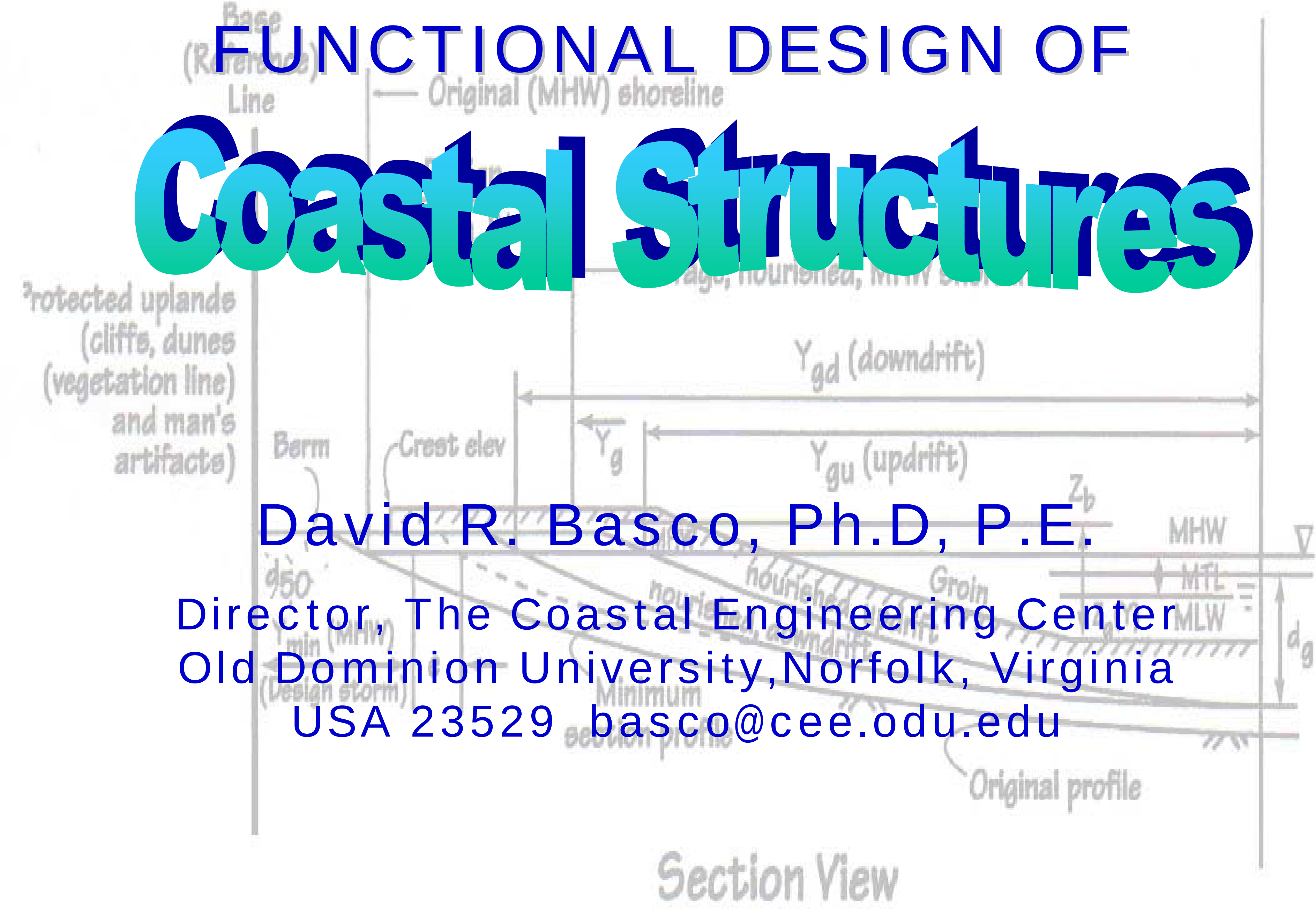
FUNCTIONAL DESIGN OF

Coastal Structures



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DESIGN OF COASTAL STRUCTURES

- Function of structure
- Structural integrity
- Physical environment
- Construction methods
- Operation and maintenance

OUTLINE

- Plan form layout
  - headland breakwaters
  - nearshore breakwaters
  - groin fields
- Wave runup and overtopping*
  - breakwaters and revetments (seawalls, beaches not covered here)
- Wave reflections (materials included in notes)

* materials from ASCE, Coastal Engineering Short Course, CEM Preview, April 2001

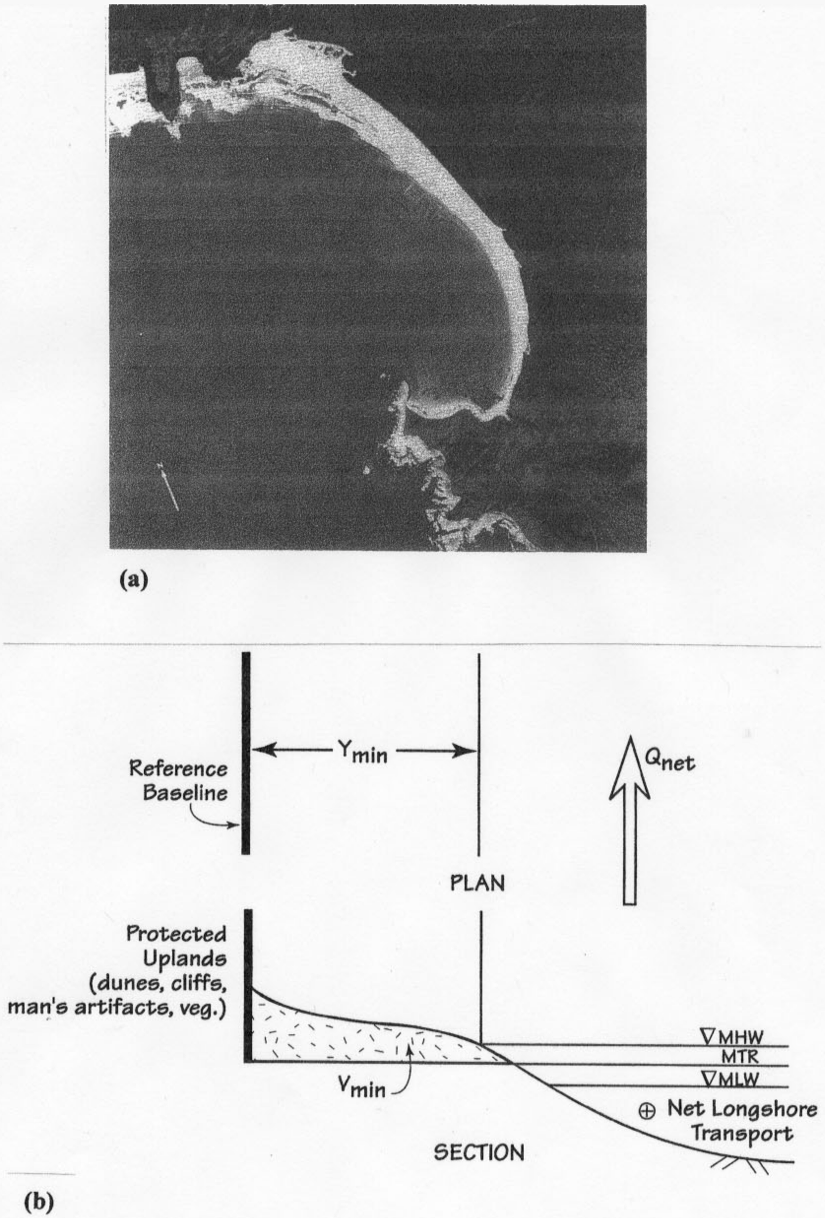


Figure V-3-10 Naturally stable shorelines with beach width dependent on stormwave energy (a) aerial photo, Bruny Island, Tasmania, Australia (from Silverster and Hsu, 1993) (b) schematic of minimum dry beach width Y_{min}

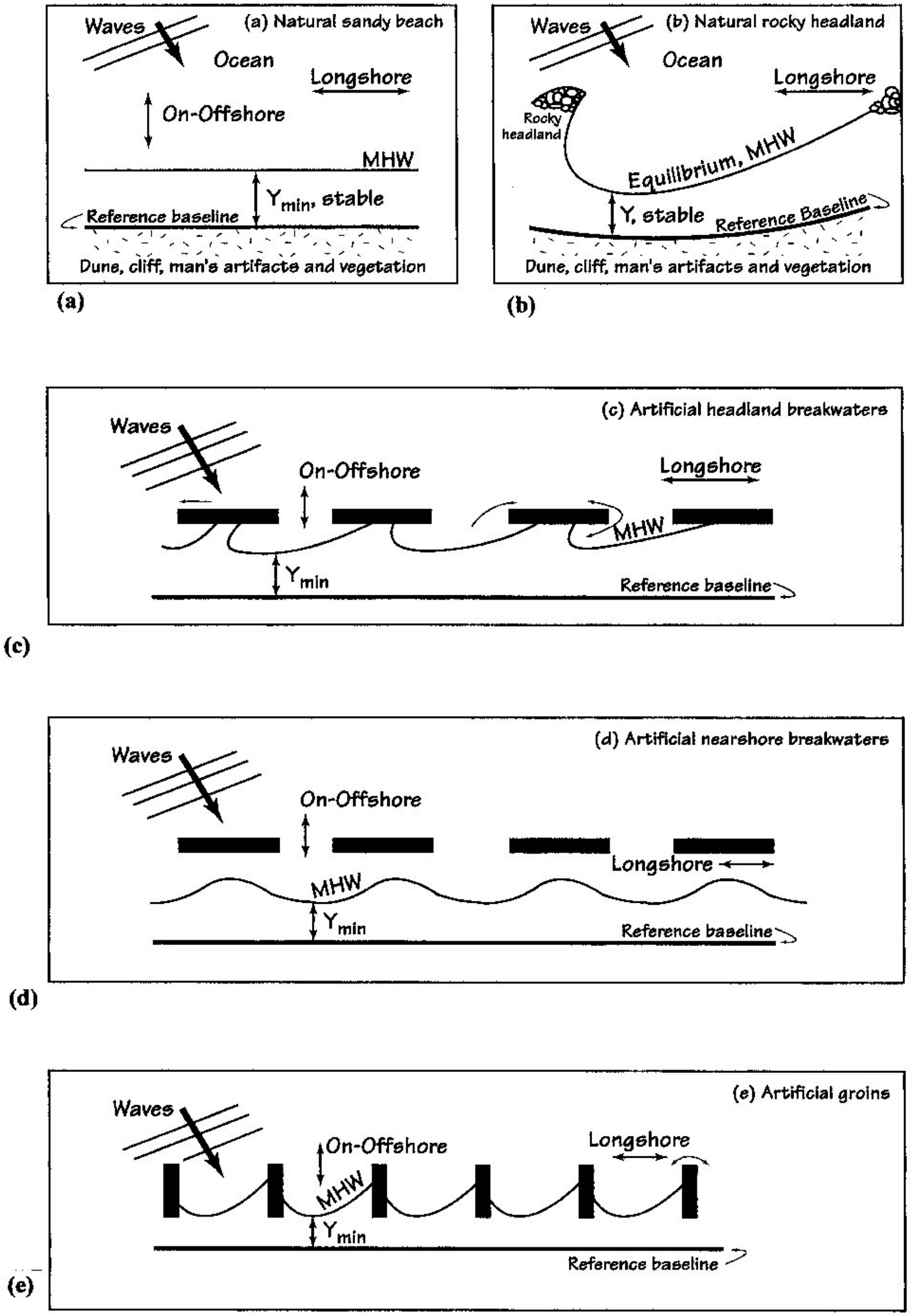
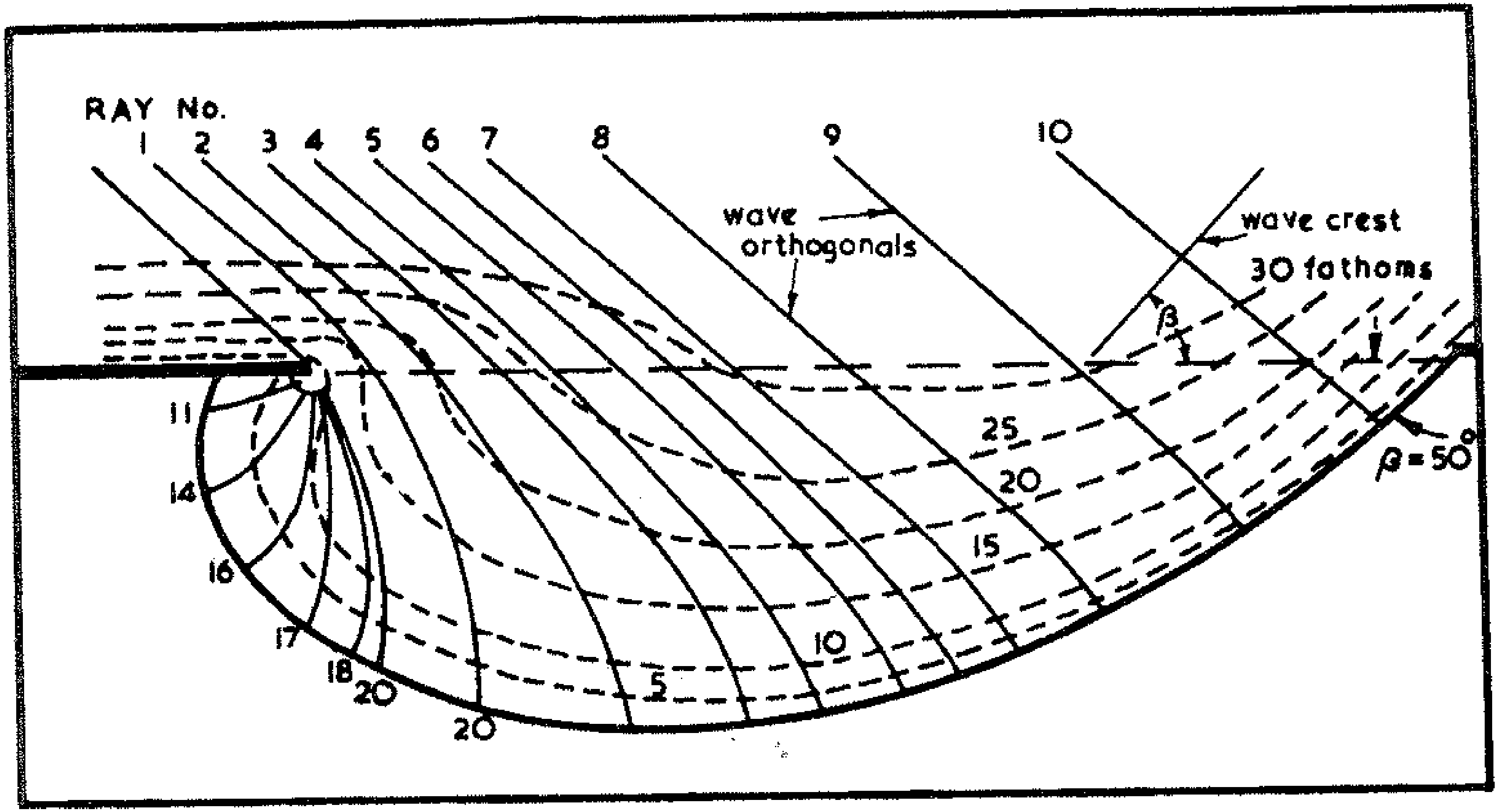


Figure V-3-11 Natural and artificially stable shorelines with minimum dry beach width, Y_{min} (a) sandy beach (b) rocky headland (c) headland breakwaters (d) nearshore breakwaters (e) groins


RAY No.
1
2
3
4
5
6
7
8
9
10
wave orthogonals
wave crest
30 fathoms
β
25
20
15
10
5
β = 50°
11
14
16
17
18
20
20

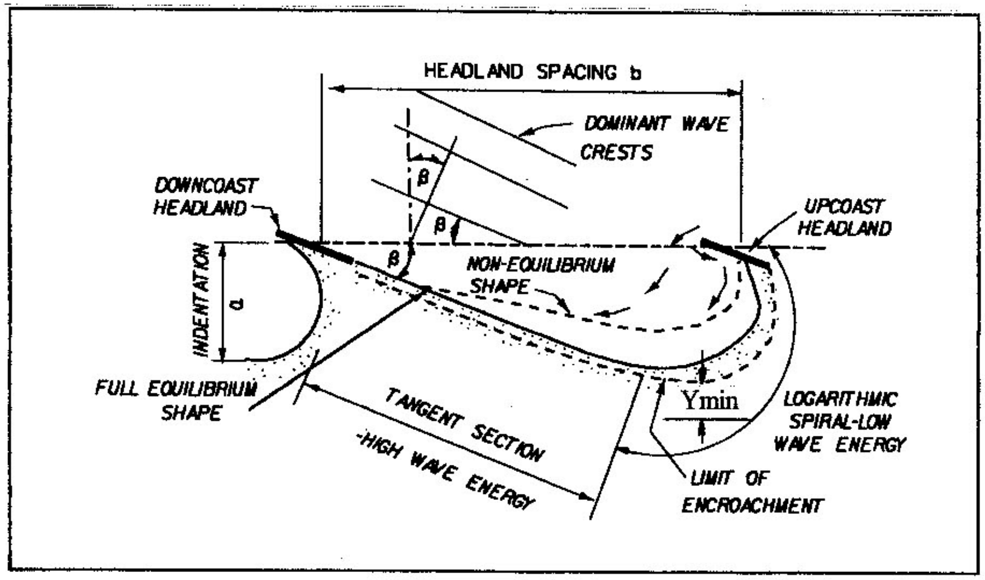


Figure V-3-12 Definition sketch of artificial headland system and beach planform (from US Army Corps of Engineers,1992)

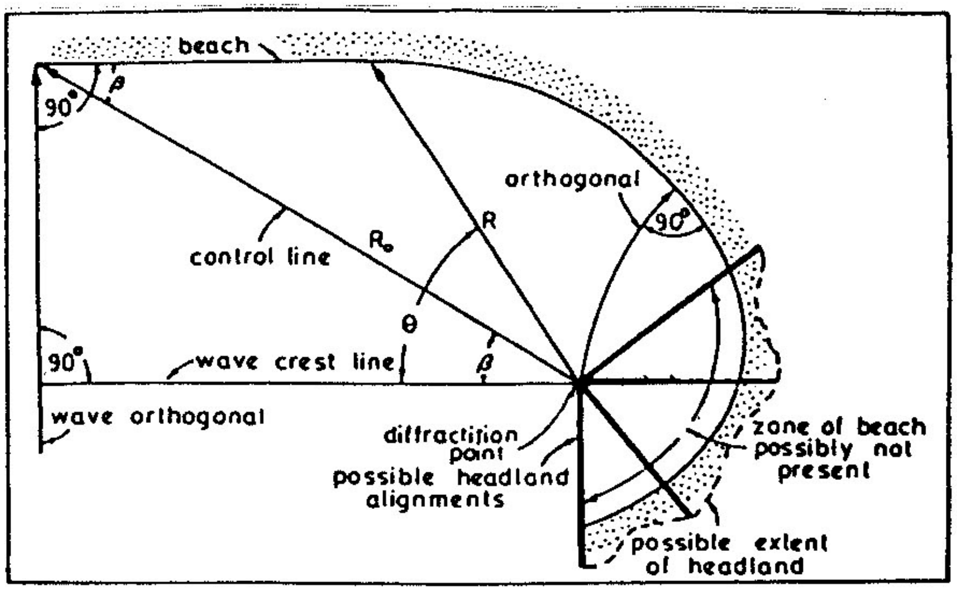
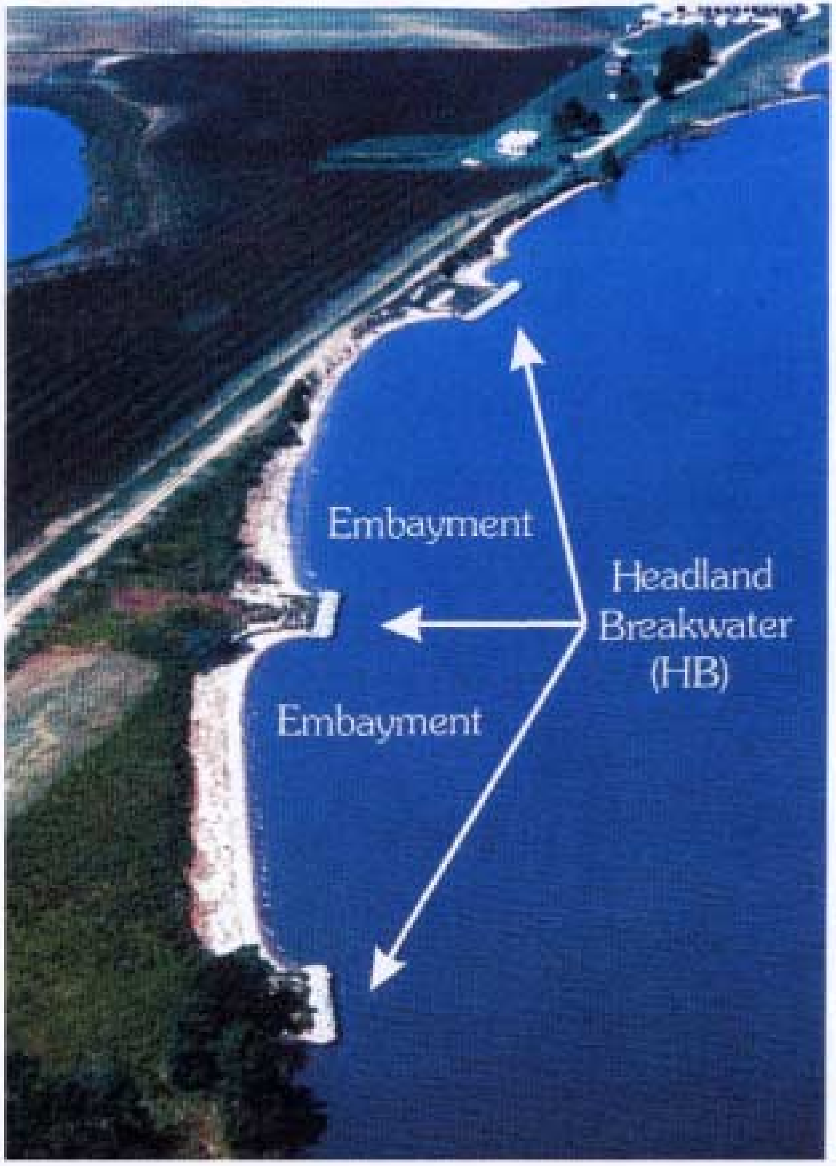
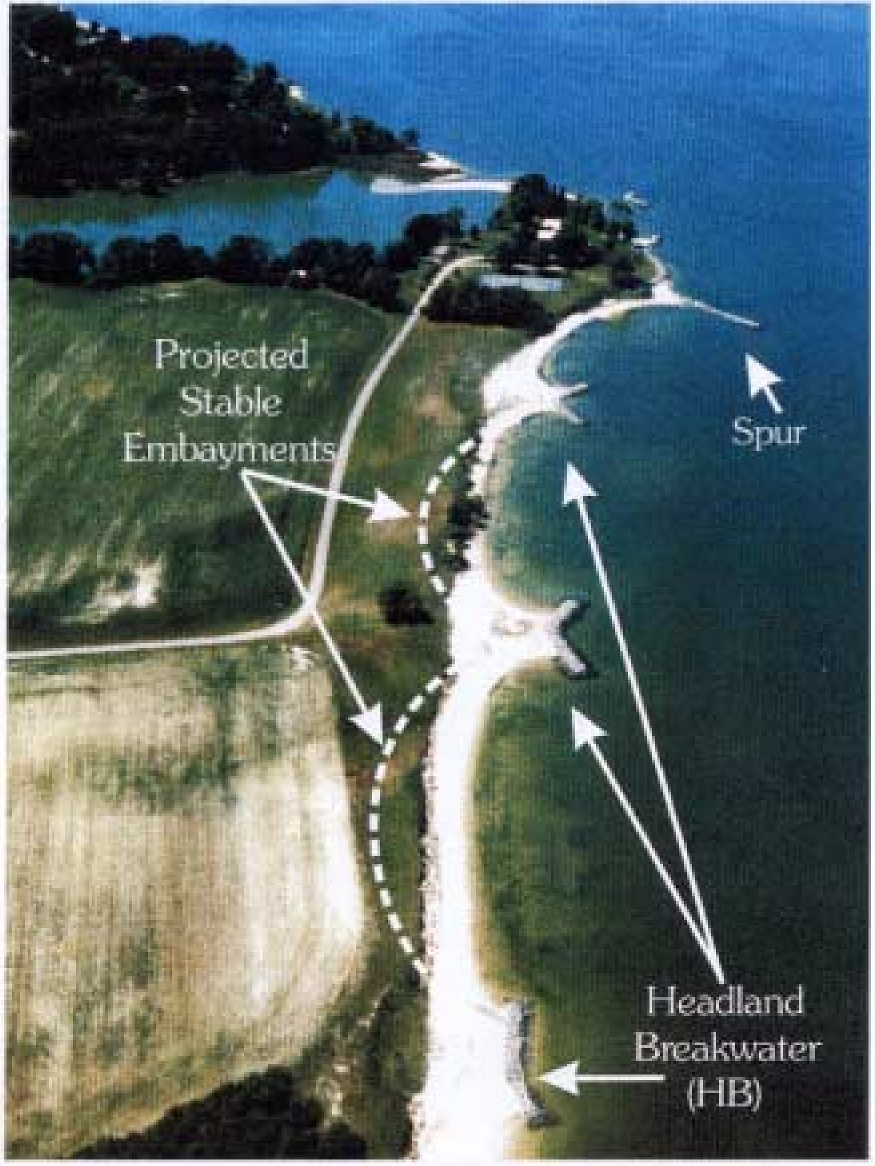
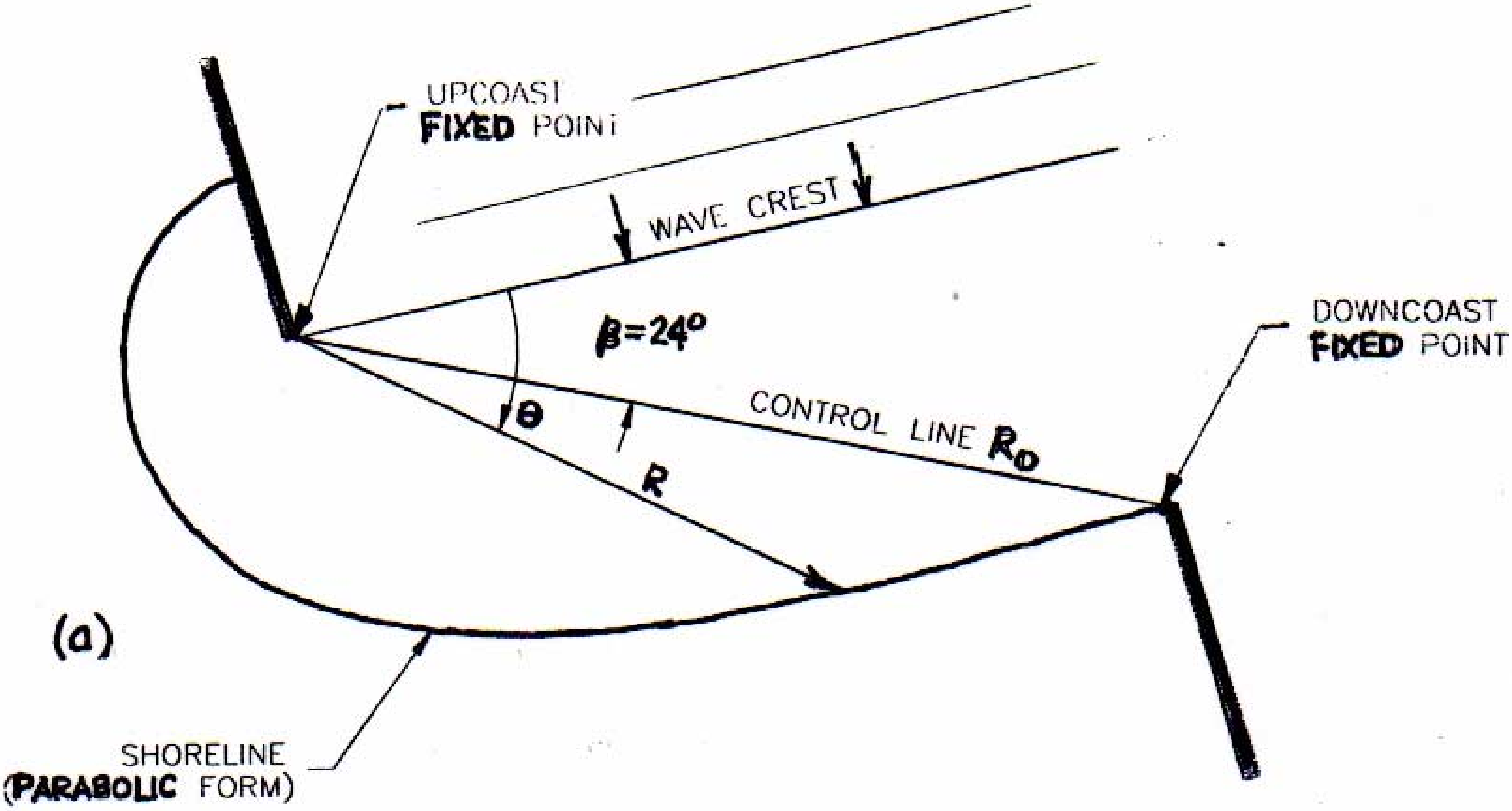


Figure V-3-13 Definition sketch of parabolic model for planform shape


Embayment
Headland
Breakwater
(HB)
Embayment


Projected
Stable
Embayments
Spur
Headland
Breakwater
(HB)

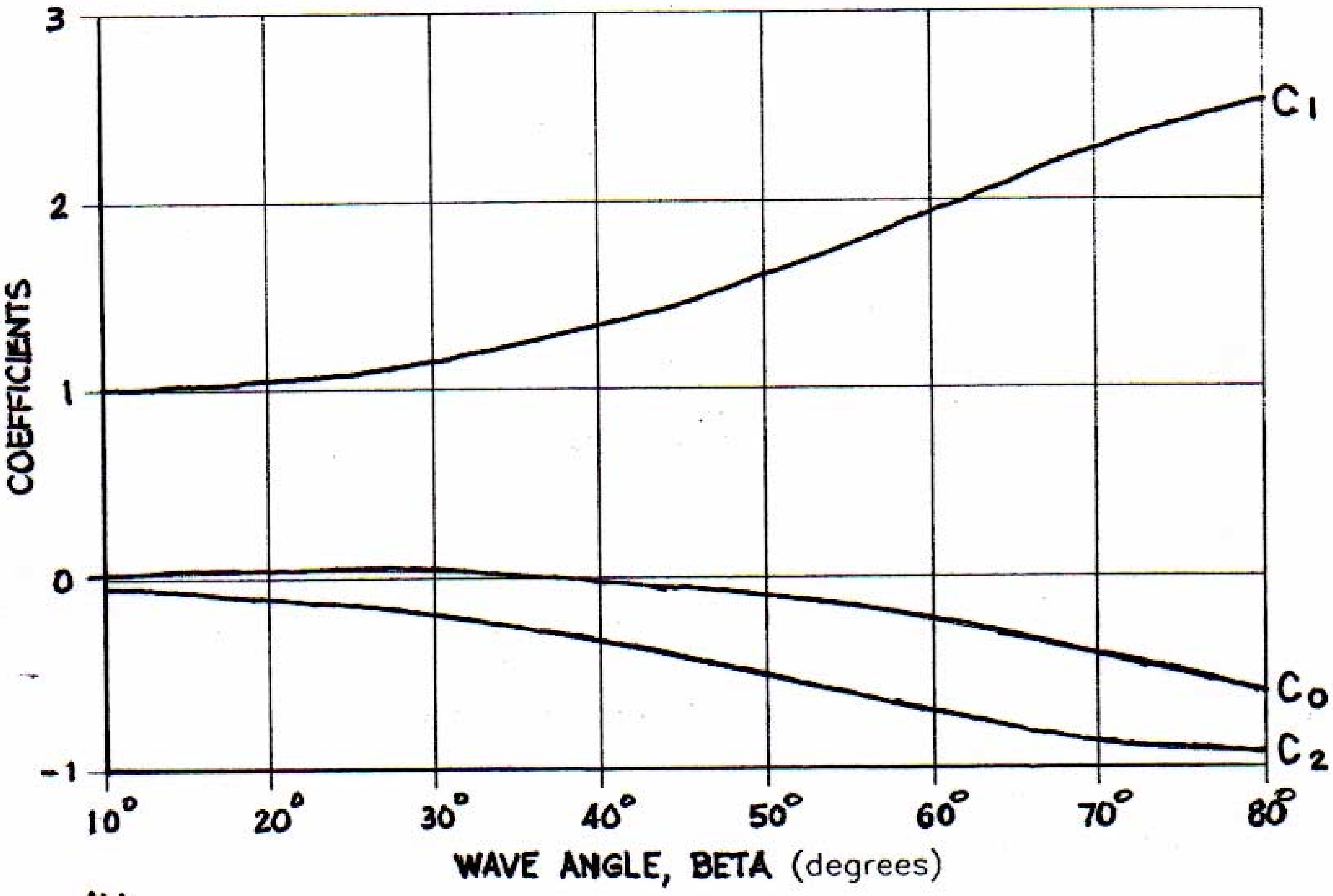

UPCOAST
FIXED POINT
WAVE CREST
β=24°
DOWNCOAST
FIXED POINT
θ
CONTROL LINE R_0
R
(a)
SHORELINE
(PARABOLIC FORM)

3. Using shoreline data from prototype bays considered to be in static equilibrium and from physical models, Hsu, Silvester, and Xia (1987, 1989a, 1989b) presented an alternate expression to approximate the shoreline in the lee of headland-type features:

$$\frac{R}{R_o} = C_o + C_1 \left(\frac{\beta}{\theta}\right) + C_2 \left(\frac{\beta}{\theta}\right)^2$$

(III-2-24 ▶)

where the geometric parameters R, R_o, β, and θ are as shown in Figure III-2-27a, and values for the coefficients C_0, C_1, and C_2 are shown in Figure III-2-27b. The distance R_o corresponds to a control line drawn between the ends of the headlands that define a given section of shoreline. In the case of a single, upcoast headland, the distance R_o is the length of a control line drawn from the end of the headland to the nearest point on the downcoast shoreline at which the shoreline is parallel with the predominant wave crest. The distance R, measured from the end of the upcoast headland, defines the location of the shoreline at angles measured from the predominant wave crest. The angle β is that between the predominant wave direction and the control line R_o.



3
2
1
0
-1
COEFFICIENTS
C1
C0
C2
10°
20°
30°
40°
50°
60°
70°
80°
WAVE ANGLE, BETA (degrees)

(b)

EXAMPLE PROBLEM III-2-8

FIND:

Compute the shoreline geometry of a crenulate bay located between two rock headlands for a shoreline where one dominant wave direction exists.

GIVEN:

The distance between the ends of the headlands is 175 m. The incident wave crests make an angle of 30 deg with a line drawn between the two headlands.

SOLUTION:

From Figure III-2-27b, the values of the coefficients for the wave angle $\beta = 30$ deg are approximately $C_0 = 0.05$, $C_1 = 1.14$, and $C_2 = -0.19$. The location of the shoreline may be predicted by plotting the distance R, measured from the end of the upwave headland, at angles θ measured from the line drawn between the headlands. The values R/R_o for various arbitrary angles between the wave angle, 30 deg, and a maximum angle, 180 deg, are computed from Equation 2-24. The corresponding dimensional values of R are then computed by multiplying R/R_o by the distance between the headlands $R_o = 175$ m. Representative examples are given below:

$$\text{For } \theta = 30 \text{ deg: } R = [\, 0.05 + 1.14(30/30) - 0.19(30/30)^2 \,](\, 175 \text{ m} \,) = 175 \text{ m}$$

$$\text{For } \theta = 75 \text{ deg: } R = [\, 0.05 + 1.14(30/75) - 0.19(30/75)^2 \,](\, 175 \text{ m} \,) = 83 \text{ m}$$

$$\text{For } \theta = 180 \text{ deg: } R = [\, 0.05 + 1.14(30/180) - 0.19(30/180)^2 \,](\, 175 \text{ m} \,) = 41 \text{ m}$$

For $\theta > 180°$, the distance *R* may be assumed to be constant and equal to the value of *R* computed at $\theta = 180°$.

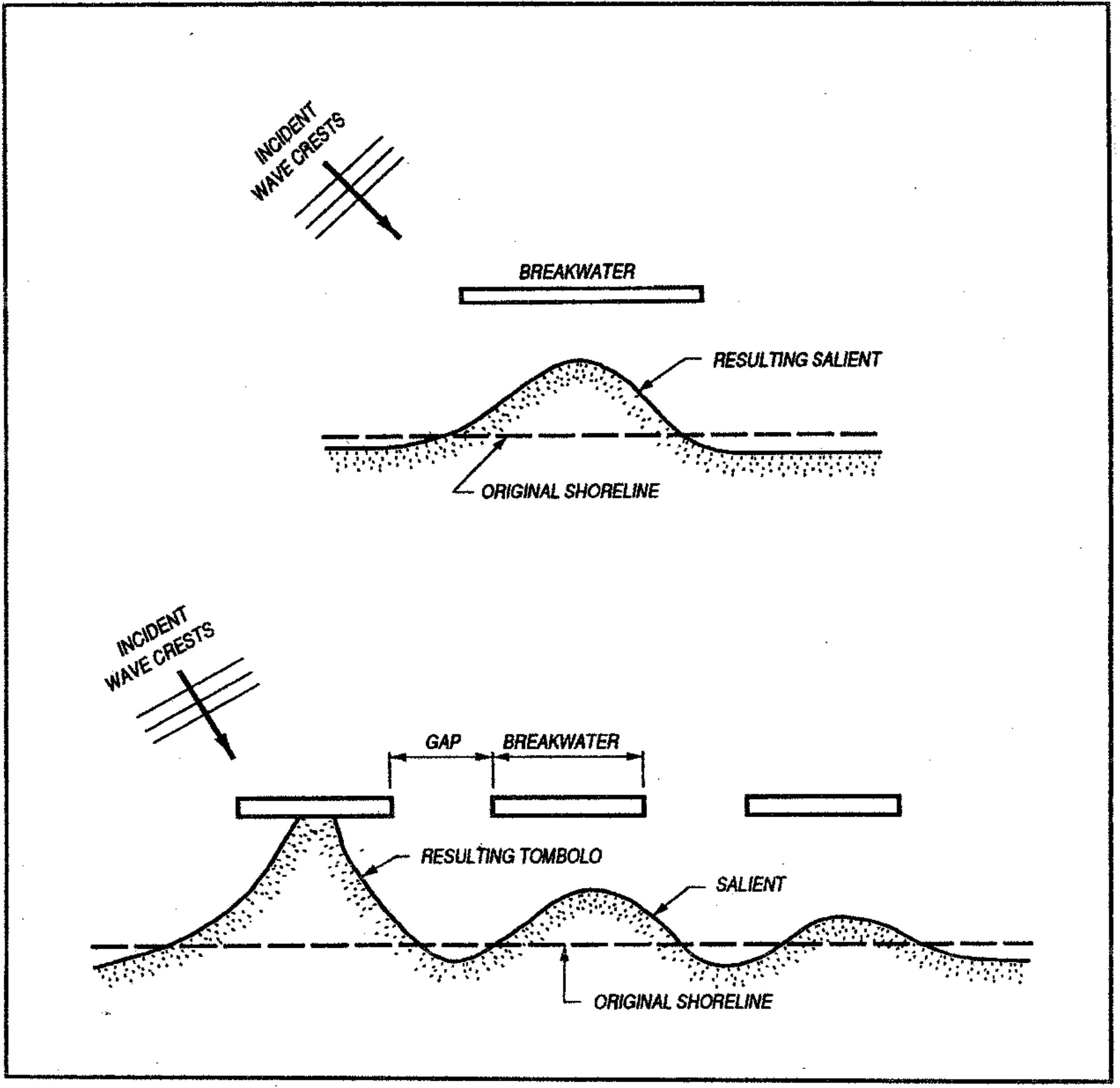
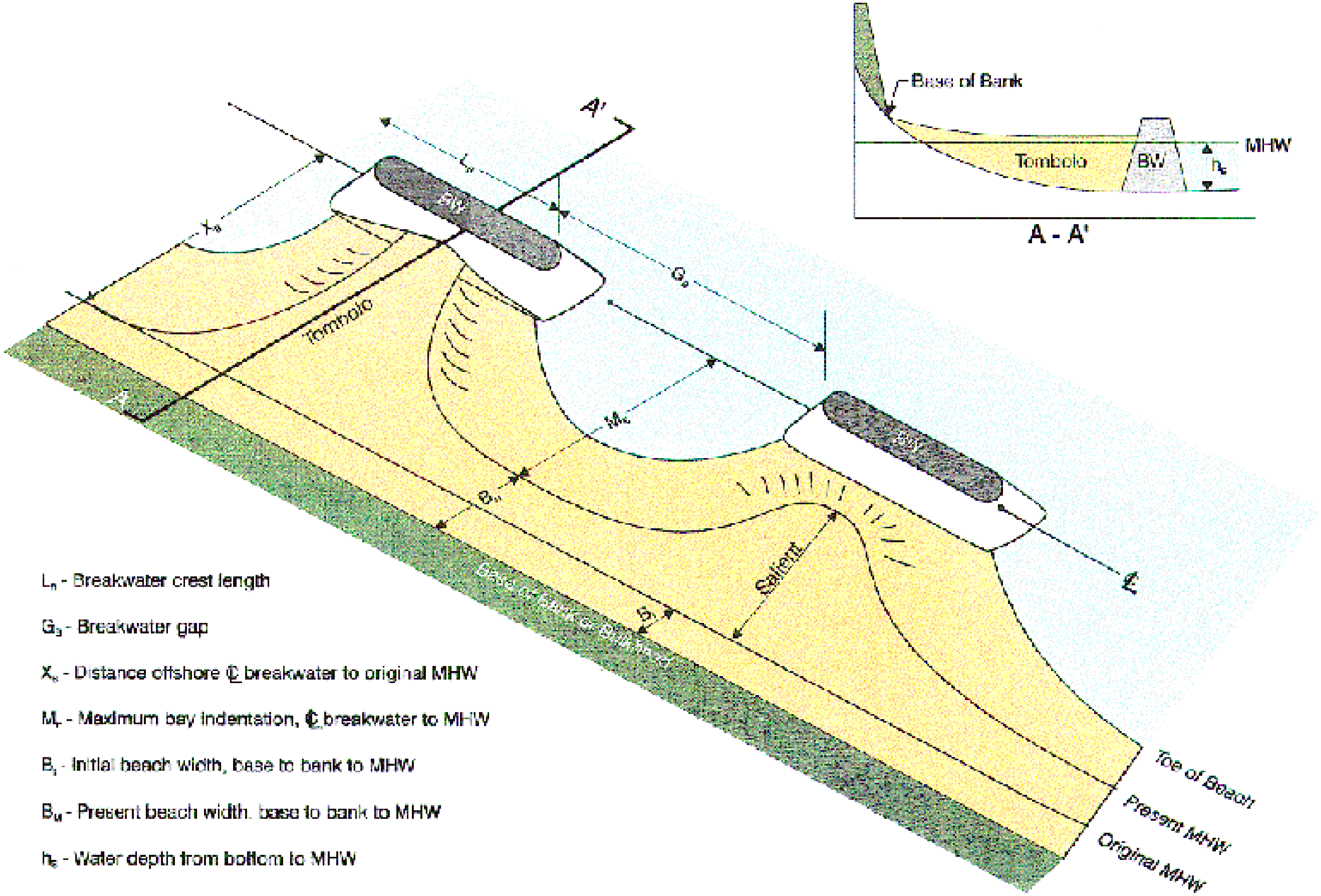


Figure V-3-17 Types of shoreline changes associated with single and multiple breakwaters (from US Army Corps of Engineers)

ne 1996

After April 1997



L_B - Breakwater crest length

G_B - Breakwater gap

X_B - Distance offshore ℄ breakwater to original MHW

M_B - Maximum bay indentation, ℄ breakwater to MHW

B_i - Initial beach width, base to bank to MHW

B_M - Present beach width. base to bank to MHW

h_s - Water depth from bottom to MHW

BW - Breakwater

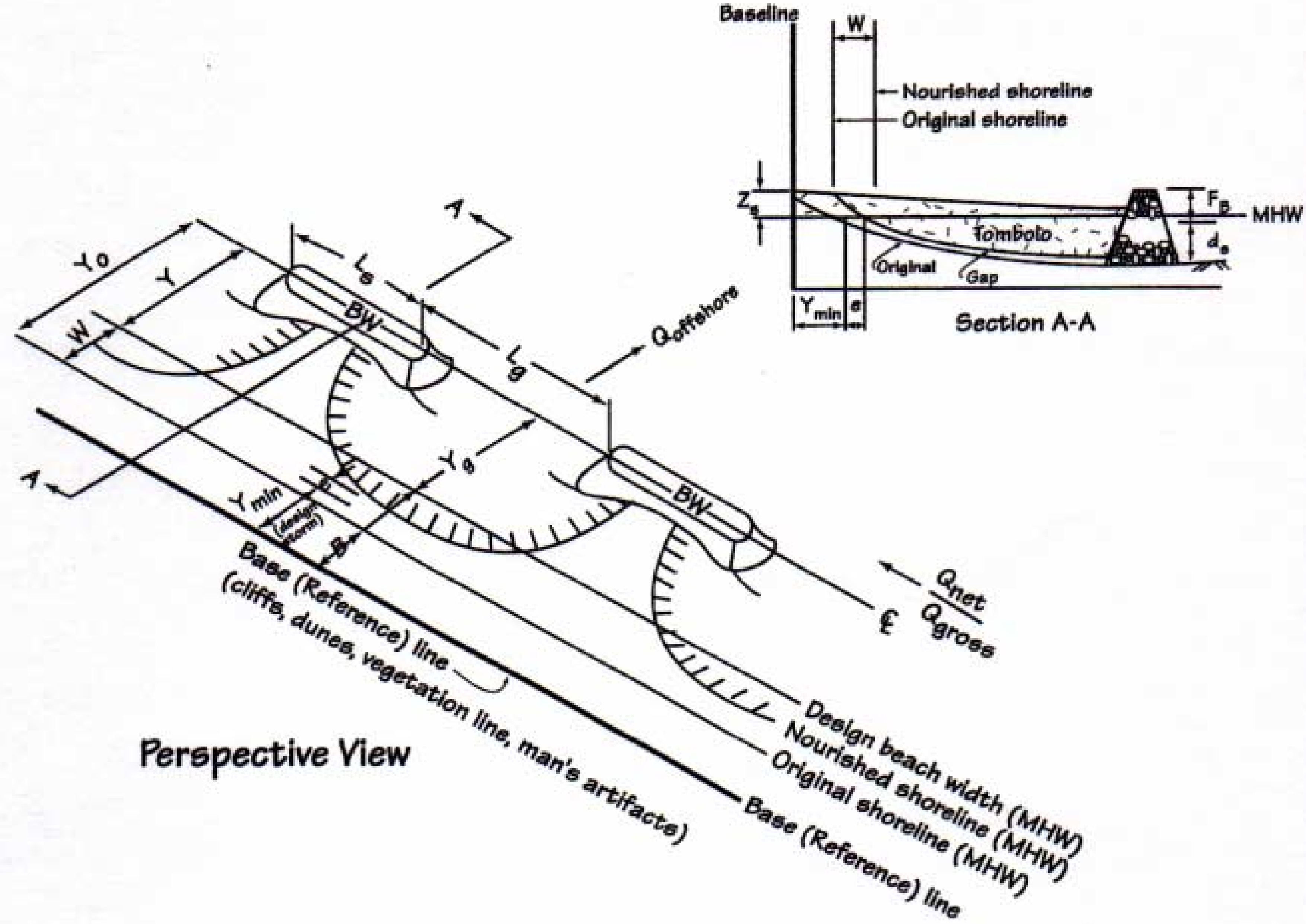


Figure V-3-14 Definition sketch, headland breakwaters

SHORE PARALLEL BREAKWATERS: HEADLAND TYPE

Design Rules, Hardaway et al. 1991

- Use sand fill to create tombolo for constriction from land
- Set berm elevation so tombolo always present at high tide
- Set Yg/Lg = 1.65 for stable shaped beach
- Set Ls/Lg = 1
- Always combine with new beach fill
- See CEM 2001 V-3 for details

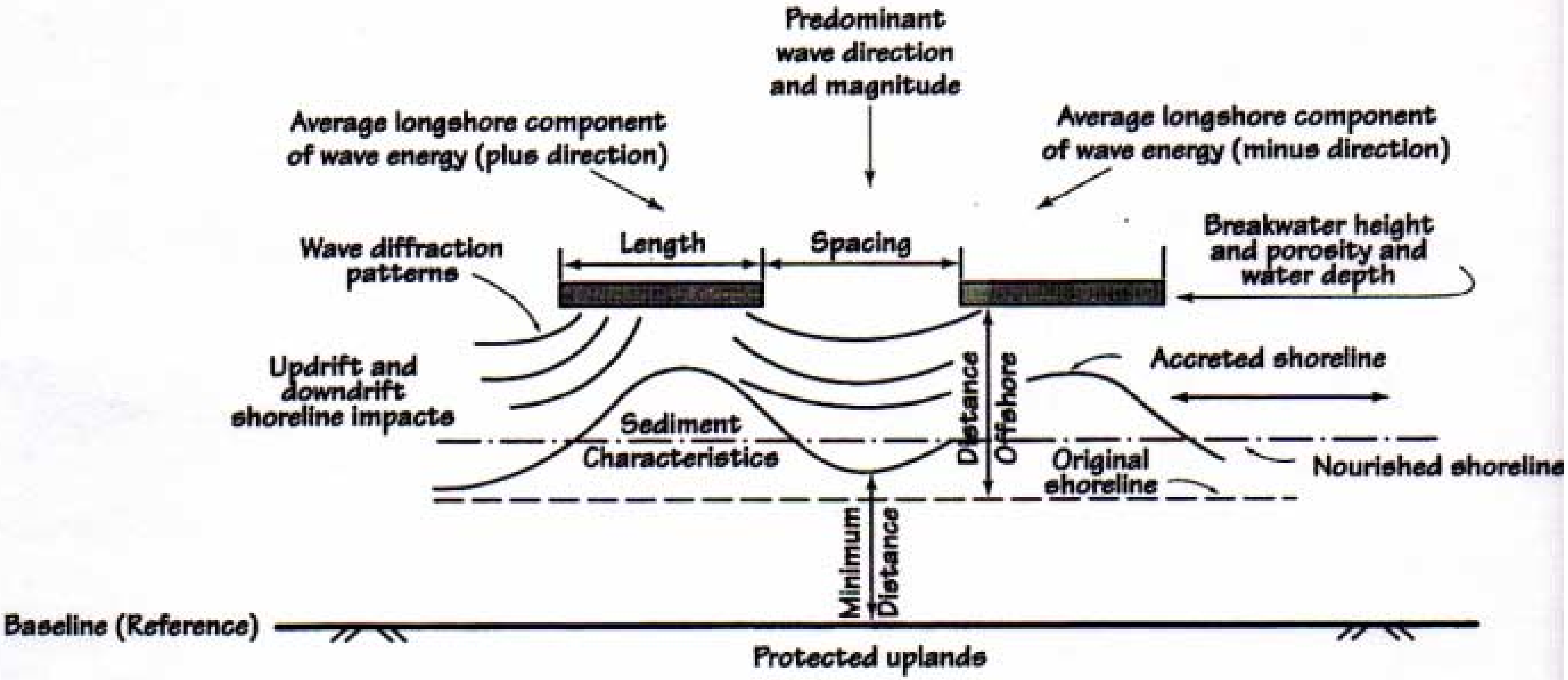
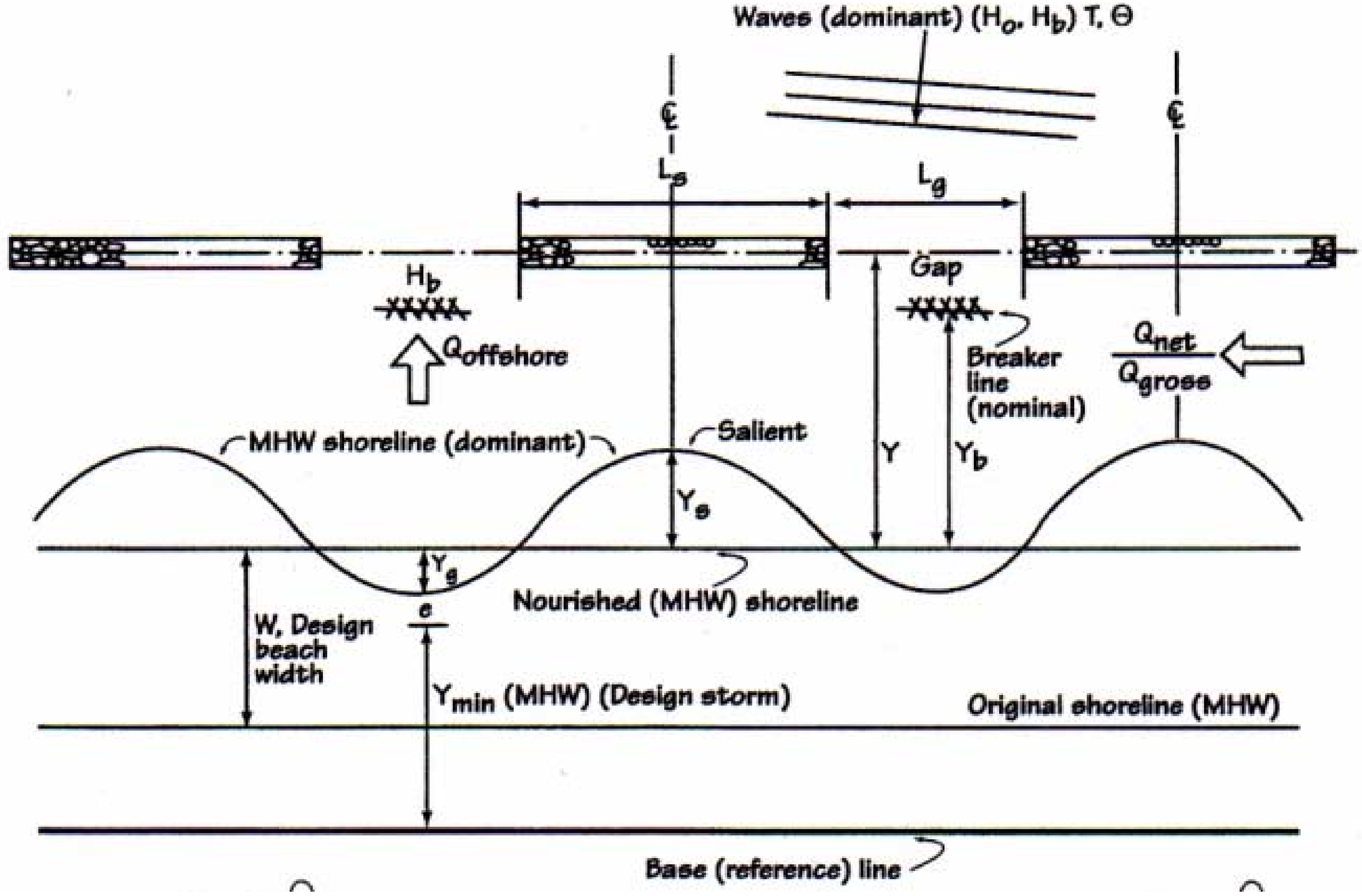
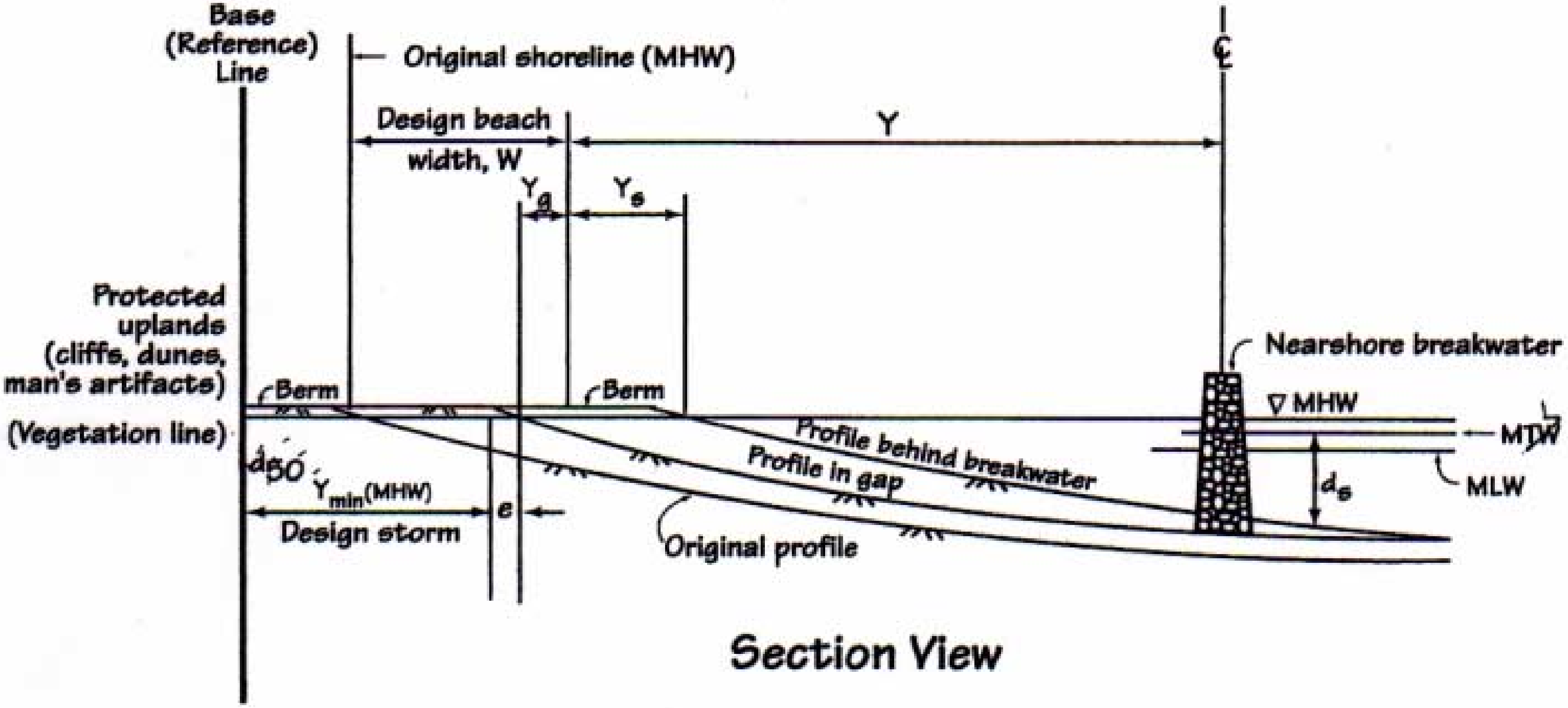


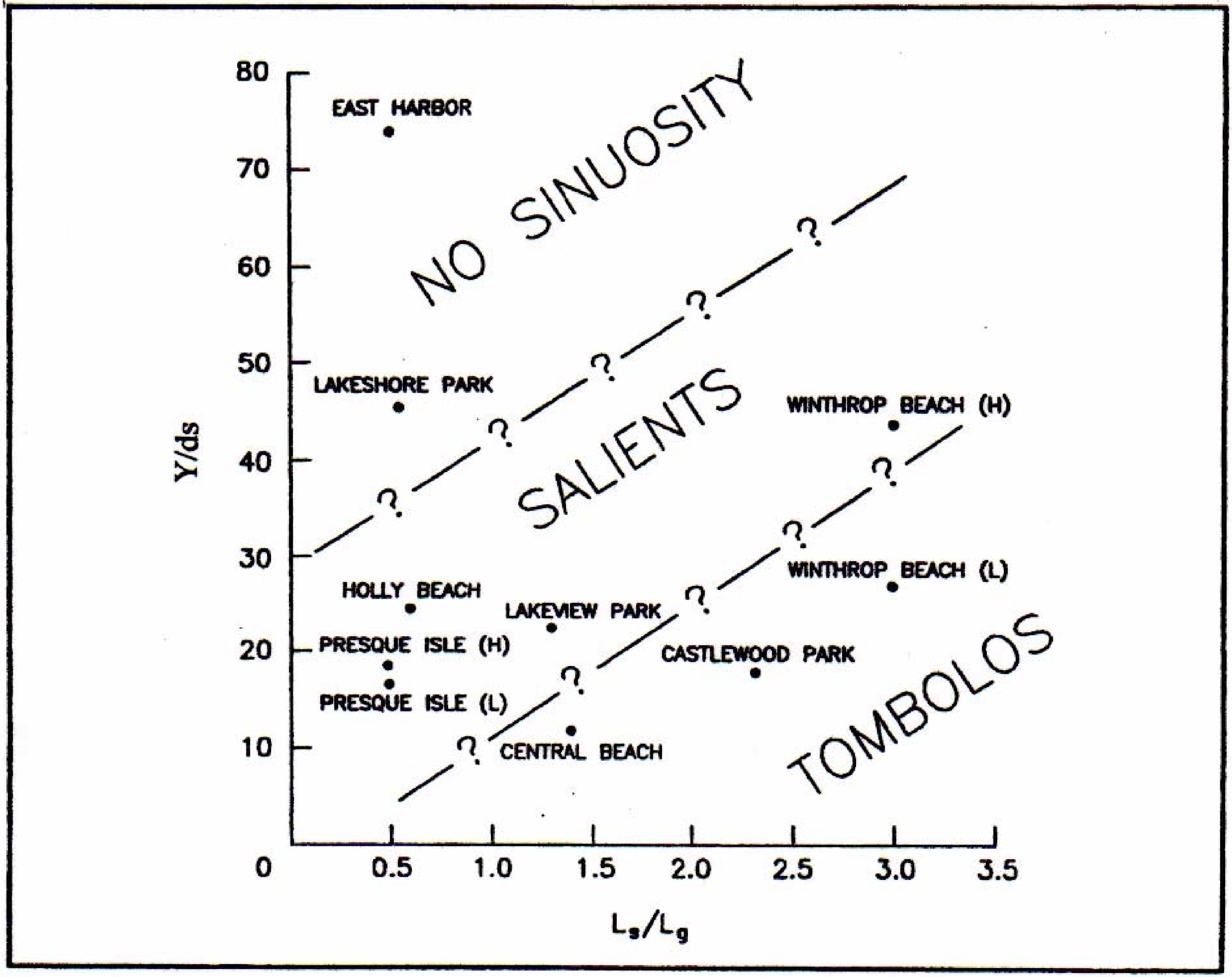
Figure V-3-20 Definition schematic for nearshore breakwaters



Waves (dominant) (H_o, H_b) T, Θ
℄
℄
L_s
L_g
H_b
Gap
$Q_{offshore}$
Breaker line (nominal)
Q_{net}
Q_{gross}
MHW shoreline (dominant)
Salient
Y
Y_b
Y_s
Y_g
Nourished (MHW) shoreline
e
W, Design beach width
Y_{min} (MHW) (Design storm)
Original shoreline (MHW)
Base (reference) line



Section View



80
70
60
50
40
30
20
10
0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Y/ds
L_s/L_g
EAST HARBOR
LAKESHORE PARK
HOLLY BEACH
LAKEVIEW PARK
PRESQUE ISLE (H)
PRESQUE ISLE (L)
CENTRAL BEACH
CASTLEWOOD PARK
WINTHROP BEACH (H)
WINTHROP BEACH (L)
NO SINUOSITY
SALIENTS
TOMBOLOS
?

KEY VARIABLES FOR NEARSHORE BREAKWATER DESIGN

Dally and Pope, 1986

Definitions:

Y = breakwater distance from nourished shoreline
L_s = length of breakwater
L_g = gap distance
d_s = water depth at breakwater (MWL)

- Tombolo formation: Ls/Y = 1.5 to 2 single
  = 1.5 system
- Salient formation: Ls/ = 0.5 to 0.67
  = 0.125 long systems

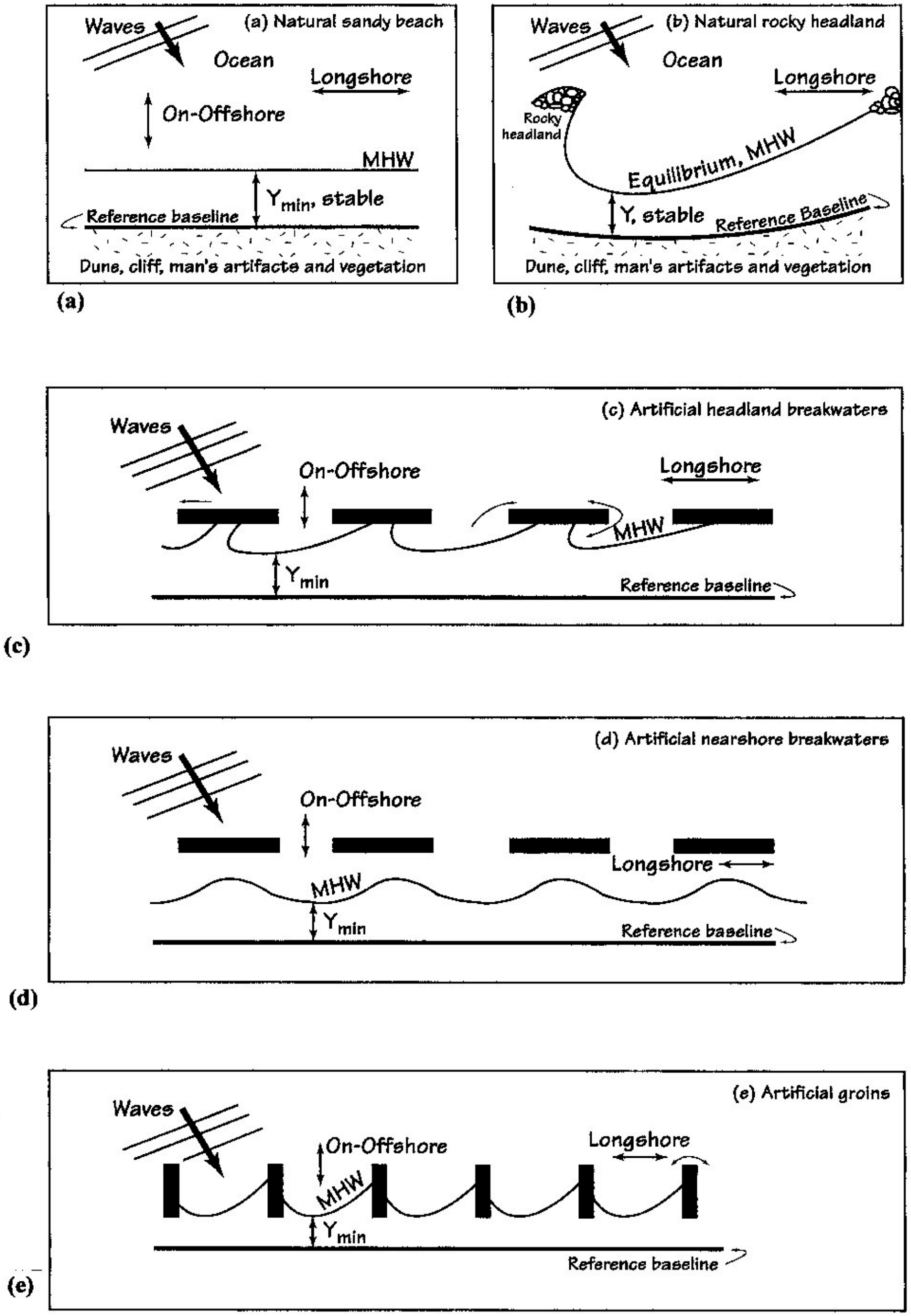
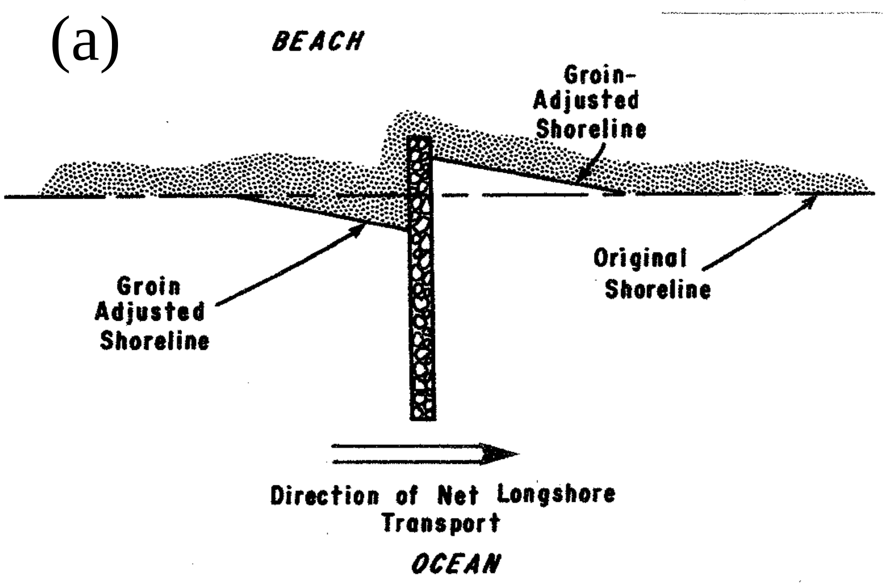
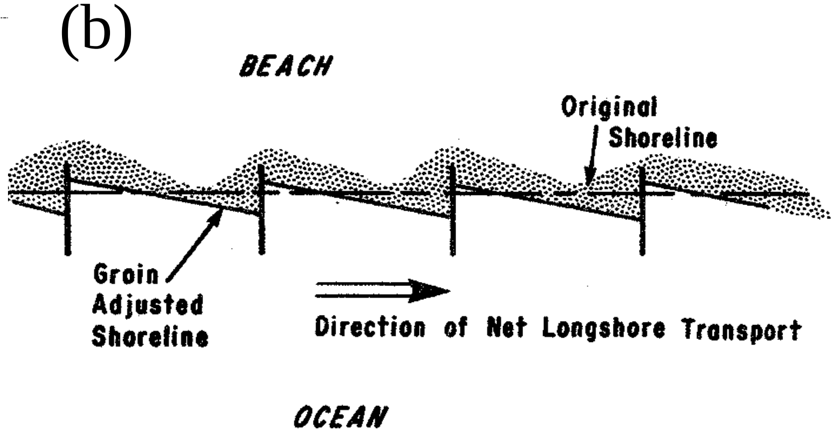


Figure V-3-11 Natural and artificially stable shorelines with minimum dry beach width, Y_{min} (a) sandy beach (b) rocky headland (c) headland breakwaters (d) nearshore breakwaters (e) groins



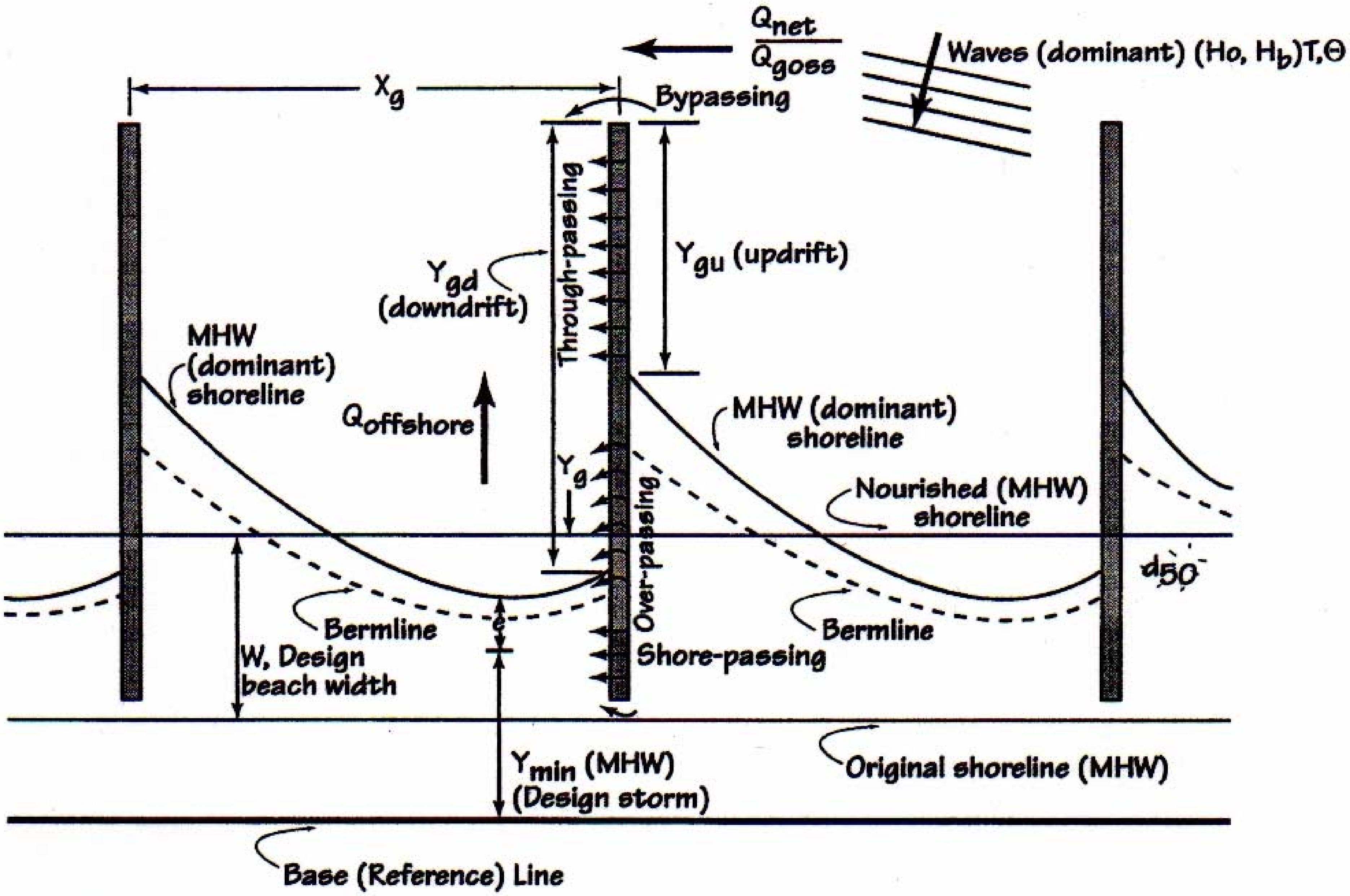


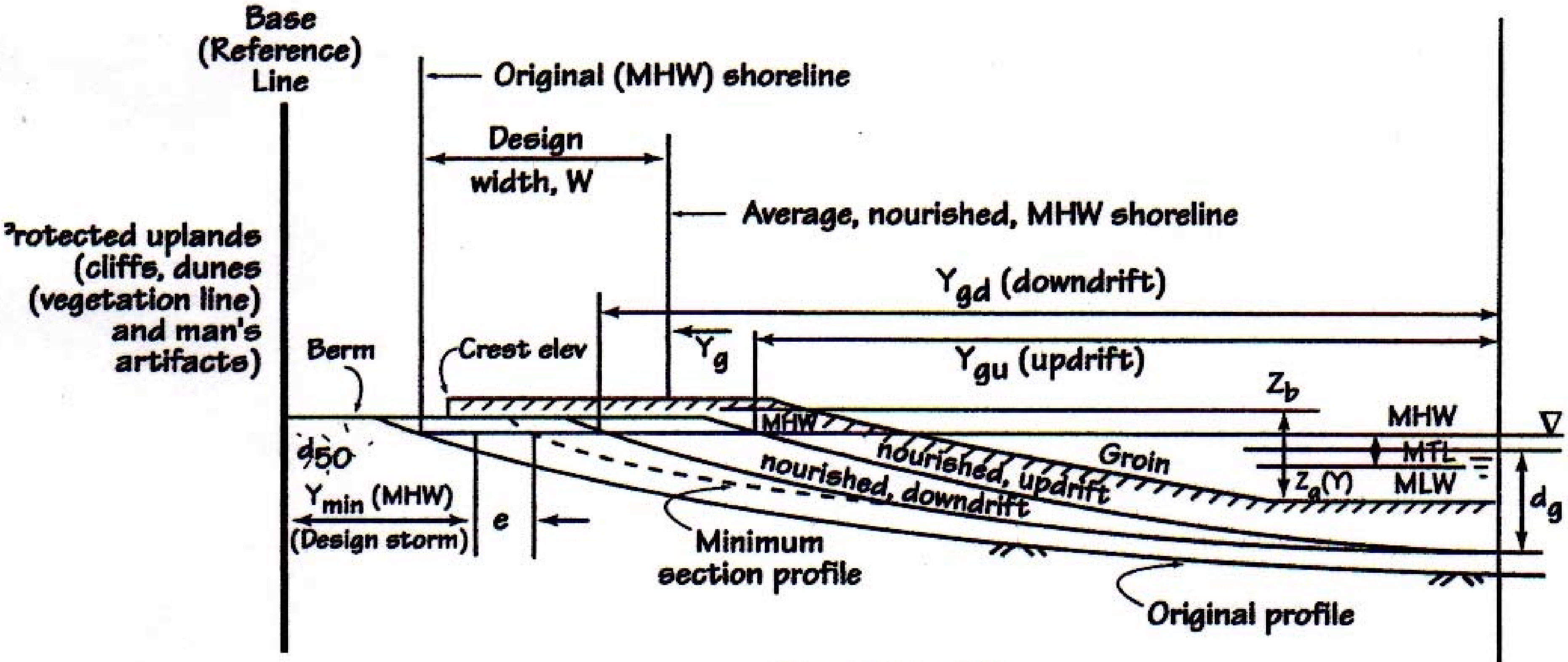
23 General shoreline adjustment for direction of net longshore transport (a) single groin (b) groinfield

Table V-3-8
Main parameters governing beach response and bypassing at groins (from Kraus et al. 1994)

Groin(s)	**Beach and Sediment**	**Waves, Wind, and Tide**
Length	Depth at tip of groin	Wave height and variability
Elevation	Depth of closure	Wave period " "
Porosity	Sediment availability	Wave angle " "
Configuration (straight, T, L, etc.)	Median grain size and variability	Tidal range
Orientation to the shoreline	Sediment density	Wind speed " "
Spacing between groins	---	Wind direction " "
Tapering	---	Wind duration " "
a) Note. Two integrated parameters governing groin functioning are (1) the ratio of net to gross longshore sand transport, and (2) the presence, location, and number of longshore bars.		

Process	Parameter	Description
1. Bypassing	D_g/H_b	Depth at groin tip/breaking wave height
2. Permeability		
• Over-passing	Z_g (y)	Groin elevation across profile, tidal range
• Through-passing	P(y)	Grain permeability across shore
• Shore-passing	Z_b/R	Berm elevation/runup elevation
3. Longshore transport	Q_n/Q_g	Net rate/gross rate


Qnet / Qgoss
Waves (dominant) (Ho, Hb)T,Θ
Xg
Bypassing
Through-passing
Ygd (downdrift)
Ygu (updrift)
MHW (dominant) shoreline
Qoffshore
Yg
Over-passing
MHW (dominant) shoreline
Nourished (MHW) shoreline
d50
Bermline
ε
W, Design beach width
Shore-passing
Bermline
Ymin (MHW) (Design storm)
Original shoreline (MHW)
Base (Reference) Line



Section View

Property	Comment
1. Wave angle and wave height are leading parameters (longshore transport)	Accepted. For fixed groin length, these parameters determine bypassing and the net and gross longshore transport rates
2. Groin length is a leading parameter for single groins. (Length controls depth at tip of groin)	Accepted, with groin length Defined relative to surfzone width.
3. Groin length to spacing ratio is a leading parameter for groin fields	Accepted. See previous item
4. Groins should be permeable.	Accepted. Permeable groins allow water and sand to move alongshore, and reduce rip current formation and cell circulation.

Property	Comment
5. Groins function best on beaches with a predominant longshore transport direction.	Accepted. Groins act as rectifiers of transport. As the ratio of gross to net transport increases, the retention functioning decreases.
6. The updrift shoreline at a groin seldom reaches the seaward end of the groin. (This observation was not found in the literature review and appears to be original to the present paper.)	Accepted. Because of sand bypassing, groin permeablitiy, and reversals in transport, the updrift shoreline cannot reach the end of a groin by longshore transport processes alone. On-shore transport is required for the shoreline to reach a groin tip, for a groin to be buried, or for a groin compartment to fill naturally.
7. Groin fields should be filled (and/or feeder beaches emplaced on the downdrift side).	Accepted. Filling promotes bypassing and mitigates downdrift Erosion.

Property	Comment
8. Groin fields should be tapered if located adjacent to an unprotected beach.	Accepted. Tapering decreases the impoundment and acts as a transItion from regions of erosion to regions of stability.
9. Groin fields should be built from the downdrift to updrift direction.	Accepted, but with the caution that the construction schedule should be coordinated with expected changes in seasonal drift direction.
10.Groins cause impoundment to the farthest point of the updrift beach and erosion to the farthest point of the downdrift beach.	Accepted. Filling a groin field does not guarantee 100% sand bypassing. Sand will be impounded along the entire updrift reach, causing Erosion downdrift of the groin(s).
11.Groins erode the offshore profile.	Questionable and doubtful. No Clear physical mechanism has been proposed.

Property	Comment
12. Groins erode the beach by rip-current jetting of sand far offshore.	Questionable. Short groins cannot jet material far offshore, and permeable groins reduce the rip-current effect. However, long impermeable jetties might produce large rips and jet material beyond the average surfzone width.
13. For beaches with a large predominant wave direction, groins should be oriented perpendicular to the breaking wave crests.	Tentatively accepted. Oblique orientation may reduce rip current generation.

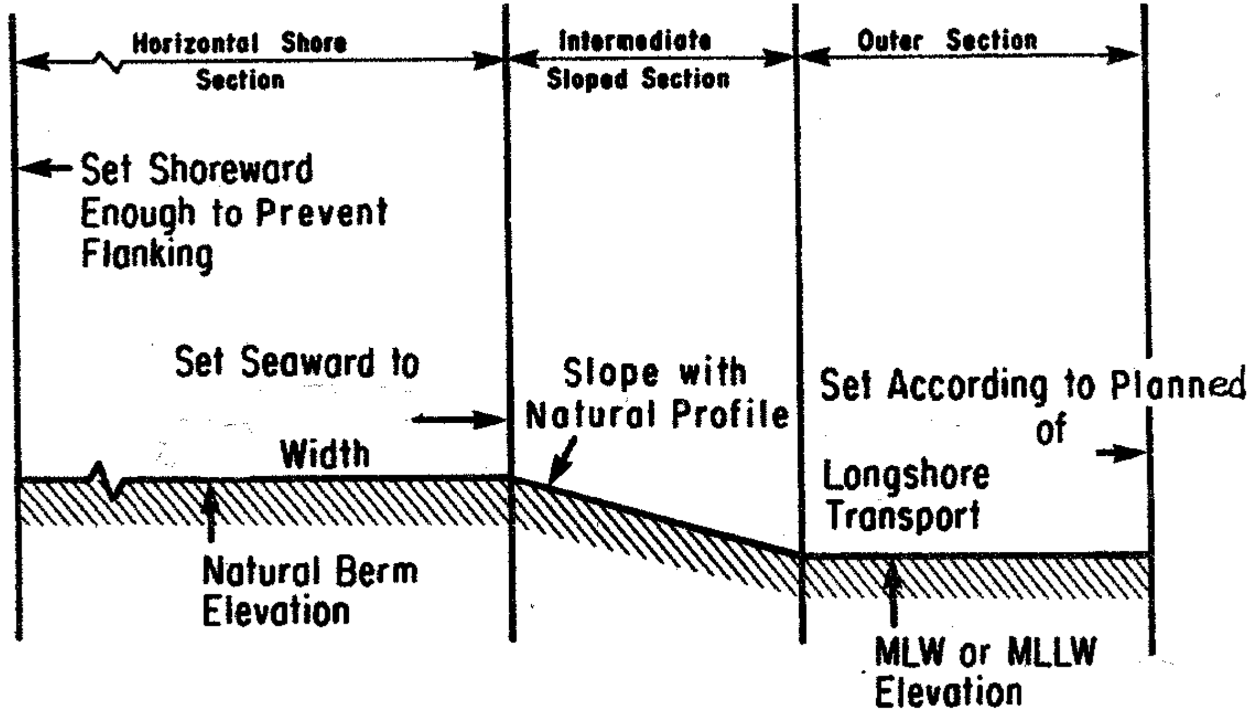


Figure V-3-31 Typical groin field with sloping section

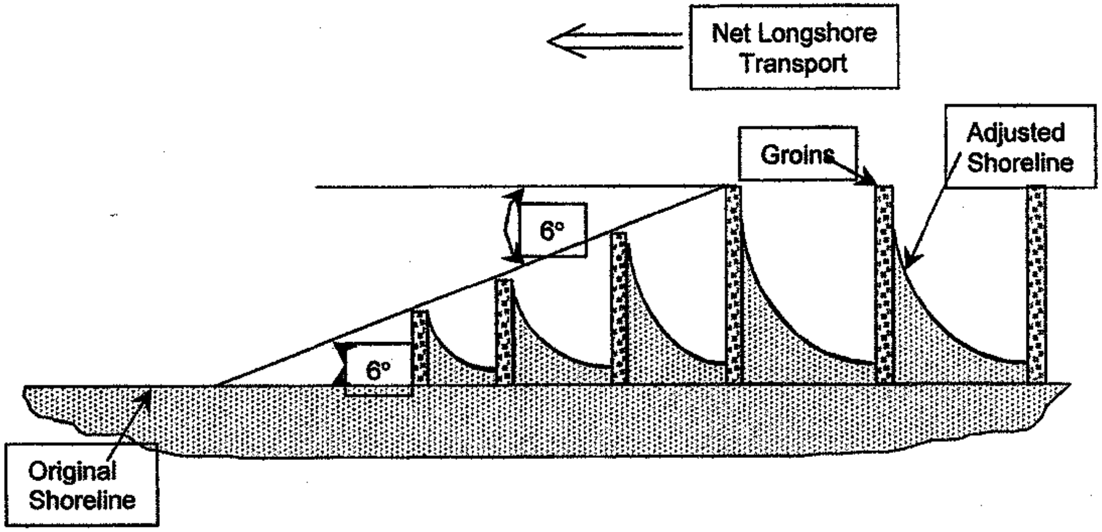


Figure V-3-32   Transition from groin field to natural beach

(6) Basic rules for functional design of groins. Ten modern rules for groins design can be summarized as follows:

Rule 0 If cross-shore sediment transport processes dominant, consider nearshore breakwater systems first.

Rule 1 Conservation of mass for transport of sediment alongshore and cross-shore means groins neither create nor destroy sediment.

Rule 2 To avoid erosion of adjacent beaches, always include a beach fill in the design

Rule 3 Agree on the minimum, dry beach width, Y_{min} for upland protection during storm events as a measured to judge success.

Rule 4 Begin with X_g/Y_g=2-3 where X_g is the longshore spacing and Y_g is the effective length of the groin from its seaward tip to the design shoreline for beach fill at time of construction.

Rule 5 Use a modern, numerical simulation model (e.g. GENESIS) to estimate shoreline change around single groins and groin fields.

Rule 6 Use a cross-shore, sediment transport model (e.g. SBEACH) to estimate the minimum, dry beach width, Y_{min} during storm events.

Rule 7 Bypassing, structure permeability and the balance between net and gross longshore transport rates are the three key factors in the functional design. Use the model simulation to iterate a final design to meet the, Y_{min} criterion.

Rule 8 Consider tapered ends, alternate planforms and cross-sections to minimize impacts on adjacent beaches.

Rule 9 Establish a field monitoring effort to determine if the project is successful and adjacent beach impacts.

Rule 10 Establish a "trigger" mechanism for decisions to provide modification (or removal) if adjacent beach impacts found not acceptable.

Methods to Calculate Gap Erosion, e for Storm Damage Mitigation

- Analytical Methods
  - See CEM Part III-3-2i (Kobayashi, 1987; Kriebel and Dean, 1993)
  - See Example Problem V-3-1
  - Method is conservative
- Numerical Methods
  - Use cross-shore sediment transport model (e.g. SBEACH, Larson and Kraus, 1989)
  - Wave diffraction neglected
  - Method is conservative

A general, three-dimensional, wave current and sediment transport model is needed.