تحلیل و طراحی سکوهای فراساحلی

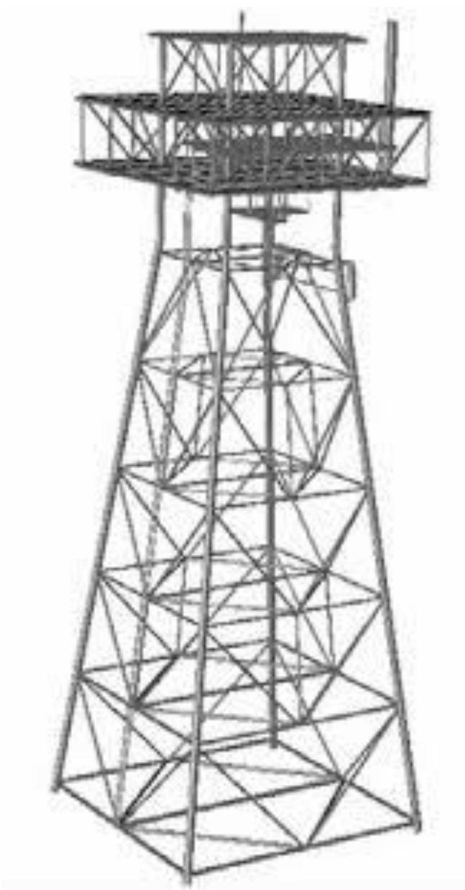
ویدئو شماره ۱: (بخشهایی از بارگذاری با SAP2000)

ویدئو شماره ۲: (تشریح و تفسیر نتایج تحلیل SAP2000)

ویدئو شماره ۳: (طراحی و خروجی SAP2000)

دانشگاه صنعتی شریف

تابش پور



توجه به تعدد نکات مربوط به

مدلسازی،

بارگذاری،

تحلیل و

طراحی

در سکوهای دریایی (شاید حدود ۳۰۰ نکته)

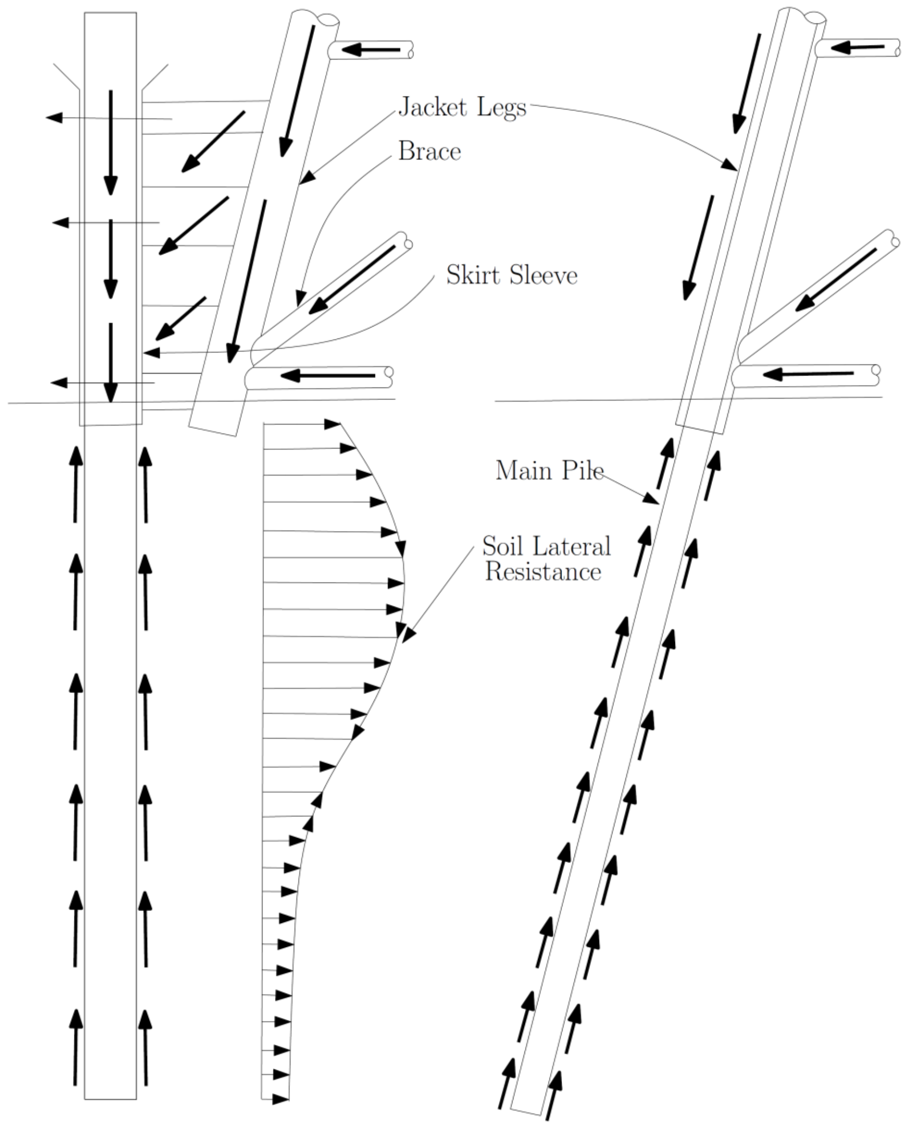


Figure 5.8: Pile Simulation for an Offshore jacket

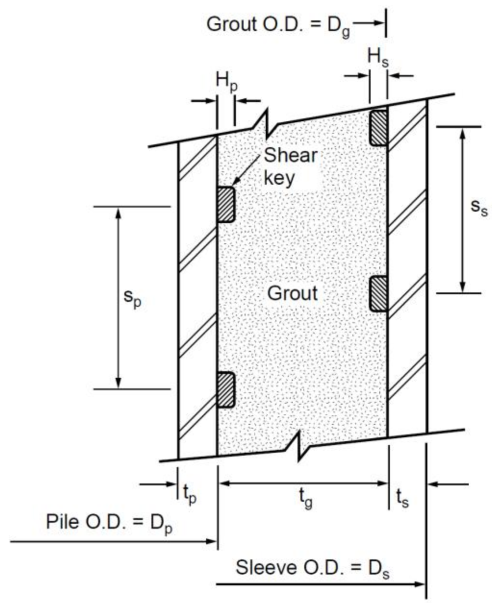


Figure 7.4.4-1—Grouted Pile to Structure Connection with Shear Keys

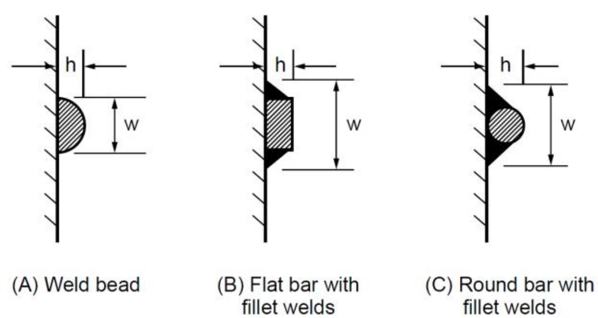
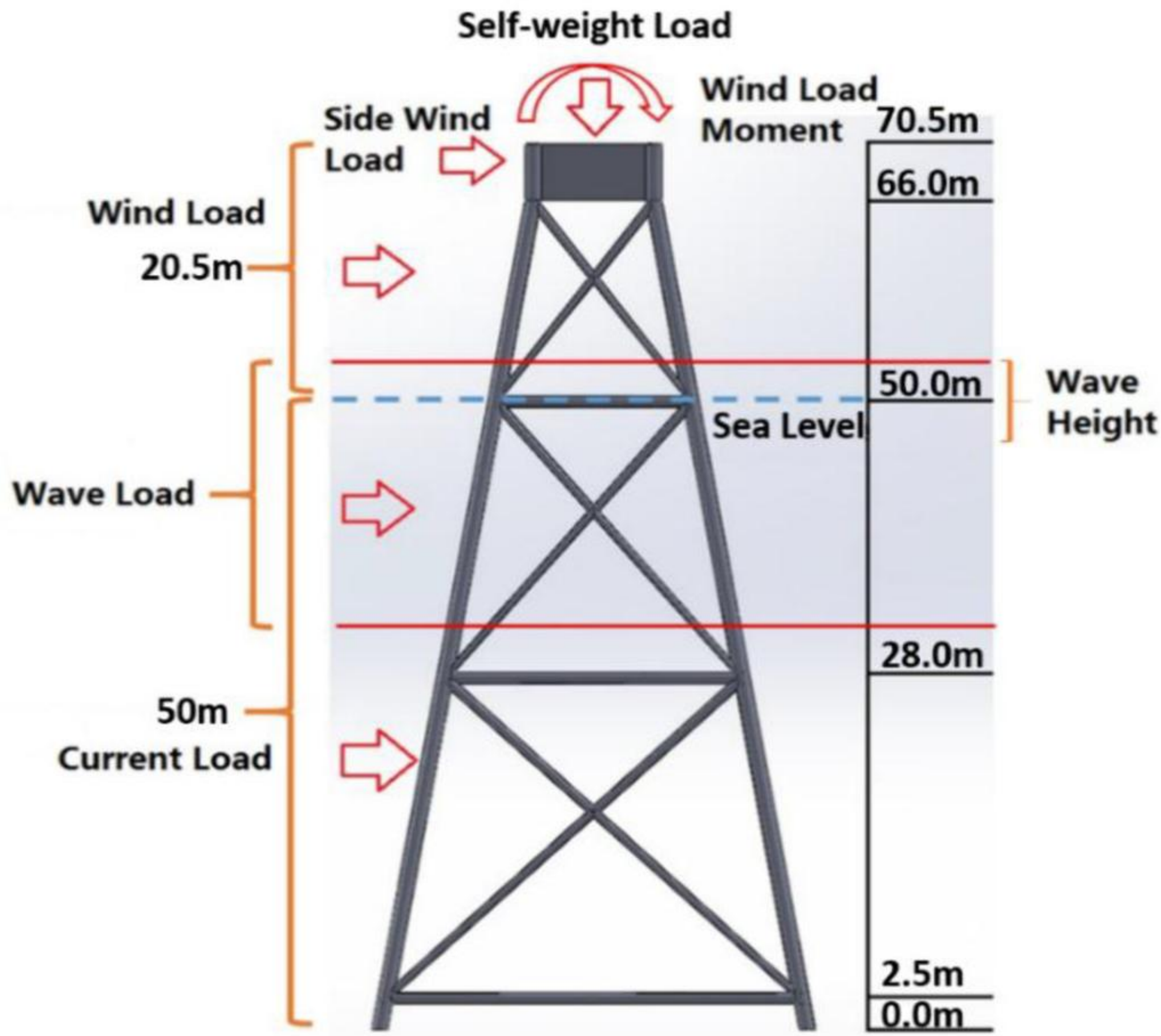


Figure 7.4.4-2—Recommended Shear Key Details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Wind Load
Moment
Side Wind
Load
Wind Load
20.5m
Wave Load
50m
Current Load
70.5m
66.0m
50.0m
Sea Level
Wave
Height
28.0m
2.5m
0.0m

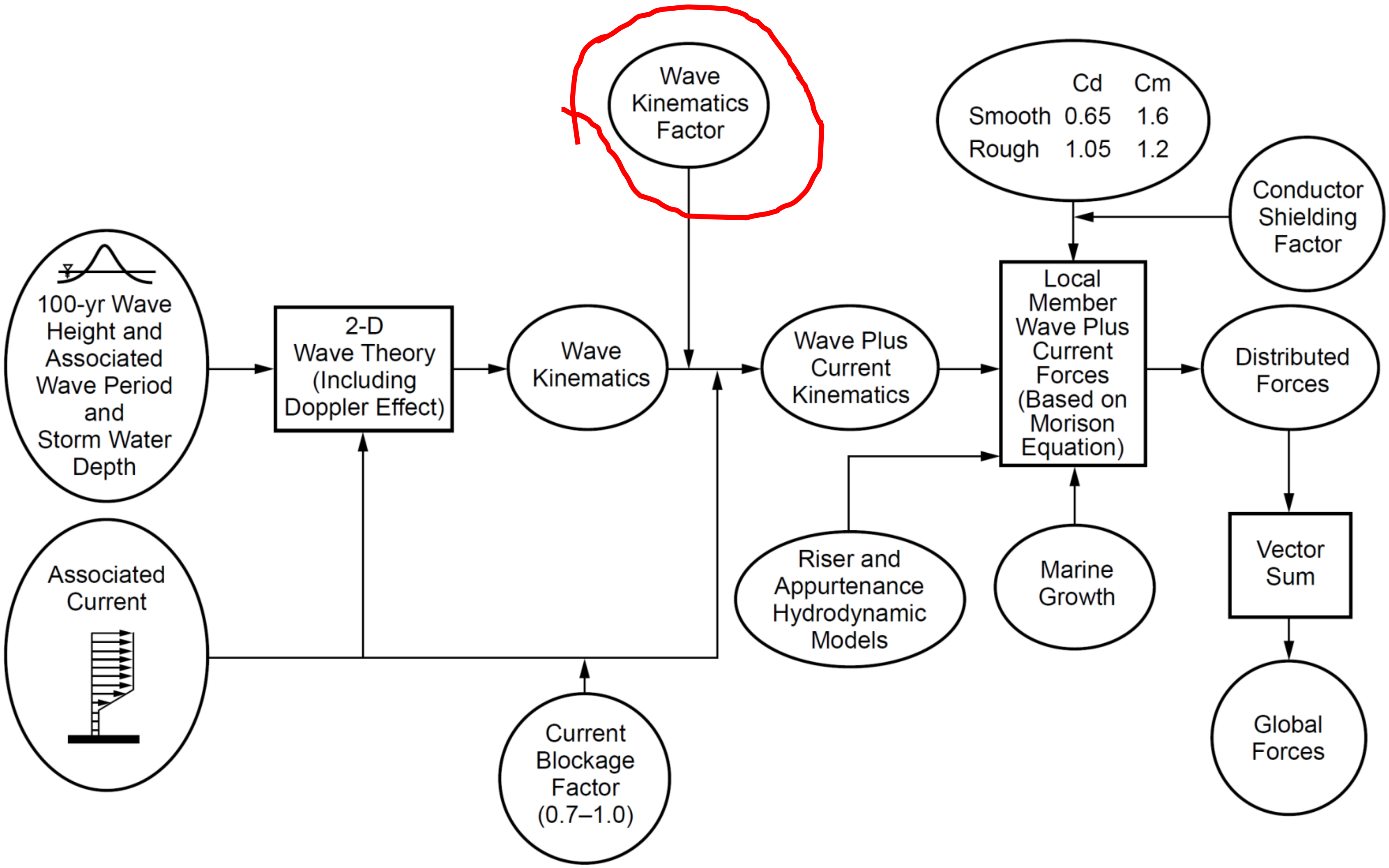
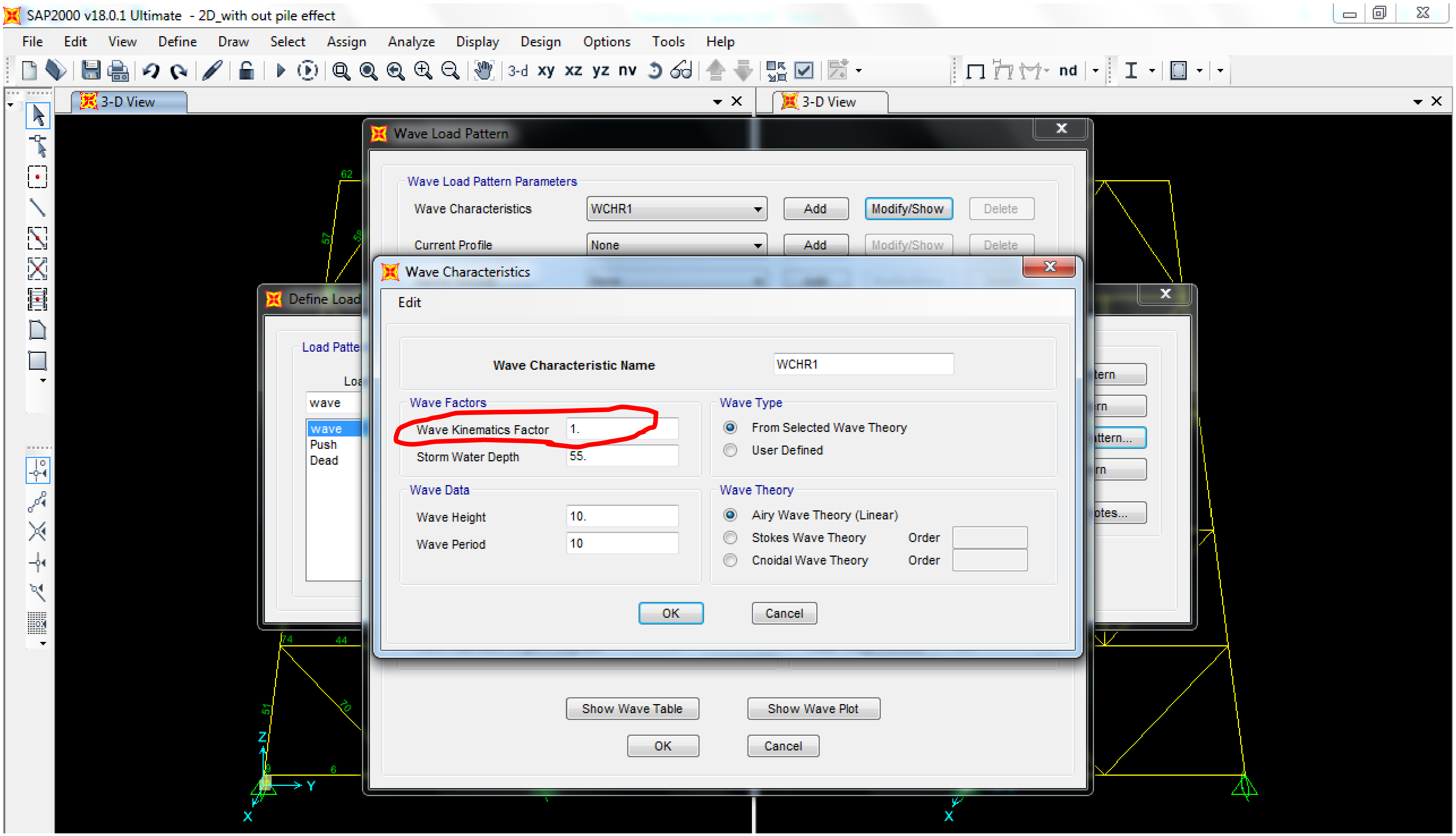


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis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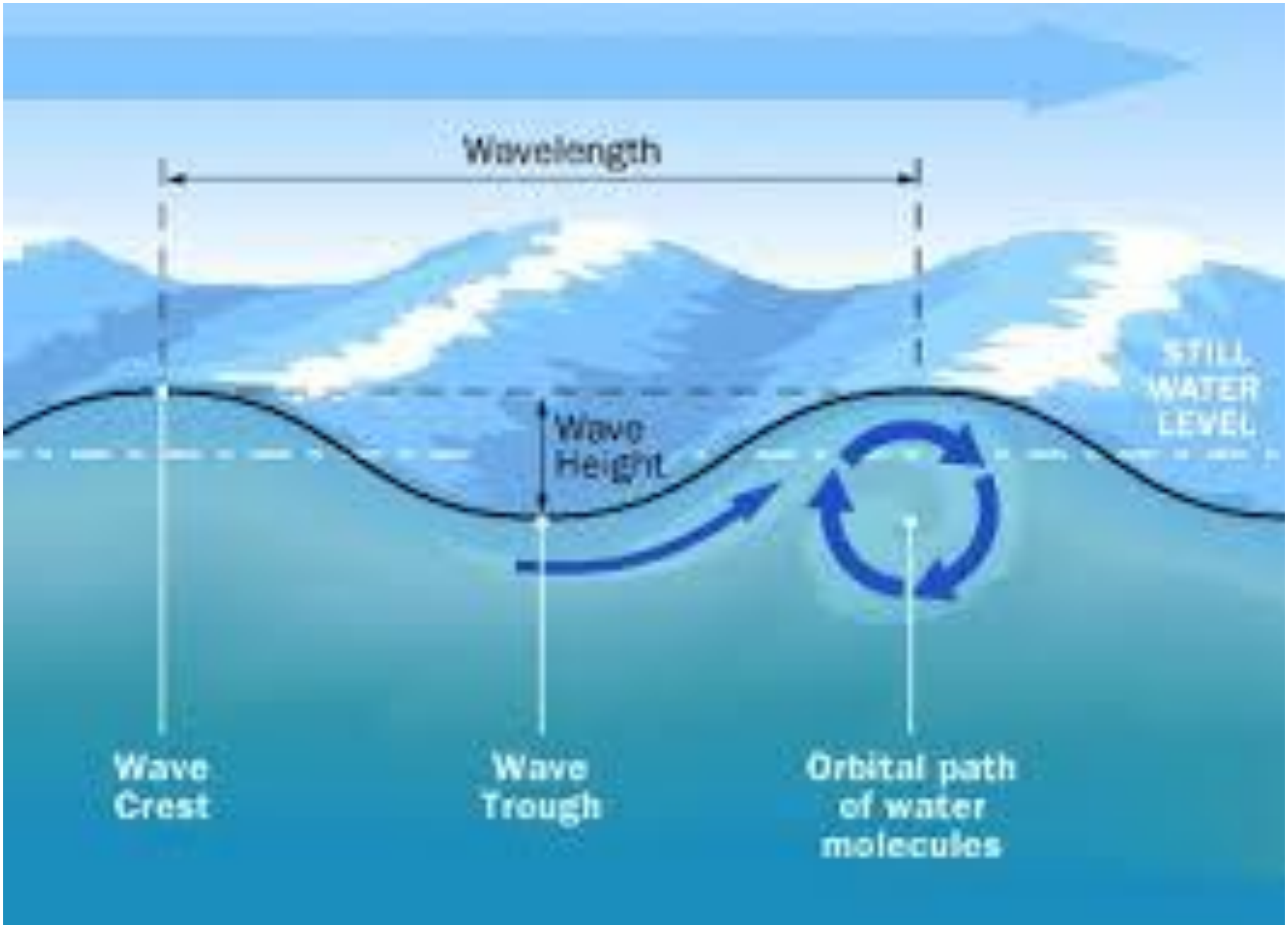
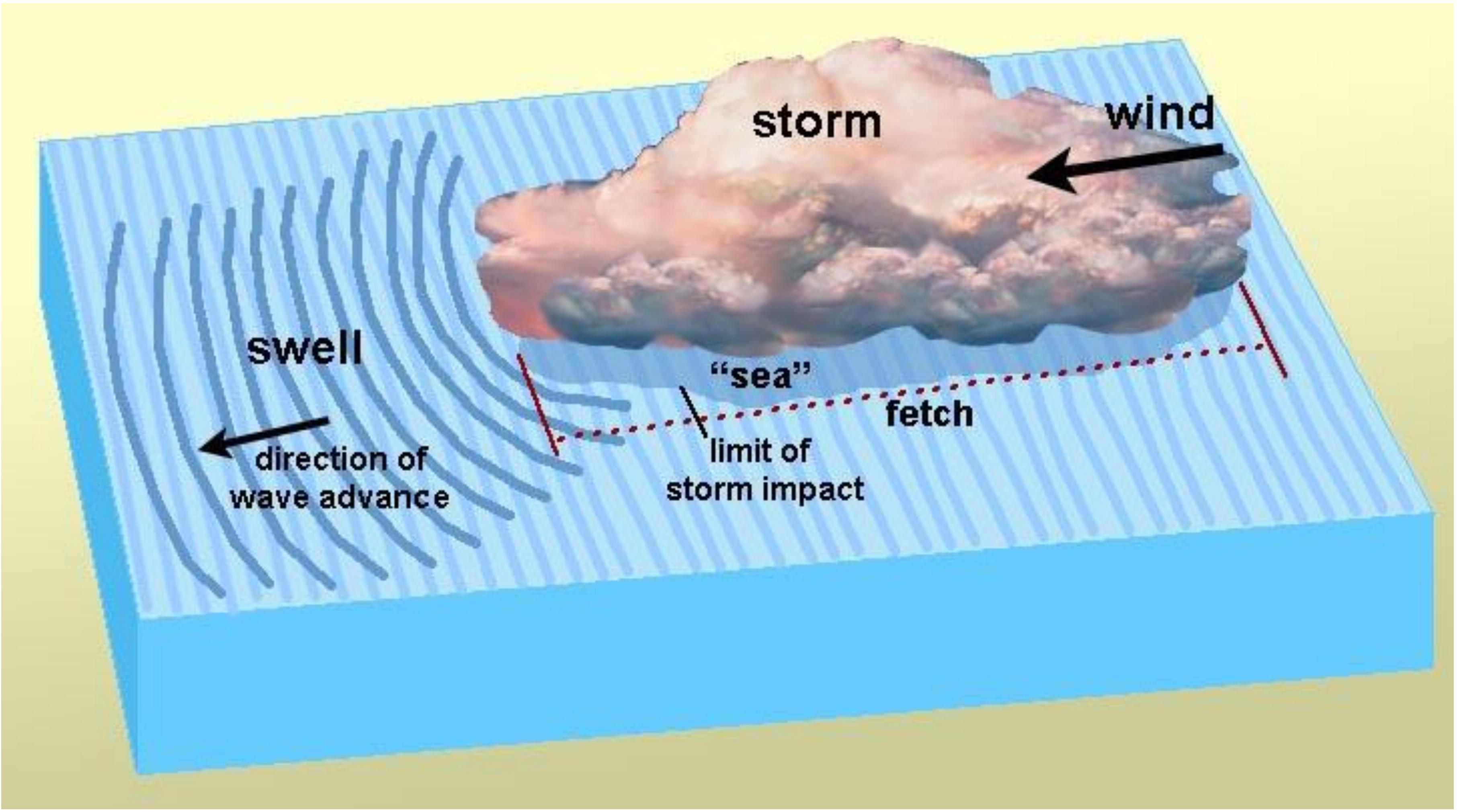
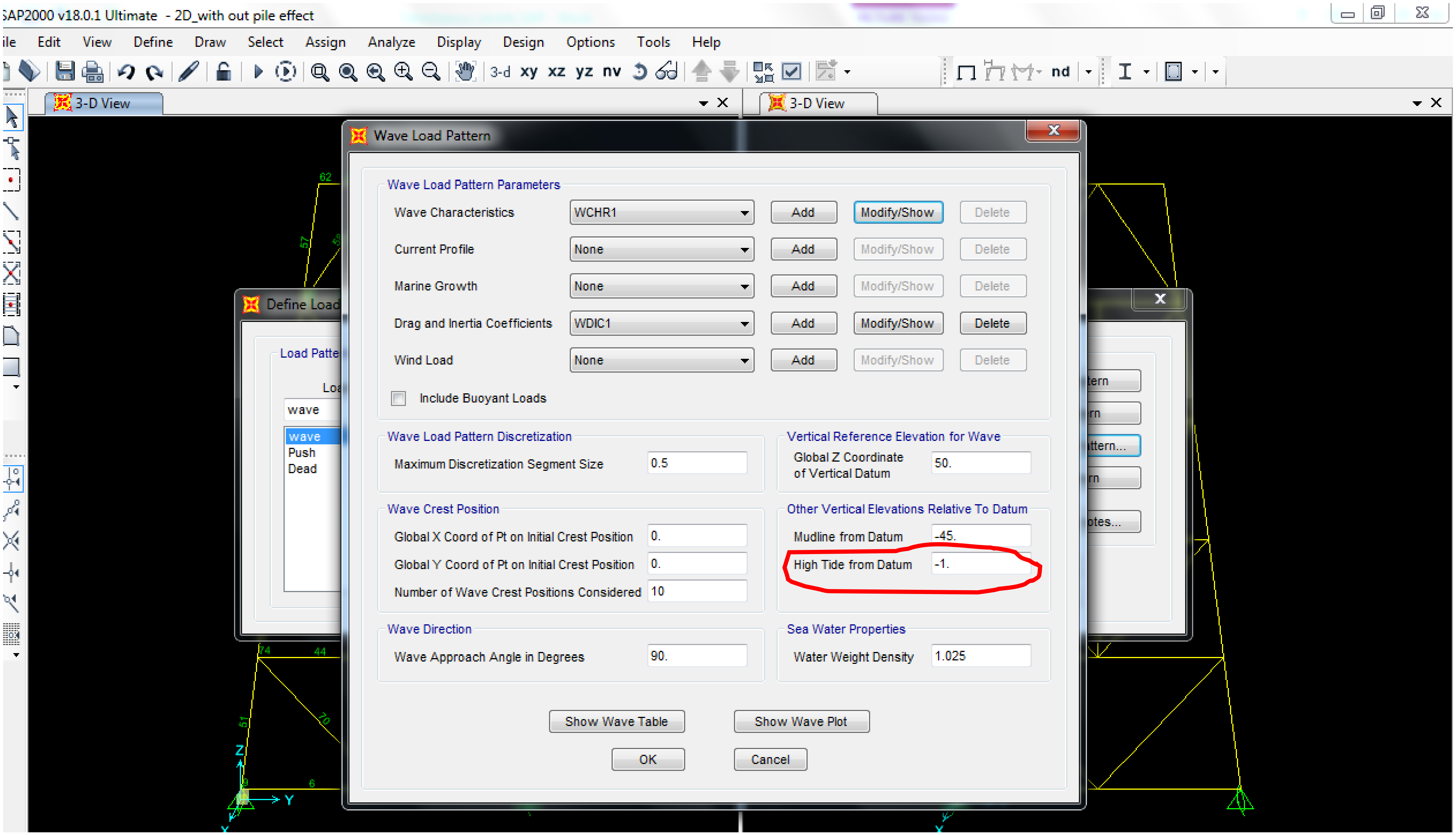
Wave Load Pattern
Wave Load Pattern Parameters
Wave Characteristics WCHR1 Add Modify/Show Delete
Current Profile None Add Modify/Show Delete
Wave Characteristics
Edit
Wave Characteristic Name WCHR1
Wave Factors
Wave Kinematics Factor 1.
Storm Water Depth 55.
Wave Type
From Selected Wave Theory
User Defined
Wave Data
Wave Height 10.
Wave Period 10
Wave Theory
Airy Wave Theory (Linear)
Stokes Wave Theory Order
Cnoidal Wave Theory Order
OK Cancel
Show Wave Table Show Wave Plot
OK Cancel
Define Load
wave
Push
Dead


Wavelength
Wave Height
STILL WATER LEVEL
Wave Crest
Wave Trough
Orbital path of water molecules


storm
wind
swell
"sea"
fetch
direction of wave advance
limit of storm impact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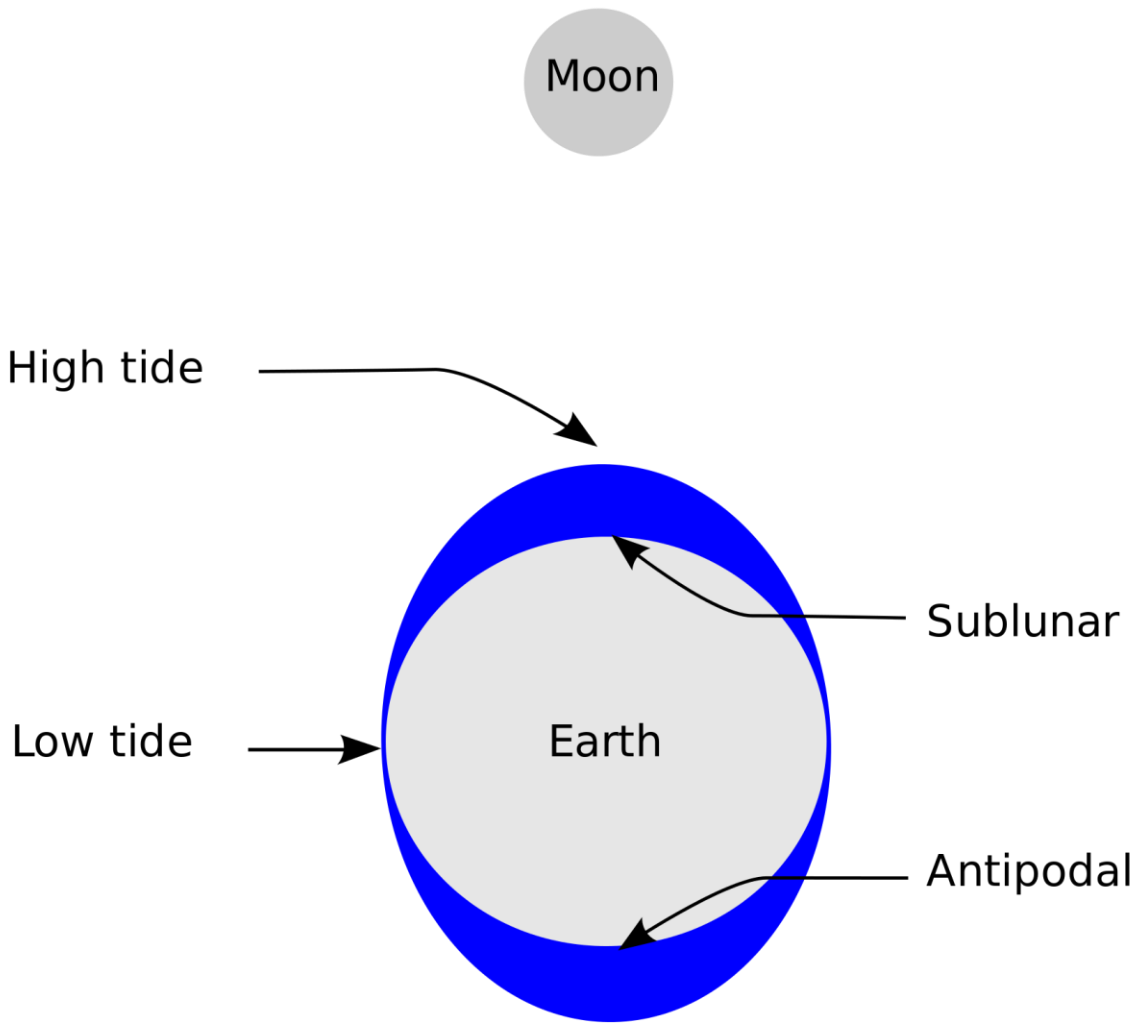
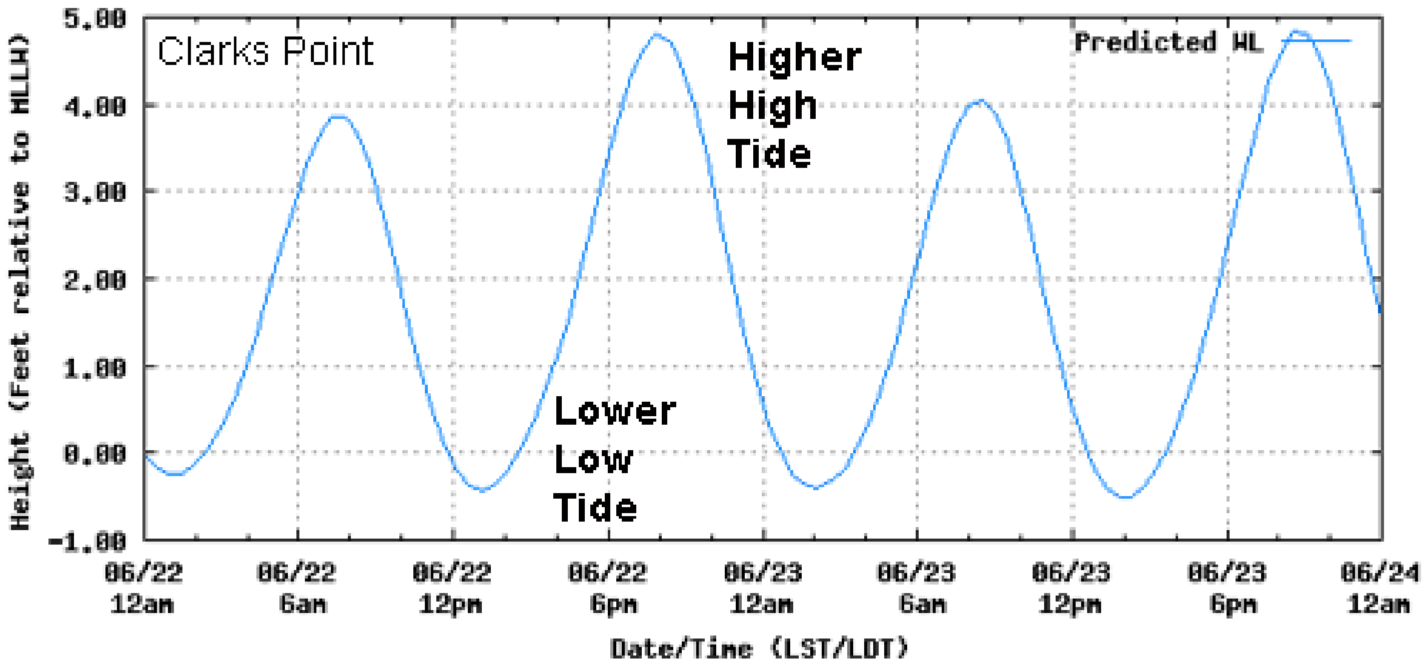
3-D View
Wave Load Pattern
Wave Load Pattern Parameters
Wave Characteristics WCHR1 Add Modify/Show Delete
Current Profile None Add Modify/Show Delete
Marine Growth None Add Modify/Show Delete
Drag and Inertia Coefficients WDIC1 Add Modify/Show Delete
Wind Load None Add Modify/Show Delete
Include Buoyant Loads
Wave Load Pattern Discretization
Maximum Discretization Segment Size 0.5
Vertical Reference Elevation for Wave
Global Z Coordinate of Vertical Datum 50.
Wave Crest Position
Global X Coord of Pt on Initial Crest Position 0.
Global Y Coord of Pt on Initial Crest Position 0.
Number of Wave Crest Positions Considered 10
Other Vertical Elevations Relative To Datum
Mudline from Datum -45.
High Tide from Datum -1.
Wave Direction
Wave Approach Angle in Degrees 90.
Sea Water Properties
Water Weight Density 1.025
Show Wave Table
Show Wave Plot
OK
Cancel
Define Load
Load Patte
wave
wave
Push
Dead

The values for the API Default drag and inertia coefficients depend on whether the location considered is above or below the specified high tide elevation as shown in the following table.

API Default Drag and Inertia Coefficients

Location	Drag Coefficient	Inertia Coefficient
Above High Tide Elevation (Smooth)	0.65	1.6
Below or At High Tide Elevation (Smooth)	1.05	1.2


Moon
High tide
Sublunar
Low tide
Earth
Antipodal


Clarks Point
Predicted WL
Higher
High
Tide
Lower
Low
Tide
5.00
4.00
3.00
2.00
1.00
0.00
-1.00
Height (Feet relative to MLLW)
06/22 12am
06/22 6am
06/22 12pm
06/22 6pm
06/23 12am
06/23 6am
06/23 12pm
06/23 6pm
06/24 12am
Date/Time (LST/LDT)

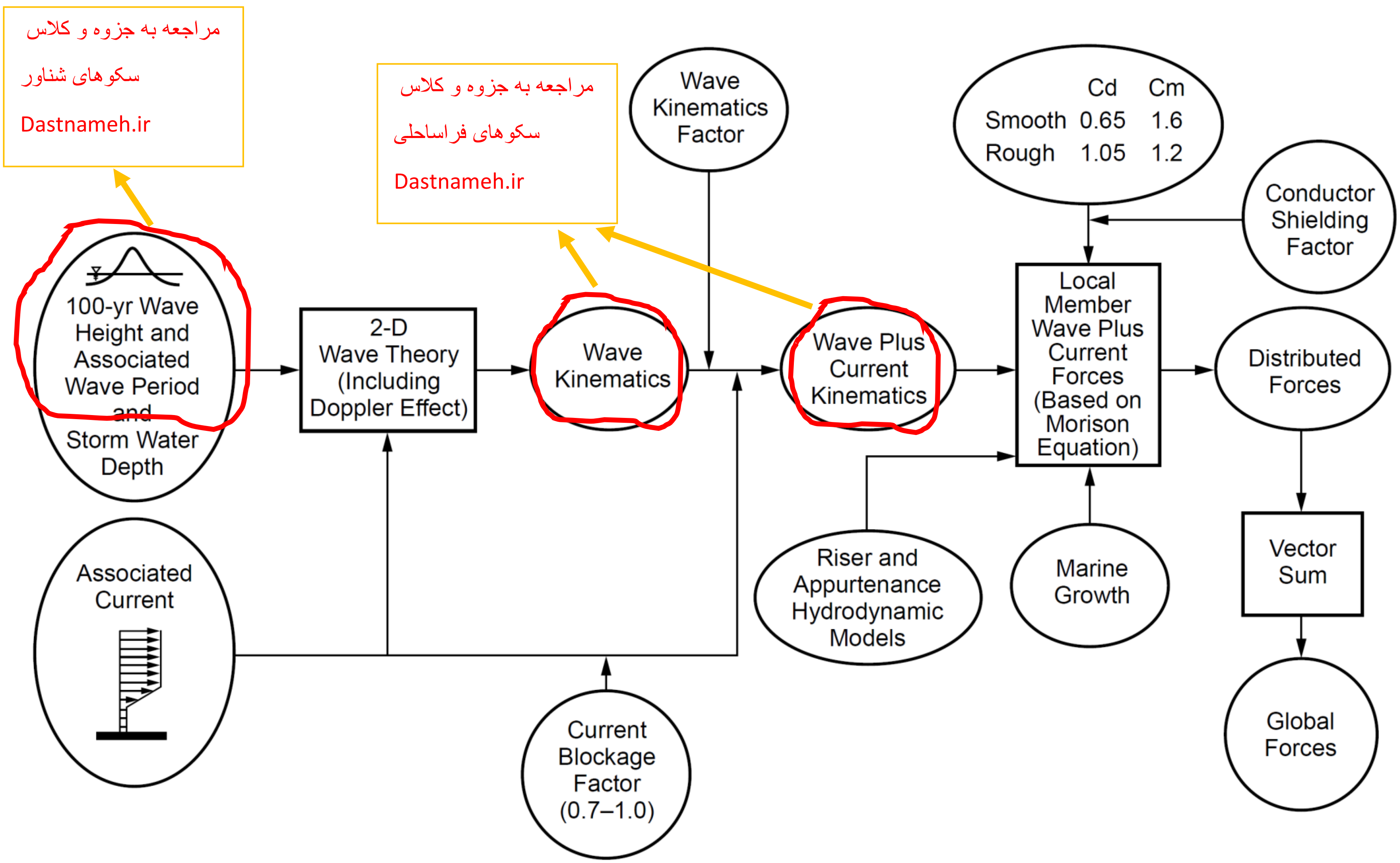


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

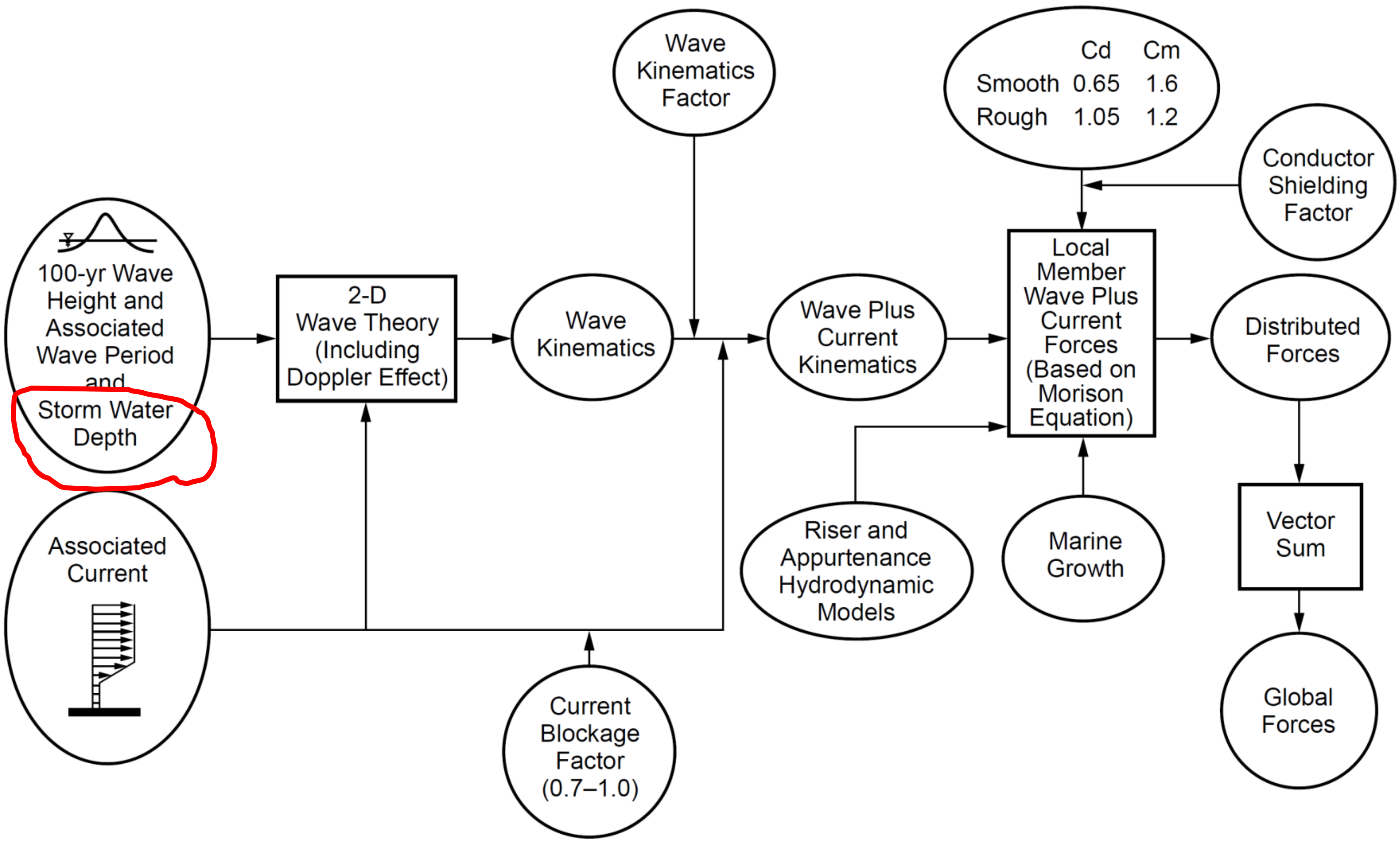
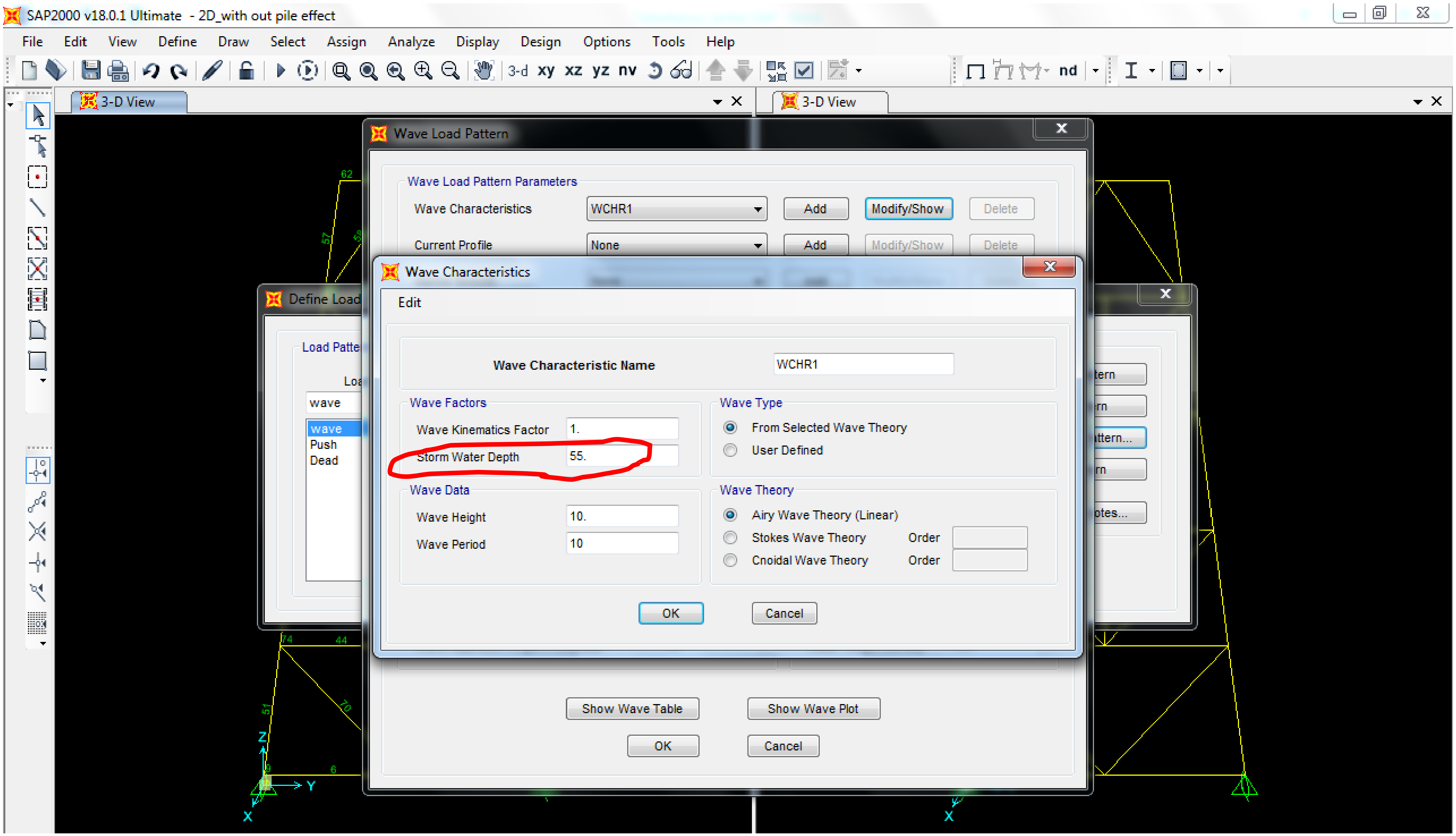


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis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3-D View
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Wave Load Pattern Parameters
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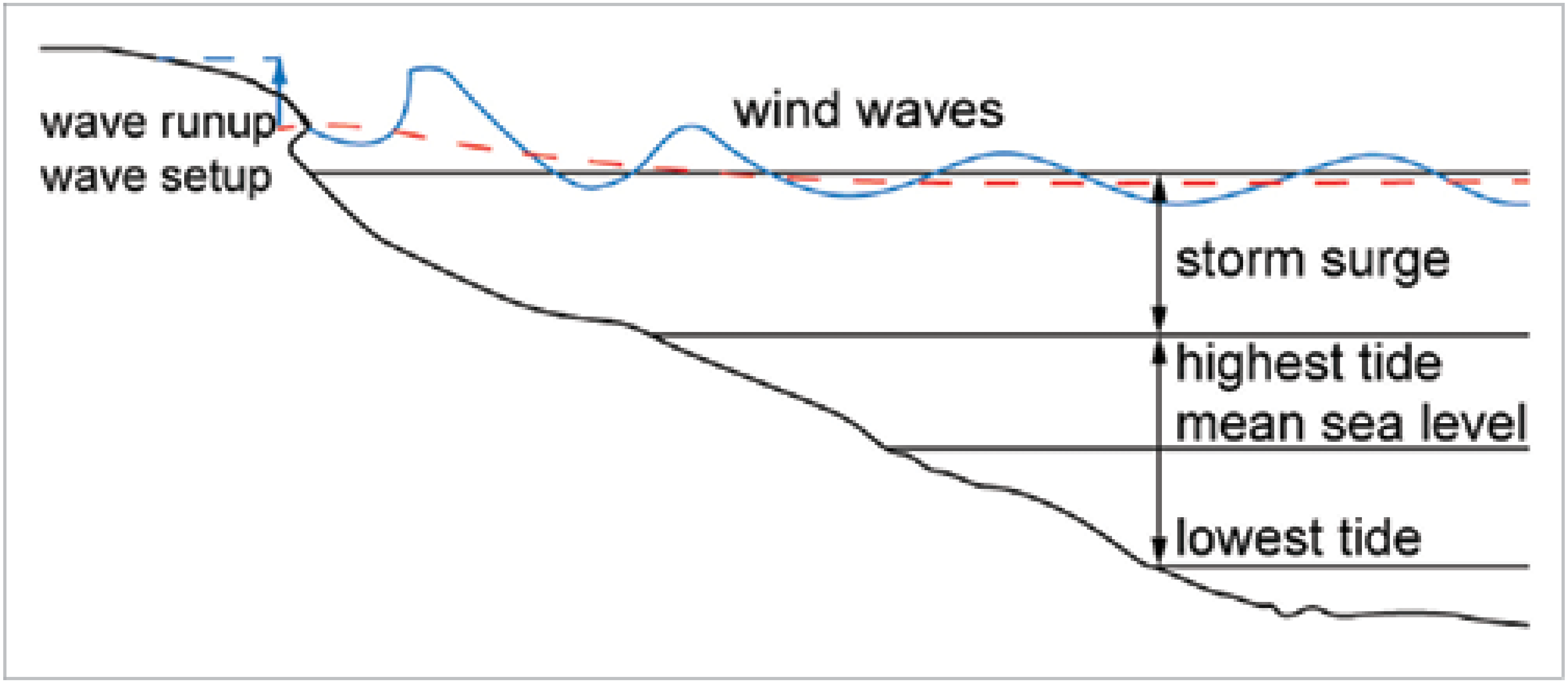
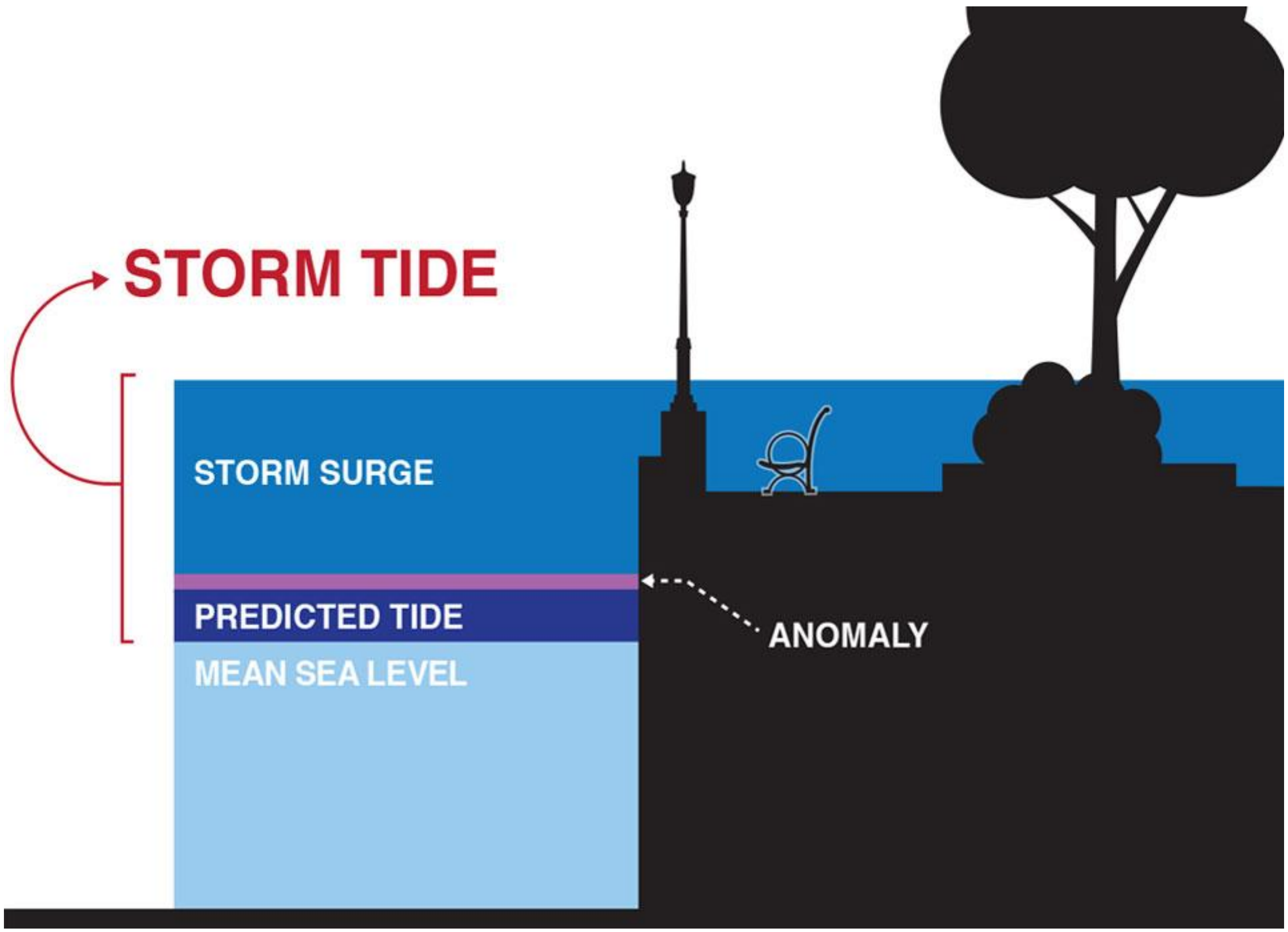
Current Profile None Add Modify/Show Delete
Wave Characteristics
Edit
Wave Characteristic Name WCHR1
Wave Factors
Wave Kinematics Factor 1.
Storm Water Depth 55.
Wave Type
From Selected Wave Theory
User Defined
Wave Data
Wave Height 10.
Wave Period 10
Wave Theory
Airy Wave Theory (Linear)
Stokes Wave Theory Order
Cnoidal Wave Theory Order
OK Cancel
Show Wave Table Show Wave Plot
OK Cancel
Define Load
wave
Push
Dead


wave runup
wave setup
wind waves
storm surge
highest tide
mean sea level
lowest tide


STORM TIDE
STORM SURGE
PREDICTED TIDE
MEAN SEA LEVEL
ANOMALY

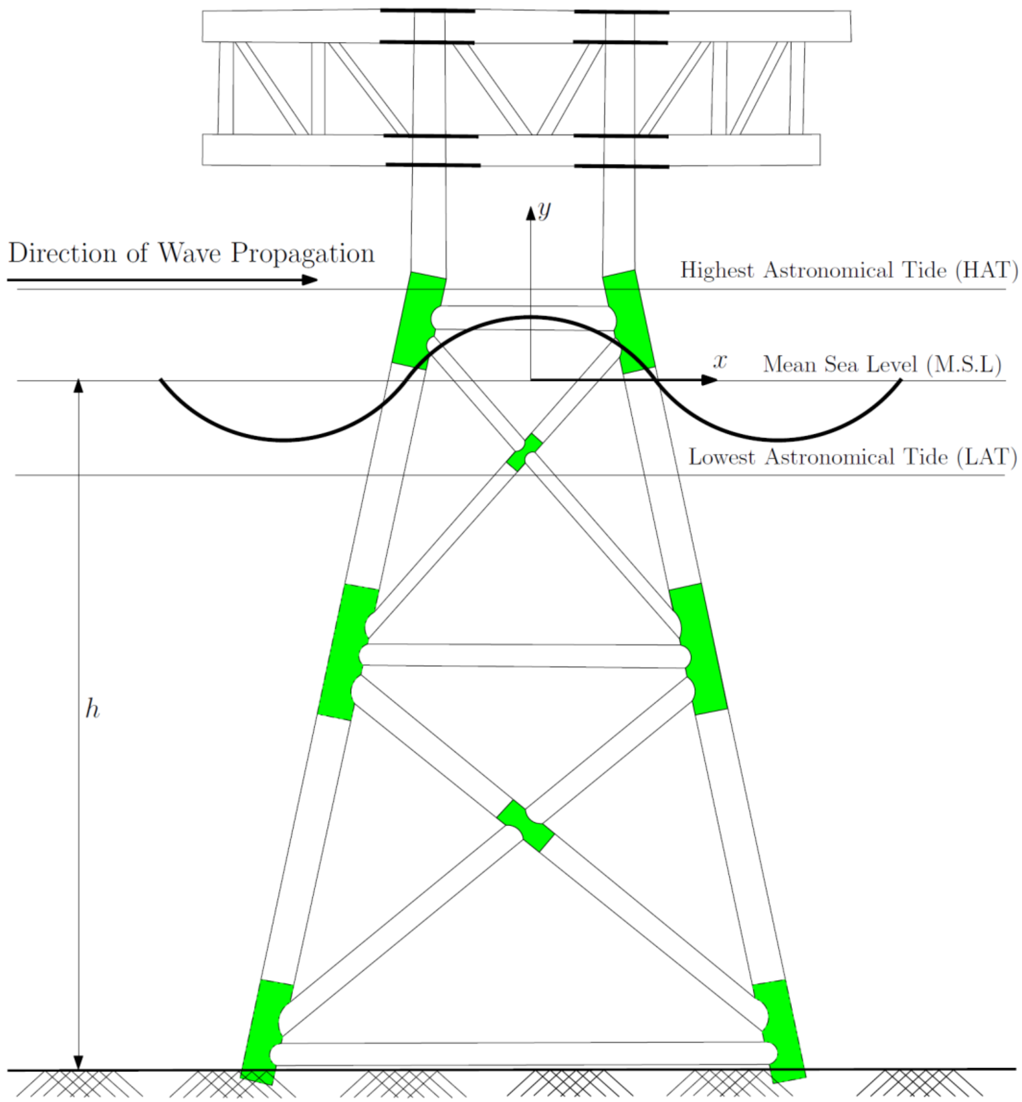
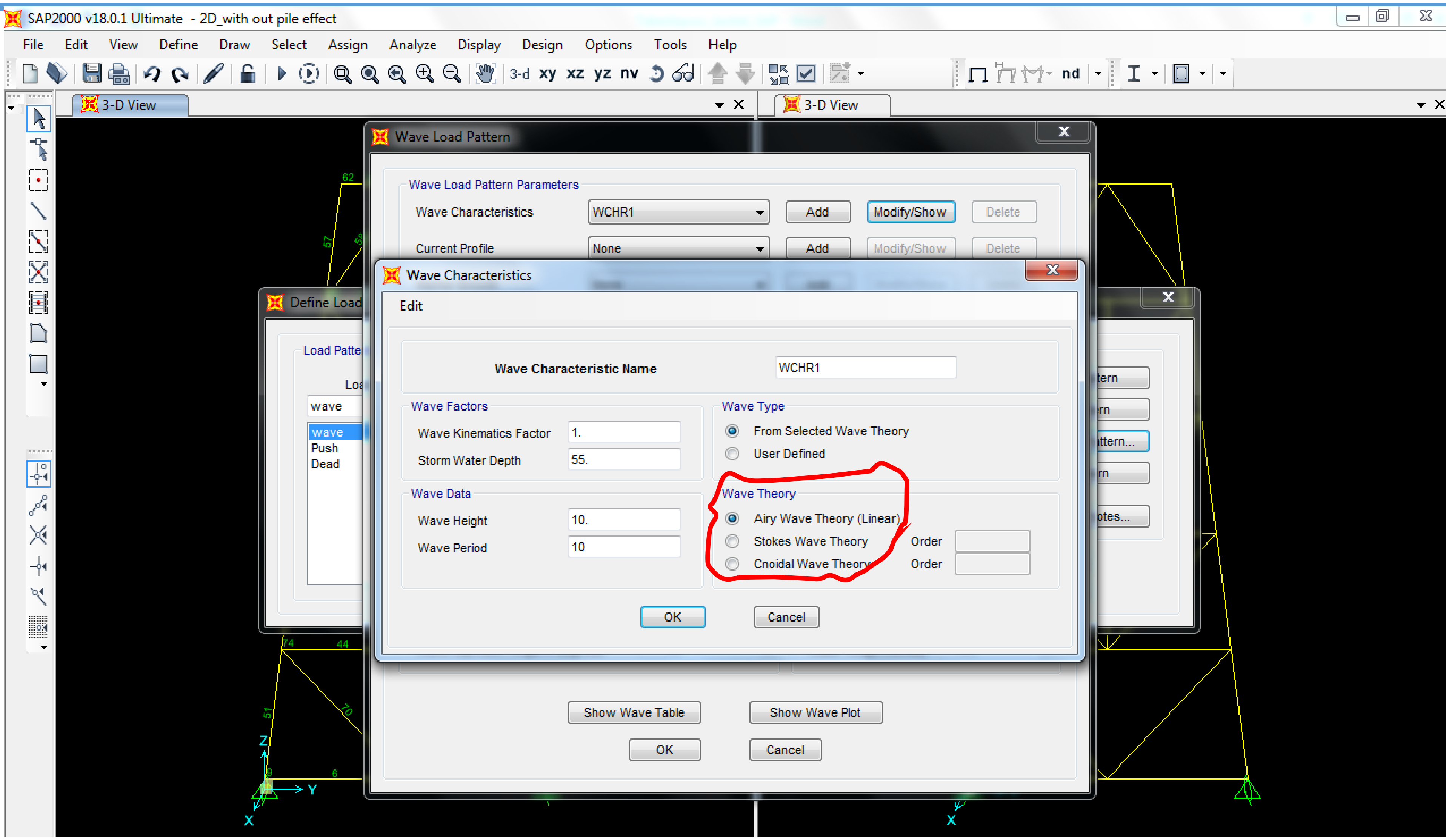


Figure 3.4: Wave Loads on Jacket Structure

3.4.7 Selection of Wave Theory

The computation of wave kinematics such as velocity and acceleration involves the equations from wave theory. There are various kinds of solutions available depending on the accuracy required, and parameters involved in the computation. The various wave theories are listed below.

- Linear / Airy Wave Theory
- Stokes Wave Theory (up to 5th order approximations)
- Stream Function Wave Theory (up to 22nd order approximations)
- Cnoidal Wave Theory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Wave Characteristics
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Current Profile
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wave
Push
Dead
Wave Characteristics
Edit
Wave Characteristic Name
WCHR1
Wave Factors
Wave Kinematics Factor
1.
Storm Water Depth
55.
Wave Type
From Selected Wave Theory
User Defined
Wave Data
Wave Height
10.
Wave Period
10
Wave Theory
Airy Wave Theory (Linear)
Stokes Wave Theory
Cnoidal Wave Theory
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OK
Cancel
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Show Wave Plot

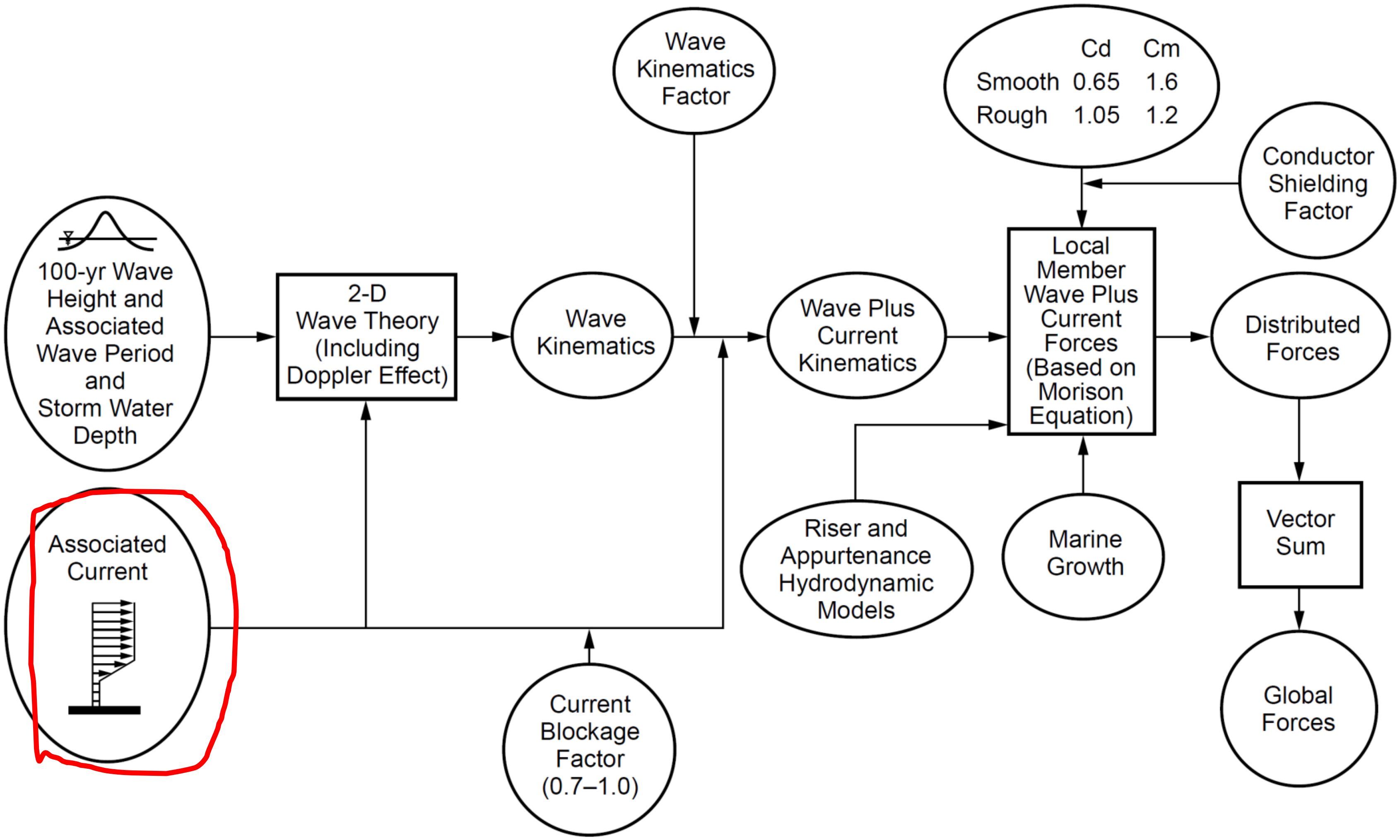


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

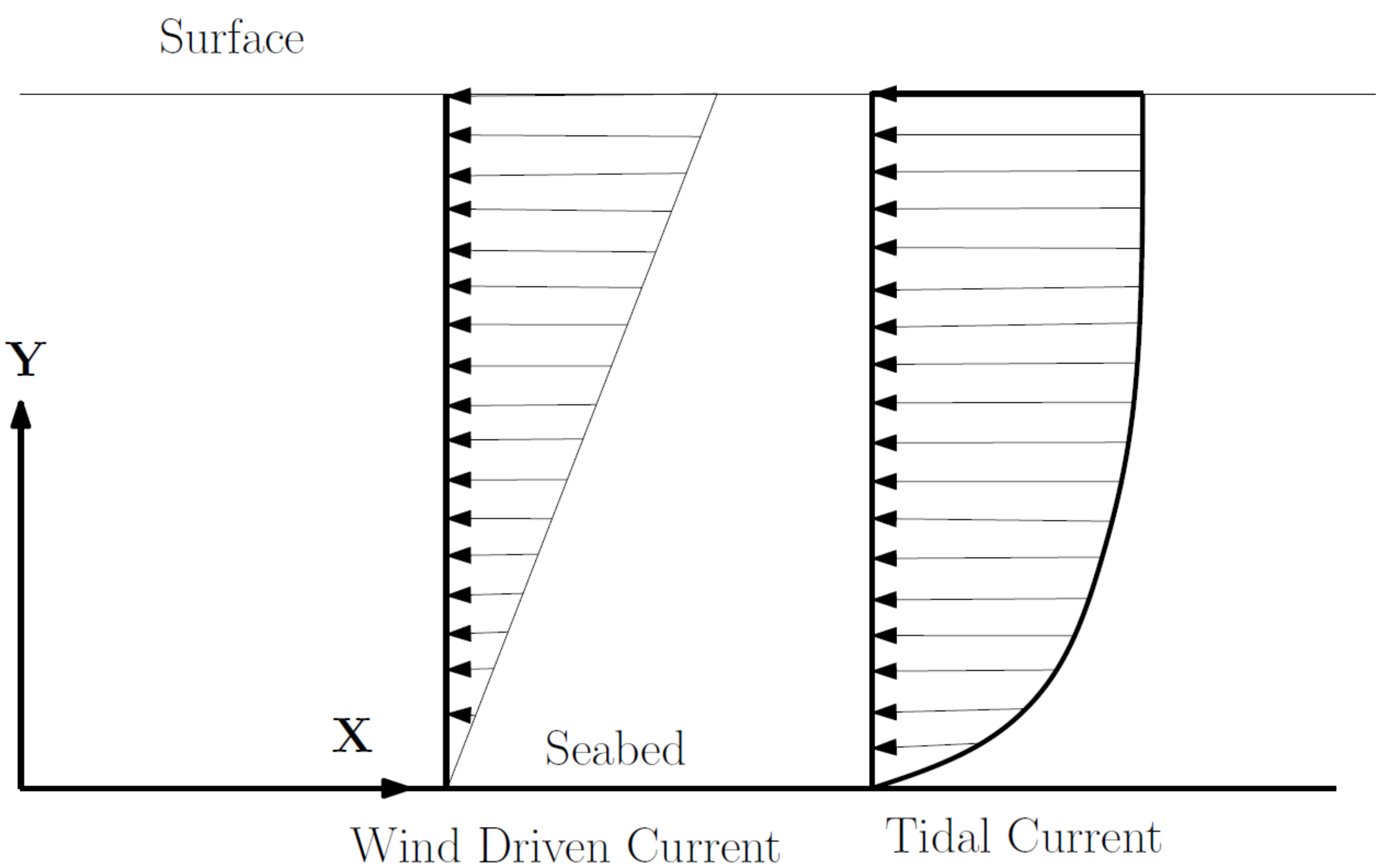


Figure 3.1: Current Profiles

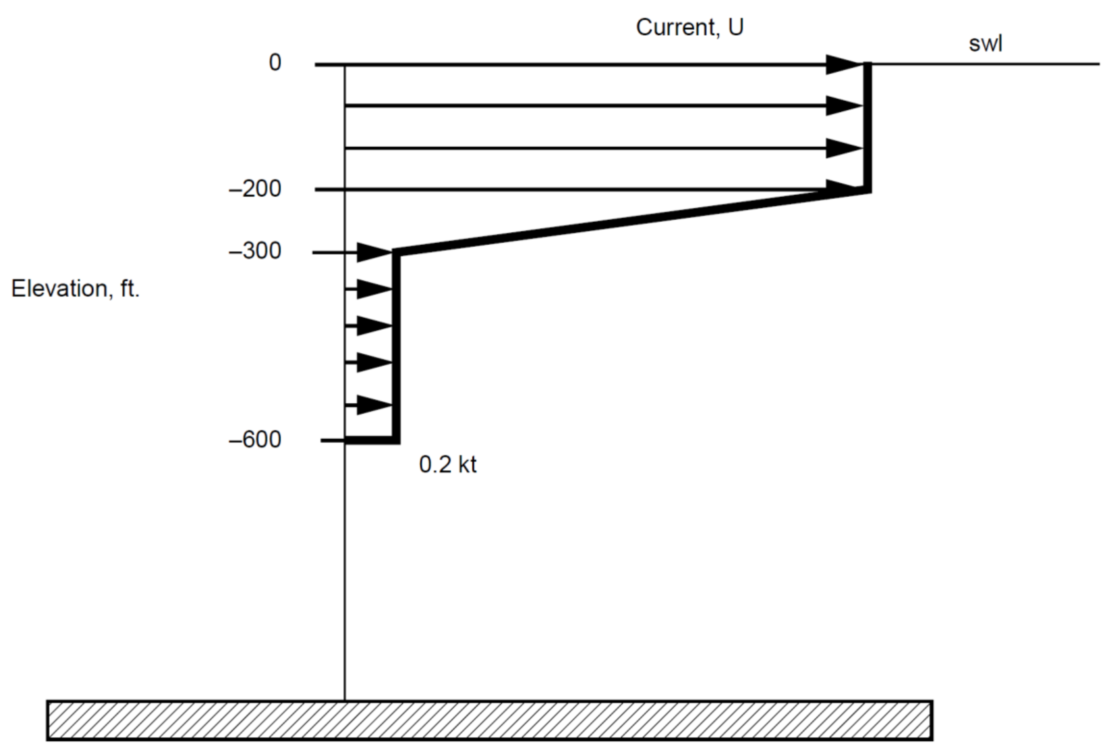


Figure 2.3.4-6—Guideline Design Current Profile for L-1, L-2, and L-3 Structures, Gulf of Mexico, North of 27°N and West of 86°W

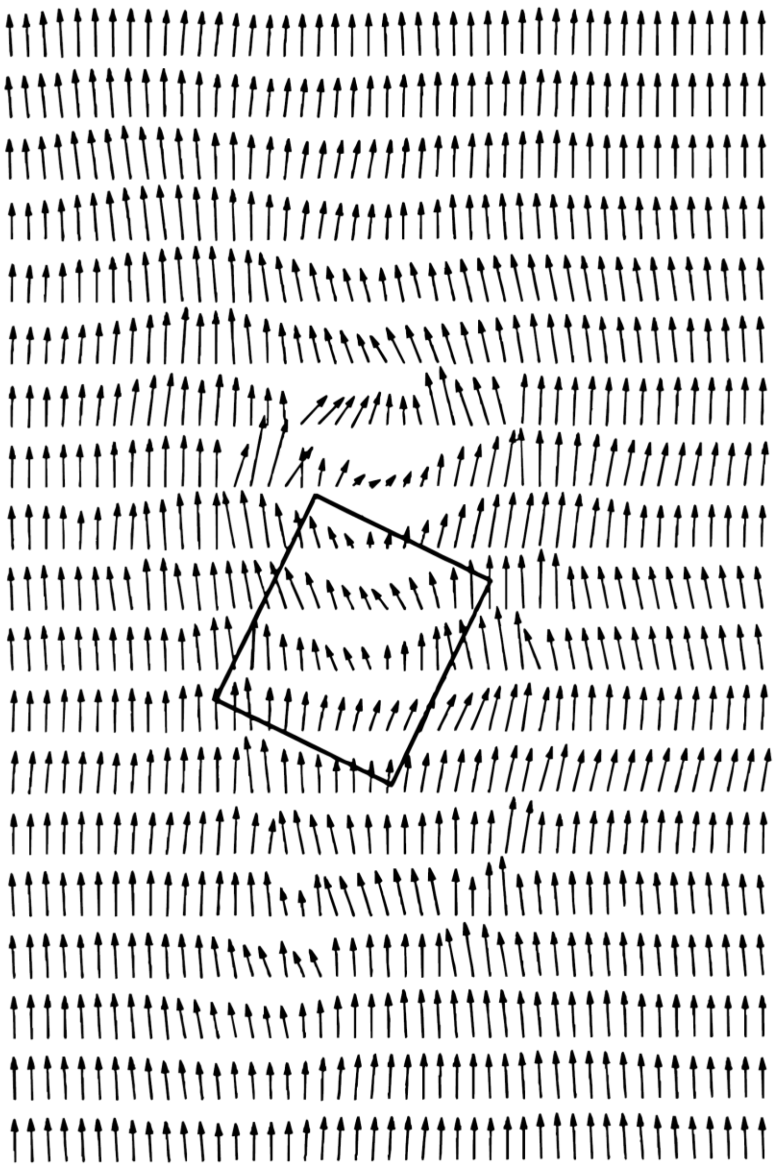
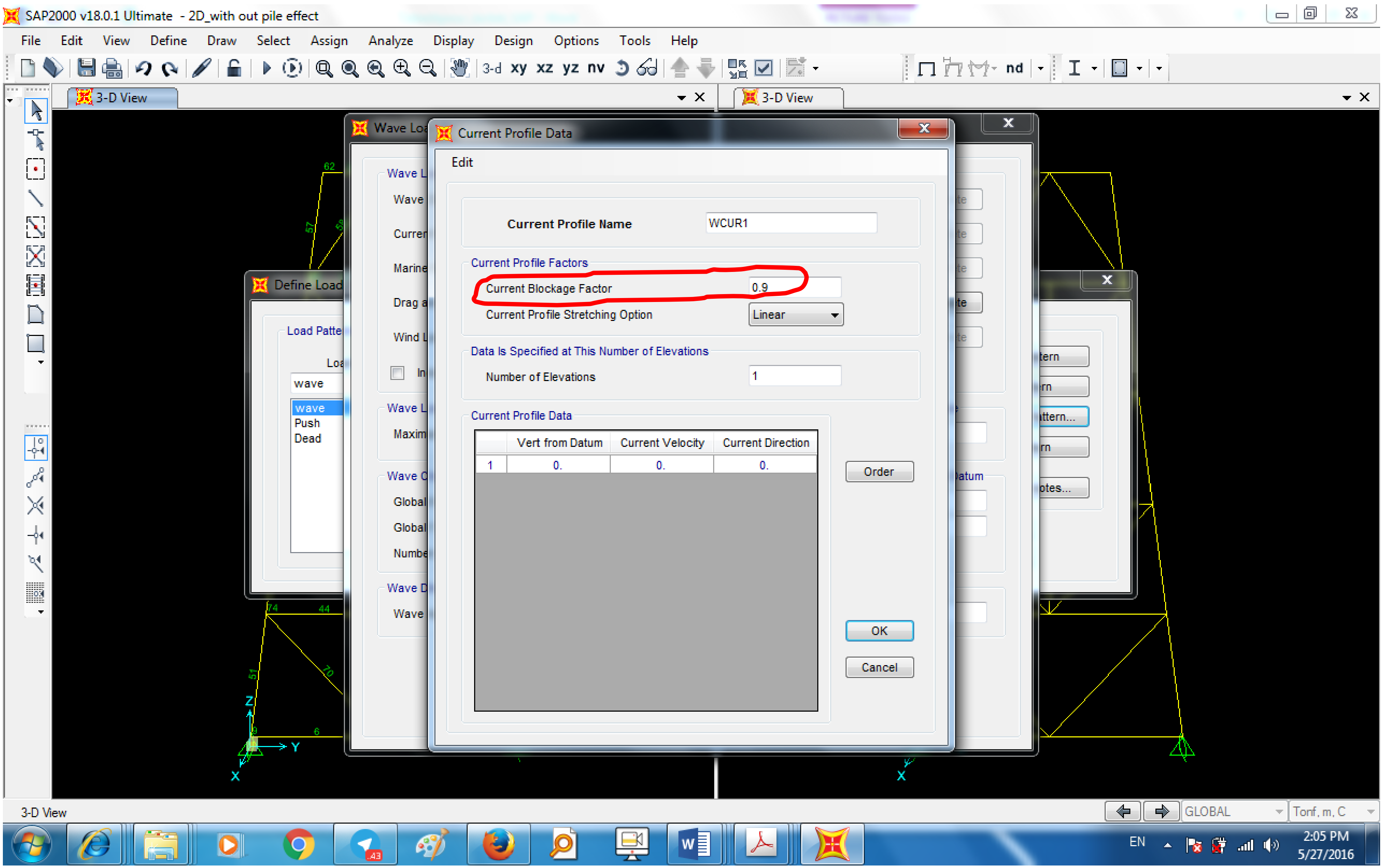


Figure C2.3.1-1—Current Vectors Computed from Doppler Measurements at 60 ft on the Bullwinkle Platform (100 cm/s →)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Current Profile Data
Edit
Current Profile Name
WCUR1
Current Profile Factors
Current Blockage Factor
0.9
Current Profile Stretching Option
Linear
Data Is Specified at This Number of Elevations
Number of Elevations
1
Current Profile Data
Vert from Datum
Current Velocity
Current Direction
Order
OK
Cancel
3-D View
GLOBAL
Tonf, m, C
2:05 PM
5/27/2016

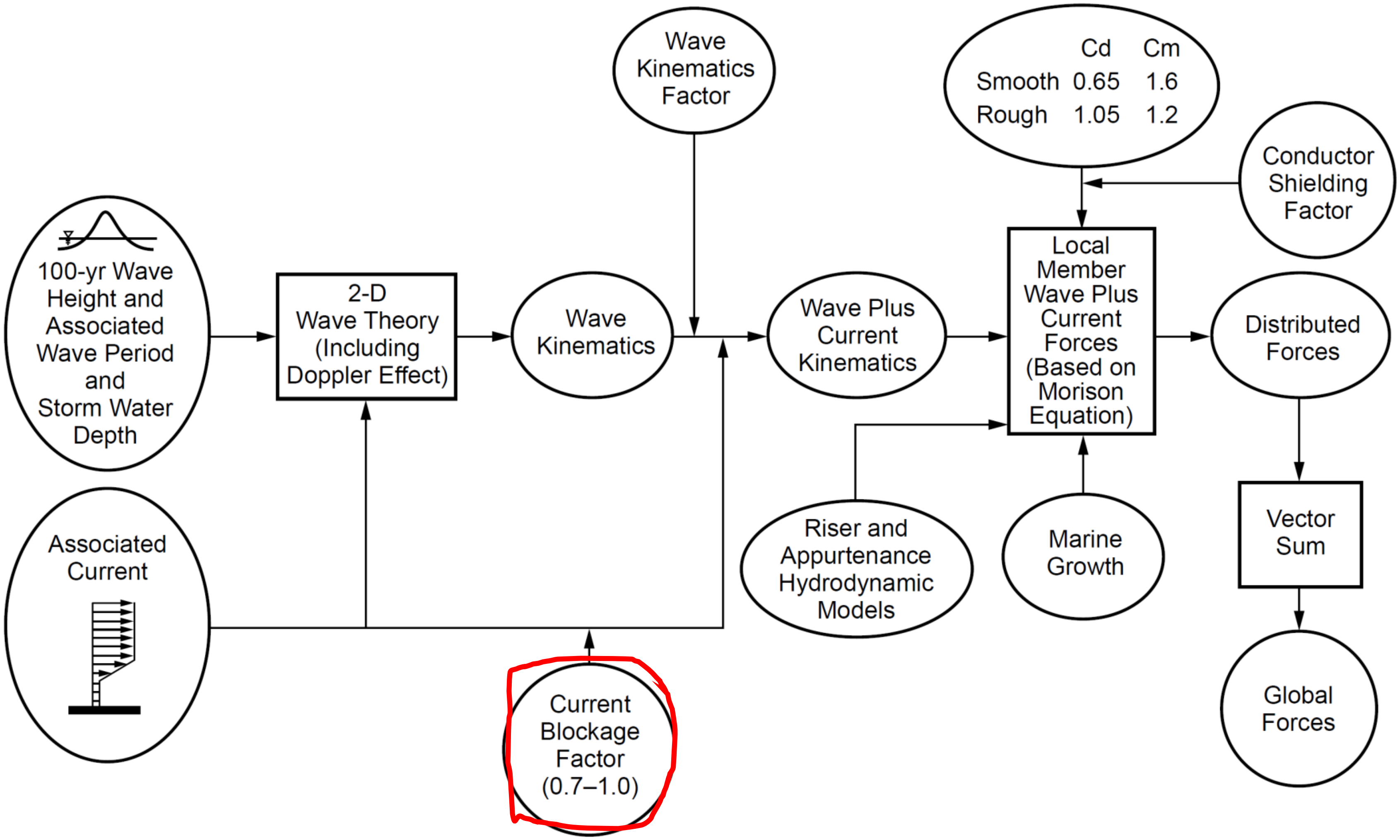


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

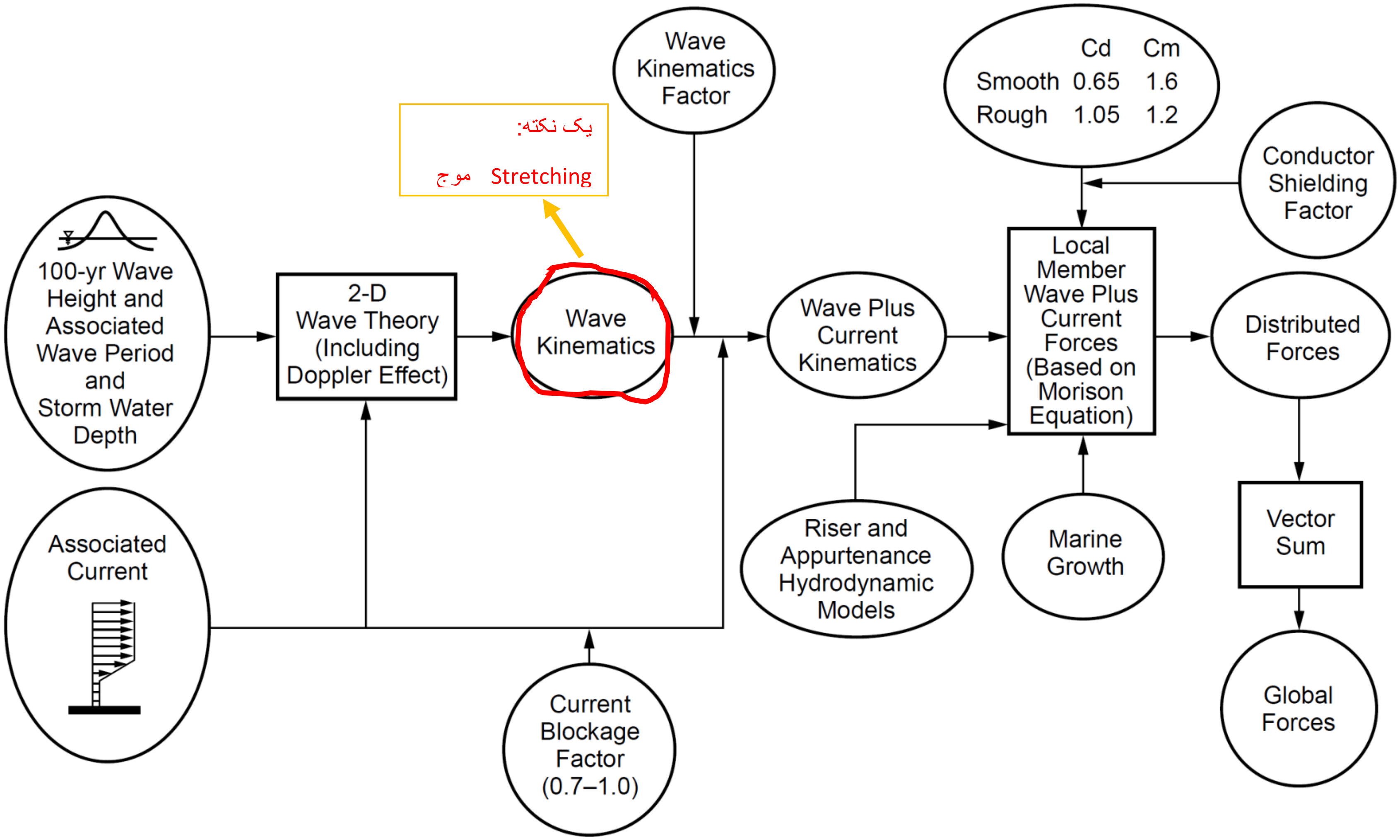
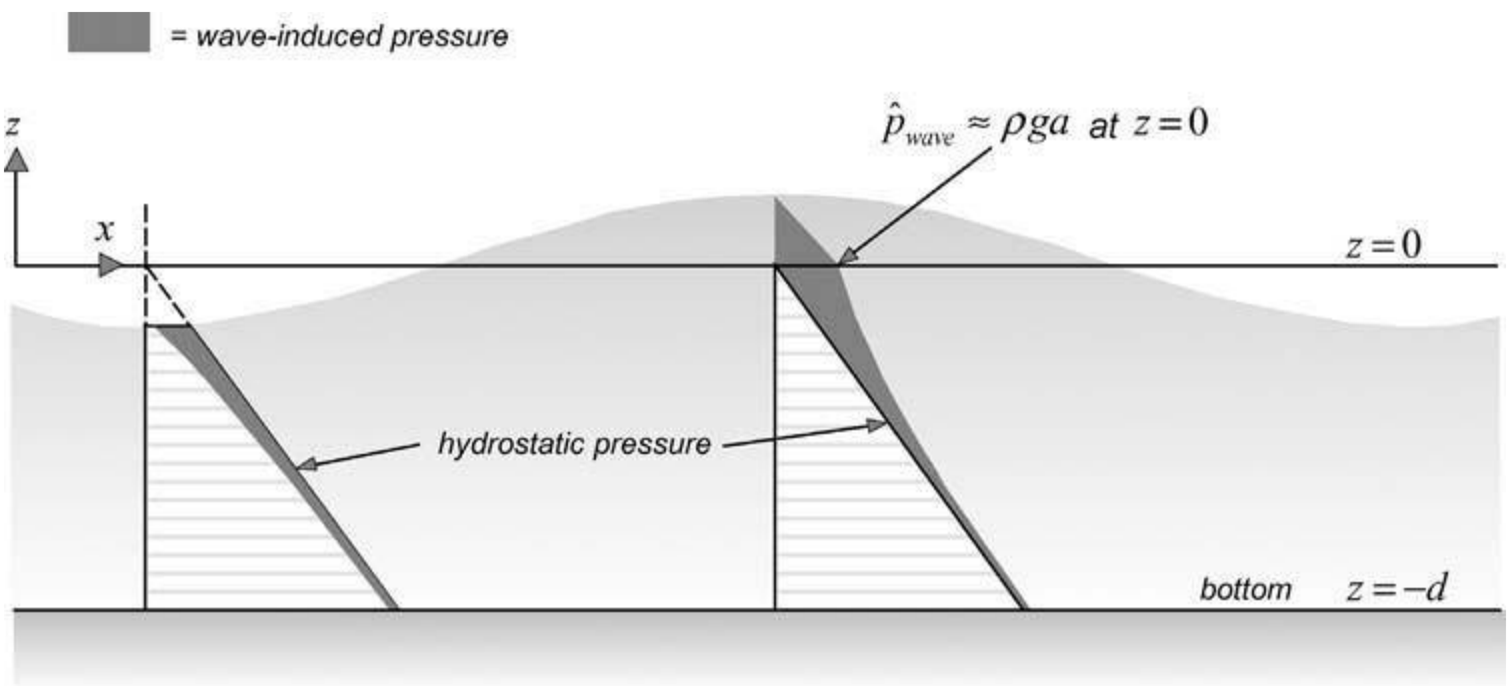


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

Stretched wave



USFOS

سرچ در

USFOS
Hydrodynamics
Theory Description of use Verification

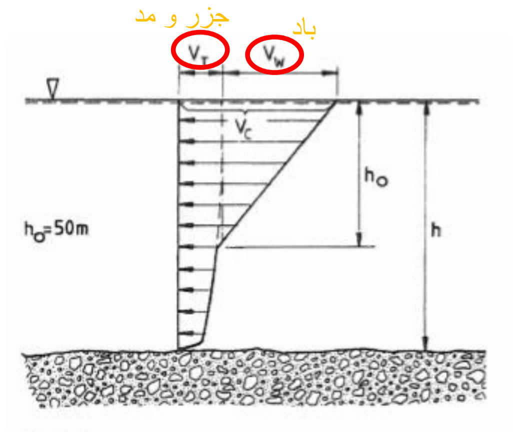


Figure 2-3
Current profile

Although the tidal current velocity can be measured in the absence of waves, and the wind generated current velocity can be calculated, the resulting current velocity in the extreme storm condition is a rather uncertain quantity.

The wind generated current may be taken as:

$$v_W = 0.017\, v_{R1}$$

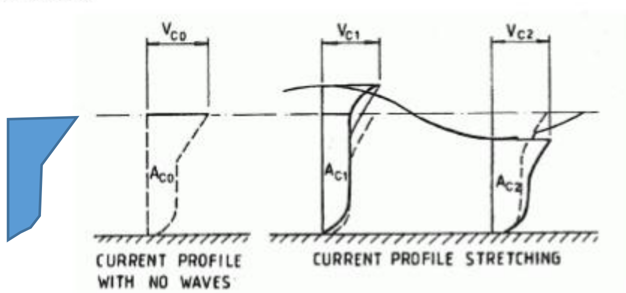
where

v_{R1} = wind velocity for z = 10 m/t = 1 min. See 2.4
z = height above still water
t = averaging period

It is normally assumed that waves and current are coincident in direction.

The variation in current profile with variation in water depth due to wave action is to be accounted for.

In such cases the current profile may be stretched or compressed vertically, but the current velocity at any proportion of the instantaneous depth is constant, see Figure 2-4. By this method the surface current component shall remain constant.



$v_{c0} = v_{c1} = v_{c2}$
$A_{c1} > A_{c0} > A_{c2}$

Figure 2-4
Recommended method for current profile stretching with waves

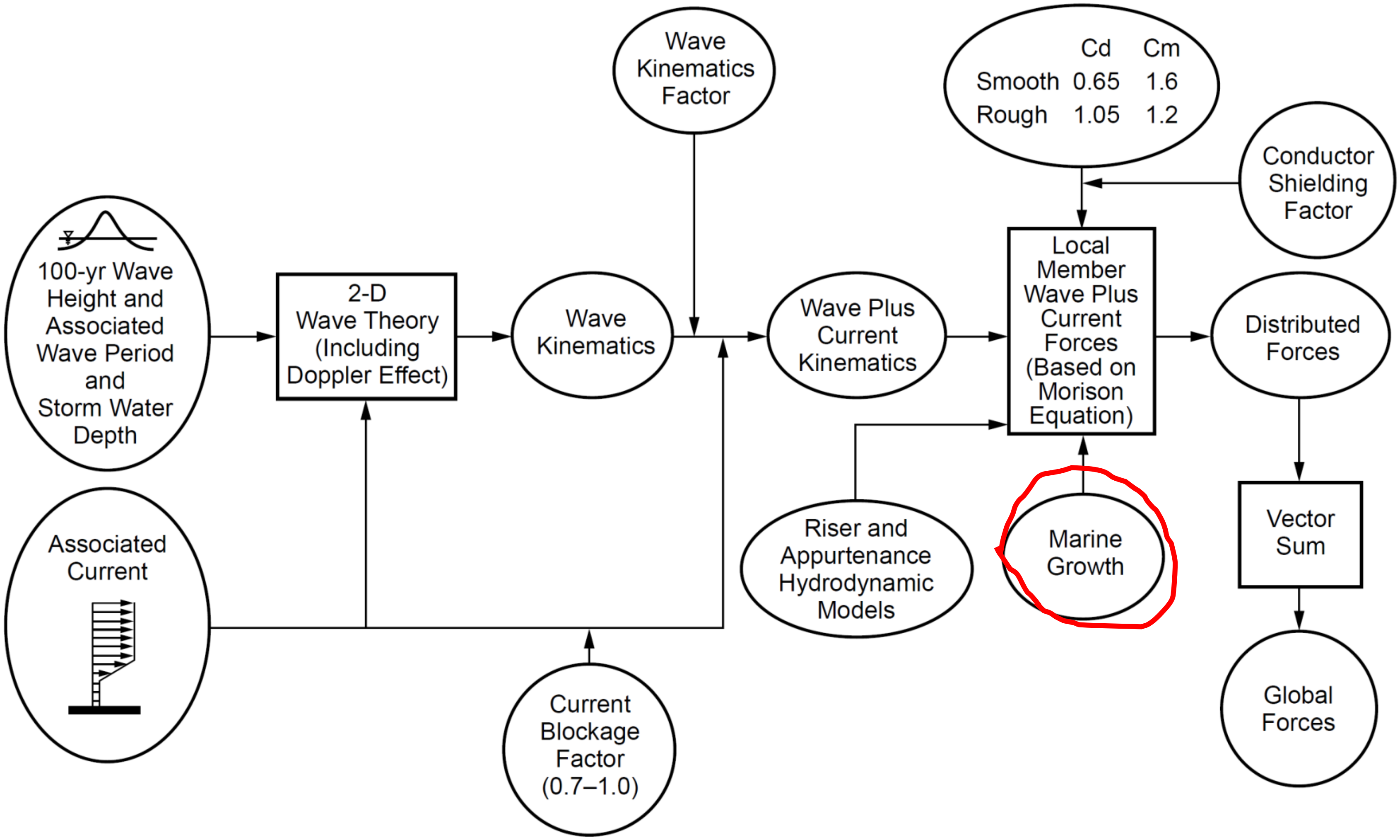
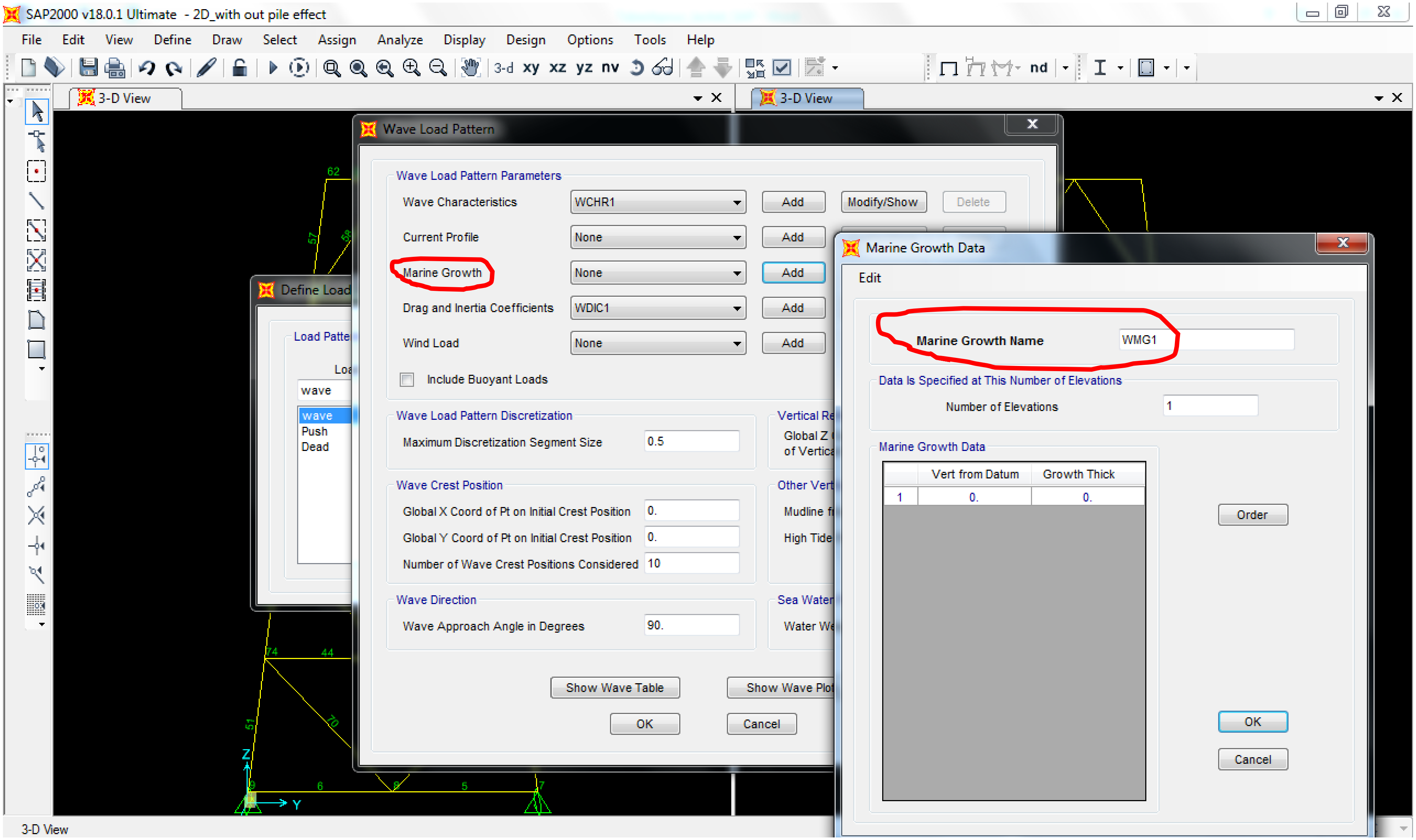


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis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Current Profile None Add
Marine Growth None Add
Drag and Inertia Coefficients WDIC1 Add
Wind Load None Add
Include Buoyant Loads
Wave Load Pattern Discretization
Maximum Discretization Segment Size 0.5
Wave Crest Position
Global X Coord of Pt on Initial Crest Position 0.
Global Y Coord of Pt on Initial Crest Position 0.
Number of Wave Crest Positions Considered 10
Wave Direction
Wave Approach Angle in Degrees 90.
Show Wave Table
OK
Cancel
Marine Growth Data
Edit
Marine Growth Name WMG1
Data Is Specified at This Number of Elevations
Number of Elevations 1
Marine Growth Data
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Order
OK
Cancel


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رویبدنیهای دریایی:

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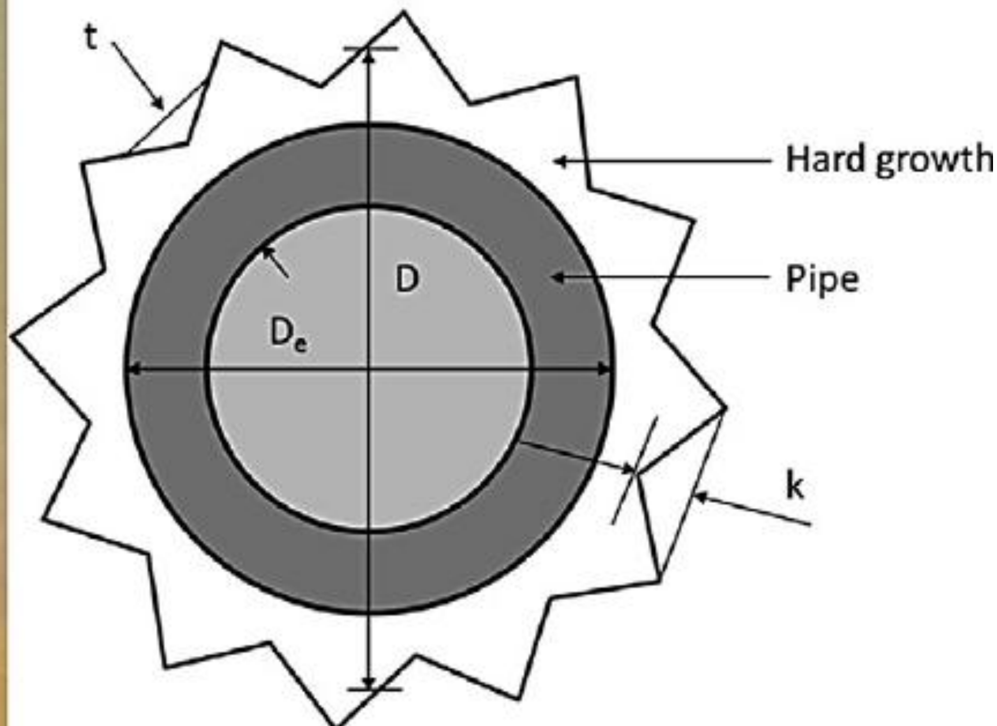
افزایش ضریب درگ به علت افزایش زبری

افزایش جرم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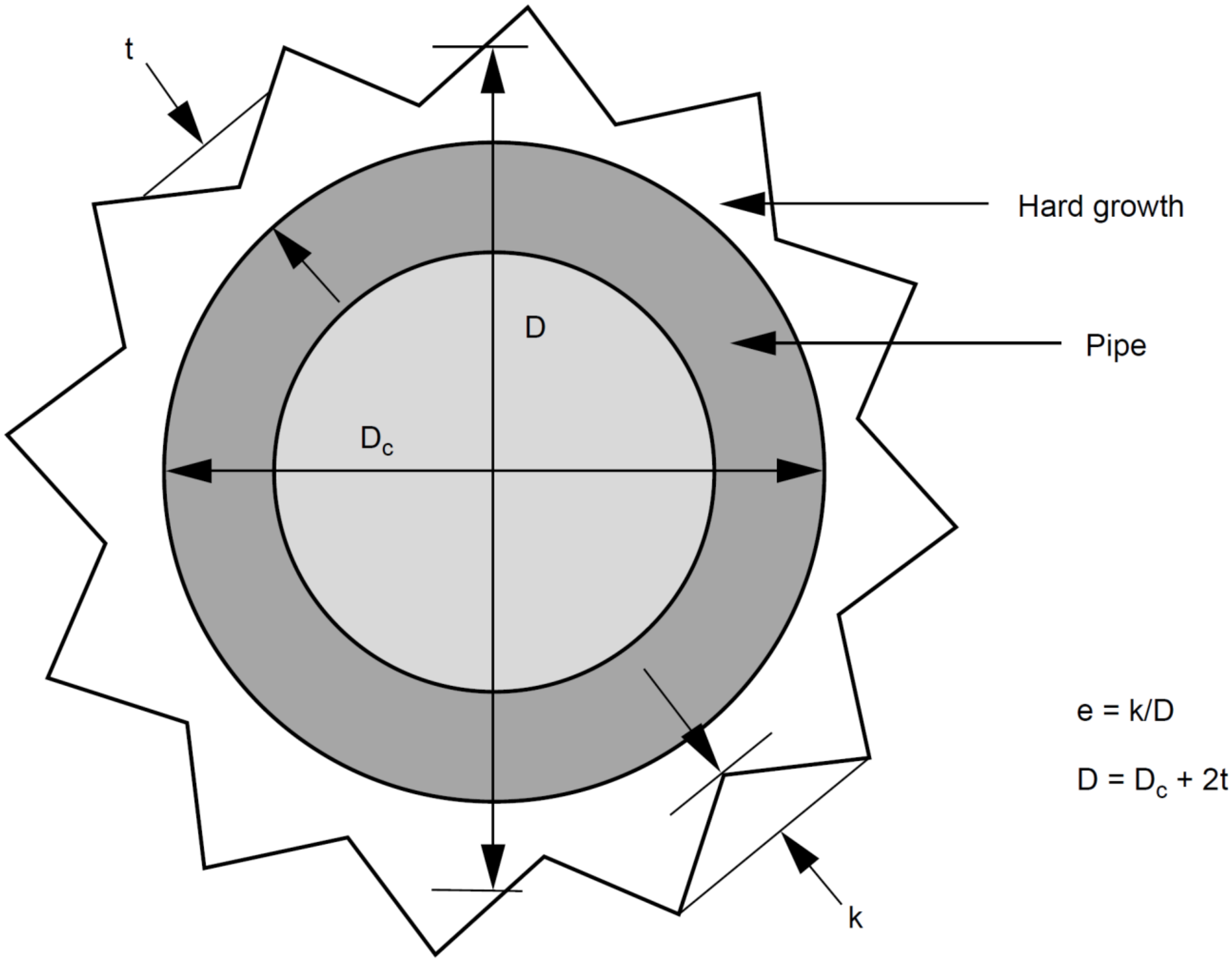
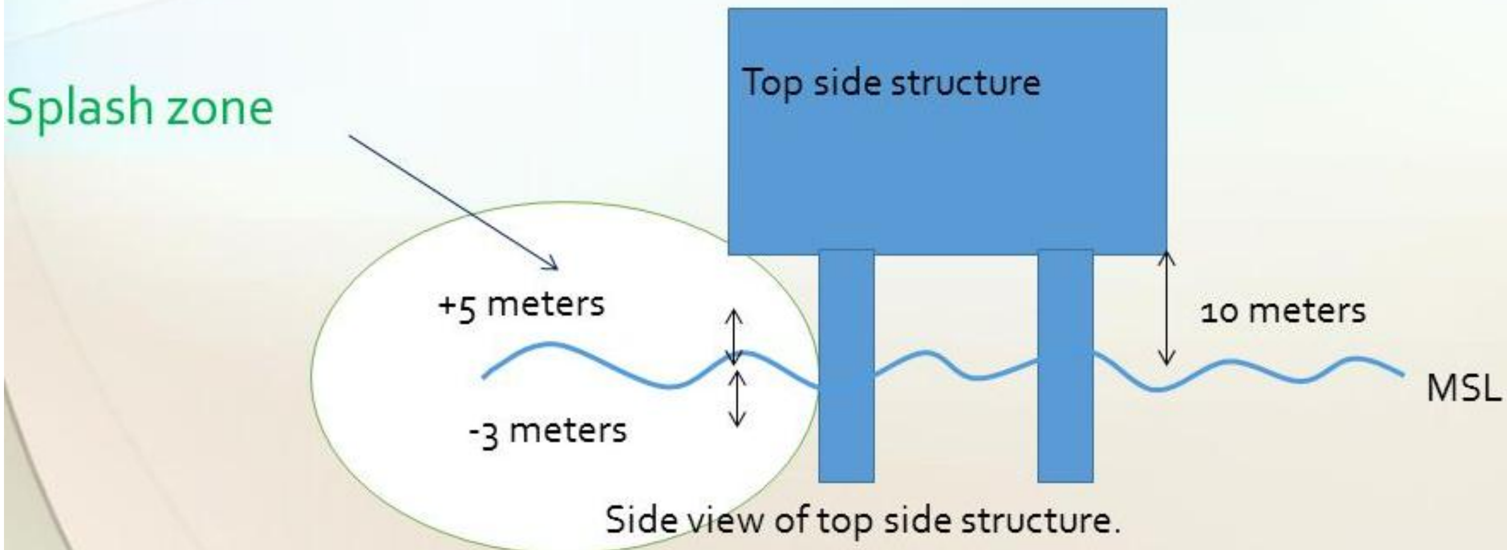


Figure C2.3.1-3—Definition of Surface Roughness Height and Thickness

Splash Zone

- The splash zone is defined as that region below +5.0m MSL and above -3.0m MSL for Malaysian waters.



Side view of top side structure.

3.4.4 Marine Growth

Marine growth is an important part in increasing the loads on offshore structures. The growth of marine algae increases the diameter and roughness of members which in turn cause the wave or current loading to increase. Detailed discussion on the member roughness and its relationship with hydrodynamic coefficients can be found in API RP2A.

The thickness of marine growth generally decrease with depth from the mean sea level and it is maximum in the splash zone. The thickness of marine growth in the splash zone can be as much as 20cm and will reduce below to 5cm. In deeper zones, the thickness may be negligible.

Splash Zone is a region where the water levels fluctuate between low to high. The actual elevation of the bottom and top of these vary from location to location due to different tidal conditions. In general terms, the splash zone will vary from -3m to +5m.

In structural analysis, the increased diameter of the member ($D = d + t_m$) shall be included so that the wave and current loads can be calculated correctly. D and d are the diameter of increased member and original member respectively and t_m is the thickness of marine growth.

The roughness of the marine growth is an important parameter in determining the drag and inertia coefficients. reference shall be made relevant API RP2A clauses for more details.

API Default Drag and Inertia Coefficients

Location	Drag Coefficient	Inertia Coefficient
Above High Tide Elevation (Smooth)	0.65	1.6
Below or At High Tide Elevation (Smooth)	1.05	1.2

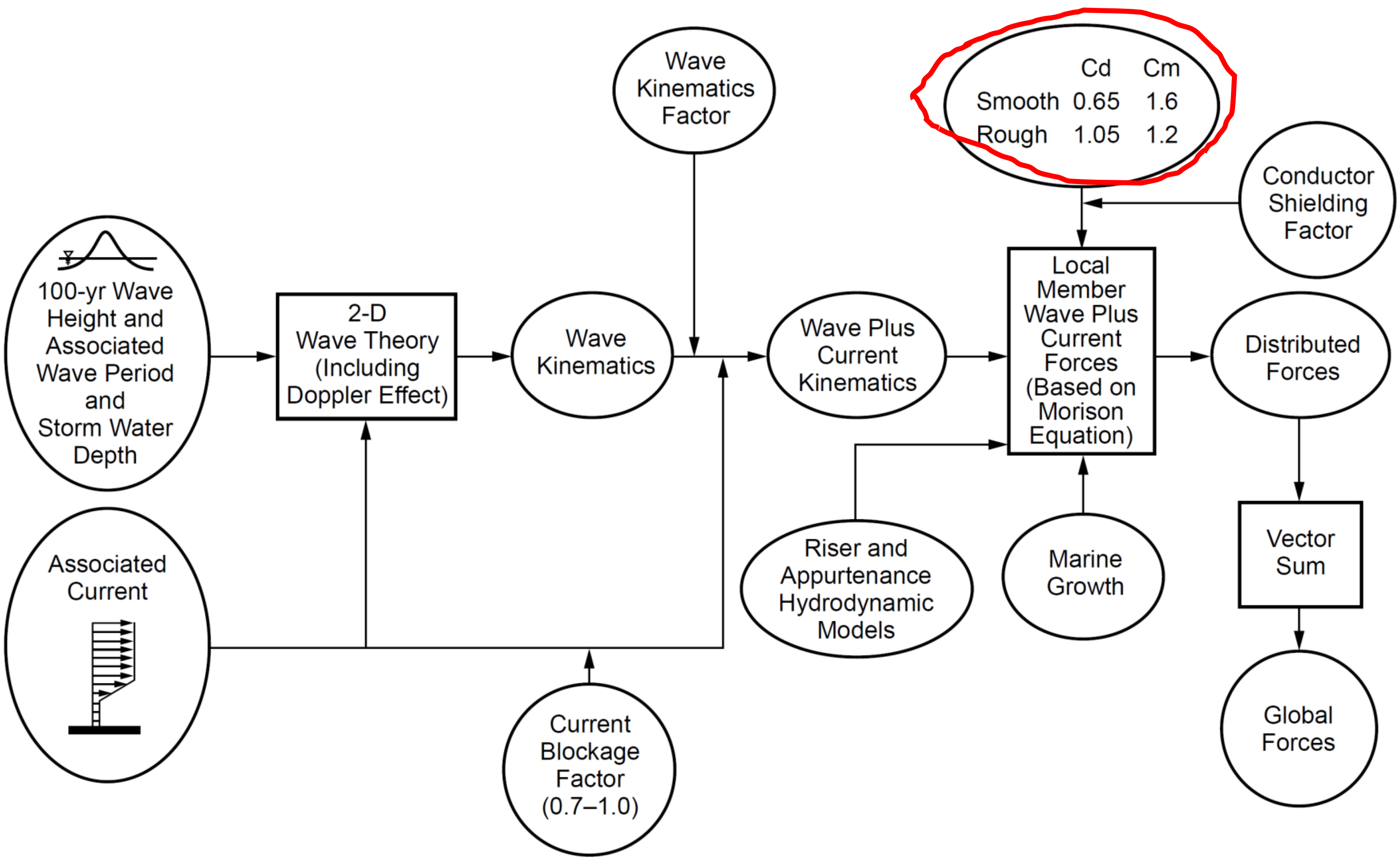


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

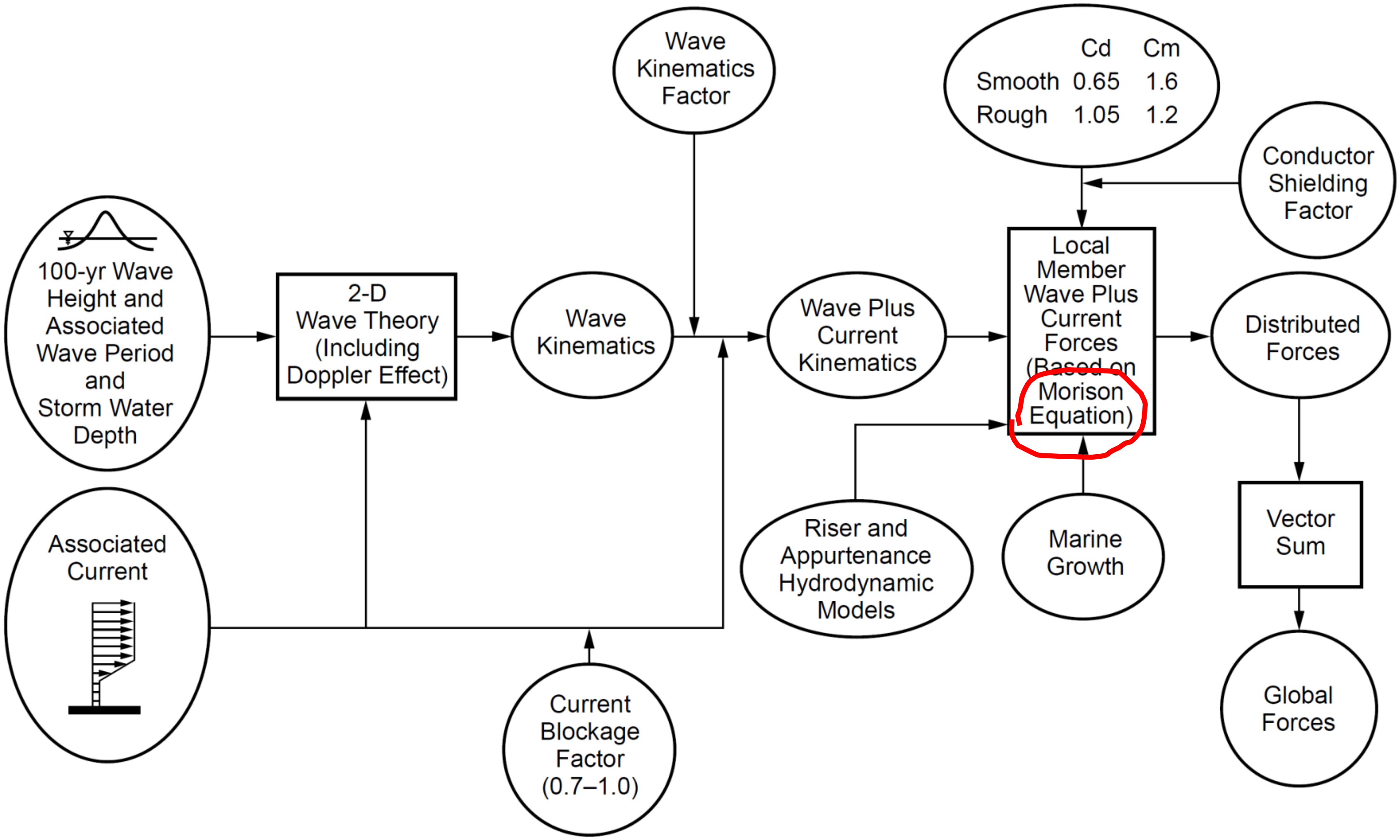


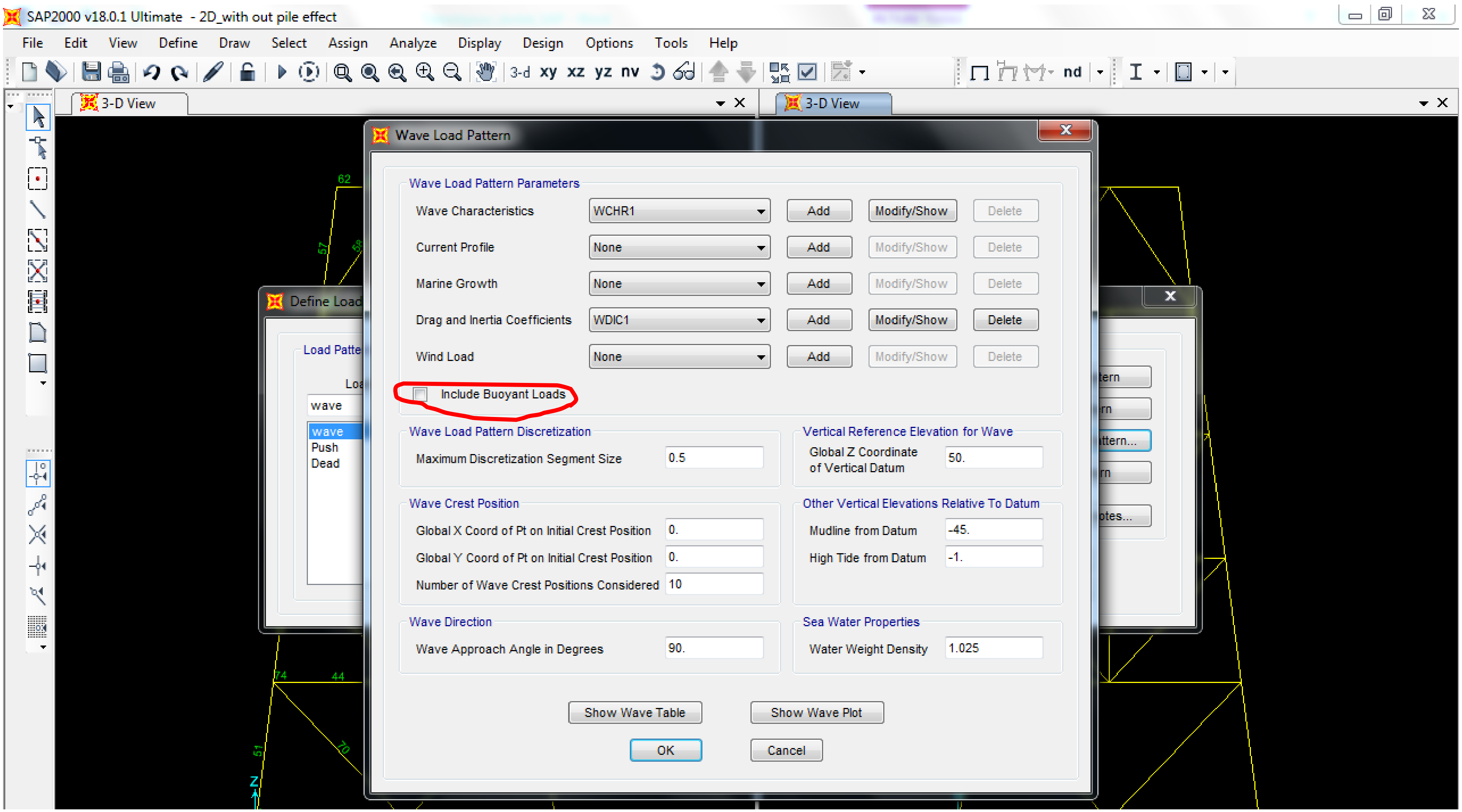
Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

3.4.5 Morison Equation

Wave and current loading can be calculated by Morison equation.

Morison equation can be written as :

$$F_T = \frac{1}{2}\, C_D\, \rho_w\, D\, V\, |V| \;+\; \frac{\pi D^2}{4}\, C_M \rho_w\, a \qquad (3.18)$$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3-D View
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Wave Load Pattern Parameters
Wave Characteristics WCHR1 Add Modify/Show Delete
Current Profile None Add Modify/Show Delete
Marine Growth None Add Modify/Show Delete
Drag and Inertia Coefficients WDIC1 Add Modify/Show Delete
Wind Load None Add Modify/Show Delete
Include Buoyant Loads
Wave Load Pattern Discretization
Maximum Discretization Segment Size 0.5
Vertical Reference Elevation for Wave
Global Z Coordinate of Vertical Datum 50.
Wave Crest Position
Global X Coord of Pt on Initial Crest Position 0.
Global Y Coord of Pt on Initial Crest Position 0.
Number of Wave Crest Positions Considered 10
Other Vertical Elevations Relative To Datum
Mudline from Datum -45.
High Tide from Datum -1.
Wave Direction
Wave Approach Angle in Degrees 90.
Sea Water Properties
Water Weight Density 1.025
Show Wave Table
Show Wave Plot
OK
Cancel
Define Load
wave
Push
Dead

3.4.10 Buoyancy Loads

The offshore structural members mostly made buoyant by air tight sealing of the welds to avoid water entry. This is purposely planned so that the overall structure will have adequate buoyancy during installation. Typical example is the jacket structure. This kind of structure requires at least a reserve buoyancy of 10% to 15%. The reserve buoyancy is defined as buoyancy in excess of its weight. To obtain this buoyancy, structural tubular members are carefully selected such that their buoyancy / weight ratio is greater than 1.0. This means that the member will float in water. On other hand, if the member is part of a structure supported at its two ends and forced to be submerged by weight of other members, this member will experience a upward force equal to the displaced volume of water. This is called buoyancy force. The buoyancy force can be calculated by two methods.

- Marine Method
- Rational Method

The marine method assumes that the member in consideration considered to have rigid body motion. This means that the weight of the member is calculated using submerged density

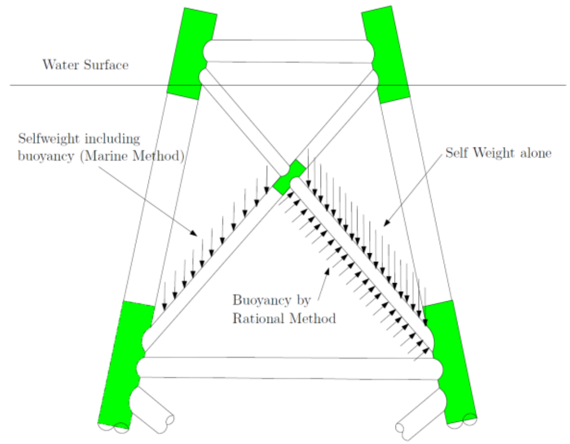


Figure 3.5: Buoyancy Calculation methods

of steel and applied to the member vertically down as an uniformly distributed load. This buoyant weight W_B of the member per unit length can be calculated as

$$W_B = \frac{1}{4}\pi(D^2 - (D-t)^2)(\rho_s - 1.025) \tag{3.44}$$

where ρ_s is the density of steel

Unlike gravity which is a true body force acting on every particle of a body, buoyancy is the resultant of fluid pressure acting on the surface of the body. These pressures can only act normal to the surface.

The rational method takes in to account this pressure distribution on the structure, results in a system of loads consisting of distributed loads along the members and concentrated loads at the joints. The loads on the members are perpendicular to the member axis and in the vertical plane containing the member. The magnitude of this distributed member load can be expressed as

$$B_B = \frac{1}{4}\pi D^2 \rho_w \cos\alpha \tag{3.45}$$

where α is the angle between the member and its projection on a horizontal plane

The joint loads consists of forces acting in the directions of all of the members meeting at the joint. These joint forces act in a direction that would compress the corresponding members

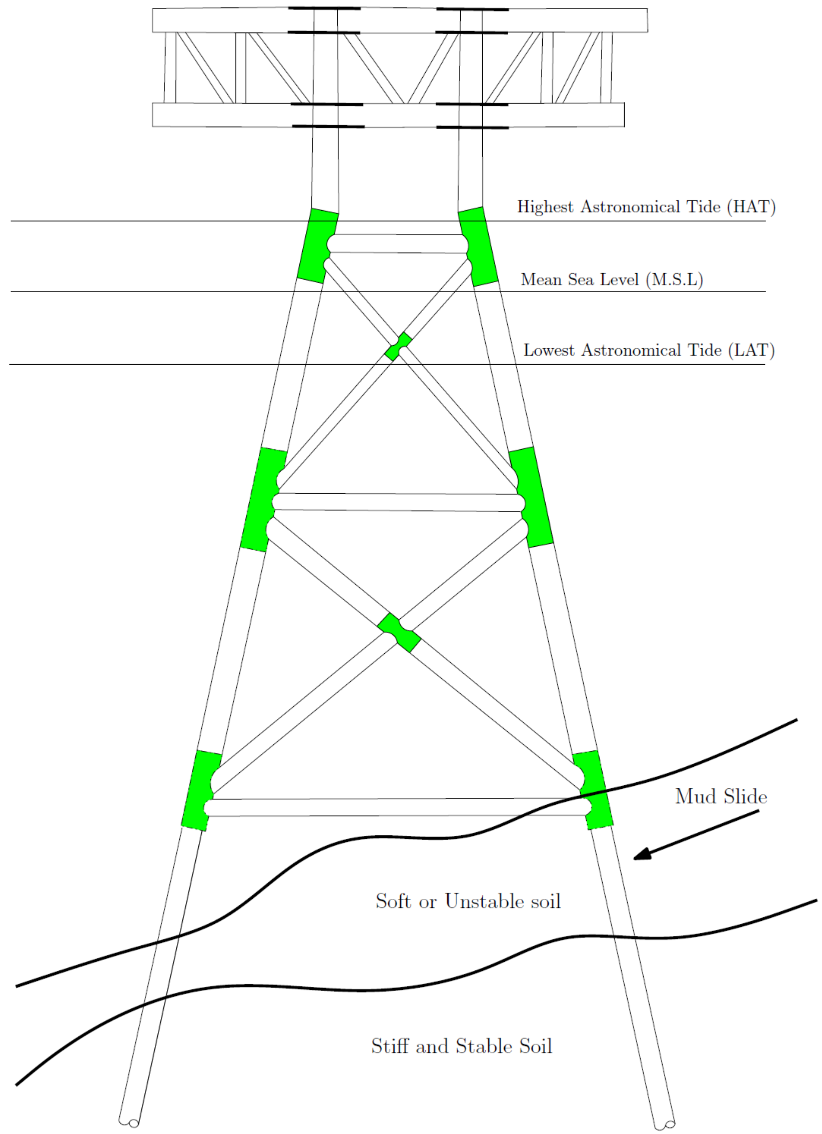
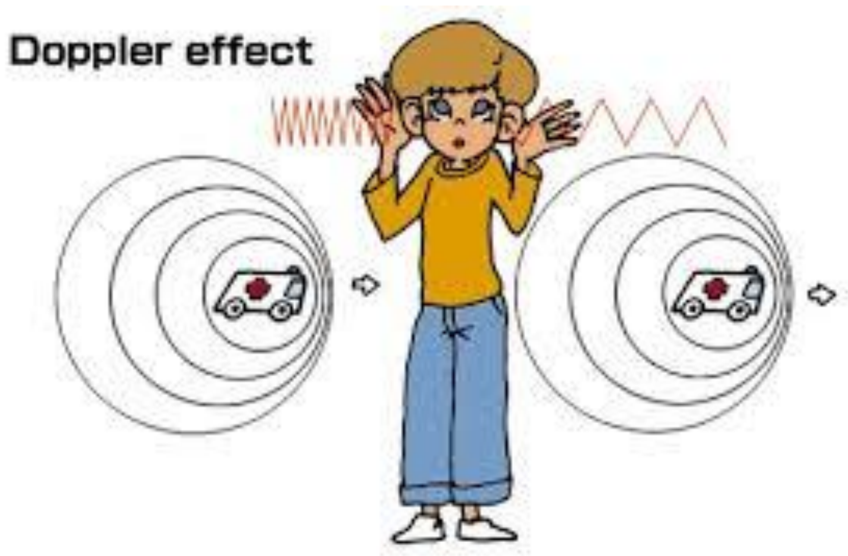


Figure 3.7: Mud Loading on a structure

Waves on a mean current: Doppler shift (مشابهت لرزه ای!)



Water waves on a mean flow (so a wave in a moving medium) experience a Doppler shift. Suppose the dispersion relation for a non-moving medium is:

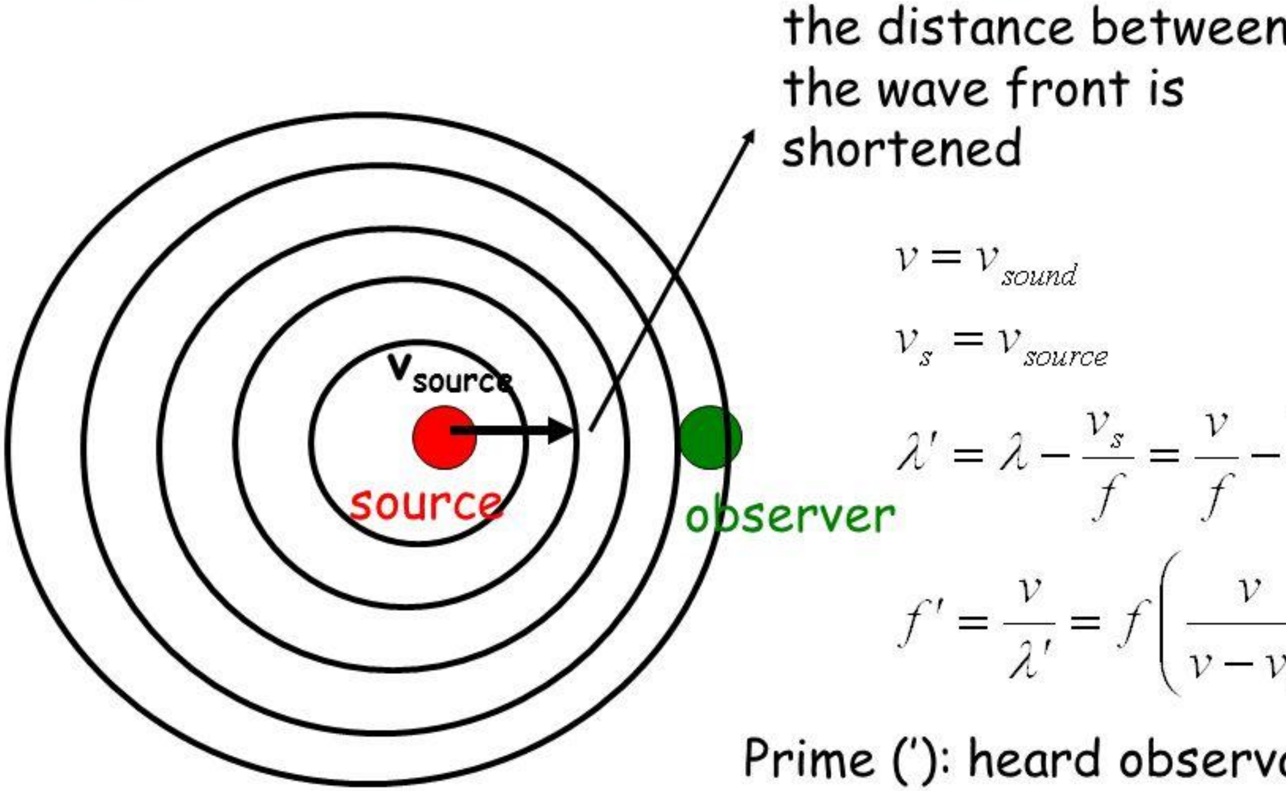
$$\omega^2 = \Omega^2(k),$$

with k the wavenumber. Then for a medium with mean velocity vector $\mathbf{V}$, the dispersion relationship with Doppler shift becomes:[19]

$$(\omega - \mathbf{k} \cdot \mathbf{V})^2 = \Omega^2(k),$$

where **k** is the wavenumber vector, related to k as: $k = |\mathbf{k}|$. The inner product $\mathbf{k} \bullet \mathbf{V}$ is equal to: $\mathbf{k} \bullet \mathbf{V} = kV \cos \alpha$, with V the length of the mean velocity vector **V**: $V = |\mathbf{V}|$. And α the angle between the wave propagation direction and the mean flow direction. For waves and current in the same direction, $\mathbf{k} \bullet \mathbf{V} = kV$.

doppler effect: a source moving towards you



$$v = v_{sound}$$

$$v_s = v_{source}$$

$$\lambda' = \lambda - \frac{v_s}{f} = \frac{v}{f} - \frac{v_s}{f}$$

$$f' = \frac{v}{\lambda'} = f\left(\frac{v}{v - v_s}\right)$$

Prime ('): heard observable

The frequency becomes larger: higher tone

....

1. **Apparent Wave Period.** A current in the wave direction tends to stretch the wave length, while an opposing current shortens it. For the simple case of a wave propagating on a uniform in-line current, the apparent wave period seen by an observer moving with the current can be estimated from Figure 2.3.1-2, in which T is the actual wave period (as seen by a stationary observer). V_I is the current component in the wave direction, d, is storm water depth (including storm surge and tide), and g is the acceleration of gravity. This figure provides estimates for $d/gT^2 > 0.01$. For smaller values of d/gT^2, the equation $(T_{app}/T) = 1 + V_I\sqrt{gd}$ can be used. While strictly applicable only to a current that is uniform over the full water depth, Figure 2.3.1-2 provides acceptable estimates of T_{app} for "slab" current profiles that are uniform over the top 165 ft (50m) or more of the water column. For other current profiles, a system of simultaneous nonlinear equations must be solved interactively to determine T_{app} (see Commentary). The current used to determine T_{app} should be the free-stream current (not reduced by structure blockage).

COMMENTARY ON WAVE FORCES, SECTION 2.3.1

C2.3.1b1 Apparent Wave Period

Kirby and Chen (1989) developed a consistent first-order solution for the apparent wave period of a wave propagating on a current with an arbitrary profile. Their procedure requires the solution of the following three simultaneous equations for T_{app}, λ, and V_I:

$$\frac{\lambda}{T} = \frac{\lambda}{T_{app}} + V_I$$

$$T_{app}^2 = \frac{2\pi\lambda}{g \tanh(2\pi d/\lambda)}$$

$$V_I = \frac{(4\pi/\lambda)}{\sinh(4\pi d/\lambda)} \int_{-d}^{0} U_c(z) \cosh\left[\frac{4\pi(z+d)}{\lambda}\right] dz$$

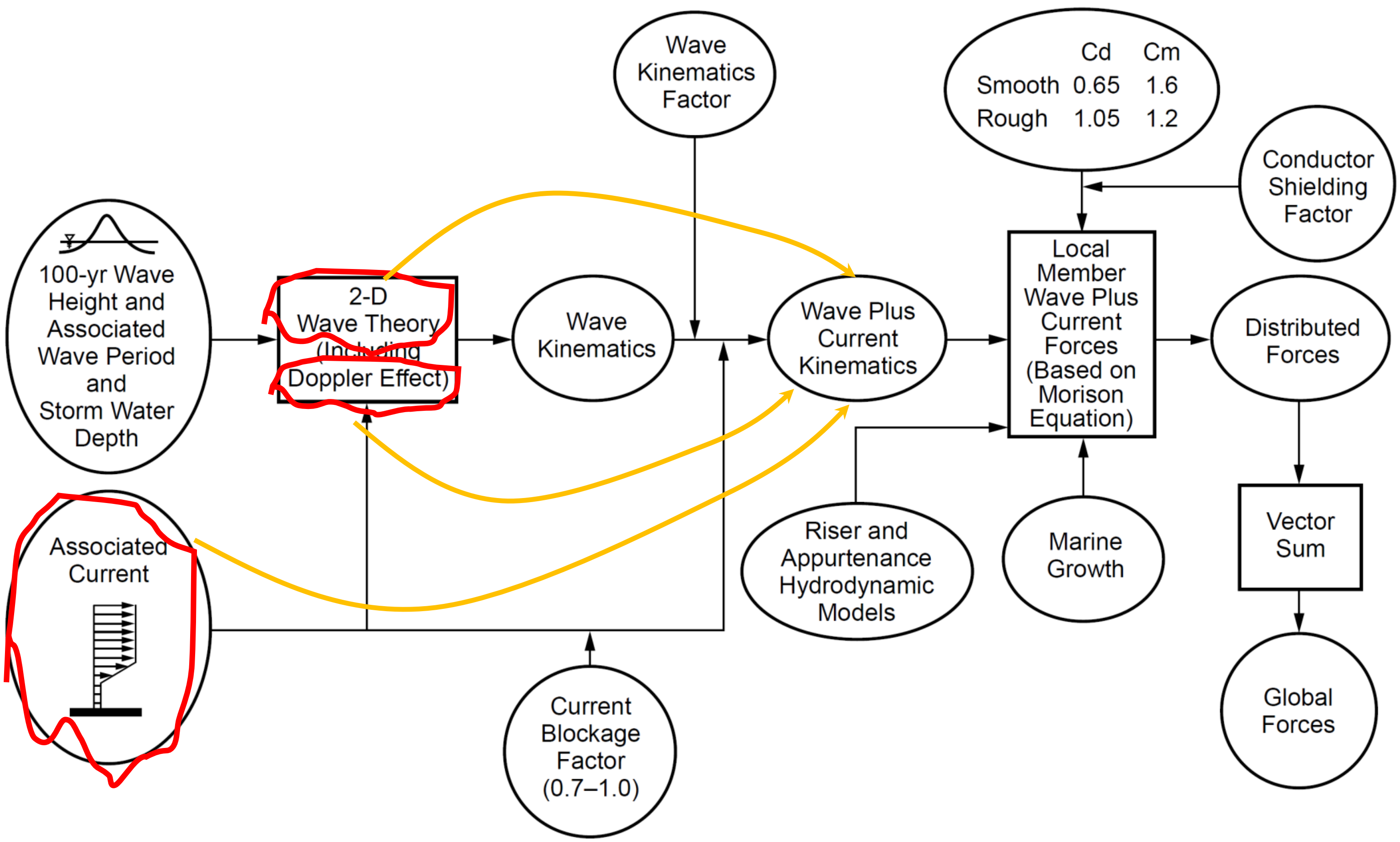
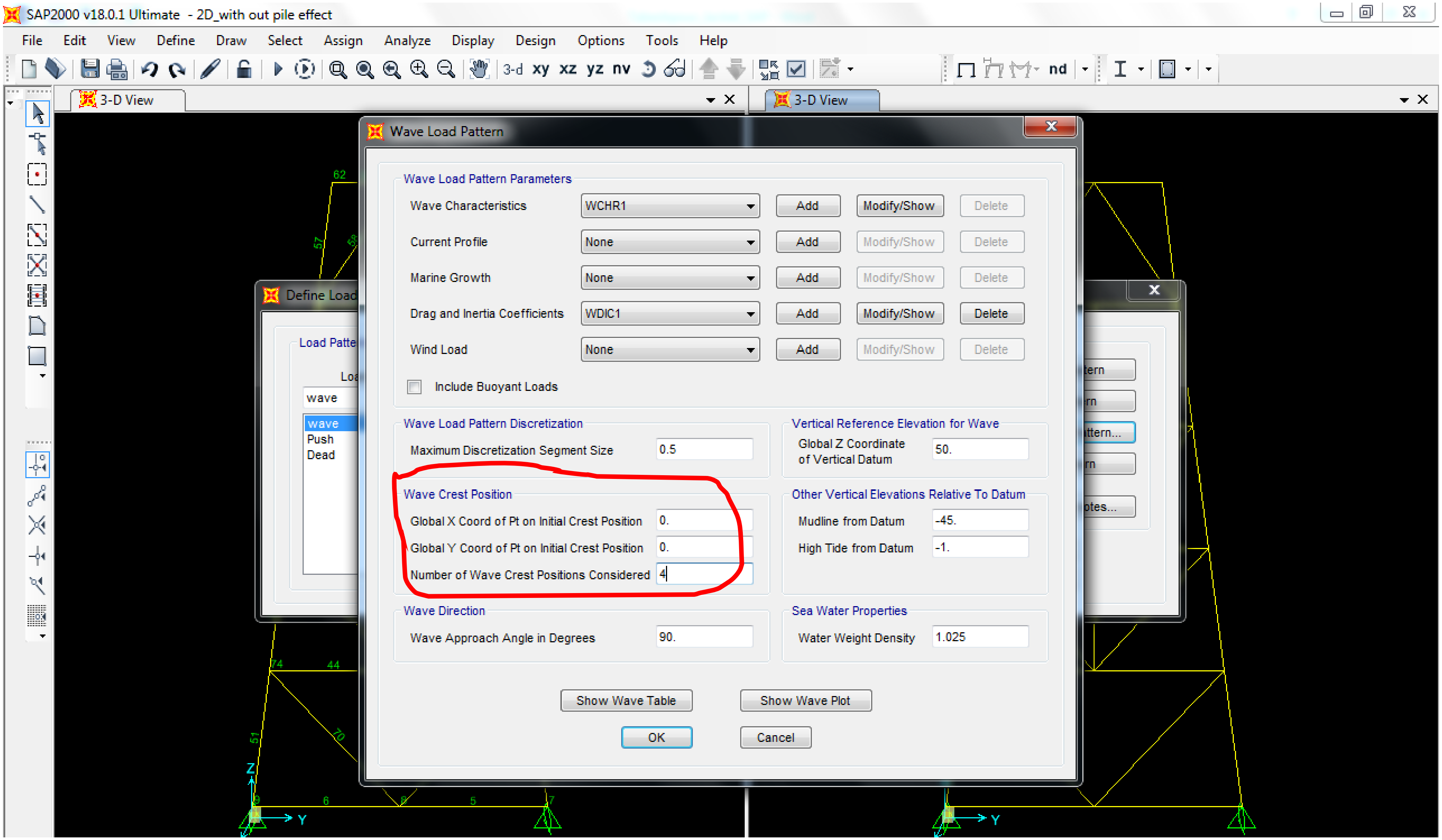
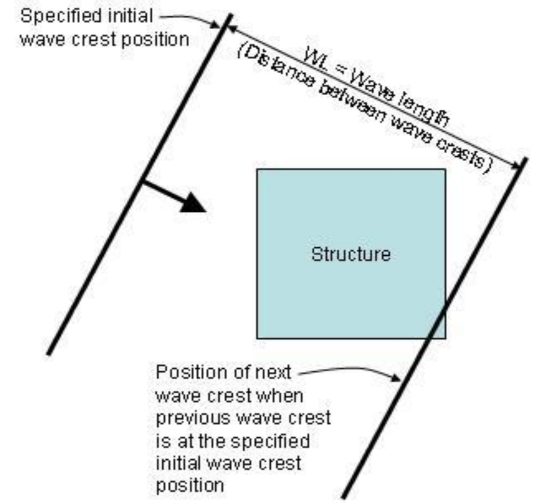
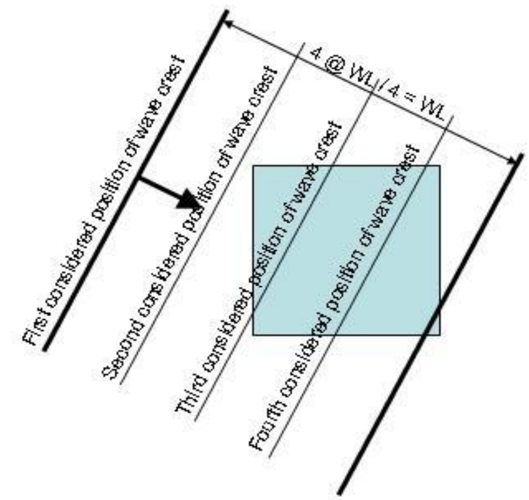


Figure 2.3.1-1—Procedure for Calculation of Wave Plus Current Forces for Static Analysis

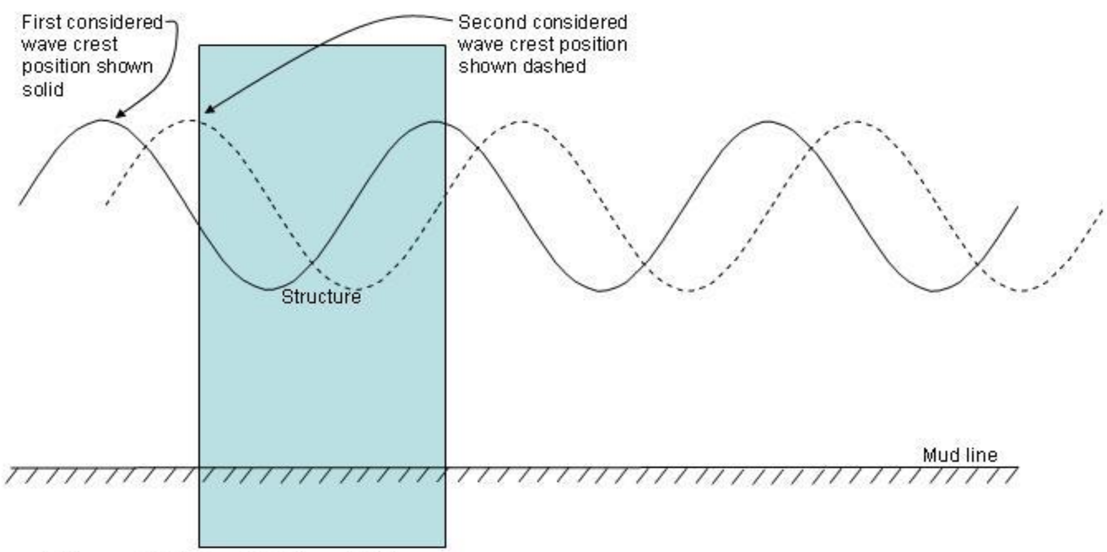

SAP2000 v18.0.1 Ultimate - 2D_with out pile effect
File Edit View Define Draw Select Assign Analyze Display Design Options Tools Help
Wave Load Pattern
Wave Load Pattern Parameters
Wave Characteristics WCHR1 Add Modify/Show Delete
Current Profile None Add Modify/Show Delete
Marine Growth None Add Modify/Show Delete
Drag and Inertia Coefficients WDIC1 Add Modify/Show Delete
Wind Load None Add Modify/Show Delete
Include Buoyant Loads
Wave Load Pattern Discretization
Maximum Discretization Segment Size 0.5
Vertical Reference Elevation for Wave
Global Z Coordinate of Vertical Datum 50.
Wave Crest Position
Global X Coord of Pt on Initial Crest Position 0.
Global Y Coord of Pt on Initial Crest Position 0.
Number of Wave Crest Positions Considered 4
Other Vertical Elevations Relative To Datum
Mudline from Datum -45.
High Tide from Datum -1.
Wave Direction
Wave Approach Angle in Degrees 90.
Sea Water Properties
Water Weight Density 1.025
Show Wave Table
Show Wave Plot
OK
Cancel



a) Initial Wave Crest Position (Plan View)



b) Considered Positions of Wave When a Total of Four Wave Crest Positions are Considered



c) Horizontal Section Cut Through Wave

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