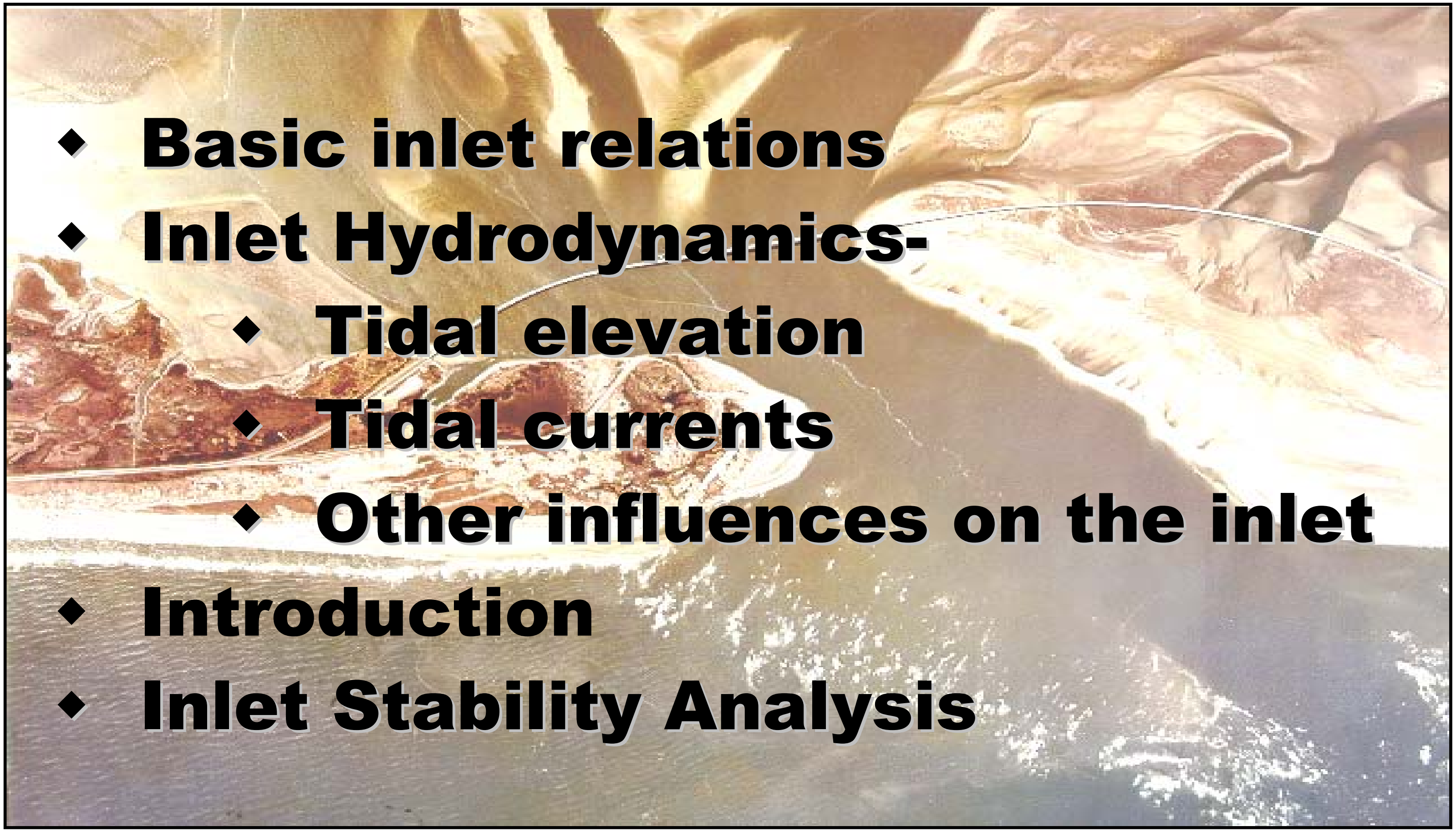
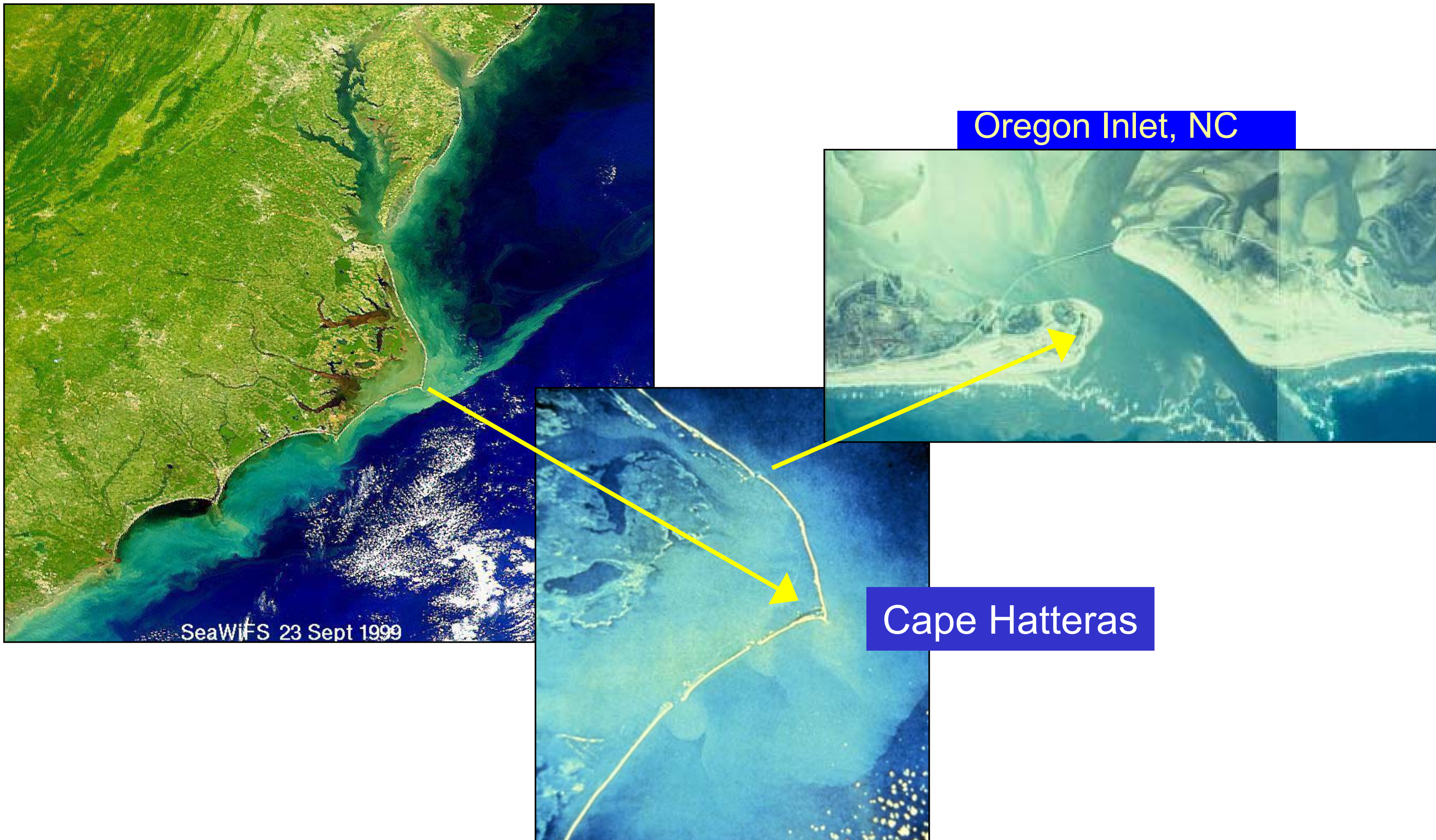
4th Annual Tech-transfer Workshop
Feb 10-12, 2003

Engineering Analysis
At Tidal Inlets

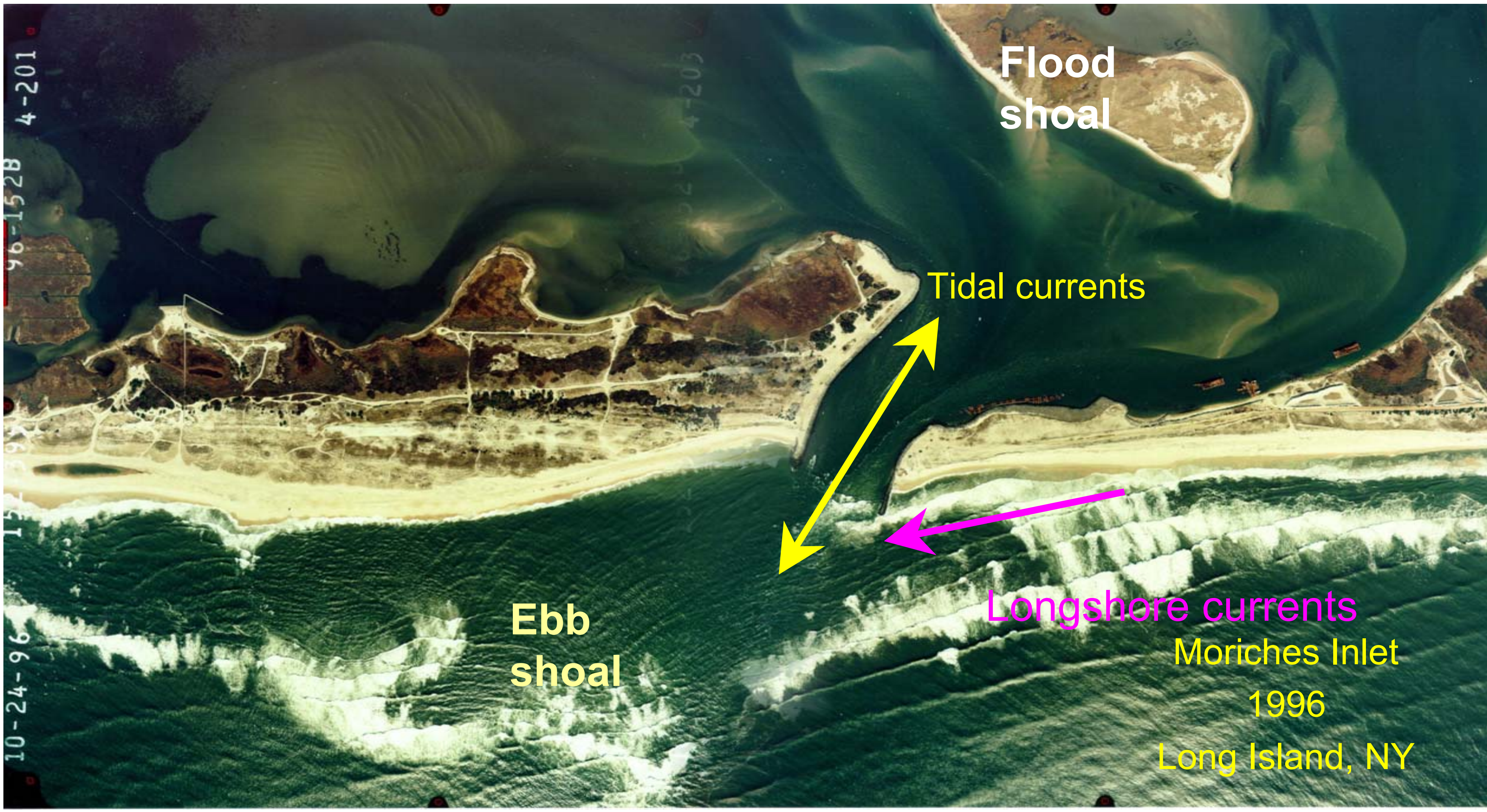


- Basic inlet relations
- Inlet Hydrodynamics-
  - Tidal elevation
  - Tidal currents
  - Other influences on the inlet
- Introduction
- Inlet Stability Analysis

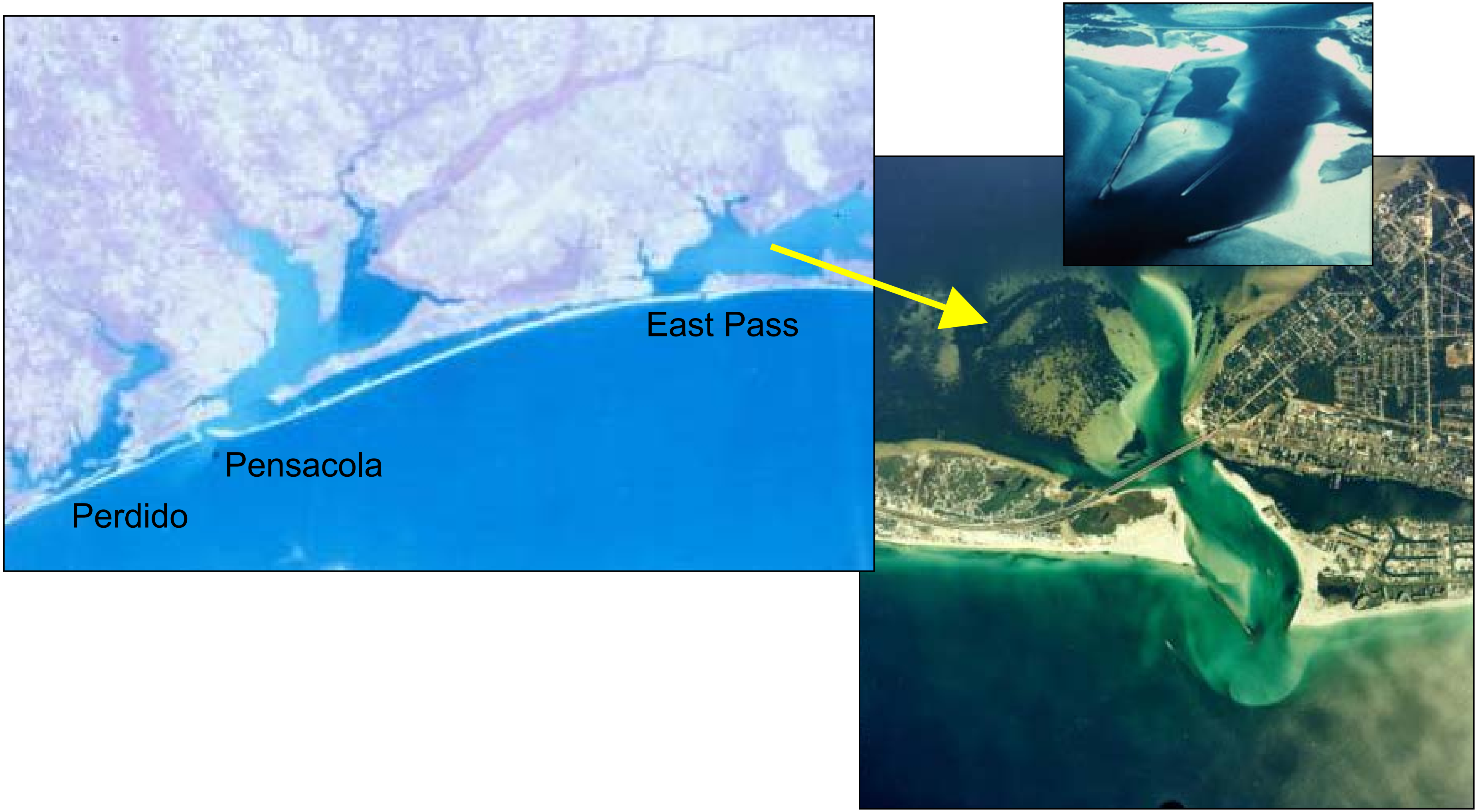
INLET SCALE



Primary Driving Forces at an Inlet



Gulf Coast

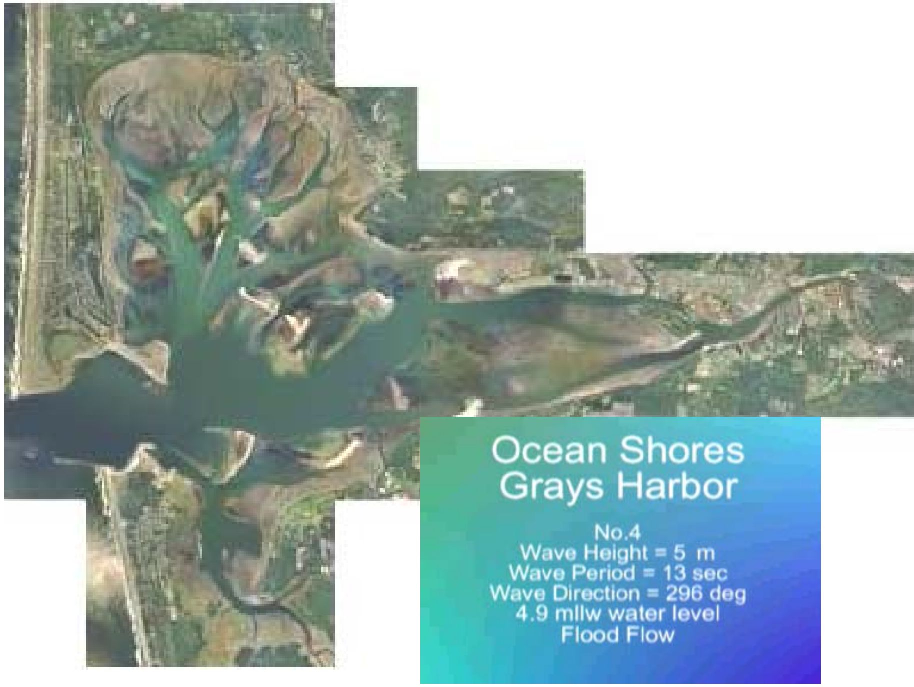


Pacific Coast

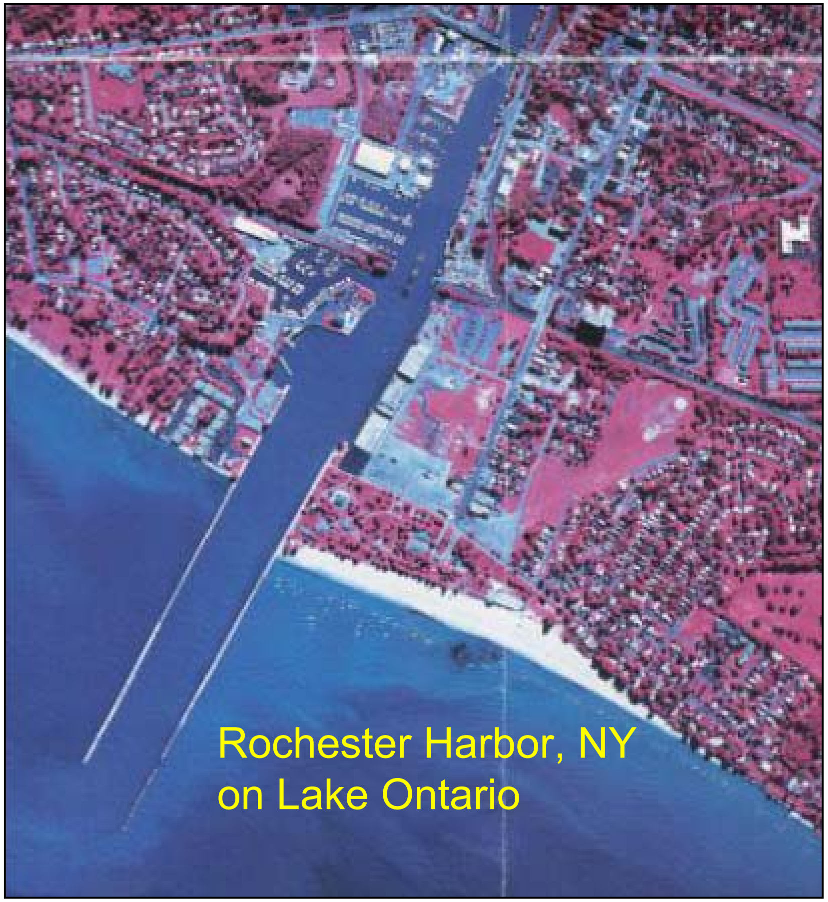
Grays Harbor, WA

Bay surface area = 93 square miles

Tidal Prism = 2.0 x 10^{10} cu ft



Don’t Forget the Great Lakes



Seiche-generated currents
in the channel can be important
(Helmholtz resonance or “pumping mode”)

Inlet Surprises

Nausett Spit, Cape Cod

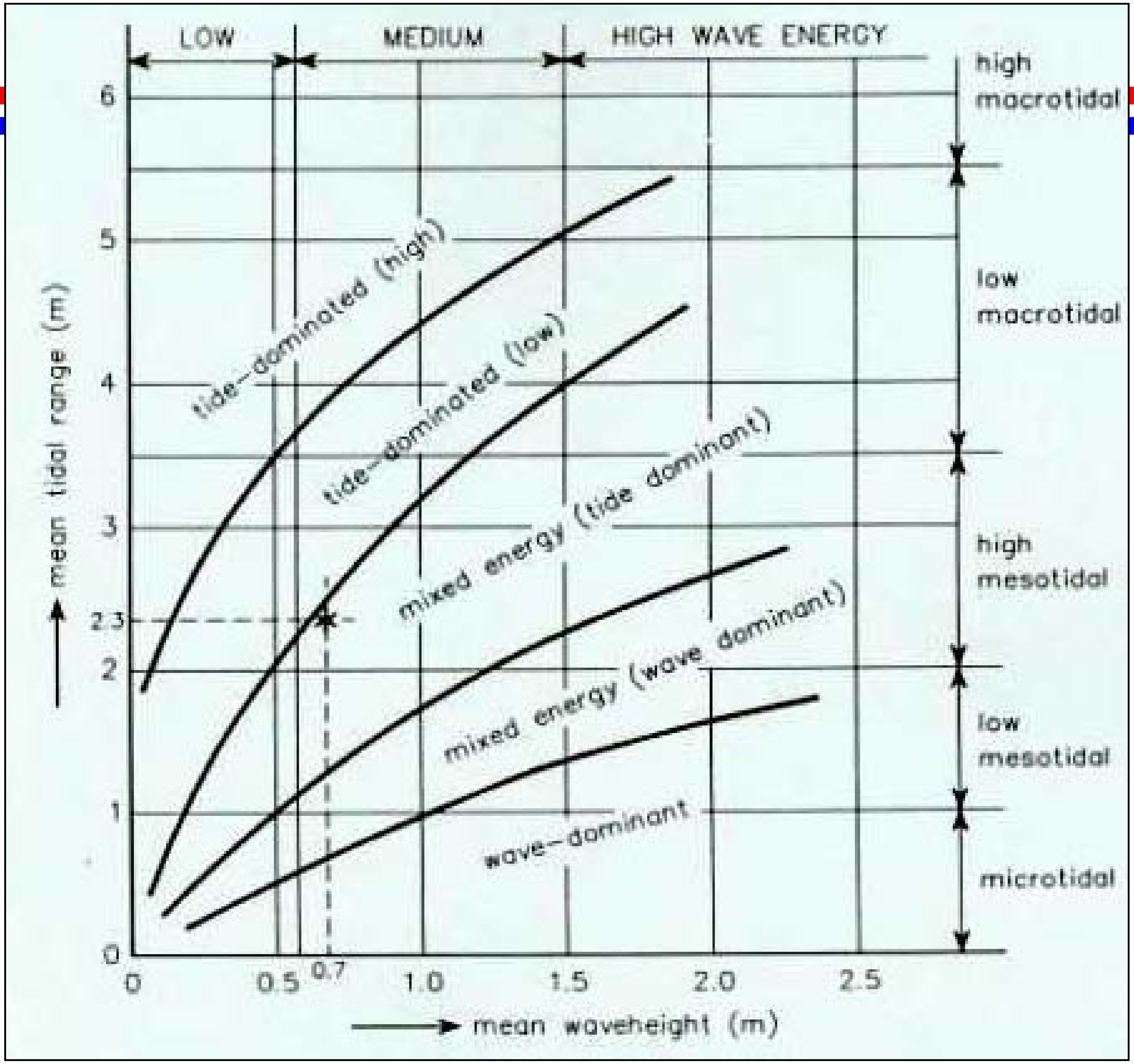
New Inlets, Natural & Man-made

Rollover Pass, Texas

Inlet Surprises Continued

Will it widen??

Hydrodynamic Classification



Hayes, 1979

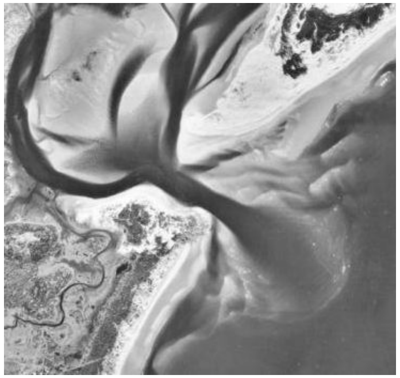
Channel Area - Tidal Prism Relationship

- O'Brien (1931) related the

cross-sectional area, A_c (below mean tide level)

to the tidal prism, P (during spring tide)

$$A_C = 5 \times 10^4 P^N$$



Some Tidal Prism vs Minimum Inlet Flow Area Relationships

Table 1. Tidal Prism-Minimum Channel Cross-sectional Area Relationships

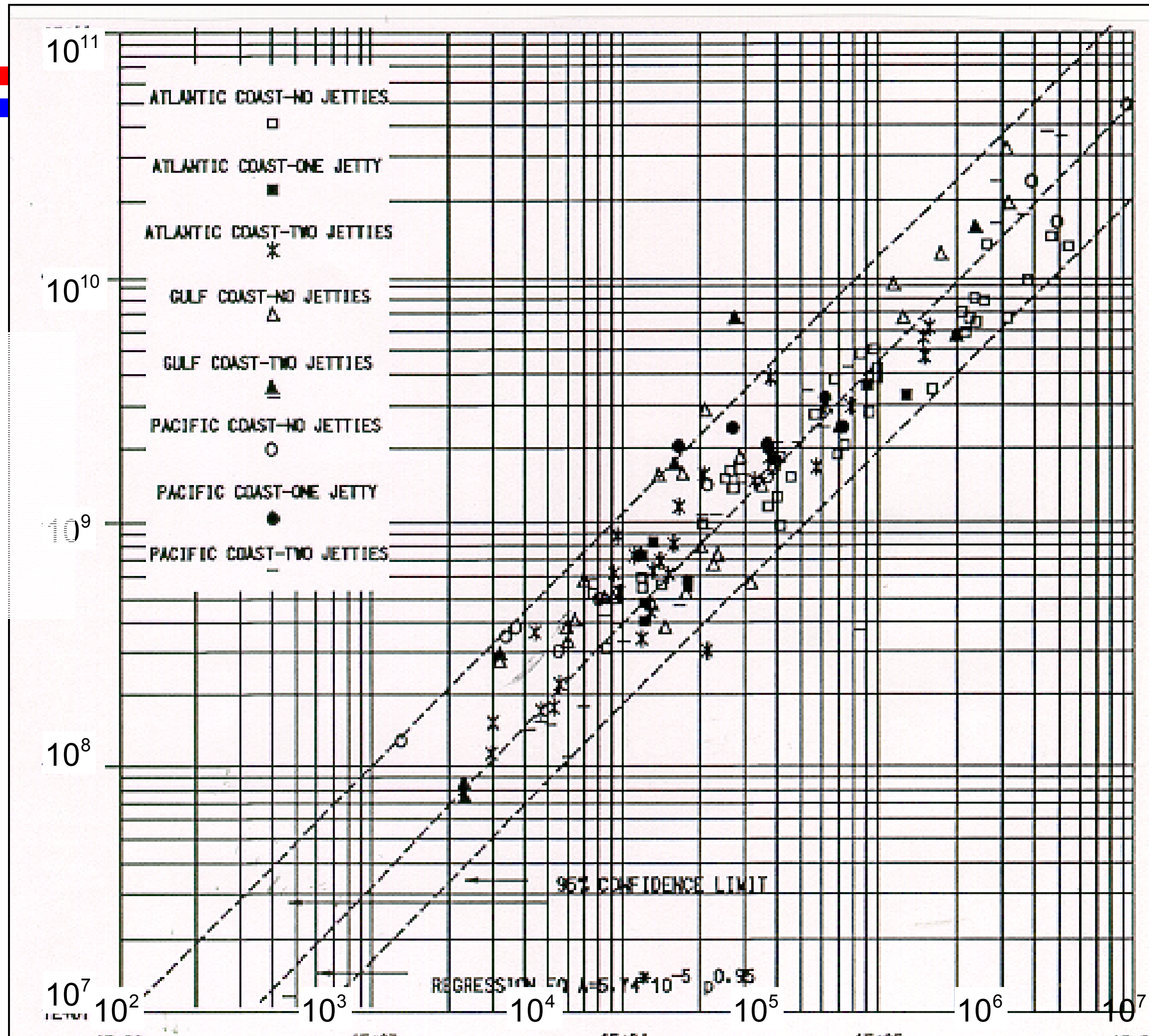
	Metric Units	American Customary Units
Atlantic Coast	$A_c = 3.039 \times 10^{-5} P^{1.05}$	$A_c = 7.75 \times 10^{-6} P^{1.05}$
Gulf Coast	$A_c = 9.311 \times 10^{-4} P^{0.84}$	$A_c = 5.02 \times 10^{-4} P^{0.84}$
Pacific Coast	$A_c = 2.833 \times 10^{-4} P^{0.91}$	$A_c = 1.19 \times 10^{-4} P^{0.91}$
Dual-Jettied Inlets (O' Brien)	$A_c = 7.489 \times 10^{-4} P^{0.86}$	$A_c = 3.76 \times 10^{-4} P^{0.86}$

A_c is the minimum cross-sectional area in square meters (square feet), P is the tidal prism in cubic meters (cubic feet).

Derived from Jarrett, 1976

Tidal Prism Vs Channel Area

Tidal Prism, ft^3



Minimum Cross-sectional Area of Inlet, ft^2

Jarrett, 1976

Tools for Inlet Engineering
Inlet Processes

Objectives

- 1)Determine inlet hydrodynamics
  - bay tide amplitude and phase
  - inlet velocity
- 2) Examine inlet stability
  - Combine inlet hydrodynamics and the tidal prism vs minimum inlet cross-sectional area relationship

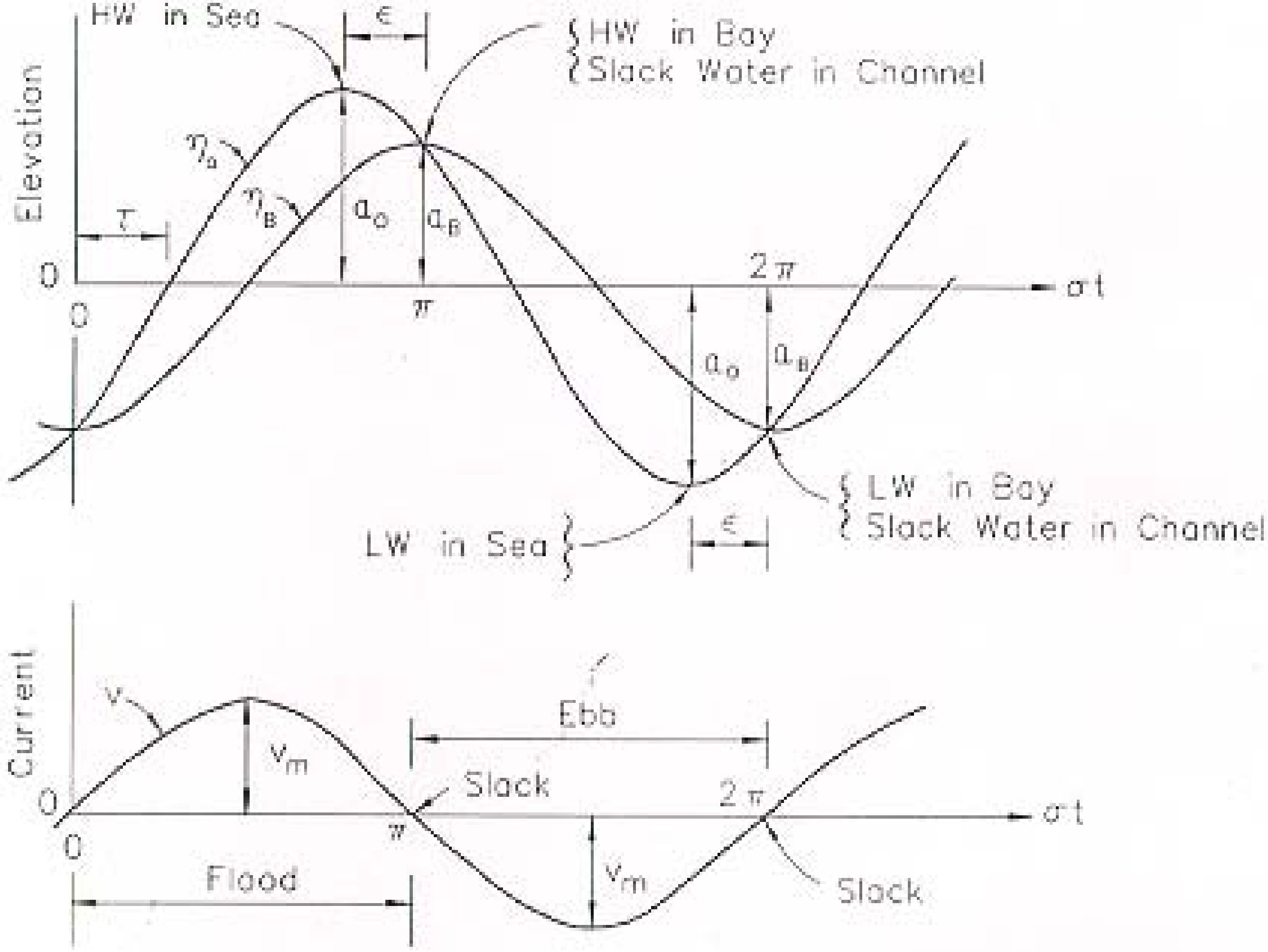
Output of Simplified Calculations for Inlet Hydrodynamics

- Tidal amplitude in bay (1/2 tide range)
- Bay tide high water time relative to ocean high water tide - phase lag
- Velocity in inlet
- Tidal prism
  - Bay tide range x bay area
  - Integrate discharge-time curve

Results From Inlet Hydrodynamics

Tide elevation

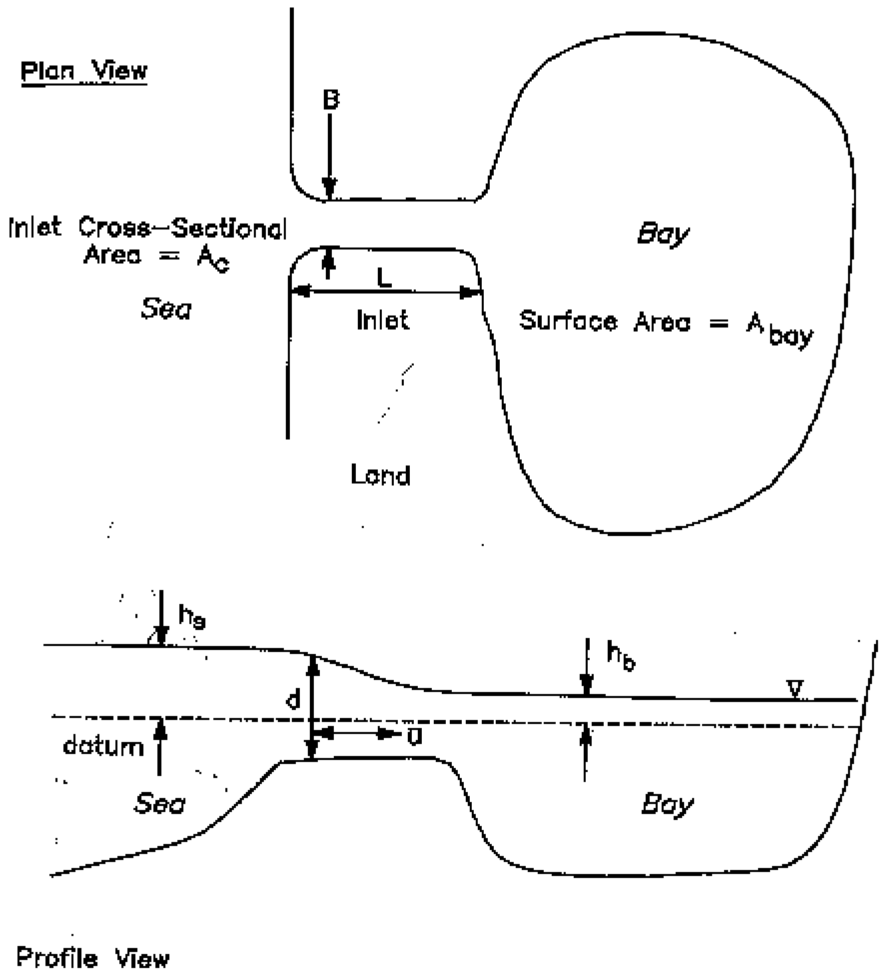
Tide Current



Some Assumptions for Simplified Inlet Hydrodynamics

- Bay walls are vertical
- No inflow from streams
- No density currents
- Ocean tide sinusoidal
- Bay water level rises uniformly
- Inlet channel flow area constant
- Inertia of water mass in channel ignored

Inlet System



1-D Approach

treat as an orifice over a given channel length, assuming velocities fall off significantly as one moves away from the entrance.

The Inlet System

1-D Equations for Inlet Hydrodynamics

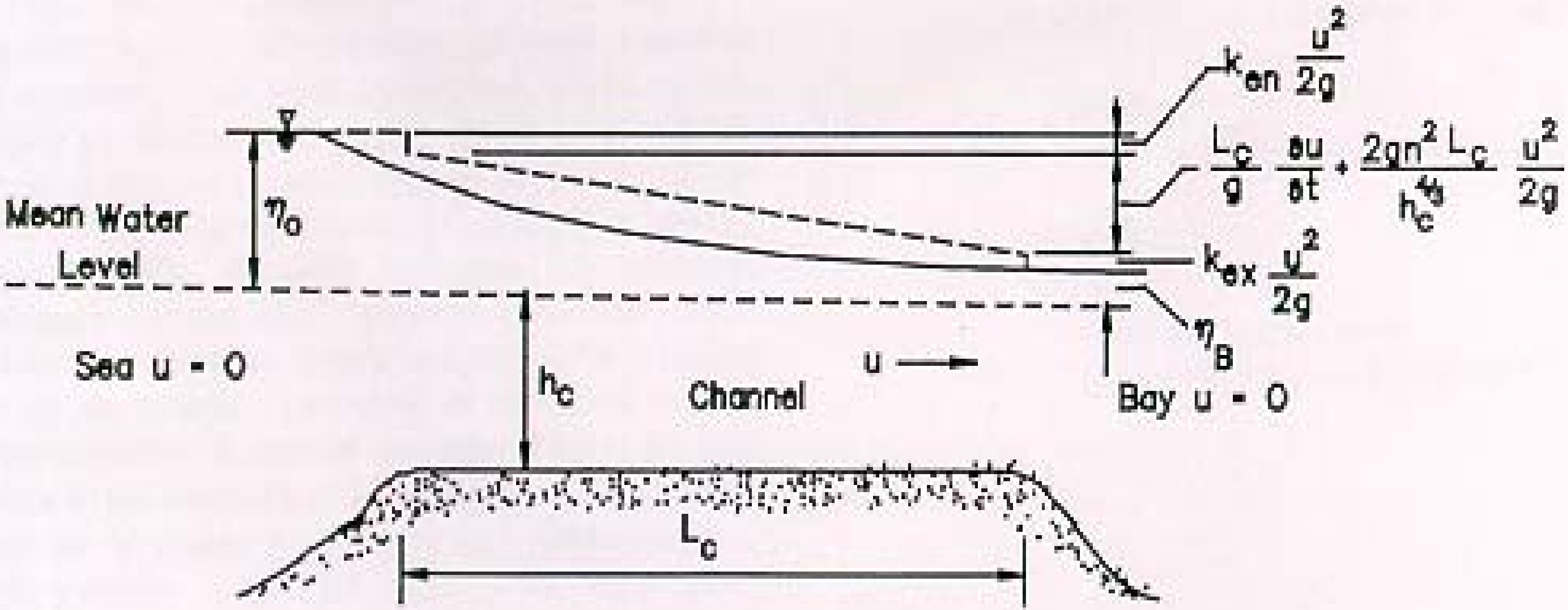
- 1-D equation of motion (II-6-2)

$$\frac{\partial u}{\partial t} + u\frac{\partial u}{\partial x} = -g\frac{\partial h}{\partial x} - \frac{f}{8R}u\left|u\right|$$

Integrating over the length of the inlet, and using equation of continuity

$$VA_{avg} = A_b\frac{\partial h_b}{\partial t}$$

Contributions to Head Loss Across Inlet Length



Keulegan K

Keulegan developed solution for velocity and bay tide containing dimensionless parameter K called coefficient of repletion (or filling)

$$K = \frac{TA_{avg}}{2\pi A_b} \sqrt{\frac{2g}{a_o \left[k_{en} + k_{ex} + \frac{fL}{4R} \right]}}$$

$f = 116n^2 / R^{1/3}$ $\quad$ $see \cdot page \cdot II-6-24$

Input Variables in Simple Inlet Modeling

- $a_{o,}$ tide amplitude (half tide range)
- T, tide period (seiche period may be used if important in forcing).
- $A_{b,}$ surface area of bay or lagoon influenced by the inlet.
- A_{avg} average area of channel

Input Variables in Simple Inlet Modeling

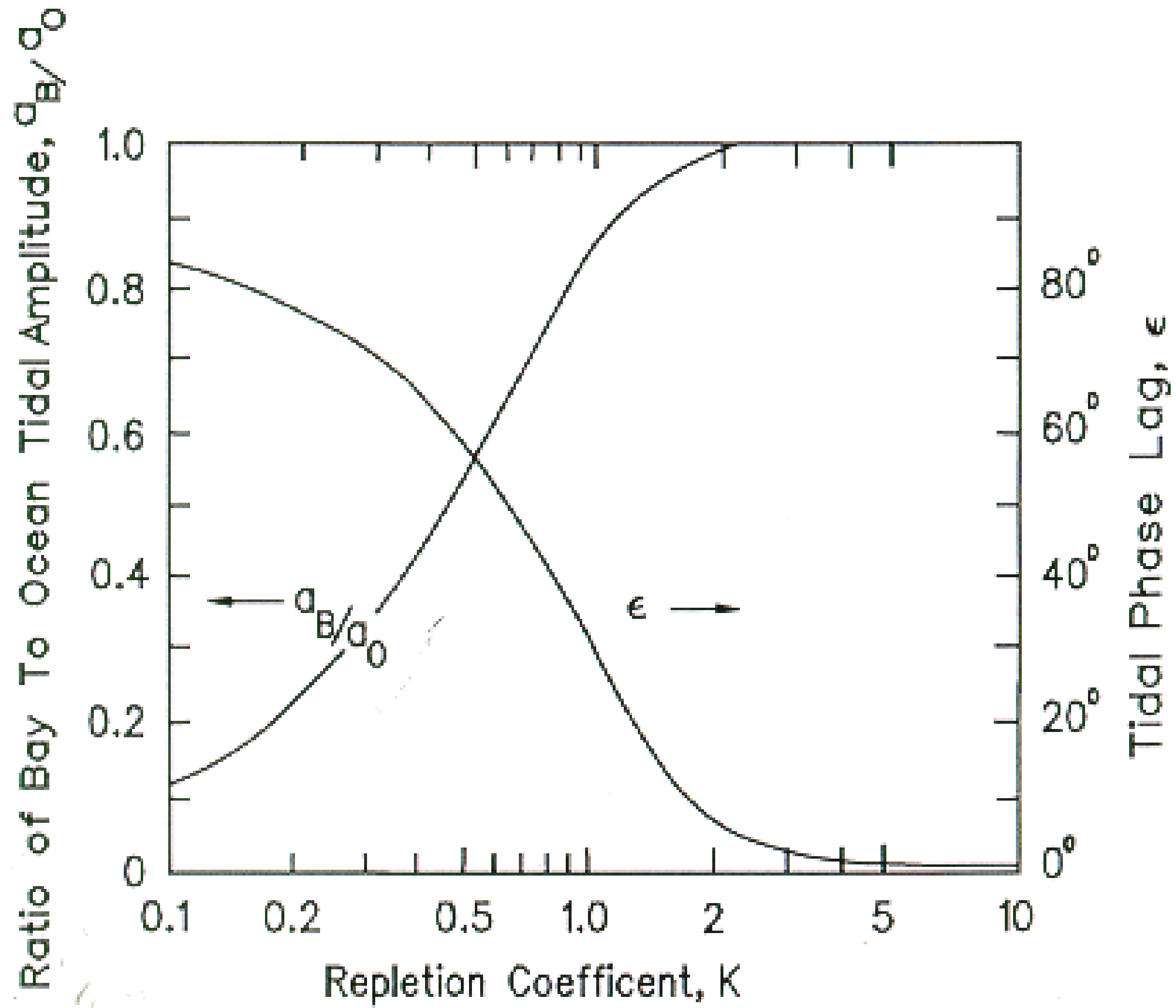
- L, channel length : Estimate based on distance between a region where current speed would be expected to significantly decrease at seaward and bayward ends of channel.
- R, channel hydraulic radius (usually average depth across channel, since inlets are relatively wide and shallow).

Input Variables in Simple Inlet Modeling

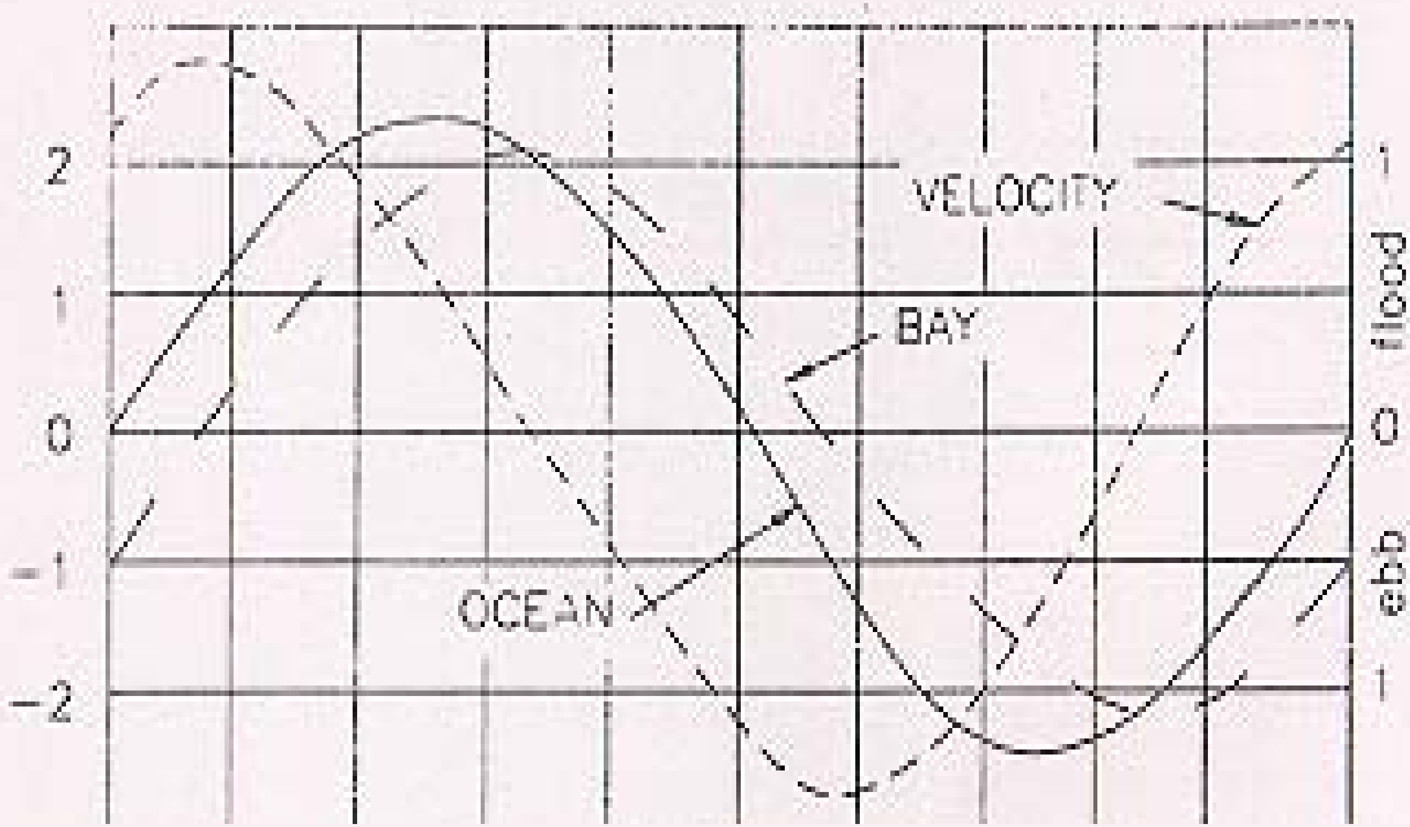
- Friction Coefficients
  - K_{en}, entrance loss
    - 0.05 value up to 0.25 for dual jetties
  - K_{ex}, exit loss
    - 1.00 value describes a relatively deep bay and complete loss of kinetic head
    - Smaller values (less than 1.0) may be tried during calibration
  - f, Darcy-Weisbach coefficient
    - 0.03 a common value or calculate from $f=0.088/R^{1/3(}$ English units, n=0.0275)

Calculating K, Determine Bay Tide Amplitude and Phase

$$K = \frac{TA_{avg}}{2\pi A_b}\sqrt{\frac{2g}{a_o\left[k_{en}+k_{ex}+\frac{fL}{4R}\right]}}$$

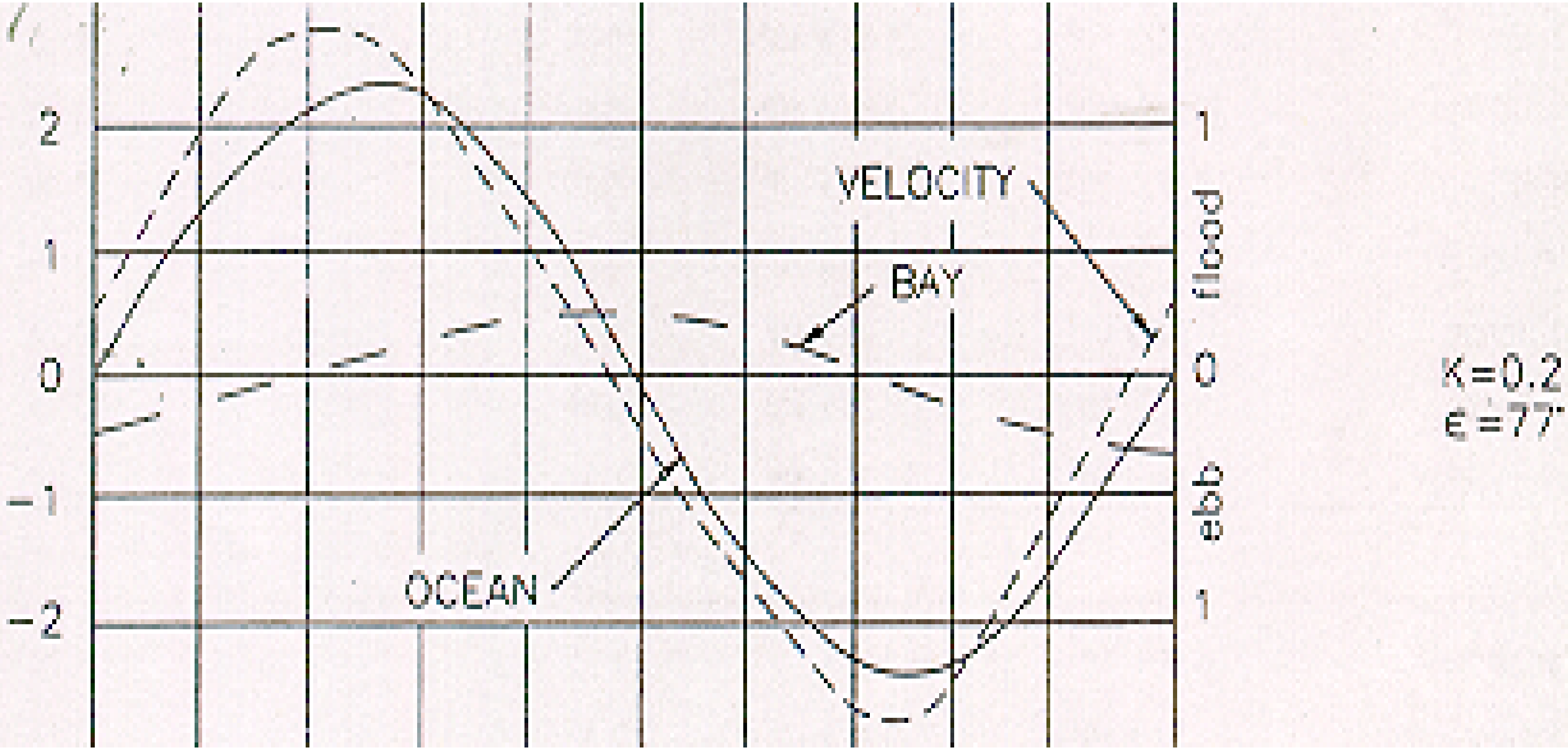


Bay Tide, Channel Velocities for K = 1.1 Value



K=1.1
ε=27'

Bay Tide, Channel Velocities for K=0.2 Value



King's Solution (Includes Inertia)

$$K_1 = \frac{a_o A_b F}{2LA_{avg}}$$

$$K_2 = \frac{2\pi}{T}\sqrt{\frac{LA_b}{gA_{avg}}}$$

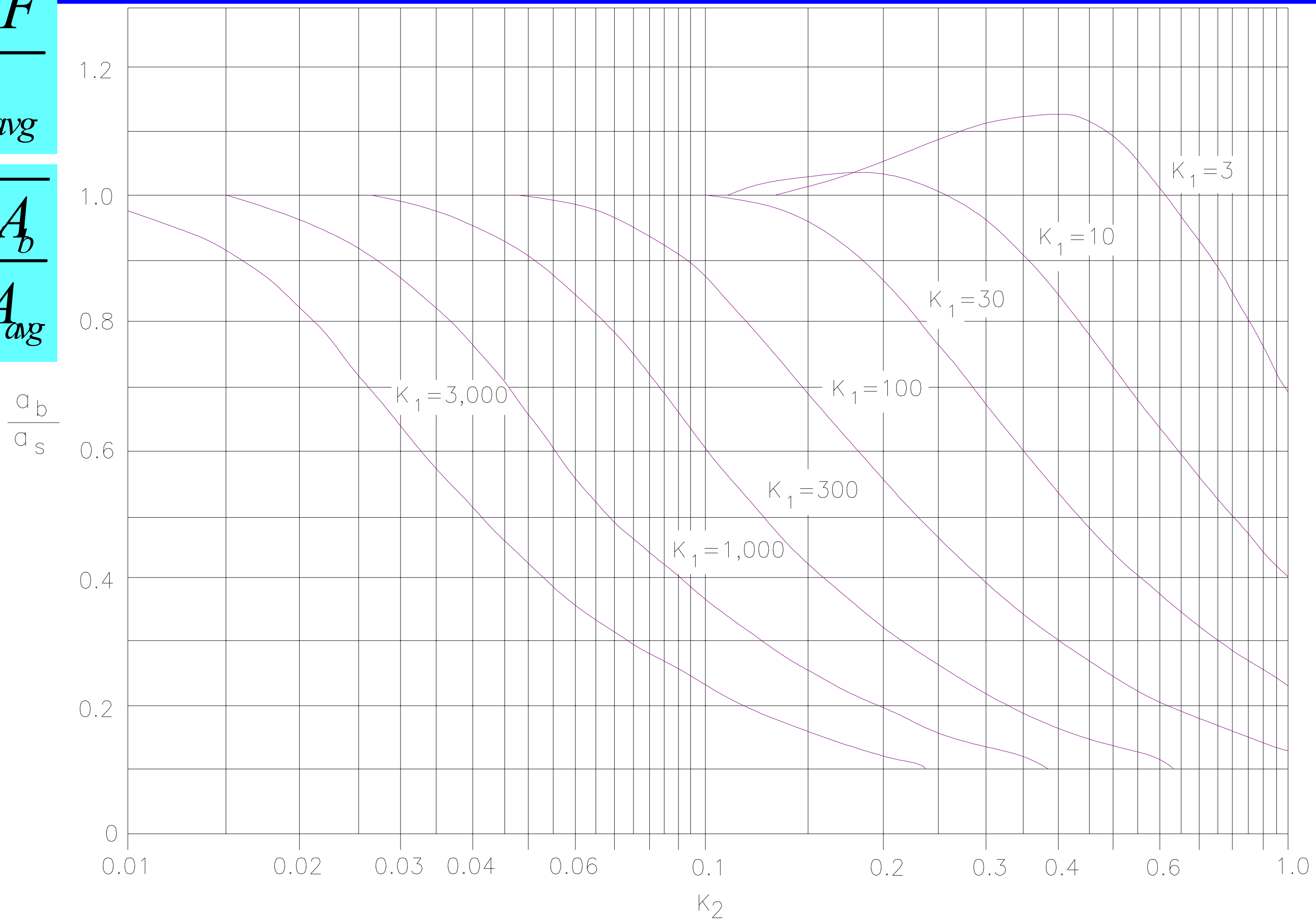
with $$F = k_{en} + k_{ex} + \frac{fL}{4R}$$

Relationship with Keulegan K: $$K = \frac{1}{K_2}\sqrt{\frac{1}{K_1}}$$

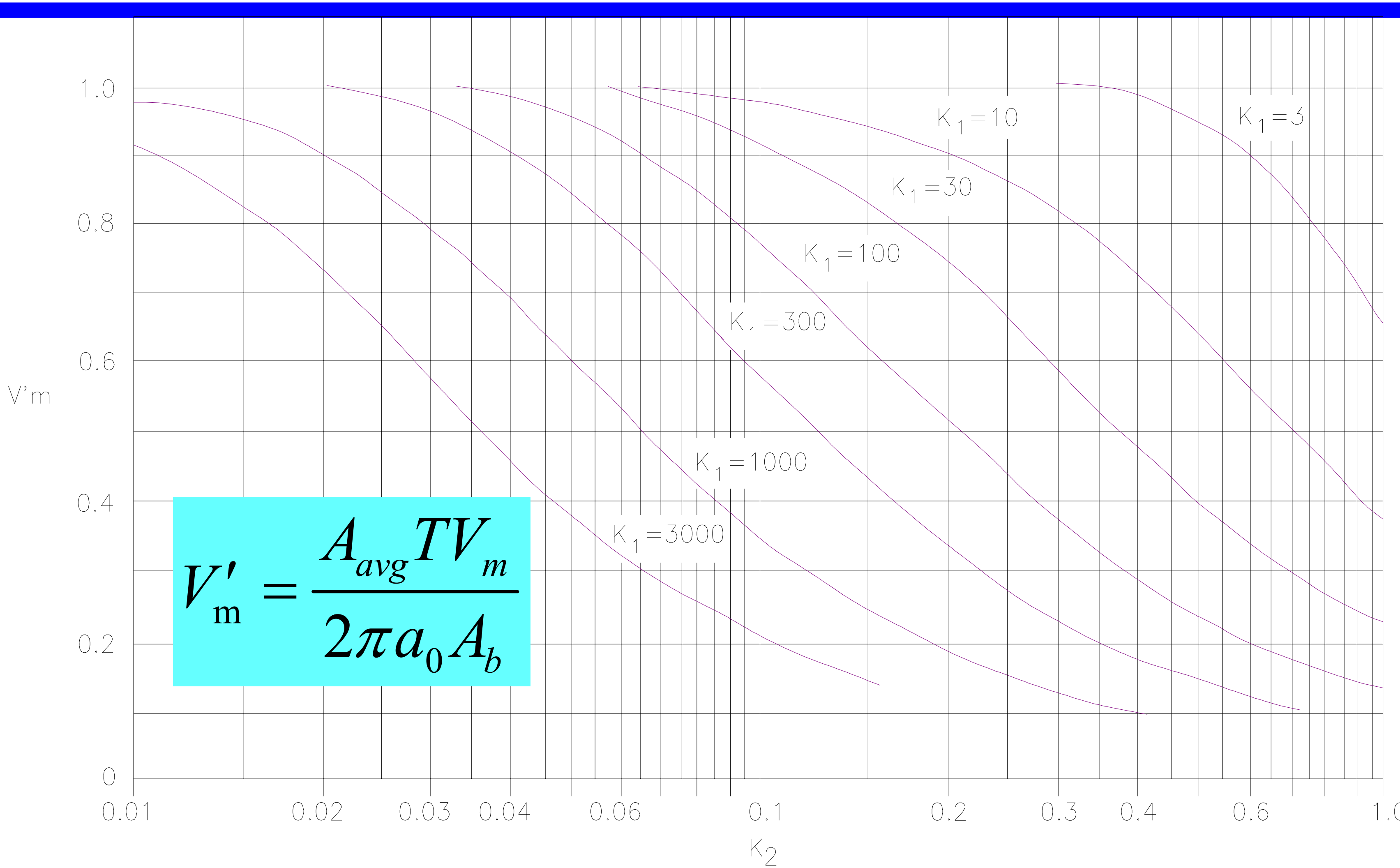
Bay Tide Amplitude

$$K_1 = \frac{a_o A_b F}{2 L A_{avg}}$$

$$K_2 = \frac{2\pi}{T}\sqrt{\frac{L A_b}{g A_{avg}}}$$

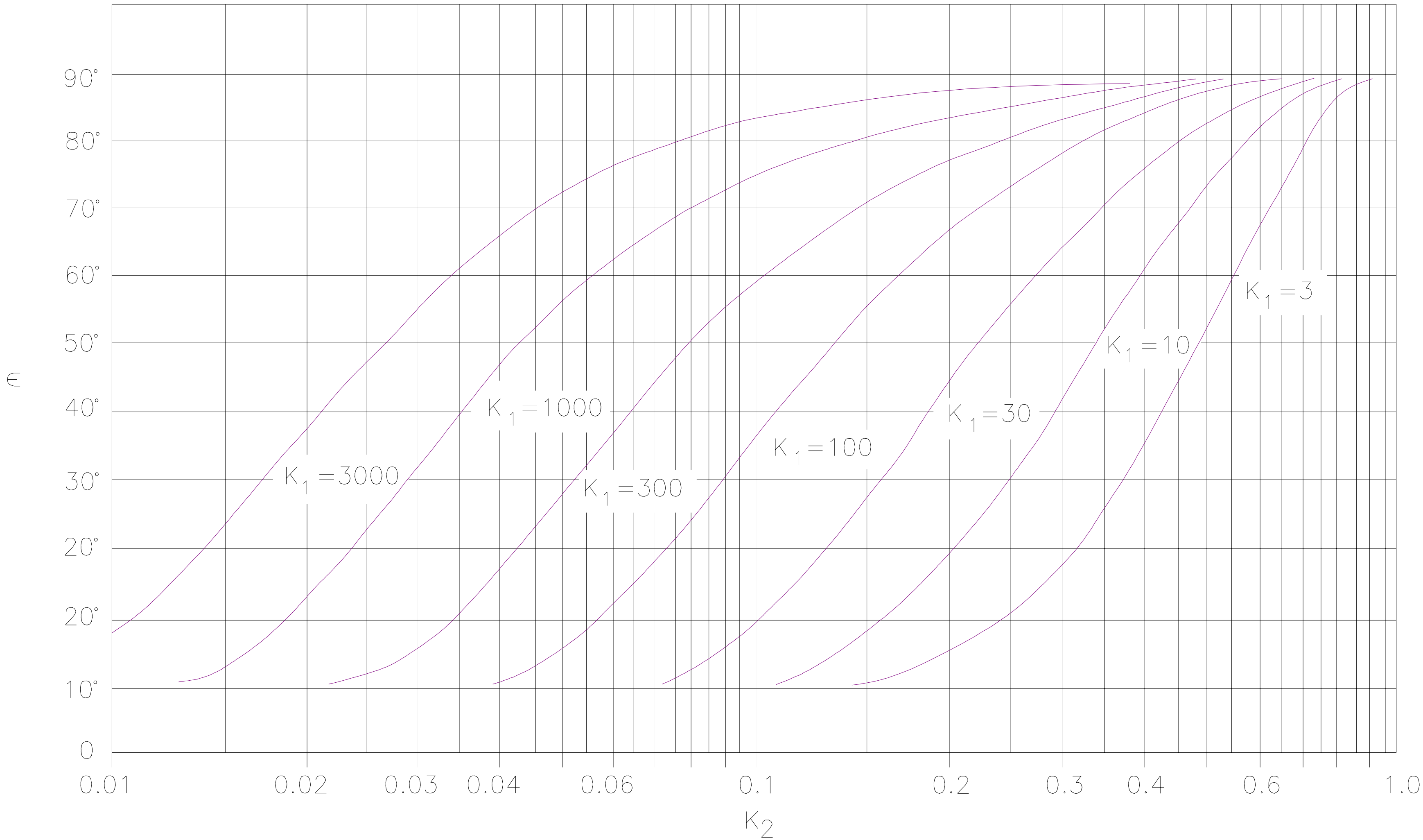


Dimensionless Velocity



$$V'_{\mathrm{m}} = \frac{A_{avg} T V_m}{2\pi a_0 A_b}$$

Bay Phase Lag



Example Output of Hydrodynamic Analysis