

GenCade: Introduction, Background, and Formulation



Ashley Frey

Ashley.E.Frey@usace.army.mil

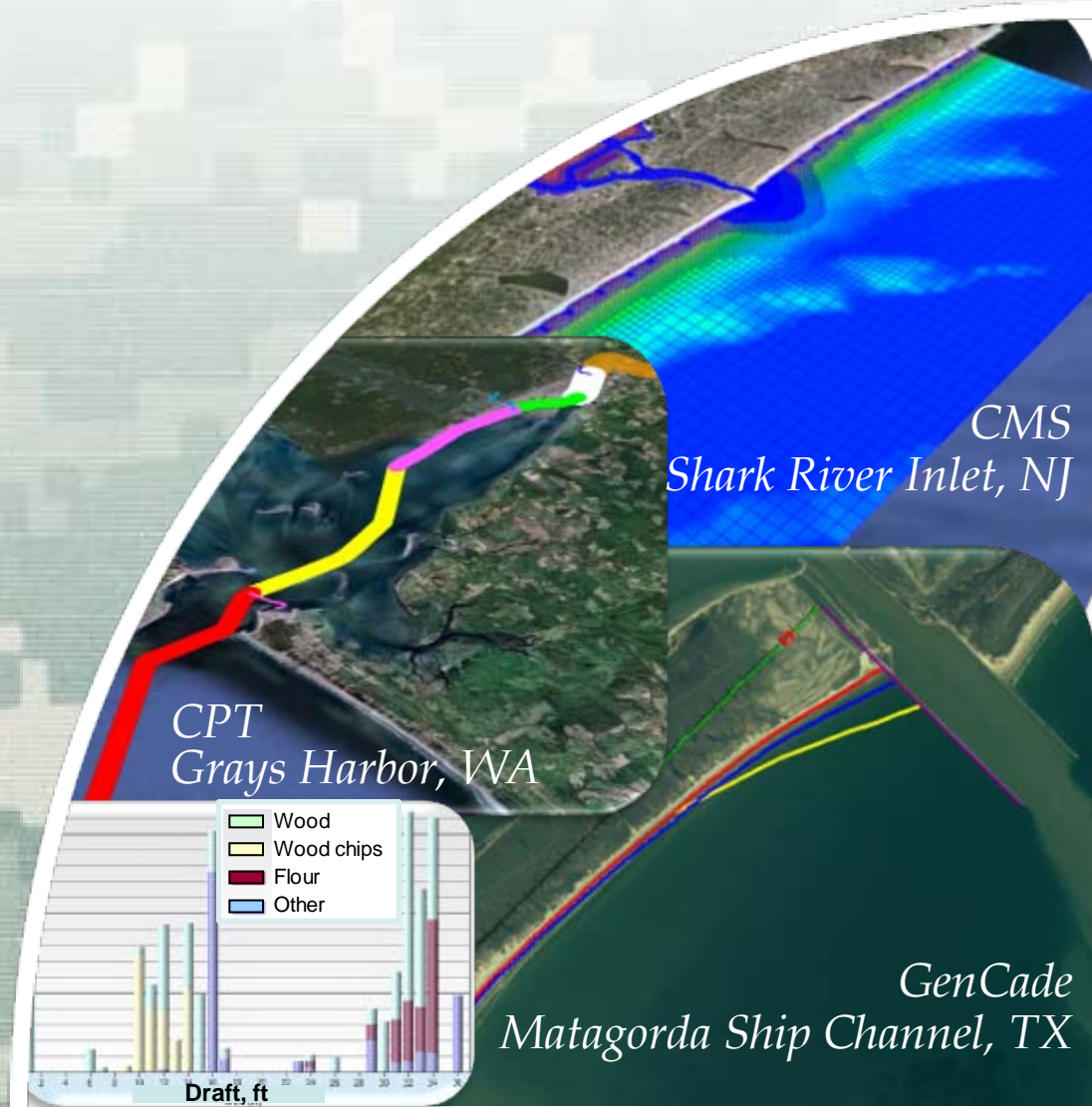
Tanya Beck

Tanya.M.Beck@usace.army.mil

March 7, 2012



US Army Corps of Engineers
BUILDING STRONG





Outline

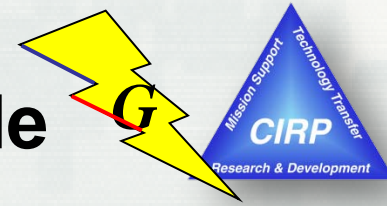


- What is GenCade?
- Background, overview, and conceptual coverage
- GenCade capabilities
- GenCade limitations and assumptions
- Workflow
- Model theory and formulation
- I/O Files and Cards
- GenCade interface in SMS
- Future Development





GENESIS + Cascade → GenCade

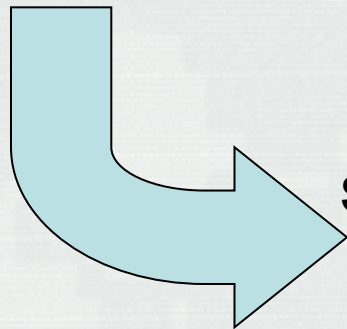


Cascade (top to bottom)

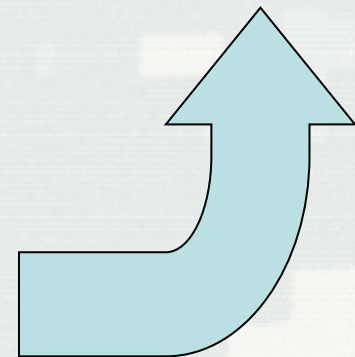
- Planning tool (RSM Support)
- Time scales: months to centuries
- Multiple inlets, shoals, and barrier islands; cumulative impacts; retains curvature of regional geomorphology
- Fast
- Typical grid resolution ~ 500 m
- Cross-shore processes in future

GENESIS (bottom to top)

- Engineering design tool
- Can represent all engineering details – structures, etc.
- Mature technology – big payback by updating
- Typical grid resolution ~ 25 m

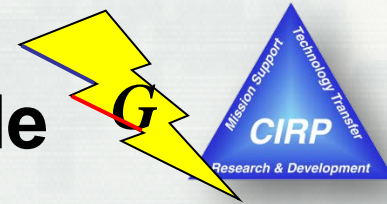


Strategy: Add Cascade capabilities to GENESIS to automatically include all GENESIS features

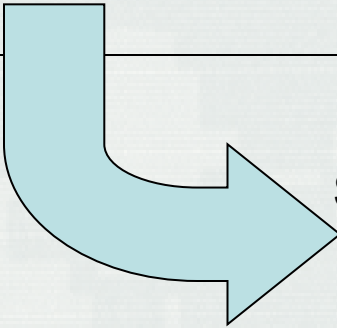




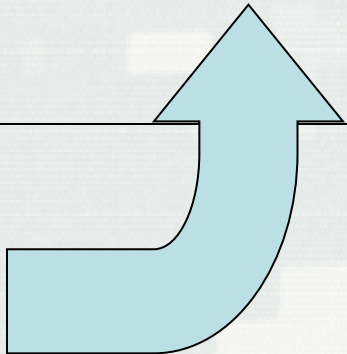
GENESIS + Cascade → GenCade



- Integrate from planning through engineering design
- Cover time scales from days to centuries
- Preserve regional trends
- Furnish regionally consistent boundary conditions to local projects
- Represent cumulative local projects interacting regionally
- Represent inlet bypassing and tidal delta evolution
- Resolve engineered elements
- Include variable grid resolution for accuracy and efficiency
- Improve computational efficiency (over GENESIS)



Strategy: Add Cascade capabilities to GENESIS to automatically include all GENESIS features



Gencade Conceptual Processes: Coastal Sediment Dynamics





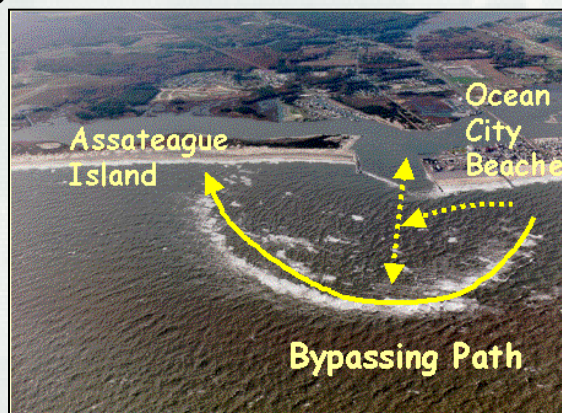
GenCade Applicability



Regional processes, Long-term morphology change



Project Planning & Design



Habitat Change



- Regional Sediment Management
 - Beach fills
 - Inlet bypassing
 - Channel maintenance
- Unifying technology for multiple projects
- Intuitive interface (SMS)
- Storm erosion hazard management
- Dune erosion, overwash, & breach susceptibility; coastal response to SLR
- Habitat evolution (Piping Plover; vegetation)

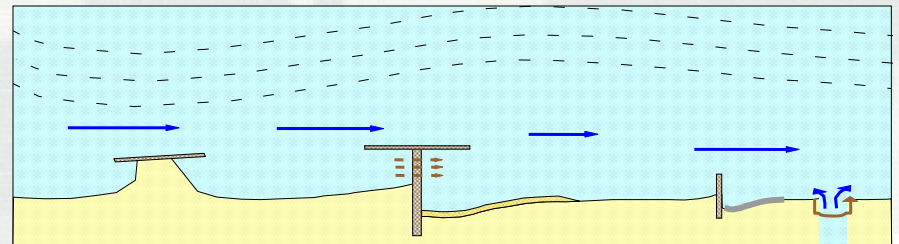




Model Functionality and Capabilities



- Variable resolution grids
- Inlet bypassing
- Inlet Reservoir Model for calculation of shoal and inlet feature sediment balance
- Representation of regional morphologic trends
- Multiple wave input forcing locations
- Representation of coastal structures: groins, jetties, seawalls, t-head groins, breakwaters, etc.
- Calculation of salients and tombolos behind breakwaters
- Time-dependent detached breakwater transmission
- Efficient calculation of breaking wave properties in internal wave model





GenCade Assumptions



- Beach profile maintains a constant average shape
- Longshore transport occurs only between top of berm and depth of closure (or active transport)
- Sand transported alongshore by breaking waves is not affected by nearshore current patterns
- There is a long-term trend in shoreline evolution





General Workflow



- Coastal Problem
 - Formulate question
 - Identify constraints
 - Develop criteria to review and evaluate the solutions
- Assemble and analyze relevant input data
- Develop engineering solutions and alternatives
- Develop and execute GenCade to optimize project solutions and alternatives
- Calibrate, Validate, Evaluate Alternatives
- Monitor and evaluate results





GenCade Workflow



- Compile project data
- Assimilate data as GenCade forcing or BC input
- Develop conceptual model from input data
- Develop GenCade project grid and alternatives

Pre-
Process

- Execute calibration simulations/sensitivity tests
- Review and analyze calibration results
- Refine setups
- Execute production simulations

Simulate

- Review results
- Analyze and post-process results

Post-
Process





®



Inputs:

- Survey data
- Waves
- Structure information
- Inlet information
- Beach Fill
- Dredging

Pre-process inputs

GenCade grid regular/irregular

Develop initial shoreline

Develop regional contour

Assign wave inputs

Supply input control parameters

Structures or coastal projects

Inlets, shoals, dredging events

Beach fill events

Simulation outputs:
GenCade solution files





®



Inputs:

GenCade Solution files;
Measured Data

Post-process

Post-process outputs:
Calculations, figures,
images, exported data

Transport rates

Sediment budgets

Shoreline Change

Inlet bypass/shoal evolution

Compare measured

Compare alternatives





®

Model Formulation

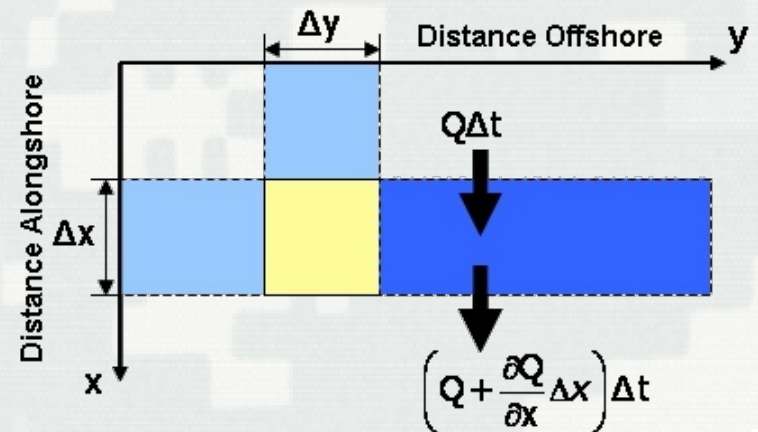
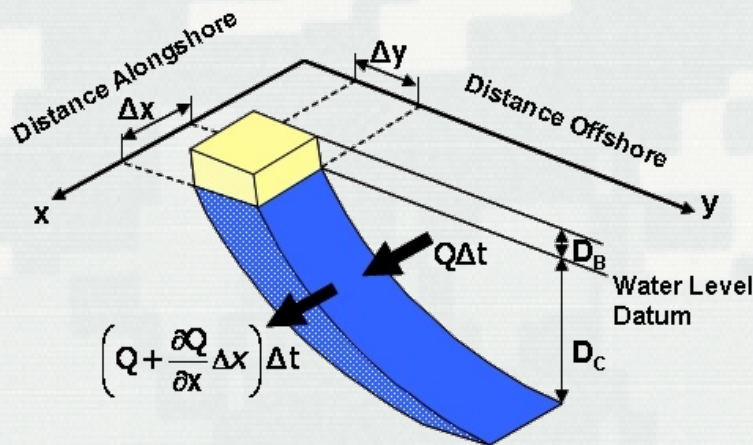


Longshore Net Volume Change:
$$\frac{dQ}{dt} = \left(\frac{\partial Q}{\partial x} \right) dx dt$$

Cross-shore Net Volume Change:
$$dq dt$$

Total Volume Change:
$$dV = dx dy (D_B + D_C) = \left(\frac{\partial Q}{\partial x} \right) dx dt + q dx dt$$

$$\therefore \text{as } dt \rightarrow 0: \frac{\partial y}{\partial t} + \frac{1}{D_B + D_C} \cdot \left[\frac{\partial Q}{\partial x} - q \right] = 0$$





®

Model Formulation

Sediment transport rate Q (m^3/s):

$$Q = \left(H^2 C_g \right)_b \left(a_1 \sin 2\alpha_{bs} - a_2 \cos \alpha_{bs} \frac{\partial H_b}{\partial x} \right)$$

Where,

H = wave height (m)

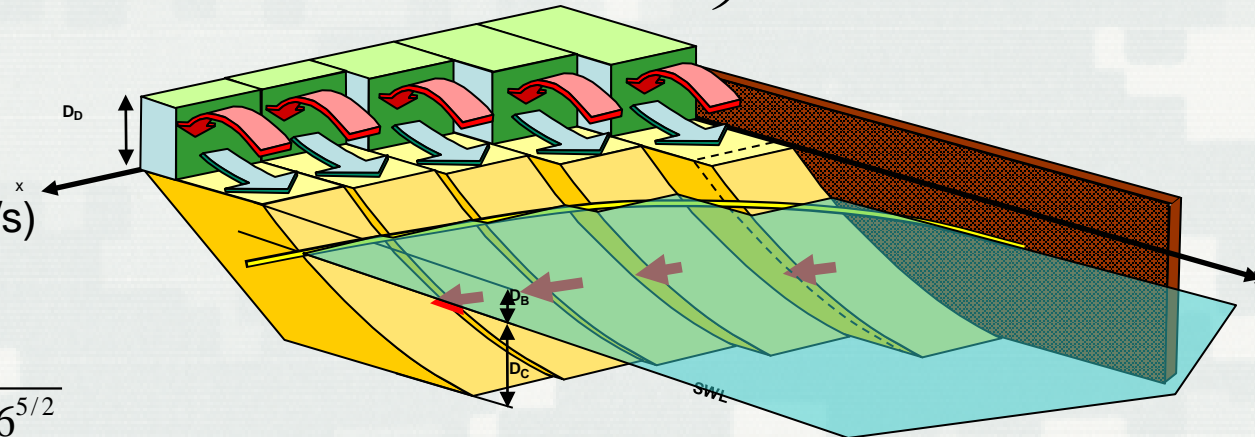
C_g = wave group speed (m/s)

α_{bs} = angle of the breaking

$$a_1 = \frac{K_1}{16(\rho_s / \rho - 1)(1 - p)1.416^{5/2}}$$

$$a_2 = \frac{K_2}{8(\rho_s / \rho - 1)(1 - p) \tan \beta 1.416^{5/2}}$$

Typically, value of K_2 is:
 $0.5K_1 < K_2 < 1.5K_1$



Where,

K_1 = Primary empirical transport coefficient
(controls magnitude of longshore transport rate)

K_2 = Secondary empirical transport coefficient
(controls distribution of sand within an area; esp. where large wave height gradients, e.g. salients)

$\tan \beta$ = average bottom slope

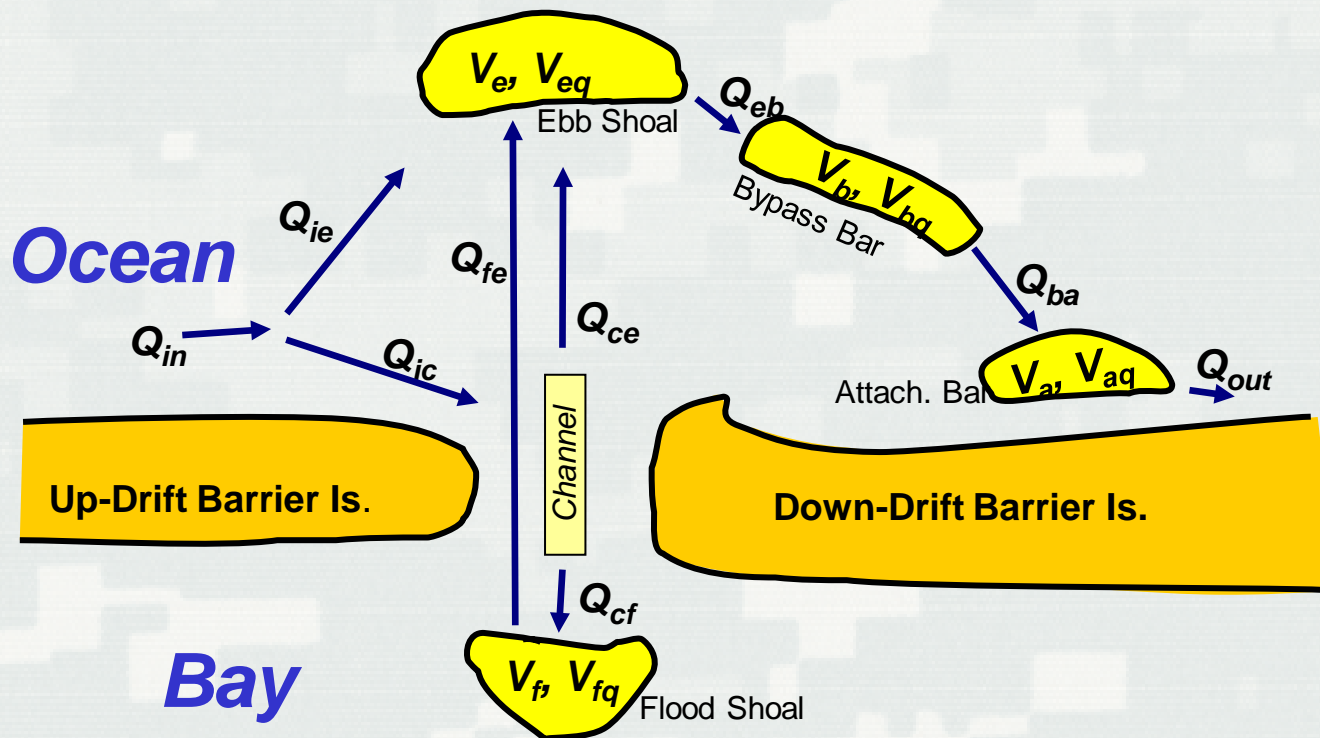




®

Inlet Reservoir Model

Inlet bypassing and evolution of inlet deltas



$$Q_{ie} = \delta Q_{in}$$

$$Q_{ic} = (1 - \delta) Q_{in}$$

$$Q_{ce} = \beta Q_{ic} = \beta (1 - \delta) Q_{in}$$

$$Q_{cf} = (1 - \beta) Q_{ic} = (1 - \beta) (1 - \delta) Q_{in}$$

$$Q_{fe} = (V_f - V_{fq}) / dt, V_f > V_{fq}$$

$$Q_{eb} = \frac{V_e}{V_{eq}} (Q_{ie} + Q_{fe} + Q_{ce})$$

$$Q_{ba} = \frac{V_b}{V_{bq}} Q_{eb}$$

$$Q_{out} = \frac{V_a}{V_{aq}} Q_{ba}$$

$$\delta = (V_e + V_f) / (V_{eq} + V_{fq})$$

$$dV_e = (Q_{ie} + Q_{fe} + Q_{ce} - Q_{eb}) dt$$

$$dV_f = (Q_{cf} - Q_{fe}) dt$$

$$dV_b = (Q_{eb} - Q_{ba}) dt$$

$$dV_a = (Q_{ba} - Q_{out}) dt$$

$$\beta = (1 - V_e / V_{eq}) / (2 - V_e / V_{eq} - V_f / V_{fq})$$





Output File Format for GenCade



Instantaneous Net Transport at Output Time (*.qtr) File

Column 1	Column 2 through Column NX
Date (yyyymmdd)	Net sediment transport ($\text{length}^3/\text{year}$) for each grid cell

Mean Net Transport Over Simulation or Specified Time (*.mqn) File

Column 1	Column 2 through Column NX
Date (yyyymmdd)	Net sediment transport ($\text{length}^3/\text{year}$) for each grid cell averaged over entire simulation (and optionally from start to specified times)

Mean Left Transport Over Simulation or Specified Time (*.mql) File

Column 1	Column 2 through Column NX
Date (yyyymmdd)	sediment transport ($\text{length}^3/\text{year}$) to left for each grid cell averaged over entire simulation (and optionally from start to specified times)

Mean Right Transport Over Simulation or Specified Time (*.mqr) File

Column 1	Column 2 through Column NX
Date (yyyymmdd)	sediment transport ($\text{length}^3/\text{year}$) to right for each grid cell averaged over entire simulation (and optionally from start to specified times)





®

Output File Format for GenCade



Shoreline Position at Output Time (*.slo) File

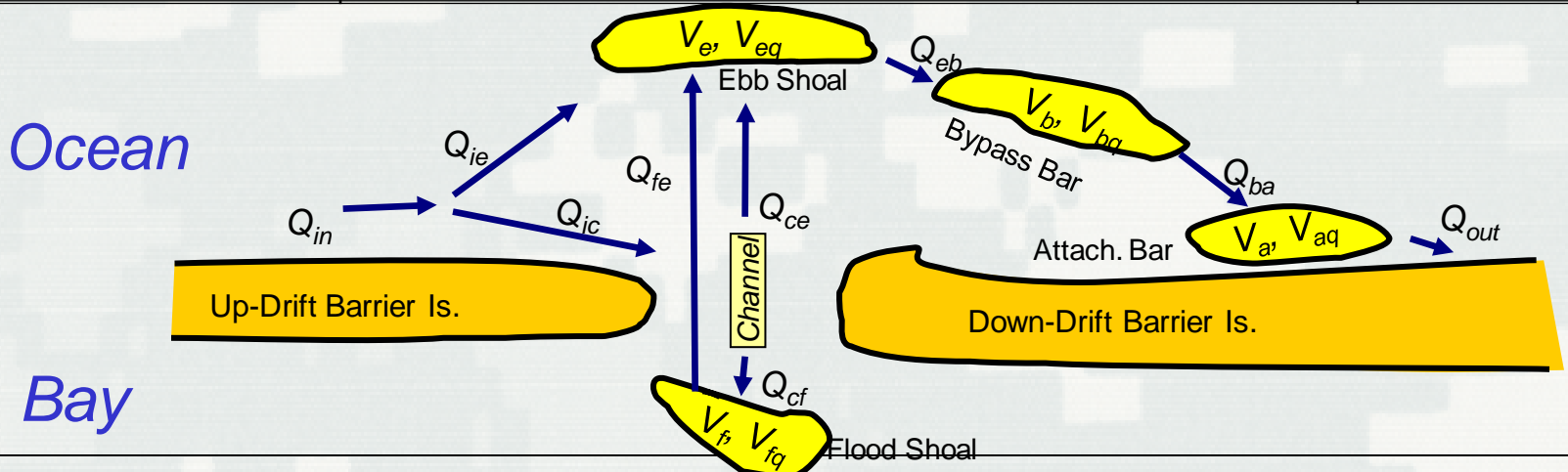
Column 1	Column 2 through Column NX
Date (yyyymmdd)	Y-position of shoreline (length unit) for each grid cell

Calculated Offshore Contour at Output Time (*.off) File

Column 1	Column 2 through Column NX
Date (yyyymmdd)	Y-position of offshore contour applied to wave transformation (length unit) for each grid cell

Inlet Shoal Volume Output (*.irv) File (one file for each inlet)

Column 1	Column 2 Through Column 16	Column 17
Time-step at which shoal volumes are printed as output	Shoal volume (length ³) or in /out volume at each shoal output time-step for the morphological shoal features identified in the figure below	Date (yyyymmdd)





GenCade Input Cards



- **TITLE** Title of simulation run
- **INIFILE** Path and name of initial shoreline file
- **REGFILE** Path and name of regional shoreline file
- **NUMWAVES** Number of wave input locations/files
- **WAVEID** Cell ID; Depth; number of wave events; and file path/name of wave input data (1 WAVEID line/file)
- **PRFILE** Path and name of printed output file
- **GENUNITS** (ft) or (m) System of units for model I/O
- **X0** X-origin
- **Y0** Y-origin
- **AZIMUTH** Angle (deg) of grid rotation about origin
- **NX** Number of alongshore cells
- **DX** Cell resolution or -1 indicates variable resolution
- **SIMDATS** YYYYMMDD Start date of simulation
- **SIMDATE** YYYYMMDD Ending date of simulation
- **DT** 5.0 Time step in hours
- **DTSAVE** 10.0 Data (shoreline/transport) output times
- **K1** 0.5 Longshore sediment transport coefficient 1
- **K2** 0.25 Longshore sediment transport coefficient 2
- **PRTOUT** Output to PRFILE yes (t), no (f)
- **PRWARN** Print warnings yes (t), no(f)
- **PRDATE** Dates to save simulated shoreline
- **ISMOOTH** 11 #cells in offshore contour smoothing
- **IREG** Include regional contour (1 = yes; 0 = no)
- **HAMP 1.0** Height amplification factor
- **THETAAMP 1.0** Angle amplification factor
- **THETADEL 0.0** Angle offset
- **LMOVY 0.0** Leftward shoreline displacement velocity
- **D50 0.33** Grain size diameter in millimeters
- **BERMHT 2** Average berm height
- **DCLOS 8** Depth of closure
- **LBCTYPE 0** Left boundary condition type
- **LMOVY 0.0** Leftward shoreline displacement velocity
- **LMOVPER 1** Simulation period (0), day(1), time step (2) period for LMOVY
- **LGROINY 0.0** Length of left groin from shoreline to seaward tip
- **RBCTYPE 0** Right boundary condition type
- **RMOVY 0.0** Rightward shoreline displacement velocity
- **RMOVPER 1** Simulation period (0), day(1), time step (2) period for RMOVY
- **RGROINY 0.0** Length of right groin from shoreline to seaward tip





GenCade – Variable Grid Alongshore



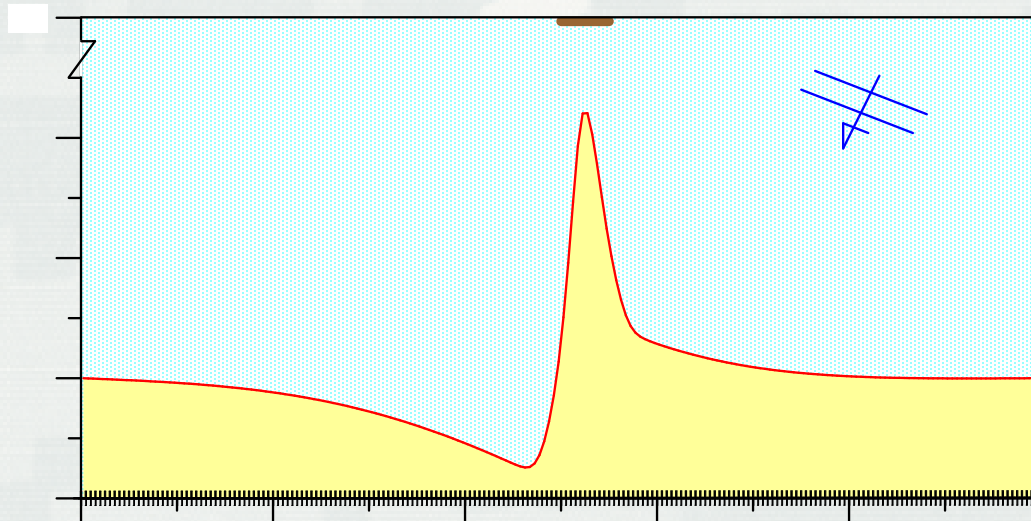
Detached Breakwater
3-month simulation

250 m offshore
100 m long

$H = 1$ m, $T = 5$ sec, $\theta = -5$ deg.

$N = 200$

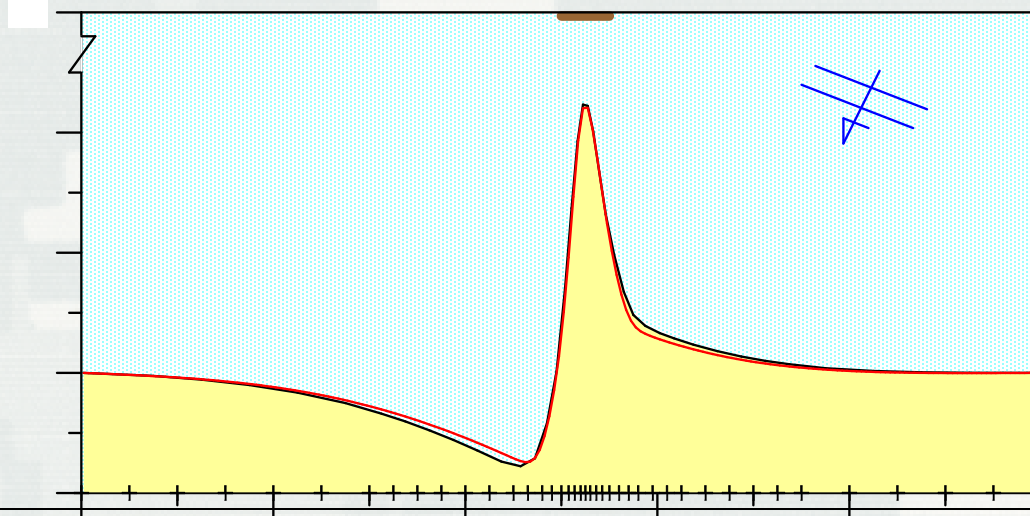
$DX = 10$ m



$N = 40$

$DX_{\max} = 100$ m

$DX_{\min} = 10$ m





GenCade – Transmissive Breakwater

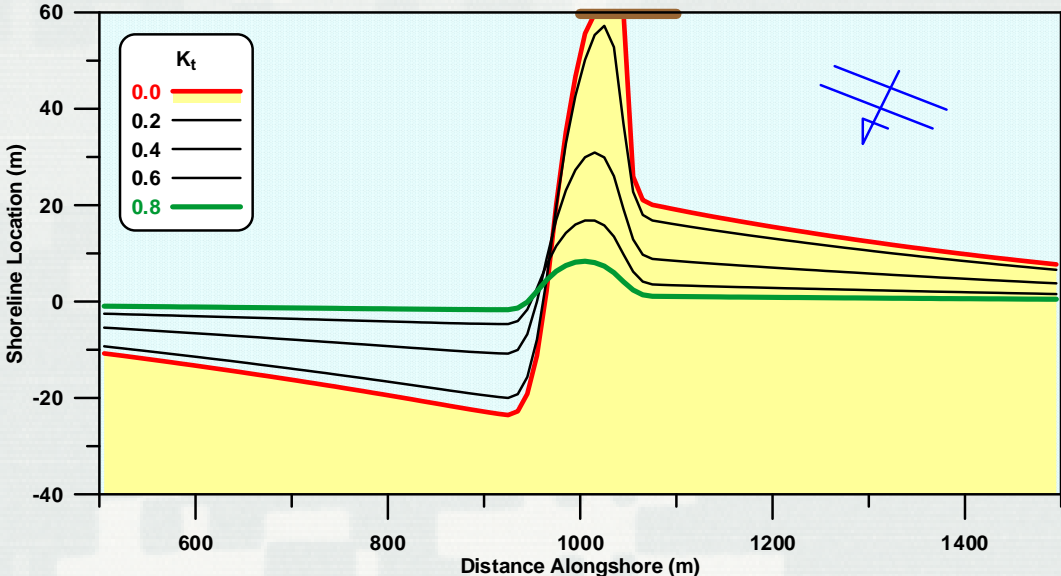


Detached Breakwater
12-month simulation

60 m offshore
100 m long

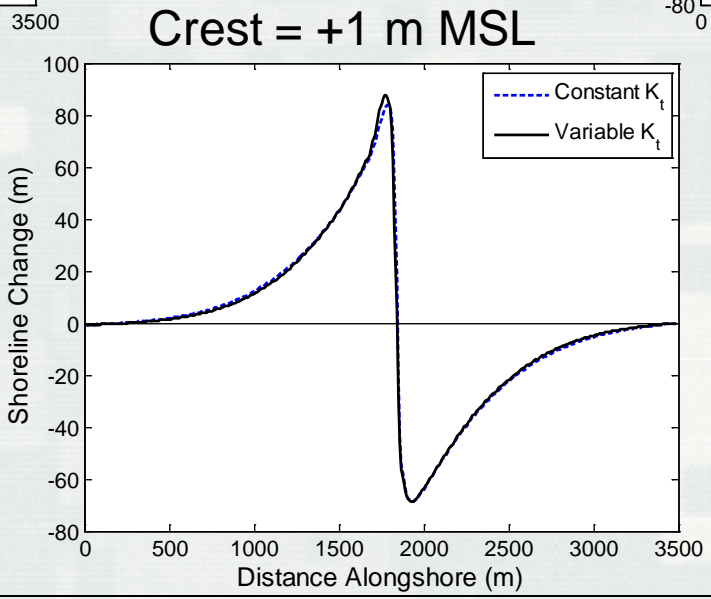
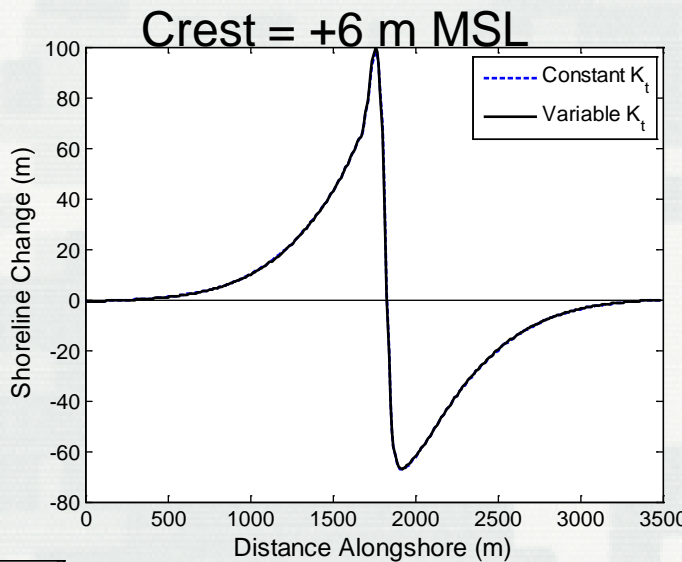
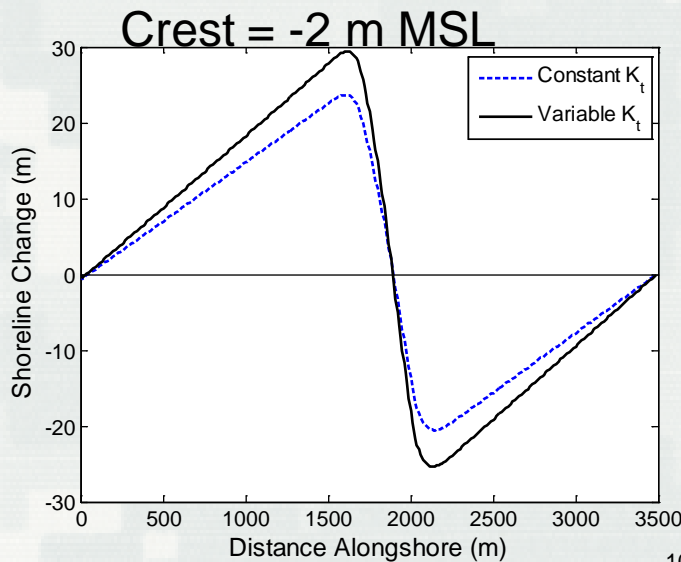
$H = 1$ m, $T = 5$ sec, $\theta = -5$ deg.

$N = 200$
 $DX = 10$ m





Example -- Variable Wave Transmission



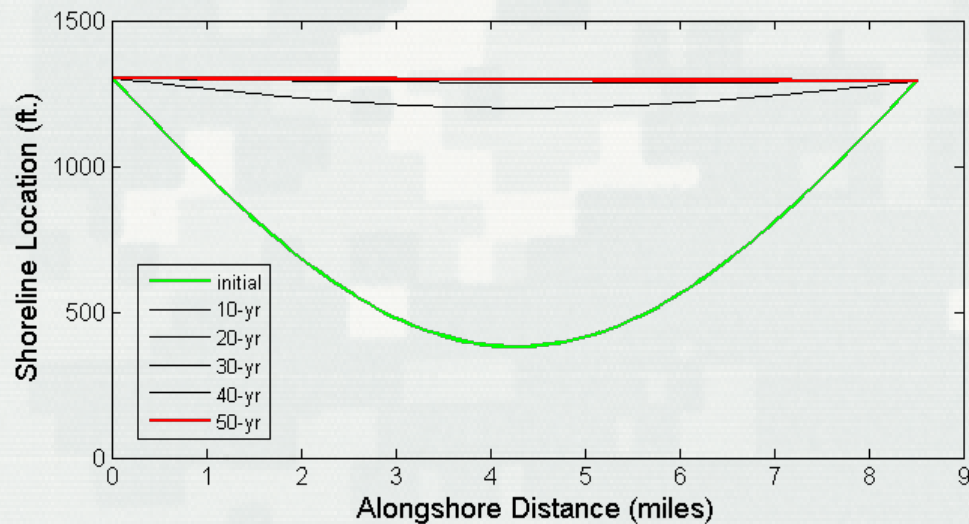


Example

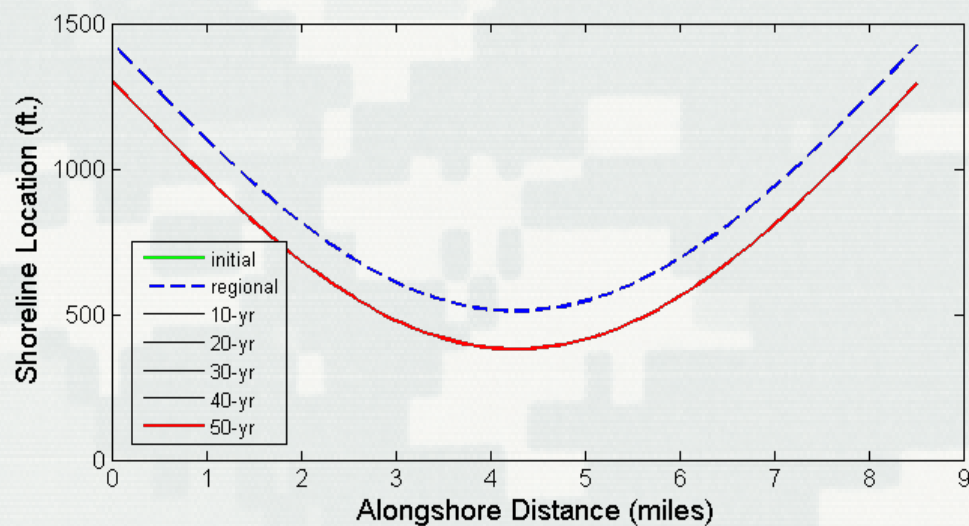
Necessity for Regional Contour



No regional contour



With Regional Contour

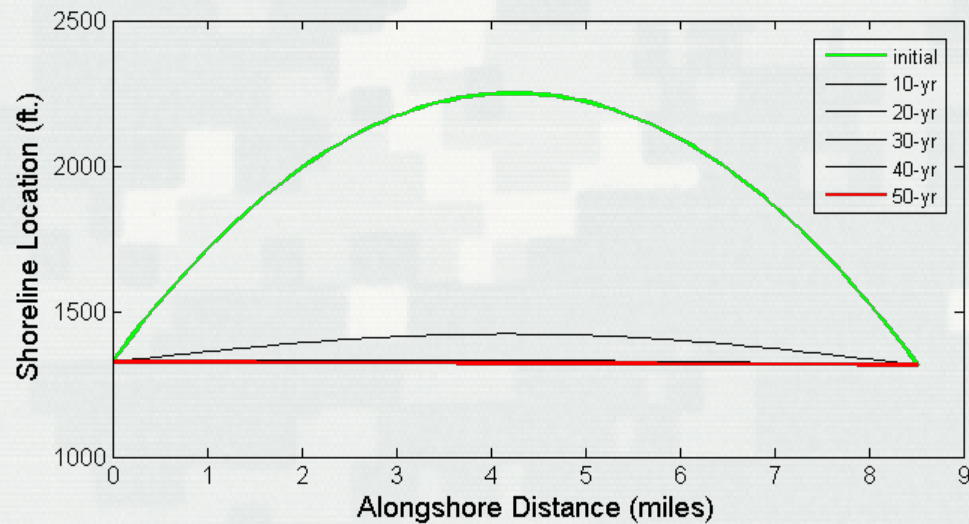




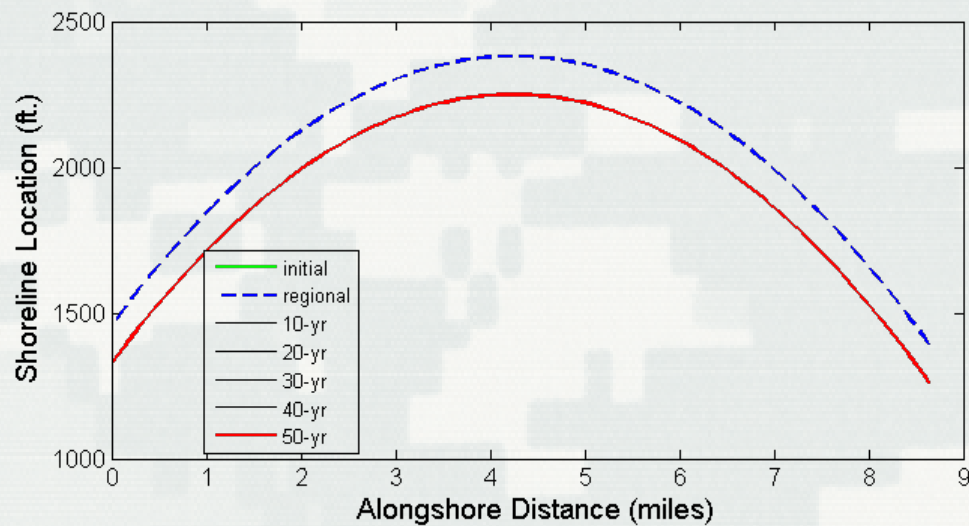
Example Convex Coast



No regional contour



With
regional contour

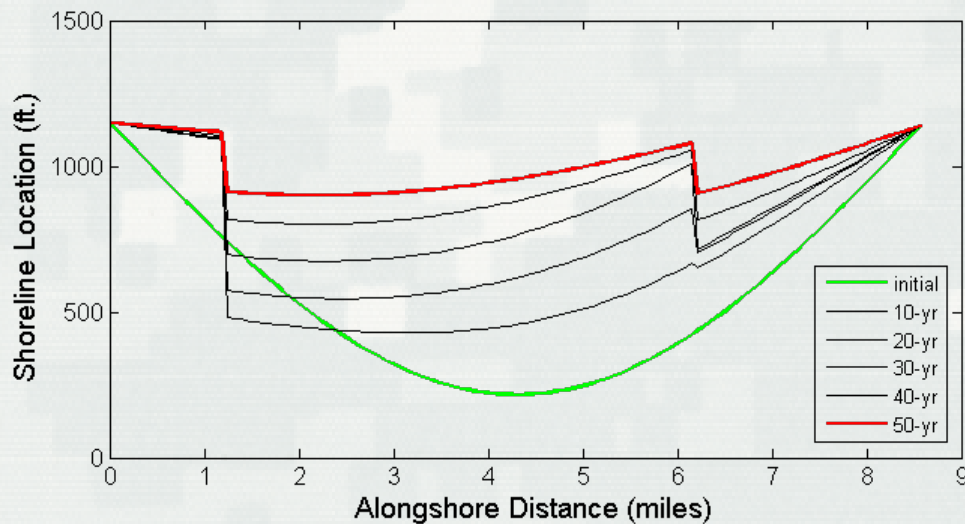




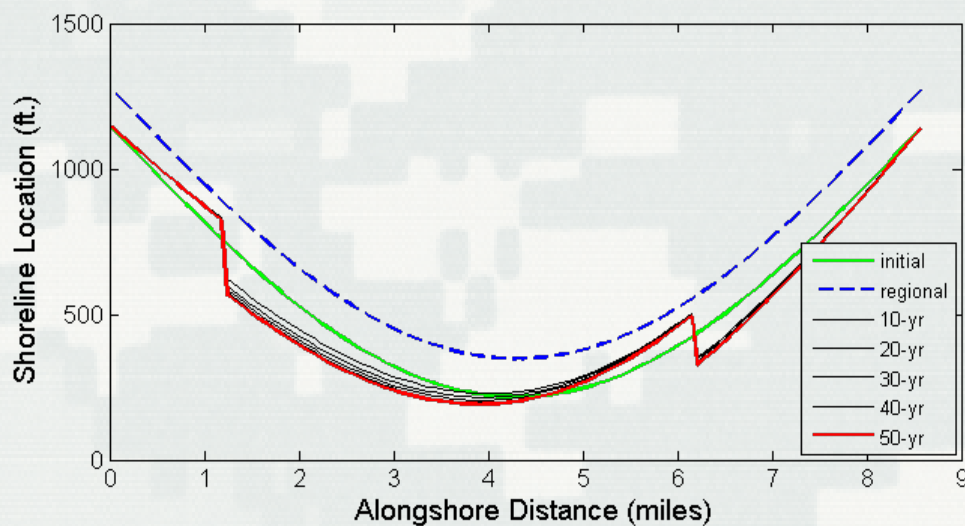
Example – Jetties on Concave Coast



No regional contour



With regional contour





GenCade in the SMS Interface Surface-water Modeling System



- Intuitive interface for project: conception → completion
 - Data entry, cleaning, and archiving
 - GenCade grid and input development: baseline and alternatives
 - GenCade simulations: baseline and alternatives
 - Post-processing, analysis, and figure generation
- World coordinates – everything georeferenced
- Datum reprojection and transformation
- Georeferenced aerial photograph support
- Improved graphics
- Potential to connect to other USACE numerical models in the SMS





GenCade in the SMS (conceptual model)



The screenshot displays the SMS 11.1 Development interface with several overlapping dialog boxes and data tables:

- GenCade Arc Attributes (top left):** Arc Options dropdown set to "Inlet".
- Inlet Shoal Volumes (top right):**

	Initial	Equilibrium
Ebb	1707300.0	2445000.0
- Groins (middle right):**

	Cell Index	Length (ft)	Permeability	Diffracting	Seaward Depth (ft)
1	0	0.0	0.0	<input checked="" type="checkbox"/>	3.0
- Inlets (middle left):** Table with columns Name, Manage, Left Bypass Coef, Right Bypass Coef.

Name	Manage	Left Bypass Coef	Right Bypass Coef
1 Beautiful	ng...	1.0	1.0
- GenCade Arc Attributes (middle):** Arc Options dropdown set to "Groin".
- Beach Fill (bottom):**

	Begin Date	End Date	Start Cell	End Cell	Added Berm Width (ft)
1	01-May-04	01-Jul-04	0	0	84.0
- Shoal to Be Mined (middle right):**

Shoal to Be Mined	Volume (ydf)
Right Bypass	950000.0
Left Bypass	950000.0
Right Bypass	950000.0
Left Bypass	950000.0
Right Bypass	950000.0

White arrows point to the "initial shoreline" and "contour" on the map background.





GenCade in the SMS (conceptual model)



SMS 11.1 Development - [example.sms]

File Edit Display Feature Objects Web Window Help

Map Data

- 1997_initial
- regional
- Merge coverage**
- default coverage
- Images
 - N-18-30_2000

GenCade grid

Wave Gages

Cell	Depth (ft)	Data...
1	0	62.0

Wave Events

	Date	H0 (m)	Period (sec)	Direction (deg)
1	01-Jan-1997 0:00	0.46	5.72	-0.3
2	01-Jan-1997 1:00	0.38	5.94	8.7
3	01-Jan-1997 2:00	0.37	6.16	15.0
4	01-Jan-1997 3:00	0.37	6.35	19.1
5	01-Jan-1997 4:00	0.4	6.48	21.8
6	01-Jan-1997 5:00	0.45	6.24	41.3
7	01-Jan-1997 6:00	0.0	4.87	0.0
8	01-Jan-1997 7:00	0.0	4.66	0.0
9	01-Jan-1997 8:00	0.0	4.64	0.0
10	01-Jan-1997 9:00	0.0	4.71	0.0
11	01-Jan-1997 10:00	0.0	4.8	0.0
12	01-Jan-1997 11:00	0.0	4.91	0.0
13	01-Jan-1997 12:00	0.0	5.01	0.0
14	01-Jan-1997 13:00	0.0	5.03	0.0
15	01-Jan-1997 14:00	0.0	5.0	0.0
16	01-Jan-1997 15:00	0.0	4.98	0.0
17	01-Jan-1997 16:00	0.0	4.94	0.0
18	01-Jan-1997 17:00	0.0	4.91	0.0
19	01-Jan-1997 18:00	0.0	4.87	0.0

Interpret Directions As

Convention: Shore Normal

- Shore Normal
- Oceanographic
- Meteorologic
- Cartesian

Refine Point

Attributes

Refine grid in l direction

Base cell size: 1.0

Wave gage

Options...

Help... OK Cancel

(2710910.0, 359580.0)





GenCade in the SMS (conceptual model)



The screenshot shows the SMS 11.1 Development interface. The main window displays a map with a red line and a grid overlay. A context menu is open over the map, with 'Convert' selected, and a sub-menu showing 'Map -> 1D Grid' and 'Map -> 2D Scatter'. A dialog box titled 'Map -> 1D Grid' is open in the foreground, showing the following settings:

Origin and Orientation

- Origin X: 2735140.000000
- Angle: 180.000000
- I size: 299900.000000 ft
- Origin Y: 357070.000000

I Cell Options

- Define cell sizes
 - Cell size: 300.000000 ft
 - Number of cells: 1000
- Use refine points
 - Maximum cell size: 10.000000 ft
 - Maximum bias: 1.100000
- Use inner growth

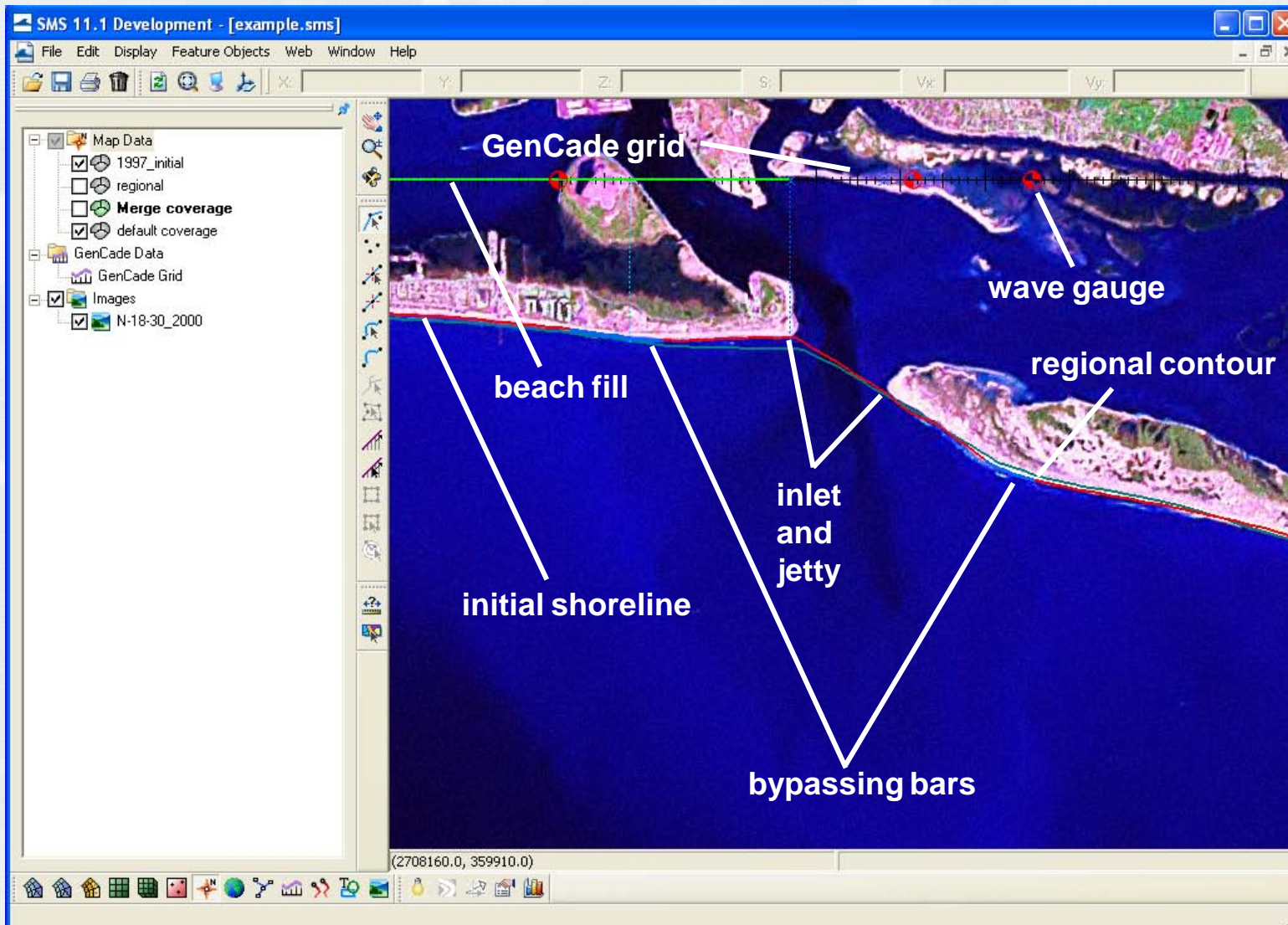
Buttons: Help..., OK, Cancel





®

GenCade in the SMS





®

GenCade in the SMS



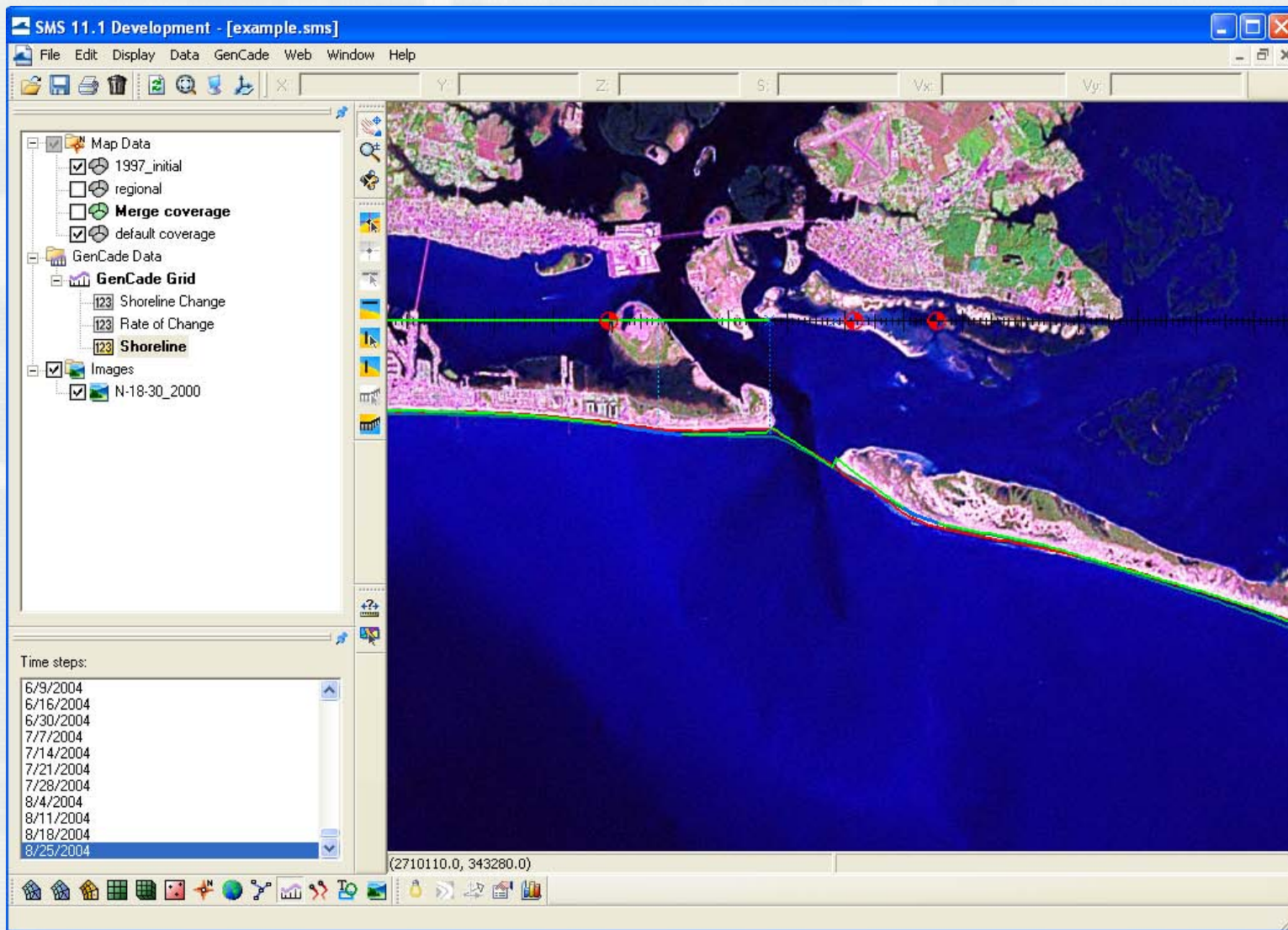
The screenshot shows the SMS 11.1 Development software interface. The main window displays a map of a coastal area. A menu is open, showing options like 'Edit Grid...', 'Edit Water Level Data...', and 'Model Control...'. The 'Model Control...' option is selected, opening the 'GenCade Model Control' dialog box. The dialog box has four tabs: 'Model Setup', 'Beach Setup', 'Seaward BC', and 'Lateral BC'. The 'Lateral BC' tab is active, showing settings for 'Left Lateral BC' and 'Right Lateral BC'. Each section has a 'Type' dropdown menu (set to 'Pinned'), a 'Length of Groin from Shoreline to Seaward Tip' text box (set to '0.0 ft'), and a 'Shoreline Displacement Velocity' text box (set to '0.0 ft per'). There are also 'Help', 'OK', and 'Cancel' buttons at the bottom of the dialog box.





®

GenCade in the SMS





®

GenCade in the SMS



SMS 11.1 Development

File Edit Display Feature Objects Web Window Help

Y: Z: S: Vx: Vy:

Map Data

- 1997_initial
- regional
- Merge coverage
- default coverage

GenCade Data

- GenCade Grid**
 - Shoreline Change
 - Rate of Change
 - Shoreline**
- Annotation Data
- Layer #1

Images

- N-18-30_2000

Plot 3

Shoreline
Shoreline Change, Time Step: 11/13/2003

Value

Distance

iwav_100.sms

(2456100.0, 344200.0)

Time steps:

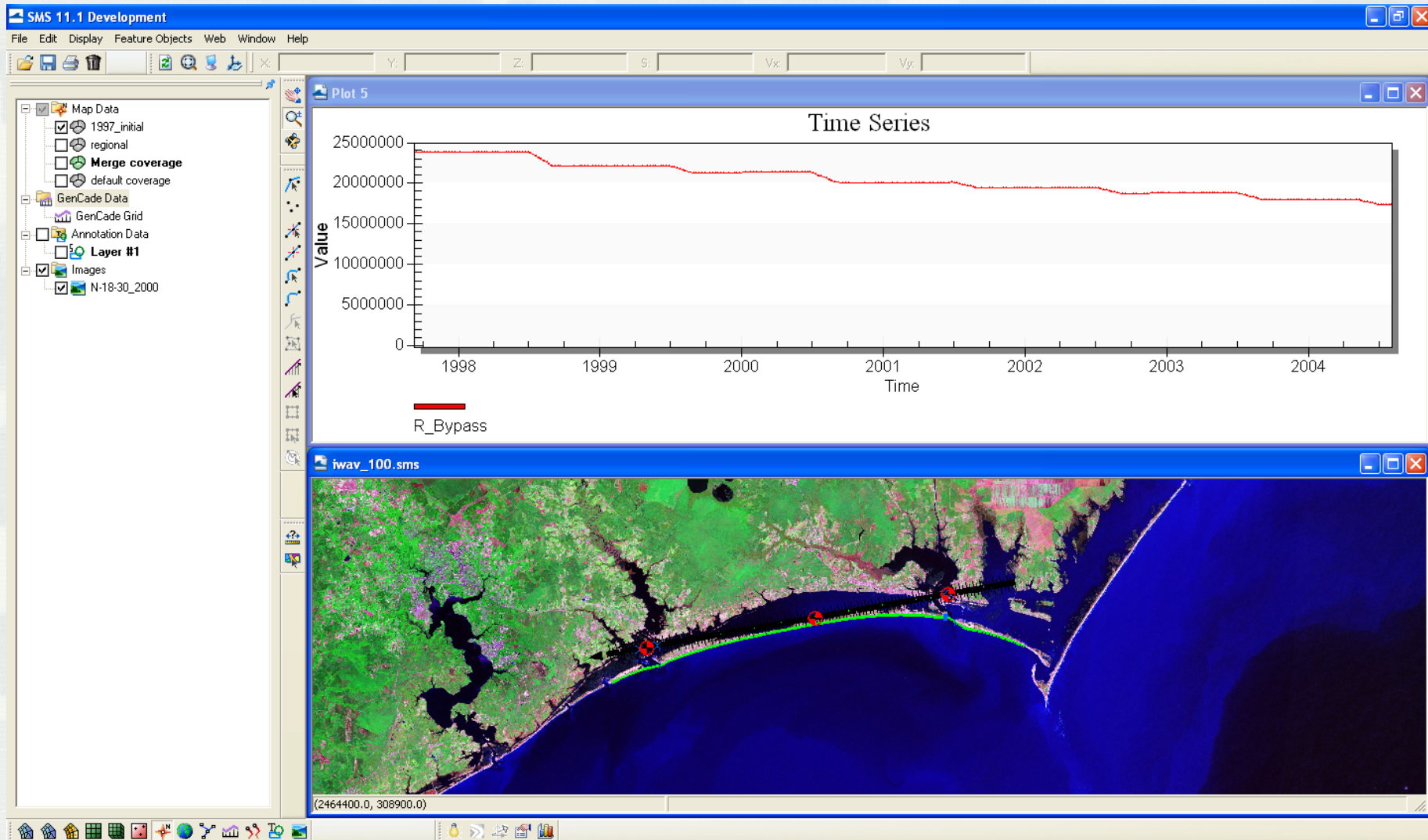
- 3/17/2004
- 3/24/2004
- 4/7/2004
- 4/14/2004
- 4/28/2004
- 5/12/2004
- 5/26/2004
- 6/2/2004
- 6/9/2004
- 6/16/2004
- 6/23/2004
- 6/30/2004
- 7/7/2004
- 7/14/2004
- 7/21/2004
- 7/28/2004
- 8/4/2004
- 8/11/2004
- 8/18/2004
- 8/25/2004**





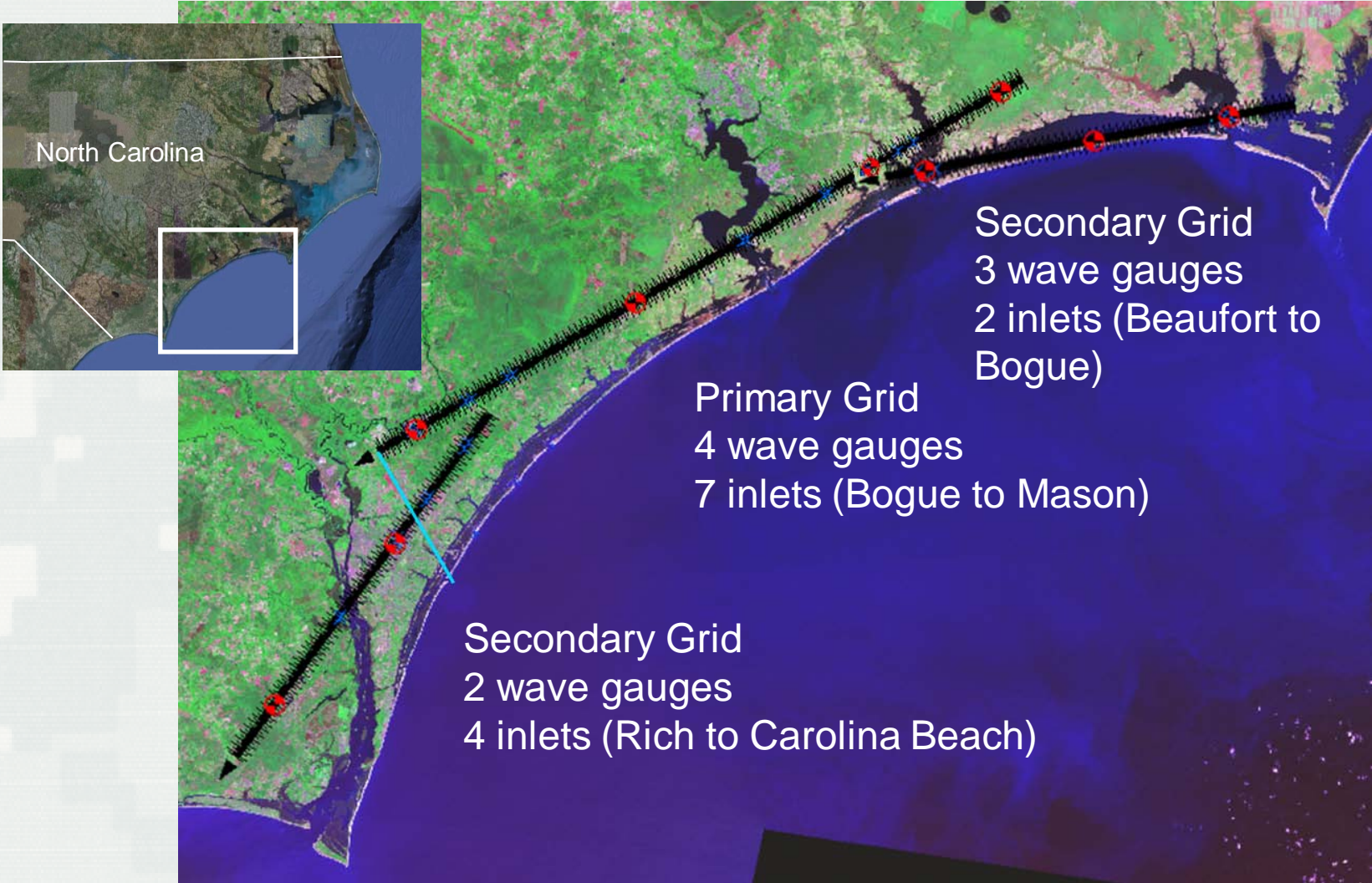
®

GenCade in the SMS



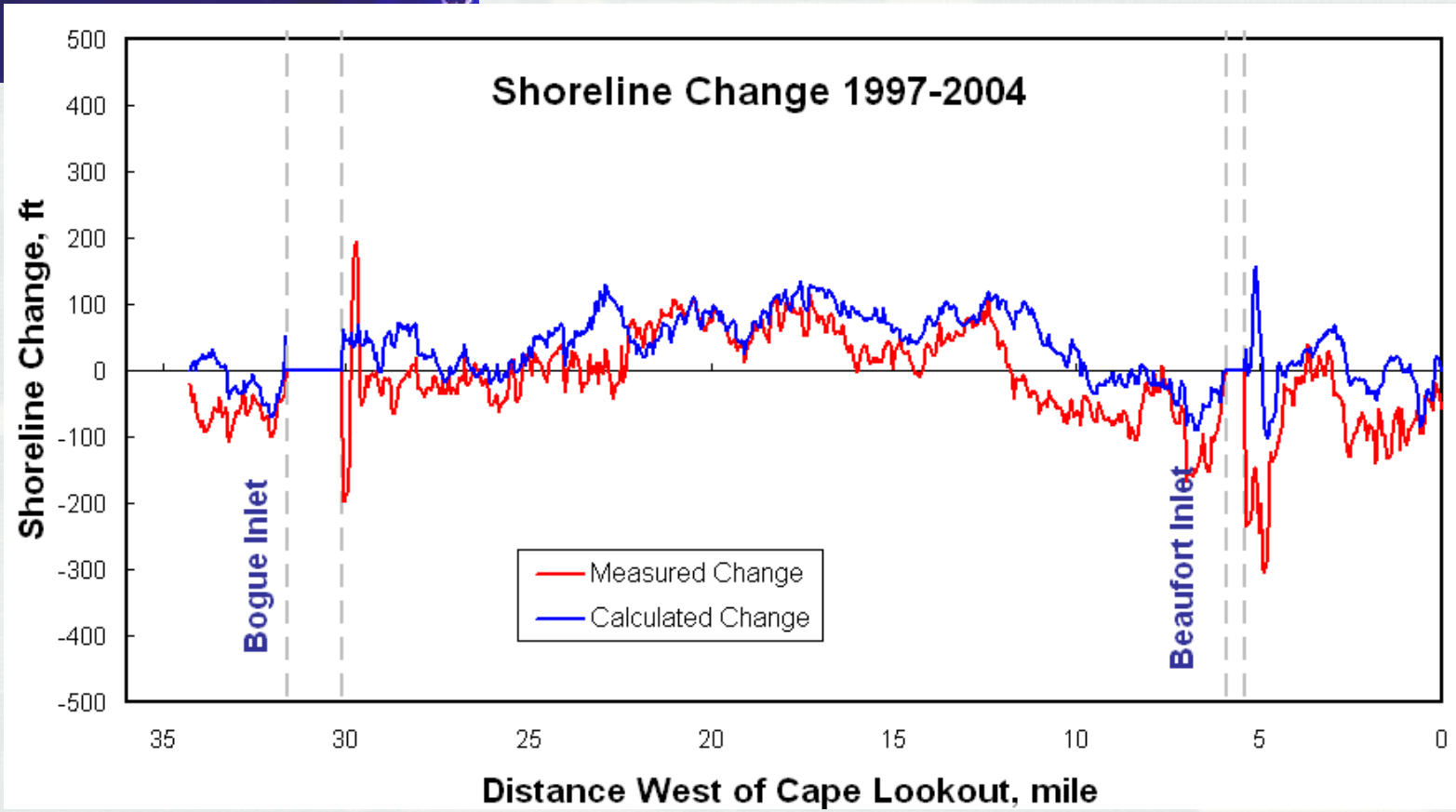
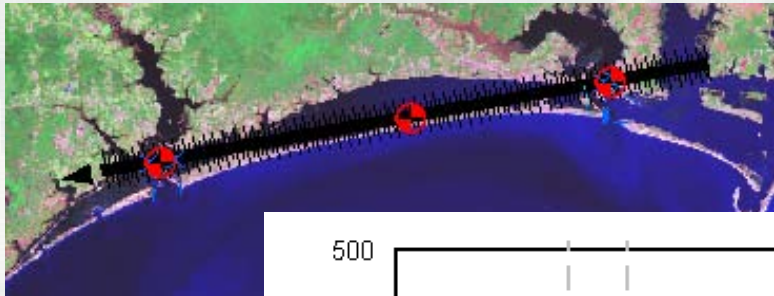


GenCade Application – Onslow Bay, NC



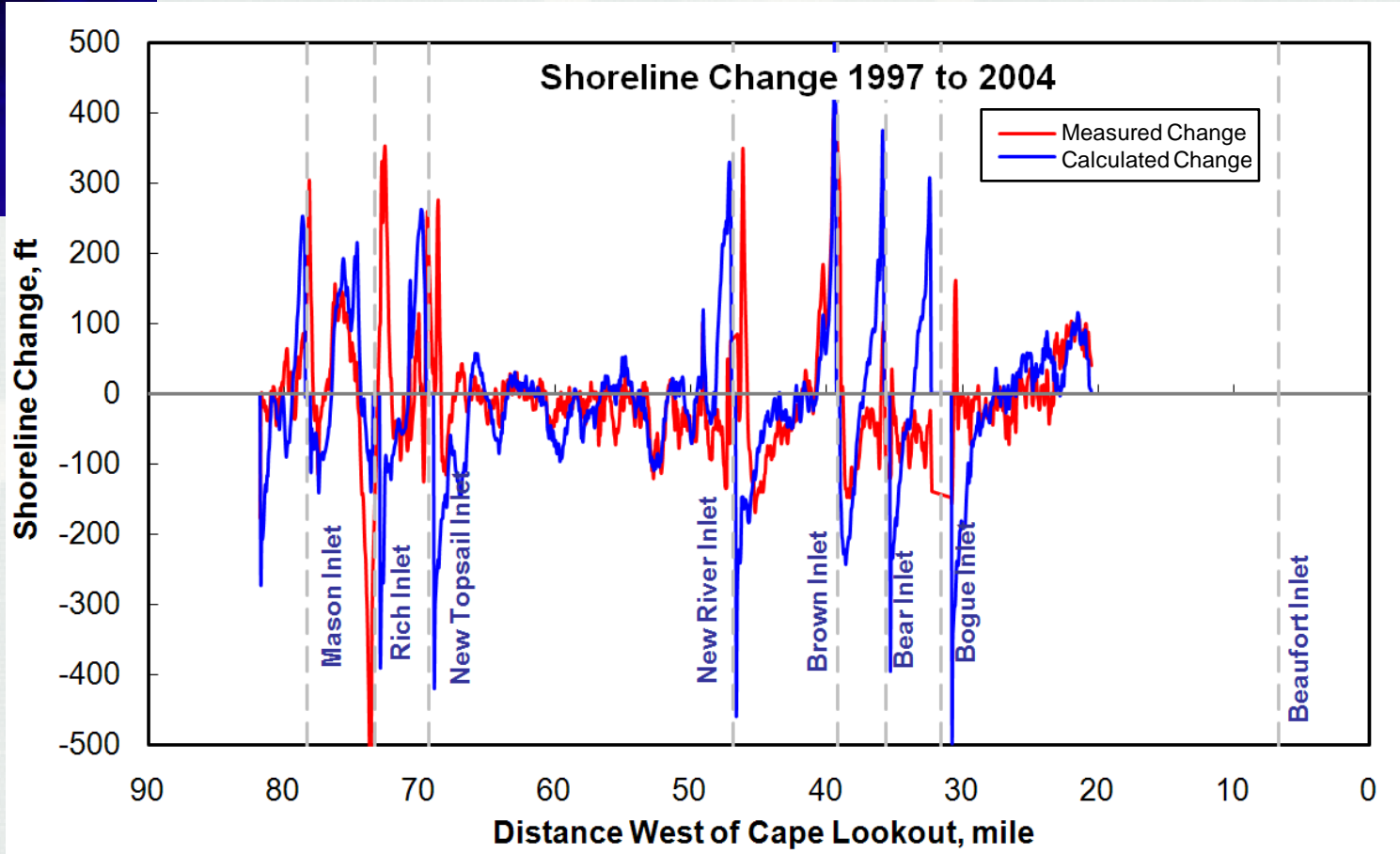
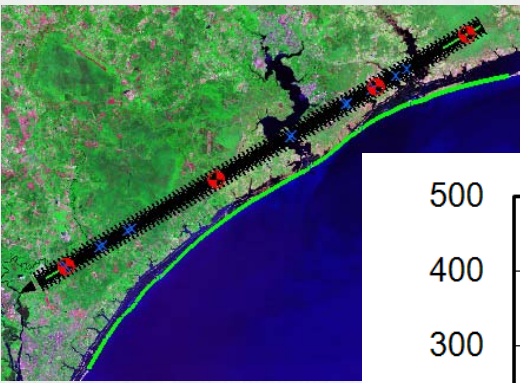


GenCade Application – Onslow Bay, NC



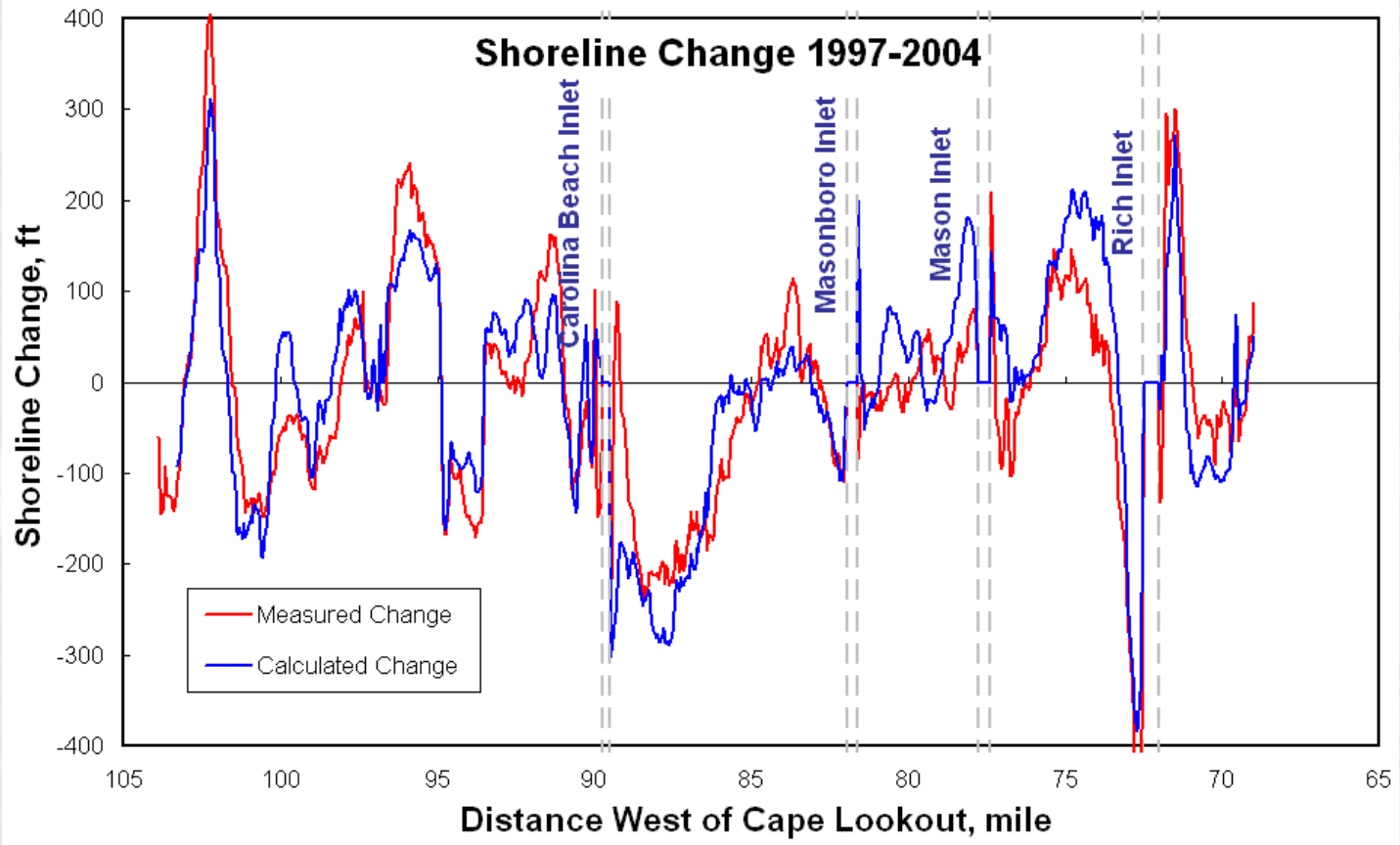


GenCade Application – Onslow Bay, NC





GenCade Application – Onslow Bay, NC





GenCade Application – Matagorda, TX



- Estimated shoreline change south of south jetty on Matagorda Peninsula for three beach placement scenarios after 10, 25, and 50 years

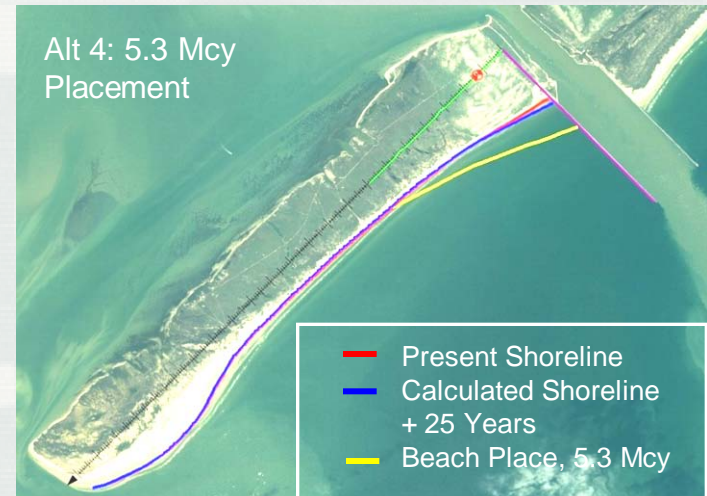
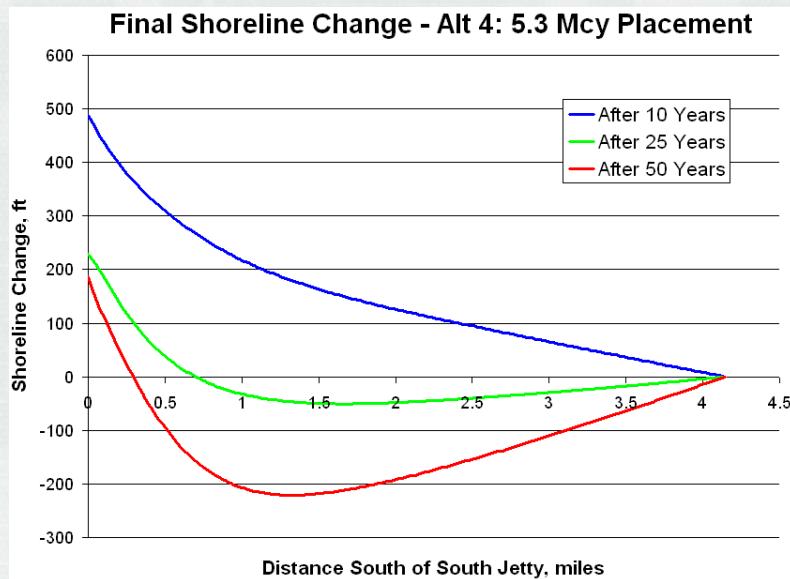




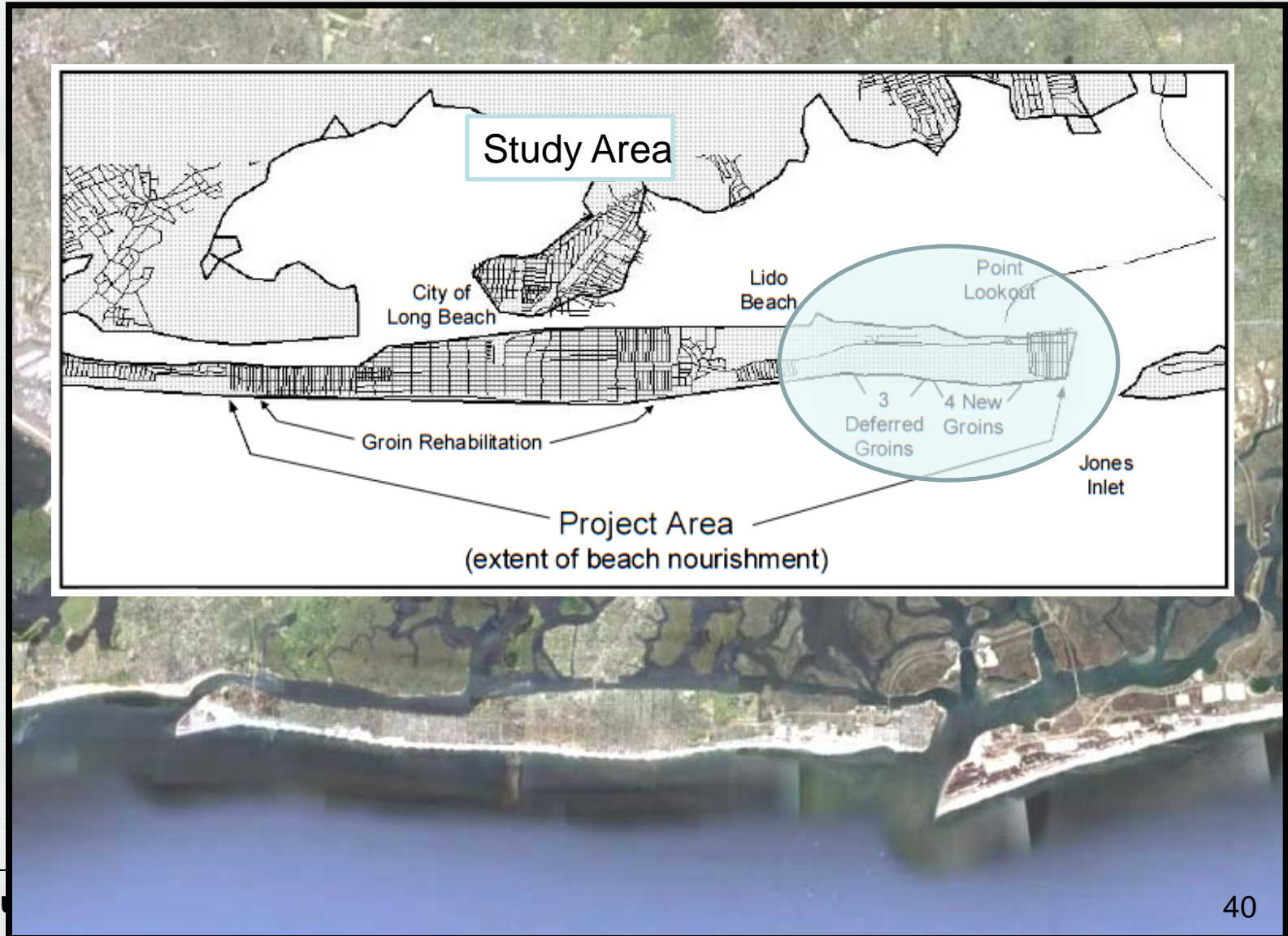
GenCade Application – Matagorda, TX



- Maximum recession after 25 years was about 200 ft for the existing scenario, 120 ft for the 2.65 Mcy placement, 80 ft for the 4 Mcy placement, and 50 ft for the 5.3 Mcy placement



GenCade Application – Point Lookout, NY



GenCade – Application at Point Lookout, NY



1994 Shoreline Comparison



- 1994 Shoreline
- Regional Contour
- IRM & Jetties
- Groins
- Seawall
- ⊕ Wave Gauge
- Modeled Shoreline



GenCade – Application at Point Lookout, NY



Modeling Results



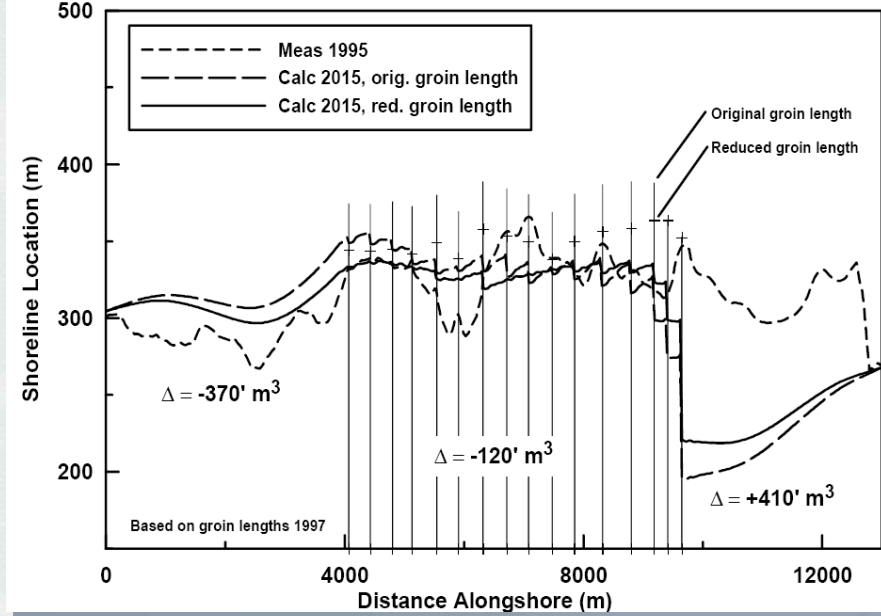
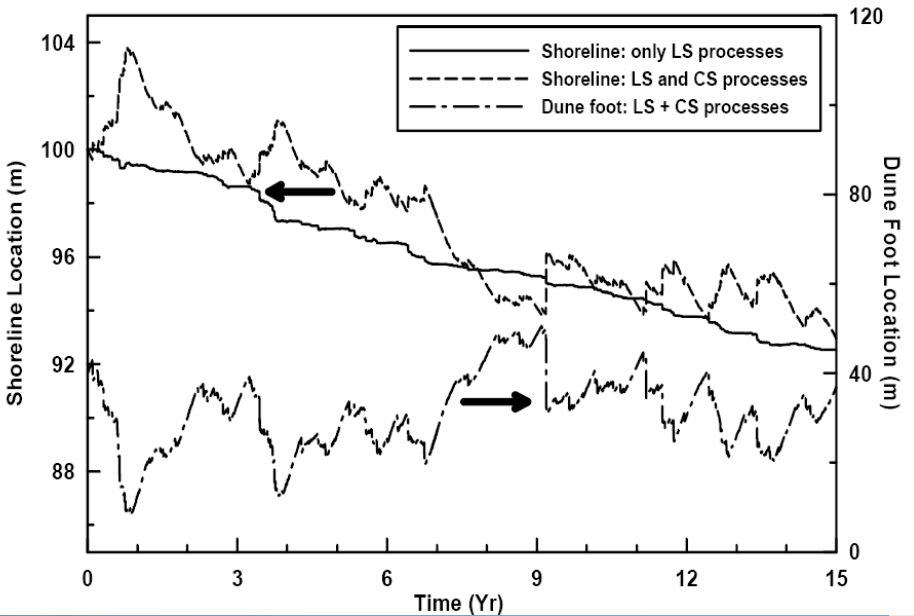


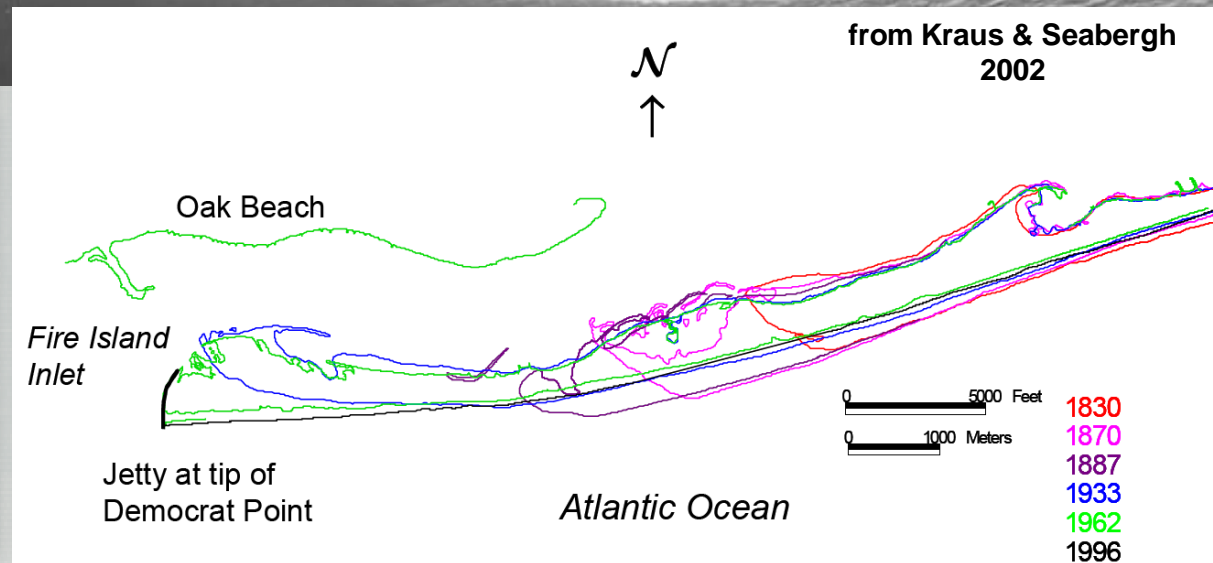
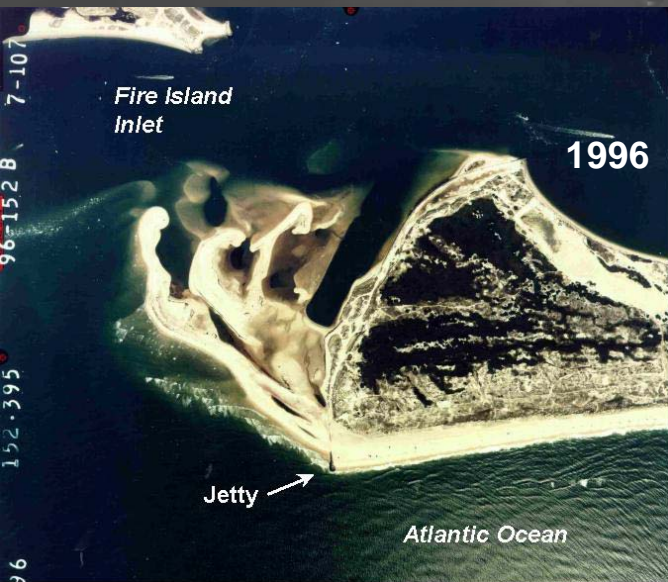
GenCade Development Available in 2012



Longshore processes only vs. longshore with cross-shore processes

Measured and calculated shoreline change and analysis of reduced groin length





Spit Growth in GenCade





GenCade Development



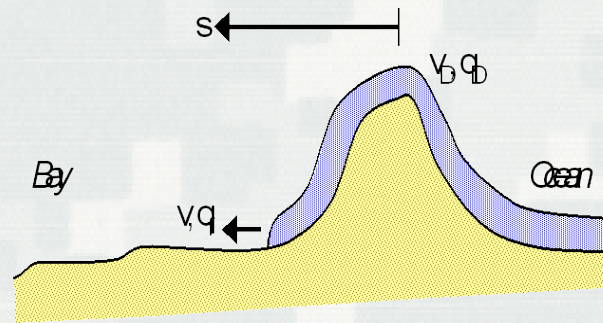
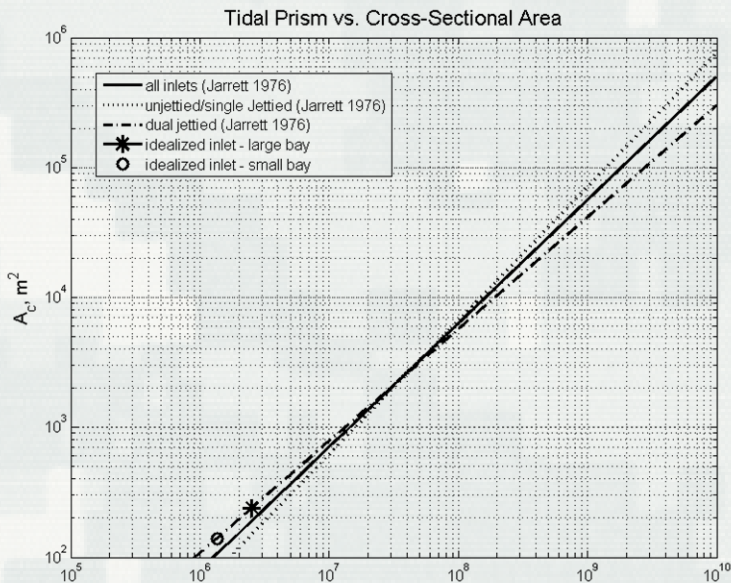
Inlet and Barrier Migration





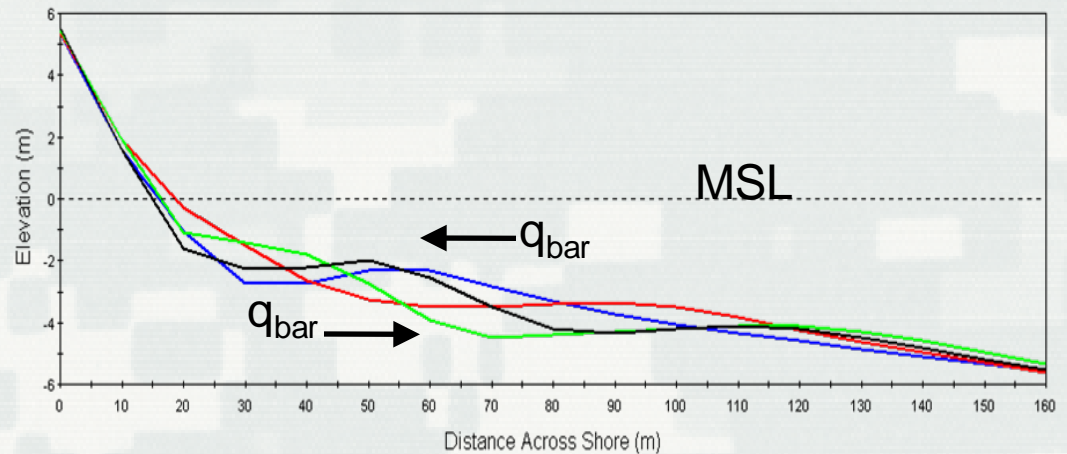
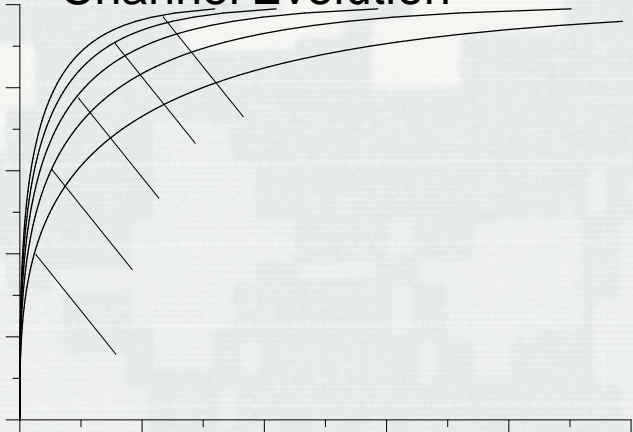
®

GenCade Development



Overwash Representation

Channel Evolution



— Average Jan-Feb
 — Average Mar-Dec
 — Average Jan-Jul
 — Average Aug-Nov

Subaqueous cross-shore response





Ashley Frey

Ashley.E.Frey@usace.army.mil

Tanya Beck

Tanya.M.Beck@usace.army.mil

<http://cirp.usace.army.mil/wiki/GenCade>

<http://cirp.usace.army.mil/products>

