Hurricane Protection and Storm Damage Reduction Evaluation Model Development Workshop

Jacksonville Beach, FL
1-2 April 2003

Current State of Model Development

Technical Working Group

- David Moser, IWR
- Mark Gravens, WES
- Norm Scheffner, WES
- Mike Wutkowski, SAW
- Cory Rogers, Josh Tirey, PMCL
- Dick Males, RMM Technical Services
- John McCormick, SAW

Timeline

- 11/2000 Scoping Meeting (Jacksonville Beach)
- 8 /2001 Design Document
- 11/2001 Review Meeting (Clearwater Beach)
  - Technical Workgroup Meeting
    - Basic Design Approach
- 3/2002 Technical Workgroup Meeting (WES)
  - 1st Prototype: profile evolution (FIMP Data)
- 12/2002 Technical Workgroup Meeting (SAW)
  - 2nd Prototype: planned nourishment; flood damage
- 4/2003 Workshop (Jacksonville Beach)
  - 3rd Prototype: erosion, wave damages; synthetic storm sequence; Bogue Banks data; dense SRD

Shore Protection Model - Objectives

- Unified Engineering-Economic Model
  - Useful in many areas
  - Data-driven
- Coastal Engineering Processes as Driving Force
  - Storm Events
  - Beach Response
  - Nourishment Events
  - Recovery
- Incorporate Risk and Uncertainty
  - Life Cycle Event-Driven Monte Carlo Simulation Model

Desired Improvements over Existing Approaches

- Incorporate impact of multiple storm events ✓
- Relax assumption that all storms impact same beach profile ✓
- Better risk / uncertainty representation ✓
- Assumptions made explicit ✓
- Modern Framework (database, GIS links) ✓
- Transparency ✓
- Visualization ✓

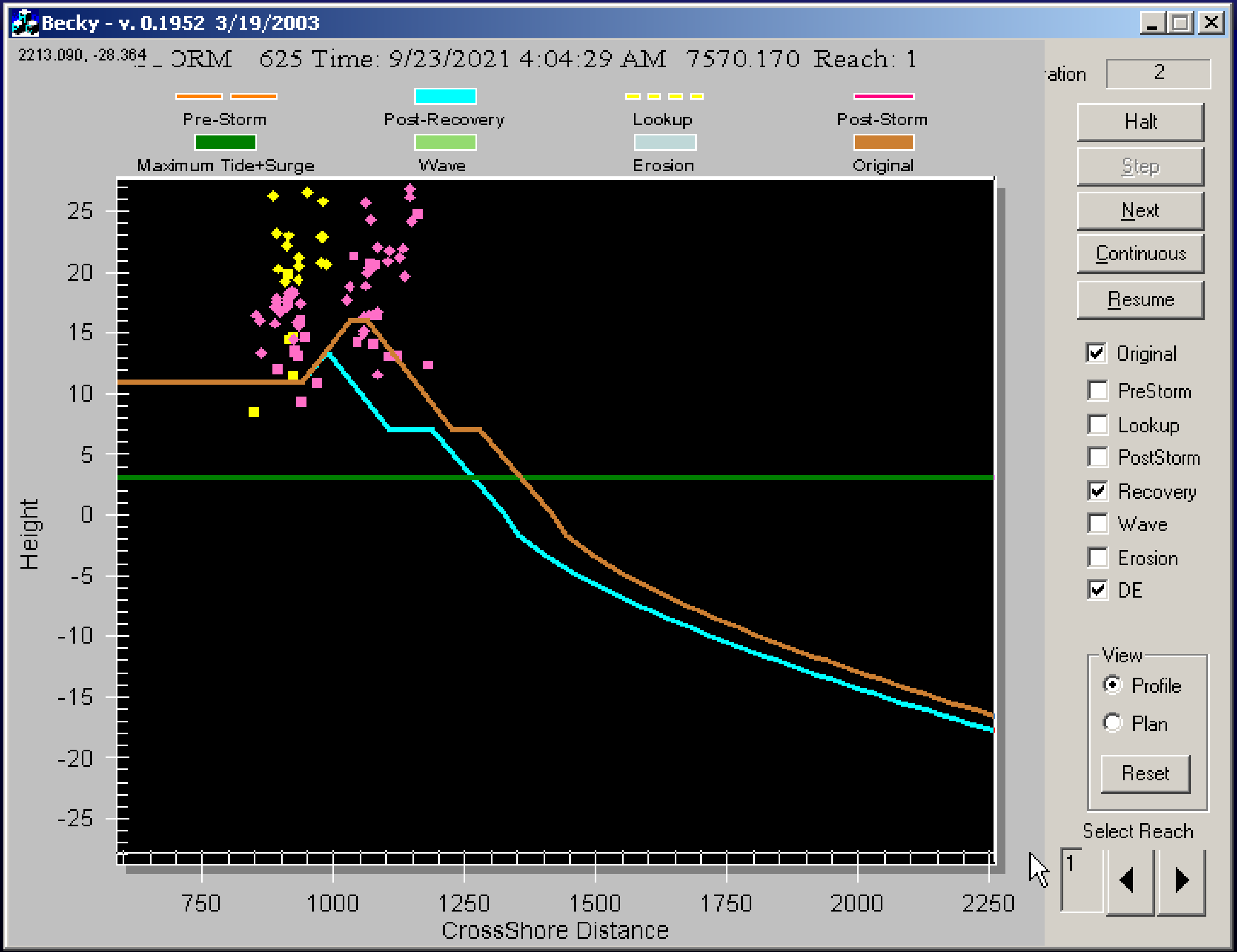
Status

- Initial Objectives Met
- Robust Framework
  - Model
  - Database
- Issues
  - Tuning of Profile Evolution
  - Additional Required Capabilities
  - Test Bed
  - Data Needs Beyond Existing Modeling Approaches?
  - Performance
- Ready for Prime Time?

Current Capabilities

- Evolve cross-shore profile in response to
  - storms
  - recovery
  - planned nourishment
- Calculate damages based on post-storm situations and user-input damage functions
- Visualization
- Detailed Outputs

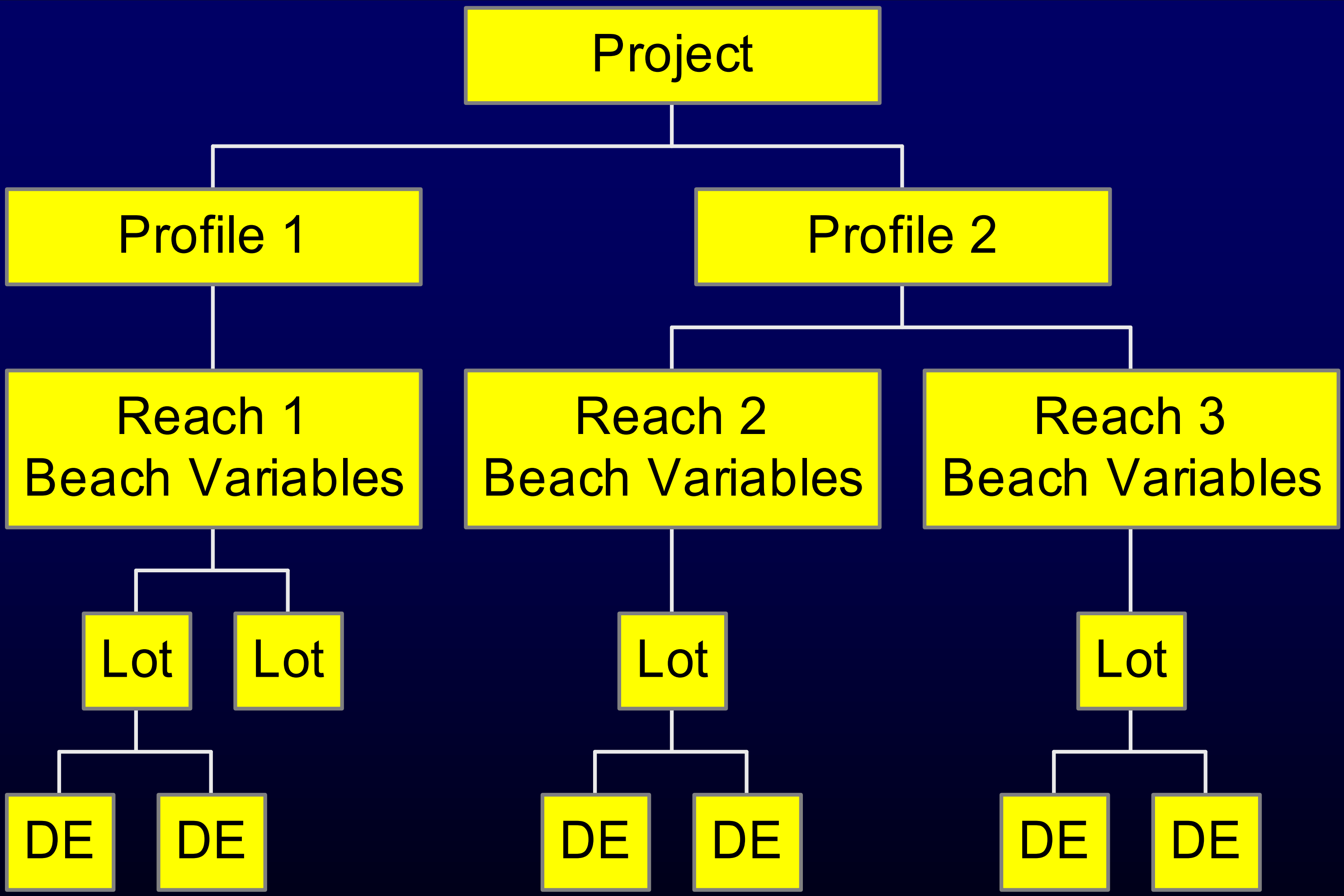
Model Overview



Basic Concepts – Profile Modification

- Event-Driven Model
  - Storm Events
  - Nourishment Events
    - Planned
    - Emergency
- Simplified Beach Profile
  - Defined by key points
  - Changed by storm, nourishment events
  - Internal short-term recovery algorithm

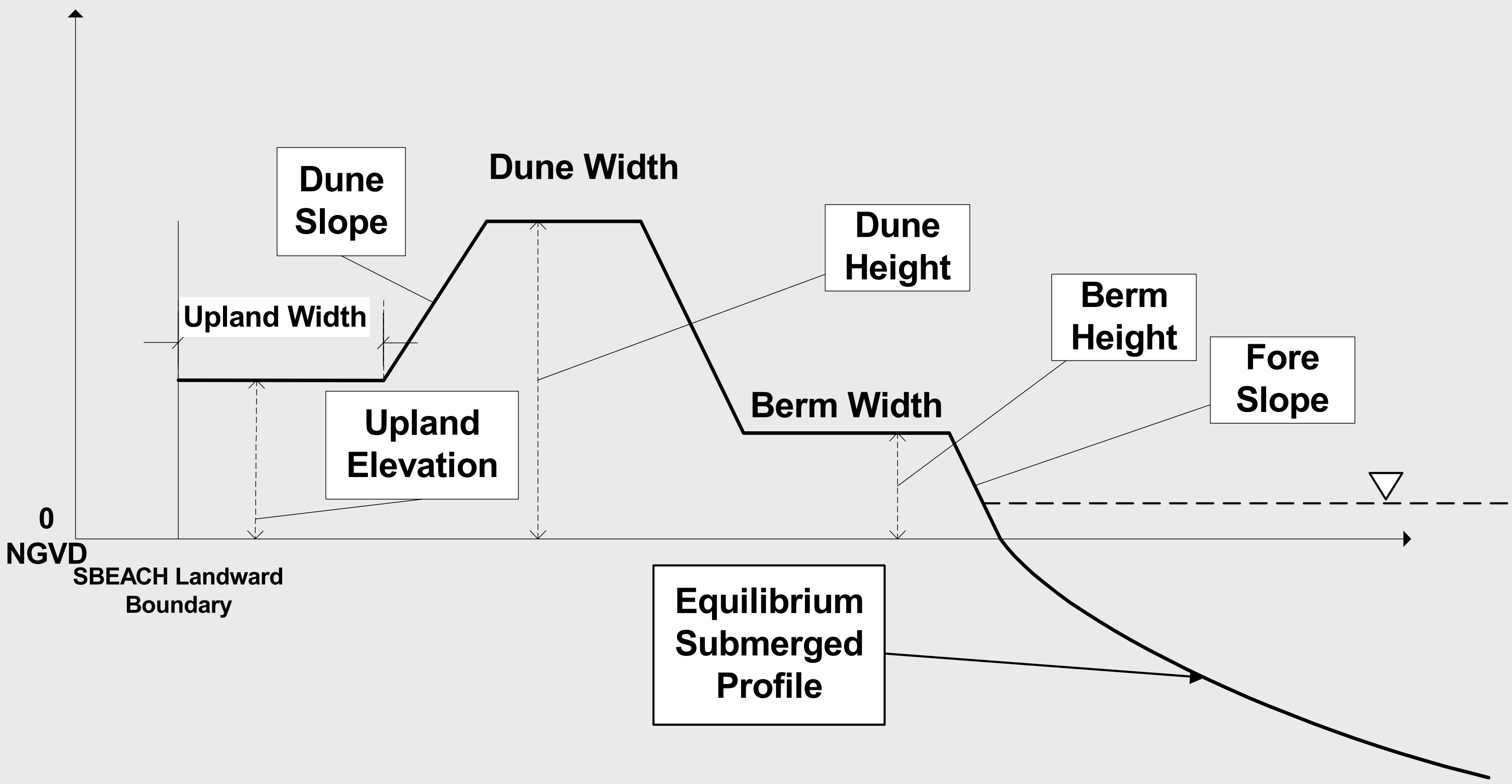
Project Hierarchy



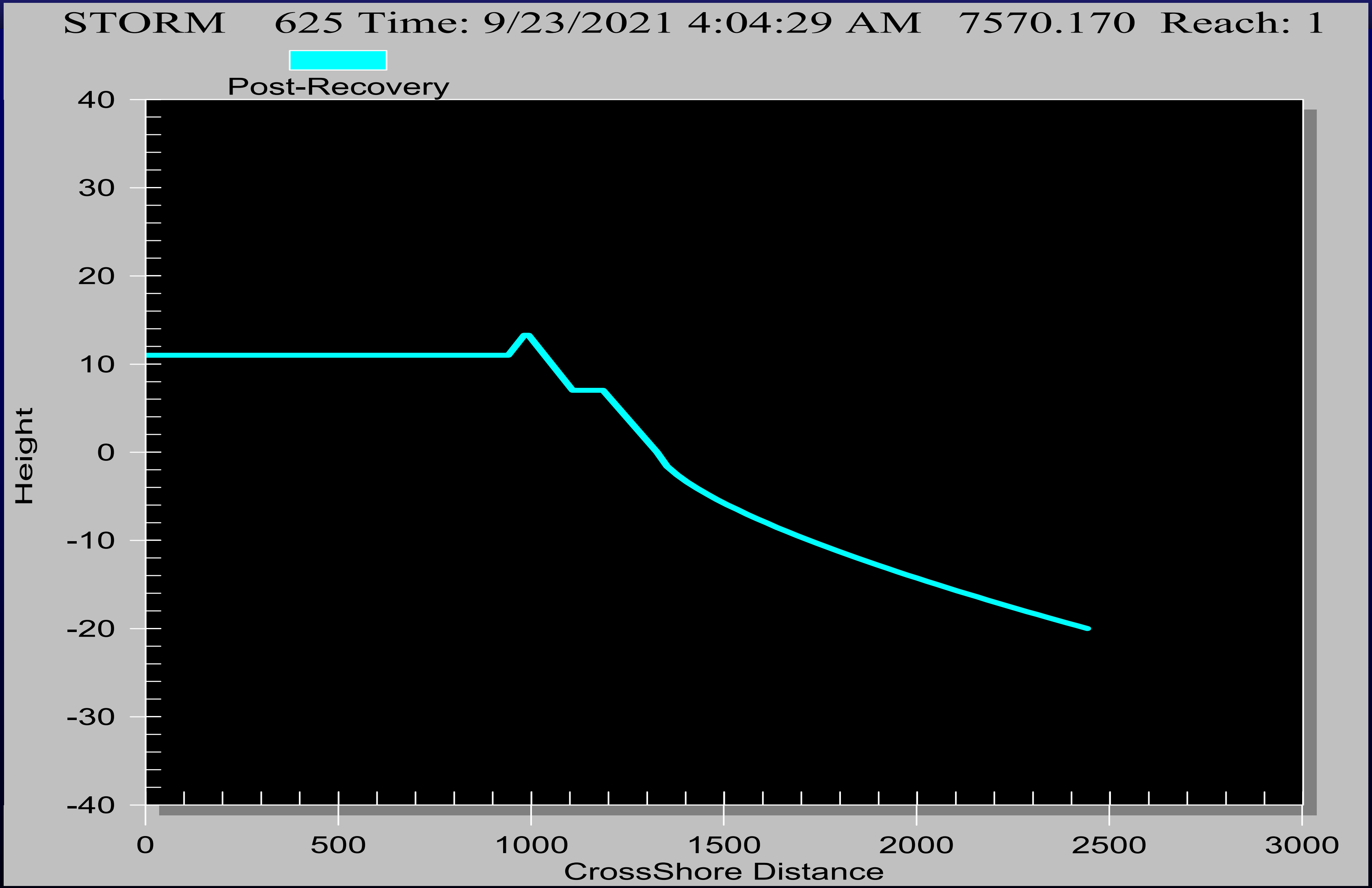
Simplified Beach Profile

- Variables (Defined At Reach Level)
  - Change with storm, management, recovery
    - Berm Width
    - Dune Width
    - Dune Height
    - Upland Distance (change by storm only)
- Constants (Defined At Profile Level)
  - Berm Height
  - Dune Slope
  - Upland Elevation
  - Foreshore Slope
  - Submerged Profile

Beach Profile



Beach Profile – Model Representation



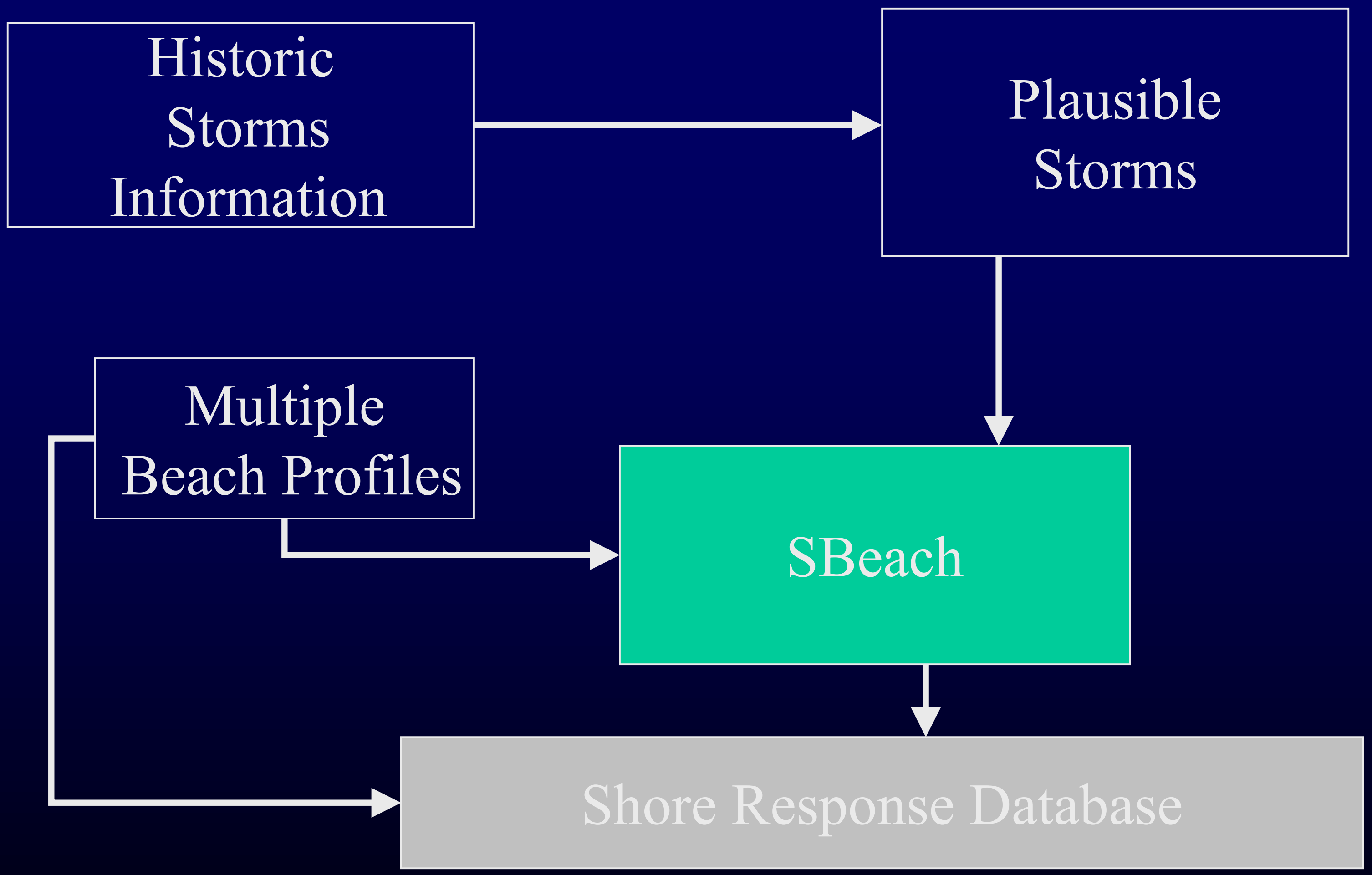
Basic Concepts – Storms

- Set of Plausible Storms
  - Based on historic
  - Tropical / ExtraTropical
- Combine storm surge with 12 representations of tide:
  - 3 tidal ranges (Mean, Spring, Neap)
  - 4 Tidal Phases (high, mean falling, low , mean rising)
- 13 plausible storms/historic storm [12 synthetic, 1 historic]
- Storm parameters
  - Storm waves / Water Levels / Storm Date
- Storm Seasons
  - Average annual # of Tropical, ExtraTropical in season
- Synthetic Storm Sequences
  - Selection / Sequencing from set of plausible storms
  - Seasonality Observed

Basic Concepts – Shore Response

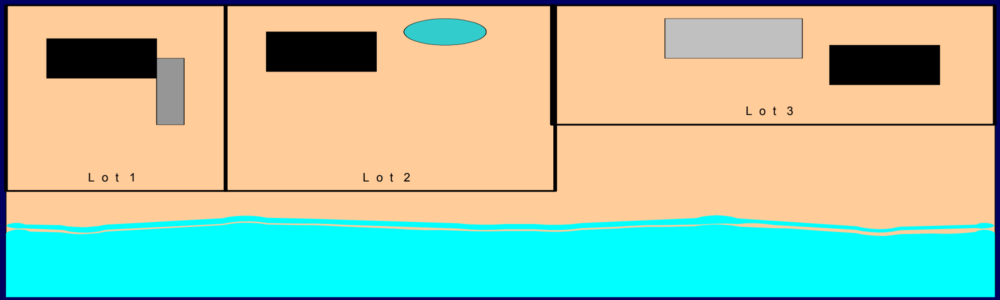
- Plausible Storms = Time Series Input to SBeach
- Range of Profiles
- SBeach Runs
  - Plausible Storms * Range of Profiles
- Extract Data From SBeach Results
  - Key point changes
    - Berm width / Dune Width / Dune Height
  - Erosion and Wave storm effects
- Store in Database (SRD)

Shore Response Database Development



Basic Concepts – Damage Estimation

- Reach
  - Lots
    - Damage Elements

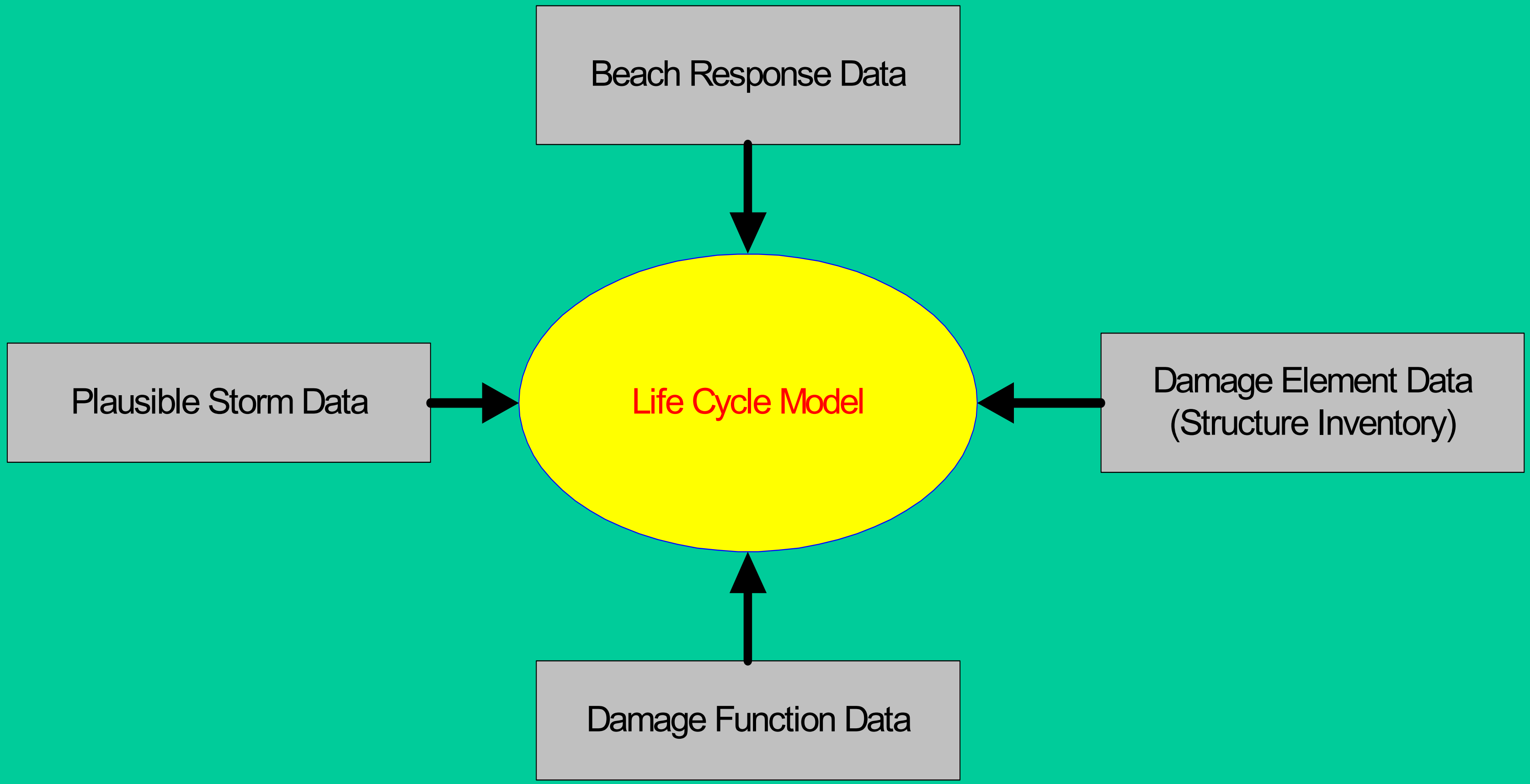


- Damage Functions
  - % Damage = f(Damage Driving Parameter)
- Damage Driving Parameters
  - Wave – water level above 1st floor elevation
  - Inundation - water level above 1st floor elevation
  - Erosion - % footprint compromised
- Combined Damages

Data Elements

- Profiles / Reaches
- Storms / Seasons
- Beach Response Data
- Damage Elements
- Damage Functions

Data Driven Model

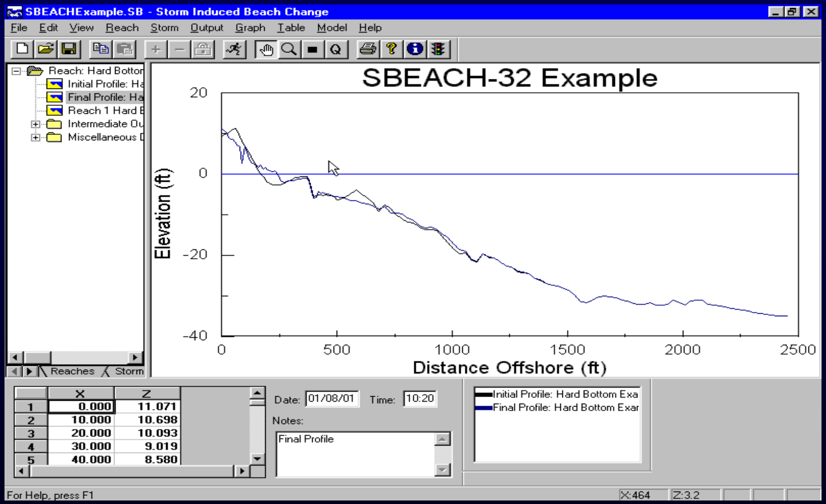


Overall Model Processing Flow

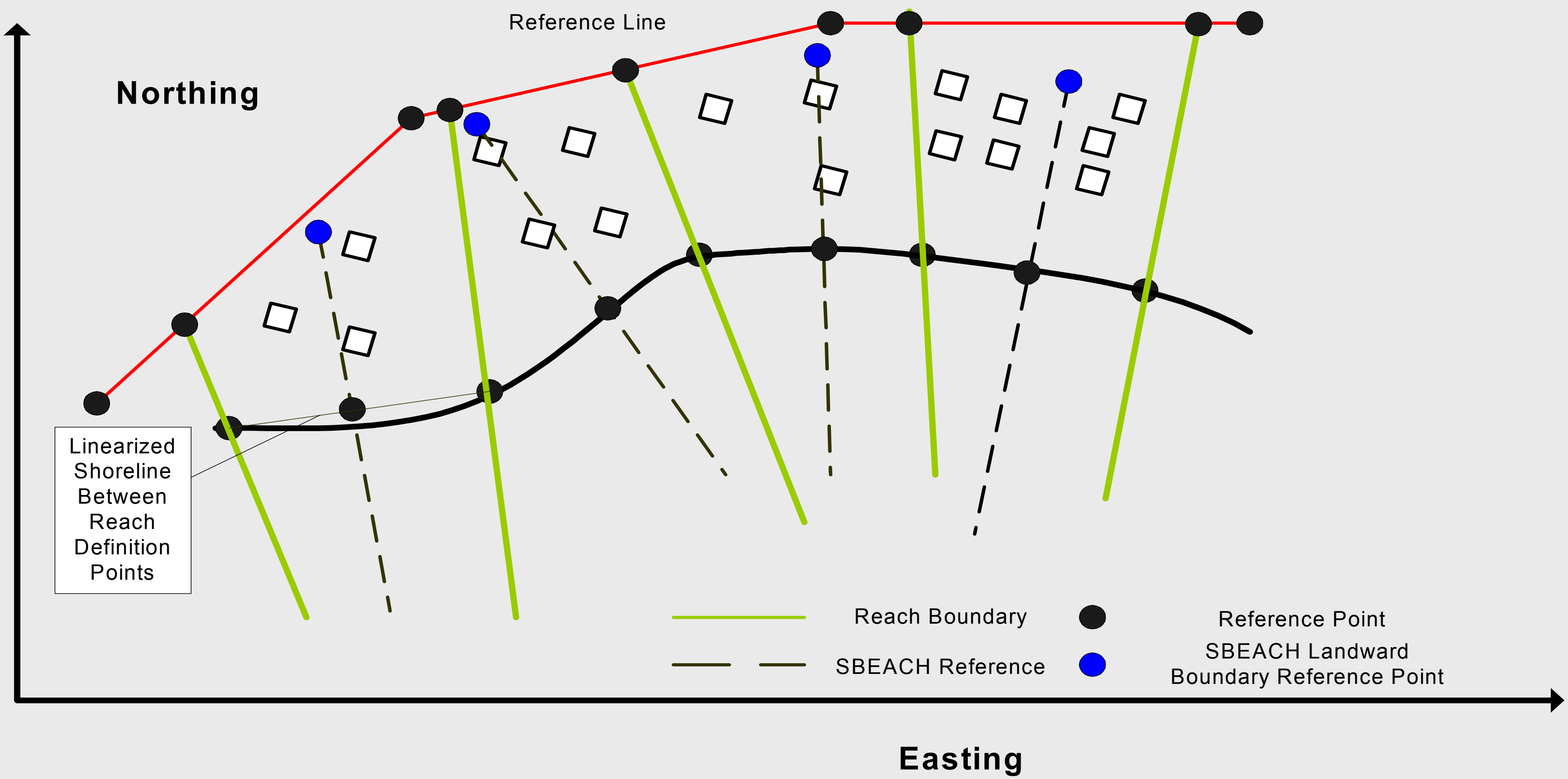
Year
- Season
  - Generate Storm Sequence (Select from Plausible Set)
    - For Each Storm
      - For Each Profile
        - Storm Response Set From SRD
          - For Each Reach Using Profile
            - Best Lookup in Storm Response Set
              - For Each Lot In Reach
                - For Each Damage Element In Lot
                  - Calculate Individual Damages
                - Combined Impact

Coordinate Systems - I

- SBeach – 2-dimensional (x,z)
  - Distance from a reference point along a line
- Structures – 3-d (x,y,z)
  - Location in space



Coordinate Systems – II



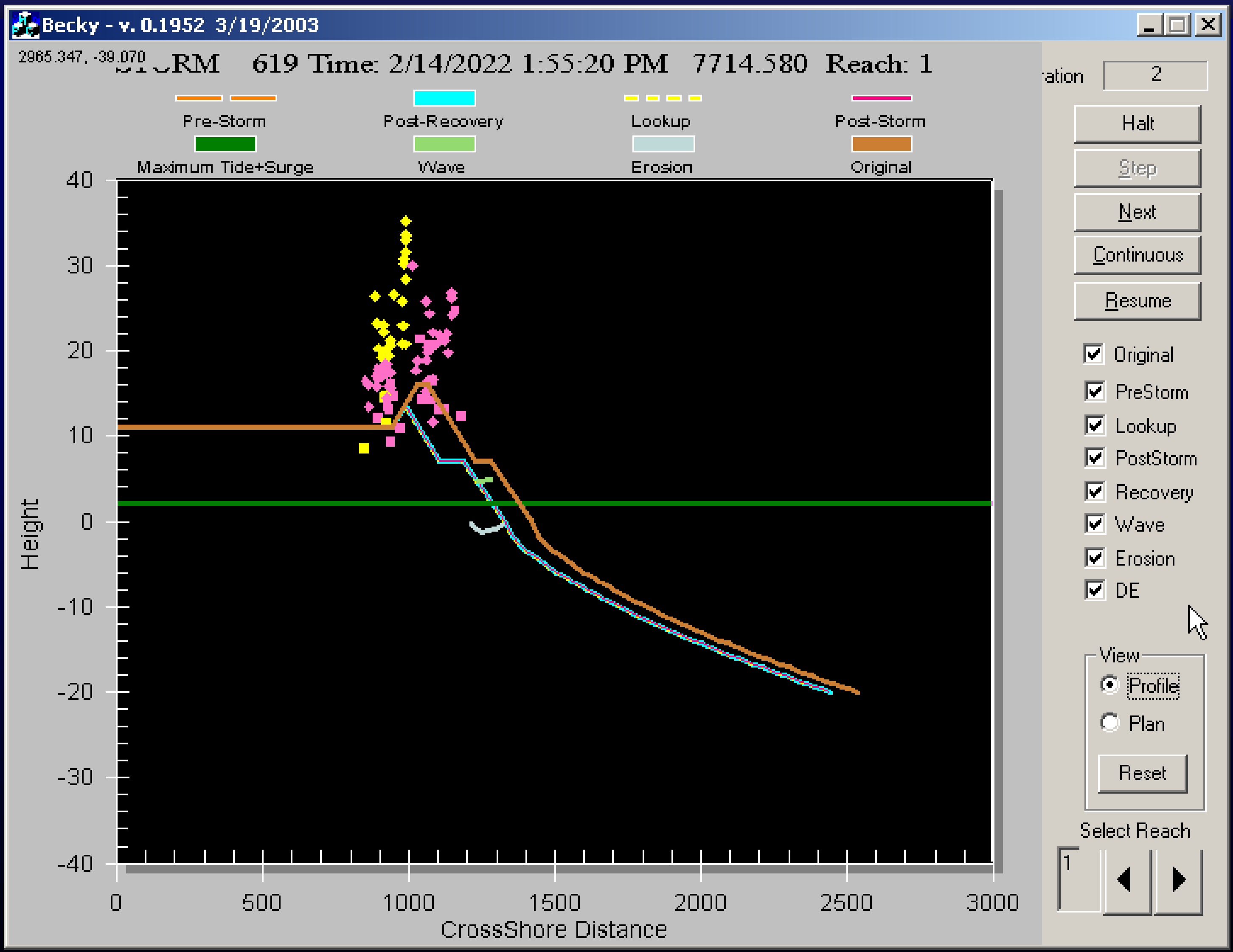
Test Data Development

- Bogue Banks Data
  - Developed for SAW 933 Study, made available for model testing
  - Structures Data
  - GIS Data – Lot and Structure Locations
  - Damage Functions (GRANDUC Format)
  - Need to Adapt for Model Structure
- Storms
  - Historic: 23 extra-tropical, 37 tropical
  - Plausible: 780 total
- SBeach Runs
  - 2 composite reaches
  - 350,000 + runs
- Coastal Storm Damage Workshop
  - SFR Damage Functions

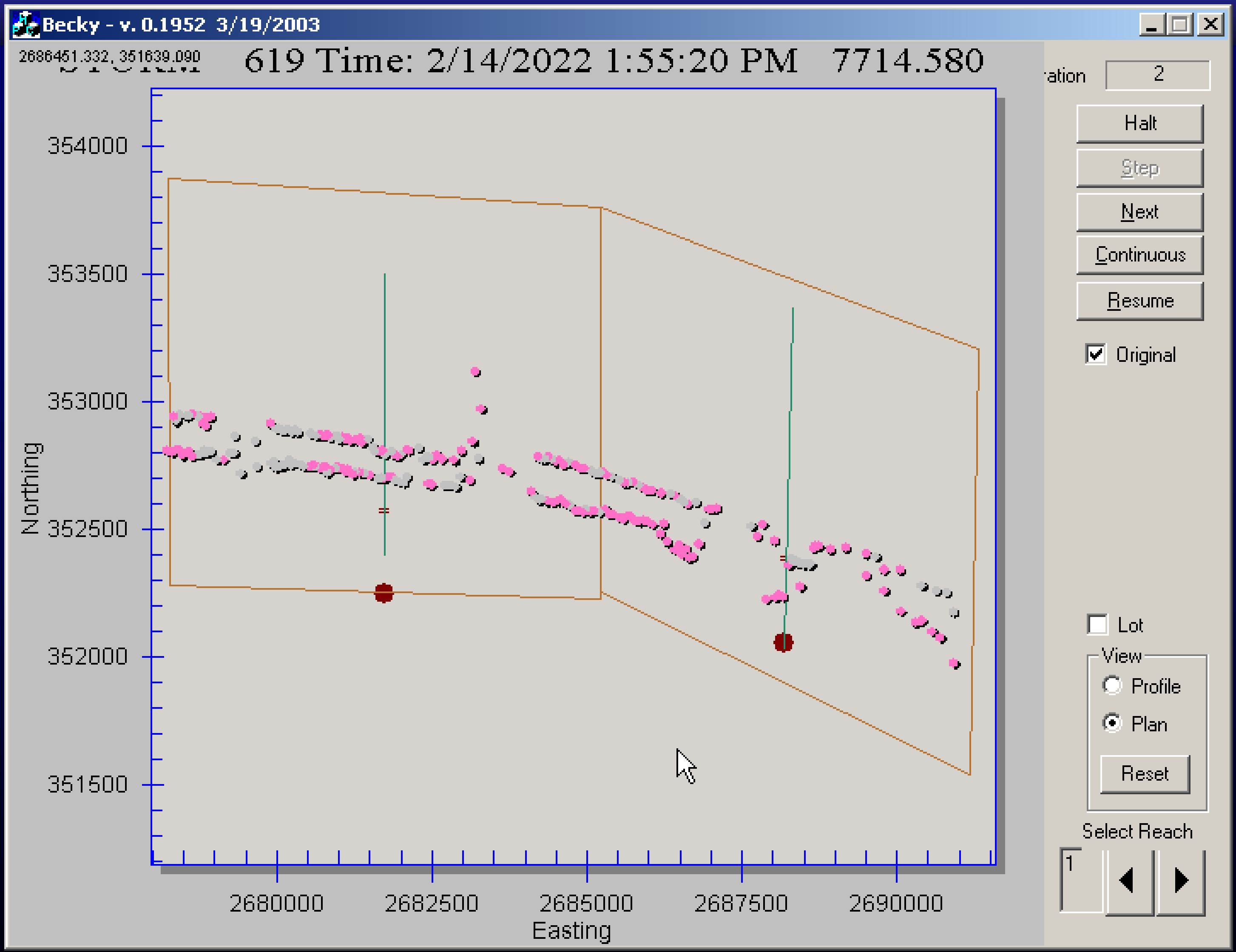
Model Outputs

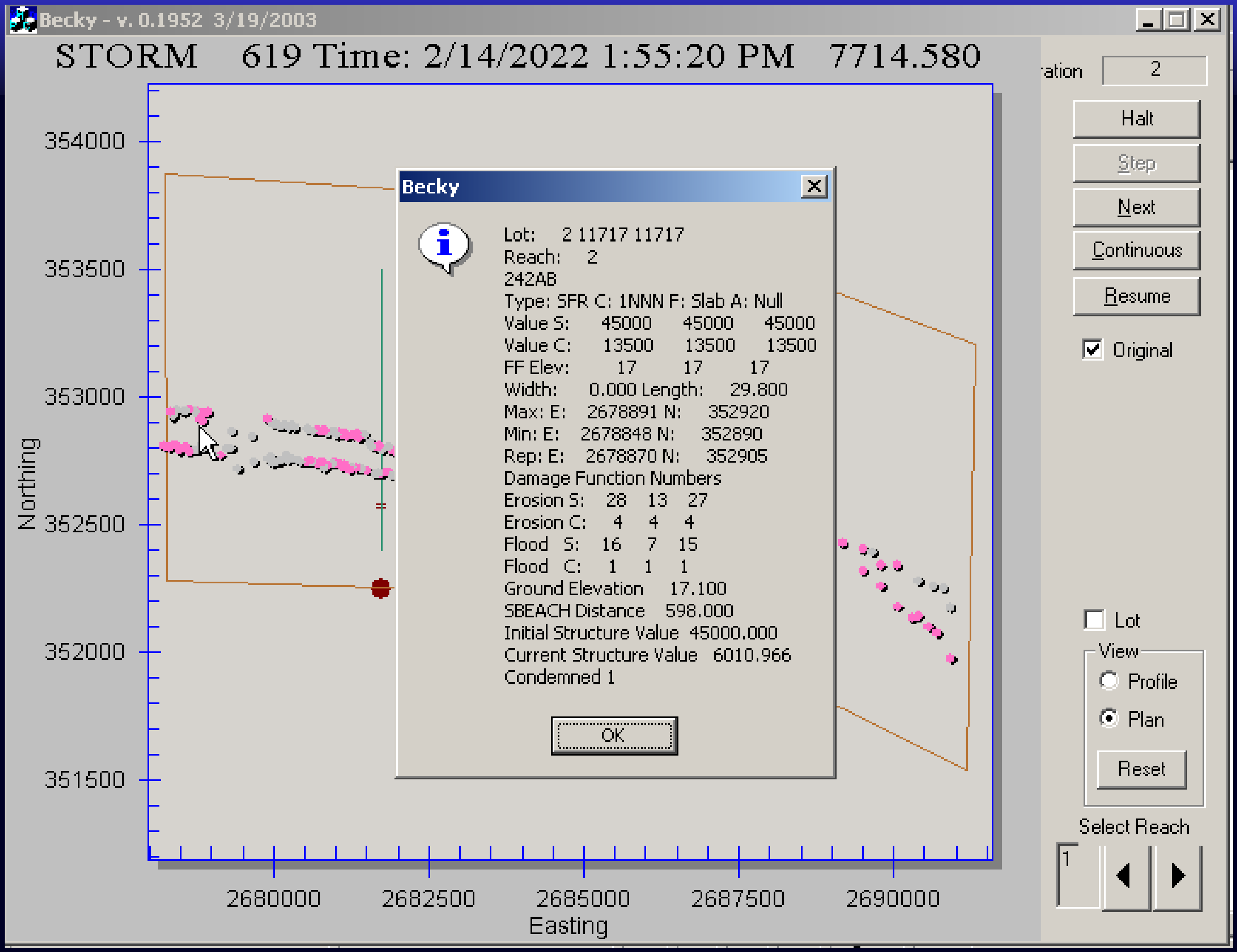
- Current
  - Visualization
  - ASCII Files
    - Statistical Summary
    - Storm
    - Event
    - Damage
    - Nourishment
    - Debug
- Future
  - Database of Results
  - Post-Processing Animation

Visualization – Profile View



Visualization - Plan View




Becky - v. 0.1952 3/19/2003
STORM 619 Time: 2/14/2022 1:55:20 PM 7714.580
Northing
354000
353500
353000
352500
352000
351500
2680000
2682500
2685000
2687500
2690000
Easting
Becky
Lot: 2 11717 11717
Reach: 2
242AB
Type: SFR C: 1NNN F: Slab A: Null
Value S: 45000 45000 45000
Value C: 13500 13500 13500
FF Elev: 17 17 17
Width: 0.000 Length: 29.800
Max: E: 2678891 N: 352920
Min: E: 2678848 N: 352890
Rep: E: 2678870 N: 352905
Damage Function Numbers
Erosion S: 28 13 27
Erosion C: 4 4 4
Flood S: 16 7 15
Flood C: 1 1 1
Ground Elevation 17.100
SBEACH Distance 598.000
Initial Structure Value 45000.000
Current Structure Value 6010.966
Condemned 1
OK
ation 2
Halt
Step
Next
Continuous
Resume
Original
Lot
View
Profile
Plan
Reset
Select Reach
1

Model Demonstration

Discussion / Q and A

Detailed Examination of Model Components

Storm Sequence Generation

Storm Information

- Set of Plausible Storms Derived From Historical record
  - Historical, Spring, Mean, Neap Tides
  - Tidal Phases (high tide, mean tide falling, low tide and mean tide rising)
- 13 Plausible Per Historical
- Actual Date and Type (Tropical / ExtraTropical) Based On Historical Storm

Seasonality

	Season	Start	End	Average NE	Average H
1	Extra Tropical Only	12/1	3/31	1.0625	0.0
2	No Storms	4/1	5/31	0.0	0.0
3	Tropical Only	6/1	8/31	0.0	0.123
4	Overlap	9/1	11/30	0.375	0.203

Sequence Generation

Plausible Storms Assigned To Season By Historic Date Of Storm

Poisson Distribution Based on Average #T, #ET

For Each Season of Each Year of Simulation:

- Get # of Storms of Each Type from Poisson Distribution = N(T), N(ET)
- Choose N Storms From List of Plausible Storms of Each Type in Season (Sampling With Replacement)
- Set Storm Date Randomly Within Season
- Create Storm Event based on Date, Selected Storm

Generated Storm Sequence

1	43.528	1	NE	2/13/2001 12:40:25 PM	19800113S3
1	327.607	4	NE	11/24/2001 2:33:26 PM	19821025PT
1	332.469	4	H	11/29/2001 11:15:42 AM	19280918S4
1	441.024	1	NE	3/18/2002 12:34:44 AM	19891208M2
1	693.319	4	NE	11/25/2002 7:38:54 AM	19821025M4
1	800.675	1	NE	3/12/2003 4:12:35 PM	19831221M4
1	936.588	3	H	7/26/2003 2:07:14 PM	19550817M3
1	973.602	4	NE	9/1/2003 2:27:18 PM	19801127M2
1	1048.554	4	NE	11/15/2003 1:18:08 PM	19801127N2

Issues

- Minimum Storm Inter-Arrival Time?
- Sample With or Without Replacement?
- Development of Seasons
- Assigning Historical Storm Date To Season
- Uniform Probability of Storm Time Within Season
- Additional Methods of Extending Historical Record?

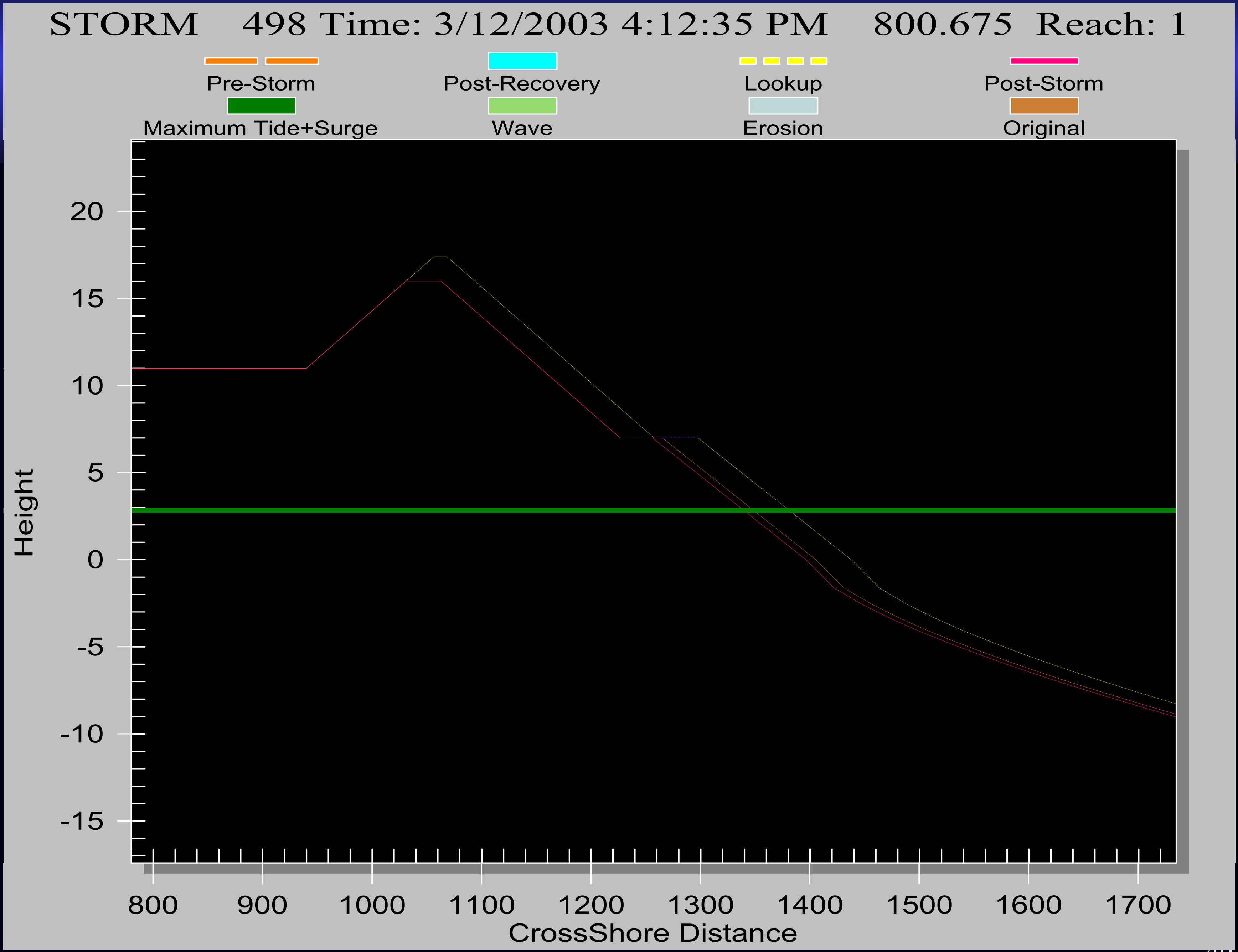
Storm Event Processing

Model Behavior for a Storm Event

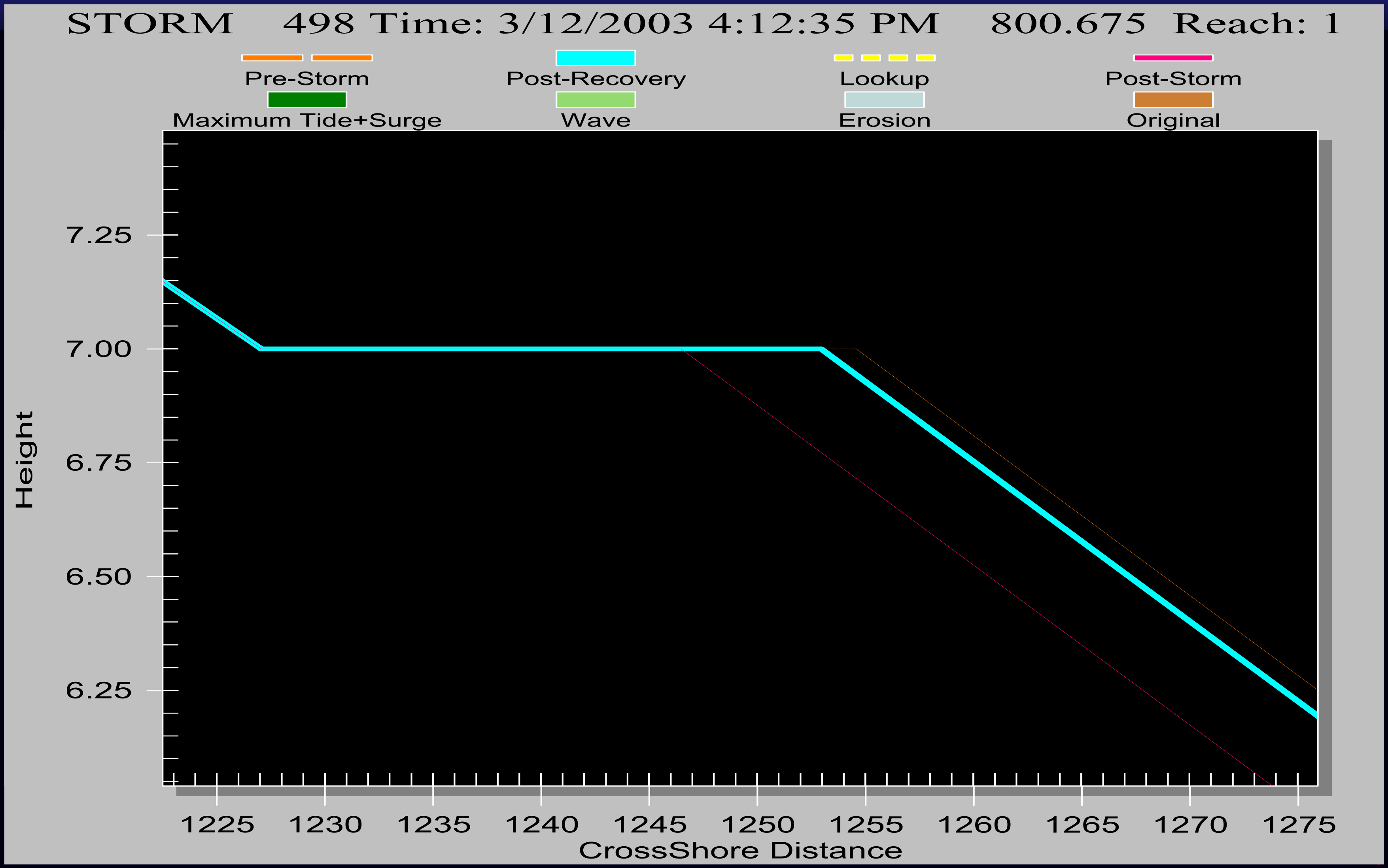
Storm Event (from Generated Sequence)

For Each Reach:

- Pre-Storm Berm Width / Dune Width / Dune Height
- Best match in Shore Response Database (Lookup Profile)
- Obtain Lookup Responses from Database
  - Berm Width Change, Dune Width Change, Dune Height Change
  - Wave Profile / Within-Storm Erosion Profile (for Damages)
- Apply Profile Evolution Algorithm to Pre-Storm to get Post-Storm Profile
- Apply Recovery to Post-Storm to get Post-Recovery (berm only)


STORM 498 Time: 3/12/2003 4:12:35 PM 800.675 Reach: 1
Pre-Storm
Post-Recovery
Lookup
Post-Storm
Maximum Tide+Surge
Wave
Erosion
Original
Height
20
15
10
5
0
-5
-10
-15
800
900
1000
1100
1200
1300
1400
1500
1600
1700
CrossShore Distance

Recovery


STORM 498 Time: 3/12/2003 4:12:35 PM 800.675 Reach: 1
Pre-Storm
Post-Recovery
Lookup
Post-Storm
Maximum Tide+Surge
Wave
Erosion
Original
Height
7.25
7.00
6.75
6.50
6.25
1225
1230
1235
1240
1245
1250
1255
1260
1265
1270
1275
CrossShore Distance

Issues

- Adequacy of Simplified Profile Representation
  - Dune Landward progression / Scarping
- Adequacy of Algorithms
  - Profile Evolution
    - Dune Invasion / Dune Lowering
  - SRD Lookup Search
  - Recovery
- Long Term Recovery
- Equilibrium Profile
- SRD Density
- Planform Evolution
- Historical Erosion Rates

Planned Nourishment

Planned Nourishment Data

- Nourishment Plan
  - start date
  - cycle interval
  - mobilization threshold
- Reach Information
  - Order of reaches to nourish
  - Design Template
    - Berm Width
    - Dune Width
    - Dune Height
  - Nourishment triggers = % of design template
  - Unit Cost
  - Production Rate
  - Borrow To Placement Ratio

Planned Nourishment Process

- Check Scheduled Nourishment Event
  - Based on start date, cycle interval
- Check reaches
  - Compare existing profile with design template
  - Calculate required nourishment volume
    - Upper beach and lower beach separately
    - Nourishment time (based on production rate)
- Check Total Required Volume > Mobilization Threshold
- In reach processing order:
  - Set Start Reach Nourishment Event
  - Set End Reach Nourishment Event = Start + Nourishment Time
    - Restore Profile To Design Template
    - Accumulate Costs

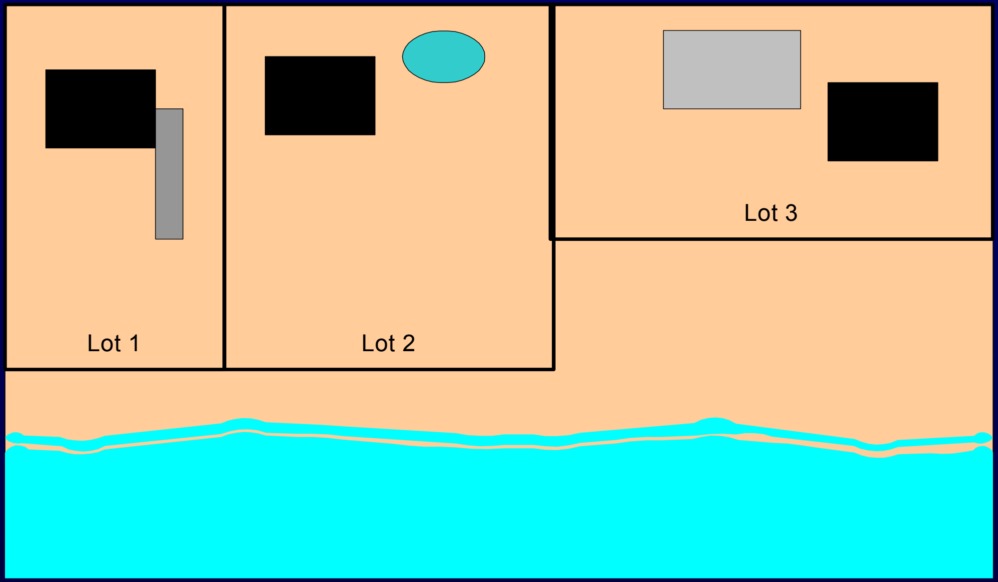
Nourishment Issues

- Emergency Nourishment
- Nourishment strategies
  - Beach placement environmental windows
  - Advance nourishment / Adaptive nourishment
  - Budget-constrained nourishment

Damage Calculations

Hierarchy – Damage Elements

- Reach
  - Lot
    - Damage Element



Damage Element Data

- Location
  - Bounding Rectangle / Representative Point (Geodetic Coords)
  - Ground and 1st Floor Elevation
- Type
  - Usage (SFR. MFR, etc.)
  - Foundation
  - Construction
  - Armoring
- Economic
  - Structure and Contents Value
  - Rebuilding allowed?
  - Time to rebuild

Damage Element Data

LotID	DamageElementTypeID	FoundationTypeID	ConstructionTypeID	ArmorTypeID	DEDescription	StructureValueP1	ContentsValueP1
9304	SFR	Pile8	2PFU	Null	1AB	250000	75000
9360	SFR	Pile8	2PFU	Null	4AB	1300000	390000
9365	SFR	Pile8	2PFU	Null	5AB	1100000	330000
9405	MFR	Pile8	3PNN	Null	7AB	1300000	390000
9434	MFR	Pile8	3PNN	Null	10AB	1300000	390000
9447	SFR	Pile8	2PFU	Null	2AB	1300000	390000
9484	SFR	Slab	1NNN	Null	12AB	1000000	300000
9510	SFR	Pile8	1PNN	Null	6AB	200000	60000
9520	MFR	Pile8	3PNN	Null	8AB	1300000	390000
9522	SFR	Pile8	2PFU	Null	3AB	1300000	390000
9539	SFR	Slab	1NNN	Null	28AB	65000	19500
9556	SFR	Slab	2NNN	Null	39AB	324000	97200
9557	SFR	Slab	2NFU	Null	38AB	150000	45000
9559	SFR	Pile8	2PFF	Null	37AB	230000	69000
9562	SFR	Pile8	2PFU	Null	36AB	325000	97500

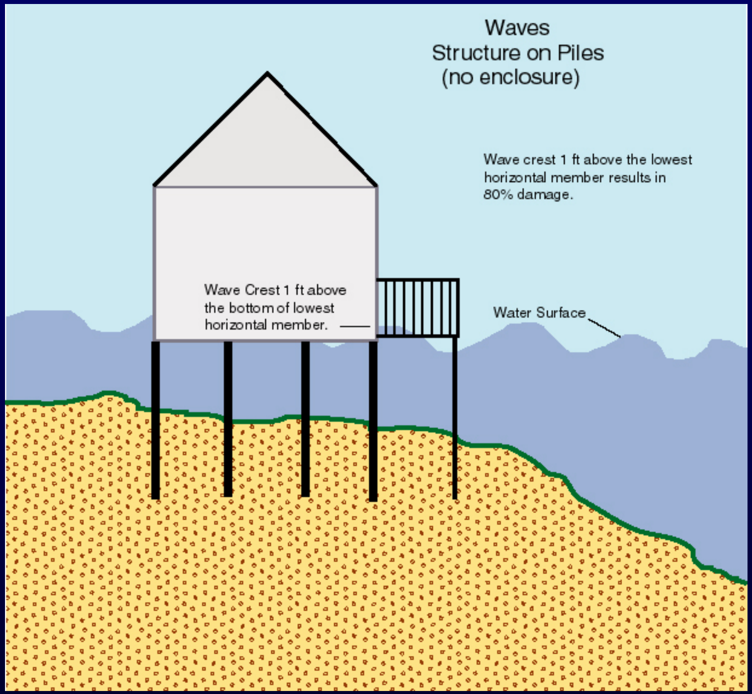
Damage Function Development

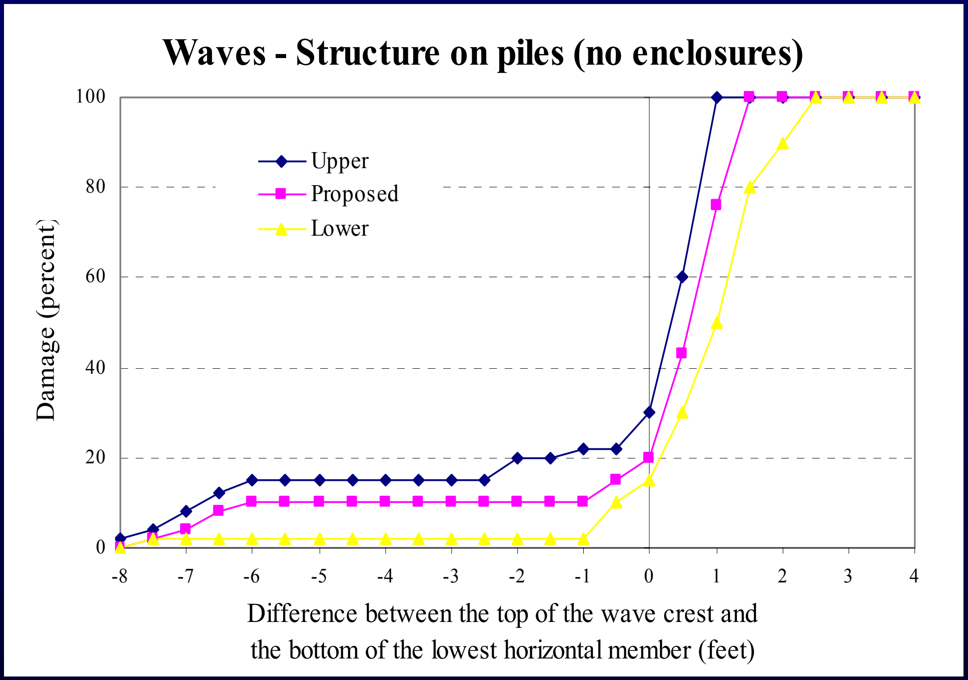
- IWR Work Unit
- Peer-Reviewed Methodology for Estimating Coastal Damages
- Coastal Storm Damage Workshop
    - Expert Elicitation
    - Single Family Residential
    - Provides context/framework for damage function development

Damage Functions

- For each:
  - Damage Element Type (house, walkway, etc.)
  - Damage Type (wave, flooding, etc.)
  - Foundation Type
  - Construction Type
  - Armor Type
- Define Curve of:
  - % Value Damaged = f(Driving Parameter)
- Driving Parameter is damage type-specific:
  - Flooding: Depth of water over lowest walking floor
  - Waves: (Wave crest) - (lowest horizontal member elevation)
  - Erosion: % of footprint compromised

Damage Function



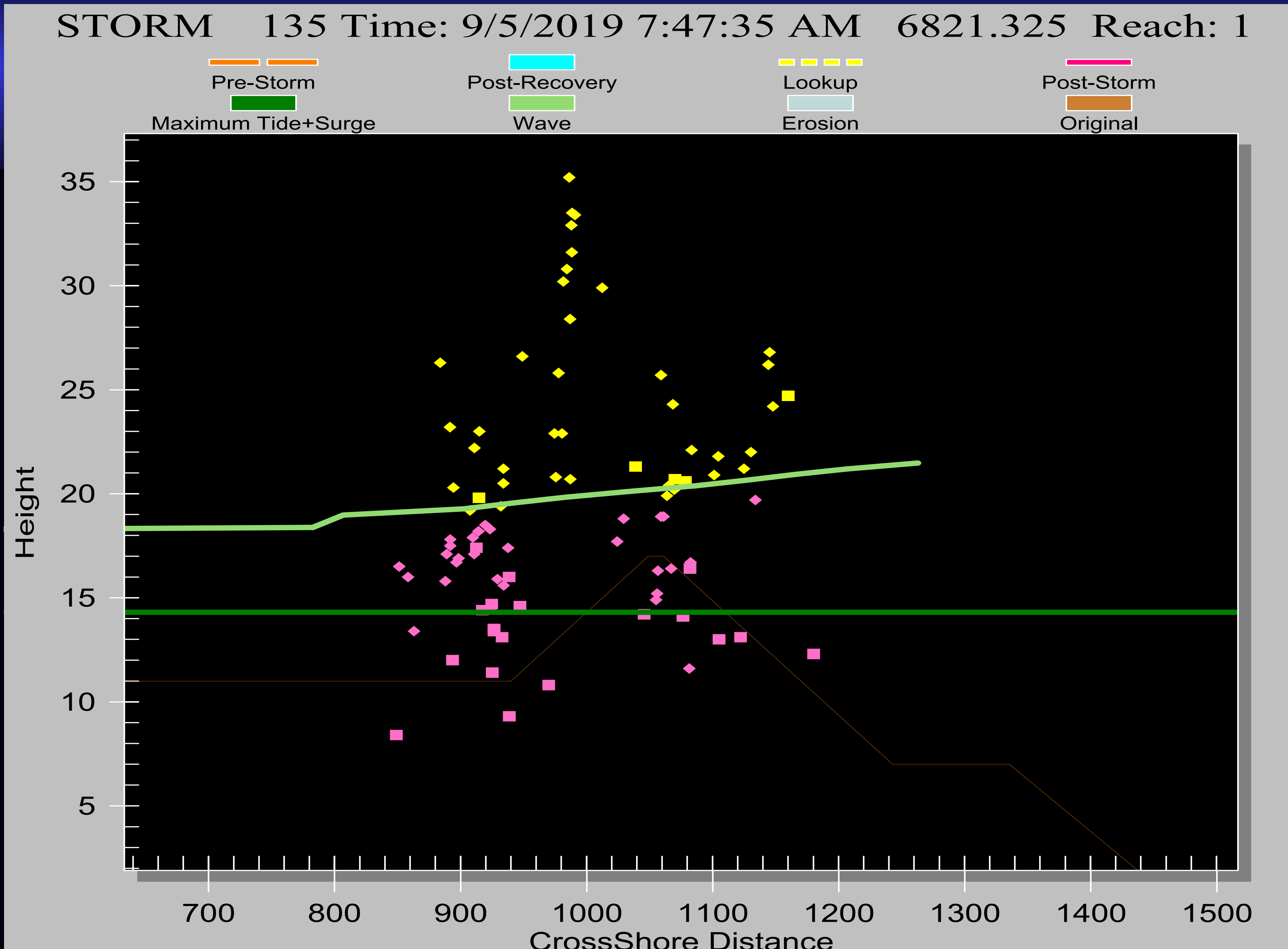


Risk and Uncertainty

- Damage Elements
  - structure value
  - contents value
  - first floor elevation
  - Time to rebuild
- Damage Functions
  - 3 curves, describe range of expert estimates of damages
  - Lower, Most Likely, Upper

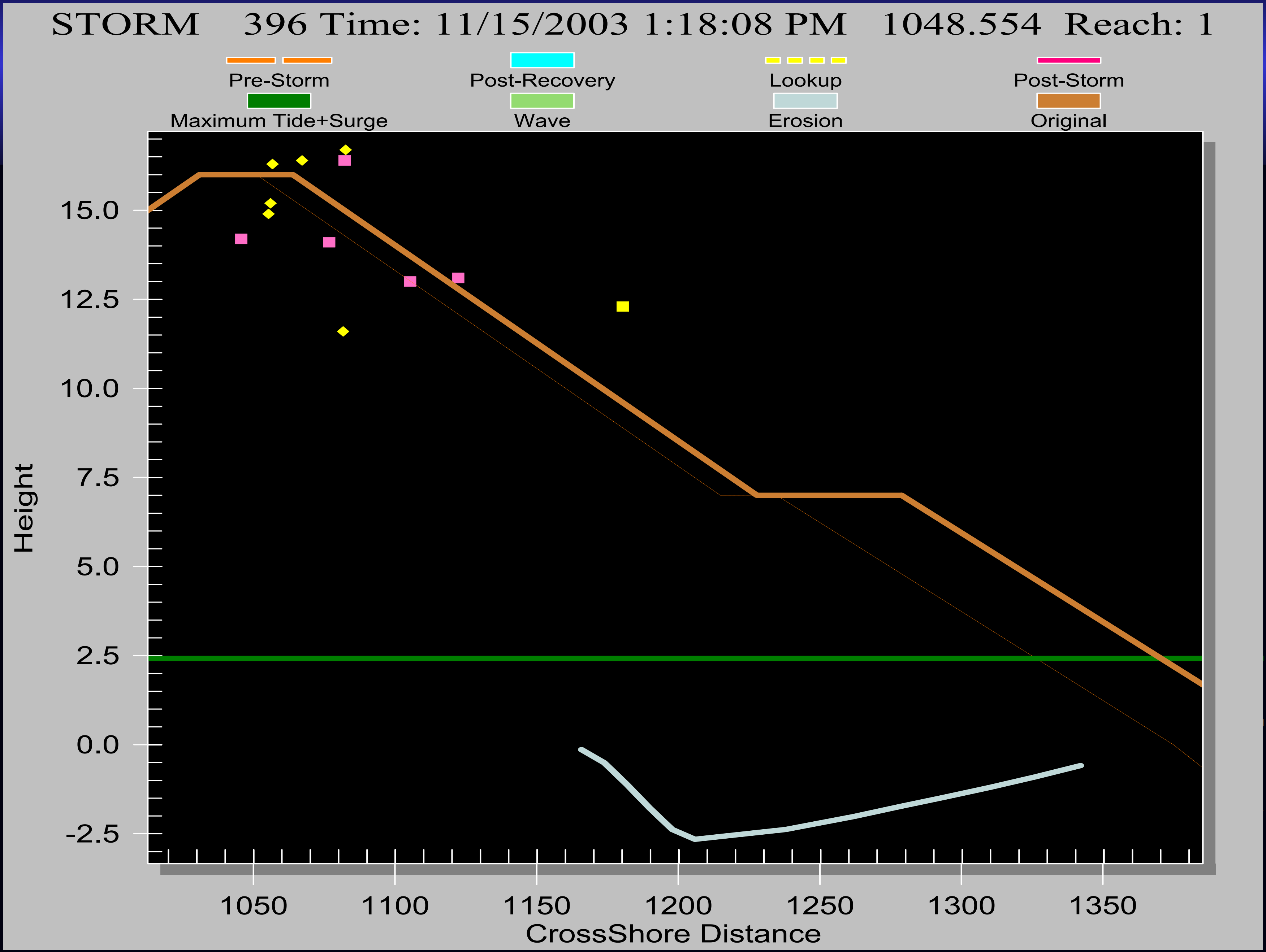
Flood and Wave Damage

- Damage Driving Parameter – water level above 1st floor elevation
- Use Wave Profile (from Lookup Response)
- For each DE
  - Determine Water Level at Representative Location of DE
  - Determine Damage Driving Parameter Based on 1st Floor Elevation of DE
  - Interpolate in 3 Damage Functions (% Damages)
  - Set Triangular Distribution
  - Sample Triangular Distribution → Final % Damage


STORM 135 Time: 9/5/2019 7:47:35 AM 6821.325 Reach: 1
Pre-Storm
Post-Recovery
Lookup
Post-Storm
Maximum Tide+Surge
Wave
Erosion
Original
Height
35
30
25
20
15
10
5
700
800
900
1000
1100
1200
1300
1400
1500
CrossShore Distance

Erosion Damage

- Damage Driving Parameter – % Footprint Compromised
- Use Erosion Profile (from Lookup Response)
- For each DE:
  - Get "Compromised" Level = f(Foundation Type)
- At 10 Points cross-shore (over length of DE):
  - Determine Cumulative Erosion To Date
    - Original Profile – PreStorm Profile
  - Determine In-Storm Erosion Based on Erosion Profile
  - Total = Cumulative + In-Storm
  - See if Compromised Level is Violated at this point
- # of points compromised*10 = % Footprint Compromised
  - Interpolate in 3 Damage Functions (% Damages)
  - Set Triangular Distribution
  - Sample Triangular Distribution → Final % Damage



STORM 396 Time: 11/15/2003 1:18:08 PM 1048.554 Reach: 1
Pre-Storm
Post-Recovery
Lookup
Post-Storm
Maximum Tide+Surge
Wave
Erosion
Original
Height
15.0
12.5
10.0
7.5
5.0
2.5
0.0
-2.5
1050
1100
1150
1200
1250
1300
1350
CrossShore Distance

Issues - Damages

- Damage Element Representation
  - Spatial representation (point vs. footprint)
  - Organization of attributes
    - Construction type /Foundation type / Other
    - Indirect assignment of damage functions vs. direct
  - Proper Distributions For Uncertainty Factors
- Polices That Change Inventory Over Time
  - Removal / Raising
- Back-Bay Flooding
- Land Loss
- Rebuilding
- Armoring
- Depreciation

Additional Topics For Discussion

Technical Capabilities

- Review of Profile Evolution Algorithm
- Land Loss
- Armoring
- Cumulative Damages / Rebuilding
- Emergency Nourishment
- Environmental Windows
- Historical Erosion Rate
- Impact of Shoreline Planform Evolution
- More complex beach profiles (hard bottoms, seawalls)

Data

- Damage Functions
- Density of SRD

Model Environment / Architecture

- User Interface
- Inline SBeach
- Performance
- Data Development Tools
- GIS Integration
  - Tighter integration with GIS?
  - What GIS?

Institutional

- Complexities of Data Development
- Model Usage Environment
  - Personnel expectations / demands
- Calibration / Validation
- External Review

Research

- Sensitivity of SBEACH to profile change, water elevation time series and tidal sequencing;
- Role of wind damage, and of carrying forward wind data through storm processing;
- Advisability of including construction berm (currently assumed no berm, a more conservative assessment, but fails to capture some benefits);
- Validity of constant equilibrium submerged profile;
- Review other available models for shoreline response;
- Examination of equilibration of construction profile;
- Examination of planform dispersion, and planform benefits outside of the project area