



*U.S. Section  
PIANC  
October 2003  
Portland, OR*



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*Deep-Draft Vessels in Narrow Waterways*

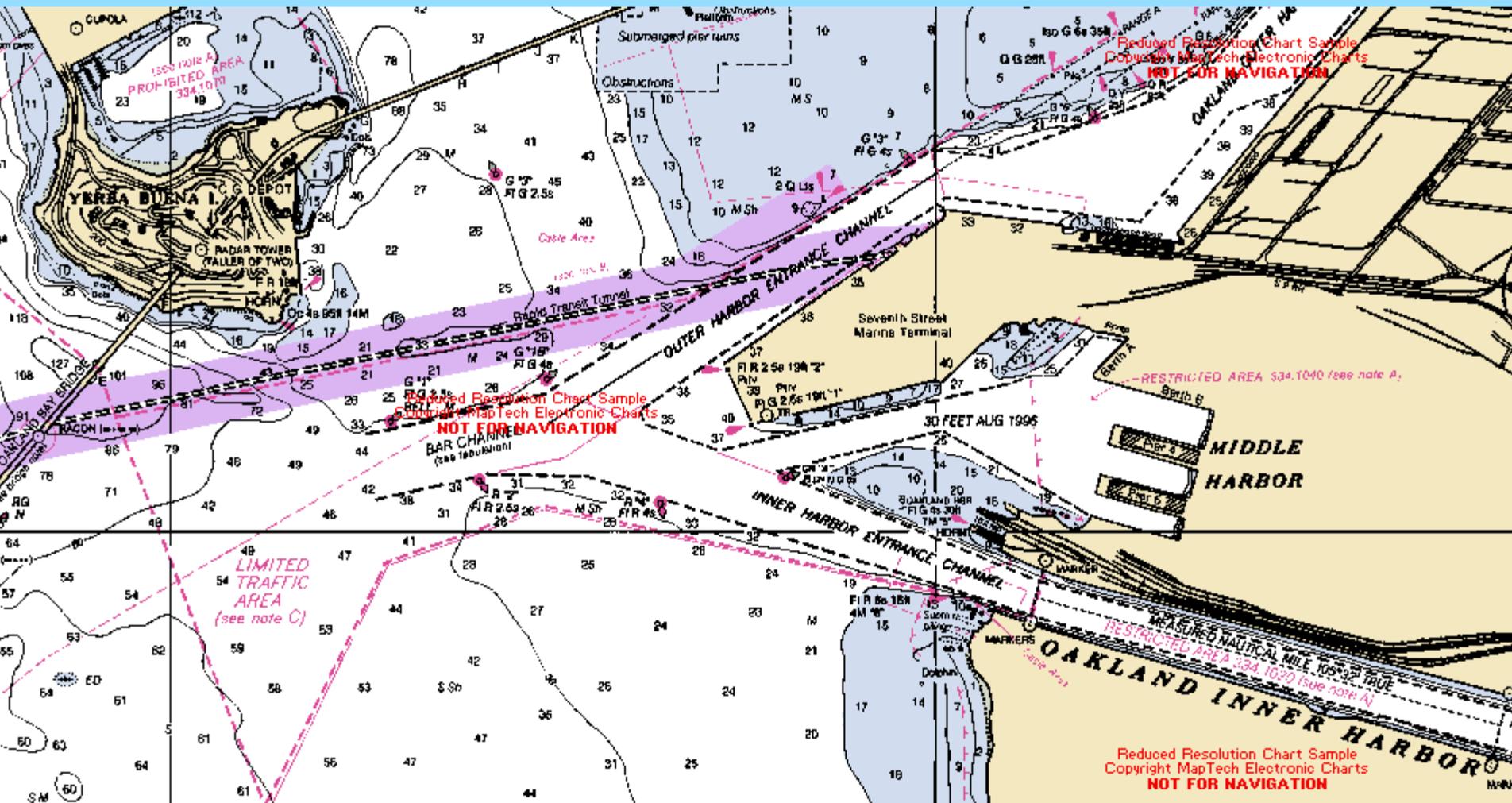
*PORT OF OAKLAND 50-FOOT DEEPENING PROJECT STUDY*

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**J. Serventi, Port of Oakland**

**R. Andrews Han-Padron Associates Engineers**

# Port of Oakland Waterways



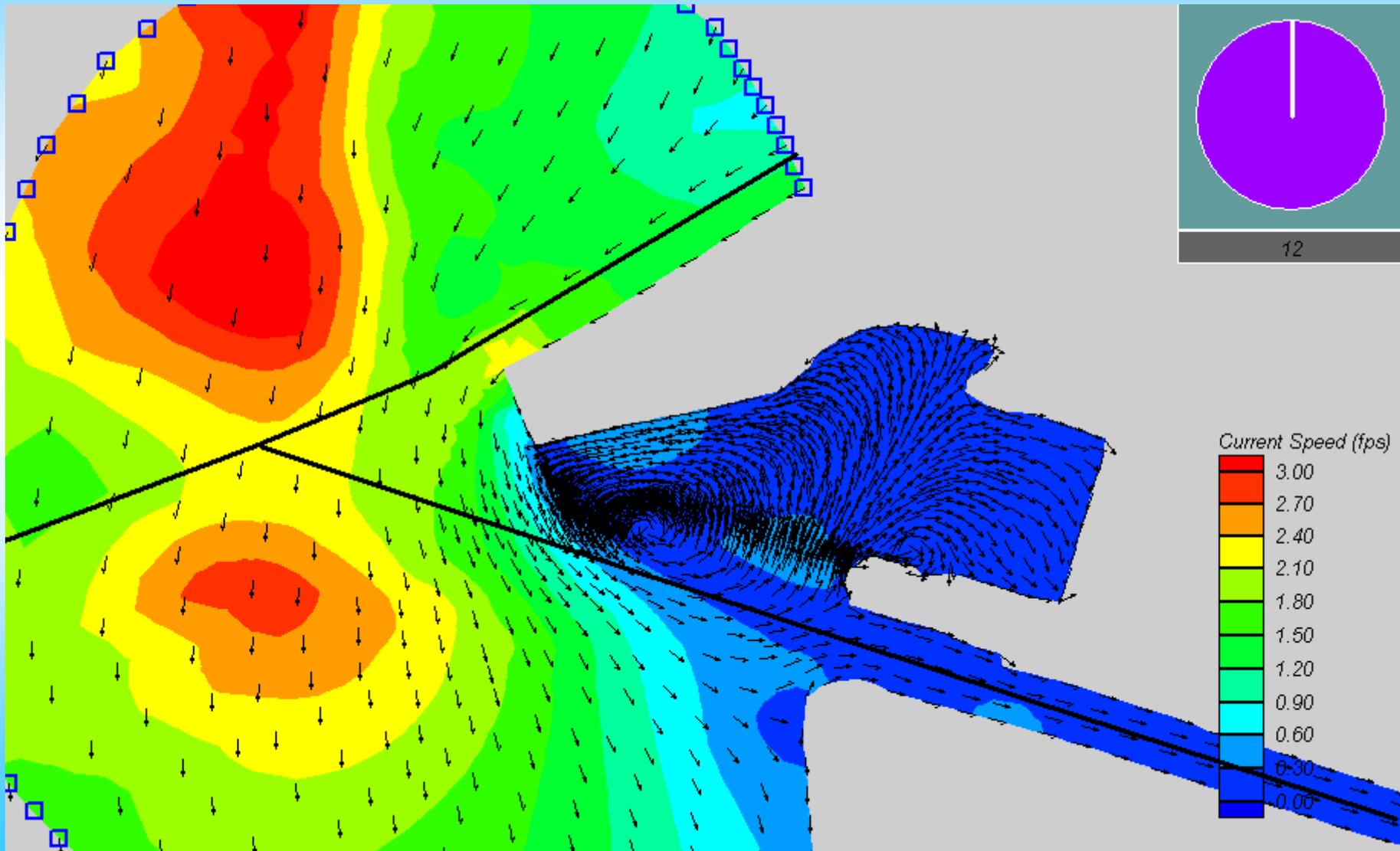


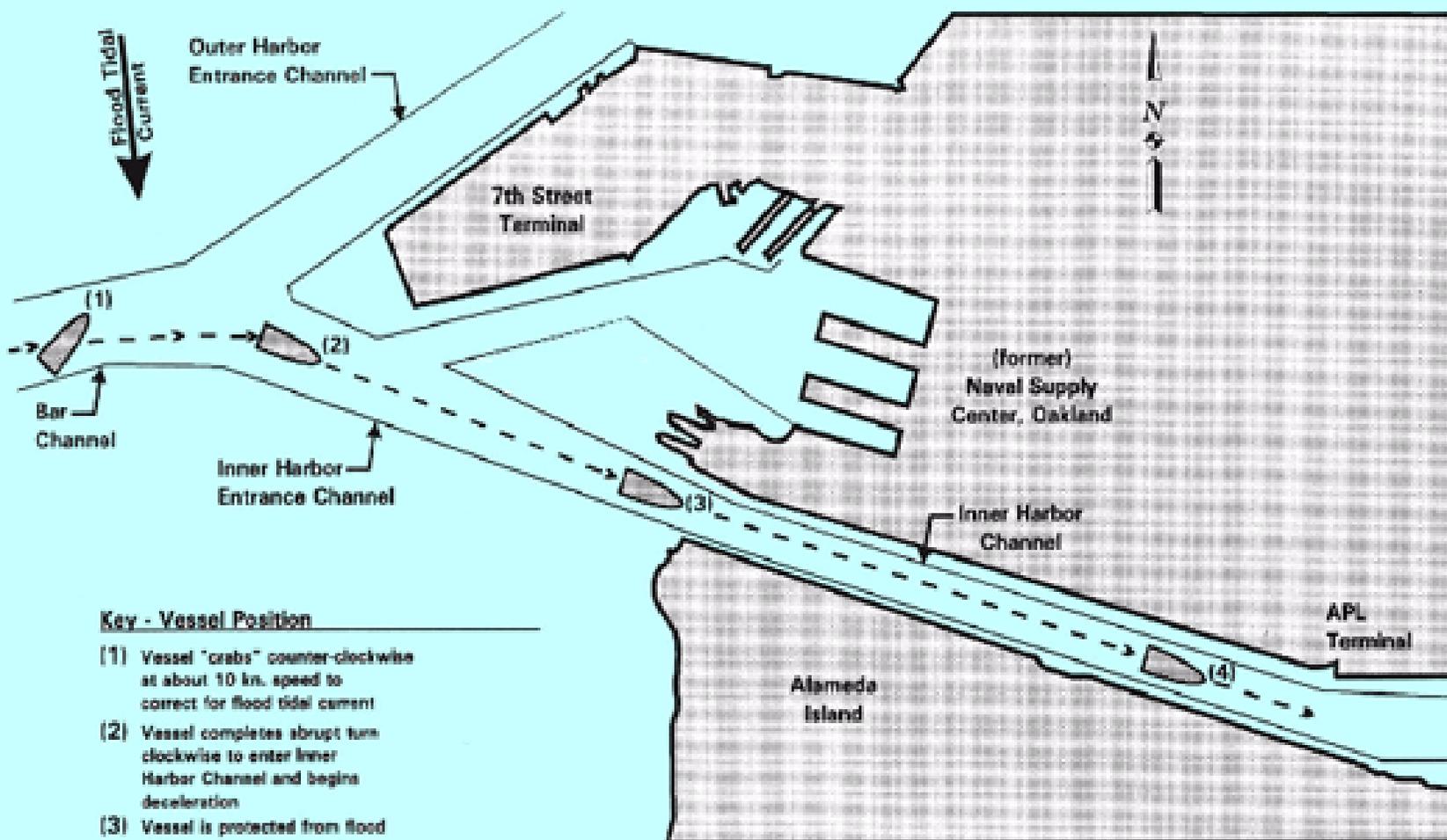
Outer Harbor Waterway

Inner Harbor Waterway



# Port of Oakland Tidal Current Simulations

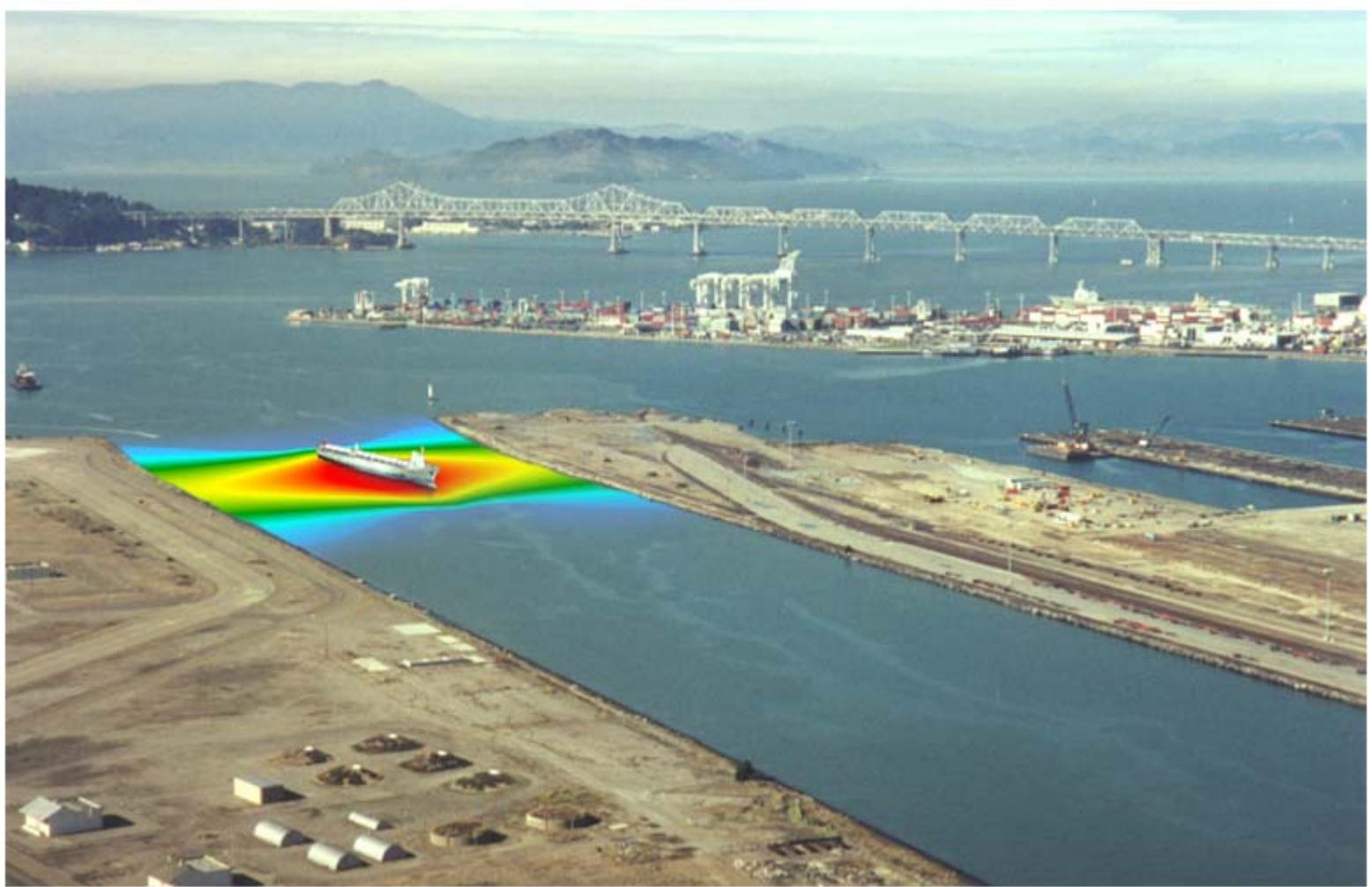




#### Key - Vessel Position

- (1) Vessel "crabs" counter-clockwise at about 10 kn. speed to correct for flood tidal current
- (2) Vessel completes abrupt turn clockwise to enter Inner Harbor Channel and begins deceleration
- (3) Vessel is protected from flood tide current and approaches Inner Harbor Channel at about 8 kn. speed
- (4) Vessel approaches APL Terminal at about 8 kn. speed

# Pressure Field Effect



# Pressure Field Effect



## Outer Harbor Vessel-Vessel Interaction





## Port of Oakland Vessel Hydrodynamic Study Objectives

- Determine Inner Harbor Waterway dimensions (depth and width) for Maersk S class vessels
- Develop engineering solution to reduce pressure field impacts at Outer Harbor Berths 35-37
- Design recommendations

# Design Parameters/Criteria

## Existing (pre-project) Inner Harbor Channel

- Width = 600 ft
- Depth = 42 ft

## New channel

- Width = ?
- Depth = 50?

## Passing Vessel Maersk –S

- Beam = 180 ft
- Draft = 48
- Length = 1143 ft

## Berthed vessel MSCXingang

- Beam = 25 ft
- Draft = 36 ff
- Length = 720 ft



## Methodology/Approach

- Develop (identify) engineering tools (models)
  - Pressure field model (VGPF, SGH)
  - Berthed vessel response model (Multi-Operational Structural Engineering Simulator)
- Validate engineering tools with field data
- Conduct analysis, solutions, develop recommendations, and design

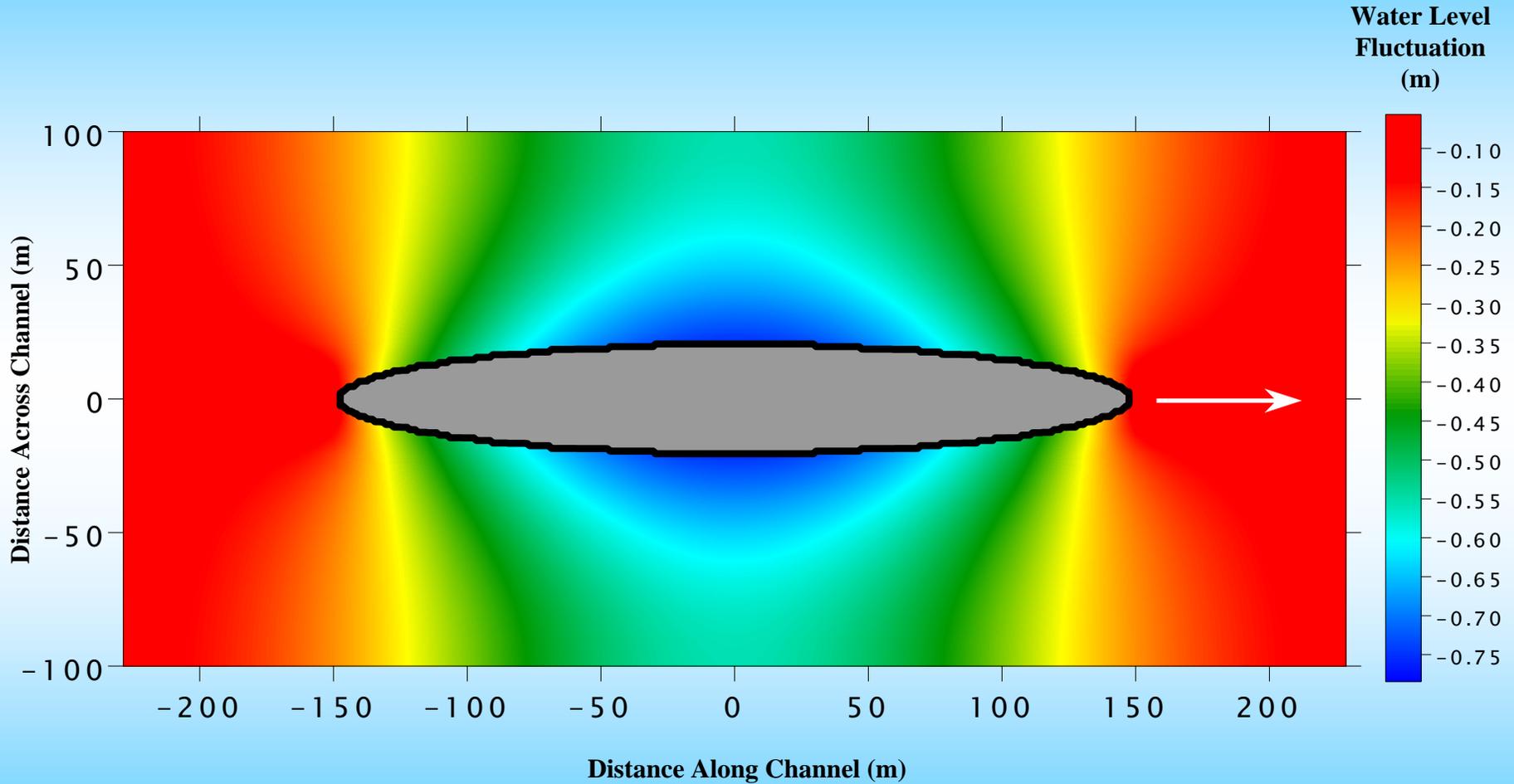
# Passing Vessel Impacts on Berthed Vessels

## Modeling Approach

- Pressure Field Models - Predict water surface elevation distribution in the channel and vessel-generated pressure field
  - VGPF Model: analytical, steady-state model for use in straight, confined channels
  - Ship-Generated Hydrodynamics (SGH) Model: time-domain model for complex waterways, vessel hull shapes and time-dependent situations
- Berthed Vessel Impacts Model- Predict impact of passing vessels on berthed vessels and mooring systems
  - Multi-Operational Structural Engineering Simulator (MOSES): structural model that predicts berthed vessel motion in 6 degrees of freedom, loads in mooring lines, loads and compression in fenders

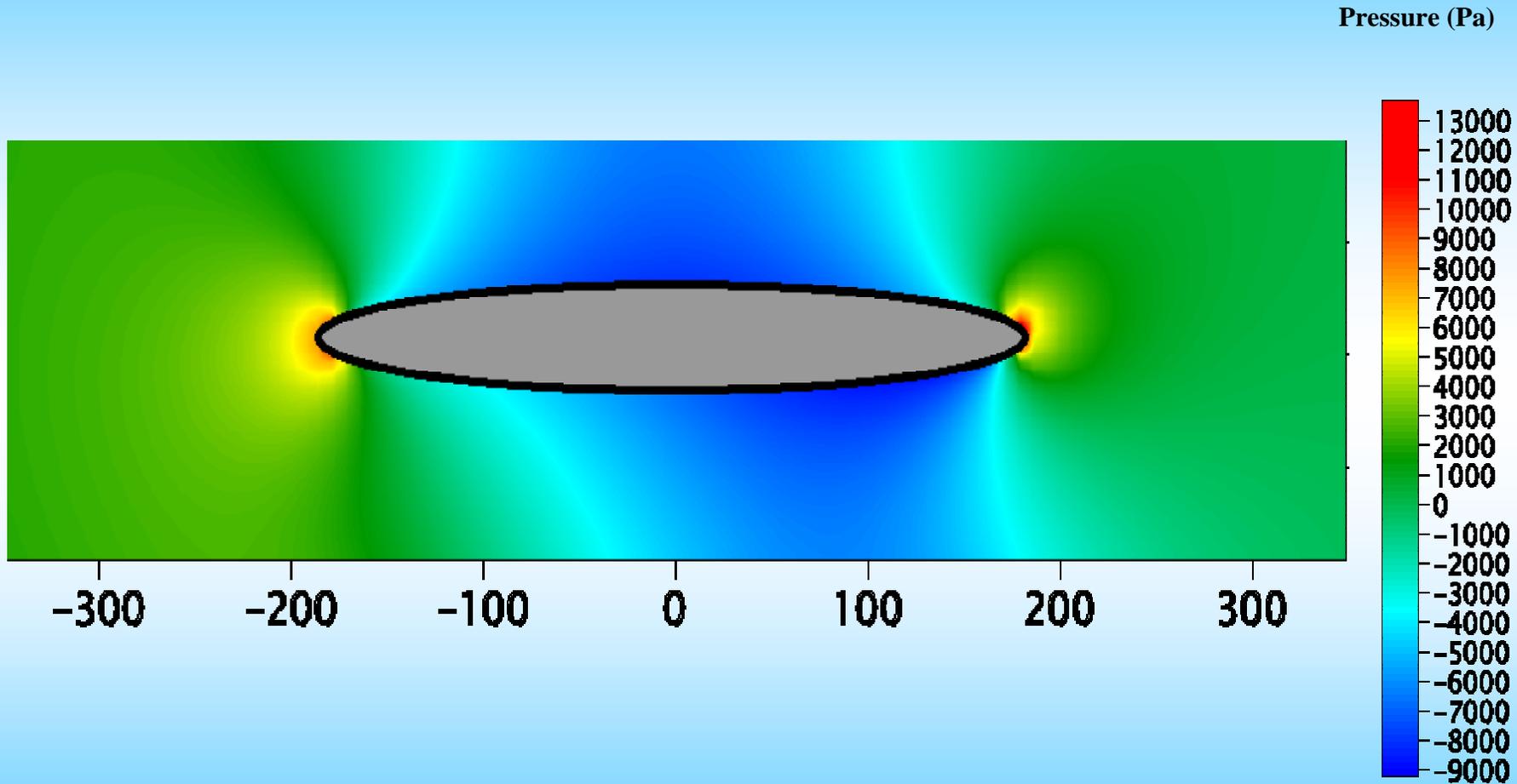
# Inner Harbor Pressure Field Modeling

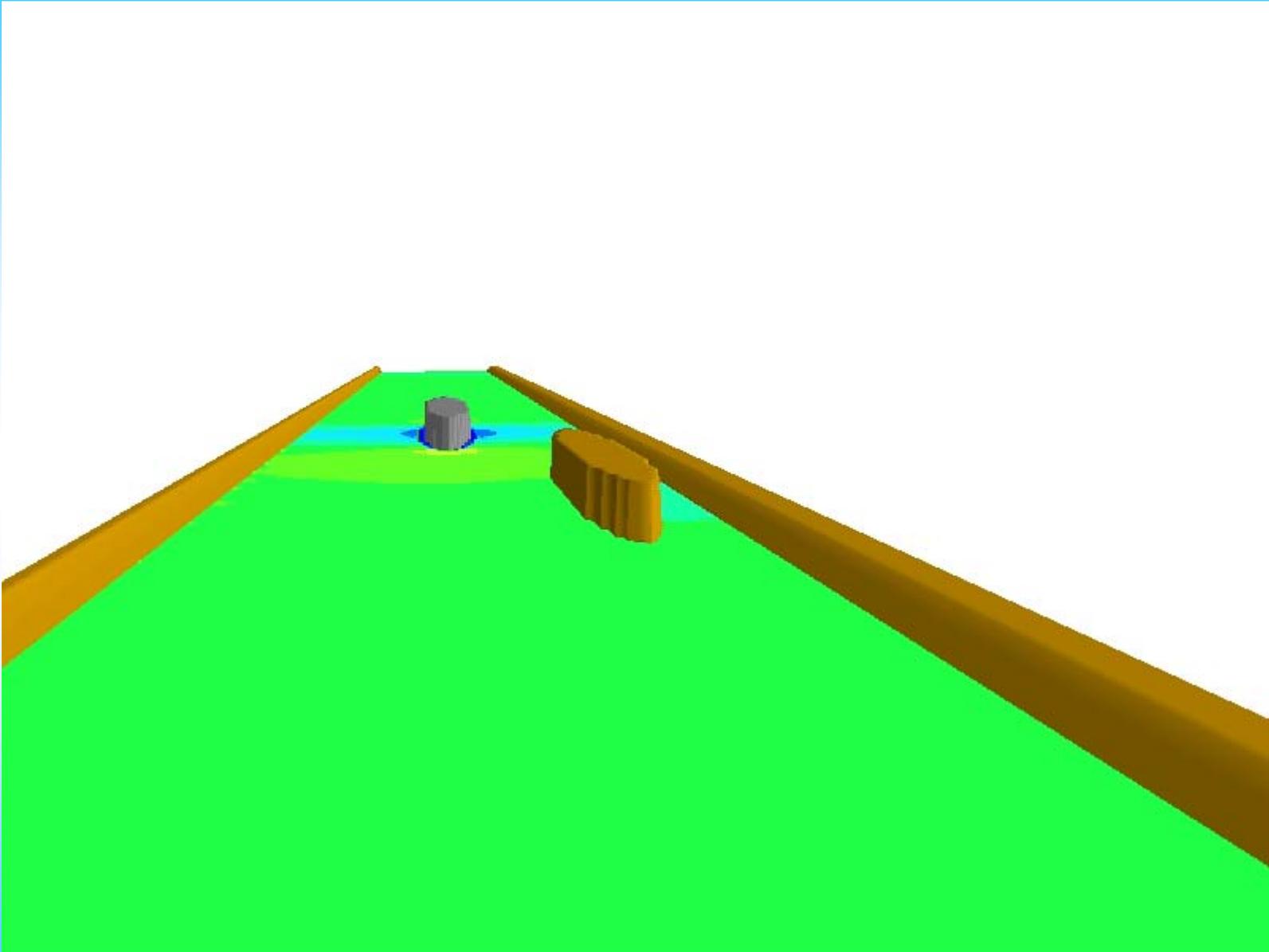
## Typical Results



# Outer Harbor Pressure Field Modeling

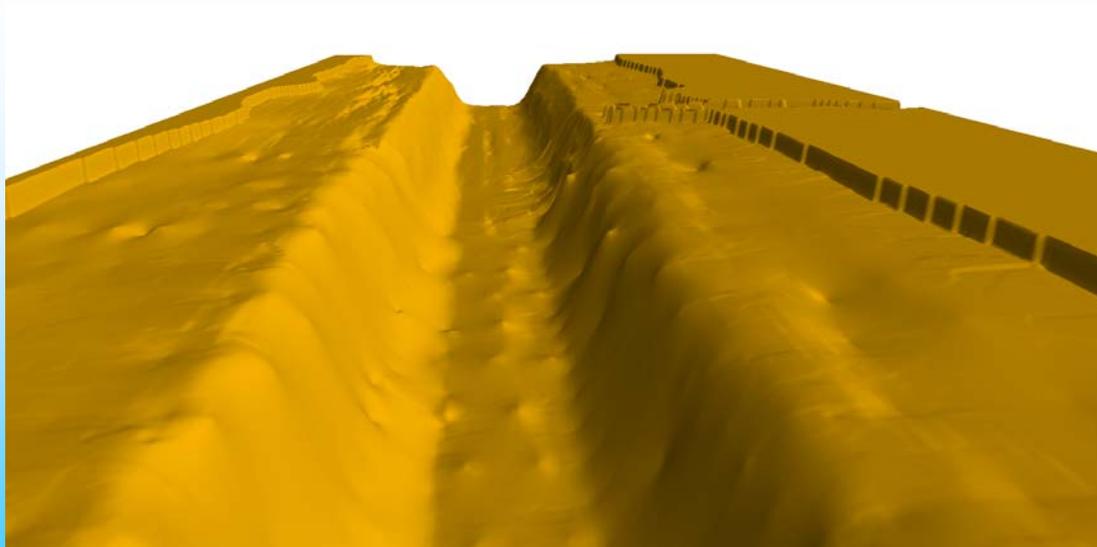
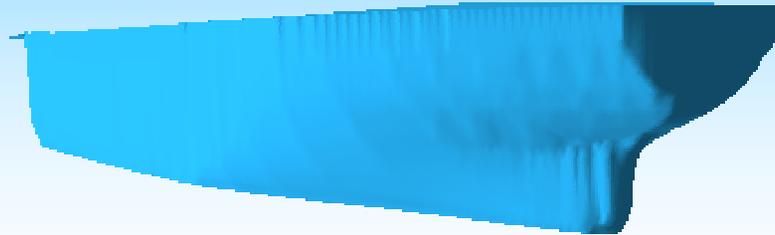
## Example of Typical Modeling Results



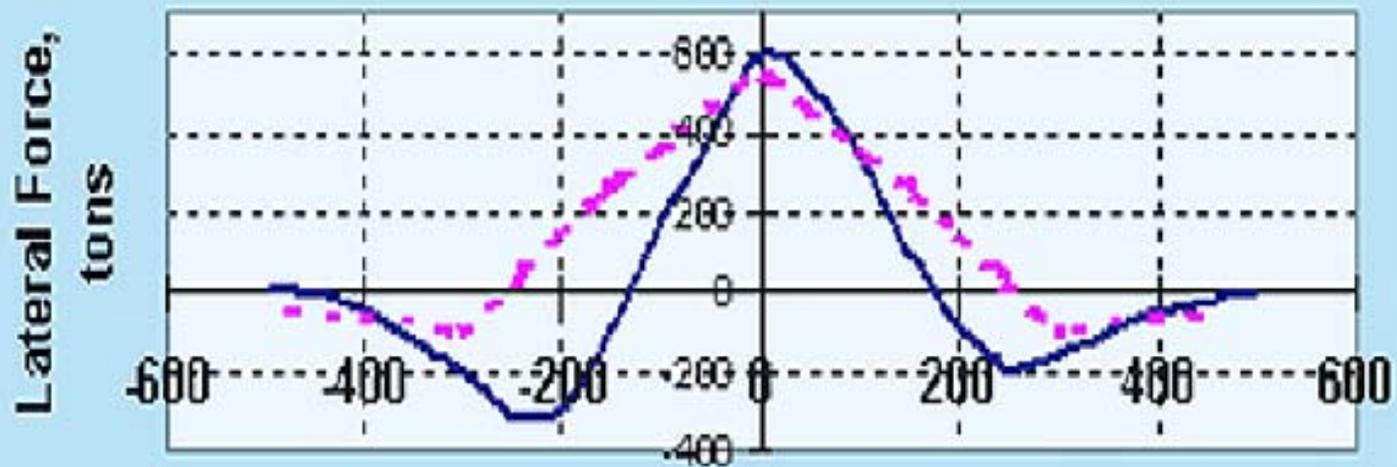


# Ship-Generated Hydrodynamics (SGH) Model Input Information

- Bathymetry
- Vessel hull shape
- Vessel sailing line, speed
- Bottom roughness map
- Ambient current field (steady or dynamic)



## Port of Oakland Inner Waterway Pressure Field Model (VGPF) Verification



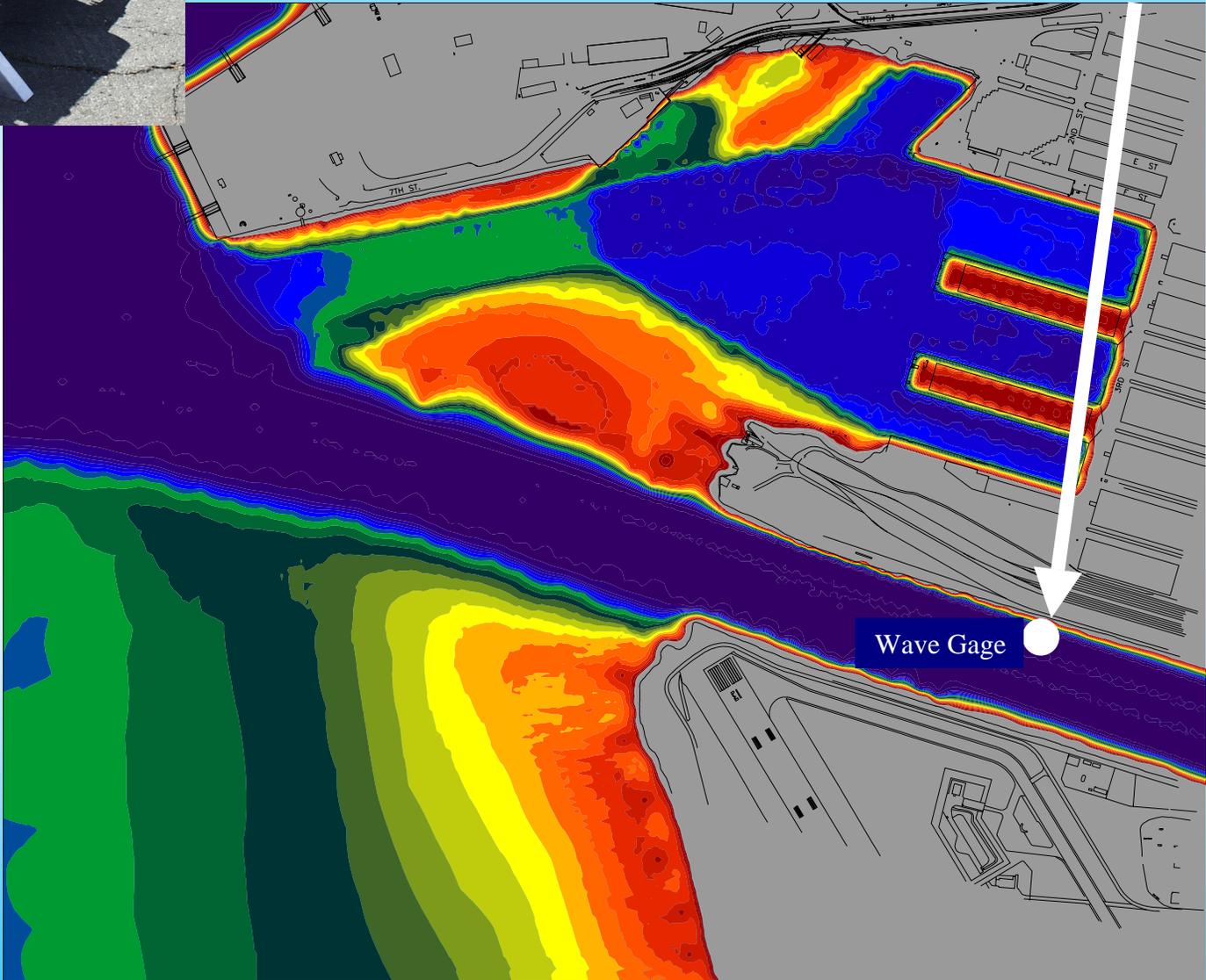
Distance Between Vessels Centerline, meters

— Physical Model, Remery    - - - Computer Model, VGFP

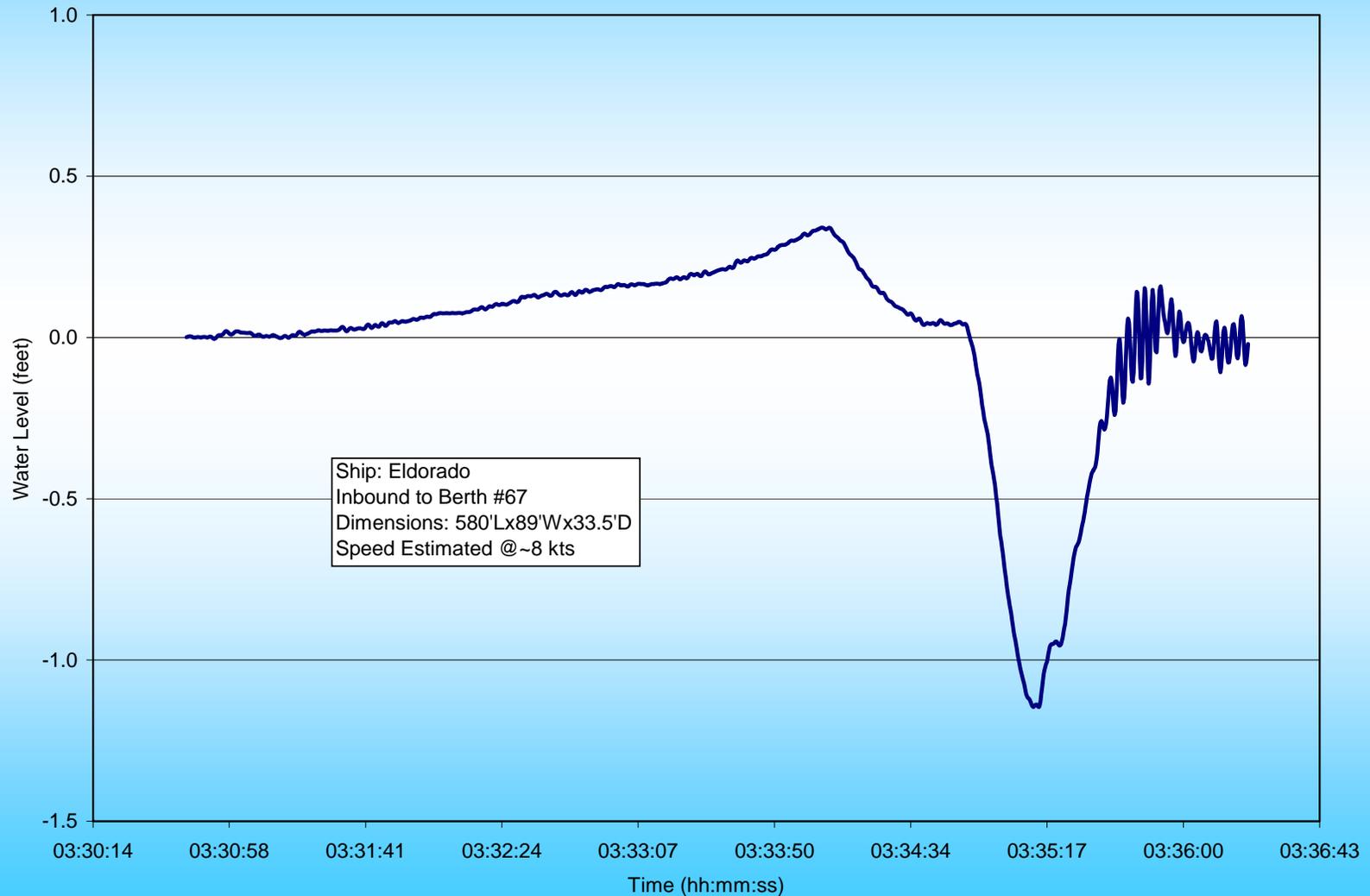
# Field Data Collection



*Station Location*



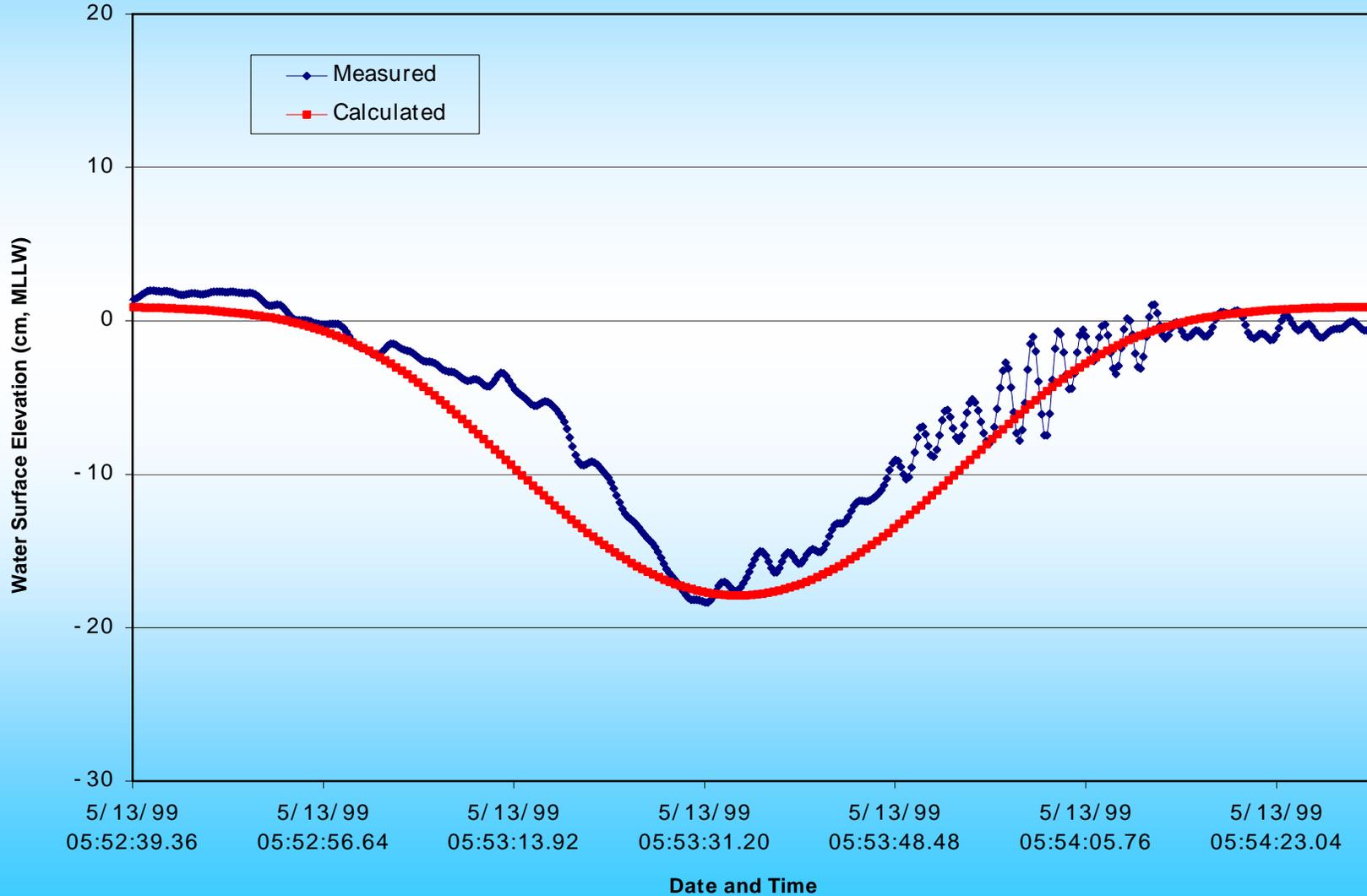
## *Pressure Field Effect Measured May 12, 1999*



# Pressure Field Modeling Verification

## Water Surface Elevation Time Series Comparison

Pressure Field Model Verification  
MSC Xingang Inbound at 7.6 knots  
05/13/99 05:53



# Pressure Field Modeling Verification

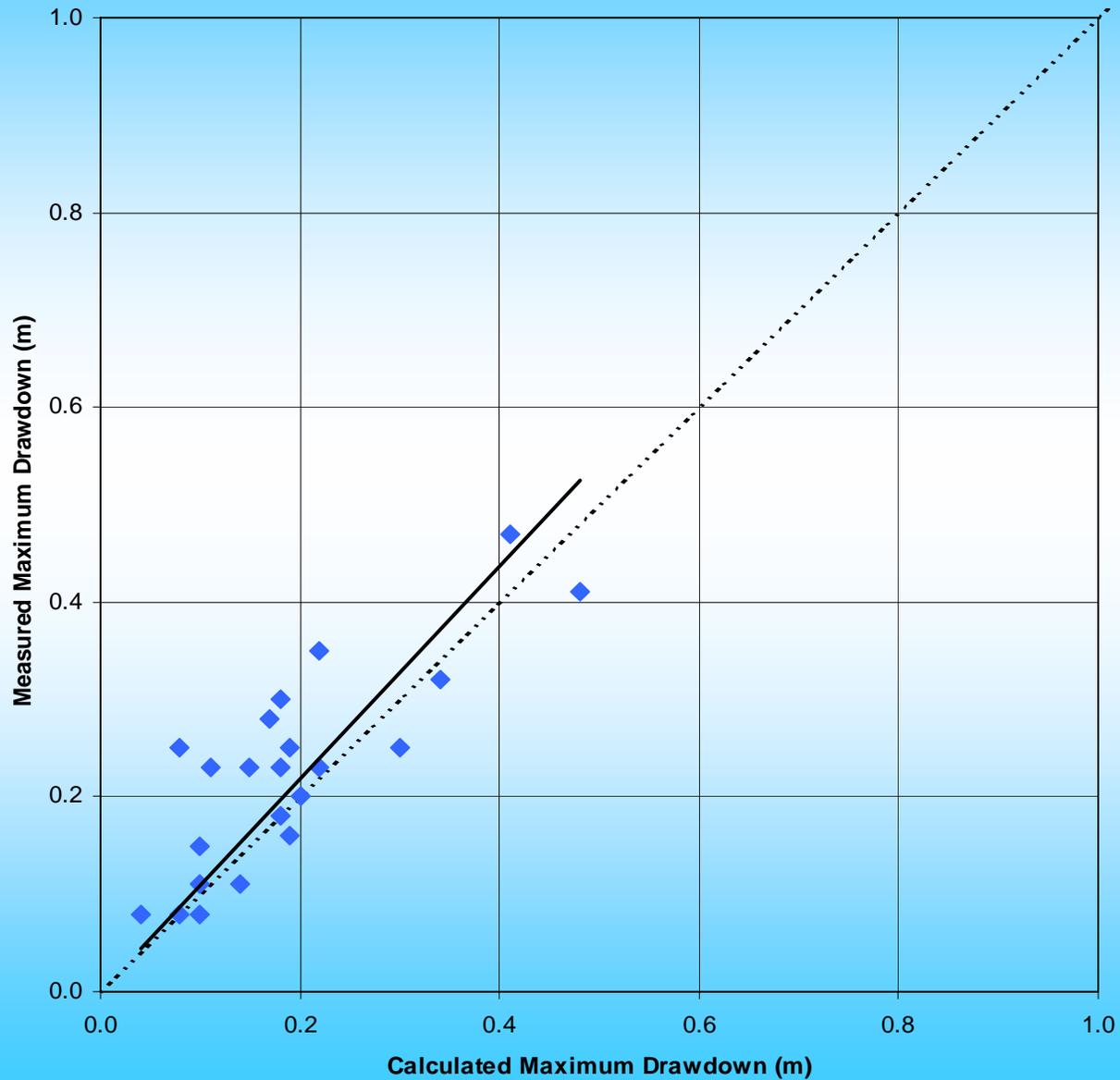
## Maximum Drawdown Comparison

**Port of Oakland Inner Harbor Waterway Pressure Field Model Verification**

<b>Measurement Date &amp; Time</b>	<b>Inbound Vessel</b>	<b>Length (m)</b>	<b>Draft (m)</b>	<b>Speed (kts)</b>	<b>Distance from Channel Edge (m)</b>	<b>Calculated Drawdown (cm)</b>	<b>Measured Drawdown (cm)</b>
5/3/99 5:30	Dong He	236	8.7	9.9	23.4	41	47
5/3/99 13:30	Polynesia	262	6.4	7.9	57.7	8	25
5/3/99 20:20	APL Spinel	294	9.8	6.9	38.7	19	25
5/9/99 15:45	Tai He	236	8.5	8.3	52.5	20	20
5/10/99 13:10	APL Tourquoise	294	11.0	5.6	69.6	10	15
5/11/99 5:40	Direct Condor	164	8.6	7.5	72.8	10	8
5/12/99 3:35	El Dorado	176	10.2	8.6	51.7	22	35
5/12/99 15:40	Fanal Trader	128	7.2	13.7	60.4	25	75
5/12/99 16:40	Star Herdla	198	7.3	9.1	62.7	17	28
5/13/99 5:55	MSC Xingang	242	8.0	7.6	65.4	18	18
5/13/99 16:35	Manoa	262	10.9	9.8	80.1	30	25
5/17/99 10:00	Vaimama	159	6.4	7.6	56.6	8	8
5/17/99 13:40	APL Sardonyx	294	10.4	6.9	22.9	22	23
5/19/99 14:55	President Jackson	275	9.4	9.0	43.4	34	32
5/26/99 0:50	President Kennedy	275	9.2	6.9	62.2	18	23
5/29/99 5:45	Star Herdla	198	10.4	10.5	40.4	48	41
6/1/99 22:00	President Adams	275	8.5	6.7	31.5	19	16
6/3/99 5:00	President Grant	260	8.8	6.4	33.0	14	11
6/9/99 0:30	President Polk	275	9.1	5.8	40.7	15	23
6/9/99 21:00	Mokihana	262	9.4	5.6	40.5	10	11
6/13/99 5:30	Dong He	236	8.0	8.0	54.0	18	30
6/13/99 22:00	Direct Falcon	189	8.3	4.6	55.9	4	8
6/14/99 14:00	APL Spinel	294	10.4	5.9	59.7	11	23

# Pressure Field Modeling Verification

## Water Surface Elevations Comparison



# Pressure Field Hydrodynamic Impact Analysis

## 3-Step Procedure

- Step 1 - Simulate pressure field effects - The VGPF model calculates the long-period wave time series and water level distribution in the channel (water surface elevations)
- Step 2 - Simulate berthed vessel response to pressure field effect - The MOSES (Multi-Operational Structural Engineering Simulator) model calculates forces in fenders, bollards, and all mooring lines
- Step 3 - Compare forces in fenders, bollards, and mooring lines to industry standards and component load capacities

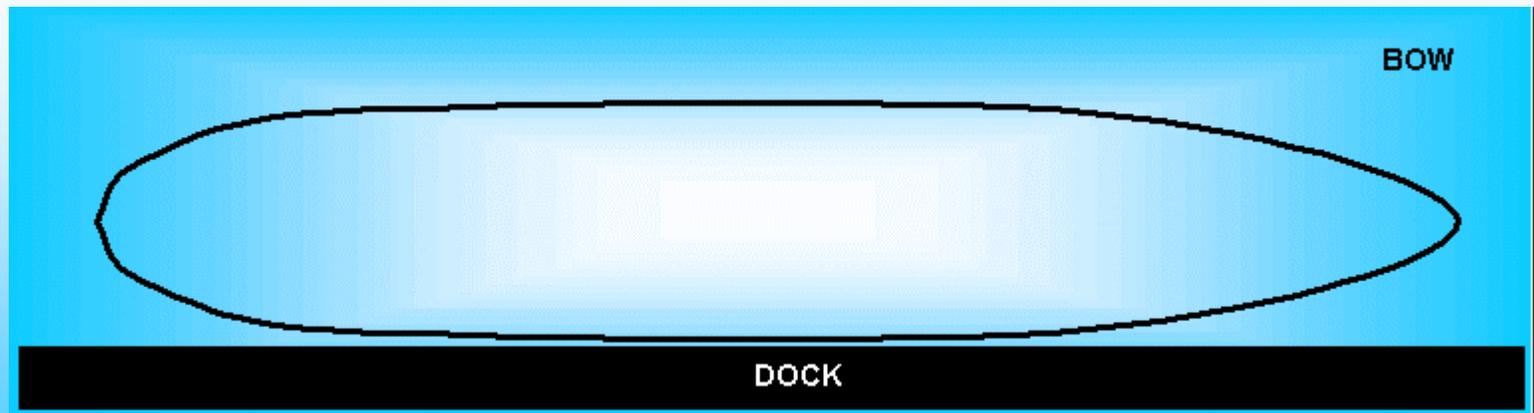
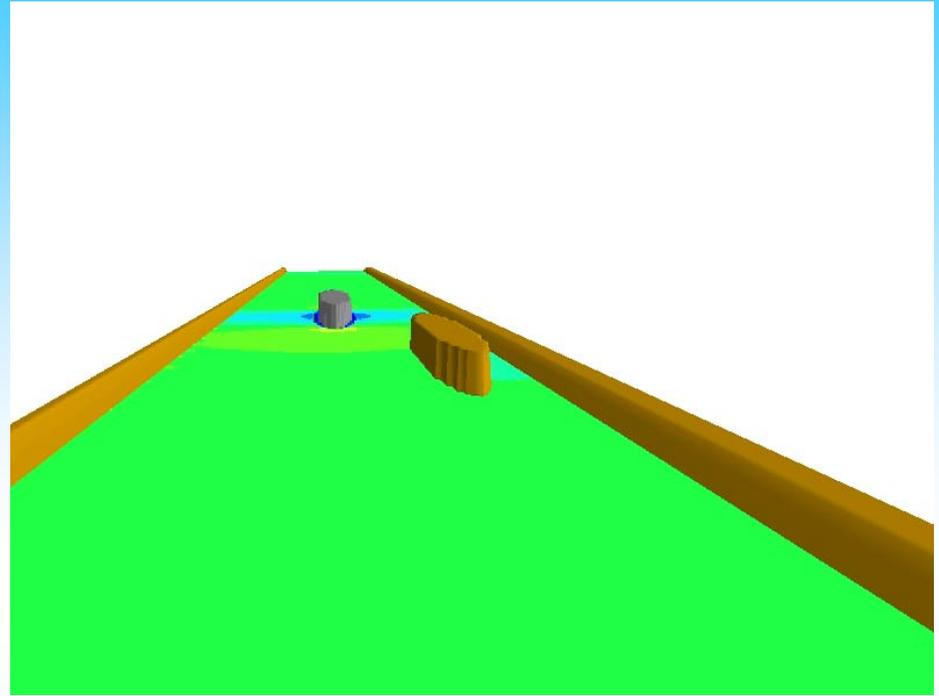
# MOSES Model Ship Response Simulations

Model of  
MSC Xingang

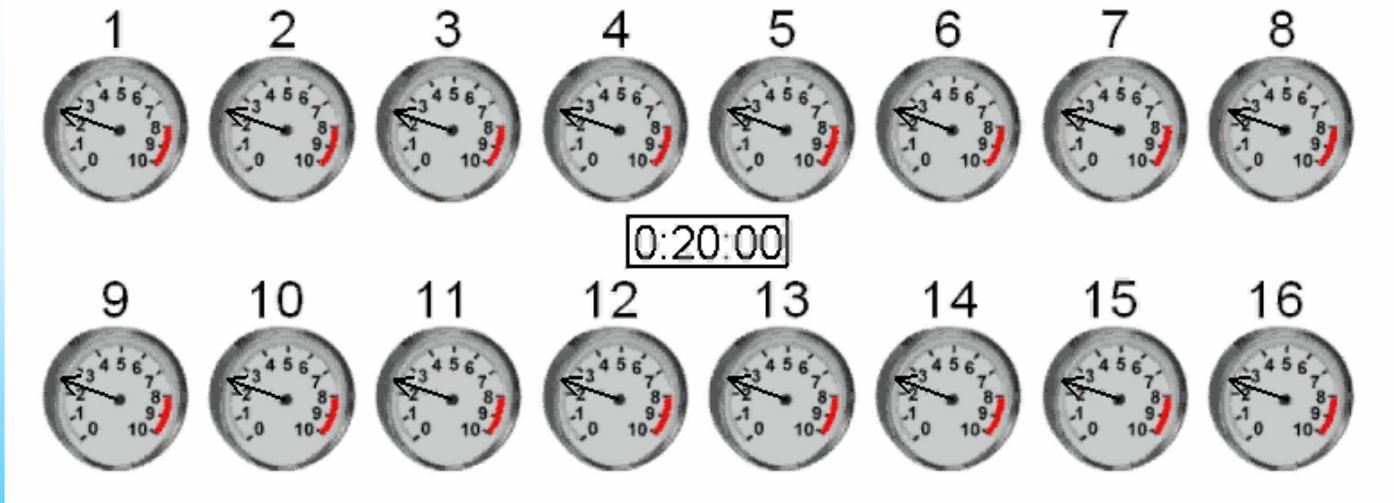


APL  
Tourmaline



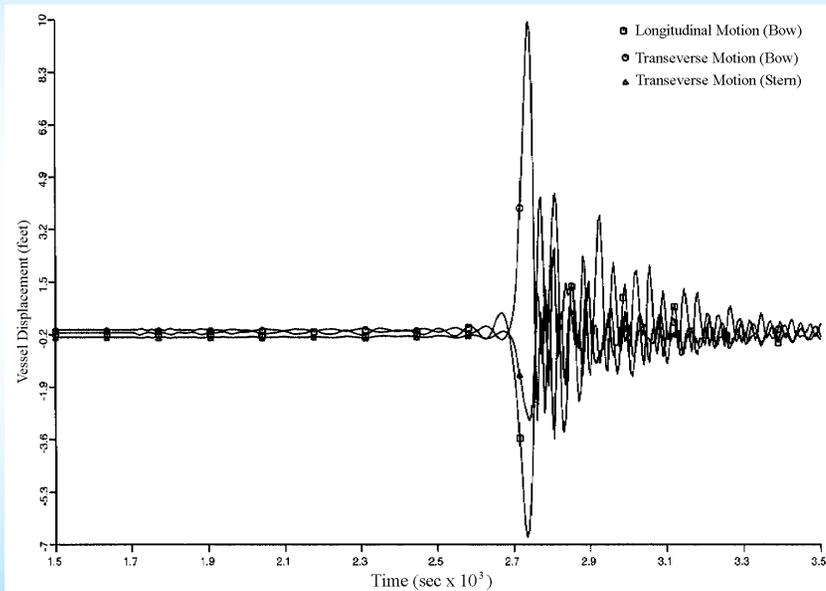


# Passing Vessel Impacts on Berthed Vessels Port of Oakland, CA

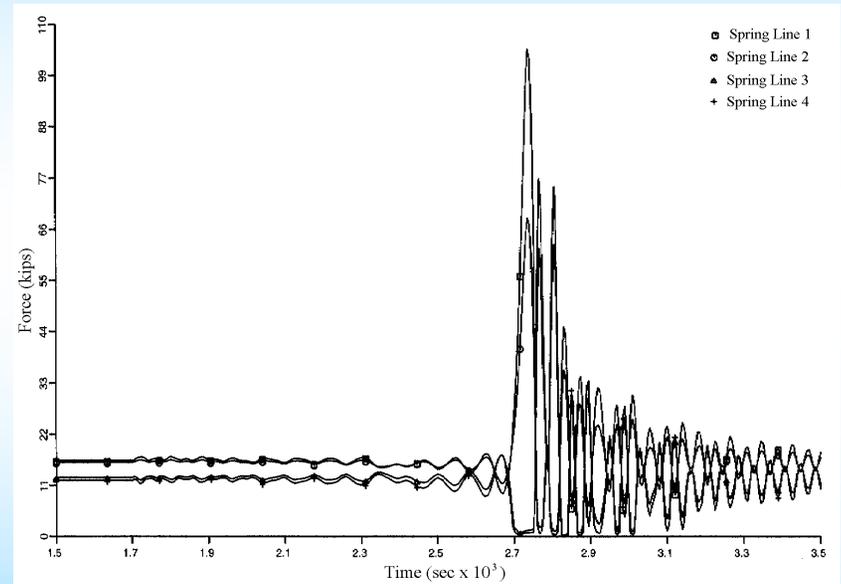


*Mooring Line Loads*

# Passing Vessel Impacts on Berthed Vessels Port of Oakland, CA



*Berthed Vessel Motion*



*Mooring Line Loads*

# MOSES Model Ship Response Simulations

## Forces in Mooring Lines

Diameter (inches)	High-Modulus Fiber	Nylon Double-Braid	Nylon Stranded & Plaited	Polyester	Polypropylene
1.0	N/A	26	22	20	13
1.5	143	57	48	42	26
2.0	262	103	84	73	46
2.5	389	161	125	110	73
3.0	546	231	180	156	103
3.5	719	337	268	227	123
4.0	961	409	323	268	172

(Forces in kips)

## Design Parameters/Criteria

### New channel

- Width = 750 ft
- Depth = 50 ft

### Passing Vessel Maersk –S

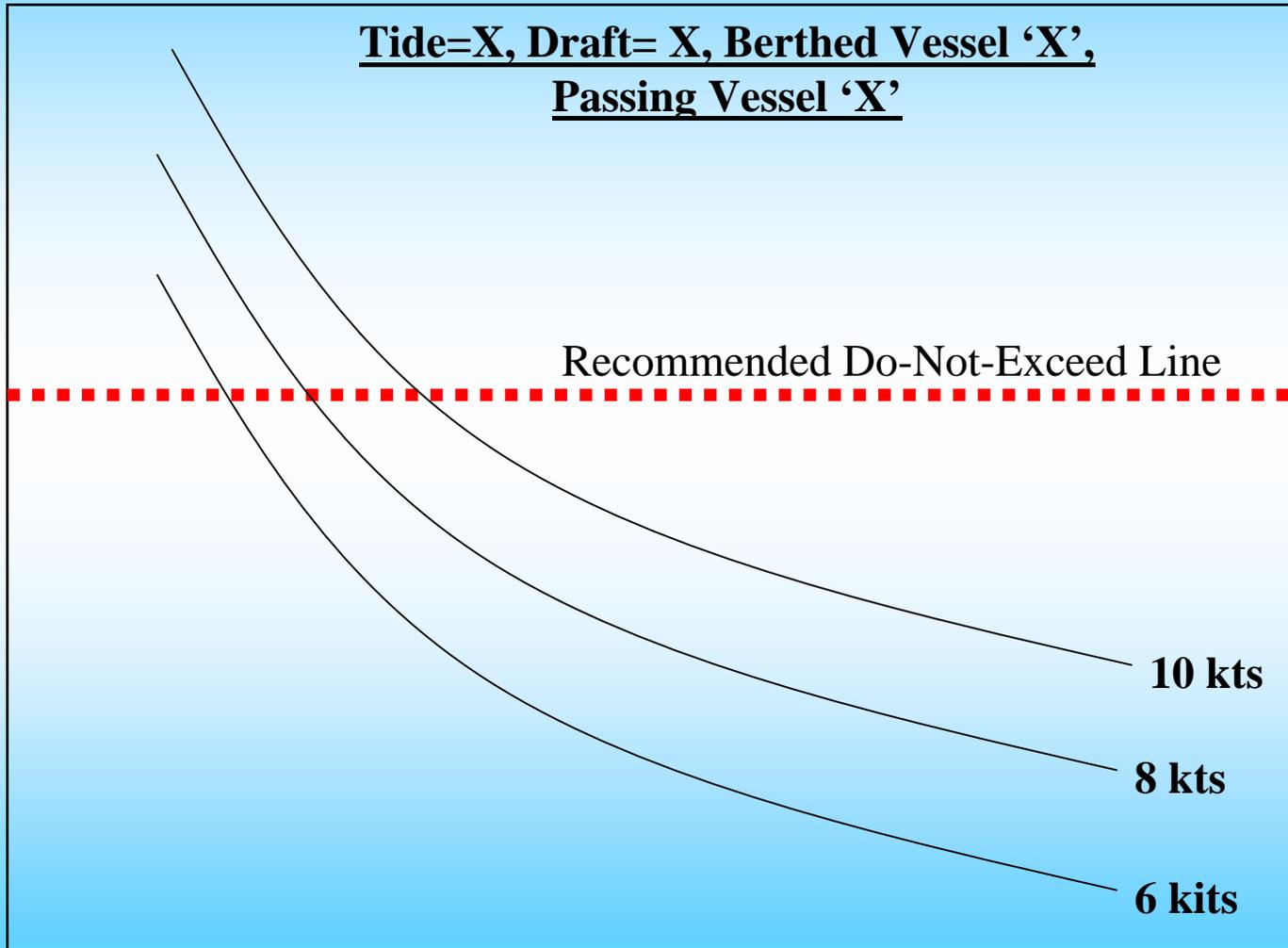
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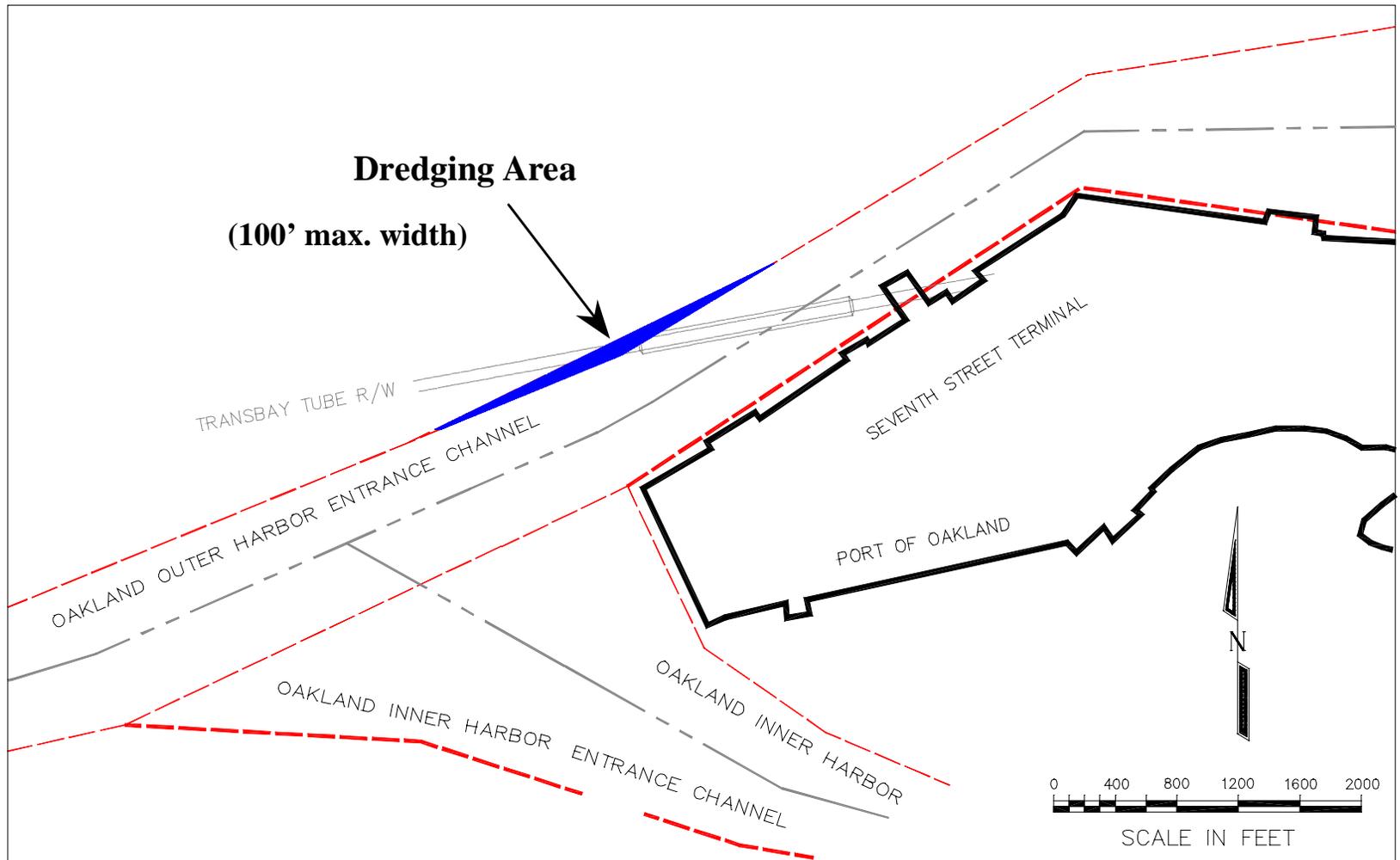


# Operational Guidance Conceptual Chart/Program



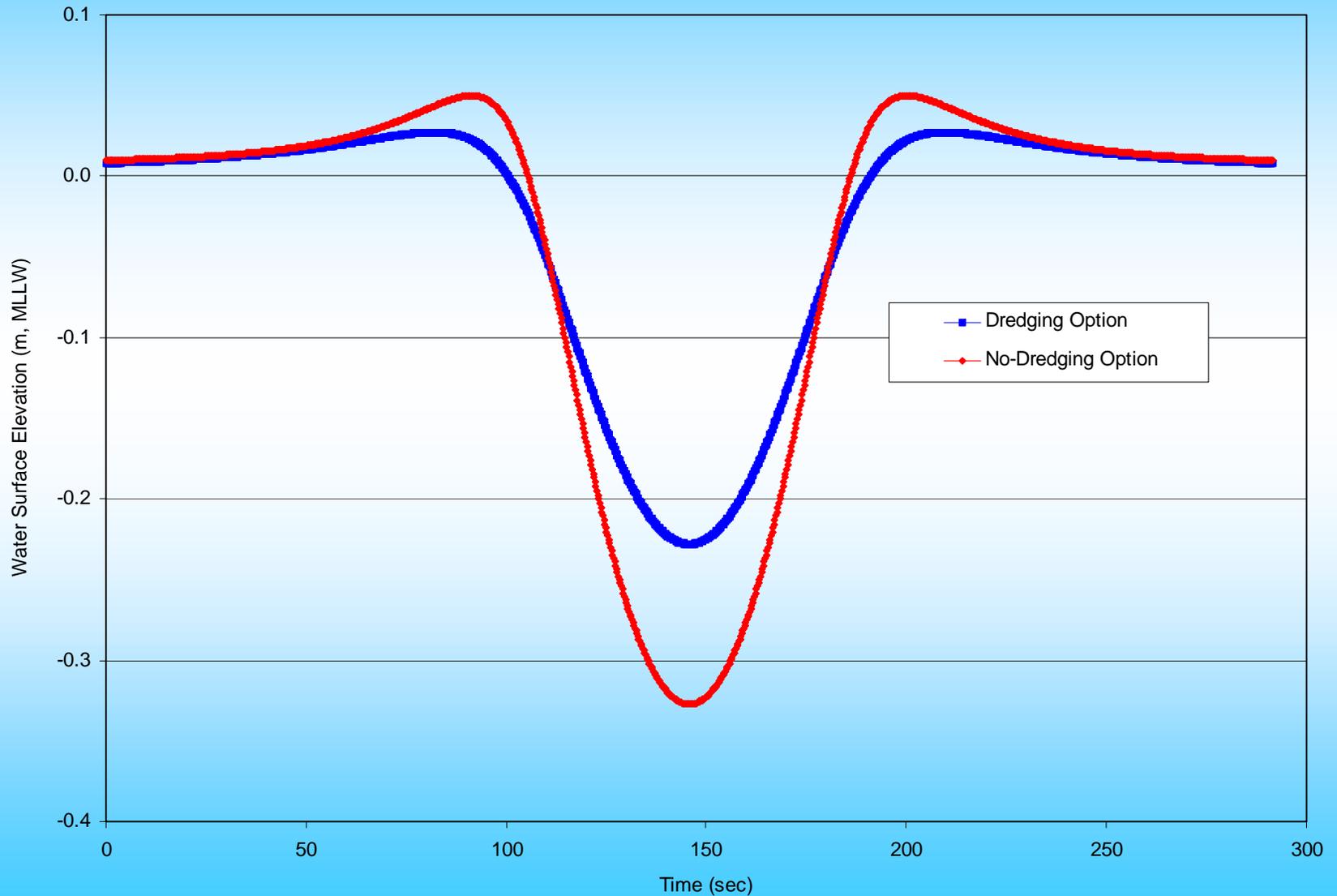
Passing Distance or Position in Channel

# Outer Harbor Pressure Field Modeling Dredging Option



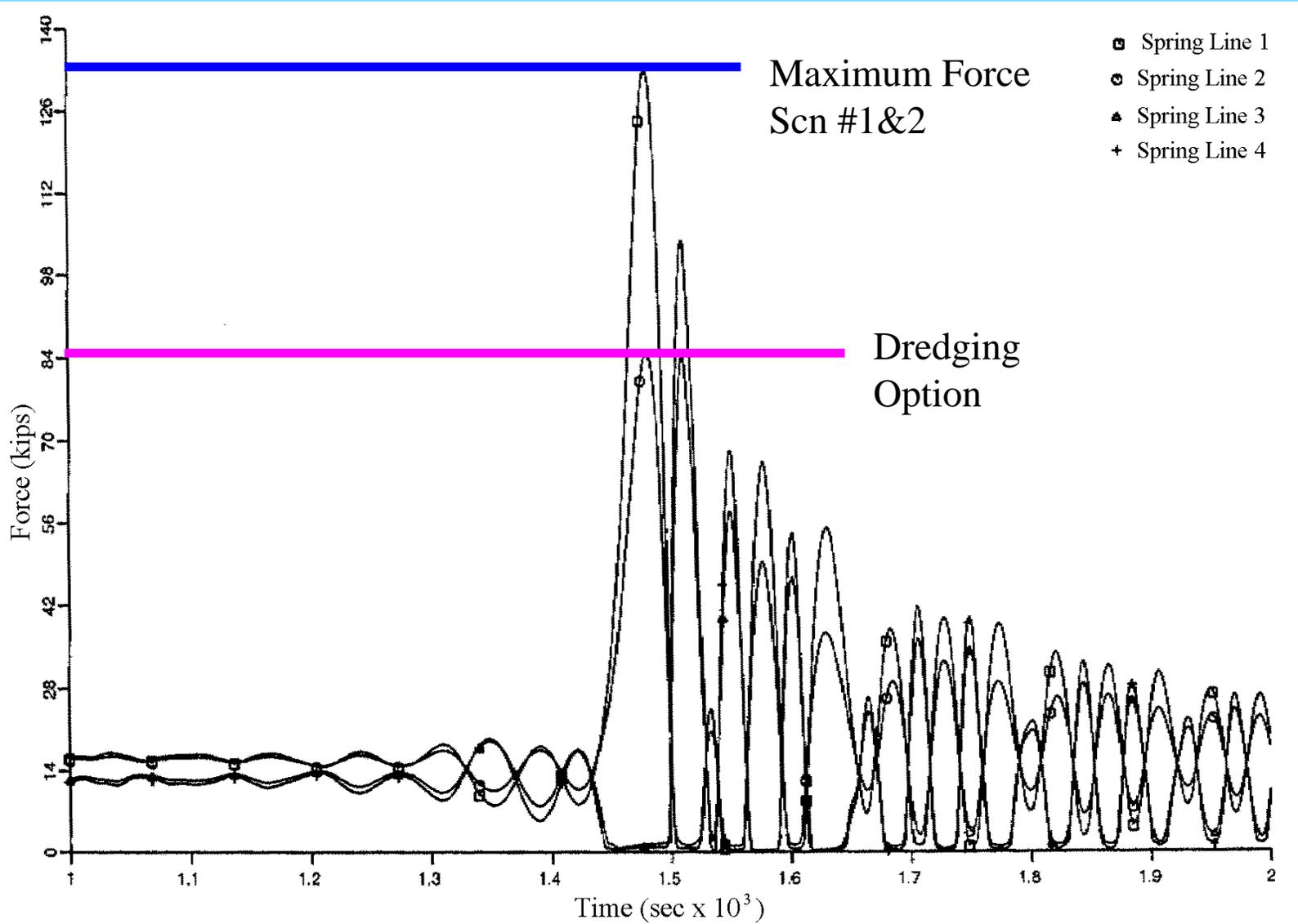
# Outer Harbor Pressure Field Modeling

## Vessel-Generated Long-Period Waves



# Outer Harbor Pressure Field Modeling

## Scenario #2 Maximum Mooring Line Forces



## Summary/Recommendations

- Inner Harbor Waterway
  - Width = 750 ft
  - Depth = 50 ft
- Outer Harbor Waterway - 100 ft width increase
- Extreme conditions (very low tide, high current velocities, etc.) - use Operational Guidance

April 1999



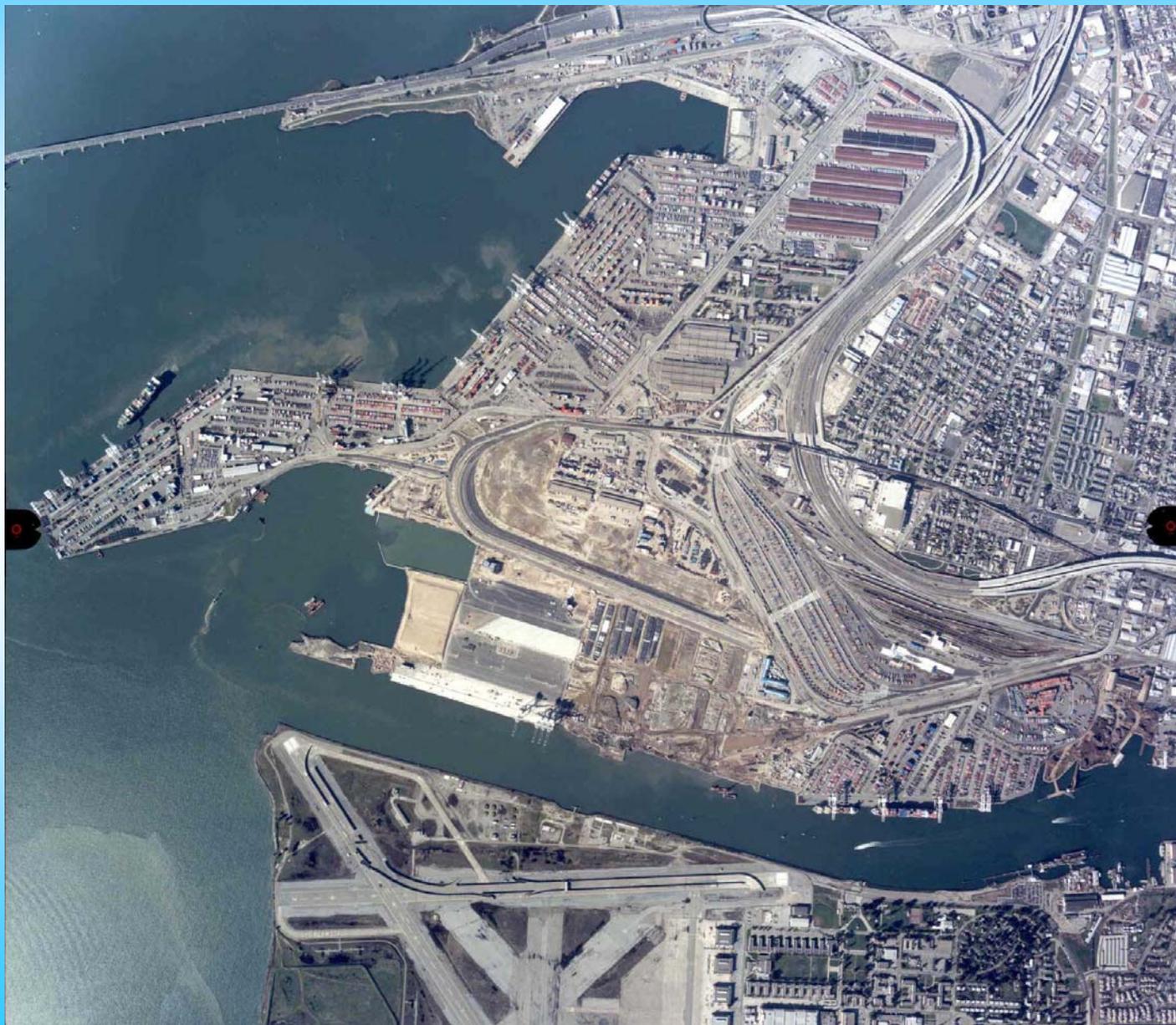
April 2000



June 2000



February 2001



May 2003



July 2003





# *Port of Oakland, CA*

**Inner Harbor Waterway**



**Outer Harbor Waterway**

