Multiple Water Quality Models to Inform TMDL Decision Making in the Neuse River Estuary

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THE NEWS&OBSERVER

Friday

July 12, 1996

Massive fish kill hits Neuse

Organic material and sewage cause oxygen levels to drop below what fish and crabs need to live.

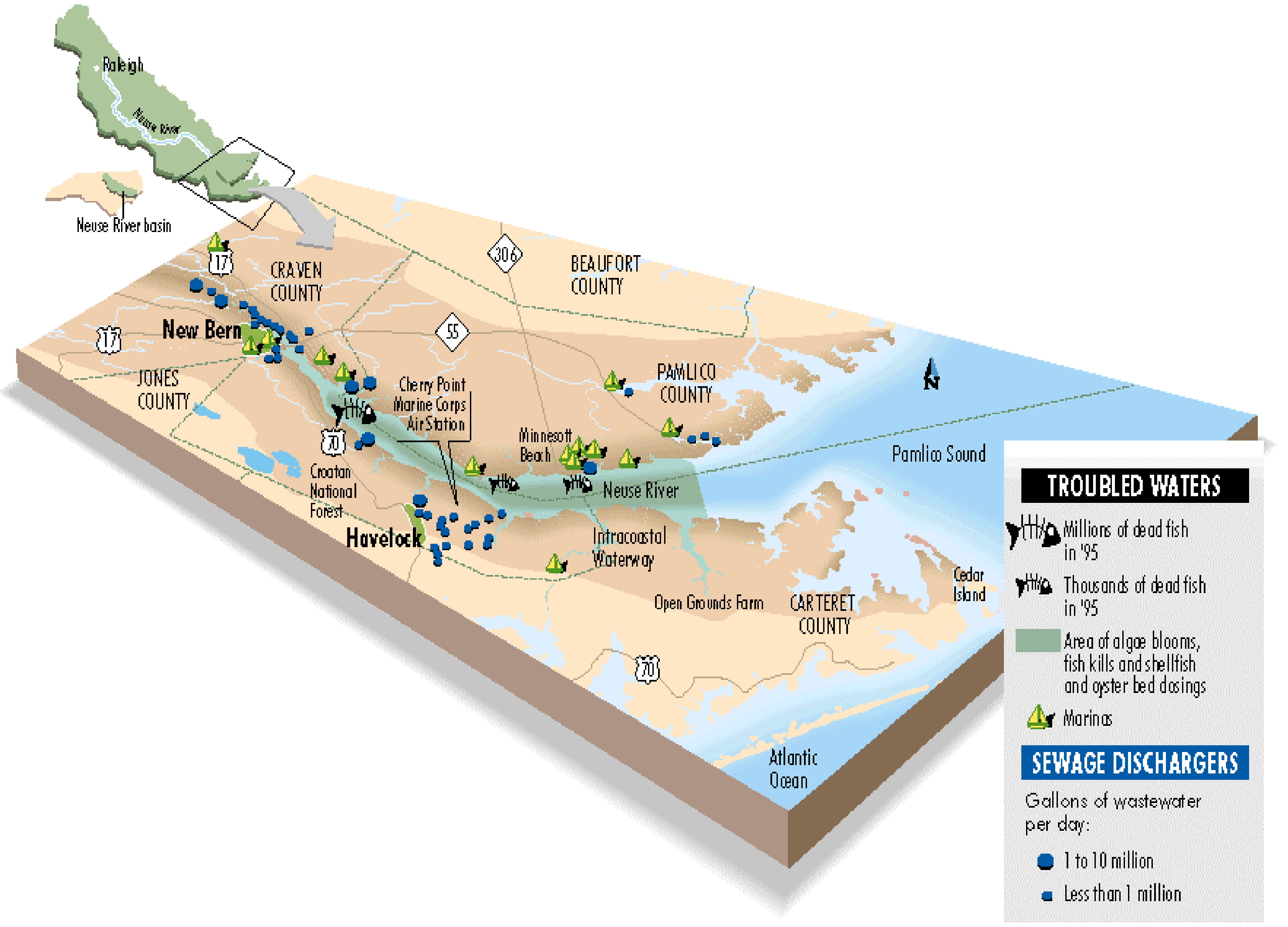
THE NEWS&OBSERVER

Friday

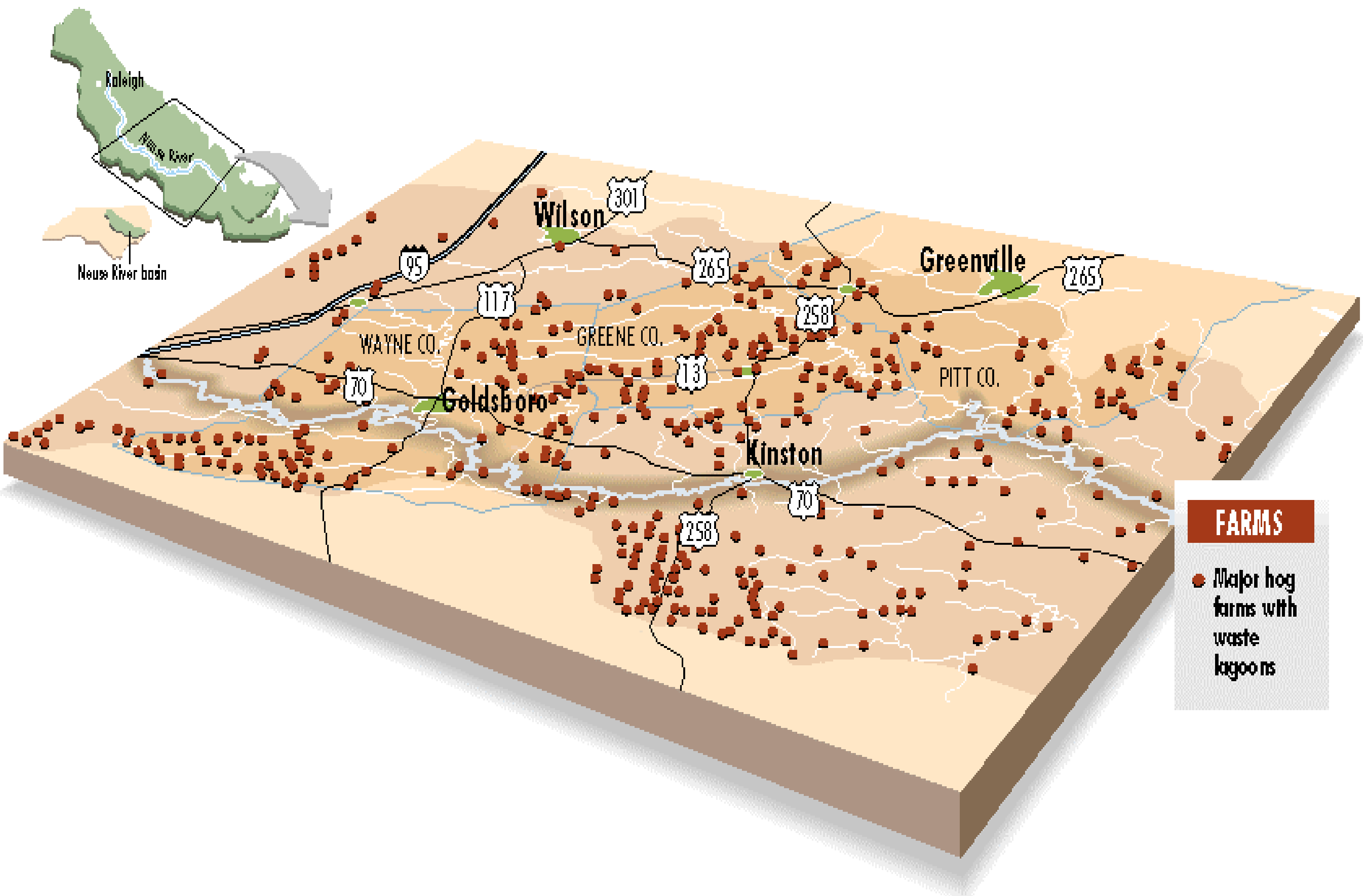
September 20, 1996

Neuse plan clears hurdle, but goals in dispute

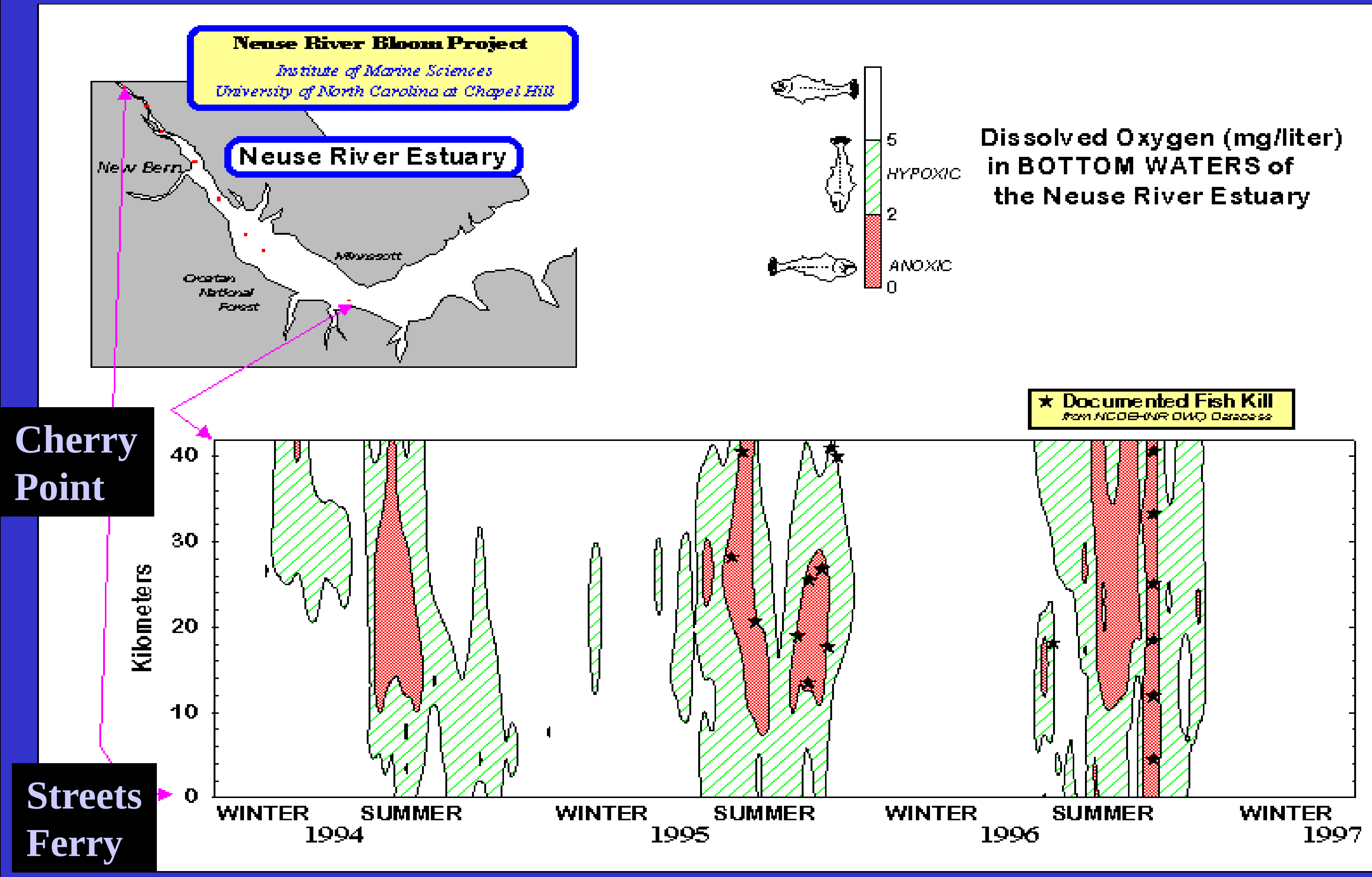
Environmental groups say the proposal should reduce pollution by 30 percent. Other officials don't want such a firm commitment.



Raleigh
Neuse River
Neuse River basin
17
CRAVEN COUNTY
306
BEAUFORT COUNTY
New Bern
55
JONES COUNTY
PAMLICO COUNTY
Cherry Point Marine Corps Air Station
70
Croatan National Forest
Minnesott Beach
Pamlico Sound
Neuse River
Havelock
Intracoastal Waterway
Open Grounds Farm
CARTERET COUNTY
Cedar Island
Atlantic Ocean
TROUBLED WATERS
Millions of dead fish in '95
Thousands of dead fish in '95
Area of algae blooms, fish kills and shellfish and oyster bed closings
Marinas
SEWAGE DISCHARGERS
Gallons of wastewater per day:
1 to 10 million
Less than 1 million


Raleigh
Neuse River
Neuse River basin
Wilson
Greenville
Goldsboro
Kinston
WAYNE CO.
GREENE CO.
PITT CO.
95
301
265
117
258
13
70
FARMS
Major hog farms with waste lagoons

Low DO and Fish Kills: 94-96

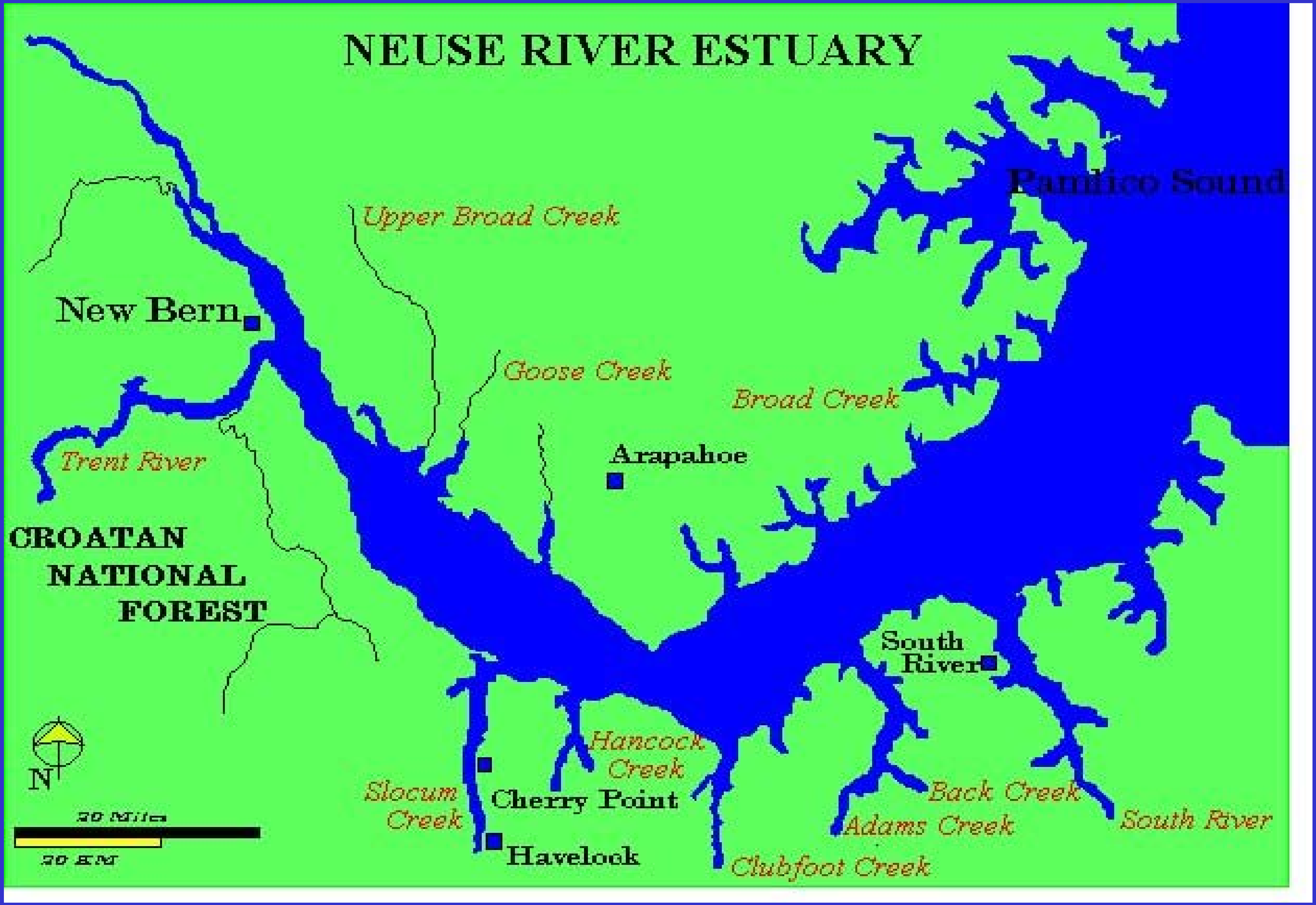


Neuse River Estuary

MODMON

An Interdisciplinary Research Project
funded by
the North Carolina Department of
Environment, Health and Natural Resources
and
The University of North Carolina
Water Resources Research Institute

Neuse River Estuary



Water Quality (TMDL) Forecasting

The problem with water quality forecasting is that we're not terribly good at it.

Result:

Prediction uncertainty is likely to be quite high but is also likely to be unknown.

How do you want it – the crystal mumbo-jumbo or statistical probability?

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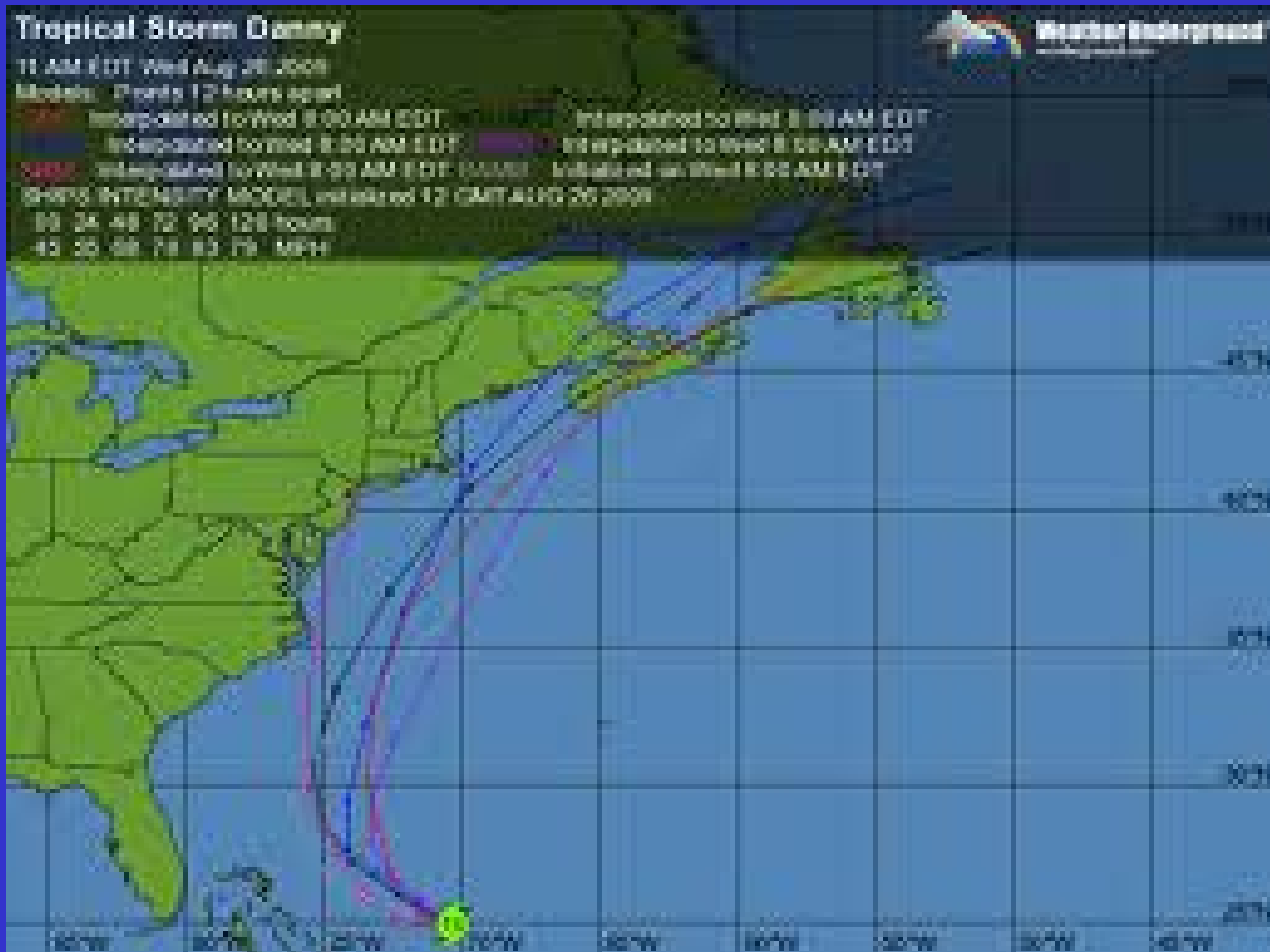
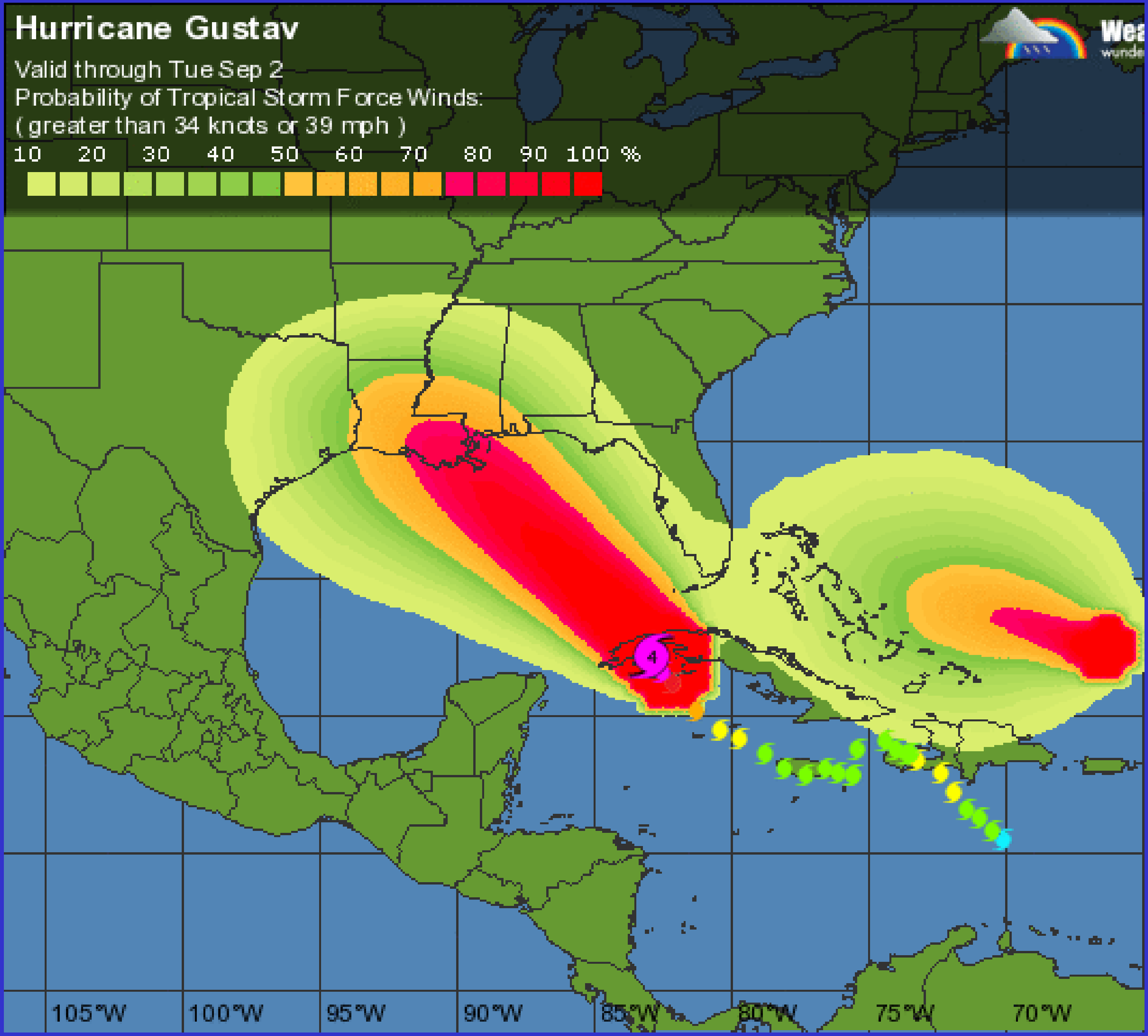
"There's a 50% chance of rain, so I only watered half the lawn."


8 DAY OUTLOOK
FOX 8 NEWS
TUE WED THU FRI SAT SUN MON TUE
49 46 58 73 75 73 70 70
35 34 48 53 55 53 55
Much Warmer
80% 70% 40% 50%
FOX8.com


Tropical Storm Danny
11 AM EDT Wed Aug 26 2009
Models: Points 12 hours apart
Weather Underground



Hurricane Gustav
Valid through Tue Sep 2
Probability of Tropical Storm Force Winds:
(greater than 34 knots or 39 mph)
10 20 30 40 50 60 70 80 90 100 %
4
105°W
100°W
95°W
90°W
85°W
80°W
75°W
70°W

Is Scientific Knowledge Sufficient for Environmental Decision Making?

There is almost always enough scientific knowledge to make an informed decision.

How Can Limited Scientific Knowledge Support Environmental Decision Making?

It depends…

on the amount of scientific uncertainty and the attitude toward risk.

How do/should we make decisions when knowledge is uncertain?

How can knowledge of scientific uncertainty improve decision making?

Decision Analysis Provides a Prescriptive Approach for Informing Decision Making Under Uncertainty

- Probability model – this characterizes (scientific) knowledge; for example, this represents the prediction from a water quality model. Since it is probabilistic, it must include uncertainty analysis.

- Utility function – this characterizes the values of the decision makers (or stakeholders).

In theory, the *optimal* decision is found by integrating the probability model with the utility function.

This integration weights the utility (value) function by the probability of various outcomes.

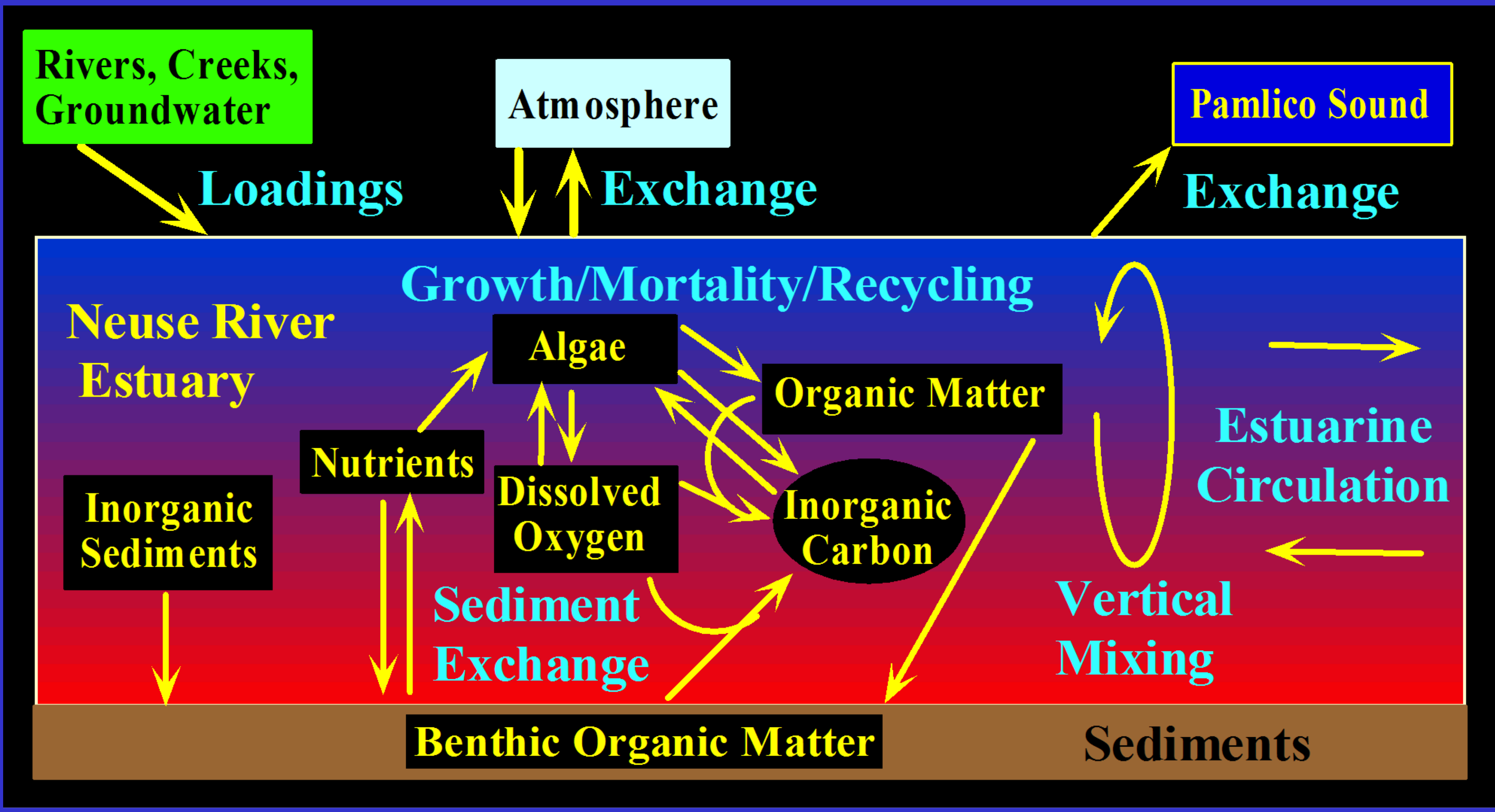
This allows a risk-averse decision maker (through the utility function) to hedge against large losses.

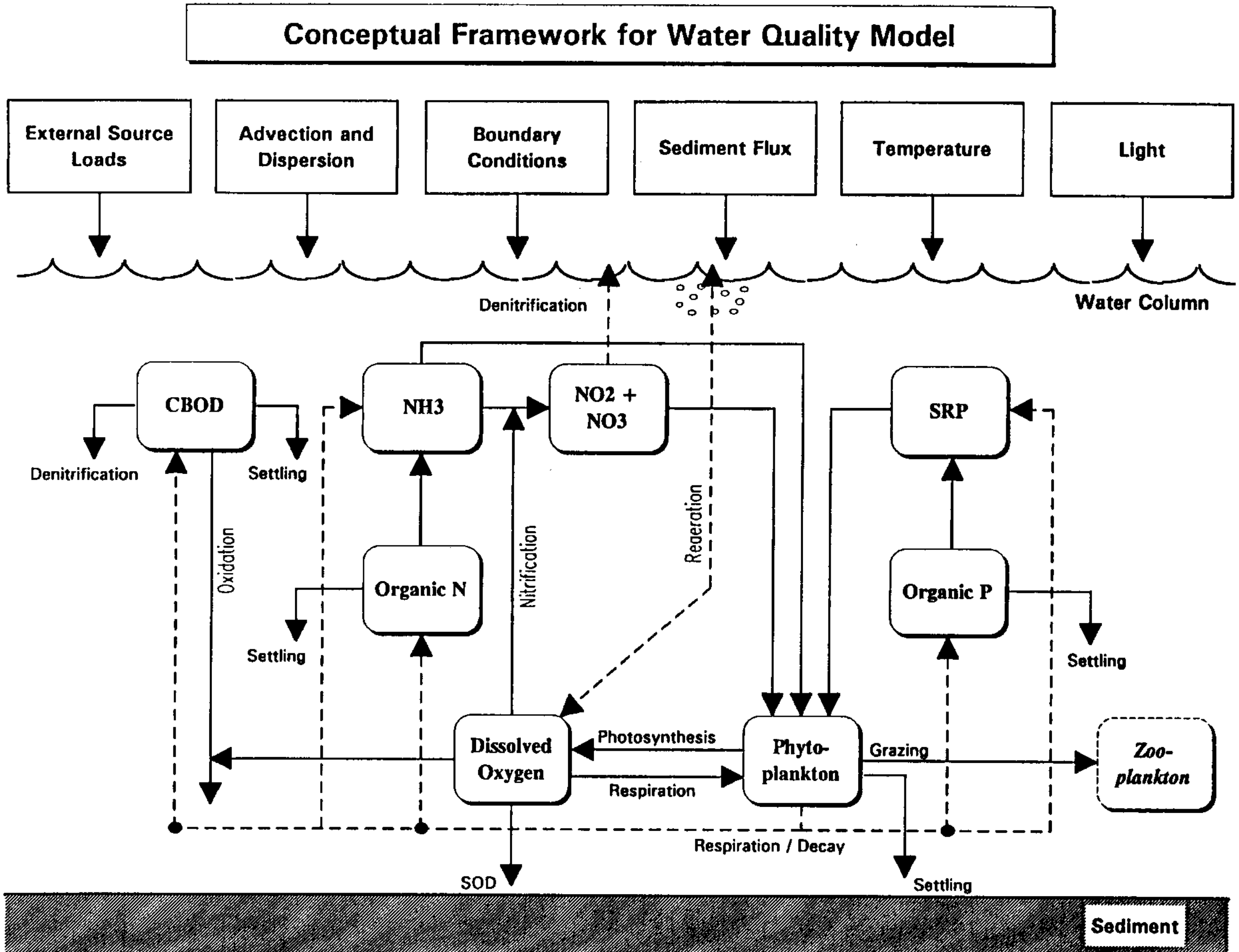
Only when the uncertainty in the scientific assessment (e.g., a WQ model) is determined, can the decision maker explicitly consider attitude toward risk.

Three Different Models were Applied

- CE-QUAL-W2 (NEEM; 2-dimensional)
- EFDC-WASP (3-dimensional)
- A Probability Network Model (Neu-BERN)

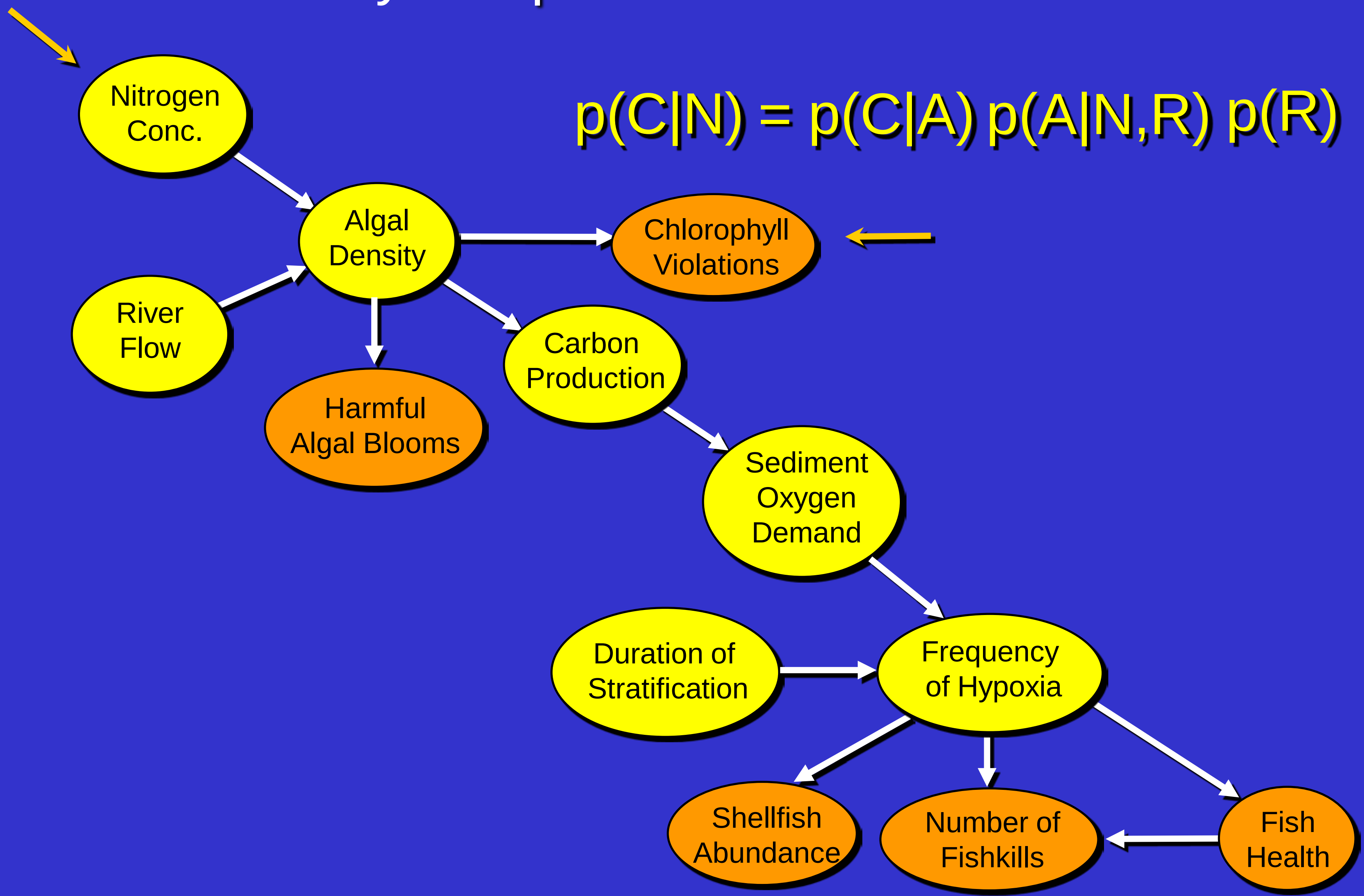
Neuse Estuary Eutrophication Model

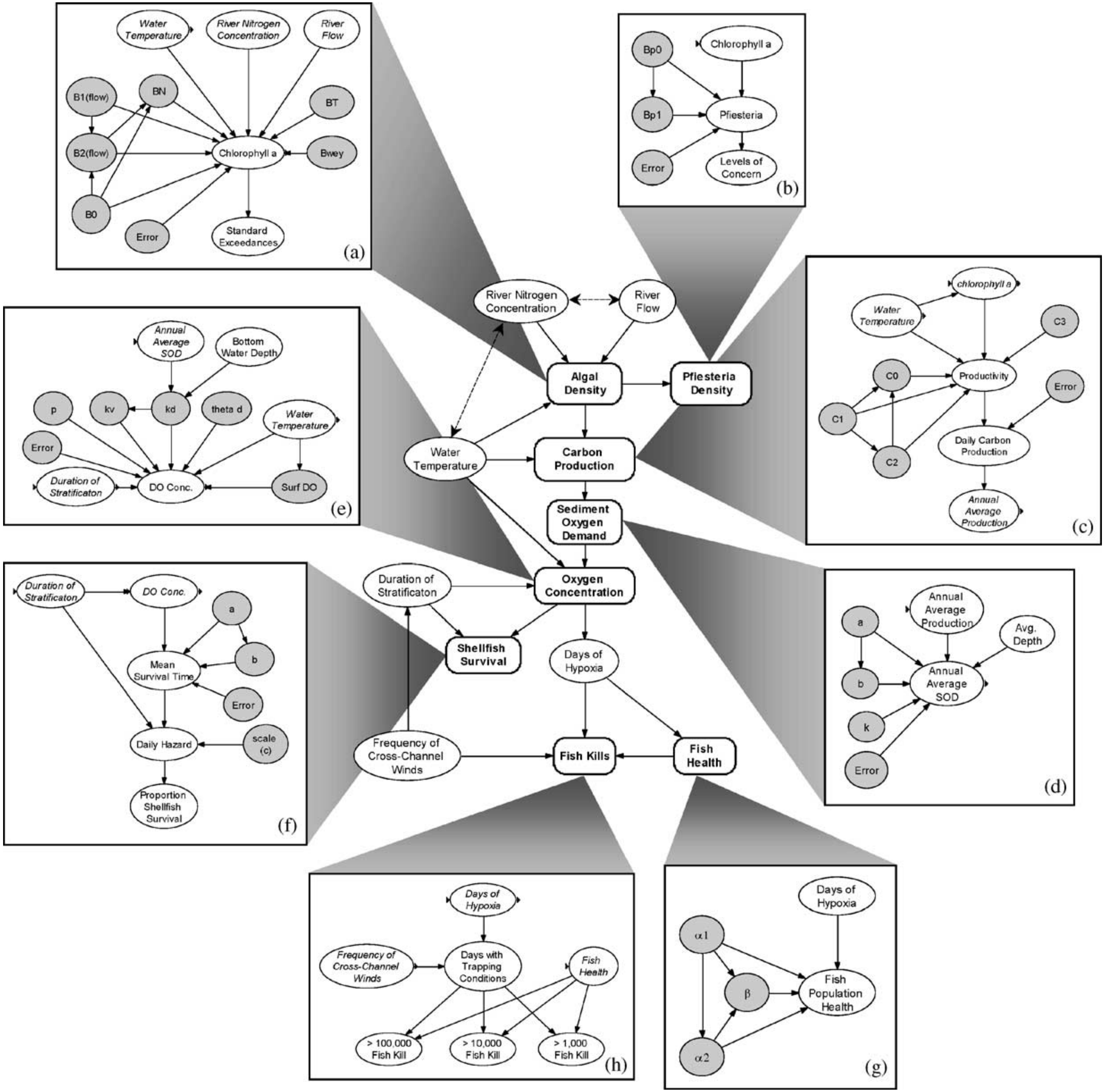


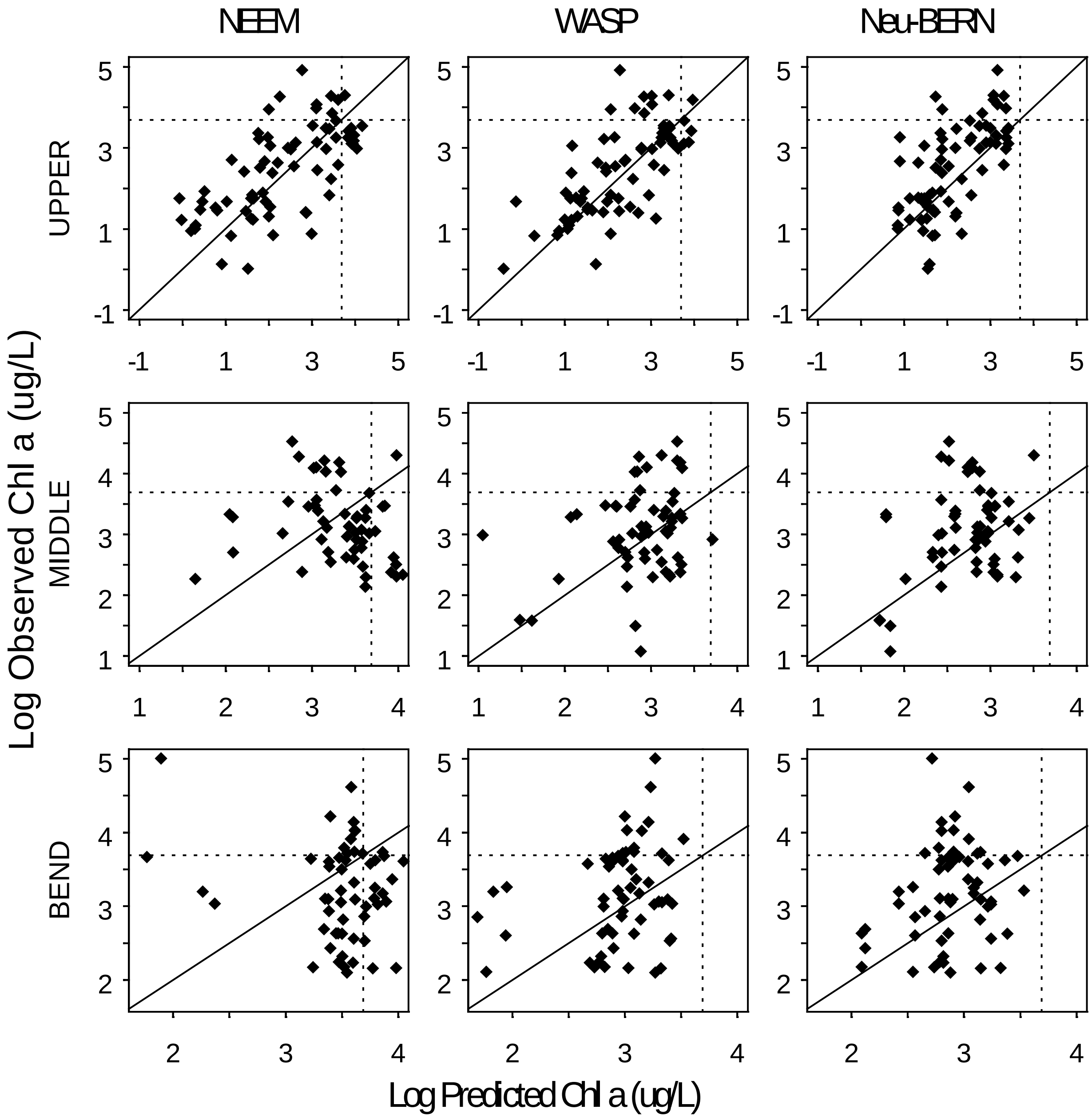

Conceptual Framework for Water Quality Model
External Source Loads
Advection and Dispersion
Boundary Conditions
Sediment Flux
Temperature
Light
Denitrification
Water Column
CBOD
NH3
NO2 + NO3
SRP
Denitrification
Settling
Oxidation
Organic N
Nitrification
Reaeration
Organic P
Settling
Settling
Dissolved Oxygen
Photosynthesis
Respiration
Phyto-plankton
Grazing
Zoo-plankton
Respiration / Decay
SOD
Settling
Sediment

Each conditional distribution can be represented by a separate sub-model.

$$p(C|N) = p(C|A)\,p(A|N,R)\,p(R)$$




River Nitrogen Concentration
River Flow
Water Temperature
Algal Density
Pfiesteria Density
Carbon Production
Sediment Oxygen Demand
Duration of Stratificaton
Oxygen Concentration
Shellfish Survival
Days of Hypoxia
Frequency of Cross-Channel Winds
Fish Kills
Fish Health
Water Temperature
River Nitrogen Concentration
River Flow
B1(flow)
BN
BT
B2(flow)
Chlorophyll a
Bwey
B0
Error
Standard Exceedances
(a)
Bp0
Chlorophyll a
Bp1
Pfiesteria
Error
Levels of Concern
(b)
chlorophyll a
Water Temperature
C3
C0
Productivity
Error
C1
C2
Daily Carbon Production
Annual Average Production
(c)
Annual Average Production
a
Avg. Depth
b
Annual Average SOD
k
Error
(d)
Annual Average SOD
Bottom Water Depth
p
kv
kd
theta d
Water Temperature
Error
Duration of Stratificaton
DO Conc.
Surf DO
(e)
Duration of Stratificaton
DO Conc.
a
b
Mean Survival Time
Error
Daily Hazard
scale (c)
Proportion Shellfish Survival
(f)
Days of Hypoxia
Frequency of Cross-Channel Winds
Days with Trapping Conditions
Fish Health
> 100,000 Fish Kill
> 10,000 Fish Kill
> 1,000 Fish Kill
(h)
Days of Hypoxia
α1
β
Fish Population Health
α2
(g)


NEEM
WASP
Neu-BERN
UPPER
MIDDLE
BEND
Log Observed Chl a (ug/L)
Log Predicted Chl a (ug/L)

For the Neuse, the Bayes Network (BN) Model Complemented the Two Mechanistic Models.

- While the BN could not provide the space/time resolution of a detailed mechanistic model to evaluate dissolved oxygen and other small-scale outcomes, it is probabilistic and highly flexible in structure.

- The probabilistic nature of a BN means that prediction uncertainty could be estimated; also, the BN flexibility allows extension of the model for probabilistic prediction of endpoints concerning fish and shellfish.