (44)

- **Location:** Northeast of Novato along the Petaluma River.
- **Wharves:** This area was used for shipping from the Mexican Period onward. Specifically, the area became an important source of grain, which was then exported to San Francisco. About a mile from the site is the former Donahue's Landing, which provided a successful ferry operation to San Francisco for over a decade staring in 1872. There may be historic resources associated with manufacturing on the site including hide tanning, tallow, and winery operations during 1847-1900. Due to the shipping and manufacturing history, there may be extant or remains of wharves, docks or piers, which may be considered historic.

- **Piers:** see Wharves
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded.

Port Sonoma (45)

- **Location:** Port Sonoma Marina, along the Petaluma River.
- **Wharves:** Ferries once traveled up the Petaluma River regularly but due to the siltation problem at the marina, the ferry line was eliminated. There may be wharves, piers, or docks associated with the project area.
- **Piers:** None recorded.
- **Shipwrecks:** None recorded.
- **Designations (National Register, National Register eligible, etc.):** None recorded.
- **Other:** None recorded.
- **Prehistoric:** None recorded. Numerous Nelson shellmounds identified at Petaluma Point.

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APPENDIX LU-A

Appendix LU-A: Agencies Contacted

Location	First Name	Last Name	JobTitle	Company	Address1	City	State	Postal Code
Vallejo	Brian	Dolan	Planning Manager	Vallejo City Hall	555 Santa Clara Street, Second Floor	Vallejo	CA	94590
9th Street	Leslie	Gould	Director	Oakland Planning and Zoning	250 Frank Ogawa Plaza #2114	Oakland	CA	94612
Alameda Point	Cynthia	Eliason	Planning Manager	Alameda Planning and Building Department	2263 Santa Clara Ave, Rm 190	Alameda	CA	94501
Alameda	Cynthia	Eliason	Planning Manager	Alameda Planning and Building Department	2263 Santa Clara Ave, Rm 190	Alameda	CA	94501
Antioch	Joseph	Brandt	Director	Antioch Community Development Department	PO Box 5007	Antioch	CA	94531-5007
Benicia	Karen	Majors	Interim Director/ Assistant City manager	Benicia Planning Department	City Hall 250 East L Street	Benicia	CA	94510
Berkeley/Albany	Andrew	Thomas	Planner	Berkeley Planning and Development Department	2118 Milvia Street, Suite 300	Berkeley	CA	94704
Candlestick	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Coyote Point	Ron	Munekawa	Chief of Planning	City of San Mateo	330 West 20th Avenue	San Mateo	CA	94403
Crockett	Catherine	Kutsuris	Deputy Director of Current Planning	Contra Costa County, Community Development Agency	651 Pine Street, 4th Floor, North Wing	Martinez	CA	94553
East Palo Alto	Lori	Reese-Brown	Senior Planner	East Palo Alto Community Development Department, Planning Division	2200 University Avenue	East Palo Alto	CA	94303
Ferry Building (SF)	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Foster City	Richard	Marks	Director	Foster City Community Development Department	610 Foster City Blvd.	Foster City	CA	94404
Gnoss Field/Port Sonoma (Sonoma County)	Pete	Parkinson	AICP, Planning Manager	Sonoma County Permit & Resource Management Department	2550 Ventura Avenue	Santa Rosa	CA	95442
Half Moon Bay	Kenneth	Curtis	Planning Director	Half Moon Bay Planning Department	501 Main Street	Half Moon Bay	CA	94019
Harbor Bay Isle (Alameda)	Cynthia	Eliason	Planning Manager	Alameda Planning and Building Department	2263 Santa Clara Ave, Rm 190	Alameda	CA	94501

Appendix LU-A: Agencies Contacted

Location	First Name	Last Name	JobTitle	Company	Address1	City	State	Postal Code
Hunter's Point	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Jack London Square	Leslie	Gould	Director	Oakland Planning and Zoning	250 Frank Ogawa Plaza #2114	Oakland	CA	94612
Larkspur	Jan	Vasquez	Director	Larkspur Planning Department	400 Magnolia Avenue	Larkspur	CA	94939
Mare Island	Brian	Dolan	Planning Manager	Vallejo City Hall	555 Santa Clara Street, Second Floor	Vallejo	CA	94590
Martinez	Dina	Tasini	Deputy Director	Martinez Community Development Department	525 Henrietta Street	Martinez	CA	94553
Mission Bay	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Oakland Army Base	Leslie	Gould	Director	Oakland Planning and Zoning	250 Frank Ogawa Plaza #2114	Oakland	CA	94612
Oyster Point	Marty	Van Duyn	Director	South San Francisco Planning Division	PO Box 711	South San Francisco	CA	94083
PacBell Park/China Basin	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Pier 41-43	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Pittsburg	Randy	Jerome	Acting Director of Planning and Building	Pittsburg Community Development Department	65 Civic Ave.	Pittsburg	CA	94565
Point Molate (Richmond)	Martin	Jacobson	Planning Director	Richmond Planning Department	City Hall, 2nd Floor 2600 Barrett Ave	Richmond	CA	94804
Redwood City	Michael	Church	Planning Manager	Redwood City Planning and Redevelopment Agency	PO Box 391	Redwood City	CA	94063-0391
Richmond	Martin	Jacobson	Planning Director	Richmond Planning Department	City Hall, 2nd Floor 2600 Barrett Ave	Richmond	CA	94804
Rodeo	Catherine	Kutsuris	Deputy Director of Current Planning	Contra Costa County, Community Development Agency	651 Pine Street, 4th Floor, North Wing	Martinez	CA	94553
San Leandro Marina	Steve	Emslie	Director	San Leandro Planning Division	835 East 14th Street	San Leandro	CA	94577
San Rafael	Robert	Brown	Director	San Rafael Community	PO Box 151560	San Rafael	CA	94915-

Appendix LU-A: Agencies Contacted

Location	First Name	Last Name	JobTitle	Company	Address1	City	State	Postal Code
				Development Department				1560
Sausalito	Charlotte	Flynn	Director	Sausalito Community Development Department	420 Litho Street	Sausalito	CA	94965
SFO	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Tiburon	Scott	Anderson	Director	Tiburon Planning and Building Department	1505 Tiburon Blvd. Town Hall	Tiburon	CA	94920
Treasure Island	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
Alameda County	Adolph	Martinelli	Director	Alameda County Community Development Agency	224 W. Winton Ave., Rm 11C	Hayward	CA	94544
Contra Costa County	Catherine	Kutsuris	Deputy Director of Current Planning	Contra Costa County, Community Development Agency	651 Pine Street, 4th Floor, North Wing	Martinez	CA	94553
Marin County	Brian C.	Crawford	Deputy Director of Planning Services	Marin County Community Development Agency, Planning Division	3501 Civic Center Drive, Rm 308	San Rafael	CA	94903
Napa County	Jeffrey R.	Redding	Director	Napa County Conservation Development and Planning Department	1195 Third Street, Room 210	Napa	CA	94559
San Francisco	Gerald R.	Green	Director	San Francisco Planning Department	1660 Mission Street	San Francisco	CA	94103
San Mateo County	Terry	Burnes	Planning Administrator	San Mateo County Environmental Services Agency, Planning and Building Division	590 Hamilton Street, 2nd Floor	Redwood City	CA	94063
Santa Clara County	Michael M.	Lopez	Land Development Coordinator	Santa Clara County Department of Planning and Development	70 West Hedding Street, 7th Floor, East Wing	San Jose	CA	95110
Sonoma County	Pete	Parkinson	AICP, Planning Manager	Sonoma County Permit & Resource Management Department	2550 Ventura Avenue	Santa Rosa	CA	95442

Tables

1.0 INTRODUCTION

This appendix includes six tables summarizing the ferry service route information for each alternative, followed by eight tables summarizing the emissions on a per-route basis for the project alternatives and mitigated emissions.

Existing Water Transit System (Null Alternative)

Corridor	Route	Vessel Type	Speed (Knots)	Headways Weekdays	Vessels	*Per Trip* Sailing Time	Idle Time	*Per Day- Minutes* Sailing Time	Idle Time	*In Minutes* Deadhead Time	Weekday Trips	Weekday Service Hrs	Weekend Service Hrs	Annualized Service Hrs	Pk Hour Seats	Annual Patronage
Transbay	Vallejo - SF	300	35	60	2	53.8	6.2	1184	136	10	22	22	22	8,030	300	736,000
	Oakland - Alameda - SF	350	25	60-120	2	24.0	6.0	624	156	30	26	13	10	4,430	500	496,000
	Harbor Bay - SF	250	25	60	1	25.2	4.8	302	58	15	12	6	0	1,560	250	114,000
	Subtotal Transbay Corridor				*5*							*41*	*32*	*14,020*	*1,050*	*1,346,000*
Golden Gate	Sausalito-San Francisco	590	15	60	1	26.4	3.6	528	72	15	20	14	10	4,690	400	454,000
	Tiburon-San Francisco	400	25	60	1	20.4	9.6	265	125	15	13	7	0	1,820	400	125,000
	Larkspur-San Francisco	400	35	15	5	31.8	13.2	1334	556	5	42	50	10	14,050	1,400	1,400,000
	Subtotal Golden Gate Corridor				*7*							*71*	*20*	*20,560*	*2,200*	*1,979,000*
GGNRA Service	Alcatraz	400	15	30	1	20.0	10.0	640	320	15	32	10	10	1,850	N/A	2,720,000
															Subtotals	
	TOTAL SYSTEM				**12**			**4,878**	**1,422**	**105**	**167**	**112**	**52**	**34,580**	**3,250**	**3,325,000**

DATE: June 20 2002
alternative null

DRAFT - FOR DISCUSSION ONLY

Alternative 1 - Aggressive Water Transit System

Corridor	Route	Vessel Type	Speed (Knots)	Headways Weekdays	Vessels	Per Trip Sailing Time	Per Trip Idle Time	Weekdays: Per Day- Minutes Sailing Time	Weekdays: Per Day- Minutes Idle Time	Weekdays: In Minutes Deadhead Time	Weekday Trips	Weekday Service Hrs	Weekends: Per Day- Minutes Sailing Time	Weekends: Per Day- Minutes Idle Time	Weekends: In Minutes Deadhead Time	Weekend Trips	Weekend Service Hrs	Annualized Service Hrs	Pk Hour Seats	Patronage Estimates: Initial MTC Model Runs	Patronage Estimates: Non MTC Estimates
Transbay	Vallejo - SF	350+	35	15	8	53.8	6.2	6459	741	40	120	128	3229	371	20	60	65	40,105	1,500	5,440	
	Benicia/Martinez - SF	350+	35	30	4	57.2	2.8	3435	165	60	60	60	1717	83	30	30	30	18,750	750	1,600	
	Antioch - SF	350+	35	30/60	6	80.7	9.3	3227	373	30	40	60	0	0	0	0	0	15,600	750	12	
	Pittsburg - SF	350+	35	30/60	5	75.4	14.6	3016	584	25	40	60	0	0	0	0	0	15,600	750	360	
	Hercules/Rodeo - SF	350+	35	30	4	43.6	16.4	2617	983	60	60	60	1309	491	30	30	30	18,750	750	1,570	
	Richmond-San Francisco	149	25	15	6	33.0	12.0	3960	1440	90	120	90	1980	720	45	60	45	28,125	600	1,860	
	Berkeley-SF	149	25	15	4	20.4	9.6	2448	1152	60	120	60	2448	1152	60	120	60	21,900	600	3,400	
	Alameda Point-Mission Bay-SF	149	25	15	4	28.8	1.2	3456	144	60	120	60	3456	144	60	120	60	21,900	600	2,600	
	Oakland Army Base -SF	149	25	15	2	14.4	0.6	1728	72	30	120	30	0	0	0	0	0	7,800	600	10	
	Oakland - SF	149	25	15	4	24.0	6.0	2880	720	60	120	60	2880	720	60	120	60	21,900	600	2,700	
	Harbor Bay - SF	149	25	15	4	25.2	4.8	3024	576	60	120	60	1512	288	30	60	30	18,750	600	1,030	
	Harbor Bay - Hunters Point	149	25	30	2	18.0	12.0	1080	720	30	60	30	540	360	15	30	15	9,375	300	1,030	
	San Leandro to San Francisco	149	35	15	6	39.6	5.4	4752	648	90	120	90	2376	324	45	60	45	28,125	600	300	
	East Bay (Harbor Bay) to So. San Francisco	149	25	15	6	30.0	15.0	3600	1800	90	120	90	1800	900	45	60	45	28,125	600	1,700	
	East Bay (San Leandro) to Coyote Point	149	25	15	4	25.2	4.8	3024	576	60	120	60	1512	288	30	60	30	18,750	600	170	
	East Bay (San Leandro) to Foster City	149	25	15	4	25.2	4.8	3024	576	60	120	60	1512	288	30	60	30	18,750	600	900	
	East Bay (San Leandro) to Redwood City	149	25	15	6	40.8	4.2	4896	504	90	120	90	2448	252	45	60	45	28,125	600	300	
	East Bay (San Leandro) to East Palo Alto	Hover	40	15	4	31.5	13.5	3780	1620	60	120	90	1890	810	30	60	45	28,125	500	900	
	East Bay (San Leandro) to Moffett Field	Hover	40	15	6	37.5	7.5	4500	900	90	120	90	2250	450	45	60	45	28,125	500	50	
	Subtotal Transbay Corridor				*89*							*1328*					*680*	*416,680*	*12,400*	*25,932*	
Golden	Sausalito-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	1224	576	30	60	30	10,950	300	6,100	
Gate	Tiburon-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	1224	576	30	60	30	10,950	300	2,600	
	Larkspur-San Francisco	350+	35	15	6	31.8	13.2	3812	1588	30	120	90	1906	794	15	60	45	28,125	1,500	14,000	
	Port Sonoma-San Francisco	350+	35	15	8	43.6	16.4	5235	1965	120	120	120	2617	983	60	60	60	37,500	750	2,230	
	Subtotal Golden Gate Corridor				*18*							*270*					*165*	*87,525*	*2,850*	*24,930*	
Peninsula	South San Francisco to San Fran	149	25	15	4	30.0	0.0	3600	0	60	120	60	1800	0	30	60	30	18,750	600	2,290	
	Coyote Point to San Francisco	149	35	30	4	40.2	19.8	2412	1188	60	60	60	1206	594	30	30	30	18,750	300	300	
	Foster City to San Francisco	149	35	30	4	36.9	23.1	2211	1389	60	60	60	1106	694	30	30	30	18,750	300	870	
	Redwood City to San Francisco	149	35	30	4	48.8	11.2	2926	674	60	60	60	1463	337	30	30	30	18,750	300	1,170	
	East Palo Alto to San Francisco	Hover	40	30	4	40.5	19.5	2430	1170	60	60	60	1215	585	30	30	30	18,750	250	2,800	
	Moffett Field to San Francisco	Hover	40	30	4	48.0	12.0	2880	720	60	60	60	1440	360	30	30	30	18,750	250	2,000	
	Subtotal Peninsula Corridor				*24*							*360*					*180*	*112,500*	*2,000*	*9,430*	
Treasure	Berkeley to Treasure Island	149	25	15	4	15.6	14.4	1872	1728	60	120	60	1872	1728	60	120	60	21,900	600		3,000
Island	Oakland to Treasure Island	149	25	15	4	21.6	8.4	2592	1008	60	120	60	2592	1008	60	120	60	21,900	600		2,000
	San Francisco to Treasure Island	149	25	15	2	13.2	1.8	1584	216	30	120	30	1584	216	30	120	30	10,950	600		5,000
	Subtotal Treasure Island Service				*10*							*150*					*150*	*54,750*	*1,800*		*10,000*
Airport	OAK Airport - SF	Hover	40	15	4	25.5	4.5	3060	540	60	120	60	3060	540	60	120	60	32,850	N/A		2,500
Access	OAK Airport - San Fran Airport	Hover	40	15	4	24.0	6.0	2880	720	60	120	60	2880	720	60	120	60	38,325	N/A		1,500
	SFO to San Francisco	Hover	40	15	4	27.0	3.0	3240	360	60	120	60	3240	360	60	120	60	32,850	N/A		4,000
	SFO to Moffett Field	Hover	40	15	6	34.5	10.5	4140	1260	30	120	90	4140	1260	30	120	90	43,800	N/A		1,500
	Subtotal Airport Access				*18*							*270*					*270*	*147,825*	N/A		*9,500*
GGNRA	GGNRA Circle Line/East Bay Svc	149	25	60	0	55.0	5.0	880	80	0	16	16	880	80	0	16	16	2,960	N/A		2,500
Service	Alcatraz	200	25	60	1	8.4	6.6	134	106	15	16	10	134	106	15	16	10	1,850	N/A		7,500
	Subtotal GGNRA Service				*1*							*26*					*26*	*4,810*	N/A		*10,000*
																			Subtotal	60,292	29,500
	TOTAL SYSTEM				**160**			**113,243**	**30,157**	**2,090**	**3,592**	**2,404**	**68,443**	**19,157**	**1,310**	**2,372**	**1,471**	**824,090**	**19,050**	**89,792**	

Alternative 2 - Robust Water Transit System

						Per Trip		Weekdays *Per Day- Minutes*		*In Minutes*			Weekends *Per Day- Minutes*		*In Minutes*					*Patronage Estimates*	
Corridor	**Route**	**Vessel Type**	**Speed (Knots)**	**Headways Weekdays**	**Vessels**	**Sailing Time**	**Idle Time**	**Sailing Time**	**Idle Time**	**Deadhead Time**	**Weekday Trips**	**Weekday Service Hrs**	**Sailing Time**	**Idle Time**	**Deadhead Time**	**Weekend Trips**	**Weekend Service Hrs**	**Annualized Service Hrs**	**Pk Hour Seats**	**Initial MTC Model Runs**	**Non MTC Estimates**
Transbay	Vallejo - SF	350+	35	15	8	53.8	6.2	6459	741	40	120	128	3229	371	20	60	65	40,105	1,500	5,440	
	Benicia/Martinez - SF	350+	35	30	4	57.2	2.8	3435	165	60	60	60	1717	83	30	30	30	18,750	750	1,600	
	Antioch - SF	350+	35	30/60	6	80.7	9.3	3227	373	30	40	50	0	0	0	0	0	13,000	750	12	
	Hercules/Rodeo - SF	350+	35	30	4	43.6	16.4	2617	983	60	60	60	1309	491	30	30	30	18,750	750	1,570	
	Richmond-San Francisco	149	25	15	6	33.0	12.0	3960	1440	90	120	90	1980	720	45	60	45	28,125	600	1,860	
	Berkeley-SF	149	25	15	4	20.4	9.6	2448	1152	60	120	60	2448	1152	60	120	60	21,900	600	3,400	
	Alameda Point-Mission Bay-SF	149	25	15	4	28.8	1.2	3456	144	60	120	60	3456	144	60	120	60	21,900	600	2,600	
	Oakland - SF	149	25	15	4	24.0	6.0	2880	720	60	120	60	2880	720	60	120	60	21,900	600	2,700	
	Harbor Bay - SF	149	25	15	4	25.2	4.8	3024	576	60	120	60	1512	288	30	60	30	18,750	600	1,030	
	San Leandro to San Francisco	149	35	15	6	39.6	5.4	4752	648	90	120	90	2376	324	45	60	45	28,125	600	300	
	East Bay (Harbor Bay) to So. San Francisco	149	25	15	6	30.0	15.0	3600	1800	90	120	90	1800	900	45	60	45	28,125	600	1,030	
	East Bay (San Leandro) to Redwood City	149	25	15	6	40.8	4.2	4896	504	90	120	90	2448	252	45	60	45	28,125	600	300	
	East Bay (San Leandro) to Moffett Field	Hover	40	15	6	37.5	7.5	4500	900	90	120	90	2250	450	45	60	45	28,125	500	50	
	Subtotal Transbay Corridor				*68*							*988*					*560*	*315,680*	*9,050*	*21,892*	
Golden Gate	Sausalito-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	1224	576	30	60	30	10,950	300	6,100	
	Tiburon-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	1224	576	30	60	30	10,950	300	2,600	
	Larkspur-San Francisco	350+	35	15	6	31.8	13.2	3812	1588	30	120	90	1906	794	15	60	45	28,125	1,500	14,000	
	Port Sonoma-San Francisco	350+	35	30/60	4	43.6	16.4	1745	655	60	40	40	0	0	0	0	0	10,400	750	1,660	
	Subtotal Golden Gate Corridor				*14*							*190*					*105*	*60,425*	*2,850*	*24,360*	
Peninsula	South San Francisco to San Fran	149	25	15	4	30.0	0.0	3600	0	60	120	60	0	0	0	0	0	15,600	600	2,290	
	Redwood City to San Francisco	149	35	30	4	48.8	11.2	2926	674	60	60	60	0	0	0	0	0	15,600	300	1,170	
	Moffett Field to San Francisco	Hover	40	30	4	48.0	12.0	2880	720	60	60	60	0	0	0	0	0	15,600	250	2,000	
	Subtotal Peninsula Corridor				*12*							*180*					*0*	*46,800*	*1,150*	*5,460*	
Treasure Island	Berkeley to Treasure Island	149	25	15	4	15.6	14.4	1872	1728	60	120	60	1872	1728	60	120	60	21,900	600		3,000
	Oakland to Treasure Island	149	25	15	4	21.6	8.4	2592	1008	60	120	60	2592	1008	60	120	60	21,900	600		2,000
	San Francisco to Treasure Island	149	25	15	2	13.2	1.8	1584	216	30	120	30	1584	216	30	120	30	10,950	600		5,000
	Subtotal Treasure Island Service				*10*							*150*					*150*	*54,750*	*1,800*		*10,000*
Airport Access	OAK Airport - SF	Hover	40	15	4	25.5	4.5	3060	540	60	120	60	3060	540	60	120	60	32,850	N/A		2,500
	OAK Airport - San Fran Airport	Hover	40	15	4	24.0	6.0	2880	720	60	120	60	2880	720	60	120	60	38,325	N/A		1,500
	SFO to San Francisco	Hover	40	15	4	27.0	3.0	3240	360	60	120	60	3240	360	60	120	60	32,850	N/A		4,000
	SFO to Moffett Field	Hover	40	15	6	34.5	10.5	4140	1260	30	120	90	4140	1260	30	120	90	43,800	N/A		1,500
	Subtotal Airport Access				*18*							*270*					*270*	*147,825*	N/A		*9,500*
GGNRA Service	GGNRA Circle Line/East Bay Svc	149	25	60	0	55.0	5.0	880	80	0	16	16	880	80	0	16	16	2,960	N/A		2,500
	Alcatraz	200	25	60	1	8.4	6.6	134	106	15	16	10	134	106	15	16	10	1,850	N/A		7,500
	Subtotal GGNRA Service				*1*							*26*					*26*	*4,810*	N/A		*10,000*
																			Subtotal	51,712	29,500
	TOTAL SYSTEM				**123**			**87,048**	**20,952**	**1,585**	**2,752**	**1,804**	**52,142**	**13,858**	**965**	**1,892**	**1,111**	**630,290**	**14,850**	**81,212**	

DATE: April 4 2002
alternative 2~rev

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"Reduced" Alternative 2 Peak Ferry Times and Distances

Ferry	Freqency (min)	Travel Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Number of Runs/Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (miles)		Per-Route Diesel w/SCR Emissions NO_x (lb/day)	SO_2(lb/day)	PM(lb/day)	CO(lb/day)	VOC(lb/day)	Per-Route Diesel EPA Tier 2 NO_x (lb/day)	SO_2(lb/day)	PM(lb/day)	CO(lb/day)	VOC(lb/day)
90_ALAMBSF	15	28.8	7.52	18.1	1.2	24.0	691	29	180		25.5	11.2	0.8	13.8	6.9	244.0	8.4	14.5	13.8	12.9
90_ALAMBSF-	15	28.8	7.52	18.1	1.2	24.0	691	29	180		25.5	11.2	0.8	13.8	6.9	244.0	8.4	14.5	13.8	12.9
Deadhead							60				2.2	1.0	0.1	1.2	0.6	21.2	0.7	1.3	1.2	1.1
90_HBFB	30	25.2	9.87	20.4	4.8	12.0	302	58	118		11.2	4.9	0.3	6.2	3.0	106.8	3.7	6.4	6.2	5.6
90_HBFB-	30	25.2	9.87	20.4	4.8	12.0	302	58	118		11.2	4.9	0.3	6.2	3.0	106.8	3.7	6.4	6.2	5.6
Deadhead							60				2.2	1.0	0.1	1.2	0.6	21.2	0.7	1.3	1.2	1.1
90_OAKFB	15	24.0	7.11	14.5	6.0	24.0	576	144	171		21.3	9.4	0.6	11.9	5.8	203.6	7.0	12.1	11.9	10.8
90_OAKFB	15	24.0	7.11	14.5	6.0	24.0	576	144	171		21.3	9.4	0.6	11.9	5.8	203.6	7.0	12.1	11.9	10.8
Deadhead							60				2.2	1.0	0.1	1.2	0.6	21.2	0.7	1.3	1.2	1.1
92_SSLTO	30	20.4	7.66	15.3	9.6	12.0	245	115	92		9.1	4.0	0.3	5.3	2.5	86.6	3.0	5.2	5.3	4.6
92_SSLTO-	30	20.4	7.66	15.3	9.6	12.0	245	115	92		9.1	4.0	0.3	5.3	2.5	86.6	3.0	5.2	5.3	4.6
Deadhead							30				1.1	0.5	0.0	0.6	0.3	10.6	0.4	0.6	0.6	0.6
93_TIBFB	30	20.4	6.90	19.0	9.6	12.0	245	115	83		9.1	4.0	0.3	5.3	2.5	86.6	3.0	5.2	5.3	4.6
93_TIBFB-	30	20.4	6.90	19.0	9.6	12.0	245	115	83		9.1	4.0	0.3	5.3	2.5	86.6	3.0	5.2	5.3	4.6
Deadhead							30				1.1	0.5	0.0	0.6	0.3	10.6	0.4	0.6	0.6	0.6
95_BERSFMBA	15	20.4	9.05	17.4	9.6	24.0	490	230	217		18.1	8.0	0.5	10.5	4.9	173.2	6.0	10.3	10.5	9.2
95_BERSFMBA-	15	20.4	9.05	17.4	9.6	24.0	490	230	217		18.1	8.0	0.5	10.5	4.9	173.2	6.0	10.3	10.5	9.2
Deadhead							60				2.2	1.0	0.1	1.2	0.6	21.2	0.7	1.3	1.2	1.1
95_RMDFB	15	33.0	9.00	25.0	12.0	24.0	792	288	216		29.3	12.9	0.9	16.7	8.0	280.1	9.6	16.7	16.7	14.8
95_RMDFB-	15	33.0	9.00	25.0	12.0	24.0	792	288	216		29.3	12.9	0.9	16.7	8.0	280.1	9.6	16.7	16.7	14.8
Deadhead							90				3.3	1.5	0.1	1.8	0.9	31.8	1.1	1.9	1.8	1.7
91_LARKN	15	43.6	12.74	16.0	13.2	24.0	1046	317	306	B	103.0	45.3	3.1	56.3	27.9	983.8	33.9	58.6	56.3	51.9
91_LARKS	15	43.6	12.74	19.1	13.2	24.0	1046	317	306	B	103.0	45.3	3.1	56.3	27.9	983.8	33.9	58.6	56.3	51.9
Deadhead							30				3.0	1.3	0.1	1.6	0.8	28.2	1.0	1.7	1.6	1.5
94_MZBFB	30	57.2	35.67	27.0	2.8	12.0	686	34	428	B	67.5	29.7	2.0	36.3	18.2	645.0	22.2	38.5	36.3	34.0
94_MZBFB-	30	57.2	35.67	27.0	2.8	12.0	686	34	428	B	67.5	29.7	2.0	36.3	18.2	645.0	22.2	38.5	36.3	34.0
Deadhead							60				5.9	2.6	0.2	3.2	1.6	56.4	1.9	3.4	3.2	3.0
94_VALFB	15	53.8	26.55	29.0	6.2	24.0	1291	149	637	B	127.0	55.9	3.8	68.6	34.3	1213.5	41.8	72.3	68.6	63.9
94_VALFB-	15	53.8	26.55	29.0	6.2	24.0	1291	149	637	B	127.0	55.9	3.8	68.6	34.3	1213.5	41.8	72.3	68.6	63.9
Deadhead							40				3.9	1.7	0.1	2.1	1.1	37.6	1.3	2.2	2.1	2.0
95_HERSF	30	43.6	19.57	26.0	16.4	12.0	523	197	235	B	51.5	22.7	1.5	28.3	13.9	492.0	16.9	29.3	28.3	26.0
95_HERSF-	30	43.6	19.57	26.0	16.4	12.0	523	197	235	B	51.5	22.7	1.5	28.3	13.9	492.0	16.9	29.3	28.3	26.0
Deadhead							60				5.9	2.6	0.2	3.2	1.6	56.4	1.9	3.4	3.2	3.0
96_PITSF	30	80.7	34.10	26.0	9.3	12.0	968	112	409	B	95.3	41.9	2.9	51.5	25.7	910.1	31.3	54.3	51.5	47.9
96_PITSF-	30	80.7	34.10	26.0	9.3	12.0	968	112	409	B	95.3	41.9	2.9	51.5	25.7	910.1	31.3	54.3	51.5	47.9
Deadhead							30				3.0	1.3	0.1	1.6	0.8	28.2	1.0	1.7	1.6	1.5
Small ferry total min.							**7072**	**1958**		Peak sum	1172	516	35	640	317	11195	385	667	640	590
Small ferry total hrs.							**117.9**	**32.6**	**Hours**	Off-peak sum	1493	657	45	819	404	14264	491	850	819	753
Large ferry total min.							**9251**	**1615**		TOTAL:	2665	1172	80	1459	721	25459	876	1518	1459	1343

"Reduced" Alternative 2 Non-Peak Ferry Times and Distances

Ferry	Freqency (min)	Travel Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Number of Runs/Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (miles)	
90_ALAMBSF	15	28.8	7.52	18.1	1.2	36.0	1037	43	271	
90_ALAMBSF-	15	28.8	7.52	18.1	1.2	36.0	1037	43	271	
90_HBFB	15	25.2	9.87	20.4	4.8	36.0	907	173	355	
90_HBFB-	15	25.2	9.87	20.4	4.8	36.0	907	173	355	
90_OAKFW	15	24.0	8.80	11.7	6.0	36.0	864	216	317	
90_OAKFW	15	24.0	8.80	11.7	6.0	36.0	864	216	317	
92_SSLTO	30	20.4	7.66	15.3	9.6	18.0	367	173	138	
92_SSLTO-	30	20.4	7.66	15.3	9.6	18.0	367	173	138	
93_TIBFW	30	20.4	5.47	9.4	9.6	18.0	367	173	98	
93_TIBFW-	30	20.4	5.47	9.4	9.6	18.0	367	173	98	
95_BERSFMBA	15	20.4	9.05	17.4	9.6	36.0	734	346	326	
95_BERSFMBA-	15	20.4	9.05	17.4	9.6	36.0	734	346	326	
95_RMDFB	15	33.0	9.00	25.0	12.0	36.0	1188	432	324	
95_RMDFB-	15	33.0	9.00	25.0	12.0	36.0	1188	432	324	
91_LARKN	15	43.6	12.74	16.0	13.2	36.0	1570	475	459	B
91_LARKS	15	43.6	12.74	19.1	13.2	36.0	1570	475	459	B
94_MZBFB	60	57.2	35.67	27.0	2.8	9.0	515	25	321	B
94_MZBFB-	60	57.2	35.67	27.0	2.8	9.0	515	25	321	B
94_VALFB	15	53.8	26.55	29.0	6.2	36.0	1937	223	956	B
94_VALFB-	15	53.8	26.55	29.0	6.2	36.0	1937	223	956	B
95_HERSF	30	43.6	19.57	26.0	16.4	18.0	785	295	352	B
95_HERSF-	30	43.6	19.57	26.0	16.4	18.0	785	295	352	B
96_PITSF	60	80.7	34.10	26.0	9.3	9.0	726	84	307	B
96_PITSF-	60	80.7	34.10	26.0	9.3	9.0	726	84	307	B
Small ferry total min.							**10930**	**3110**		
Small ferry total hrs.							**182.2**	**51.8**	**Hours**	
Large ferry total min.							**11065**	**2205**		
Large ferry total hrs.							**184.4**	**36.8**	**Hours**	

Ferry	Per-Route Diesel w/SCR Emissions					Per-Route Diesel EPA Tier 2					Per-Route Diesel w/SCR Emissions				
	NO_x (lb/day)	SO_2(lb/day)	PM(lb/day)	CO(lb/day)	VOC(lb/day)	NO_x (lb/day)	SO_2(lb/day)	PM(lb/day)	CO(lb/day)	VOC(lb/day)	NO_x (lb/day)	SO_2(lb/day)	PM(lb/day)	CO(lb/day)	VOC(lb/day)
90_ALAMBSF	38.3	16.9	1.1	20.7	10.3	366.0	12.6	21.8	20.7	19.3	82.7	0.0	0.0	17.3	4.1
90_ALAMBSF-	38.3	16.9	1.1	20.7	10.3	366.0	12.6	21.8	20.7	19.3	82.7	0.0	0.0	17.3	4.1
90_HBFB	33.5	14.8	1.0	18.6	9.1	320.5	11.0	19.1	18.6	16.9	72.4	0.0	0.0	15.6	3.6
90_HBFB-	33.5	14.8	1.0	18.6	9.1	320.5	11.0	19.1	18.6	16.9	72.4	0.0	0.0	15.6	3.6
90_OAKFW	32.0	14.1	1.0	17.9	8.7	305.3	10.5	18.2	17.9	16.1	69.0	0.0	0.0	15.0	3.5
90_OAKFW	32.0	14.1	1.0	17.9	8.7	305.3	10.5	18.2	17.9	16.1	69.0	0.0	0.0	15.0	3.5
92_SSLTO	13.6	6.0	0.4	7.9	3.7	129.9	4.5	7.7	7.9	6.9	29.3	0.0	0.0	6.6	1.5
92_SSLTO-	13.6	6.0	0.4	7.9	3.7	129.9	4.5	7.7	7.9	6.9	29.3	0.0	0.0	6.6	1.5
93_TIBFW	13.6	6.0	0.4	7.9	3.7	129.9	4.5	7.7	7.9	6.9	29.3	0.0	0.0	6.6	1.5
93_TIBFW-	13.6	6.0	0.4	7.9	3.7	129.9	4.5	7.7	7.9	6.9	29.3	0.0	0.0	6.6	1.5
95_BERSFMBA	27.2	11.9	0.8	15.8	7.4	259.9	8.9	15.5	15.8	13.8	58.7	0.0	0.0	13.2	3.0
95_BERSFMBA-	27.2	11.9	0.8	15.8	7.4	259.9	8.9	15.5	15.8	13.8	58.7	0.0	0.0	13.2	3.0
95_RMDFB	44.0	19.3	1.3	25.0	12.0	420.1	14.4	25.0	25.0	22.3	94.9	0.0	0.0	21.0	4.8
95_RMDFB-	44.0	19.3	1.3	25.0	12.0	420.1	14.4	25.0	25.0	22.3	94.9	0.0	0.0	21.0	4.8
91_LARKN	154.5	68.0	4.6	84.4	41.8	1475.8	50.8	88.0	84.4	77.8	333.3	0.0	0.0	70.8	16.7
91_LARKS	154.5	68.0	4.6	84.4	41.8	1475.8	50.8	88.0	84.4	77.8	333.3	0.0	0.0	70.8	16.7
94_MZBFB	50.6	22.3	1.5	27.2	13.7	483.7	16.7	28.8	27.2	25.5	109.3	0.0	0.0	22.8	5.5
94_MZBFB-	50.6	22.3	1.5	27.2	13.7	483.7	16.7	28.8	27.2	25.5	109.3	0.0	0.0	22.8	5.5
94_VALFB	190.5	83.9	5.7	102.9	51.5	1820.2	62.7	108.5	102.9	95.9	411.1	0.0	0.0	86.3	20.6
94_VALFB-	190.5	83.9	5.7	102.9	51.5	1820.2	62.7	108.5	102.9	95.9	411.1	0.0	0.0	86.3	20.6
95_HERSF	77.2	34.0	2.3	42.4	20.9	738.0	25.4	44.0	42.4	38.9	166.7	0.0	0.0	35.6	8.4
95_HERSF-	77.2	34.0	2.3	42.4	20.9	738.0	25.4	44.0	42.4	38.9	166.7	0.0	0.0	35.6	8.4
96_PITSF	71.4	31.5	2.1	38.6	19.3	682.6	23.5	40.7	38.6	36.0	154.2	0.0	0.0	32.4	7.7
96_PITSF-	71.4	31.5	2.1	38.6	19.3	682.6	23.5	40.7	38.6	36.0	154.2	0.0	0.0	32.4	7.7
	1492.9	656.9	44.8	818.6	404.1	14264.0	491.0	850.2	818.6	752.6	3221.6	0.0	0.0	686.1	161.5

Alternative 3 - Enhanced (Existing) Water Transit System

Corridor	Route	Vessel Type	Speed (Knots)	Headways Weekdays	Vessels	Per Trip: Sailing Time	Per Trip: Idle Time	Weekdays: Per Day- Minutes Sailing Time	Weekdays: Per Day- Minutes Idle Time	Weekdays: In Minutes Deadhead Time	Weekday Trips	Weekday Service Hrs	Weekends: Per Day- Minutes Sailing Time	Weekends: Per Day- Minutes Idle Time	Weekends: In Minutes Deadhead Time	Weekend Trips	Weekend Service Hrs	Annualized Service Hrs	Pk Hour Seats	Patronage Estimates: Initial MTC Model Runs	Patronage Estimates: Non MTC Estimates
Transbay	Vallejo - SF	350+	35	15	8	53.8	6.2	6459	741	40	120	128	3229	371	20	60	65	40,105	1,500	6,500	
	Alameda Point-Mission Bay-SF	149	25	15	4	28.8	1.2	3456	144	60	120	60	3456	144	60	120	60	21,900	600	2,600	
	Oakland - SF	149	25	15	4	24.0	6.0	2880	720	60	120	60	2880	720	60	120	60	21,900	600	2,700	
	Harbor Bay - SF	149	25	15	4	25.2	4.8	3024	576	60	120	60	1512	288	30	60	30	18,750	600	1,030	
	Subtotal Transbay Corridor				*20*							*308*					*215*	*102,655*	*3,300*	*12,830*	
Golden Gate	Sausalito-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	612	288	15	30	15	9,375	300	6,100	
	Tiburon-San Francisco	149	25	30	2	20.4	9.6	1224	576	30	60	30	612	288	15	30	15	9,375	300	2,600	
	Larkspur-San Francisco	350+	35	15	6	31.8	13.2	3812	1588	30	120	90	1906	794	15	60	45	28,125	1,500	14,000	
	Subtotal Golden Gate Corridor				*10*							*150*					*75*	*46,875*	*2,100*	*22,700*	
GGNRA Service	Alcatraz	200	25	60	1	8.4	6.6	134	106	15	16	10	134	106	15	16	10	1,850	N/A		7,500
	Subtotal GGNRA Service				*1*							*10*					*10*	*1,850*	N/A		*7,500*
																			Subtotals	35,530	7,500
	TOTAL SYSTEM				**31**			**22,213**	**5,027**	**325**	**736**	**468**	**14,342**	**2,998**	**230**	**496**	**300**	**151,380**	**5,400**	**43,030**	

DATE: 09-Apr-02
alternative 3~rev

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Summary of Marine Emissions for the No Project and Alternative 1 Project Scenarios
Assuming EPA Tier 2 Emissions Standards for Diesel Engines

	Year 2025 No Project	Year 2025 Alternative 1	
Large Ferry Power Rating (kW)	--	5369.1	2 engines
Small Ferry Power Rating (kW)	--	1946.3	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		309.3266667	
Total Transit Hours (hr/day) -small ferry	52.2	441.6	
Large Ferry Total Power Usage (kW-hr)		1110171.3	
Small Ferry Total Power Usage (kW-hr)	128582	595227.8	
Total Idle Hours (hr/day) - Large ferry		71.3	
Total Idle Hours (hr/day) - Small ferry	9.4	116.2	
NOx Emissions (lb/day)	2021	26811	
SO2 Emissions (lb/day)	70	923	
PM Emissions (lb/day)	120	1598	
CO Emissions (lb/day)	115	1543	
VOC Emissions (lb/day)	107	1415	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		392.8	
Total Operating Hours (hr/day) - Small Ferry	35.4	644.1	
Large Ferry Total Power Usage (kW-hr)		1409720.7	
Small Ferry Total Power Usage (kW-hr)	87345	868235.4	
Total Idle Hours (hr/day) large		98	
Total Idle Hours (hr/day)- small	6.8	177.1	
NOx Emissions (lb/day)	1373	35816	
SO2 Emissions (lb/day)	47	1233	
PM Emissions (lb/day)	82	2135	
CO Emissions (lb/day)	78	2066	
VOC Emissions (lb/day)	72	1891	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3394	62627	**59233**
SO2 Emissions (lb/day)	117	2156	**2039**
PM Emissions (lb/day)	202	3733	**3531**
CO Emissions (lb/day)	194	3609	**3415**
VOC Emissions (lb/day)	179	3306	**3127**

Summary of Marine Emissions for the No Project and Alternative 1 Project Scenarios
Assuming Diesel Engines with SCR

	Year 2025 No Project	Year 2025 Alternative 1	
Large Ferry Power Rating (kW)	--	5369.1	2 engines
Small Ferry Power Rating (kW)	--	1946.3	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		309.3266667	
Total Transit Hours (hr/day) -small ferry	52.2	441.6	
Large Ferry Total Power Usage (kW-hr)		1110171.3	
Small Ferry Total Power Usage (kW-hr)	128582	595227.8	
Total Idle Hours (hr/day) - Large ferry		71.3	
Total Idle Hours (hr/day) - Small ferry	9.4	116.2	
NOx Emissions (lb/day)	2021	2806	
SO2 Emissions (lb/day)	70	1235	
PM Emissions (lb/day)	120	84	
CO Emissions (lb/day)	115	1543	
VOC Emissions (lb/day)	107	760	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		392.8	
Total Operating Hours (hr/day) - Small Ferry	35.4	644.1	
Large Ferry Total Power Usage (kW-hr)		1409720.7	
Small Ferry Total Power Usage (kW-hr)	87345	868235.4	
Total Idle Hours (hr/day) large		98	
Total Idle Hours (hr/day)- small	6.8	177.1	
NOx Emissions (lb/day)	1373	3749	
SO2 Emissions (lb/day)	47	1649	
PM Emissions (lb/day)	82	112	
CO Emissions (lb/day)	78	2066	
VOC Emissions (lb/day)	72	1015	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3394	6555	**3161**
SO2 Emissions (lb/day)	117	2884	**2767**
PM Emissions (lb/day)	202	197	**-6**
CO Emissions (lb/day)	194	3609	**3415**
VOC Emissions (lb/day)	179	1775	**1596**

Summary of Marine Emissions for the No Project and Alternative 2 Project Scenarios
Assuming EPA Tier 2 Emissions Standards for Diesel Engines

	Year 2025 No Project	**Year 2025 Alternative 2**	
Large Ferry Power Rating (kW)	--	5705.0	2 engines
Small Ferry Power Rating (kW)	--	1638.0	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		296.4266667	
Total Transit Hours (hr/day) -small ferry	52.2	316.2	
Large Ferry Total Power Usage (kW-hr)		1063873.3	
Small Ferry Total Power Usage (kW-hr)	128582	426225.6	
Total Idle Hours (hr/day) - Large ferry		58.7	
Total Idle Hours (hr/day) - Small ferry	9.4	80.0	
NOx Emissions (lb/day)	2021	23423	
SO2 Emissions (lb/day)	70	806	
PM Emissions (lb/day)	120	1396	
CO Emissions (lb/day)	115	1343	
VOC Emissions (lb/day)	107	1236	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		375.7	
Total Operating Hours (hr/day) - Small Ferr	35.5	464.3	
Large Ferry Total Power Usage (kW-hr)		1348348.9	
Small Ferry Total Power Usage (kW-hr)	87550	625852.5	
Total Idle Hours (hr/day) large		79	
Total Idle Hours (hr/day)- small	6.9	122.9	
NOx Emissions (lb/day)	1376	31035	
SO2 Emissions (lb/day)	47	1068	
PM Emissions (lb/day)	82	1850	
CO Emissions (lb/day)	79	1783	
VOC Emissions (lb/day)	73	1638	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3397	54459	**51062**
SO2 Emissions (lb/day)	117	1875	**1758**
PM Emissions (lb/day)	202	3246	**3044**
CO Emissions (lb/day)	194	3126	**2932**
VOC Emissions (lb/day)	179	2873	**2694**

Summary of Marine Emissions for the No Project and Alternative 2 Project Scenarios
Assuming Diesel Engines with SCR

	Year 2025 No Project	Year 2025 Alternative 2	
Large Ferry Power Rating (kW)	--	5705.0	2 engines
Small Ferry Power Rating (kW)	--	1638.0	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		296.4266667	
Total Transit Hours (hr/day) -small ferry	52.2	316.2	
Large Ferry Total Power Usage (kW-hr)		1063873.3	
Small Ferry Total Power Usage (kW-hr)	128582	426225.6	
Total Idle Hours (hr/day) - Large ferry		58.7	
Total Idle Hours (hr/day) - Small ferry	9.4	80.0	
NOx Emissions (lb/day)	2021	2452	
SO2 Emissions (lb/day)	70	1079	
PM Emissions (lb/day)	120	74	
CO Emissions (lb/day)	115	1343	
VOC Emissions (lb/day)	107	663	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		375.7	
Total Operating Hours (hr/day) - Small Ferr	35.5	464.3	
Large Ferry Total Power Usage (kW-hr)		1348348.9	
Small Ferry Total Power Usage (kW-hr)	87550	625852.5	
Total Idle Hours (hr/day) large		79	
Total Idle Hours (hr/day)- small	6.9	122.9	
NOx Emissions (lb/day)	1376	3248	
SO2 Emissions (lb/day)	47	1429	
PM Emissions (lb/day)	82	97	
CO Emissions (lb/day)	79	1783	
VOC Emissions (lb/day)	73	879	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3397	5700	**2303**
SO2 Emissions (lb/day)	117	2508	**2391**
PM Emissions (lb/day)	202	171	**-32**
CO Emissions (lb/day)	194	3126	**2932**
VOC Emissions (lb/day)	179	1543	**1364**

Summary of Marine Emissions for the No Project and "Reduced" Alternative 2 Project Scenarios Assuming EPA Tier 2 Emissions Standards for Diesel Engines

	Year 2025 No Project	Year 2025 Alternative 2	
Large Ferry Power Rating (kW)	--	5705.0	2 engines
Small Ferry Power Rating (kW)	--	1638.0	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		154.1866667	
Total Transit Hours (hr/day) -small ferry	52.2	117.9	
Large Ferry Total Power Usage (kW-hr)		553374.9	
Small Ferry Total Power Usage (kW-hr)	128582	158865.8	
Total Idle Hours (hr/day) - Large ferry		26.9	
Total Idle Hours (hr/day) - Small ferry	9.4	32.6	
NOx Emissions (lb/day)	2021	11195	
SO2 Emissions (lb/day)	70	385	
PM Emissions (lb/day)	120	667	
CO Emissions (lb/day)	115	640	
VOC Emissions (lb/day)	107	590	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		184.4	
Total Operating Hours (hr/day) - Small Ferr	35.5	182.2	
Large Ferry Total Power Usage (kW-hr)		661846.3	
Small Ferry Total Power Usage (kW-hr)	87550	245537.0	
Total Idle Hours (hr/day) large		37	
Total Idle Hours (hr/day)- small	6.9	51.8	
NOx Emissions (lb/day)	1376	14264	
SO2 Emissions (lb/day)	47	491	
PM Emissions (lb/day)	82	850	
CO Emissions (lb/day)	79	819	
VOC Emissions (lb/day)	73	753	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3397	25459	**22062**
SO2 Emissions (lb/day)	117	876	**759**
PM Emissions (lb/day)	202	1518	**1315**
CO Emissions (lb/day)	194	1459	**1265**
VOC Emissions (lb/day)	179	1343	**1164**

Summary of Marine Emissions for the No Project and "Reduced" Alternative 2 Project Scenarios Assuming Diesel Engines with SCR

	Year 2025 No Project	Year 2025 Alternative 2	
Large Ferry Power Rating (kW)	--	5705.0	2 engines
Small Ferry Power Rating (kW)	--	1638.0	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		154.1866667	
Total Transit Hours (hr/day) -small ferry	52.2	117.9	
Large Ferry Total Power Usage (kW-hr)		553374.9	
Small Ferry Total Power Usage (kW-hr)	128582	158865.8	
Total Idle Hours (hr/day) - Large ferry		26.9	
Total Idle Hours (hr/day) - Small ferry	9.4	32.6	
NOx Emissions (lb/day)	2021	1172	
SO2 Emissions (lb/day)	70	516	
PM Emissions (lb/day)	120	35	
CO Emissions (lb/day)	115	640	
VOC Emissions (lb/day)	107	317	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		184.4	
Total Operating Hours (hr/day) - Small Ferr	35.5	182.2	
Large Ferry Total Power Usage (kW-hr)		661846.3	
Small Ferry Total Power Usage (kW-hr)	87550	245537.0	
Total Idle Hours (hr/day) large		37	
Total Idle Hours (hr/day)- small	6.9	51.8	
NOx Emissions (lb/day)	1376	1493	
SO2 Emissions (lb/day)	47	657	
PM Emissions (lb/day)	82	45	
CO Emissions (lb/day)	79	819	
VOC Emissions (lb/day)	73	404	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3397	2665	**-732**
SO2 Emissions (lb/day)	117	1172	**1056**
PM Emissions (lb/day)	202	80	**-123**
CO Emissions (lb/day)	194	1459	**1265**
VOC Emissions (lb/day)	179	721	**542**

Summary of Marine Emissions for the No Project and "Reduced" Alternative 2 Project Scenarios Assuming Diesel Engines with SCR

	Year 2025 No Project	Year 2025 Alternative 2	
Large Ferry Power Rating (kW)	--	5705.0	2 engines
Small Ferry Power Rating (kW)	--	1638.0	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		154.1866667	
Total Transit Hours (hr/day) -small ferry	52.2	117.9	
Large Ferry Total Power Usage (kW-hr)		553374.9	
Small Ferry Total Power Usage (kW-hr)	128582	158865.8	
Total Idle Hours (hr/day) - Large ferry		26.9	
Total Idle Hours (hr/day) - Small ferry	9.4	32.6	
NOx Emissions (lb/day)	2021	1172	
SO2 Emissions (lb/day)	70	516	
PM Emissions (lb/day)	120	35	
CO Emissions (lb/day)	115	640	
VOC Emissions (lb/day)	107	317	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		184.4	
Total Operating Hours (hr/day) - Small Ferr	35.5	182.2	
Large Ferry Total Power Usage (kW-hr)		661846.3	
Small Ferry Total Power Usage (kW-hr)	87550	245537.0	
Total Idle Hours (hr/day) large		37	
Total Idle Hours (hr/day)- small	6.9	51.8	
NOx Emissions (lb/day)	1376	1493	
SO2 Emissions (lb/day)	47	657	
PM Emissions (lb/day)	82	45	
CO Emissions (lb/day)	79	819	
VOC Emissions (lb/day)	73	404	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3397	2665	**-732**
SO2 Emissions (lb/day)	117	1172	**1056**
PM Emissions (lb/day)	202	80	**-123**
CO Emissions (lb/day)	194	1459	**1265**
VOC Emissions (lb/day)	179	721	**542**

Summary of Marine Emissions for the No Project and Alternative 3 Project Scenarios
Assuming EPA Tier 2 Emissions Standards for Diesel Engines

	Year 2025 No Project	Year 2025 Alternative 3	
Large Ferry Power Rating (kW)	--	5369.1	2 engines
Small Ferry Power Rating (kW)	--	1946.3	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		79.08666667	
Total Transit Hours (hr/day) -small ferry	52.2	74.2	
Large Ferry Total Power Usage (kW-hr)		283841.5	
Small Ferry Total Power Usage (kW-hr)	128582	100029.1	
Total Idle Hours (hr/day) - Large ferry		15.5	
Total Idle Hours (hr/day) - Small ferry	9.4	15.5	
NOx Emissions (lb/day)	2021	6034	
SO2 Emissions (lb/day)	70	208	
PM Emissions (lb/day)	120	360	
CO Emissions (lb/day)	115	345	
VOC Emissions (lb/day)	107	318	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		116.9	
Total Operating Hours (hr/day) - Small Ferry	35.4	104.9	
Large Ferry Total Power Usage (kW-hr)		419481.5	
Small Ferry Total Power Usage (kW-hr)	87345	141450.7	
Total Idle Hours (hr/day) large		23	
Total Idle Hours (hr/day)- small	6.8	23.3	
NOx Emissions (lb/day)	1373	8817	
SO2 Emissions (lb/day)	47	304	
PM Emissions (lb/day)	82	526	
CO Emissions (lb/day)	78	504	
VOC Emissions (lb/day)	72	465	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3394	14850	**11457**
SO2 Emissions (lb/day)	117	511	**394**
PM Emissions (lb/day)	202	885	**683**
CO Emissions (lb/day)	194	849	**656**
VOC Emissions (lb/day)	179	783	**604**

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Summary of Marine Emissions for the No Project and Alternative 3 Project Scenarios
Assuming Diesel Engines with SCR

	Year 2025 No Project	Year 2025 Alternative 3	
Large Ferry Power Rating (kW)	--	5369.1	2 engines
Small Ferry Power Rating (kW)	--	1946.3	2 engines
Existing Ferry Average Power Rating (kW)	2464.5		
Peak Hours			
Total Transit Hours (hr/day) -large ferry		79.08666667	
Total Transit Hours (hr/day) -small ferry	52.2	74.2	
Large Ferry Total Power Usage (kW-hr)		283841.5	
Small Ferry Total Power Usage (kW-hr)	128582	100029.1	
Total Idle Hours (hr/day) - Large ferry		15.5	
Total Idle Hours (hr/day) - Small ferry	9.4	15.5	
NOx Emissions (lb/day)	2021	631	
SO2 Emissions (lb/day)	70	278	
PM Emissions (lb/day)	120	19	
CO Emissions (lb/day)	115	345	
VOC Emissions (lb/day)	107	171	
Off Peak Hours			
Total Operating Hours (hr/day) - Large Ferry		116.9	
Total Operating Hours (hr/day) - Small Ferry	35.4	104.9	
Large Ferry Total Power Usage (kW-hr)		419481.5	
Small Ferry Total Power Usage (kW-hr)	87345	141450.7	
Total Idle Hours (hr/day) large		23	
Total Idle Hours (hr/day)- small	6.8	23.3	
NOx Emissions (lb/day)	1373	923	
SO2 Emissions (lb/day)	47	406	
PM Emissions (lb/day)	82	28	
CO Emissions (lb/day)	78	504	
VOC Emissions (lb/day)	72	250	
Total Daily Emissions			**Increase in Emissions from Future Baseline (lb/day)**
NOx Emissions (lb/day)	3394	1554	**-1839**
SO2 Emissions (lb/day)	117	684	**567**
PM Emissions (lb/day)	202	47	**-156**
CO Emissions (lb/day)	194	849	**656**
VOC Emissions (lb/day)	179	421	**242**

APPENDIX AIR-B

BAY AREA
AIR QUALITY
MANAGEMENT
DISTRICT

February 20, 2003

RECEIVED
FEB 25 REC'D
SAN FRANCISCO BAY AREA
WATER TRANSIT AUTHORITY

Thomas G. Bertken
Chief Executive Officer
Water Transit Authority
120 Broadway
San Francisco, CA 94111

Dear Mr. Bertken:

The Bay Area Air Quality Management District has completed its independent air quality analysis of the Water Transit Authority (WTA) Implementation and Operations Plan (IOP). A copy of the completed analysis is enclosed. Our analysis was reviewed at public meetings held on February 13 and 19, 2003, and was approved by the Air District's Board of Directors. We believe that this analysis fulfills the requirements of the California Health and Safety Code Section 66540.22k.

As noted in our report, the expansion of ferry service proposed in the WTA's IOP should result in less emissions than the current passenger ferry services in the Bay Area. However, there is a potential for concentrations of nitrogen dioxide and particulate matter at the San Francisco terminal to be above state and federal ambient air quality standards.

We recommend that the WTA examine the potential for further reductions in emissions from future ferry vessels by scaling back non-peak service on some routes and through the use of alternative diesel fuels, such as water emulsion fuels and biodiesel. We also recommend that vessel design, pier design, and system operations be carefully planned to minimize local exposure to air pollutants and associated cancer risk.

I would like to express my appreciation for the efforts of you and your staff in providing technical data for our work and comments on our draft analysis. I look forward working with the WTA in its ongoing efforts to expand ferry service in the Bay Area in a manner that minimizes impacts to the region's air quality.

Please contact Michael Murphy, Principal Planner, at 415/749-4644, if you have any questions regarding the enclosed analysis.

Sincerely,

William C. Norton

William C. Norton
Executive Officer/APCO

Enclosure

WCN:MRM

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BAY AREA AIR QUALITY MANAGEMENT DISTRICT **5**

Memorandum

To: Chairperson Smith and
Members of the Mobile Source Committee

From: Thomas Perardi
Director of Planning

Date: February 6, 2003

Re: Independent Analysis of the Bay Area Water Transit Authority's *Implementation and Operations Plan*

RECOMMENDED ACTION:

Consider recommending to the Board of Directors that the Executive Officer forward the Air District's independent analysis of the air quality impacts from the Bay Area Water Transit Authority's (WTA) *Implementation and Operations Plan – December 2002* to the Water Transit Authority. The WTA will include the independent analysis in their final plan to the Legislature when it is submitted in Spring 2003.

BACKGROUND

The WTA was created in 1999 by SB428 (Perata). The WTA was created to "*... operate a comprehensive San Francisco Bay regional public water transit system, that includes water-transit terminals, feeder buses and any other transport and facilities supportive of the system." (Health & Safety Code §66540.24)* The legislation also directed the WTA to "*... prepare and adopt a San Francisco Bay Area Water Transit Implementation and Operations Plan. The plan shall include all appropriate landside, vessel, and support elements, operational and performance standards, and policies. " (Health & Safety Code §66540.20)* A draft Implementation and Operations Plan (IOP) was submitted to the Legislature on December 13, 2002. A final plan, along with environmental documentation, is due to the legislature by the Spring 2003.

The final plan is to be accompanied by "*.. an independent evaluation conducted by the Bay Area Air Quality Management District to assess the air quality impacts of the complete water transit system, as set forth in the ... Implementation and Operations Plan, in comparison to transporting the same number of people over the same distance by motor vehicles and other modes of transportation." (Health & Safety Code §66540.22(k))* This staff report represents the independent evaluation of the WTA's IOP and covers both regional and localized impacts from the proposed expansion of ferry service in the Bay Area.

SUMMARY FINDINGS

1. Implementation of the WTA's proposal will result in overall emissions that are lower than those attributable to current passenger ferry service.

2. If the future ferry service passengers used automobiles and other modes of transportation (rail, bus, carpools), regional emissions would also be less than current emissions from passenger ferry service. In comparison to the WTA's proposal, regional emissions of

oxides of nitrogen and particulate matter would be less, but hydrocarbon emissions would be higher.

3. The proposed increase in ferry service at the San Francisco Ferry Building has the potential to increase local concentrations of nitrogen dioxide (NO_2) and particulate matter (PM_{10} & $PM_{2.5}$). Future impacts will depend on actual design of boats and piers, and future operating procedures. Based on available information and reasonable assumptions, the NO_2 concentrations could exceed California's ambient air quality standard, unless dockside operations are limited to approximately 5 minutes per landing. The State PM_{10} & $PM_{2.5}$ standards are already exceeded in most urban areas of California, including San Francisco. The Air District staff's analysis shows that the WTA proposal could add from 6 to 55% to existing concentration values, depending on pollutant, boat design, and dockside idle time. Additionally, the Air District staff's analysis indicates that the potential for localized increases in exposure to particulate matter at the San Francisco terminal could lead to a significant increase in cancer risk. Boat design and exhaust height specifications could be used to mitigate local air quality impacts and risk.

DISCUSSION

During the two-year development of the IOP, the WTA studied four alternatives for service expansion: 1) A comprehensive region-wide system based on the Water Transit Initiative developed by the Bay Area Council and Bay Area Economic Forum; 2) an expanded region-wide system that could be implemented within 10 years; 3) enhancements to the existing ferry system; and 4) A "No-Build" scenario based on the Metropolitan Transportation Commission's *2001 Regional Transportation Plan* (RTP), which envisions future ferry service to be similar to today's ferry routes and frequencies.

The current WTA proposal in the IOP is a subset of the second studied alternative -- enhancements to services on existing routes, plus new services between San Francisco and terminals in San Mateo, Alameda, Sonoma, and Contra Costa Counties. As shown in Table 1, the WTA is proposing more frequent service on six existing routes and new service on eight routes.

TABLE 1
PROPOSED FERRY ROUTES AND PROJECT 2025 DAILY RIDERSHIP

Existing Routes	Oakland – Alameda – San Francisco	4032
	Bay Farm Island – San Francisco	679
	Vallejo – San Francisco	4411
	Sausalito – San Francisco	5118
	Larkspur – San Francisco	6576
	Tiburon – San Francisco	2649
New Routes	Berkeley – San Francisco – Mission Bay	2357
	Richmond – San Francisco	1780
	Treasure Island – San Francisco	2485
	Antioch/Pittsburg – Martinez – San Francisco	2038
	Hercules/Rodeo – San Francisco	933
	South San Francisco – San Francisco	2496
	Redwood City – San Francisco	1420
	Port Sonoma – San Francisco	1657
	Total Daily Ridership	38,631

Source: WTA, *Implementation and Operations Plan – December 2002*, page2

Building on MTC's regional transportation model, WTA has projected that the IOP would result in 38,631 weekday ferry passengers in 2025 (See Table 1). This is approximately 14,000 passengers more than the ridership level projected in the 2001 RTP. The WTA assumed that ferry service would operate on an hourly basis on most routes. Service would be provided for 14 to 16 hours per day. They also assumed that bridge tolls will be $3.00 per vehicle and that parking at BART stations will be $2.00 per car.

Integral to the WTA's plan is the deployment of ferry vessels with engines that are 85% cleaner than the EPA's 2007 marine engine emissions standards. In making this commitment, the WTA is following the recommendations of a 1999 study by the California Air Resources Board (CARB). In their study, CARB staff projected significant increases in overall emissions unless the engines in the ferry vessels were very low emitting.

A comprehensive examination by the WTA of potential emission control technologies concluded that several different mixes of engine and fuel types could achieve the very-low-emission goals adopted by the WTA. Rather than select a preferred approach to controlling the emissions from the future ferry vessels, the WTA proposes to set forth their emission goals in the design specifications for new ferries and leave selection of engines and fuel types to the boat building industry.

Regional Air Quality Impacts

In order to assess the potential impact on regional air quality, Air District staff assessed the potential net emissions of oxides of nitrogen (NOx), hydrocarbons (HC) and particulate matter (PM_{10}) for the following scenarios:

1) Existing ferry service (excluding recreational/tourist services);
2) IOP proposed service in 2025 with engines 85% cleaner than the EPA 2007 emissions standards;
3) IOP projected ferry passengers in 2025 travel by motor vehicles, buses and rail transit – with no ferry service provided.

Results of our analysis are shown in Table 2. For each scenario, Air District staff determined net emissions by estimating the emission reductions that will occur from reduced automobile travel by ferry passengers and then added back in the estimated emissions that will occur from the ferry vessels and from the transit and shuttle buses servicing the ferry terminals. A positive number in Table 2 indicates that emissions reductions achieved by removing vehicles from the roadways are exceeded by emissions from the vessels and/or buses. A negative number (shown in parentheses) indicates that the emissions reductions achieved by removing vehicles from the roadways are greater than the emissions from the vessels and buses.

TABLE 2
ESTIMATED EXISTING AND 2025 EMISSIONS (tons/day)

Scenario	**NOx**	**HC**	**PM_{10}***	**$PM_{2.5}$***
Existing ferry service (excluding recreational/tourist services)	2.32	(0.02)	0.12	0.12
IOP proposed service in 2025 with engines 85% cleaner than the EPA 2007 emissions standards	1.04	(0.42)	0.02	0.02
IOP projected ferry passengers in 2025 travel by motor vehicles, buses and rail transit – no ferry service.	0.29	0.07	0.02	0.02

* PM emissions will be fine particulate < 2.5 micrometer, so $PM_{10} = PM_{2.5}$

Current weekday ferry service contributes 2.32 tons per day (t/d) of NOx and 0.12 t/d of PM_{10} emissions to the Bay Area, while providing a net reduction of 0.02 t/d of HC. The WTA proposed expansion of ferry service would decrease the amount of NOx and PM_{10} that ferry service contributes to the region, and further reduce hydrocarbon emissions. If the same number of ferry passengers as projected by the WTA instead used automobiles (either alone or as carpools) or rode on transit buses, BART and Caltrain, then regional emissions of NOx and PM10 would be further reduced, but HC emissions would increase.

While Air District staff has generally used data on ridership, service frequency and vessel characteristics provided by the WTA, there are differences in several assumptions between Air District staff's analysis and the analysis in the DEIR:

1) Air District staff used only weekday travel and hours of operation; the DEIR included weekend service.

2) Air District staff used lower daily ridership numbers, as provided by the WTA, and less frequent headways than those used in the DEIR analysis.

3) Air District staff assumed longer idling times for some routes, because the WTA's DEIR contained idling times on these routes of less than five minutes.

4) Air District assumed that the future engines would be 85% cleaner than future EPA standards, while the DEIR assumed the engines would be approximately 90% cleaner.

Despite the differences in these assumptions, the results of Air District staff's analysis show the same relative conclusions as the analysis in the WTA's DEIR and CARB's 1999 study: the deployment of very-low-emitting ferry vessels would result in a reduction of the current regional emissions attributable to passenger ferry service.

Localized Air Quality Impacts

In addition to examining the regional impacts of the WTA's IOP, Air District staff analyzed the potential for increases in localized concentrations of three pollutants – carbon monoxide (CO), NO_2 and particulate matter (both PM_{10} and $PM_{2.5}$) – at the proposed ferry terminals. A review of the proposed ferry service indicated that only the San Francisco terminal would have sufficient numbers of vessel operations to warrant additional consideration. Air District staff used currently available data and computer models to predict pollutant concentrations under three scenarios: existing conditions, one that assumed idling times consistent with the regional analysis of the IOP discussed above and another that limited dock-side idling under the IOP proposal to five minutes per vessel operation.

Methodology

The computer model chosen to predict the localized impact is an EPA Guideline Model, the Industrial Source Complex Version 3 Model. This is a Gaussian air quality model routinely used to model impacts from a variety of sources.

Two meteorological data sets were considered for use in modeling the impacts at the terminal: data from the San Francisco International Airport (SFO) and data from the Oakland International Airport (OAK). Meteorological data from other Bay Area monitoring stations were analyzed and determined not to be representative of the area around the ferry Terminal. Modeling was performed using both data sets: the latest three years available from SFO (1989-1991) and from OAK (1981-1983). Receptors were placed on all of the gates and other locations around the terminal, inland to a distance of 0.8 miles, to model exposure to passengers and others that would frequent the areas around the San Francisco terminal. Receptors were not placed over San Francisco Bay.

The Air District maintains and operates regional air monitoring stations around the Bay Area. The closest monitoring station, San Francisco - Arkansas Street, is located just 2 miles south of the Terminal. As a regional monitoring station, it is believed that the Arkansas Street monitoring station provides a good representation of the background concentrations around the San Francisco terminal area. Background PM_{10}, $PM_{2.5}$, CO and NO_2 data were available for the last three years (1999-2001). To represent a worst-case situation, background concentrations were assumed to remain constant into the future.

It is important to point out that this analysis of localized impacts, while complete, is only a preliminary analysis. As such it may reflect an overestimation of future pollutant concentrations. With the dedication of more resources and more site-specific information regarding meteorological and ambient air quality conditions, vessel characteristics, and terminal layout, the analysis could be refined to provide better estimates of the potential impacts.

Existing Conditions

For the analysis of the existing situation, we used the current physical layout of the San Francisco terminal and the current vessel fleet. The current fleet consists of a mix of vessel designs – single hull and catamarans – and most significantly for our analysis, varying locations of exhaust pipes. Some of the single hull vessels have exhaust pipes located mid-vessel 24 feet or higher above the water, while others have exhaust pipes located at the rear of the vessels, at about six to eight feet above the water. The catamaran vessels have their exhaust pipes either in the rear, approximately three feet above the water line, or vent exhaust into the space between the two vessel hulls. As discussed below, localized pollutant concentrations are sensitive to the location of the engine exhaust pipes: venting emissions higher above the water tends to lessen concentrations of pollutants at dockside. Emission rates for the current engines were derived from test data published by engine manufacturers and the WTA. Emission rates take into account the benefits achieved through recent engine replacements on a number of current ferry vessels via funding from the Air District's Carl Moyer Program.

Table 3 shows the predicted maximum air quality impacts for the existing fleet of vessels at the existing San Francisco Ferry terminal. Currently, concentrations of particulate matter exceed the California 24-hour and annual PM_{10} standards and the California annual $PM_{2.5}$ standard.

TABLE 3
MAXIMUM EXISTING CONCENTRATIONS
AT SAN FRANCISCO FERRY TERMINAL ($\mu g/m^3$)

Pollutant/Averaging period	Maximum impact	Max. 3-year background	Impact plus Background [1]	California Standard	Federal Standard
CO					
1-hour	306.1	6,111	6,417	23,000	40,000
8-hour	87.3	4,090	4,177	10,000	10,000
NO_2					
1-hour	127.2	193.6	321	470	-
annual	6.3	39.5	46	-	100
PM_{10}					
24-hour	2.0	77.9	**80**	50	150
annual	0.37	26	**26**	20 [2]	50
$PM_{2.5}$					
24-hour	2.0	45.1	47	-	65
annual	0.37	12.6	**13**	12 [2]	15

1 Concentrations exceeding a standard are shown in bold type
2 Adopted by CARB on June 20, 2002; final approval by the Office of Administrative Law is pending.

Future Conditions – WTA IOP

For the two IOP idling scenarios, the future physical layout of the San Francisco terminal was based on a figure in the Draft IOP, published in September 2002. This layout, while very conceptual, reflects the configuration of two recently constructed gates at the terminal. Ferry vessels were modeled as point sources adjacent to each side of six gates (two ferry vessels per gate). Hourly emission rates were calculated based on the estimated number of ferry vessels per hour that would dock to load and unload passengers at each gate.

For the purposes of our analysis, we have assumed that all existing vessel would have been retired from service. Ferry vessels in 2025 would use diesel engines that are compliant with EPA's 2007 emission standards, in conjunction with selective catalytic reduction (SCR) devices and diesel particulate filters (DPF). The use of the SCR and DPF control devices would reduce NOx and PM_{10} from engine exhaust by at least 85%. We selected these control devices to be consistent with the DEIR and the IOP. It should be noted that by assuming the use of diesel engines, we are modeling a reasonable worst-case scenario in terms of exposure to diesel particulate. The use of other engine types and/or cleaner fuels might show different results.

Vessel characteristics were based on conceptual designs published by the WTA in the technical appendix to the IOP. The newest ferries operating on the Bay have exhaust points located approximately three feet above the water. This design was incorporated into the modeling analysis for future local impacts.

Tables 4 and 5 show the predicted maximum air quality impacts for the two future idling scenarios. Table 4 shows that for the regional analysis idling scenario the federal 24-hour and annual $PM_{2.5}$ standards and four California ambient air quality standards could be exceeded -- the one-hour NO_2 standard, the 24-hour and annual PM_{10} standards, and the annual $PM_{2.5}$ standard. Table 5 shows that if the idling for each ferry is limited to a maximum of five minutes at each of the gates, the California 24-hour and annual PM_{10} standards, and California annual $PM_{2.5}$ standard could be exceeded; and the margins would be much smaller.

TABLE 4
MAXIMUM CONCENTRATIONS FROM IOP IDLING SCENARIO – WITH LOW EXHAUST HEIGHT ($\mu g/m^3$)

Pollutant/Averaging period	Maximum impact	Max. 3-year background	Impact plus Background [1]	California Standard	Federal Standard
CO					
1-hour	2,970.1	6,111	9,081	23,000	40,000
8-hour	1016.3	4,090	5,106	10,000	10,000
NO_2					
1-hour	430.6	193.6	**624**	470	-
annual	33.8	39.5	73	-	100
PM_{10}					
24-hour	24.3	77.9	**102.2**	50	150
annual	6.7	26	**33**	20 [2]	50
$PM_{2.5}$					
24-hour	24.3	45.1	**69**	-	65
annual	6.7	12.6	**19**	12 [2]	15

1 Concentrations exceeding a standard are shown in bold type.
2 Adopted by CARB on June 20, 2002; final approval by the Office of Administrative Law is pending.

TABLE 5
MAXIMUM CONCENTRATIONS FROM IOP IDLING SCENARIO, WITH IDLING TIME LIMITED TO 5 MINUTES – WITH LOW EXHAUST HEIGHT ($\mu g/m^3$)

Pollutant/Averaging period	Maximum impact	Max. 3-year background	Impact plus Background [1]	California Standard	Federal Standard
CO					
1-hour	927.6	6,111	7,039	23,000	40,000
8-hour	338.8	4,090	4,429	10,000	10,000
NO_2					
1-hour	192.1	193.6	386	470	-
Annual	18.1	39.5	58	-	100
PM_{10}					
24-hour	7.9	77.9	**86**	50	150
Annual	2.3	26	**28**	20 [2]	50
$PM_{2.5}$					
24-hour	7.9	45.1	53	-	65
Annual	2.3	12.6	**15**	12 [2]	15

1 Concentrations exceeding a standard are shown in bold type.
2 Adopted by CARB on June 20, 2002; final approval by the Office of Administrative Law is pending.

Health Risk Screening

A health risk screening -- consisting of a screening cancer risk analysis[1] and a chronic health risk analysis[2] -- was also conducted for the existing ferry service and terminal configuration, the IOP scenario, and the IOP scenario with idling limited to five minutes. Under the Air District's *CEQA Guidelines,* a project is acceptable if the associated incremental cancer risk is equal to or less than ten in a million. Additionally, a chronic hazard index of 1.0 or above is considered significant. Table 6 shows the incremental cancer risk and chronic hazard index associated with the existing conditions and the two future IOP idling scenarios.

The estimated existing incremental cancer risk from ferry operations at the San Francisco terminal currently exceeds the Air District's threshold for risk from exposure to diesel particulate matter. Incremental cancer risk is estimated to increase significantly in the future under both IOP idling scenarios because of the increase in ferry operations that is proposed by the WTA. It is estimated that there is not currently nor under the IOP scenarios significant risk for non-cancer health problems due to exposure to diesel particulate matter.

TABLE 6
SUMMARY OF HEALTH RISK ASSESSMENT RESULTS

	Existing idling scenario	IOP idling scenario low exhaust height	IOP scenario with idling limited to 5 minutes low exhaust height
Incremental Cancer Risk	3 in a million	58 in a million	20 in a million
Chronic Hazard Index	0.003	0.059	0.020

As noted above, the results of the health risk assessment were sensitive to the height of the exhaust pipes above the waterline. The higher location of the exhaust pipes on some of the existing vessels, as compared to the assumed height of three feet for future vessels, explains why potential cancer risk under the IOP scenarios is higher than under existing conditions. Since we estimated that future emissions would be less than under existing conditions, we would expect future cancer risk due to exposure to diesel particulate matter to also be lower than under existing conditions.

To test the assumption that the height of the exhaust pipes influenced the Incremental Cancer Risk results shown in Table 6, we conducted a separate health assessment wherein we assumed that for all three scenarios exhaust pipes were located 20 feet above the water. As can be seen from the results shown in Table 7, assuming higher exhaust heights significantly reduces the estimated Incremental Cancer Risk. It should also be noted that higher exhaust locations also should result in lower concentrations in PM_{10} and $PM_{2.5}$.

Although the WTA has already committed to very-low-emission engines in future vessels, the health risk assessment suggests that additional actions and emissions controls to reduce diesel particulate may be warranted.

1 A screening risk analysis estimates the maximum offsite cancer risk from exposure to toxic air pollutants.

2 A chronic health risk analysis is used to estimate the risk of the development of long-term non-cancer health issues, such as asthma, emphysema, high blood pressure, etc. The result of this analysis is expressed in terms of a risk index to allow comparisons between different scenarios and projects.

TABLE 7
SENSITIVITY MODELING OF HEALTH RISK ASSESSMENT
(WITH EXHAUST STACKS AT 20 FEET ABOVE THE WATER)

	Existing idling scenario	IOP idling scenario	IOP scenario with idling limited to 5 minutes
Incremental Cancer Risk	3 in a million	2.6 in a million	1.3 in a million

CONCLUSIONS

The implementation of the WTA's IOP, including the deployment of low emitting ferry vessels, should result in a reduction of current emissions attributable to passenger ferry service. It is recommended that the WTA examine the potential for further reductions in NOx and particulate matter emissions from the ferry vessels by scaling back non-peak service on some routes and through the use of alternative diesel fuels, such as water emulsion fuels and biodiesel.

There is a potential for localized increases of concentrations of NO_2 and particulate matter (PM_{10} and $PM_{2.5}$) above applicable state and federal ambient air quality standards at the San Francisco terminal. Boat design, pier design, and system operations should be carefully planned to minimize local exposure and associated cancer risk.

The WTA should specifically examine the feasibility of reducing local impacts through the use of alternative fuels and through the location of exhaust points on future ferry vessels. It is also recommended that a more thorough examination of localized impacts be conducted once the WTA's operational plans, ferry vessel design and gate layout for the San Francisco terminal are finalized.

BUDGET CONSIDERATIONS/FINANCIAL IMPACT

Staff resources were drawn from Program 605 – Mobile Source Measures, using General Fund revenues. Subsequent work, if any, will draw upon the same resource. State law required the Air District to perform this analysis, but our requests for state funding of the work were not successful.

Respectfully submitted,

Thomas Perardi
Director of Planning

Prepared by: Michael Murphy and Glen Long

Forwarded ______________________

APPENDIX AIR-A

Table 1
Base-Peak

Ferry	Freqency (min)	Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Runs/ Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (mi)	Running Hours/ Route
90_FBALA	40	34.94	7.86	13.5	6.6	9.00	314	59	71	
Deadhead							15			5.5
Alcatraz	60	10	4.00	17.3	5	6.00	60	30	24	
Alcatraz	60	10	4.00	17.3	5	6.00	60	30	24	
Deadhead							15			2.3
90_HBFB	99.99	29.03	9.87	20.4	6	3.60	105	22	36	
90_HBFB-	99.99	29.03	9.87	20.4	13.2	3.60	105	48	36	
Deadhead							60			4.5
90_OAKFB	60	29.42	7.11	14.5	13.2	6.00	177	79	43	
Deadhead							60			3.9
91_LARKN	60	47.78	12.74	16	13.2	6.00	287	79	76	
91_LARKS	30	40.02	12.74	19.1	13.2	12.00	480	159	153	
Deadhead							30			13.3
92_SSLTO	60	30.04	7.66	15.3	9.6	6.00	180	58	46	
92_SSLTO-	60	30.04	7.66	15.3	9.6	6.00	180	58	46	
Deadhead							30			6.5
93_TIBFB	50	21.79	6.9	19	9.6	7.20	157	69	50	
93_TIBFB-	50	21.79	6.9	19	9.6	7.20	157	69	50	
Deadhead							30			5.7
94_VALFB	60	54.93	26.55	29	6.2	6.00	330	37	159	
94_VALFB-	60	54.93	26.55	29	6.2	6.00	330	37	159	
Deadhead							30			11.5
Total min.							**3,190**	**834**		
Total hrs.							**53.2**	**13.9**	**Hours**	

Table 2
Base Off - Peak

Ferry	Freqency (min)	Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Runs/ Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (mi)	Running Hours/ Route
90_FWALA	90	44	8.8	12	6.6	4.3	191	29	38	3.2
Alcatraz	60	10	4.00	17.3	5	6.5	65	33	26	
Alcatraz	60	10	4.00	17.3	5	6.5	65	33	26	2.2
90_OAKFW	90	45.12	8.8	11.7	6	4.3	196	26	38	3.3
91_LARKN	90	47.78	12.74	16	13.2	4.3	207	57	55	
91_LARKS	90	40.02	12.74	19.1	13.2	4.3	173	57	55	6.3
92_SSFW	99.99	37.31	5.41	8.7	9.6	3.9	146	37	21	
92_SSFW-	99.99	37.31	5.41	8.7	9.6	3.9	146	37	21	
92_SSLTO	90	30.04	7.66	15.3	9.6	4.3	130	42	33	
92_SSLTO-	90	30.04	7.66	15.3	9.6	4.3	130	42	33	9.2
93_TIBFW	99.99	34.91	5.47	9.4	9.6	3.9	136	37	21	
93_TIBFW-	99.99	34.91	5.47	9.4	9.6	3.9	136	37	21	4.5
94_VALFB	90	54.93	26.55	29	6.2	4.3	238	27	115	
94_VALFB-	90	54.93	26.55	29	6.2	4.3	238	27	115	7.9
Total Min.							**2196**	**521**		
Total Hrs.							**36.6**	**8.7**	**Hours**	

Table 3
Proposed Project – Peak

	Freqency	Travel Time	Distance	AveSpd	Idle Time	Runs/	Total Run Time/	Total Idle Time/	Total Distance/	
Ferry	**(min)**	**(min)**	**(miles)**	**(mph)**	**(min)**	**Period**	**Period (min)**	**Period (min)**	**Period (miles)**	
90_ALASF	30	28.8	7.52	18.1	1.2	12.0	346	14	90	
90_ALASF-	30	28.8	7.52	18.1	1.2	12.0	346	14	90	
Deadhead							60			
Alcatraz	60	8.4	4.00	13.5	6.6	6.0	50	40	24	
Alcatraz	60	8.4	4.00	13.5	6.6	6.0	50	40	24	
Deadhead							15			
90_HBFB	60	25.2	9.87	20.4	4.8	6.0	151	29	59	
90_HBFB-	60	25.2	9.87	20.4	4.8	6.0	151	29	59	
Deadhead							60			
90_OAKFB	30	24.0	7.11	14.5	6.0	12.0	288	72	85	
90_OAKFB	30	24.0	7.11	14.5	6.0	12.0	288	72	85	
Deadhead							60			
92_SSLTO	30	20.4	7.66	15.3	9.6	12.0	245	115	92	
92_SSLTO-	30	20.4	7.66	15.3	9.6	12.0	245	115	92	
Deadhead							30			
93_TIBFB	30	20.4	6.90	19.0	9.6	12.0	245	115	83	
93_TIBFB-	30	20.4	6.90	19.0	9.6	12.0	245	115	83	
Deadhead							30			
95_BERSFMBA	30	20.4	9.05	17.4	9.6	12.0	245	115	109	
95_BERSFMBA-	30	20.4	9.05	17.4	9.6	12.0	245	115	109	
Deadhead							60			
95_RDWCSF	60	48.8	24.57	32.0	11.2	6.0	293	67	147	
95_RDWCSF-	60	48.8	24.57	32.0	11.2	6.0	293	67	147	
Deadhead							60			
95_RMDFB	30	33.0	9.00	25.0	12.0	12.0	396	144	108	
95_RMDFB-	30	33.0	9.00	25.0	12.0	12.0	396	144	108	
Deadhead							90			
95_SSFSF	30	30.0	10.44	32.0	0.0	12.0	360	0	125	
95_SSFSF-	30	30.0	10.44	32.0	0.0	12.0	360	0	125	

Table 3 (Continued)
Proposed Project – Peak

Ferry	Freqency (min)	Travel Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Runs/ Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (miles)	
Deadhead							60			
96_SFTI	30	13.2	2.11	16.0	1.8	12.0	158	22	25	
96_SFTI-	30	13.2	2.11	16.0	1.8	12.0	158	22	25	
Deadhead							30			
91_LARKN	20	43.6	12.74	16.0	13.2	18.0	785	238	229	B
91_LARKS	20	43.6	12.74	19.1	13.2	18.0	785	238	229	B
Deadhead							30			
94_VALFB	30	53.8	26.55	29.0	6.2	12.0	646	74	319	B
94_VALFB-	30	53.8	26.55	29.0	6.2	12.0	646	74	319	B
Deadhead							40			
95_HERSF	60	43.6	19.57	26.0	16.4	6.0	262	98	117	B
95_HERSF-	60	43.6	19.57	26.0	16.4	6.0	262	98	117	B
Deadhead							60			
96_PITSF	60	80.7	34.10	26.0	9.3	6.0	484	56	205	B
96_PITSF-	60	80.7	34.10	26.0	9.3	6.0	484	56	205	B
Deadhead							30			
									3,636	**Total Miles**
Small ferry total min.							**6109**	**1466**		Peak sum
Small ferry total hrs.							**101.8**	**24.4**	**Hours**	Off-peak sum
Large ferry total min.							**4512**	**932**		TOTAL:
Large ferry total hrs.							**75.2**	**15.5**	**Hours**	

Table 4
Proposed Project - Off-Peak

Ferry	Freqency (min)	Travel Time (min)	Distance (miles)	AveSpd (mph)	Idle Time (min)	Runs/ Period	Total Run Time/ Period (min)	Total Idle Time/ Period (min)	Total Distance/ Period (miles)	
90_ALASF	60	28.8	7.52	18.1	1.2	9.0	259	11	68	
90_ALASF-	60	28.8	7.52	18.1	1.2	9.0	259	11	68	
Alcatraz	60	8.4	4.00	12.0	6.6	9.0	76	59	36	
Alcatraz	60	8.4	4.00	12.0	6.6	9.0	76	59	36	
90_HBFB	0									
90_HBFB-	0									
90_OAKFW	60	24.0	8.80	11.7	6.0	9.0	216	54	79	
90_OAKFW	60	24.0	8.80	11.7	6.0	9.0	216	54	79	
92_SSLTO	60	20.4	7.66	15.3	9.6	9.0	184	86	69	
92_SSLTO-	60	20.4	7.66	15.3	9.6	9.0	184	86	69	
93_TIBFW	60	20.4	5.47	9.4	9.6	9.0	184	86	49	
93_TIBFW-	60	20.4	5.47	9.4	9.6	9.0	184	86	49	
95_BERSFMBA	60	20.4	9.05	17.4	9.6	9.0	184	86	81	
95_BERSFMBA-	60	20.4	9.05	17.4	9.6	9.0	184	86	81	
95_RDWCSF	60	48.8	24.57	32.0	11.2	9.0	439	101	221	
95_RDWCSF-	60	48.8	24.57	32.0	11.2	9.0	439	101	221	
95_RMDFB	60	33.0	9.00	25.0	12.0	9.0	297	108	81	
95_RMDFB-	60	33.0	9.00	25.0	12.0	9.0	297	108	81	
95_SSFSF	60	30.0	10.44	32.0	0.0	9.0	270	0	94	
95_SSFSF-	60	30.0	10.44	32.0	0.0	9.0	270	0	94	
96_SFTI	30	13.2	2.11	16.0	1.8	18.0	238	32	38	
96_SFTI-	30	13.2	2.11	16.0	1.8	18.0	238	32	38	
91_LARKN	60	43.6	12.74	16.0	13.2	9.0	392	119	115	B
91_LARKS	60	43.6	12.74	19.1	13.2	9.0	392	119	115	B
94_VALFB	60	53.8	26.55	29.0	6.2	9.0	484	56	239	B
94_VALFB-	60	53.8	26.55	29.0	6.2	9.0	484	56	239	B
95_HERSF	240	43.6	19.57	26.0	16.4	2.3	98	37	44	B
95_HERSF-	240	43.6	19.57	26.0	16.4	2.3	98	37	44	B
96_PITSF	200	80.7	34.10	26.0	9.3	2.7	218	25	92	B
96_PITSF-	200	80.7	34.10	26.0	9.3	2.7	218	25	92	B
									2613	**Total Miles**
Small ferry total min.							**4691**	**1249**		
Small ferry total hrs.							**78.2**	**20.8**	**Hours**	
Large ferry total min.							**2385**	**473**		
Large ferry total hrs.							**39.8**	**7.9**	**Hours**	

Table 5
Vehicle Emissions Calculations

PASSENGER VEHICLES

Vehicle Miles Traveled

2025 No Project	**177,851,516**
2025 Proposed Project	**177,709,056**

Year 2025 No Project

	EMFAC2000 Emission Factors (g/mi) - Year 2025	Running Emissions (lb/day)	AM Cold Start Emissions (lb/day)	PM Cold Start Emissions (lb/day)	Total Vehicle Emissions (lb/day)
NO_x	0.152	59,598	2,752	1,480	63,830
PM_{10}	0.015	5,881	153	74	6,108
CO	1.544	605,385	70,493	33,141	709,019
ROG	0.158	61,950	6,346	2,885	71,181

Year 2025 Proposed Project

	EMFAC2000 Emission Factors (g/mi) - Year 2025	Running Emissions (lb/day)	AM Cold Start Emissions (lb/day)	PM Cold Start Emissions (lb/day)	Total Vehicle Emissions (lb/day)
NO_x	0.152	59,550	2,751	1,478	63,779
PM_{10}	0.015	5,877	153	74	6,104
CO	1.544	604,900	70,452	33,097	708,449
ROG	0.158	61,900	6,342	2,881	71,123

BUSES TO NEW FERRY TERMINALS

Vehicle Miles Traveled: 9,942

Year 2025 Proposed Project

	EMFAC2000 Emission Factors (g/mi) -	Emissions (lb/day)
NO_x	0.325	7
PM_{10}	0.038	1
CO	2.203	48
ROG	0.368	8

Figures

1.0 INTRODUCTION

This appendix presents example impact analyses for five sites representing the major shoreline types in the Bay. Predicted wake characteristics from the ferry service alternatives were compared to the significance criteria developed in Appendix WAKE-D.

Existing wind-driven wave characteristics were evaluated as discussed in Appendix A.

Wake wash characteristics of existing conventional and high-speed ferry vessels operating on the six services in San Francisco Bay were measured over a three-day period in February 2002 for this assessment. Details of the measurements are presented in Appendix WAKE-B.

The following representative sites were selected for this assessment:

Potential Concern	Location
California Clapper Rail Nesting Area	Petaluma River Wetlands
Wetland	Point Pinole (Chinese Cove)
Seal Haul-Out	Yerba Buena
Narrow Channel	New York Slough
Marina	Paradise Cay

The locations of these sites are shown on Figure WAKE-E-1.

2.0 CLAPPER RAIL NESTING AREA - PETALUMA RIVER WETLANDS

The Petaluma River Wetlands are located in the North Bay, adjacent to Highway 37, which connects Highways 101 and 80. The wetlands, consisting mostly of farmed baylands, tidal marshes, and bay flats, surround the Petaluma River and the mouth of the river that meets the San Pablo Bay (Figure WAKE-E-2). At the entrance to the river, there is a swinging railroad bridge and a wetland bird sanctuary. Potential California clapper rail nesting areas were identified in a slough on both sides of the channel as shown on Figure 3.5-12 in Section 3.5, Biology (Jules Evens, personal communication).

This site was used to evaluate both wake wash impacts to wetlands and potential impacts from inundation of clapper rail nests.

There is currently no ferry service impacting this site. Alternatives 1 and 2 include service to a North Bay terminal such as Port Sonoma. Alternative 3 does not include service to these locations. The routes would involve a long transit in the shallow and narrow channel, which leads to the Petaluma River. The proposed vessel would be 350 passenger, 35+ knots.

2.1 IMPACTS TO SHORELINE

The potential impacts to the physical shoreline were evaluated using the decision tree presented in Section 3.3.2 of the Wake Wash Assessment Section (Figure 3.3-5). The ferry route would be within 1,500 m of the potentially sensitive shoreline, and the route could not be adjusted to be more than 1,500 m from the shore.

The significant wave height for wake waves was calculated via the method described in Appendix WAKE-B. As discussed in Appendix WAKE-B, the height of individual waves in the wake wash wave train attenuate at a rate inversely proportional to the cube root of the ratio of distances. The wave height attenuation is given by the following equation:

$$\frac{H_2}{H_1} = \sqrt[3]{\frac{d_1}{d_2}}$$

where H_1 = Wave height measured

H_2 = Wave height at location of concern

d_1 = Distance of measurement from vessel line of travel

d_2 = Distance of location of concern from vessel line of travel

Although the route would require a 350-passenger/35+kt vessel, the vessel would likely have to be slowed to about 10 kts in the approach to a terminal for navigational purposes. Therefore the calculations were done for 10-kt speed. Wake wave height for a 350-pax vessel traveling 10 kts at 300 m is 24.8 cm. Based on a distance of 50 m from the route to the shoreline, the calculated wake wave height at the shoreline would be 45 cm. This is larger than the 16- cm significance criterion.

Wind-driven wave characteristics were calculated for the site, as described in Appendix WAKE-A. Monthly average significant wave height is 1.3 m and the monthly maximum significant wave height is 1.6 m. The calculated wake wave height is less than half the average for the site (63 cm). Therefore, no significant impacts would be anticipated.

2.2 IMPACTS TO CLAPPER RAIL

There are reported clapper rail nesting sites in the Petaluma Wetlands (Jules Evens, personal communication). An attempt to evaluate wake wash attenuation in a small slough, which leads to the wetlands, was performed on February 12, 2002. The wash characteristics (wave height and energy) of the *F.T. Provider* used in the study were measured, and were found to be very similar to those of a 149 passenger ferry. Wave height was 28 cm for the *Provider* and 15 for the ferry at 300 m. Energy was 820 J/m for the *Provider* and 800 J/m for the ferry. Although the *Provider* is a smaller and lighter vessel than a ferry, the blunt shape of this trawler hull produces wake energy at 10 kts similar to the energy of a larger but more efficient ferry hull operated at the same speed.

Given the very shallow water in the channel and necessity for slow speed navigation, a direct measure of wash in the slough could not be made. Instead a pressure buoy was positioned as close to the slough as possible in order to measure the wash height and period. The work boat *F.T. Provider* made several runs at maximum allowable speed (10 kts) past the slough as close as possible to the mouth. Through direct observation, no motion was detected in the slough, suggesting that the wash energy from the *Provider* was spent on the beach of the channel and did not enter the slough. The experiment was documented on videotape.

Based on these results, significant impacts to clapper rail nesting sites would not be anticipated.

3.0 WETLAND –CHINESE COVE (POINT PINOLE)

Point Pinole is at the tip of the Point Pinole Regional Shoreline in the North Bay, a 2,315-acre parkland area that juts out into the San Pablo Bay (Figure WAKE-E-3). Chinese Cove is a wetland area on the eastern side of the point. There is current ferry service from Vallejo to and from San Francisco. This area is a marshy wetland and could be subject to wash from current San Francisco-Vallejo route and additional proposed routes from San Francisco to Benicia (Alternative 1), Antioch (Alternative 1), Pittsburg (Alternatives 1 and 2), and Martinez (Alternatives 1 and 2). The routes would pass at an average of approximately 950 m from the point on northbound trips and at an average 1,950 m (off map it's 3,750) from the cove shoreline on southbound trips. However, only wash from southbound trips was included in this analysis. Because the site is located on the eastern side of the point and is sheltered, wash from northbound trips would not impact the site.

Because the proposed route is more than 1,500 m from the potentially sensitive shoreline, no significant impacts are anticipated.

4.0 SEAL HAUL-OUT - YERBA BUENA

Yerba Buena Island is located adjacent to Treasure Island in the Central Bay, about midway along the Bay Bridge (Figure WAKE-E-4). The southern end of Yerba Buena Island is one of the San Francisco Bay's major seal haul-out sites, which are areas where seals pull themselves from the water to rest. (There is another haul-out site located on the northeastern side of the island, but only the southern site was evaluated for this assessment.) The sea haul-out site at the southern end of Yerba Buena Island is currently subject to the wash from the East Bay ferries that are going to and from the San Francisco Ferry Terminal (Oakland-San Francisco and Harbor Bay-San Francisco). Figure WAKE-E-5 is a photo of the seal haul out habitat on the south shore of Yerba Buena Island. The splash seen on the beach is wake wash from *M.V. Zelinsky* traveling eastbound.

Potential service that could impact this area of Yerba Buena Island includes the existing as well as potential new routes from Oakland Army Base to San Francisco (Alternative 1) and from Harbor Bay to Hunter's Point (Alternative 1).

4.1 IMPACTS TO SHORELINE

No significant impacts to the shoreline are anticipated for this site because the shoreline is rocky. Rocky shorelines can withstand extreme weather events, which exert wave energy many orders of magnitude greater than that in wake wash.

4.2 IMPACTS TO PACIFIC HARBOR SEALS

It is not apparent that increased wave activity would be a disturbance at haul-out sites as seal haul outs are often on exposed rocky sites subject to significant wave energy. Existing evidence (see Biology Section) suggests that seals at haul-out sites are primarily disturbed by changes in vessel patterns or vessels suddenly changing course which invoke a startle response. The potential ferry routes would be approximately ½ kilometer from the Yerba Buena haul-out site and would be unlikely to disturb seals (the NMFS guideline [see Biology Section] for minimum avoidance distance of seals and sea lions to reduce disturbance 30 meters.)

5.0 NARROW CHANNEL - NEW YORK SLOUGH

New York Slough is located in Suisun Bay, which is in the far eastern part of the North Bay (Figure WAKE-E-6). It is a narrow passage near Antioch, with potential industrial activity on the south side. There are currently no ferry routes passing near the slough. Proposed service would use a Mare Island Class vessel (350-pax/35+kts). Although no specific problems have been identified in this area, wake wash from potentially proposed service from San Francisco to Antioch (Alternative 1) and Pittsburg (Alternatives 1 and 2) could be an issue when industrial activity is in progress. Alternative 3 would not have ferry routes passing the slough. The routes would pass approximately 120 m from the shore facilities on the south side of the slough.

The potential impacts to the physical shoreline were evaluated using the decision tree. The ferry routes would pass approximately 120 m from the potentially sensitive shoreline.

The significant wave height for wake waves was calculated as described in the previous section. Wake wave height for a Mare Island Class vessel (350-pax/35-kt) is 27 cm at 300 m. Based on a distance of 120 m from the route to the shoreline, the calculated wake wave height at the shoreline would be 37 cm. This is larger than the 16-cm significance criterion.

Wind-driven wave characteristics were calculated for the site, as described in Appendix WAKE-A. Monthly average significant wave height is 27 cm and the monthly maximum significant wave height is 40 cm. (The relatively small wind-driven waves are due to very limited fetch in the area.) The calculated wake wave height is more than half the average for the site (13.5 cm).

New York Slough has significant traffic from other vessels. Although, it was not included as part of this study, for an actual analysis, wake at the shoreline from other vessels should be measured. If the predicted wake from the ferries smaller than that measured for other vessels, no significant impacts would be anticipated. If it were larger, the analysis would continue and it would need to be evaluated whether wake could be redirected away from sensitive receptors, whether the shoreline could be protected, whether impacts could be mitigated, whether lower wash vessels could be used, or whether operational controls, such as slowing the vessels down would allow the criteria to be met.

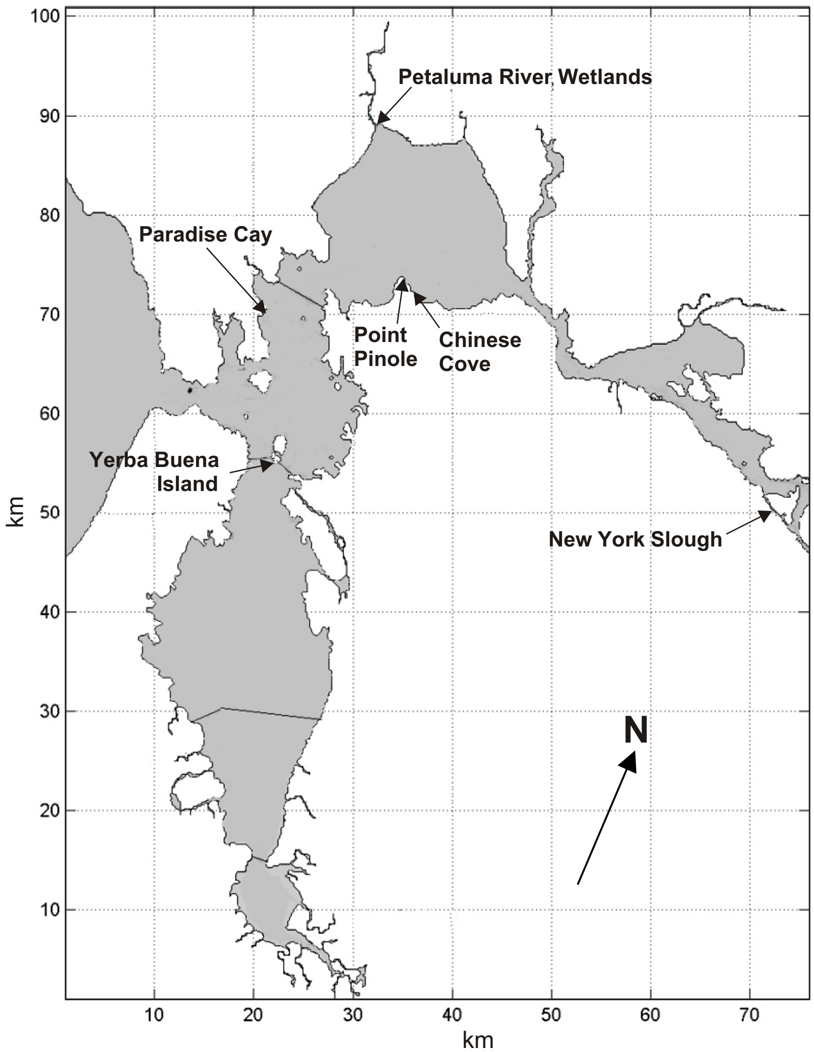
6.0 MARINA - PARADISE CAY

Paradise Cay Marina is located on the eastern side of the Tiburon peninsula (Figure WAKE-E-7). The Larkspur-San Francisco route currently passes the area at a distance of approximately

2,750 meters. Both Mare Island class (350-pax/35+kt) and Spaulding class (725 pax/20-kt) vessels are currently used on this route. The number of ferry transits would be significantly increased under all three alternatives, but only 350-pax/35+kt vessels would be used. When passing the marina at Paradise Cay at service speed, wash from new ferries could cause some movement of moored vessels and floating piers. Individual wave height and energy are the primary factors of concern for impacts to the marina.

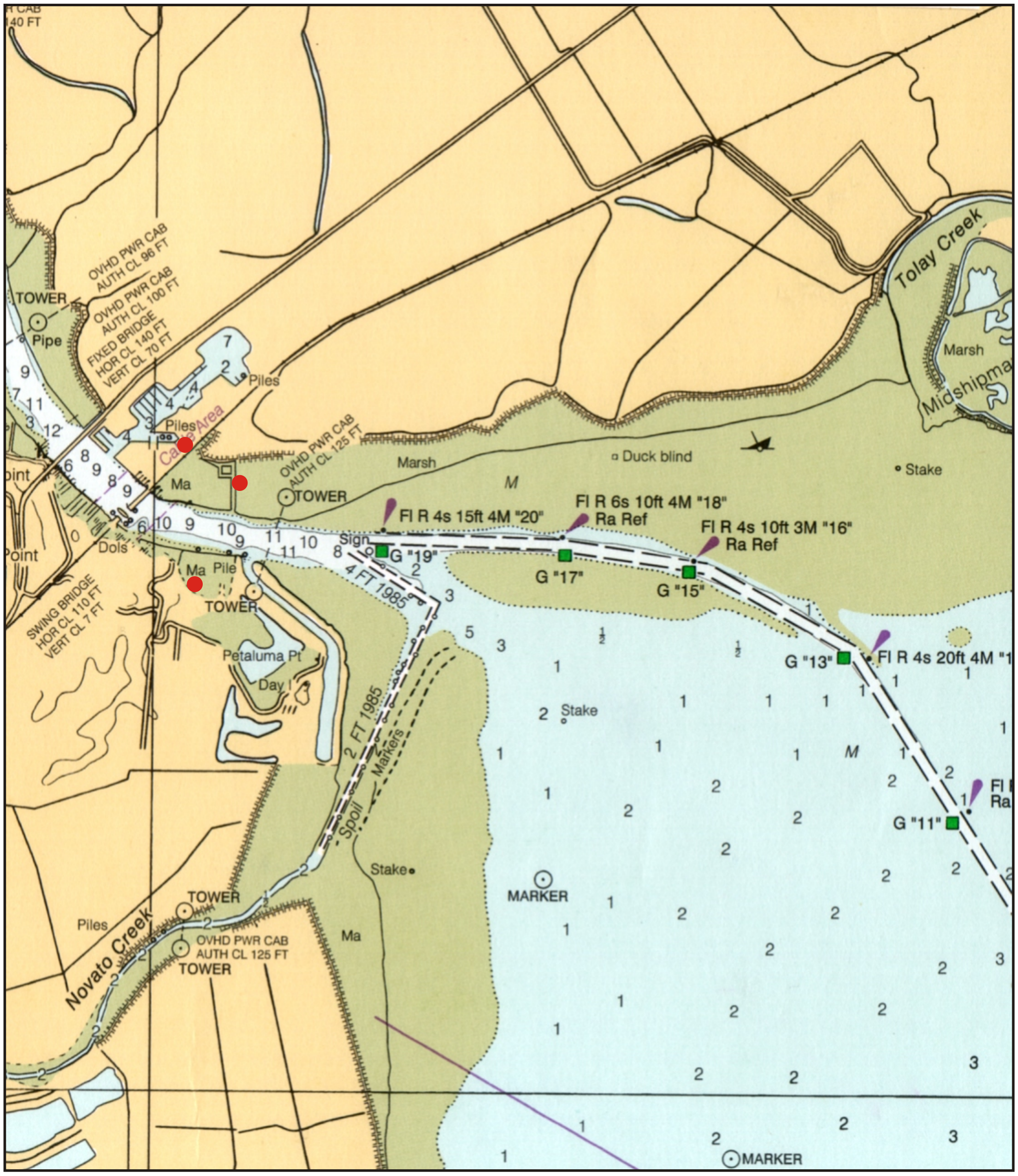
Because the proposed route is more than 1,500 m from the potentially sensitive shoreline, no significant impacts are anticipated.

APPENDIX WAKE-E FIGURES



URS	Water Transit Authority Programmatic EIR Project No. 43-00066890	Representative Site Locations	Figure WAKE-E-1

8/05/02 vsa ...43-00066890.13\WE1_repsitloc.cdr



Source:
U.S. Dept of Commerce,
Soundings in Feet, San Pablo Bay, CA 1999

LEGEND

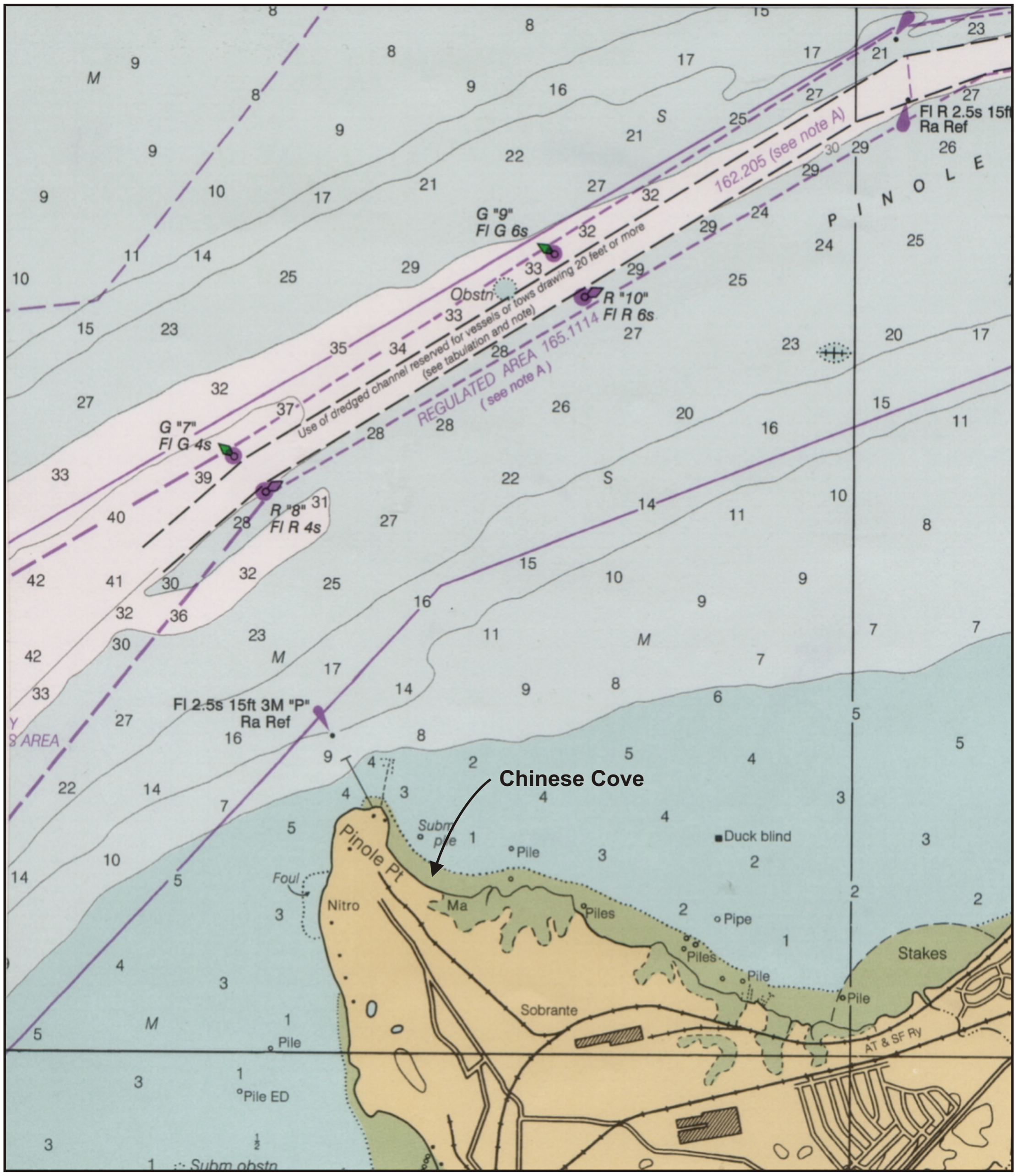
● General Location of Potential Clapper Rail Nest Sites

N

0 0.5 1

Scale in Nautical Miles
1:40,000

URS	Water Transit Authority Programmatic EIR	Map of Petaluma Wetlands – Clapper Rail Nesting Area	Figure WAKE-E-2
	Project No. 43-00066890		



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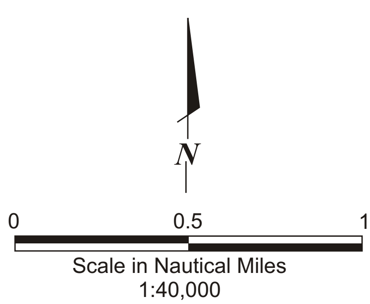
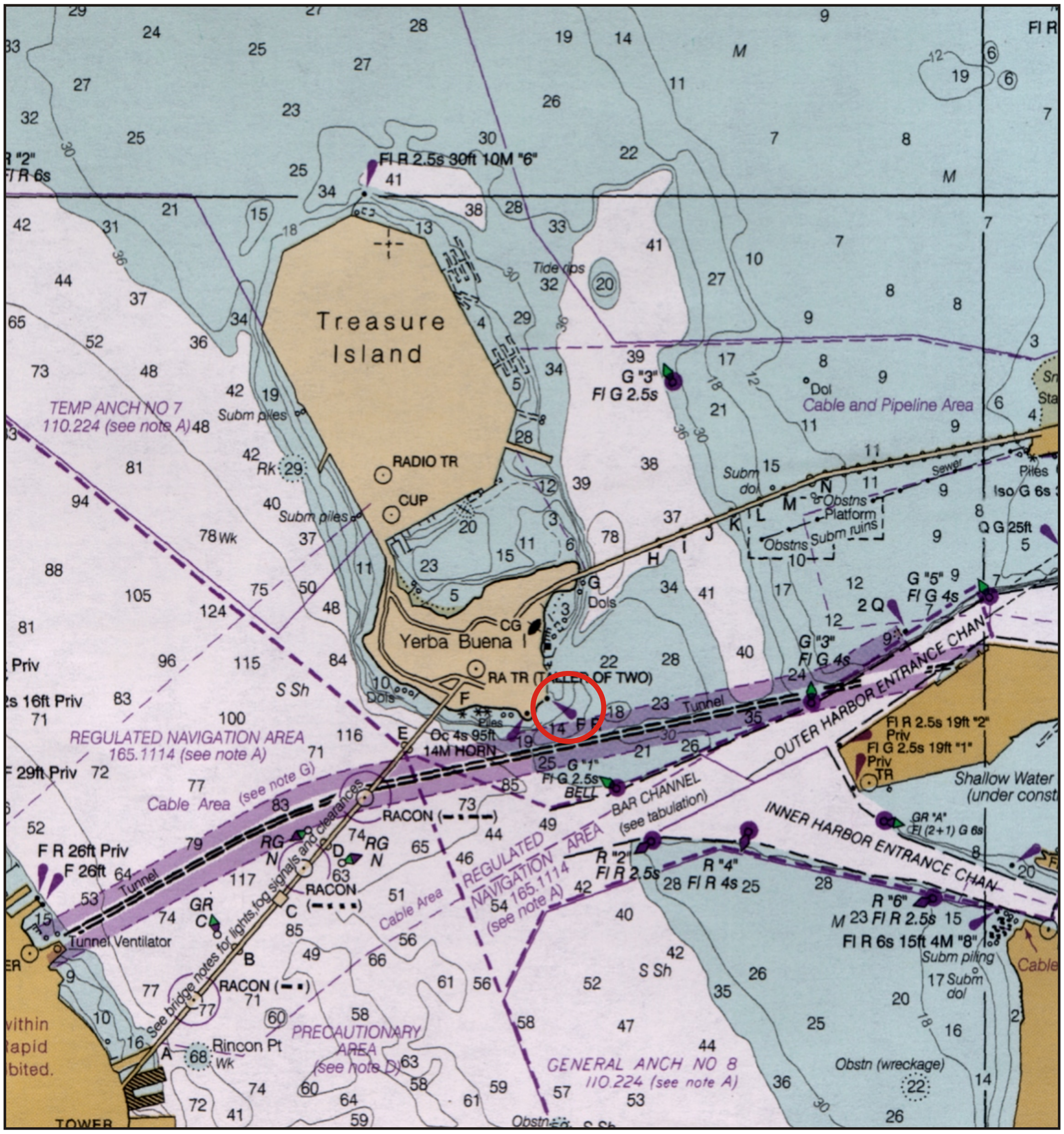
U.S. Dept of Commerce,
Soundings in Feet, San Pablo Bay, CA 1999



URS	Water Transit Authority Programmatic EIR	Map of Pinole Point – Chinese Cove Wetlands	Figure WAKE-E-3
	Project No. 43-00066890		



Source:
U.S. Dept of Commerce,
Soundings in Feet, Entrance to San Francisco Bay, CA 2001

N

0 0.5 1
Scale in Nautical Miles
1:40,000

LEGEND

Harbor Seal Haul-Out Sites

URS	Water Transit Authority Programmatic EIR	Map of Yerba Buena – Seal Haul-Out	Figure WAKE-E-4
	Project No. 43-00066890		

8/05/02 vsa ...43-00066890.13\WE4_yerbabuena.cdr

URS	Water Transit Authority Programmatic EIR	Seal Haul-Out at Yerba Buena Island	Figure WAKE-E-5
	Project No. 43-00066890		

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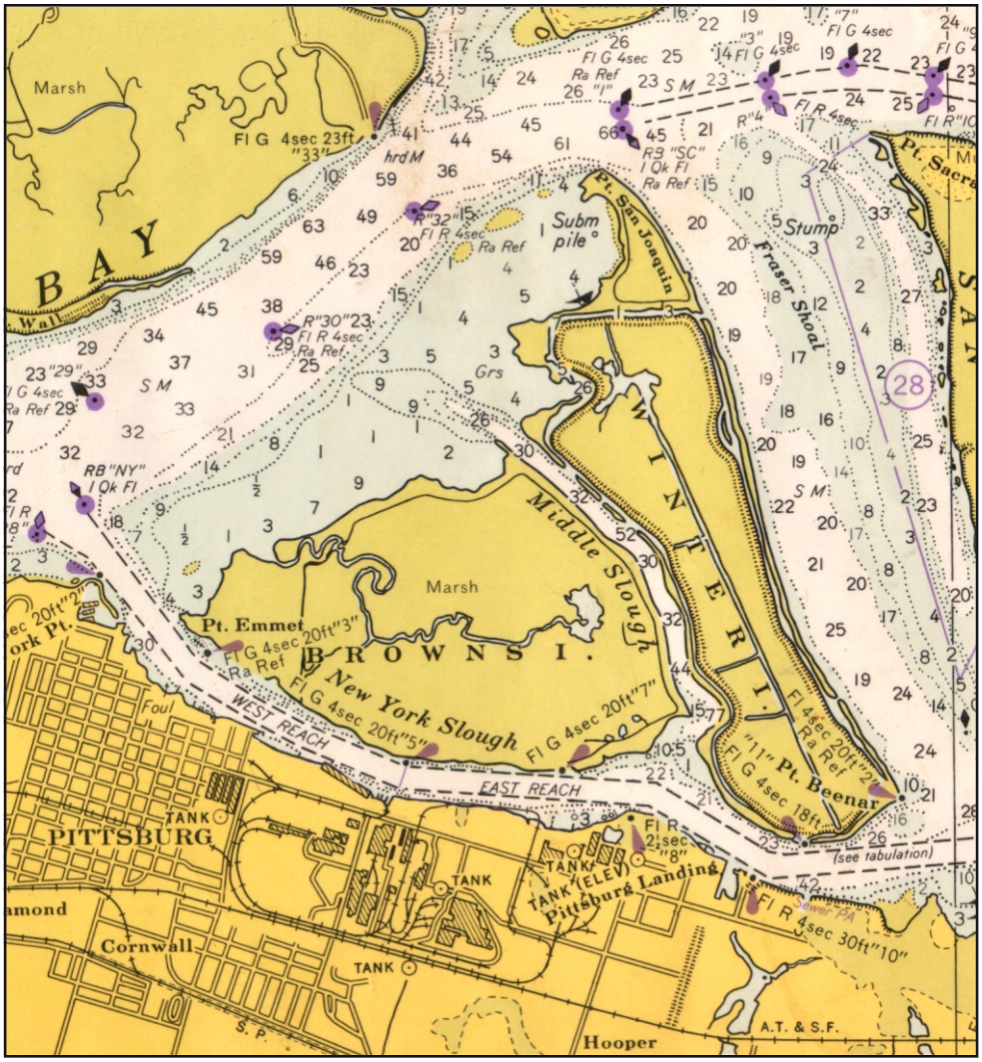

Source:
U.S. Dept of Commerce,
Soundings in Feet, Suisun Bay, CA 1975

N

0 0.5 1

Scale in Nautical Miles
1:40,000

URS	Water Transit Authority Programmatic EIR	Map of New York Slough – Narrow Channel	Figure WAKE-E-6
	Project No. 43-00066890		

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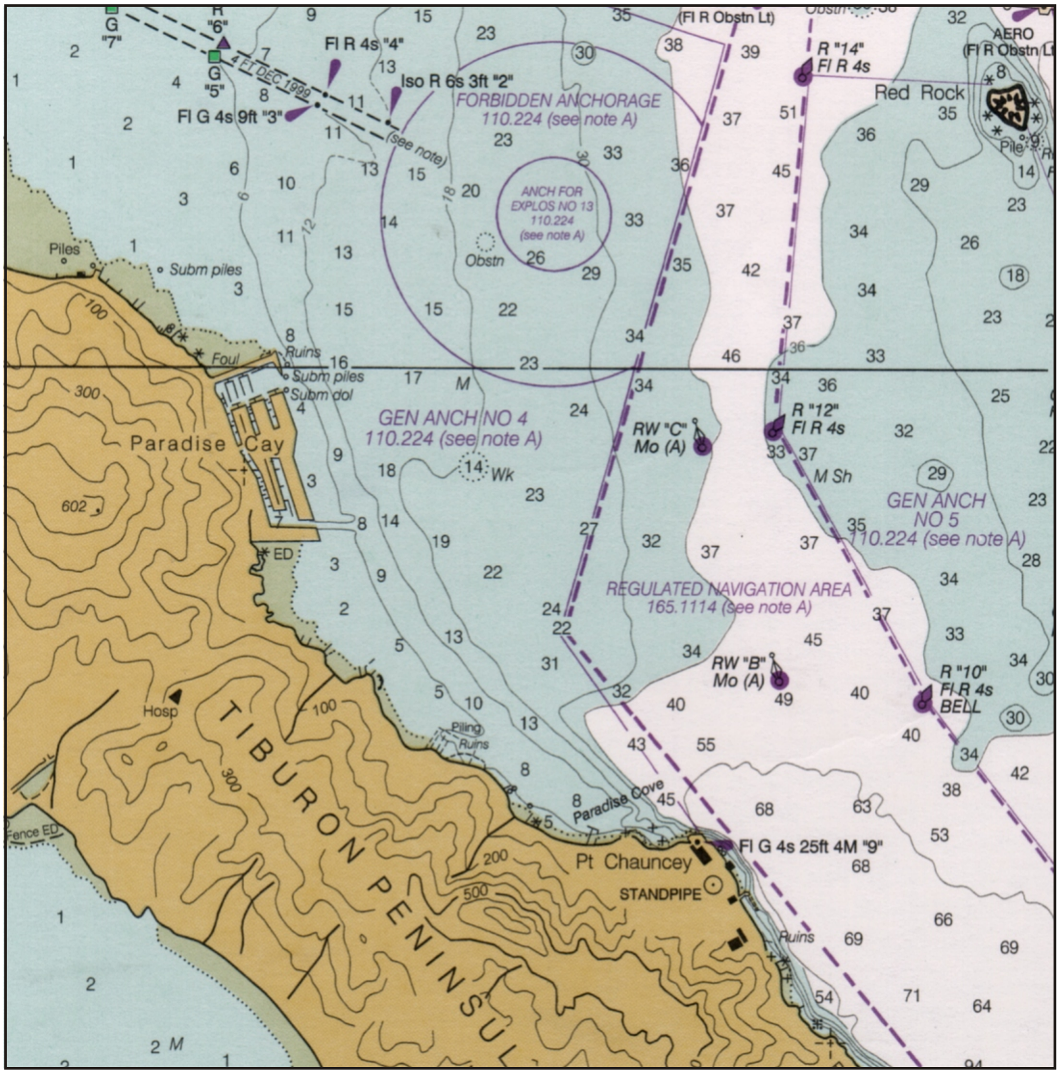

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U.S. Dept of Commerce,
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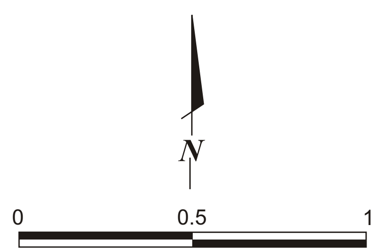

URS	Water Transit Authority Programmatic EIR Project No. 43-00066890	Map of Paradise Cay – Marina	Figure WAKE-E-7

Tables

Figures

1.0 INTRODUCTION

This appendix presents the technical approach used to develop significance criteria for the wake wash assessment. The methodology evaluates the characteristics of wake wash from high-speed vessels in comparison with those of naturally occurring wind waves. A discussion of wake wash is presented in Section 2 of this appendix. The corresponding discussion of the wind wave climate in San Francisco Bay is presented in Appendix WAKE-A. In Section 3 of this Appendix, the significance criteria used in the wake wash impact evaluation are developed.

2.0 INTRODUCTION TO WAKE

Waves occur in the natural environment as the result of energy, usually from wind, transferred to the water surface. Naturally occurring waves transfer significant energy to shorelines, which account for significant variations in shorelines during different seasons.

Vessels with submerged hulls also create waves, referred to as vessel wake or wake wash. Vessel wake results from water pushed aside, or displaced, by the hull and the resistance of the water to hull movement. The displaced water first moves up whereupon gravity acts upon it resulting in the familiar form of an undulating wave with predictable shape and properties. These waves can be approximated mathematically as harmonic waveforms or sinusoidal waves, similar to wind-driven waves as described in Appendix WAKE-A.

The waves move towards the shoreline, where, depending on the water depth and type of shoreline, they may either dissipate harmlessly or may cause undesirable impacts, such as erosion. The detailed characteristics of wake wash when it reaches the shoreline depend on the size and shape of the vessel hull, vessel speed, vessel direction, and water depth (Stumbo, Fox, and Elliot 1999).

If vessel wake results in waves at a shoreline that have significantly greater wave heights or energy compared to natural wind waves, the wake wash can lead to excess re-suspension of shoreline sediments and erosion, or can cause damage to shoreline development. Wake wash is of concern in the Bay Area where wetlands, other sensitive habitat, and marinas are in close proximity to ferry routes.

In areas of sensitive wetlands or tidal mudflats, wake wash can lead to environmental changes by reducing natural sedimentation and hence influence benthic and other organisms (Austin and Bruzzone 1999). Of particular concern in marshlands, are species such as the California clapper rail (*Rallus longirostris obsoletus)*, an endangered species, which is a yearlong resident of emergent salt and tidal marshlands of the Bay (Goals Project 2000; Avocet Research, Collins, and Evens 1992). Disturbances to clapper rail habitat, such as inundation of nests by unexpectedly larger waves, could potentially have a negative impact on the endangered species' survivability during the nesting season.

Fortunately, there are a number of ways to mitigate the potential for wake wash impacts. Operational controls, such as slowing vessels down near sensitive habitats, can be utilized to minimize impacts. For example, existing high-speed ferry service operations out of Larkspur and Vallejo are both subject to speed restrictions in their approach channels. In Larkspur the primary concerns are impacts to Corte Madera marsh and to the marina at Paradise Cay, while in

Vallejo, the concern is for houses and private slips that have been built close to the shoreline along the mouth of the Napa River. Advanced design and technologies also have the potential to create low wake or no-wake vessels. Hovercraft are an example of very low wake vessels. Ferry routes can also be modified to redirect wave energy away from sensitive areas and if, necessary, operational controls such as speed restrictions can be used to limit wake energy.

2.1 WAKE WASH AND VESSEL SPEED

Waves generated by conventional vessels occur in two or more “trains.” At slow speed, as a vessel gains speed, the first waves that are seen are the stern “transverse” waves, which appear to be following the ship. As the vessel gains speed, a second set of “divergent” waves form along the bow. The pattern formed by these two wave trains is known as a “Kelvin wave pattern,” shown as the top pattern on Figure WAKE-D-1. The waves are moving faster than the vessel that creates them and the speed of the vessel is termed “subcritical.” After these waves have traveled some distance from the line of travel, the waves will have formed into one or more sets of waves, usually dominated by the divergent bow waves.

In order to compare vessels of various configurations, size and speeds, several investigators established a standardized distance of 300 meters (~1,000 feet) for taking measurements (Stumbo, Fox, and Elliot 1999). Some investigations have used different distances because of different waterway conditions. Measurements taken reasonably close to 300 meters can be corrected to this distance by some simple calculations (Doctors et al. 2001).

Conventional vessels and ferries travel at subcritical speeds, rarely exceeding 70% of the wave speed. By contrast, high-speed vessels and ferries travel faster than the waves they generated. In order to do so, they have to catch up with the waves, and pass through them. A high-speed vessel uses the greatest amount of power at the critical speed.

The middle portion of Figure WAKE-D-1 shows a vessel traveling at “critical” speed, or the same speed as the waves in the wake. This speed is also called the “hump speed.” The wake is a single wave moving out at 90 degrees from the vessel. When the vessel passes through the “hump” and travels faster than the wake waves, it is at “supercritical speed.” The wake forms the pattern shown on the lower portion of Figure WAKE-D-1. At this point, increasing speed, and particularly after the vessel reaches hump speed, the transverse waves seem to diminish in size while the divergent waves increase.

Vessels that plane across the surface of the water or are slightly elevated above the water on an air-cushion, such as surface-effect and hovercraft, produce significantly smaller wake wash than comparably sized hulled vessels. Hovercraft only displace a few inches of water under the center of the vessel and therefore create almost no wash. Hovercraft can be used in some situations, where engine noise is not an issue, to mitigate wake wash impacts.

Before the development of high-speed ferries, the amount of wake wash a vessel generates was considered to be directly proportional to speed. While this relationship is generally true for conventional and large vessels with large displacement hulls, such as tankers that travel at subcritical speeds, the opposite is often true with lightweight vessels such as high speed ferries (Stumbo, Fox, and Elliot 1999). High-speed ferries traveling at their design operational speeds are planing on the water so they displace less water than they do at slower speeds. Therefore, they create less wake.

Figure WAKE-D-2 shows the wake wash height (directly proportional to wave energy) for three vessels studies performed by Stumbo, Fox, and Elliot (1999). The hump speed is shown as a vertical arrow. The figure shows a 350-passenger Mare Island class ferry (the Washington State Ferry *Chinook*), the *Bravest,* a 350-passenger light-weight, low-wake, high-speed ferry operating in New York, and the *Slice*, a prototype wave piercing sea-platform with submerged pontoons designed by Lockheed Marine for ferry operations between Hawaiian Islands. The Mare Island class and *Bravest* curves are similar, showing wave height increasing approximately linearly with speed until the hump speed is reached, after which the wake height drops considerably.

It should be noted that for the Mare Island class of vessels, the wake height at operational speeds (34 to 36 knots) is approximately the same as at 12 knots. Therefore, in order to reduce wake wash from that at operation speeds, the vessel speed would need to be 12 knots or lower.

2.2 WAKE DECAY AND DISSIPATION

There are some significant differences between the growth and decay characteristics of wind waves and wake wash waves. Wind-driven waves increase in energy and height as they approach the shoreline because wind is constantly acting on the waves and, hence, adding to the wind wave energy. By contrast, individual wake wash waves obtain their energy from a vessel and then lose height and some energy as they waves propagate away from a vessel. Wake waves disperse over distance, meaning individual waves become smaller in height while the total number of waves in the wave train increases. Some energy from vessel wakes is lost through interaction with wind-driven waves or by friction as the waves travel over great distances. However, the remainder of the wave energy will reach the shoreline, especially if the vessel route is near shore. Those waves that reach the shoreline expend themselves in a predictable manner and the height of the wake waves and the amount of energy that will reach the shoreline can be calculated. A detailed description of this calculation is presented in Appendix WAKE-B.

3.0 DEVELOPMENT OF SIGNIFICANCE CRITERIA

In order to develop a wake wash significance criteria for evaluation of potential impacts to the Bay shoreline and mudflats, the Bay wave data presented in Appendix WAKE-A were analyzed to develop both a vessel wake wash height criterion and shoreline wave height criteria. The vessel wake criterion was needed in order to predict the wake wave height attenuation and energy propagation towards the shoreline. The shoreline wave height criteria enable the potential impacts of vessel wake wave heights and energy to be evaluated.

In the following analysis, a 27-cm wave height criterion (measured at 300 m from the vessel) is developed as the criteria for the vessel wave wake height. Analysis of the shoreline wave heights indicates that a 16-cm wave (6 in) will not cause significant shoreline or mudflat erosion impacts. Based on wave height attenuation calculations, a 27-cm wave will attenuate to 16 cm over a 1,500-m distance in calm conditions and will attenuate much faster under typical wind conditions. Hence, the 16-cm shoreline wave height and 1,500-m distance are used as the shoreline impact significance criteria. These criteria are based on the natural wind waves resulting from typical wind conditions in the Bay. Extreme wind conditions, which cause the largest wind waves, were not considered.

A similar methodology was used by Washington State Ferries to develop a 28-cm wave height criteria (measured 300 m from vessel) based on a combination of oceanographic and biological considerations. The 28-cm wave height was considered not to cause significant wave damage to the shoreline.

3.1 WAKE CHARACTERISTICS CRITERION

3.1.1 27-cm Vessel Wake Wave Height Criterion

Wind wave heights resulting from average winds were calculated as described in Appendix WAKE-A and are presented in Table WAKE-D-1. Because wave height is a function of wind speed, duration and fetch length, a range of wave heights occurs each month. The wind wave heights shown in Table WAKE-D-1 are the monthly average sustained wind waves and are also the average of the waves with the greatest energy. As these wave occur naturally, the shoreline is in dynamic equilibrium with these levels of wind wave energy.

The average of the sustained wind wave heights that occur regularly on a monthly basis were calculated to range from a minimum of 27 cm at New York Slough to maximum of 1.3 m offshore of Petaluma wetlands. The maximum of the sustained wind wave heights that occur on a monthly basis range from 0.4 m New York Slough to 2.6 m at Yerba Buena.

The minimum of the average sustained winds wave heights is 27 cm (10.6 in). This wave height value is exceeded 100% of the time at 9 of the 15 locations and is exceeded 92% of the time at all of the 15 typical locations evaluated. Because the 27-cm wave height is naturally exceeded a very high percentage to time, it was selected as the criteria for the vessel wake measured at the standard distance of 300m from the vessel. Note that the 27-cm height is not the acceptable shoreline wake wash height even though it naturally occurs at the shoreline and is often exceeded. This criterion is only the vessel wake wash criteria. Wake wash heights at the shoreline will be less than 27-cm at distances greater than 300m because of the wave height attenuation described in Appendix WAKE-B.

The Naval Architects (Kenneth Fox and Stan Stumbo) developing the vessel specification for the Water Transit Authority indicated that the 27-cm (at 300 m) wake wash height criterion is achievable for a 350-px/35-kt high-speed ferry. The Washington State Ferry criterion for a similar vessel is 28 cm measured at 300 m.

3.1.2 16-cm Shoreline Wake Wave Height Criterion

A very conservative estimate of the wave height above which impacts could be considered significant was developed by considering the average daily wind waves arriving at the shoreline. As waves approaching a shoreline, they refract (bend towards the shoreline), shoal and break. Even the smallest waves resuspend a small amount of sediment when they reach the shoreline. However, the sediment rapidly resettles and there is not net movement or loss of sediment.

The naturally occurring wind wave energy was developed for 15 typical shoreline locations as described in Appendix WAKE-A. The data are presented in Table WAKE-D-2 along with daily wind wave energy and wave height calculations. In order to calculate the wave heights below which sediment re-suspension and re-deposition would not be considered significant, average daily energy values were calculated using the monthly data. Assuming waves with a 3-second period arrive throughout the day, the equivalent daily wave heights were calculated as shown on Table WAKE-D-2. These are the height of waves that would arrive every 3 seconds if the waves were all of the same height in order to deliver the daily average wave energy. In reality, the larger waves arriving at the shoreline carry most of the energy (see Table WAKE-D-1). However, the equivalent daily wave heights are a conservative measure of the wave heights with which the sediment is in equilibrium.

The average of the daily equivalent heights is 33 cm removing the extreme high daily values. A conservative value of 50% of this average was selected to be shoreline wave height criteria which is 16 cm rounding down to add further conservatism. As 16-cm is 6.2 inches, this criterion indicates that if the wake wash waves attenuate to a height of 6 inches at the shoreline, significant erosion or other impacts are not expected.

3.1.3 1,500-m Distance Criterion

Short-period waves (waves which take less than 5 seconds to pass a given location) are dispersive, which means that a single wave transforms into many smaller waves. For example a vessel wake train that contains 4 waves when the wake is measured 100 meters from a vessel may have transformed at a distance of 1 km from the vessel route into a train of 15 or more much smaller waves. The dispersive phenomena means that wake wave heights decrease with distance. The attenuation in wave height can be predicted using a cube root rule (see Appendix WAKE-B).

The attenuation calculations indicate a distance of 1,500 m is required for a 27-cm wake height (measured at 300 m) to reduce to a 16-cm wave height measured at the shoreline.

The wave energy in an individual 16-cm wave is 35% of the energy in a 27-cm wave because wave energy is directly proportional to the square of wave height. Therefore with distance, a short-period wave train transforms into one that delivers much smaller packets of energy at the shoreline.

In typical wind conditions, the wake wave height will attenuate faster than that predicted by the attenuation equation because of wind effects which adds further conservatism to the 1,500-m distance criterion. Wake wash waves lose height and energy over distance in comparison with wind waves, which continue to grow. Wake waves lose energy as they travel away from a vessel and are “flattened” by the wind and by interaction with the wind generated waves. The stronger the wind and the smaller the wake wash, the more quickly wake wash energy is lost. The wake waves also lose energy once they begin to be influenced by the bottom. Waves lose energy through friction and the transformation process as they refract, shoal, and eventually break.

3.1.4 Site-Specific Sustained Wind Wave Criterion

Even if the 16-cm and 1,500-m criteria are not met, wake wave impacts may not be significant but comparison with site-specific data is necessary for determination. If predicted wake waves at the shoreline are less than 50% of the average sustained wind wave height on a monthly basis, significant impacts are not anticipated because the wake wash waves would be indistinguishable from the natural variation of the wind driven waves.

3.2 BIOLOGICAL CRITERION – CLAPPER RAIL NEST INUNDATION

The California clapper rail (*Rallus longirostris obsoletus)*, an endangered species, are yearlong residents of emergent salt and tidal marshlands of San Francisco Bay. Based on discussion with Bay Area biologists and representatives of resource agencies, inundation of California clapper rail nests was used as an indicator of potential biological significance for this assessment. If wake wash has the potential to inundate the nests while the young are in them, the impact would be significant.

Clapper rail nests are constructed such that the nest tops are at the maximum water line during the nesting season. Collins, Evens, and Grewell (1994) indicate that clapper rails nest from 100 m to several kilometers inland from the tidal marsh shoreline. During a 1992 study (Advocet Research, Collins, and Evens 1992) one nest was found at a distance of 25 m from the shoreline built on a pile of dredge spoils. The dredge spoil environment is not a natural habitat and, therefore, a distance of 100 m from the marsh fringe is more representative of the closest distance rails will nest to the shoreline in unaltered environments.

The USACE Shore Protection Manual (1984) and FEMA (1988) present methodologies for predicting the decay of waves through marsh and other shoreline vegetation. The most thorough evaluation method is presented as part of the documentation for the Wave Height Analysis for Flood Insurance Studies (WHAFIS) model developed by FEMA (1988). The model includes a method of calculating wave energy dissipation by specific marsh grasses. Input parameters include the type of marsh grass, grass density, height, diameter, as well as other site-specific parameters such as shoreline slope.

Initial evaluation of these methodologies, and field experiments conducted as part of this and other studies, indicates that wave energy attenuates very rapidly in healthy tidal marshes. In a study conducted in 1992 on the Napa River to assess the impact of Navy assault vessels on clapper rails nests, the decay of wake was measured along a small slough and through tidal marsh vegetation (Avocet Research, Collins, and Evens 1992). A 4-m boat was spun during high water to create a wake of approximately 0.6-m high at the entrance of a 3-m wide slough on the Napa River. Instrumentation was placed 24 m along the slough. The wake was measured to decrease by 50 percent within 8 m and to zero within 15 m. The wake decreased approximately twice as rapidly in the emergent vegetation, to 50 percent within 3 m and to zero within 8 m.

Other studies have had similar findings. Knutson et al. (1982) found that wave attenuation in natural *Spartina alterniflora* salt marshes was on the order of 72 percent for a wave with an initial height of 15 cm traveling across 5 m of marsh. Tiner (1985) reported that a 2.4-m fringe of saltmarsh grass reduced wave energy by over 50 percent.

Marsh grasses are very effective at absorbing excess wave energy which is likely why clapper rails locate their nests at least 100 m from marsh fringe. Because clapper rail nests are fixed to marsh vegetation and do not float, they are not able to rise above extreme water levels. Extreme wave and storm events do occur during the spring breeding season and those individuals, which built nests beyond the influence of extreme storm events, would be more likely to survive and successfully raise young. Wake wash from ferries would not add to the extreme event conditions, which could potentially inundate nests within 100 m from the marsh fringe, as it is unlikely vessels would operate at speed during such storm events.

Given the uncertainties in detecting clapper rail nests (Advocet Research, Collins, and Evens 1992) a more conservative distance of 50 m was considered in this assessment. The worst case scenario of an unbroken wake wave entering the marsh fringe during maximum high water was considered. Because of wave breaking and refraction, as discussed below, this situation is unlikely to occur.

As described in Appendix WAKE-E, the wash characteristics (wave height and energy) of the *Provider* were measured, and showed to be very similar to those of a 149-passenger ferry. Wave height was 28 cm for the *Provider* and 15 for the ferry at 300 m. Energy was 820 J/m for the *Provider* and 800 J/m for the ferry. Although the *Provider* is a smaller and lighter vessel than a ferry, the blunt shape of this trawler hull produces wake energy at 10 kts similar to the energy of a larger but more efficient ferry hull operated at the same speed.

On February 12, 2002, wake was created at the entrance to a small slough near the mouth of the Petaluma River, which leads to a possible clapper rail nesting site in the Petaluma Wetlands (Jules Evens, personal communication). Given the very shallow water in the channel and necessity for slow speed navigation, a direct measure of wash in the slough could not be made. Instead a pressure buoy was positioned as close to the slough as possible in order to measure the wash height and period. The work boat *F.T. Provider* made several runs at maximum allowable speed (10 kts) past the slough as close as possible to the mouth. Through direct observation, no motion was detected in the slough, suggesting that the wash energy from the *Provider* was spent on the beach of the channel and did not enter the slough. The experiment was documented on videotape.

The results of this evaluation suggest that wake from passenger ferries near clapper rail nesting sites would not have detrimental impacts on nests located more than 50 m from a healthy marsh fringe. It is possible that wake wash could impact nesting areas less than 50 m from a marsh fringe, under conditions of high wake energy and no wake attenuation (degraded marsh habitat). In areas where a clapper rail expert considers a nest site within 50 m of the marsh fringe could occur, a detailed prediction of the wave propagation through the marsh should be conducted.

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APPENDIX WAKE-D TABLES

Table WAKE-D-1
Monthly Sustained Wind Wave Heights (m) for Selected Locations in San Francisco Bay, 1992-1993

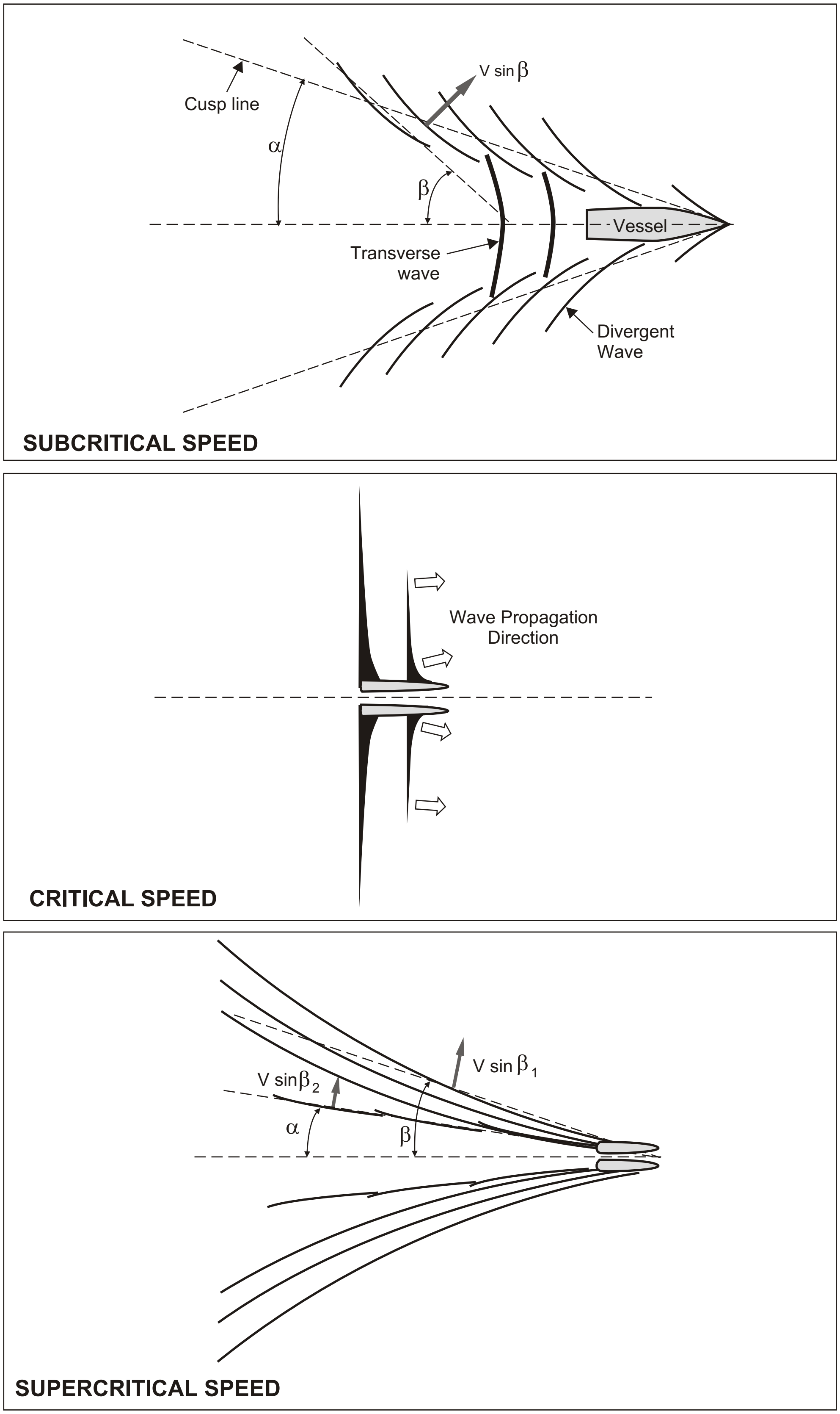
Location	Month												Avg.	Max
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
Petaluma Wetlands	1.6	1.5	1.0	1.1	1.3	1.3	1.3	1.4	1.2	1.2	0.88	1.4	1.3	1.6
Hercules (Martinez)	0.86	0.84	0.96	0.96	1.1	1.1	0.94	0.85	0.74	0.69	1.0	0.90	0.91	1.1
Gallinas Creek	0.82	0.96	0.59	0.52	0.55	0.31	0.21	0.26	0.21	0.86	0.64	0.79	0.56	1.0
Corte Madera Marsh	1.6	0.84	0.78	0.99	0.69	0.58	0.29	0.20	0.46	0.99	0.49	0.89	0.73	1.6
Paradise Cay	1.6	1.1	1.0	1.2	0.77	0.62	0.28	0.24	0.44	0.96	0.50	0.87	0.80	1.6
Sausalito	1.3	1.1	1.0	0.76	0.76	0.60	0.33	0.33	0.31	0.96	0.49	0.84	0.73	1.3
Yerba Buena	0.94	1.4	2.6	1.4	1.0	0.82	0.55	0.63	0.91	0.72	0.64	0.94	1.04	2.6
Oyster Point	0.87	0.82	0.56	0.70	0.51	0.51	0.34	0.25	0.25	0.59	0.52	0.79	0.56	0.9
Redwood City Channel	0.64	0.64	0.42	0.34	0.31	0.31	0.37	0.28	0.25	0.25	0.37	0.52	0.39	0.6
Coyote Creek	0.36	0.39	0.41	0.41	0.42	0.40	0.45	0.44	0.42	0.37	0.40	0.36	0.40	0.5
Alameda Creek	0.89	0.84	0.90	0.90	0.93	0.91	1.0	0.99	0.93	0.78	0.87	0.85	0.90	1.0
San Leandro Channel	1.2	0.83	0.89	0.97	1.0	1.1	1.2	0.95	0.83	0.62	1.0	0.86	0.95	1.2
Berkeley	0.62	0.82	1.2	0.64	0.68	0.68	0.68	0.62	0.58	0.49	0.68	0.68	0.69	1.2
Point Pinole	1.1	0.77	0.78	0.86	1.1	0.99	0.87	0.78	0.77	0.61	1.1	1.0	0.89	1.1
New York Slough	0.36	0.40	0.27	0.28	0.22	0.21	0.21	0.22	0.18	0.32	0.22	0.36	0.27	0.4

Table WAKE-D-2
Monthly Wave Energy (MJ/m) Reaching the Shore for Selected Locations in San Francisco Bay, 1992-1993

Location	Monthly Wave Energy (MJ/m) Reaching the Shore														Daily Average Energy (KJ/m)	Average Wave Height (cm)[1]
	Month												Avg.	Max		
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec				
Petaluma Wetlands	197.7	268.1	298.5	157.7	1178	1541	2444	2907	1671	528.0	56.2	463.3	975.9	2907	32,102	94
Hercules (Martinez)	393.4	106.6	164.7	606.0	288.7	391.3	87.6	58.7	61.9	70.2	279.3	357.7	238.8	606.0	7,856	47
Gallinas Creek	599.7	212.5	52.4	7.6	12.3	1.0	0.5	2.0	1.6	26.3	198.6	545.5	138.3	599.7	4,550	35
Corte Madera Marsh	114.9	201.6	81.7	29.6	29.7	7.8	0.7	0.5	1.7	23.1	24.0	137.4	54.4	201.6	1,789	22
Paradise Cay	159.2	232.6	111.4	37.0	48.4	11.8	3.2	1.9	3.7	29.8	34.8	165.1	69.9	232.6	2,300	25
Sausalito	56.0	111.6	86.3	45.4	71.4	48.5	33.5	23.2	21.3	30.1	15.4	66.6	50.8	111.6	1,670	21
Yerba Buena	90.2	129.3	128.5	124.8	175.7	143.5	104.2	88.1	65.4	59.9	43.3	91.1	103.7	175.7	3,410	31
Oyster Point	77.7	108.5	32.0	20.3	24.7	8.1	5.0	3.9	4.8	10.9	34.8	121.5	37.7	121.5	1,239	19
Redwood City Channel	38.7	36.5	14.1	10.2	12.6	10.7	10.6	8.9	10.0	8.8	19.4	48.3	19.1	48.3	627	13
Coyote Creek	10.0	9.2	35.7	73.8	75.8	91.9	102.8	121.7	104.5	51.6	34.9	12.0	60.3	121.7	1,985	23
Alameda Creek	100.0	88.6	239.1	550.9	634.8	823.0	798.6	860.4	682.8	316.8	236.3	129.8	455.1	860.4	14,970	64
San Leandro Channel	77.7	111.7	186.2	438.9	512.2	688.1	512.3	348.4	202.2	114.7	79.5	119.1	282.6	688.1	9,296	51
Berkeley	30.9	52.4	122.0	239.5	268.2	325.5	258.6	209.0	162.2	103.8	59.1	31.8	155.3	325.5	5,107	38
Point Pinole	1021	251.6	184.4	490.9	397.0	540.0	256.6	153.3	131.6	110.8	435.7	877.9	404.2	1021	13,297	61
New York Slough	3.5	6.0	4.0	4.3	5.6	7.0	10.7	13.8	7.9	2.6	1.9	7.7	6.2	13.8	205	8

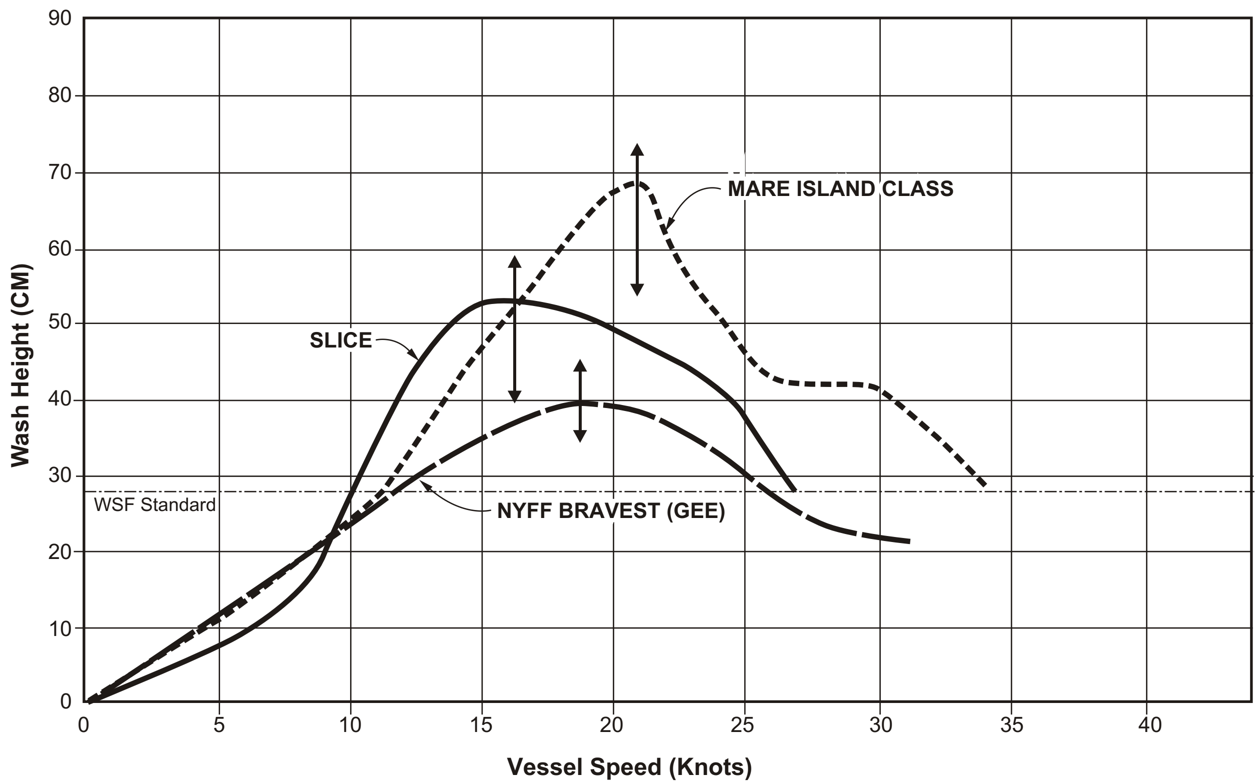
Notes:
1) Based on 3 second period

APPENDIX WAKE-D FIGURES



Source: Stumbo et. al., 1999

URS	Water Transit Authority Programmatic EIR Project No. 43-00066890	Vessel Wake Diagram	Figure WAKE-D-1



Source: Modified from Stumbo et. al., 1999

URS	Water Transit Authority Programmatic EIR	Comparison of Vessel Wash Height at 300 Meters	Figure WAKE-D-2
	Project No. 43-00066890		

There are currently no federal, state, or local wave wash regulations. However, a search of information available on the internet was conducted to identify legislative criteria or operational guidelines for wave wash generated from high-speed ferries around the world.

For the majority of areas, specific criteria for wake wash generated from high-speed ferries were not identified within legislation, regulations, or guidelines. However, the issue is assessed in some areas during the Environmental Impact Assessment process (in particular in Denmark, Australia, New Zealand, Italy, and United Kingdom). The following sections summarize available information on worldwide wake wash regulations.

1.0 UNITED STATES: WASHINGTON STATE FERRIES

The Washington State Ferries (WSF) system currently operates two high-speed catamaran passenger-only ferries, the *Chinook* and *Snohomish*, from Bremerton to Seattle. The route passes through Rich Passage, which is approximately 3 miles long and ½ mile wide at the narrowest point. Before going out for bid for the high-speed catamarans, WSF performed a wake study (Hartman 1990) to determine the minimum design criteria that would not cause significant harm to the shoreline. The criteria that were developed were based on the wake generated by the existing WSF passenger-only monohulls running at 12 knots (Long 1999). These criteria were chosen because ferry system shoreline experts stated this level of wake would not harm the Rich Passage shoreline, and did not generate complaints from property owners (Long 1999). The goal was to make vessel operation "relatively imperceptible on the Rich Passage shoreline." The established WSF criteria for measured wake wash in the Rich Passage area are:

- Wave Height: 28 centimeters;
- Energy Density: 2,450 joules per meter; and
- Measurement: 300 meters from the wake centerline (in deep water).

The *Chinook* began service in May 1998 and the ferry was generally run at 34-35 knots. A second high-speed ferry, the Snohomish, was scheduled to begin service in September 1999. In April 1999, Bainbridge Island landowners along Rich Passage filed a lawsuit, charging that wake wash from the ferries was damaging their waterfront bulkheads, eroding beaches, and harming marine life.

In August 1999, as a result of the lawsuit, WSF was ordered to reduce the speed of the ferries to 12 knots in the vicinity of Rich Passage. While the court did not find that the *Chinook* operations had caused impacts to the shoreline, it stated that operations had the potential for affecting the environment. The judge's ruling stated that WSF did not perform an Environmental Impact Study under the State Environmental Protection Act (SEPA).

The slowdown increased the commute time from 30 to 50 minutes, which is the same as the time for existing 16-knot vehicle/passenger ferries, which also make the Bremerton - Seattle run (Long 1999). WSF, the county, and a commuter group filed an appeal stating that the SEPA does not apply, and has never been applied to marine vessels (Long 1999). In addition, the appeal stated that the court improperly weighed the interests of the private property owners over public interests. The decision was appealed and the court-ordered slowdown was lifted in April 2000 (Kucera vs. State).

The *Snohomish* began operations in November 1999. In 2000 and 2001, a wave action study was performed to form the basis for further recommendations (RPWAST 2001). Ten study sites (along the Seattle-Bremerton route) and three reference sites were monitored for one year. Overall, the reference sites experienced little physical change in terms of erosion or accretion. Biological changes, in terms of abundance, were variable. Some of the study sites showed no evidence of POFF wave impacts. One stretch of shoreline, however, experienced substantial erosion.

Starting October 1, 2001, state ferry officials enacted a slowdown to 12 kts in a section of Rich Passage, lengthening the crossing by 10 minutes (Pritchett 2001). The slowdown did not extend the entire length of Rich Passage as the previous slowdown had, but was based on the results of the Rich Passage Wave Action Study (RPWAST 2001).

2.0 EUROPE

2.1 DENMARK

In 1997, the Danish Maritime Authority issued a governmental order (Order No. 307) on "the Approval of the Safe Navigation of High-Speed Ferries" (DMA 1997). The order requires shipping companies to present documentation to the fact that the waves generated by the high-speed ferry do not constitute an unnecessary risk to navigation safety and to leisure activities in coastal areas based on the following calculation for maximum wave height:

$$H_h = 0.5 \sqrt{(4.5/T_h)}$$

Where:

- H_h is the maximum wave height (m) of the generated long periodic waves, measured in water 3 m deep and in calm water;
- T_h is the average generated wave period of the long periodic waves, measured in seconds;
- "Coastal areas" are areas where water depths do not exceed 3 meters; and
- "High-speed ferry" are defined as high-speed craft capable of a maximum speed of 3.7 x $V^{0.1667}$ m/s or more, where V is the displacement corresponding to the design waterline (m^3), corresponding to the definition in the International "High-speed Craft Code" (IMO Resolution MSC.36(63)).

For example, the height of a long periodic wave with an average wave frequency of 9 seconds may not exceed 0.35 m when measured in calm water 3 m deep. The criteria are based on theoretical and experimental research based on bathymetry of Danish waters.

The Danish Maritime Authority's approval has to be obtained before a shipping company establishes a high-speed ferry route operating in a Danish port, or puts a new high-speed ferry into service on an existing route. The shipping company is required to present documentation to the effect that the limit value calculated is not exceeded on the route in question, illustrated for example by results of model tests, full-scale measurements, or numerical simulation. The documentation shall be prepared by recognized institutes, including an institute in other EU Member States and in countries which are covered by the EEA agreement, and which gives appropriate and satisfactory guarantees of a technical, professional and independent nature. However, the documentation may be based on other information representing at least the same degree of accuracy.

2.2 ITALY

Two studies on the impact of wave wash associated with high-speed ferries were noted during the study for this EIR, which may provide the basis for development of criteria in the future. These studies comprised the Low Impact Urban Transport Water Omnibus (LUITO) Project by the Maritime Research Institute Netherlands for use in Venice, Italy and funded by the European Union.

The objectives of the LUITO Project, which was completed in 1999, were to design and develop a novel urban waterbus for use on the Venice waterways; and extension, application, and validation of the latest tools for predicting and minimizing wave wash (MRIN 2002).

2.3 UNITED KINGDOM

In the United Kingdom, the Maritime and Coastguard Agency, is currently working with Marinetech South Limited on the Ships Wash Impact Management (SWIM) Research Project Collaboration. The objectives of the SWIM Project, which is due for completion in 2003, are:

- Development of validated techniques for predicting “near-field” wave generation, identifying the impact of hull form, trim, speed and water depth on wash characteristics;
- Enhancement of methods for predicting wash propagation from “near-field” to “far-field” validation against model and full scale data;
- Development of methodologies to quantify ecological impacts of wash, addressing littoral stress and seabed particle resuspension and key safety implications; and
- Proposal of guidelines for managing wash impacts, addressing ship design and operation factors as well as regulatory procedures based on understanding of wash effects (Maritime and Coastguard Agency (UK) 2002).

The project is supported by the Maritime Safety Committee of the International Marine Organization (IMO).

3.0 NEW ZEALAND

In 1994, 35-knot fast ferries began operating on the Marlborough Sounds in New Zealand (MDC 2002). Soon after they began operating, the Marlborough District Council (MDC) received numerous complaints about the effects of wake wash. Several environmental groups made unsuccessful attempts to halt fast ferry operations. There were also safety concerns. In response to the concerns, the Maritime Safety Authority and Marlborough District Council established measures for voluntary trial by all ferries during the 1999/2000 summer (MDC 2002). The council also had a formal risk assessment performed. Based on the results, the council determined that the level of risk from fast ferry operations was higher than considered appropriate and that some remedial action was necessary.

The Danish Hydraulic Institute was retained to determine whether the Danish ferry criteria would be appropriate for the area. Based on results of a continuing ferry wash monitoring program, and various reports and consultations, the council approved a bylaw imposing an 18-knot speed restriction on high-speed craft. The Navigation Bylaw 2000 became operative in December 2000. It includes an exemption if ferry operators can demonstrate that waves generated by their vessels will not exceed prescribed levels (MDC 2002).

In December 2001, the MDC released a “Draft Variation Discussion Document” on proposed controls for high-speed vessels to be included in an updated “Marlborough Sounds Resource Management Plan” (MDC 2001). The options were released for public comment in December 2000.

Comments received from an initial discussion document released in December 2000 (MDC 2000) were considered in the development of the proposed option. A second public comment period ended in February 2002. Seven options were considered, including no action, central governmental controls (national policy), economic incentives for operators, and local regulatory controls. The proposed control was a regulatory option with two parts. Based on anecdotal evidence, the 18-knot bylaw reduced erosion in the Sounds (MDC 2001). The MDC also noted that wake from slower vessels could also be environmentally detrimental. Therefore, a trigger level of 15 knots would be established for travel on the existing national transportation route (inner Queen Charlotte Sound and Tory Channel). Vessels proposing travel at speeds greater than 15 knots would require a wake assessment based on the Bylaw methodology. Those meeting the criteria would be granted a “Resource Consent” to operate.

In order to reduce the area in the coastal environment that could be affected by shipping activity, MDC also proposed to encourage operators to restrict travel to within the existing national transportation route, suggesting it may be necessary to prohibit travel outside of this route at speeds greater than 15 knots.

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Characteristics of wake waves reaching a shoreline can be calculated based on measured wake parameters for specific vessels. The following sections present a description of the wake assessment methodology used for this study.

1.0 WAKE WASH MEASUREMENTS

The wake wash characteristics of existing conventional and high-speed ferry vessels operating on the six services in San Francisco Bay were measured over a three-day period in February 2002 for this assessment. The weather during the field measurements was unusually calm, with essentially no wind.

Measurements were made of the following vessels at the eight listed locations:

Location	Vessels Measured
East of Alcatraz	*Mendocino, Zelinsky, Mare Island, Del Norte, Intinoli, San Francisco, Solana* – Pusher Tug, *Sonoma, Scarlet Trader* – Tanker
Paradise Cay (210 m from breakwater)	*Sonoma, Mendocino*
Oakland	*Tokyo Express* – Container Ship, Tug, *Encinal*, (entrance to Estuary) Tug, *Bay Breeze*
South of Carquinez Strait	*Intintoli, Mare Island*
Petaluma	USACE Boat, Fishing Boat, *Provider* (in Petaluma Channel)
Larkspur Channel	*Marin, Mendocino*
East of San Mateo (near Coyote Point Marina)	*Provider*
South of Yerba Buena	*Encinal*

A video was made of the wake of some of the ferries. The wake of the *Provider* (50-ft work boat from which measurements were made) was also recorded as it traveled towards a slough leading to clapper rail breeding habitat on the Petaluma Channel.

Wave heights and periods of vessel wash were measured using a submerged pressure measuring/recording instrument package that measures pressure 4 times per second and records data to computer memory. The instrument package was anchored to the bottom, in up to 200 feet of water, and suspended from a buoy that was held 6 to 10 feet below the surface of the water by a taut line to the anchor. A marker buoy on the surface was used for location and recovery. After the data was gathered, custom software converted the pressure readings to wave heights as a function of time, enabling measurements and plots to be made of wave patterns passing over the buoy.

The actual distance to the vessel being observed was measured using a laser rangefinder accurate to ± 1.0 meter. All data that was consistent and repeatable was analyzed. Each run's data was normalized to a distance off centerline of travel of 300 meters and, where possible, any multiple run data for each speed or vessel was averaged.

2.0 WAKE DECAY AND DISSIPATION

There are some significant differences between the characteristics of wind waves and the wake wash waves. Whereas wind-driven waves increase in energy with fetch as they approach the shoreline, individual wake wash waves slowly lose energy with distance of travel, becoming smaller in height and longer in wavelength, while the total number of waves in the wave train increases. Wind waves occur nearly continuously, in random form, at various levels of intensity, direction, and sustained length. Vessel waves occur in a single train, usually lasting for 3 to 10 minutes with each passing, at predictable levels of intensity, direction and sustained length. The profile of a typical vessel wave over its life at a given point will show 2 to 6 significant waves, nearly identical in form, followed by several of diminishing intensity.

Some energy from vessel wakes dissipates in the Bay in reaction to wind-driven waves or by friction as the waves travel over great distances. However, the remainder of the wave energy will reach the shoreline, especially if the vessel route is near shore. Those waves that reach the shoreline expend themselves in a predictable manner. As waves move towards the shore, they encounter the sloping near-shore bottom. When a wave reaches a depth of about 1.3 times the wave height, the wave collapses or breaks (USACE 1984). Breaking results in a dissipation of wave energy, which can be the cause of erosion.

Wave parameters include:

H = Wave Height (m)

λ = Wavelength (m)

T = Wave Period (s) the time that it takes a given point on a wave (say the crest) to pass a fixed point

F = Wave Frequency (1/s) – the reciprocal of wave period.

C = Wave Celerity (m/s) - the apparent speed of advance of a wave perpendicular to a line passing through the peak of the wave.

The degree of impact from wake wash to a shoreline (or passing vessel, etc.) is a function of the amount of energy in the wash that is expended when the waves hit the shoreline. The total wave energy (E_{total}) in one wavelength per unit crest can be defined as:

$$E_{total} = \rho g H^2 \lambda / 8$$

where ρ = density of water (1,025 kg/m^3 for saltwater and 1,000 kg/m^3 for fresh water), and g = the gravitational constant (9.8 m/s^2)

Energy Density (E) is the average of the energy along the length of the wave:

$$E = E_{total}/\lambda = \rho g H^2/8 \qquad (1)$$

Wavelength and wave period (T) are related as:

$$\lambda = gT^2/2\pi \qquad (2)$$

Substituting for λ based on equation 2 yields:

$$E = \rho g^2 H^2 T^2/16\pi \qquad (3)$$

Equation 3 allows wave energy reaching the shoreline to be calculated based on deeper water measurements of wave height and period.

3.0 WAKE ATTENUATION CALCULATIONS

Wave height attenuation is important as it is the highest or tallest waves, which carry the greatest energy and hence have the greatest potential to do the damage. The height of the tallest wave can be compared with the height of natural wind-generated waves to assess whether erosion is likely and also to estimate the height of the tallest wave approaching a marsh fringe.

In analyzing each of the potentially wake wash sensitive areas, several factors were considered. For dispersive vessel-generated waves, the following characteristics are important:

- The height of each wave in the wave train attenuates with distance proportional to the inverse cube root of the distance from the sailing line.
- The period of each wave in the wave train remains constant.
- The energy of each individual wave in a wave train attenuates with distance, but the total energy in the wave train remains constant.

In deep water, as the distance from a vessel line of travel increases, while the period of a ship-generated wave stays constant with increasing distance, the height of individual waves in the wake wash wave train attenuate at a rate inversely proportional to the cube root of the ratio of distances. The wave height attenuation is given by equation 4:

$$\frac{H_2}{H_1} = \sqrt[3]{\frac{d_1}{d_2}} \qquad (4)$$

where H_1 = Wave height measured

H_2 = Wave height at location of concern

d_1 = Distance of measurement from vessel line of travel

d_2 = Distance of location of concern from vessel line of travel

This relationship holds true for relatively short changes in distances. There is a great deal of discussion among those working with wake wash evaluations as to the exact attenuation factor for long distances, for example attenuation over 2 kilometers. The above relationship, however, remains a good approximation with less than 10% error even at such distances.

Energy attenuation in the highest individual wave in the train can be calculated from the scaled wave height and measured parameters by equation 5:

$$E_2 = E_1 (H_2/H_1)^2 \quad (5)$$

where H_1 = wave height measured

H_2 = wave height at location of concern

E_1 = wave energy measured

E_2 = wave energy at location of concern

If there is no attenuation of wake wash waves by wind waves (flat calm), the total energy in a wake wash wave train is conserved for long distances. As distance from the sailing line is increased and the wash height decreases, dispersion creates a higher number of these waves of lesser height. Though the total energy is largely conserved, the wave train takes longer to pass a given point the farther the point is from the sailing line.

4.0 REFERENCES

USACE, 1984. Shore Protection Manual, U.S. Army Engineer Waterways Experiment Station Coastal Engineering Research Center.

Tables

Figures

Wind-driven wave energy was calculated for various Bay area locations from available wind data. This technique, termed "hindcasting," provides estimates of wave characteristics, such as wave height and energy, using empirical equations based on past meteorological conditions. Because there are no comprehensive measurements of waves in San Francisco Bay, wave hindcasting was conducted using computer models for 15 representative locations throughout the Bay. Analysis of wind data from Oakland and San Francisco airports indicates that the 1992-1993 year was a typical or representative wind year for winds that have occurred over the last 20 years. Therefore, the 1992-1993 wind records from these airports and data from a wind station in San Pablo Bay were used in this analysis.

The following sections present an introduction to wind-driven waves and describes the hindcasting methodology, which is based on the equations derived in the Shore Protection Manual (USACE 1984).

1.0 INTRODUCTION TO WIND-DRIVEN WAVES

Wind blowing over water produces a shear force at the water's surface, which generates waves. The size of the waves depends predominantly on the velocity of the wind, wind direction, the distance over which the wind blows ("fetch"), and the depth of the water.

Waves can be described by a combination of the wave height, the wave period or the time for a wave to pass, the speed of the wave, the length of the wave, and direction. Measures commonly used to describe waves include the significant wave height (H_s), mean wave period (T_m), wavelength (λ), and celerity (C). Significant wave height is the average of the highest third of wave heights measured at a point over some period of time. Mean wave period is the average time between the passage of two successive wave crests past a given point. Wavelength is the distance between two successive wave crests. Celerity is the speed at which the wave is traveling. Wave direction is the direction *from* which a wave is traveling. These parameters are illustrated on Figure WAKE-A-1.

The energy in a wave is a combination of the potential energy due to the change in the position of the water from a still water level and the kinetic energy due to the movement of water within a wave. The energy per unit area (E) in a wave of height H is given by:

$$E = \rho \, g \, H^2 / 8$$

where ρ is the density of seawater and g is the acceleration due to gravity.

Once waves have been generated and they are traveling towards a shallow area, such as a mudflat or beach, the waves will be influenced by the depth of water beneath the waves. At one extreme, when the water depth is less than approximately 1.3 times the wave height, the wave will break, dissipating its energy. At intermediate depths, the wave will "feel" the bottom and begin to bend (refract). It is often convenient to measure water depth in terms of the wavelength. "Deep" water, in which the bottom does not influence wave dynamics, is generally taken to be twice the wavelength. Water depths in the Bay are shown on Figure WAKE-A-2.

2.0 WIND ESTIMATES

Typical wind conditions (i.e., wind speed and direction) were calculated from measured wind data in and around San Francisco Bay. The selection criteria for the measured wind data is listed below:

- Hourly observations spanning multiple years
- Wind measurements from all regions of the Bay (i.e., South Bay, Central Bay, and North Bay)
- All wind measurements must be collected during coincident time periods

Using the above selection criteria, three different wind stations during the years 1992 and 1993 were selected. The three wind stations—San Francisco International Airport (SFO), Oakland International Airport (OAK), and San Pablo Bay—represent measurements for the South Bay, Central Bay, and North Bay, respectively. For the purposes of this study, the South Bay was defined as the area south of the Oakland Bay Bridge, the Central Bay was the region north of the Oakland Bay Bridge and south of Point San Pablo (located near the Richmond Bridge), and the North Bay was the region north of Point San Pablo and extending up towards the Delta. The wind stations are shown on Figure WAKE-A-2.

The length of the records collected was restricted to 1992 and 1993 due to the limited availability of wind measurements for San Pablo Bay. Wind data from SFO and OAK were collected from the National Climatic Data Center (NCDC). San Pablo Bay wind data was retrieved from the United States Geological Survey (USGS) ANIMAR database. Multiple years of wind measurements were obtained to ensure a more accurate assessment of "typical" monthly wind conditions.

Once all of the wind data was collected, the data for each wind station was separated into 12 data packets, each packet representing data measurements for one of the 12 months. Wind rose plots for each wind station for each month are shown in Figures WAKE-A-3 through WAKE-A-5 for SFO, OAK, and San Pablo Bay, respectively. The data packets, or monthly wind data files, were further separated into 24 different files, each file representing one of the 24 wind directions, or "bins" (360 degrees $\div$ 15 degrees per bin = 24 bins). At this point in the analysis, data from each of the three wind stations has been separated into 288 different files, each file representing a particular wind direction for a particular month (12 months $\times$ 24 bins = 288 files per wind station). The mean wind speed for each of the 288 files for each station was calculated and used as the wind input parameter for the wave height and wave period calculations. Tables WAKE-A-1 through WAKE-A-3 list the mean wind speed and percent occurrence for each month for each bin for SFO, OAK, and San Pablo Bay, respectively.

A similar process was performed to determine the maximum wind speeds during each month for each wind station. Maximum wind speeds were used to determine the maximum amount of energy found in a single wave during the course of one month. The maximum wind speed was selected from each wind direction bin for every month. Results of the maximum wind speed analysis for SFO, OAK, and San Pablo Bay are listed in Tables WAKE-A-4 through WAKE-A-6, respectively.

3.0 FETCH LENGTH ESTIMATES

The fetch is defined as the distance over water the wind blows in the wave generating area. Fetch is commonly calculated as the distance between the point of interest and the nearest land point in the windward direction. Within San Francisco Bay, fetch length ranges from 0 to 50 kilometers depending on the wind direction. Fetch length may be restricted by land mass obstructions between the water and the wind. This "shading" by land mass obstructions is common between the Oakland Bay Bridge and the Richmond Bridge due to the presence of Treasure Island, Angel Island, and Alcatraz Island. For the purposes of this study, fetch was defined as the unobstructed distance between the point of interest and the nearest land point in the windward direction.

4.0 WAVE GROWTH ESTIMATES

The first step in the wave growth calculations was to calculate the adjusted wind speed based on neutral stability at a 10-meter elevation for each of the three wind stations shown in Figure WAKE-A-2. Since winds measured at SFO and OAK were recorded at the 10-meter elevation, no adjustment was necessary. The San Pablo Bay winds, however, were measured near the water surface and were adjusted accordingly using Equation 1 shown below:

$$U(10) = U(z)\left(\frac{10}{z}\right)^{1/7} \qquad (1)$$

where U(10) = adjusted wind speed at 10-meter elevation in m/s
z = height of recorded wind speed in meters

Once the wind speed is determined at a 10-meter elevation, the wind-stress factor, U_A, was calculated using Equation 2.

$$U_A = 0.71 \cdot U(10)^{1.23} \qquad (2)$$

where U_A = wind-stress factor in m/s
U(10) = adjusted wind speed at 10-meter elevation in m/s

The term "shallow water" refers to the ratio of the water depth over wavelength (h/L), which is called the relative depth (Kinsman 1965). Shallow water has a small relative depth. That is, the water depth is much smaller than the wavelength. Water at the Golden Gate, the deepest part of San Francisco Bay, may be considered "shallow" if very long waves are running on the surface.

Water depth affects wave generation. For a given set of wind and fetch conditions, wave heights will be smaller and wave periods shorter if generation takes place in shallow water rather than deep water. The SPM (USACE 1984) addresses shallow water wave predictions of wave height and wave period using Equations 3 and 4 shown below:

$$\frac{gH}{U_A^2} = 0.283 \cdot \tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]\tanh\left\{\frac{0.00565\left(\frac{gF}{U_A^2}\right)^{1/2}}{\tanh\left[0.530\left(\frac{gd}{U_A^2}\right)^{3/4}\right]}\right\} \tag{3}$$

$$\frac{gT}{U_A^2} = 7.54 \cdot \tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]\tanh\left\{\frac{0.0379\left(\frac{gF}{U_A^2}\right)^{1/3}}{\tanh\left[0.833\left(\frac{gd}{U_A^2}\right)^{3/8}\right]}\right\} \tag{4}$$

where g = acceleration of gravity in m/s^2
H = wave height in meters
U_A = wind-stress factor in m/s
d = average depth across the fetch in meters
F = fetch in meters
T = wave period in seconds

These equations were used for each of the winds listed in Tables WAKE-A-1 through WAKE-A-6. A significant limitation of this method is that the winds are assumed to blow for an infinite period of time and that the waves develop instantaneously. In reality, waves take some time to develop and this time is often referred to as the duration. According to the SPM (USACE 1984), duration may be computed using the following expression:

$$\frac{gt}{U_A} = 537 \cdot \left(\frac{gT}{U_A}\right)^{7/3} \tag{5}$$

where t = duration in seconds

Fortunately, the mean wind speeds used in this analysis often occur for hours at a time. The maximum sustained wind speeds, on the other hand, usually last one to two hours at a time, but it can be shown that the resulting wave heights and wave periods calculated during this analysis are within the confines of Equation 5. Therefore, this justifies the use of fetch-limited, shallow water equations.

Once the wave height was calculated, the energy density, $\bar{E}$, was calculated via the Airy theory (i.e., all waves propagate in the same direction) as discussed in SPM (USACE 1984), Dean and

Dalrymple (1984), and Le Mehaute (1976). The energy density is the total average energy per unit surface area of the wave. Energy density is calculated using Equation 6 shown below:

$$\overline{E} = \frac{\rho g H^2}{8} \tag{6}$$

where $\overline{E}$ = energy density in J/m
ρ = density of seawater in kg/m^3

Once the energy density was calculated, the next step in the analysis was to determine the rate at which the wave energy propagated into the shoreline, or the energy flux. To accomplish this, the group velocity of the wave field was calculated. Group velocity, as defined in SPM (USACE 1984), is function of wavelength, L, which is calculated using Equation 7.

$$L = \frac{gT^2}{2\pi}\tanh\left(\frac{2\pi d}{L}\right) \approx \frac{gT^2}{2\pi}\sqrt{\tanh\left(\frac{4\pi^2 d}{Tg}\right)} \tag{7}$$

where L = wave length in m

Once the wave length was calculated, the group velocity, C_g, was determined via Equation 8 shown below:

$$C_g = \frac{L}{2T}\left(1 + \frac{4\pi d/L}{\sinh\left(4\pi d/L\right)}\right) \tag{8}$$

where C_g = group velocity in m/s

Finally, using the energy density, $\overline{E}$, and the group velocity, C_g, the amount of energy flux, or wave power, as described in SPM (USACE 1984) was determined using Equation 9.

$$\overline{P} = \overline{E}C_g \tag{9}$$

where $\overline{P}$ = energy flux in J/s

Energy flux was calculated for every wind direction bin for every month. Using the percent occurrence, or frequency, of each wind condition, the amount of energy reaching the shoreline on a monthly basis in terms of Joules per meter shoreline was determined.

For the maximum energy found in a single wave, Equations 1 through 5 are used to determine the wave height and wave period. However, instead of calculating the energy flux of the wave field as was done using Equations 6 through 9, the energy in one wavelength per unit crest width was calculated using Equation 10 shown below as described in SPM (USACE 1984):

$$E = \frac{\rho g H^2 L}{8} \tag{10}$$

where E = energy in one wavelength in J/m

5.0 RESULTS

Table WAKE-A-7 presents the monthly wave energies reaching the shoreline for selected locations within the Bay. The locations are shown on Figure WAKE-A-6. Each monthly value represents the total energy from all 24 wind directions for that particular month. The amount of wave energy reaching the shoreline is highly variable depending on location within the Bay and the time of year. The average monthly wave energy, or the second column from the right in Table WAKE-A-7, differs by as much as two orders of magnitude depending on location within the Bay. The difference is mostly due to fetch limitations, but is also dependent on wind speed.

Table WAKE-A-8 lists the maximum wave energy found in a single wave per unit wavelength for selected locations within the Bay. The maximum value represents the greatest amount of energy across all 24 wind directions. Much like the monthly wave energy reaching the shore, the maximum wave energy found in a single wave differs by more than two orders of magnitude depending on location in the Bay. Again, these differences are mostly due to fetch limitations, but wind speed also plays a significant role. Table WAKE-A-9 lists the significant wave heights for selected locations within the Bay.

6.0 REFERENCES

Dean, R.G., and R. A. Dalrymple, 1984. *Water Wave Mechanics for Engineers and Scientists,* New Jersey: Prentice Hall, Inc.

Kinsman, B., 1965. *Wind Waves: Their Generation and Propagation on the Ocean Surface,* New York: Dover Publications, Inc.

LeMehaute, B., 1976. An Introduction to Hydrodynamics and Water Waves, New York: Springer-Verlag.

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APPENDIX WAKE-A TABLES

Table WAKE-A-1

Mean Monthly Wind Speed (m/s) and Percent Occurrence for the Given Wind Direction at SFO, 1992-1993

Bin (degrees)	Wind Parameter	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	*Mean Wind Speed (m/s)*	4.0	2.8	3.0	4.5	3.4	3.1	3.2	3.4	3.2	3.0	4.9	3.8
	% Occurrence	3.3	1.3	0.6	0.9	0.6	0.4	0.7	0.8	0.7	0.9	2.2	2.2
15 to 30	*Mean Wind Speed (m/s)*	3.3	3.3	2.7	3.4	3.5	3.5	3.5	3.2	3.4	2.7	3.8	3.0
	% Occurrence	6.0	2.7	1.4	0.6	1.0	1.0	1.1	1.0	1.5	2.4	1.7	2.9
30 to 45	*Mean Wind Speed (m/s)*	3.0	3.3	2.9	3.0	3.7	3.2	3.3	3.4	3.3	2.9	2.8	3.4
	% Occurrence	9.9	3.9	3.0	1.9	1.2	2.6	2.9	1.4	2.8	4.1	3.1	5.0
45 to 60	*Mean Wind Speed (m/s)*	3.0	2.9	3.2	2.8	3.6	3.6	3.4	3.2	3.4	2.7	3.1	3.8
	% Occurrence	3.5	2.2	1.9	0.9	1.1	1.0	1.2	1.5	1.0	1.4	2.3	3.4
60 to 75	*Mean Wind Speed (m/s)*	3.8	3.6	2.9	2.9	3.4	3.2	3.2	3.2	2.9	2.7	4.2	3.8
	% Occurrence	6.9	4.0	2.9	2.3	1.7	1.1	1.3	0.9	1.6	2.3	4.7	7.4
75 to 90	*Mean Wind Speed (m/s)*	4.0	3.1	2.9	3.4	3.3	3.4	2.9	4.0	3.6	2.0	3.1	3.4
	% Occurrence	3.6	1.4	0.7	0.4	0.6	0.2	0.1	0.1	0.1	0.2	1.4	3.2
90 to 105	*Mean Wind Speed (m/s)*	3.8	3.7	3.3	2.9	3.8	2.8	2.6	2.4	3.0	2.9	3.2	3.8
	% Occurrence	5.0	4.3	2.9	0.9	0.6	0.4	0.4	0.3	0.7	1.9	2.8	3.9
105 to 120	*Mean Wind Speed (m/s)*	3.6	3.5	3.5	2.8	3.7	1.3	1.8	0.0	2.7	1.6	3.0	4.2
	% Occurrence	2.0	2.6	0.6	0.4	0.5	0.1	0.1	0.0	0.1	0.2	1.3	2.0
120 to 135	*Mean Wind Speed (m/s)*	3.8	4.2	3.3	4.1	4.3	4.0	2.4	2.6	2.6	2.7	3.1	4.4
	% Occurrence	5.7	9.3	3.4	1.1	1.2	0.4	0.3	0.4	0.6	1.4	4.7	8.7
135 to 150	*Mean Wind Speed (m/s)*	3.6	4.8	3.8	3.9	3.6	4.2	2.7	2.7	2.4	3.3	3.2	4.0
	% Occurrence	4.1	5.5	2.4	0.6	0.8	0.4	0.2	0.1	0.4	1.4	4.0	6.4
150 to 165	*Mean Wind Speed (m/s)*	3.4	3.8	3.5	4.7	3.7	3.1	3.1	3.1	2.3	2.6	2.6	3.7
	% Occurrence	7.1	10.3	4.7	1.7	2.7	0.7	0.2	0.1	0.4	3.0	5.5	7.7
165 to 180	*Mean Wind Speed (m/s)*	3.6	3.8	3.1	3.7	4.2	3.9	4.0	2.1	2.8	3.4	2.5	4.5
	% Occurrence	2.7	4.1	3.4	1.1	1.5	0.4	0.2	0.3	0.8	1.7	2.1	3.8
180 to 195	*Mean Wind Speed (m/s)*	3.6	4.6	3.6	4.1	5.2	4.7	3.1	4.0	3.0	3.2	2.4	4.8
	% Occurrence	7.2	8.0	5.7	2.6	4.4	2.1	1.0	0.9	0.7	3.7	3.3	7.4
195 to 210	*Mean Wind Speed (m/s)*	4.2	4.5	3.9	2.7	5.2	3.2	6.2	3.9	3.4	3.7	3.0	4.7
	% Occurrence	4.0	3.6	2.7	1.6	3.5	1.2	0.4	1.2	0.4	2.1	2.3	3.4
210 to 225	*Mean Wind Speed (m/s)*	4.3	3.7	3.7	4.3	5.6	5.1	4.1	5.0	2.8	3.4	2.3	5.1
	% Occurrence	5.1	4.4	5.4	3.4	5.4	2.3	2.2	2.4	1.6	6.1	5.8	5.8
225 to 240	*Mean Wind Speed (m/s)*	3.4	3.7	3.7	3.7	5.4	4.9	4.7	4.0	3.4	3.5	2.3	4.5
	% Occurrence	2.1	2.8	3.0	2.2	2.9	1.6	1.5	1.6	1.6	4.3	3.1	3.2
240 to 255	*Mean Wind Speed (m/s)*	3.6	3.8	3.4	3.8	4.9	4.5	4.2	4.5	3.7	3.3	2.5	3.3
	% Occurrence	4.9	7.5	6.3	5.7	7.9	5.9	4.1	5.4	6.2	9.5	7.7	5.1
255 to 270	*Mean Wind Speed (m/s)*	4.2	4.3	4.2	4.5	5.5	5.8	5.6	5.4	4.9	4.0	2.7	4.7
	% Occurrence	1.5	2.4	4.2	3.4	5.3	5.4	4.4	5.8	5.5	3.3	2.7	1.7
270 to 285	*Mean Wind Speed (m/s)*	5.2	5.4	5.2	6.7	7.1	7.8	7.6	6.4	5.8	5.1	5.0	5.2
	% Occurrence	2.6	6.6	15.0	24.4	19.5	26.9	22.4	19.8	15.3	9.5	9.3	3.6
285 to 300	*Mean Wind Speed (m/s)*	5.6	4.8	6.0	7.0	7.3	8.2	7.1	6.9	6.1	5.0	5.6	5.2
	% Occurrence	2.4	4.2	11.8	19.0	11.4	14.9	12.2	10.1	11.9	9.3	7.3	2.3
300 to 315	*Mean Wind Speed (m/s)*	5.0	4.7	5.3	6.1	6.6	6.6	6.4	6.9	6.5	5.7	5.8	5.4
	% Occurrence	5.6	6.5	14.7	22.2	22.1	24.6	34.7	37.3	37.4	24.2	15.2	6.2
315 to 330	*Mean Wind Speed (m/s)*	3.4	3.2	3.8	5.1	6.0	6.7	6.7	7.1	7.0	5.6	4.6	4.9
	% Occurrence	1.2	0.7	1.1	1.3	2.4	3.6	5.2	5.4	5.2	3.8	2.0	1.3
330 to 345	*Mean Wind Speed (m/s)*	2.8	2.5	2.8	4.0	5.2	5.7	4.8	5.0	4.5	3.7	3.6	3.8
	% Occurrence	1.7	1.1	1.6	1.1	1.6	2.3	2.7	1.9	2.6	2.4	2.7	2.4
345 to 360	*Mean Wind Speed (m/s)*	3.9	2.7	3.1	4.9	5.0	3.6	3.7	3.6	4.5	3.1	4.5	4.1
	% Occurrence	2.1	0.6	0.6	0.5	0.3	0.5	0.5	1.2	0.8	0.8	2.8	1.1

Table WAKE-A-2

Mean Monthly Wind Speed (m/s) and Percent Occurrence for the Given Wind Direction at OAK, 1992-1993

Bin (degrees)	Wind Parameter	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	*Mean Wind Speed (m/s)*	4.8	3.3	2.5	2.7	2.5	4.0	0.0	2.7	2.4	4.2	4.9	3.8
	% Occurrence	1.8	0.9	0.3	0.2	0.1	0.5	0.0	0.1	0.2	0.2	2.9	2.1
15 to 30	*Mean Wind Speed (m/s)*	4.2	3.2	2.9	2.1	2.7	3.4	2.8	1.8	2.3	3.2	3.5	3.5
	% Occurrence	3.6	1.5	0.9	0.2	0.1	0.5	0.2	0.5	0.4	0.4	4.3	3.5
30 to 45	*Mean Wind Speed (m/s)*	4.1	2.8	3.4	2.3	2.7	6.2	2.7	2.5	2.2	2.2	3.3	3.8
	% Occurrence	7.2	4.1	1.5	1.0	0.4	0.4	0.1	0.7	0.4	1.6	4.8	7.7
45 to 60	*Mean Wind Speed (m/s)*	3.9	3.3	2.4	5.3	2.5	2.2	0.0	0.0	2.7	2.8	3.1	3.8
	% Occurrence	4.7	1.7	0.4	0.6	0.1	0.2	0.0	0.0	0.1	0.7	2.8	4.3
60 to 75	*Mean Wind Speed (m/s)*	3.9	3.2	2.9	2.7	2.6	2.1	1.3	1.6	2.8	2.5	2.9	3.1
	% Occurrence	8.2	3.8	2.2	1.1	0.5	0.4	0.1	0.1	0.5	1.9	5.0	6.1
75 to 90	*Mean Wind Speed (m/s)*	3.6	3.4	3.1	2.6	2.7	0.0	0.0	0.0	2.7	2.2	3.2	3.3
	% Occurrence	3.4	2.3	1.2	0.3	0.2	0.0	0.0	0.0	0.1	0.8	2.5	2.7
90 to 105	*Mean Wind Speed (m/s)*	3.6	4.0	3.8	3.1	3.1	2.3	2.7	2.5	2.4	2.8	2.9	3.5
	% Occurrence	7.4	5.5	3.2	1.5	1.8	0.7	0.1	0.3	0.6	1.9	4.0	6.0
105 to 120	*Mean Wind Speed (m/s)*	4.2	4.5	4.1	3.0	3.3	3.1	0.0	4.0	3.4	2.4	3.4	4.0
	% Occurrence	3.1	5.3	1.9	1.0	1.1	0.1	0.0	0.1	0.2	1.5	3.5	5.9
120 to 135	*Mean Wind Speed (m/s)*	4.9	6.3	4.9	5.1	5.1	8.3	2.0	2.3	2.2	3.7	3.6	5.1
	% Occurrence	8.4	12.8	5.2	1.8	2.0	0.2	0.3	0.4	0.5	2.4	5.6	12.4
135 to 150	*Mean Wind Speed (m/s)*	5.9	6.2	5.4	6.5	5.6	6.2	3.7	2.7	4.3	5.2	4.1	6.3
	% Occurrence	5.4	8.9	3.8	1.8	1.3	0.5	0.3	0.1	0.2	1.9	2.6	5.9
150 to 165	*Mean Wind Speed (m/s)*	4.9	5.4	5.8	4.5	5.1	4.4	1.8	2.9	2.6	4.8	3.3	4.9
	% Occurrence	5.3	8.7	6.1	1.4	3.2	0.6	0.2	0.1	1.4	2.4	2.8	6.1
165 to 180	*Mean Wind Speed (m/s)*	3.5	5.3	4.2	5.2	6.4	4.3	3.8	4.5	3.6	2.9	2.5	4.0
	% Occurrence	1.6	2.4	2.2	0.7	1.4	0.6	0.1	0.1	0.2	0.8	0.8	1.6
180 to 195	*Mean Wind Speed (m/s)*	4.1	5.1	3.9	3.5	4.6	3.4	3.8	3.1	2.5	3.7	2.8	3.9
	% Occurrence	2.9	3.8	4.8	1.8	3.1	1.8	1.2	1.0	0.8	2.6	2.9	4.9
195 to 210	*Mean Wind Speed (m/s)*	3.9	3.8	4.5	3.6	4.7	4.0	3.5	3.6	3.8	2.9	3.3	4.0
	% Occurrence	2.8	2.7	3.6	2.2	1.8	2.1	2.5	1.0	1.6	2.8	2.0	1.2
210 to 225	*Mean Wind Speed (m/s)*	2.9	4.4	4.2	4.7	4.5	4.8	3.9	4.1	3.3	3.5	3.2	3.7
	% Occurrence	1.9	3.2	5.9	5.3	6.7	4.3	3.6	5.4	4.1	3.9	2.9	2.9
225 to 240	*Mean Wind Speed (m/s)*	2.6	4.2	5.2	5.1	5.4	4.9	4.5	4.6	4.2	4.1	3.1	4.1
	% Occurrence	1.2	2.4	3.0	4.4	4.3	3.8	3.5	4.6	3.7	2.6	1.7	2.0
240 to 255	*Mean Wind Speed (m/s)*	3.2	4.6	4.6	5.3	5.1	5.3	5.0	4.5	4.3	4.0	3.8	3.5
	% Occurrence	3.1	6.4	11.7	16.7	15.6	17.0	13.0	14.8	13.5	13.7	8.4	4.0
255 to 270	*Mean Wind Speed (m/s)*	3.5	4.4	4.8	5.2	5.5	5.7	5.3	4.6	4.6	4.0	3.9	3.2
	% Occurrence	2.3	4.0	7.8	12.2	12.2	14.0	12.1	9.6	10.4	10.7	5.6	2.8
270 to 285	*Mean Wind Speed (m/s)*	4.4	4.7	4.7	5.3	5.5	5.8	5.2	5.0	4.7	4.2	4.3	4.4
	% Occurrence	6.8	8.0	18.0	23.7	26.0	27.1	26.8	24.2	24.5	21.9	12.7	5.0
285 to 300	*Mean Wind Speed (m/s)*	4.3	4.1	4.3	5.2	5.3	5.8	5.4	5.2	4.9	4.3	4.6	4.7
	% Occurrence	3.8	3.1	5.4	8.6	7.7	9.5	12.1	13.6	11.8	8.4	4.7	2.7
300 to 315	*Mean Wind Speed (m/s)*	4.0	4.1	4.2	4.6	5.3	5.8	5.4	5.2	4.5	4.0	4.1	4.8
	% Occurrence	4.9	3.9	5.5	6.0	5.6	7.1	11.2	12.6	12.7	7.8	6.5	4.2
315 to 330	*Mean Wind Speed (m/s)*	3.8	3.0	3.4	4.3	4.4	4.5	5.1	3.7	3.8	3.6	4.0	3.8
	% Occurrence	2.6	1.7	1.6	3.5	1.3	3.1	3.9	4.5	4.5	3.0	3.7	1.6
330 to 345	*Mean Wind Speed (m/s)*	3.4	3.3	3.3	3.6	3.8	4.2	4.0	3.2	3.5	3.0	3.7	3.6
	% Occurrence	4.3	1.7	2.6	2.8	1.9	3.9	5.6	4.5	5.5	4.8	6.0	3.1
345 to 360	*Mean Wind Speed (m/s)*	4.0	2.9	2.9	2.8	3.1	3.5	3.8	3.2	3.0	3.5	3.8	2.8
	% Occurrence	3.2	1.4	1.2	1.0	1.6	1.7	3.1	1.6	2.3	1.3	1.4	1.3

Table WAKE-A-3

Mean Monthly Wind Speed (m/s) and Percent Occurrence for the Given Wind Direction at the San Pablo Bay Station, 1992-1993

Bin (degrees)	Wind Parameter	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	*Mean Wind Speed (m/s)*	4.6	2.3	2.2	4.0	1.8	4.8	0.0	0.0	1.4	2.0	3.5	2.6
	% Occurrence	3.9	2.0	1.7	0.3	0.3	0.1	0.0	0.0	0.2	0.7	4.9	3.2
15 to 30	*Mean Wind Speed (m/s)*	2.7	2.3	2.3	1.9	2.3	0.0	0.0	0.0	0.3	1.2	2.7	2.2
	% Occurrence	2.6	2.0	1.1	0.1	0.3	0.0	0.0	0.0	0.1	0.7	2.6	2.3
30 to 45	*Mean Wind Speed (m/s)*	2.7	2.2	2.7	2.1	0.5	0.7	0.0	0.0	0.0	1.6	2.6	3.3
	% Occurrence	3.1	1.8	1.6	0.1	0.1	0.1	0.0	0.0	0.0	0.7	2.0	1.9
45 to 60	*Mean Wind Speed (m/s)*	5.0	2.8	2.3	0.9	1.2	0.0	0.0	0.3	0.9	2.6	3.7	6.0
	% Occurrence	7.9	3.1	0.9	0.1	0.3	0.0	0.0	0.1	0.1	0.7	3.9	11.0
60 to 75	*Mean Wind Speed (m/s)*	6.8	4.6	3.7	4.5	0.0	0.0	0.0	0.0	0.0	4.2	5.6	7.1
	% Occurrence	25.5	9.4	2.2	0.3	0.0	0.0	0.0	0.0	0.0	1.4	8.9	22.4
75 to 90	*Mean Wind Speed (m/s)*	6.8	5.4	4.6	4.4	3.8	0.0	0.0	0.0	0.6	5.1	6.1	6.0
	% Occurrence	17.9	13.4	2.8	0.5	0.3	0.0	0.0	0.0	0.1	1.5	10.2	8.7
90 to 105	*Mean Wind Speed (m/s)*	3.6	2.8	3.4	3.1	2.7	2.2	0.0	0.0	1.9	3.1	3.7	3.8
	% Occurrence	2.8	3.6	1.3	0.1	0.3	0.3	0.0	0.0	0.1	0.6	3.0	3.4
105 to 120	*Mean Wind Speed (m/s)*	2.5	2.2	2.3	2.5	2.6	0.0	0.0	0.0	0.0	1.4	2.5	2.7
	% Occurrence	1.9	3.1	1.3	0.1	0.9	0.0	0.0	0.0	0.0	0.8	1.5	2.7
120 to 135	*Mean Wind Speed (m/s)*	2.8	3.1	2.2	2.5	3.4	0.1	1.5	1.0	1.6	2.0	2.4	3.0
	% Occurrence	1.9	4.4	2.1	0.3	0.9	0.1	0.1	0.1	0.1	1.3	2.4	1.9
135 to 150	*Mean Wind Speed (m/s)*	3.3	4.1	4.2	2.0	3.3	0.9	1.5	2.0	1.3	2.3	2.1	3.5
	% Occurrence	2.2	4.5	1.7	0.7	0.9	0.1	0.1	0.3	0.2	1.2	2.4	2.7
150 to 165	*Mean Wind Speed (m/s)*	5.8	4.9	4.3	4.0	3.5	2.6	1.9	1.1	1.4	4.0	2.7	6.8
	% Occurrence	2.9	6.1	2.7	0.7	1.1	0.3	0.1	0.2	0.2	2.0	1.3	5.5
165 to 180	*Mean Wind Speed (m/s)*	4.9	5.1	4.6	5.8	5.0	5.4	5.6	6.5	6.6	4.1	3.3	6.4
	% Occurrence	3.3	5.6	3.7	1.5	0.9	0.7	0.6	1.9	1.5	2.6	1.7	5.6
180 to 195	*Mean Wind Speed (m/s)*	5.1	4.2	5.2	5.0	7.9	8.2	8.2	7.8	7.2	5.6	4.0	5.4
	% Occurrence	3.0	5.6	6.3	2.8	8.7	13.1	21.6	30.5	21.9	10.8	2.6	3.3
195 to 210	*Mean Wind Speed (m/s)*	4.2	4.1	4.4	5.3	7.0	6.8	6.8	6.7	5.8	5.0	3.4	6.0
	% Occurrence	2.6	3.8	8.4	4.7	16.9	19.2	26.7	28.3	24.3	14.6	3.8	2.8
210 to 225	*Mean Wind Speed (m/s)*	3.9	3.7	5.0	4.8	6.6	6.5	6.5	6.2	4.7	4.6	3.6	4.8
	% Occurrence	1.9	5.3	10.5	10.1	20.6	17.6	18.8	12.4	13.3	13.8	3.2	1.9
225 to 240	*Mean Wind Speed (m/s)*	3.1	3.5	4.0	4.1	6.1	5.5	5.7	5.4	4.5	3.6	2.8	3.9
	% Occurrence	1.6	5.0	7.4	9.0	12.0	10.1	12.6	8.2	9.5	7.2	3.3	1.3
240 to 255	*Mean Wind Speed (m/s)*	3.5	3.7	3.2	4.2	5.0	5.6	5.8	4.8	4.6	3.2	3.4	3.6
	% Occurrence	1.6	3.3	6.4	9.5	9.7	9.2	9.7	6.1	7.5	7.3	3.1	1.3
255 to 270	*Mean Wind Speed (m/s)*	5.2	4.2	3.9	5.2	5.3	6.5	5.5	4.9	4.2	3.3	4.2	3.9
	% Occurrence	1.6	4.1	7.7	11.4	9.1	12.2	5.6	4.8	8.3	7.7	4.3	1.9
270 to 285	*Mean Wind Speed (m/s)*	3.0	3.9	4.2	5.5	6.0	7.1	6.0	4.3	3.9	3.3	4.1	4.4
	% Occurrence	1.3	4.8	10.9	21.8	9.0	10.2	3.2	4.2	5.1	10.0	5.9	2.4
285 to 300	*Mean Wind Speed (m/s)*	3.0	3.0	3.6	4.7	5.4	5.4	3.3	4.2	3.4	3.0	3.6	3.8
	% Occurrence	2.3	2.1	6.9	13.5	3.6	4.0	0.7	1.3	4.0	5.3	7.8	2.5
300 to 315	*Mean Wind Speed (m/s)*	3.6	2.5	3.4	5.0	4.6	4.7	1.7	2.6	2.1	2.2	3.5	3.5
	% Occurrence	2.2	1.5	6.0	7.9	2.7	1.6	0.1	0.6	1.4	3.0	6.8	2.9
315 to 330	*Mean Wind Speed (m/s)*	2.6	2.1	2.6	3.4	2.6	3.1	1.5	1.6	1.9	1.8	2.6	2.9
	% Occurrence	1.5	1.5	2.8	2.1	0.4	0.3	0.1	0.2	0.9	2.4	3.5	2.6
330 to 345	*Mean Wind Speed (m/s)*	2.6	1.6	1.9	2.8	3.7	2.8	2.6	1.7	1.9	2.0	2.7	3.9
	% Occurrence	1.5	1.1	1.3	1.3	0.5	0.1	0.1	0.3	0.9	1.6	3.5	2.7
345 to 360	*Mean Wind Speed (m/s)*	3.7	1.8	1.8	3.1	3.4	4.8	1.8	2.1	1.0	1.7	4.1	3.4
	% Occurrence	2.9	2.9	2.2	1.1	0.5	0.6	0.1	0.5	0.3	2.2	7.5	3.2

Table WAKE-A-4
Maximum Monthly Wind Speed (m/s) for the Given Wind Direction at SFO, 1992-1993

Bin (degrees)	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	10.3	4.5	5.8	7.2	4.0	4.5	4.0	4.9	4.0	4.0	13.9	13.0
15 to 30	10.3	7.2	3.6	4.9	6.7	4.9	5.8	4.9	5.8	4.0	7.2	4.9
30 to 45	10.3	10.3	4.9	5.8	4.9	4.5	6.3	4.9	4.5	4.5	5.8	8.0
45 to 60	10.3	6.7	7.6	3.6	4.5	4.5	4.0	4.0	4.9	4.0	6.3	9.4
60 to 75	12.5	9.4	4.9	4.0	4.5	4.0	4.0	4.5	4.5	4.0	8.0	8.0
75 to 90	9.4	7.2	4.9	4.0	4.0	4.0	3.1	4.0	4.0	2.7	6.7	6.3
90 to 105	11.2	9.4	6.3	4.5	5.8	3.6	3.1	2.7	4.0	6.3	7.2	6.3
105 to 120	6.7	7.2	4.9	4.0	5.8	1.3	1.8	0	2.7	1.8	4.5	7.2
120 to 135	9.4	9.8	8.0	7.2	6.7	5.8	4.0	3.1	3.6	4.5	6.3	11.2
135 to 150	9.4	11.2	7.2	6.7	7.2	7.2	3.1	2.7	3.1	5.8	6.3	9.4
150 to 165	10.3	8.0	7.6	9.4	6.7	5.8	4.0	3.1	3.1	8.0	6.3	10.3
165 to 180	9.8	11.2	5.8	6.3	8.0	8.5	7.2	2.7	4.9	8.5	7.2	10.3
180 to 195	16.5	17.4	7.6	10.3	13.4	10.3	7.2	7.2	7.2	10.7	8.0	15.2
195 to 210	14.8	14.3	8.0	8.0	13.0	7.6	9.4	9.4	8.5	10.3	8.0	13.0
210 to 225	13.0	12.5	9.4	9.8	14.8	9.8	9.4	10.3	7.2	9.8	7.2	13.4
225 to 240	14.8	11.2	8.0	9.4	10.7	11.2	9.4	9.8	8.0	8.5	6.3	11.6
240 to 255	11.6	12.5	7.6	8.5	11.2	9.8	9.4	8.0	10.3	9.4	7.2	13.4
255 to 270	10.7	11.2	8.5	11.6	11.6	10.3	13.0	13.0	11.6	8.0	10.3	7.6
270 to 285	17.9	12.5	13.4	14.8	15.2	17.0	17.9	14.3	12.5	9.4	15.2	11.2
285 to 300	14.8	9.8	14.3	14.8	14.8	15.2	14.3	13.9	12.5	10.3	14.3	12.5
300 to 315	11.2	12.5	13.4	13.4	13.9	13.0	15.2	14.8	13.9	11.6	13.0	11.2
315 to 330	6.3	4.5	7.2	7.6	10.7	12.5	10.7	12.5	11.2	10.7	9.4	10.7
330 to 345	4.5	3.6	4.0	6.7	8.9	8.9	8.0	7.6	9.4	7.6	9.4	8.0
345 to 360	10.3	3.6	4.0	8.9	6.7	4.9	5.8	4.9	6.7	4.9	9.4	9.8

Table WAKE-A-5

Maximum Monthly Wind Speed (m/s) for the Given Wind Direction at OAK, 1992-1993

Bin (degrees)	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	15.2	4.5	3.6	2.7	2.7	10.3	0	3.6	2.7	4.5	11.2	9.4
15 to 30	11.2	6.3	4.9	2.2	2.7	7.6	3.1	2.7	2.7	4.9	8.5	7.6
30 to 45	15.2	4.9	7.6	4.5	3.6	10.3	2.7	3.1	2.7	2.7	6.7	10.3
45 to 60	8.0	7.2	2.7	23.2	2.7	2.7	0	0	2.7	6.3	4.9	8.5
60 to 75	8.5	9.4	4.9	4.0	3.6	2.7	1.3	1.8	3.1	3.6	4.9	4.9
75 to 90	11.2	8.0	4.0	3.1	2.7	0	0	0	2.7	2.7	6.7	4.9
90 to 105	8.5	9.4	6.7	4.5	4.9	3.6	2.7	3.1	2.7	4.5	6.3	6.7
105 to 120	10.3	8.5	7.6	4.5	4.9	3.1	0	4.5	4.0	4.0	6.7	10.3
120 to 135	11.2	14.3	10.3	10.3	10.3	10.3	2.7	3.6	3.1	11.2	6.3	11.6
135 to 150	23.2	11.6	11.2	14.3	10.3	8.0	4.9	2.7	7.2	14.3	7.6	13.0
150 to 165	11.6	13.9	13.0	10.3	10.3	8.5	2.7	4.0	4.0	12.5	7.2	11.2
165 to 180	9.4	11.2	7.6	9.4	9.8	9.4	4.9	4.5	4.0	4.0	3.1	10.7
180 to 195	10.3	15.2	11.2	7.6	11.2	8.0	6.3	4.5	3.6	8.0	4.0	10.3
195 to 210	10.3	13.0	27.7	6.7	10.7	9.4	6.7	4.9	10.3	6.3	7.6	10.3
210 to 225	6.3	9.4	8.9	9.4	12.5	10.3	8.0	9.4	8.5	6.7	6.3	9.8
225 to 240	3.6	9.4	23.2	9.4	10.3	9.4	11.6	10.3	7.6	7.6	6.3	9.4
240 to 255	4.9	13.0	8.0	11.2	11.2	11.2	10.3	10.3	10.3	8.0	9.4	10.3
255 to 270	8.5	10.3	11.2	11.2	11.2	10.3	10.3	9.4	8.5	7.6	9.4	10.3
270 to 285	10.3	13.0	10.3	10.3	11.2	11.2	10.3	10.3	9.4	8.5	11.2	9.4
285 to 300	7.6	8.0	9.4	10.3	10.3	10.7	11.2	10.3	9.8	7.6	9.4	11.2
300 to 315	7.2	10.7	7.6	8.0	10.3	10.3	10.7	10.7	8.5	7.6	9.4	10.7
315 to 330	9.4	4.5	6.7	8.5	7.6	9.4	12.5	7.2	7.2	6.7	8.0	7.6
330 to 345	7.6	6.3	4.9	7.6	8.0	10.3	10.3	9.4	6.3	7.2	10.3	9.4
345 to 360	11.2	6.3	4.0	5.8	6.3	6.3	5.8	6.3	4.9	7.2	7.6	4.9

Table WAKE-A-6
Maximum Monthly Wind Speed (m/s) for the Given Wind Direction at the San Pablo Bay Station, 1992-1993

Bin (degrees)	January	February	March	April	May	June	July	August	September	October	November	December
0 to 15	12.1	5.2	4.2	5.7	2.8	6.6	0	0	2.1	3.2	11.6	5.5
15 to 30	8.6	7.4	4.6	2.1	3.7	0	0	0	0.3	2.1	7.2	4.3
30 to 45	5.9	4.8	4.8	2.1	0.5	0.7	0	0	0	3.9	4.8	7.5
45 to 60	11.8	6.2	4.4	0.9	2.2	0	0	0	0.9	5.2	8.2	10.3
60 to 75	13.6	8.5	6.3	7.1	0	0	0	0	0	7.7	10.5	12.2
75 to 90	12.3	9.9	8.0	7.1	5.1	0	0	0	0.6	6.7	10.6	13.4
90 to 105	9.9	7.2	5.6	3.1	4.4	3.8	0	0	2.7	5.8	8.2	6.9
105 to 120	6.0	4.5	5.8	2.8	5.7	0	0	0	0.0	2.4	4.4	8.0
120 to 135	7.4	7.9	5.6	3.9	5.3	0.1	1.5	1.0	1.9	4.1	4.5	6.7
135 to 150	9.3	10.0	7.3	4.4	6.1	0.9	1.5	2.7	1.5	8.4	4.8	9.3
150 to 165	12.7	14.7	8.9	8.3	7.4	4.3	1.9	1.3	1.7	13.3	6.5	13.3
165 to 180	12.2	14.0	9.3	12.7	8.2	9.7	8.6	11.3	10.0	10.4	6.7	10.9
180 to 195	15.0	14.1	9.2	9.9	11.8	11.7	11.8	12.5	11.0	11.1	8.1	12.6
195 to 210	8.6	14.3	10.1	10.9	12.7	11.5	11.3	12.1	10.7	10.3	7.0	11.2
210 to 225	12.5	7.9	9.6	9.3	12.8	13.3	14.4	13.1	10.1	9.7	7.1	9.3
225 to 240	5.9	10.5	7.4	10.4	12.9	11.8	10.6	11.1	10.4	9.3	5.5	8.1
240 to 255	9.5	9.4	6.9	7.7	10.2	10.3	9.3	10.3	11.3	6.9	8.4	8.4
255 to 270	11.3	10.5	9.9	10.0	10.5	11.6	9.7	10.3	10.5	7.3	11.7	8.4
270 to 285	5.3	9.8	10.0	10.9	13.1	12.4	11.0	10.0	8.0	7.8	12.2	9.1
285 to 300	5.5	7.5	10.0	9.4	8.4	9.7	5.4	8.4	7.8	7.3	8.4	8.2
300 to 315	7.7	6.0	8.7	10.0	8.6	8.1	1.7	4.5	7.0	4.0	8.3	7.8
315 to 330	6.8	4.7	5.9	6.2	4.7	4.6	1.5	2.2	3.4	4.6	6.1	7.9
330 to 345	6.9	3.4	3.4	9.4	7.5	4.7	2.6	3.5	3.0	4.1	6.7	9.7
345 to 360	10.3	3.5	4.7	8.3	7.5	6.5	2.1	3.6	1.4	3.0	12.8	11.5

Table WAKE-A-7

Monthly Wave Energy (MJ/m) Reaching the Shore for Selected SF Bay Locations, 1992-1993

Location	Month												Monthly Average	Monthly Max
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
Petaluma Wetlands	197.7	268.1	298.5	157.7	1178.0	1541.0	2444.8	2906.6	1670.8	528.0	56.2	463.3	975.9	2906.6
Hercules	393.4	106.6	164.7	606.0	288.7	391.3	87.6	58.7	61.9	70.2	279.3	357.7	238.8	606.0
Gallinas Creek	599.7	212.5	52.4	7.6	12.3	1.0	0.5	2.0	1.6	26.3	198.6	545.5	138.3	599.7
Corte Madera Marsh	114.9	201.6	81.7	29.6	29.7	7.8	0.7	0.5	1.7	23.1	24.0	137.4	54.4	201.6
Paradise Cay	159.2	232.6	111.4	37.0	48.4	11.8	3.2	1.9	3.7	29.8	34.8	165.1	69.9	232.6
Sausalito	56.0	111.6	86.3	45.4	71.4	48.5	33.5	23.2	21.3	30.1	15.4	66.6	50.8	111.6
Yerba Buena	90.2	129.3	128.5	124.8	175.7	143.5	104.2	88.1	65.4	59.9	43.3	91.1	103.7	175.7
Oyster Point	77.7	108.5	32.0	20.3	24.7	8.1	5.0	3.9	4.8	10.9	34.8	121.5	37.7	121.5
Redwood City Channel	38.7	36.5	14.1	10.2	12.6	10.7	10.6	8.9	10.0	8.8	19.4	48.3	19.1	48.3
Coyote Creek	10.0	9.2	35.7	73.8	75.8	91.9	102.8	121.7	104.5	51.6	34.9	12.0	60.3	121.7
Alameda Creek	100.0	88.6	239.1	550.9	634.8	823.0	798.6	860.4	682.8	316.8	236.3	129.8	455.1	860.4
San Leandro	77.7	111.7	186.2	438.9	512.2	688.1	512.3	348.4	202.2	114.7	79.5	119.1	282.6	688.1
Berkeley	30.9	52.4	122.0	239.5	268.2	325.5	258.6	209.0	162.2	103.8	59.1	31.8	155.3	325.5
Point Pinole	1020.9	251.6	184.4	490.9	397.0	540.0	256.6	153.3	131.6	110.8	435.7	877.9	404.2	1020.9
New York Slough	3.5	6.0	4.0	4.3	5.6	7.0	10.7	13.8	7.9	2.6	1.9	7.7	6.2	13.8

Table WAKE-A-8
Maximum Energy in a Single Wave (kJ/m) for Selected Locations in SF Bay, 1992-1993

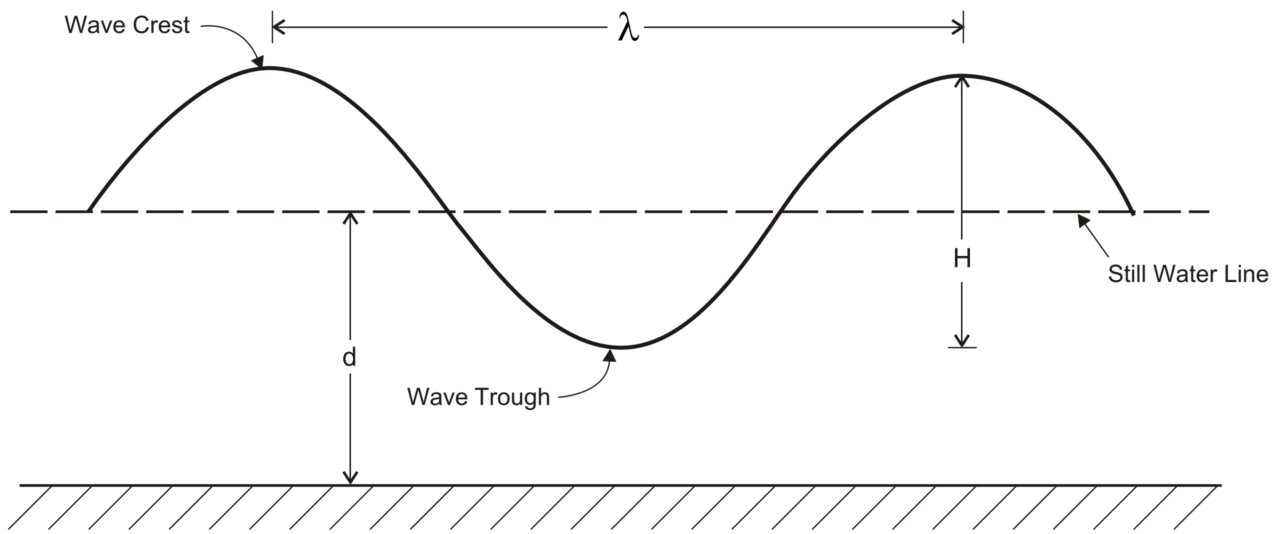
Location	Monthly Maximum in a Single Wave												Monthly	Monthly
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec	Average (kJ/m)	Maximum
Petaluma Wetlands	99.7	85.6	27.5	33.8	54.2	53.0	54.2	63.0	45.0	46.1	19.1	64.3	53.8	99.7
Hercules (Martinez)	14.5	14.6	22.3	23.1	31.5	27.4	20.0	15.4	11.0	9.0	26.2	17.8	19.4	31.5
Gallinas Creek	11.8	17.6	5.4	3.5	5.0	0.9	0.2	0.4	0.3	13.4	7.3	13.5	6.6	17.6
Corte Madera Marsh	88.5	14.5	11.9	23.8	8.9	5.1	0.8	0.2	2.8	23.8	3.4	17.9	16.8	88.5
Paradise Cay	86.0	31.5	25.8	42.0	12.6	6.8	0.7	0.5	2.6	23.2	3.8	16.7	21.0	86.0
Sausalito	39.9	31.6	25.6	12.0	12.0	6.4	0.8	0.8	0.9	22.8	3.5	15.8	14.3	39.9
Yerba Buena	23.8	70.2	386.3	54.4	30.4	16.1	5.2	6.8	21.6	11.3	8.0	23.8	54.8	386.3
Oyster Point	16.8	15.3	5.2	10.0	4.0	4.0	1.1	0.5	0.5	6.2	4.0	13.4	6.8	16.8
Redwood City Channel	7.1	7.1	2.1	1.2	0.8	0.8	1.6	0.7	0.5	0.5	1.3	3.9	2.3	7.1
Coyote Creek	1.2	1.5	1.7	1.7	1.8	1.6	2.2	2.1	1.8	1.3	1.6	1.2	1.6	2.2
Alameda Creek	20.5	15.8	19.0	19.0	20.7	20.5	26.3	24.3	20.7	13.4	17.3	17.9	19.6	26.3
San Leandro	37.9	14.8	17.9	23.1	25.0	33.3	37.9	21.3	14.8	6.8	25.0	16.3	22.8	37.9
Berkeley	6.3	13.5	29.6	6.8	8.3	8.3	8.0	6.3	5.2	3.3	8.3	8.0	9.3	29.6
Point Pinole	28.9	11.0	11.0	14.4	25.1	21.3	14.8	11.0	10.9	5.9	29.3	25.1	17.4	29.3
New York Slough	0.9	1.2	0.4	0.4	0.2	0.2	0.1	0.1	0.1	0.7	0.2	0.9	0.5	1.2

Table WAKE-A-9

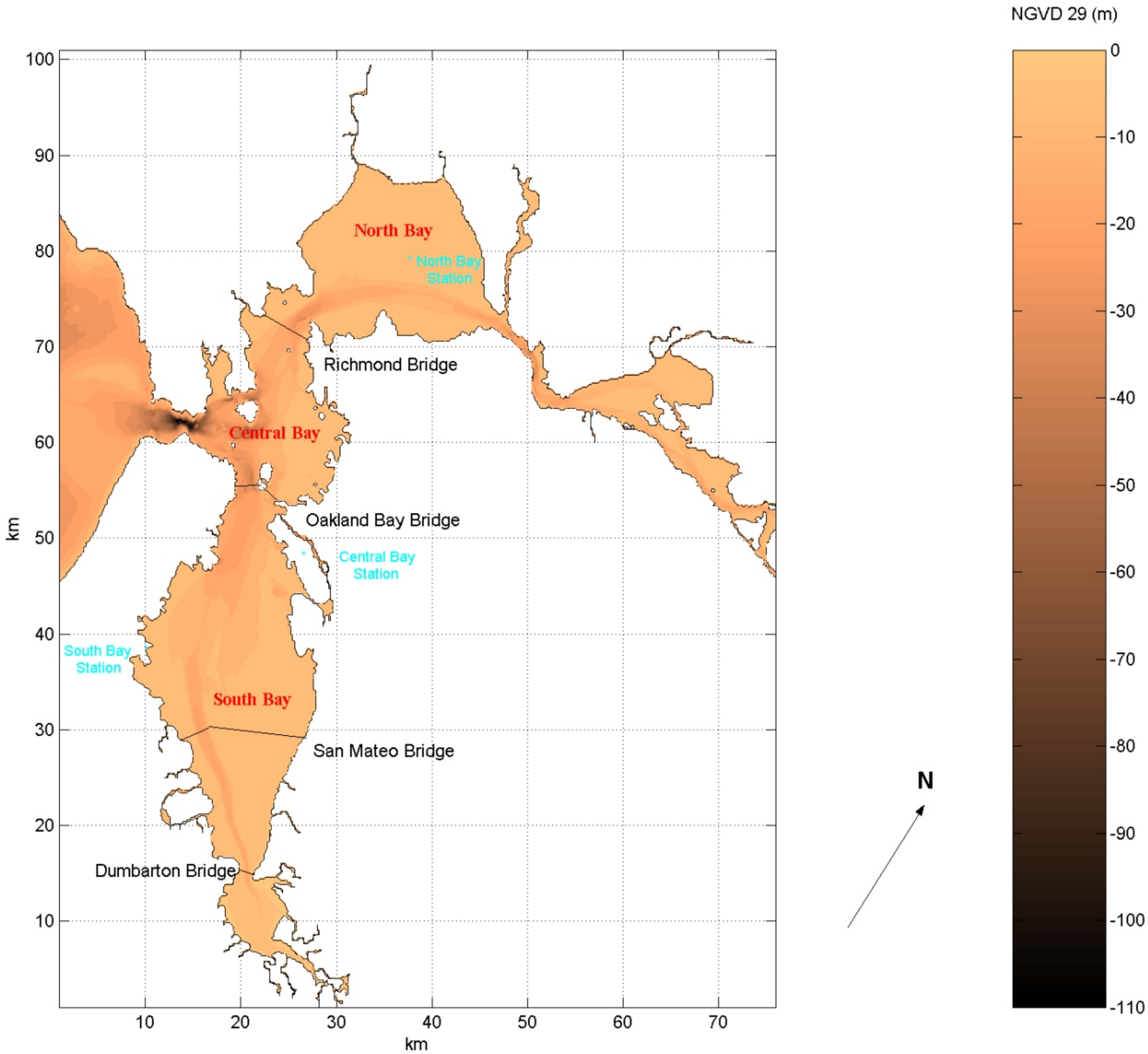
Monthly Maximum Wave Heights in Meters for Selected Locations in SF Bay, 1992-1993

Location	Monthly Maximum Wave Height in meters												Avg	Max
	Jan	Feb	Mar	Apr	May	June	July	Aug	Sept	Oct	Nov	Dec		
Petaluma Wetlands	1.6	1.5	1.0	1.1	1.3	1.3	1.3	1.4	1.2	1.2	0.88	1.4	1.3	1.6
Hercules	0.86	0.84	0.96	0.96	1.1	1.1	0.94	0.85	0.74	0.69	1.0	0.90	0.91	1.1
Gallinas Creek	0.82	0.96	0.59	0.52	0.55	0.31	0.21	0.26	0.21	0.86	0.64	0.79	0.56	1.0
Corte Madera Marsh	1.6	0.84	0.78	0.99	0.69	0.58	0.29	0.20	0.46	0.99	0.49	0.89	0.73	1.6
Paradise Cay	1.6	1.1	1.0	1.2	0.77	0.62	0.28	0.24	0.44	0.96	0.50	0.87	0.80	1.6
Sausalito	1.3	1.1	1.0	0.76	0.76	0.60	0.33	0.33	0.31	0.96	0.49	0.84	0.73	1.3
Yerba Buena	0.94	1.4	2.6	1.4	1.0	0.82	0.55	0.63	0.91	0.72	0.64	0.94	1.04	2.6
Oyster Point	0.87	0.82	0.56	0.70	0.51	0.51	0.34	0.25	0.25	0.59	0.52	0.79	0.56	0.9
Redwood City Channel	0.64	0.64	0.42	0.34	0.31	0.31	0.37	0.28	0.25	0.25	0.37	0.52	0.39	0.6
Coyote Creek	0.36	0.39	0.41	0.41	0.42	0.40	0.45	0.44	0.42	0.37	0.40	0.36	0.40	0.5
Alameda Creek	0.89	0.84	0.90	0.90	0.93	0.91	1.0	0.99	0.93	0.78	0.87	0.85	0.90	1.0
San Leandro	1.2	0.83	0.89	0.97	1.0	1.1	1.2	0.95	0.83	0.62	1.0	0.86	0.95	1.2
Berkeley	0.62	0.82	1.2	0.64	0.68	0.68	0.68	0.62	0.58	0.49	0.68	0.68	0.69	1.2
Point Pinole	1.1	0.77	0.78	0.86	1.1	0.99	0.87	0.78	0.77	0.61	1.1	1.0	0.89	1.1
New York Slough	0.36	0.40	0.27	0.28	0.22	0.21	0.21	0.22	0.18	0.32	0.22	0.36	0.27	0.4

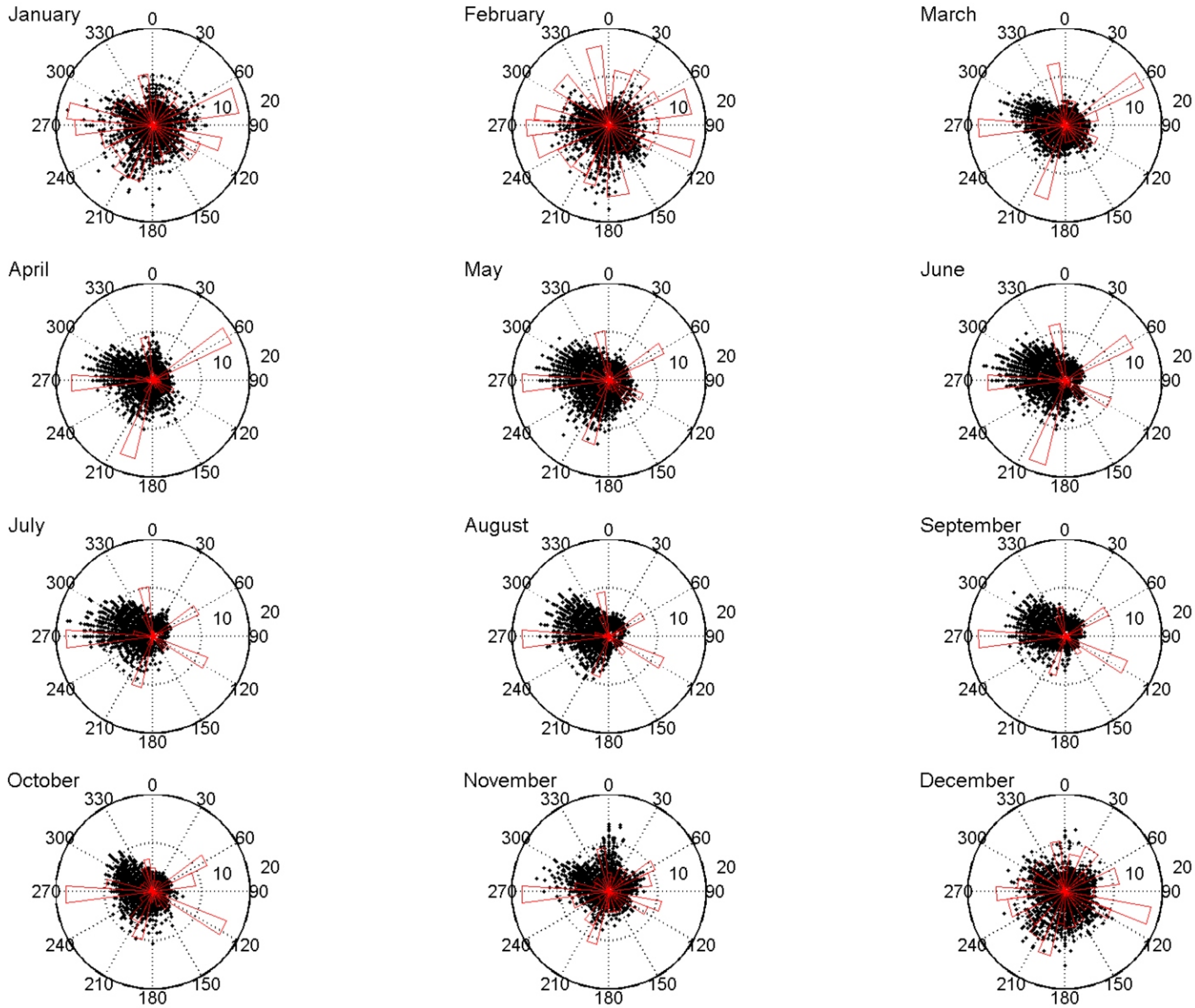
APPENDIX WAKE-A FIGURES



URS	Water Transit Authority Project No. 43-00066890.10	Wave Parameter Diagram	Figure WAKE-A-1

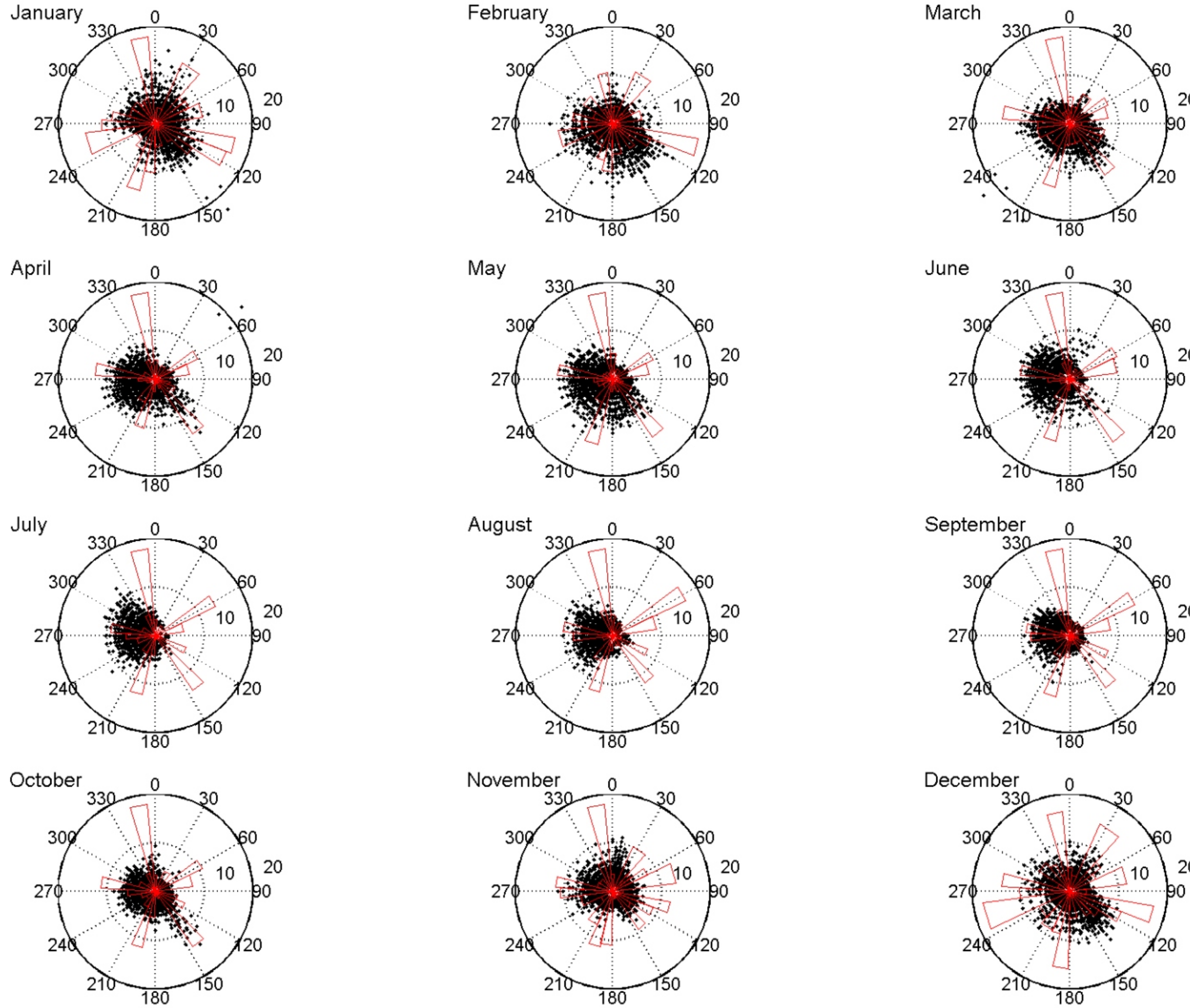


URS	Water Transit Authority Project No. 43-00066890.10	San Francisco Bay Water Depth in meters at Mean Lower Low Water (MLLW) relative to NGVD 1929	Figure WAKE-A-2



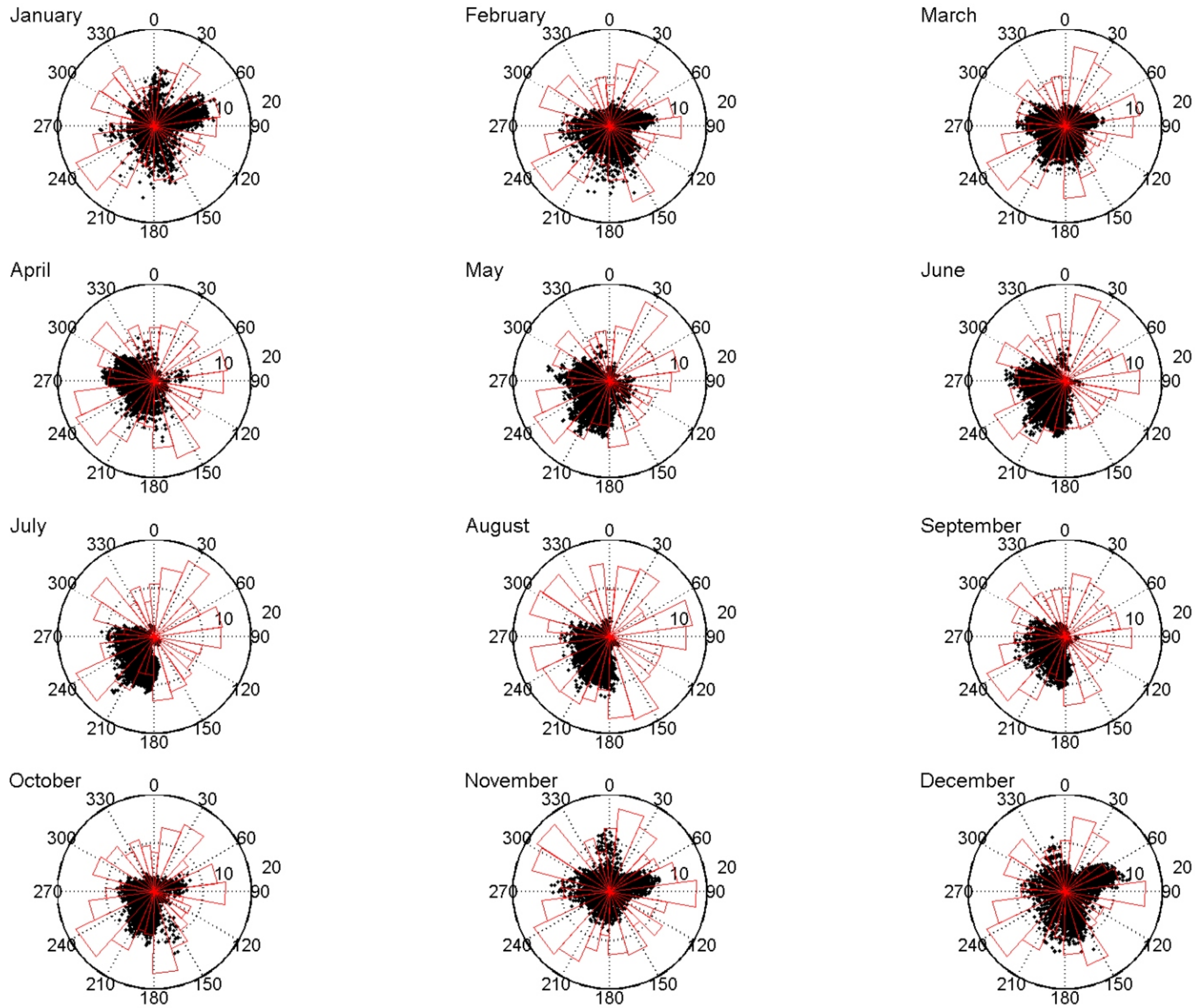
Relative percent frequency of wind direction is illustrated as red lines.
Individual wind speed in meters per second along with the corresponding
wind direction is shown as black points. (Data Source: NCDC)

URS	Water Transit Authority Project No. 43-00066890.10	Monthly wind rose plots for years 1992-1993 at San Francisco International Airport	Figure WAKE-A-3



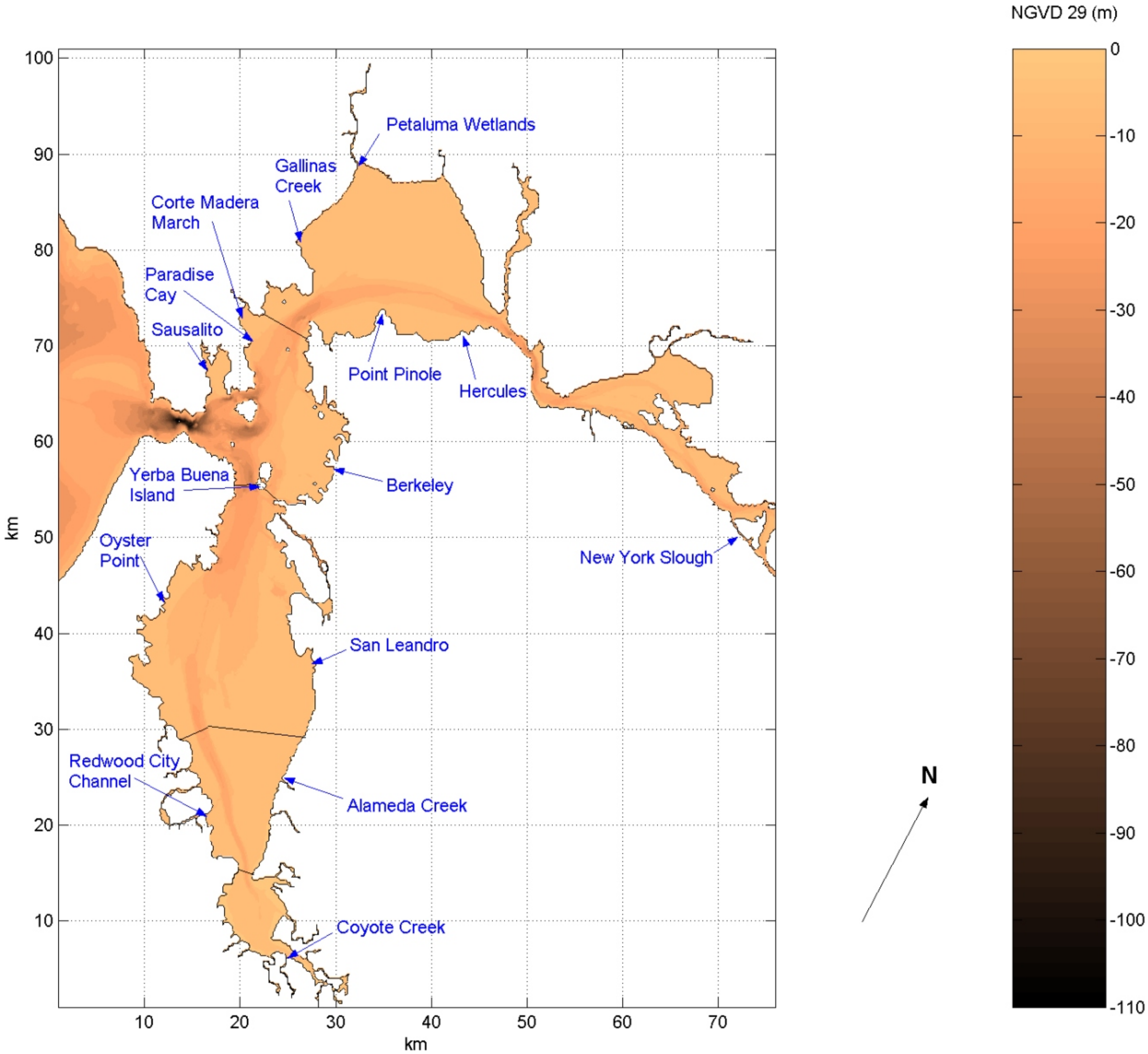
Relative percent frequency of wind direction is illustrated as red lines.
Individual wind speed in meters per second along with the corresponding
wind direction is shown as black points. (Data Source: NCDC)

URS	Water Transit Authority Project No. 43-00066890.10	Monthly wind rose plots for years 1992-1993 at Oakland International Airport	Figure WAKE-A-4



Relative percent frequency of wind direction is illustrated as red lines.
Individual wind speed in meters per second along with the corresponding
wind direction is shown as black points. (Data Source: NCDC)

URS	Water Transit Authority Project No. 43-00066890.10	Monthly wind rose plots for years 1992-1993 at San Pablo Bay	Figure WAKE-A-5



URS	Water Transit Authority Project No. 43-00066890.10	Map of wave station locations used for wave calculations	Figure WAKE-A-6

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APPENDIX

WAKE-A

Wind-Driven Wave Calculation Methodology

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Wake Wash Measurement Methodology

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WAKE-C
Wake Wash Regulations Worldwide

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Wake Wash Significance Criteria Development

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Evaluation of Wake Wash at Representative Shoreline Types

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AIR-A
Air Quality Analysis Calculations – Proposed Project

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AIR-B
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ENRG-B
Energy Calculations – Alternatives 1 Through 4

Tables

1.0 ENERGY CALCULATIONS FOR TRANSIT MODES OTHER THAN FERRIES

Energy consumption for automobiles, trucks, public buses, and transit rail vehicles were calculated using projected vehicle miles traveled (VMT), a factor that converts VMT to British thermal units (Btus) by transit mode and the estimated number of passengers per vehicle type. Because this is a comparative analysis that evaluates the difference between the No Project and alternative (Alternative 4) and each of the first three alternatives, this method provides a suitable means of determining whether there is a substantial impact in energy consumption by alternative.

VMT data for the project alternatives is provided in the Section 3.12 (Transportation) of the program Environmental Impact Report for this project. The passenger per vehicle data for automobiles, buses, and rail transit modes are based on the Metropolitan Transportation Commission (MTC) travel forecast model and are shown in Table ENRG-B-1.

Daily energy consumption per passenger mile traveled (PMT) for each of the above transit modes and for all of the project alternatives is shown in Table ENRG-B-1. Energy consumption per PMT is calculated by adding the total energy consumed for all transit modes (except for ferries) and dividing this value by the total PMT for all transit modes (except for ferries). PMT is calculated by multiplying the VMT value for the particular mode of transit and the appropriate load factor. Total energy consumed is calculated by multiplying the appropriate energy factor with the VMT value.

2.0 ENERGY CALCULATIONS FOR FERRIES

Energy consumption for ferries was calculated using predicted power outputs of the ferry engines, planned running times and distances of the ferry services, and estimated patronage. Ferry energy was analyzed by power output of the engines. This is the only available and complete energy consumption data of the current ferries and the predicted procured ferries for Alternatives 1, 2, and 3. This information simplifies parts of this energy analysis in terms of which fuel source and engine technology would be used because “transmission” (i.e., how many gallons of fuel would be consumed per Btu of engine output) and fuel consumption for future planned ferry engines is not known. Daily energy consumption by the ferries was calculated by multiplying the power output of the ferries by the running time of the anticipated ferry schedules for each project alternative.

For the Alternative 4, average power outputs were assumed for each route, based on the current ferries in use on these routes[1]. Characteristics of the current ferries are available in the working document, “New Technologies and Alternative Fuels,” prepared for Water Transit Authority by JJMA (JJMA 2002). For Alternatives 1, 2, and 3, two ferry fleets were assumed. One fleet would consist of estimated 400-passenger ferries with a maximum power output of 5,966 kW. The other fleet would consist of estimated 149-passenger ferries with a maximum power output of 2,163 kW. These two fleets would have a maximum service output of 5,369 kW and 1,946 kW, a slow speed power output of 424 kW and 284 kW, and an idling output of 107 kW and 111

[1] For the Larkspur ferry route, only the newer catamaran vessels used on this route were assumed to be used for the no project alternative. The monohull boats used on this route were constructed in the 1970’s and will be taken out of commission by 2025.

kW, respectively. It was estimated that the ferries would operate at service speed for 76 percent of the time of each run and at slow speed for 24 percent of the time (Hutchison 2002). Deadhead time, which is the time spent by a ferry traveling from its berthing dock to a ferry terminal at the beginning and end of each day, was also calculated and factored into the calculation of energy consumption. The anticipated ferry schedules are listed in Appendix AIR-1 in this report.[2] The ferry schedules were divided into peak and off-peak hours. Peak hours are the 6 hours (3 hours in the morning and 3 hours in the evening) where ferry patronage volume is expected to be the highest. Off-peak hours are the 9 hours of ferry service where patronage volumes are expected to be lower than peak hour times. Table ENRG-B-2 gives an example of the estimated daily energy consumption under Alternative 1.

Average daily PMT for the ferries was calculated by multiplying the passenger per run factor by the predicted VMT. This factor, shown in Table ENRG-B-3 for the different project alternatives, is calculated by dividing the estimated daily patronage by the number of ferry trips. The predicted VMT was calculated using information regarding the anticipated ferry routes, schedules, and distances covered during an average daily ferry service. Table ENRG-B-3 shows the estimated average daily PMT for the different project alternatives.

[2] This energy analysis did not account for the ferry service that would occur at the Oakland Airport and the San Francisco because available transit models did not produce patronage estimates for these routes. The GGNRA Circle Route was also not analyzed. The reduction of road-based PMT energy consumption for these recreation routes would not have a measurable effect in changing the energy consumption of transit in the Bay Area.

Table ENRG-B-1
Bay Area Energy Consumption for Cars, Trucks, Buses, and Passenger Rail In 2025

		Auto	Small Truck	Medium Truck	Large Truck	Bus	Light Rail	BART	Commuter Rail	Total
Alternative 1	Total Bay Area VMT	177,573,856	4,387,888	329,661	1,710,635	333,497	19,256	31,391	8,507	**184,394,691**
	Load Factor (persons/vehicle)	1.17	1.00	1.00	1.00	52.99	108.38	1,040.71	963.91	**-**
	Total Passenger Miles Traveled	207,761,412	4,387,888	329,661	1,710,635	17,671,965	2,087,013	32,668,803	8,199,995	**274,817,371**
	Energy Consumption (Btu/day)	1,105,574,828,010	27,318,990,514	8,656,903,634	44,921,275,021	12,306,039,300	194,485,600	2,266,430,200	839,640,900	**1,202,078,593,179**
	Energy Consumption per PMT (Btu/PMT)	5,321	6,226	26,260	26,260	696.4	93.19	69.38	102.4	**4,374**
Alternative 2	Total Bay Area VMT	177,618,525	4,387,888	329,661	1,710,635	333,497	19,256	31,391	8,507	**184,439,360**
	Load Factor (persons/vehicle)	1.17	1.00	1.00	1.00	55.79	110.39	1,052.92	971.36	**-**
	Total Passenger Miles Traveled	207,813,675	4,387,888	329,661	1,710,635	18,604,195	2,125,606	33,052,084	8,263,327	**276,287,071**
	Energy Consumption (Btu/day)	1,105,852,937,991	27,318,990,514	8,656,903,634	44,921,275,021	12,306,039,300	194,485,600	2,266,430,200	839,640,900	**1,202,356,703,160**
	Energy Consumption per PMT (Btu/PMT)	5,321	6,226	26,260	26,260	661.5	91.50	68.57	101.6	**4,352**
Alternative 3	Total Bay Area VMT	177,811,385	4,387,888	329,661	1,710,635	329,050	19,256	31,391	8,507	**184,627,773**
	Load Factor (persons/vehicle)	1.17	1.00	1.00	1.00	57.52	110.57	1,061.23	980.67	**-**
	Total Passenger Miles Traveled	208,039,320	4,387,888	329,661	1,710,635	18,927,393	2,129,149	33,312,983	8,342,568	**277,179,596**
	Energy Consumption (Btu/day)	1,107,053,680,158	27,318,990,514	8,656,903,634	44,921,275,021	12,141,938,217	194,485,600	2,266,430,200	839,640,900	**1,203,393,344,245**
	Energy Consumption per PMT (Btu/PMT)	5,321	6,226	26,260	26,260	641.5	91.34	68.03	100.6	**4,342**
Alternative 4	Total Bay Area VMT	177,851,516	4,387,888	329,661	1,710,635	323,225	19,256	31,391	8,507	**184,662,079**
	Load Factor (persons/vehicle)	1.17	1.00	1.00	1.00	58.70	110.75	1,061.52	952.07	**-**
	Total Passenger Miles Traveled	208,086,273	4,387,888	329,661	1,710,635	18,974,168	2,132,620	33,322,155	8,099,280	**277,042,681**
	Energy Consumption (Btu/day)	1,107,303,536,626	27,318,990,514	8,656,903,634	44,921,275,021	11,927,002,500	194,485,600	2,266,430,200	839,640,900	**1,203,428,264,995**
	Energy Consumption per PMT (Btu/PMT)	5,321	6,226	26,260	26,260	628.6	91.20	68.02	103.7	**4,344**

Source: JJMA 2002; Outwater 2002; Hutchison 2002

Table ENRG-B-2
Ferry Energy Consumption for Alternative 1

Peak Hours (including Deadhead hours)	400-Passenger Ferry	Transit Hours at Service Speed (hr/day)	203
		Power Rating at Service Speed (kW)	2,605
		Energy used at Service Speed (kWh/day)	530,045
		Transit Hours at Slow Speed (hr/day)	64
		Power Rating at Slow Speed (kW)	206
		Energy used at Slow Speed (kWh/day)	13,236
		Idling Hours (hr/day)	63
		Power Rating at Idle (kW)	165
		Energy used at Idle (kWh/day)	10,375
		Total Energy Used (kWh/day)	553,657
	149-Passenger Ferry	Transit Hours at Service Speed (hr/day)	293
		Power Rating at Service Speed (kW)	1,128
		Energy used at Service Speed (kWh/day)	330,299
		Transit Hours at Slow Speed (hr/day)	92
		Power Rating at Slow Speed (kW)	89
		Energy used at Slow Speed (kWh/day)	8,232
		Idling Hours (hr/day)	105
		Power Rating at Idle (kW)	71
		Energy used at Idle (kWh/day)	7,487
		Total Energy Used (kWh/day)	346,018
	Peak Hours Total		**899,675**
Off-Peak Hours	400-Passenger Ferry	Transit Hours at Service Speed (hr/day)	253
		Power Rating at Service Speed (kW)	2,605
		Energy used at Service Speed (kWh/day)	660,046
		Transit Hours at Slow Speed (hr/day)	80
		Power Rating at Slow Speed (kW)	206
		Energy used at Slow Speed (kWh/day)	16,483
		Idling Hours (hr/day)	86
		Power Rating at Idle (kW)	165
		Energy used at Idle (kWh/day)	14,152
		Total Energy Used (kWh/day)	690,680
	149-Passenger Ferry	Transit Hours at Service Speed (hr/day)	427
		Power Rating at Service Speed (kW)	1,128
		Energy used at Service Speed (kWh/day)	481,732
		Transit Hours at Slow Speed (hr/day)	135
		Power Rating at Slow Speed (kW)	89
		Energy used at Slow Speed (kWh/day)	12,006
		Idling Hours (hr/day)	160
		Power Rating at Idle (kW)	165
		Energy used at Idle (kWh/day)	26,428
		Total Energy Used (kWh/day)	520,166
	Off-Peak Hours Total		**1,210,846**
Total Daily Energy Usage (kW-hr/day)			**2,110,521**
Total Daily Energy Usage (Btu/day)			**7,203,209,218**

Source: JJMA 2002; Hutchison 2002

Table ENRG-B-3
PMT Values for Ferries

	Alternative 1	Alternative 2	Alternative 3	Alternative 4
VMT per Day	57,530	29,373	11,436	1,566
Passengers per Run Factor	17.1	21.5	37.6	151
Total Patronage per Day	49,210	46,295	25,385	23,238
PMT per Day	984,023	630,431	430,074	236,461

Source: Outwater 2002