Lecture 4

We Have to Employ Systems Engineering Concepts in the 21st Century

J. David Rogers, Ph.D., P.E., R.G.

Karl F. Hasselmann Chair in Geological Engineering

Missouri University of Science & Technology

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The National Debate that has erupted since Katrina….

- Can we build levees that won't fail?
- Should we, as a society, allow or encourage urban development of lands that are either: 1) below sea level; or, 2) barely above sea level?
- People who choose to live in high risk areas should pay greater insurance premiums for the privilege of living in those areas
- Should we bother trying to save the Mississippi Delta? Why? *New Orleans ships the greatest volume of exported goods from the USA, mostly wheat, corn, and soy.*

For engineers designing flood protection systems, the core value should be SURVIVABILTY

Above all else, flood barriers, such as levees, should be constructed to withstand short-term overtopping <u>without catastrophic failure</u>.

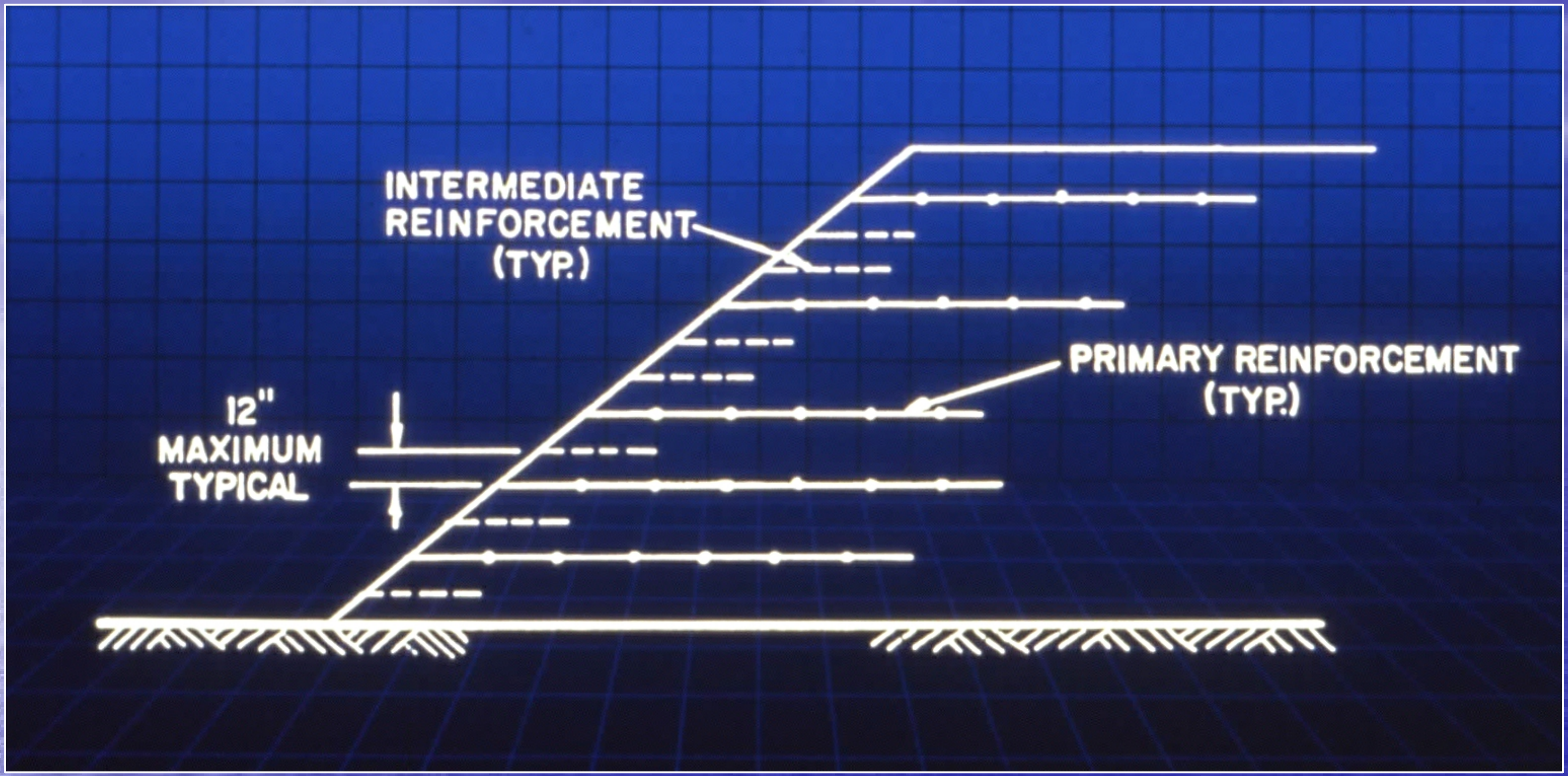
Earthen Levees are old technology; they are not reliable on soft soils

Levees are susceptible to erosion by *overtopping*, by *edified flow*, and by *undercutting*.

Once flood waters overtop an embankment they quickly scour the land-side toe of the embankment, and scour deep holes that develop on either side of the "*hydraulic jump.*"

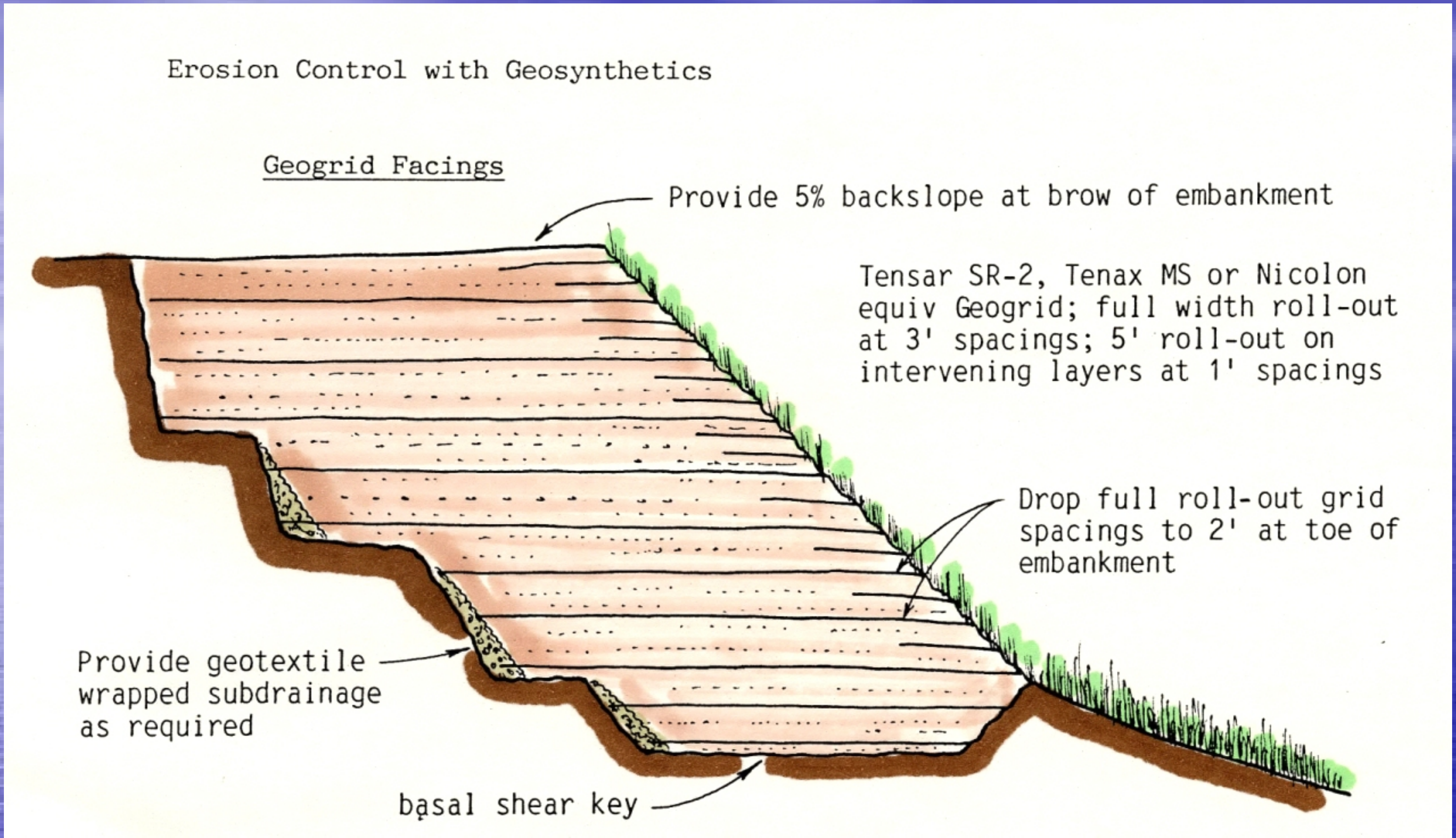
COULD *SOIL REINFORCEMENT* TECHNOLOGIES BE APPLIED TO CREATE MORE ROBUST LEVEES?

- Geogrid-wrapped hay bales or gravel filled HDPE baskets can be used as facing elements for **mechanically-stabilized embankments**.
- These materials do not corrode and plants and trees can take root in them, so they are more “environmentally friendly”

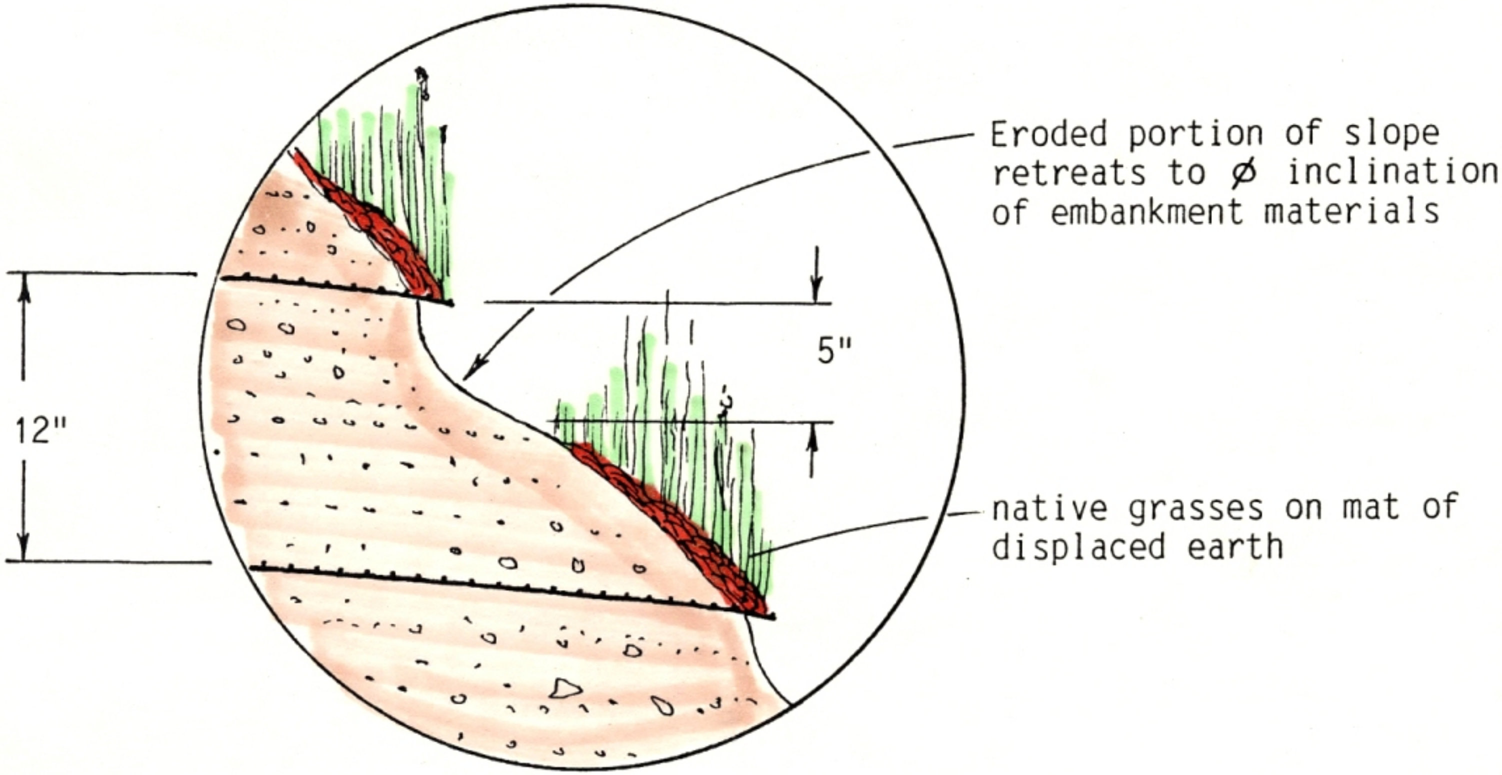


- We can make embankments slopes as steep as we desire by using "false layers," of geotextiles, between primary reinforcement layers of mechanically stabilized embankments (MSE).
- These false layers restrict slope raveling and erosion

- **Example of a 45 degree fill face supporting a shopping center complex adjacent to a line of mature trees. The embankment was constructed using false layers of geotextiles spaced 1 foot apart (from Rogers, 1992)**



- **Section through a MSE embankment with a 1:1 (45 degree) finish face inclination. The embankment utilized false layers every 12 inches, extending just 5 feet into the slope (from Rogers, 1992)**

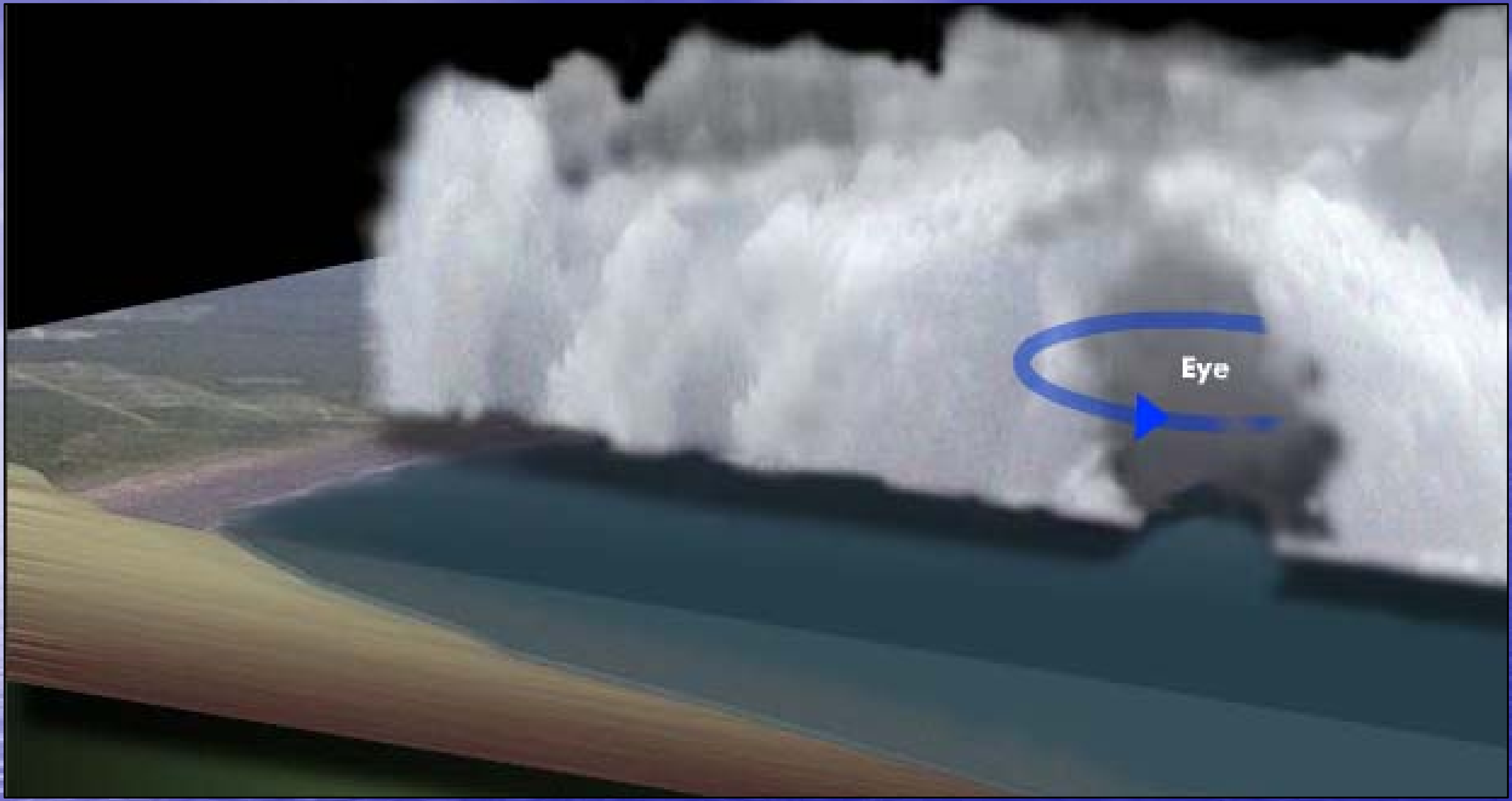


Detail view of the erosion which can be expected to occur between Geogrid layers. The effective slope height is reduced to 12" by embedment of the Geogrid.

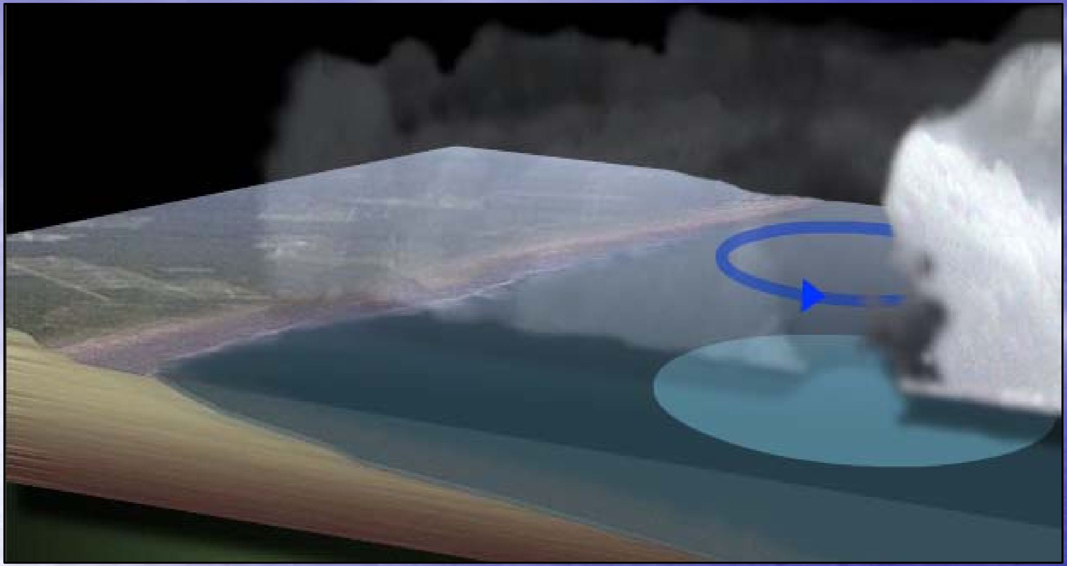
- **Detail of geotextile "false layers", placed every 12 inches to retard surafce erosion (from Rogers, 1992)**

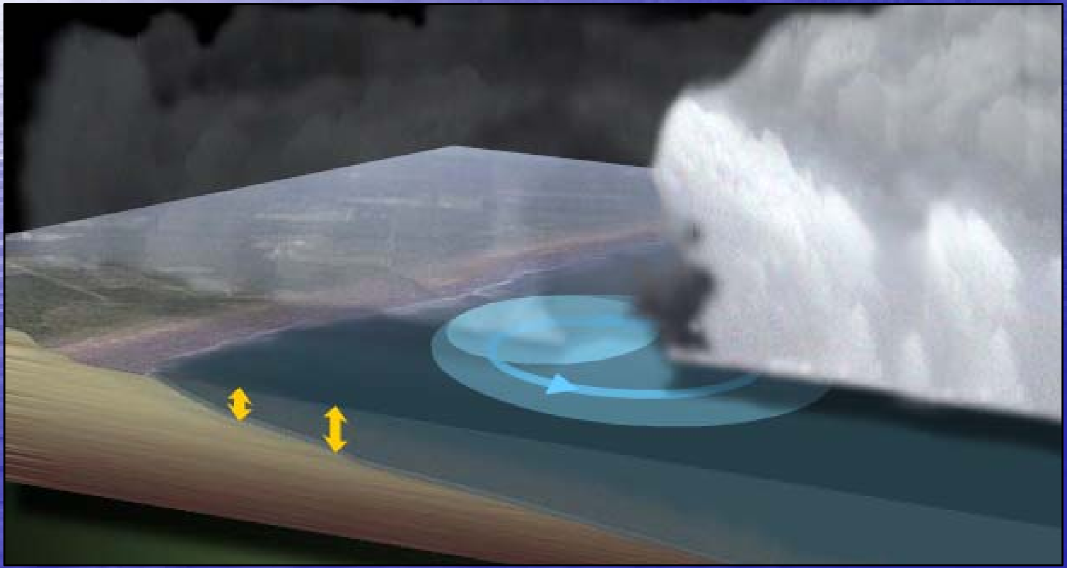
- **Same 45 degree fill slope after hydroseeding and sprouting of fescue grass mix (from Rogers, 1992).**

ENGINEERING FOR STORM SURGE AND WAVE ENERGY DISSIPATION



- **Storm or tidal surges** are caused by lifting of the oceanic surface by abnormal low atmospheric pressure beneath the eye of a hurricane. The faster the winds, the lower the pressure; and the greater the storm surge. At its peak, Hurricane Katrina caused a surge **53 feet high** under its eye as it approached the Louisiana coast, triggering a storm surge advisory of 18 to 28 feet in New Orleans (image from USA Today).



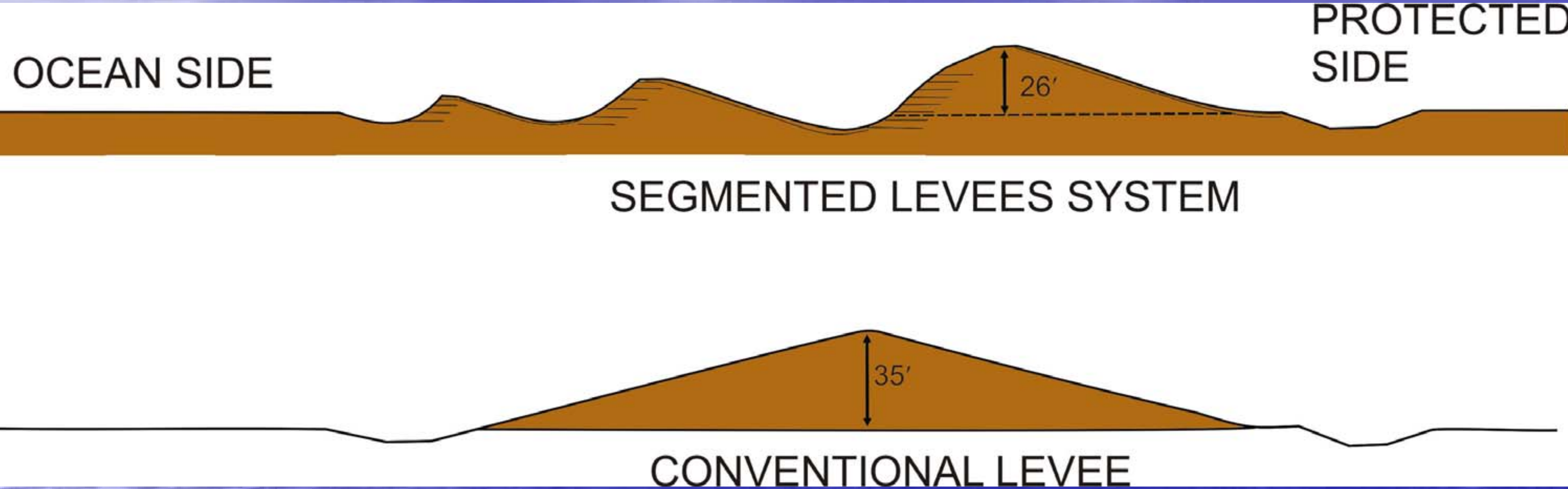


Images from USA Today

Storm Surge

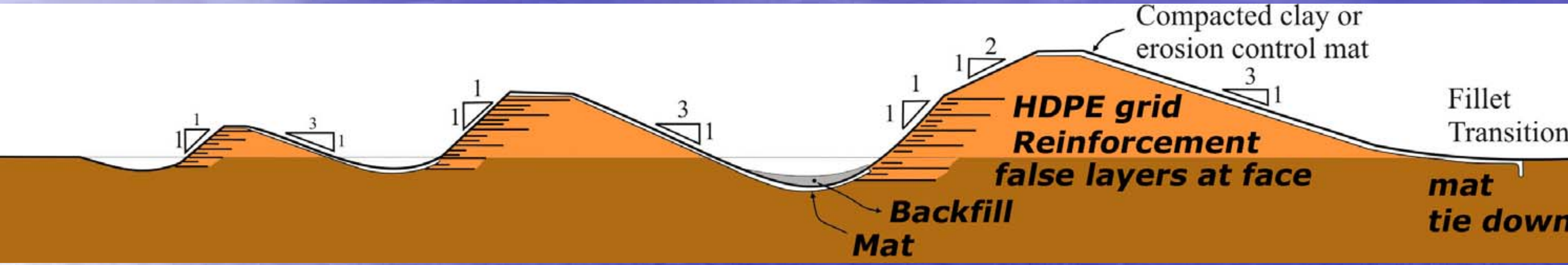
- The surge effect is minimal in the open ocean, because the water falls back on itself
- As the storm makes landfall, water is lifted onto the continent, locally elevating the sea level, much like a tsunami, but with much higher winds

Segmental Levee Systems

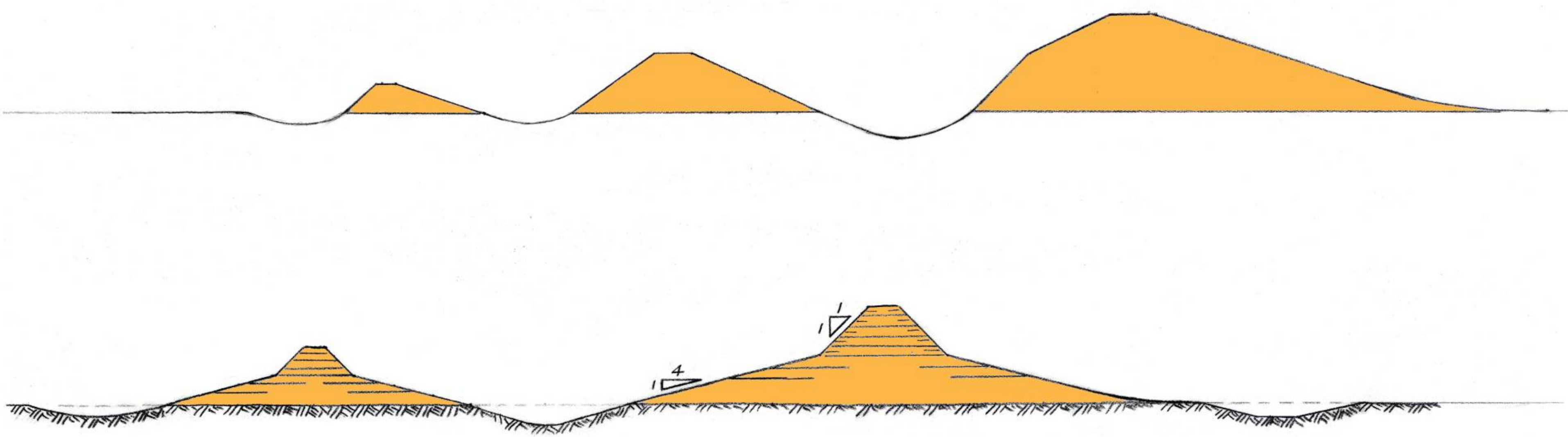


- **In areas exposed to storm surge some thought might be given to equipping levees to be more efficient *energy dissipation systems*; and not just simple barriers. *Though more complicated, they might not have to be as high.***

Soil Reinforcement



- Soil reinforcement could be applied to engender greater shear strength, allowing much steeper cross sections
- Steeper side slopes form more efficient barriers to dissipate forward wave energy
- Note curved troughs between the embankments.



- **HDPE geogrid soil reinforcement could be also be employed to engender *greater flexibility* in levee profiles, as suggested here.**
- **Levees could be molded into more efficient barriers to retard and survive storm surge**
- **The lower sketch shows how bearing loads could be reduced by employing soil reinforcement, allowing greatly reduced cross sections.**

Cypress Swamp die-off

The entire delta is slowly subsiding. If new sources of sediment do not replenish the swamp, the young cypress shoots cannot germinate in water > 2 feet deep; and Cypress forests die off all at once, becoming a treeless, grassy marsh, with a forest of dead tree trunks.

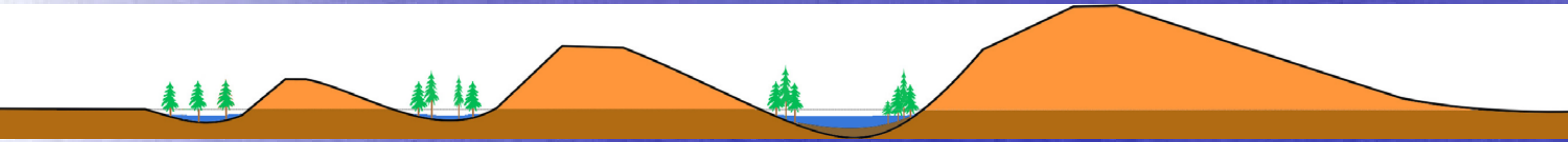
Mature Cypress swamps retard storm surges by mechanically dissipating incoming wave energy

Much propaganda has been circulated concerning the potential mollifying effects of cypress forest dispelling wave energy, when hurricanes make landfall along the Louisiana Coast.

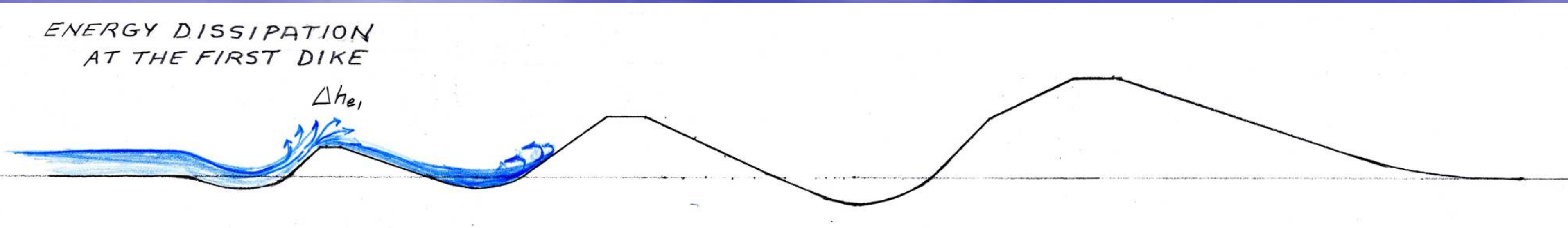
The most common-cited figure is 1 foot of storm surge reduction for every 2.4 miles of mature cypress swamp.

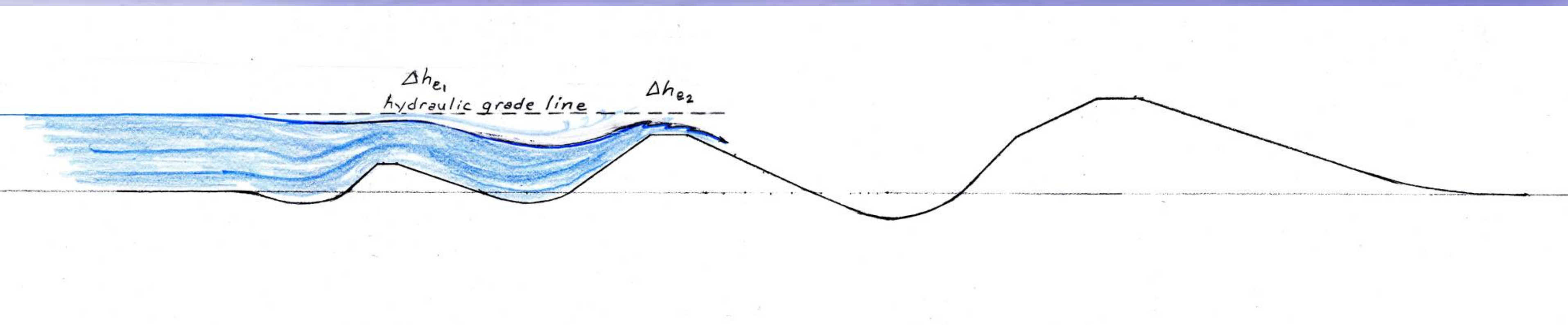
This value is not valid for the entire coastline. The actual impact depends on a number of physical factors.

Green Levees: Create troughs to promote growth of cypress trees as mechanical barriers

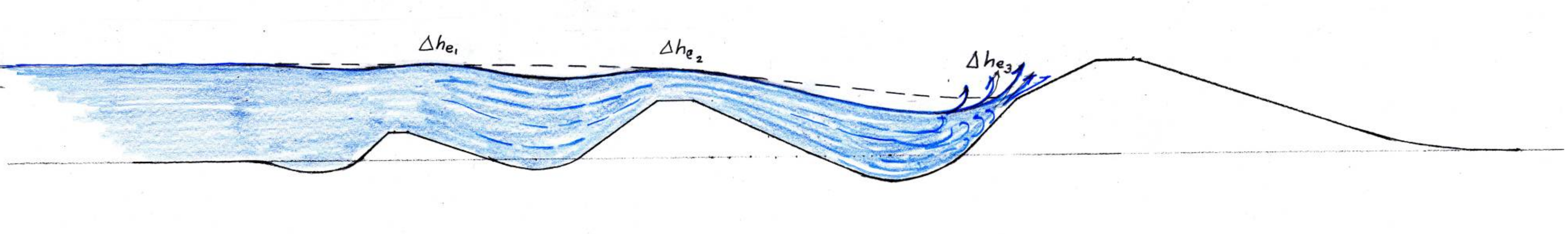


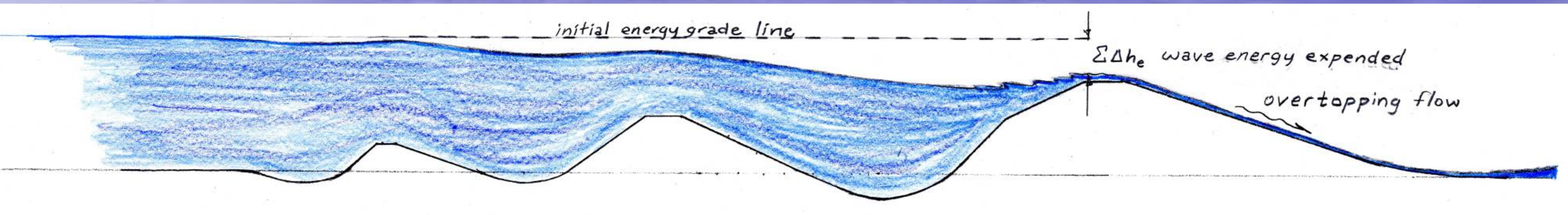
- Segmental levee systems could be crafted into "green" systems, which would employ swamp troughs between the embankments
- As the cypress trees mature, their impact on storm surge dissipation would increase, helping to offset freeboard losses caused by regional settlement





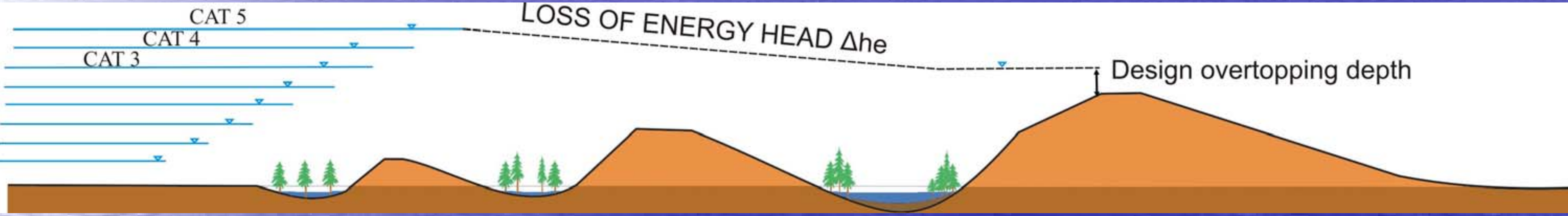
- **Each flow obstruction will drain energy head from the advancing storm surge.**
- **Troughs with steep faces are some of the most efficient energy dissipaters, because the deflect forward energy upward.**





- **As the obstructions get larger, more and more wave energy is bled off and expended**
- **This might allow for a LOWER crest elevation for the highest embankment**
- **<u>The system should be designed to survive short-term overtopping</u> (e.g. 12 hours)**

Maximum Flexibility, with Innumerable Design Options



- **Green segmented levee protection systems could be tweaked for any number of variables; including a *design overtopping depth* to accommodate low frequency events; without using as much earth fill as conventional embankments.**