

# CIEG 440-010

# Water Resources Engineering



## Introduction to Water Resources Engineering Sep 3, 2008



Gerald J. Kauffman PE



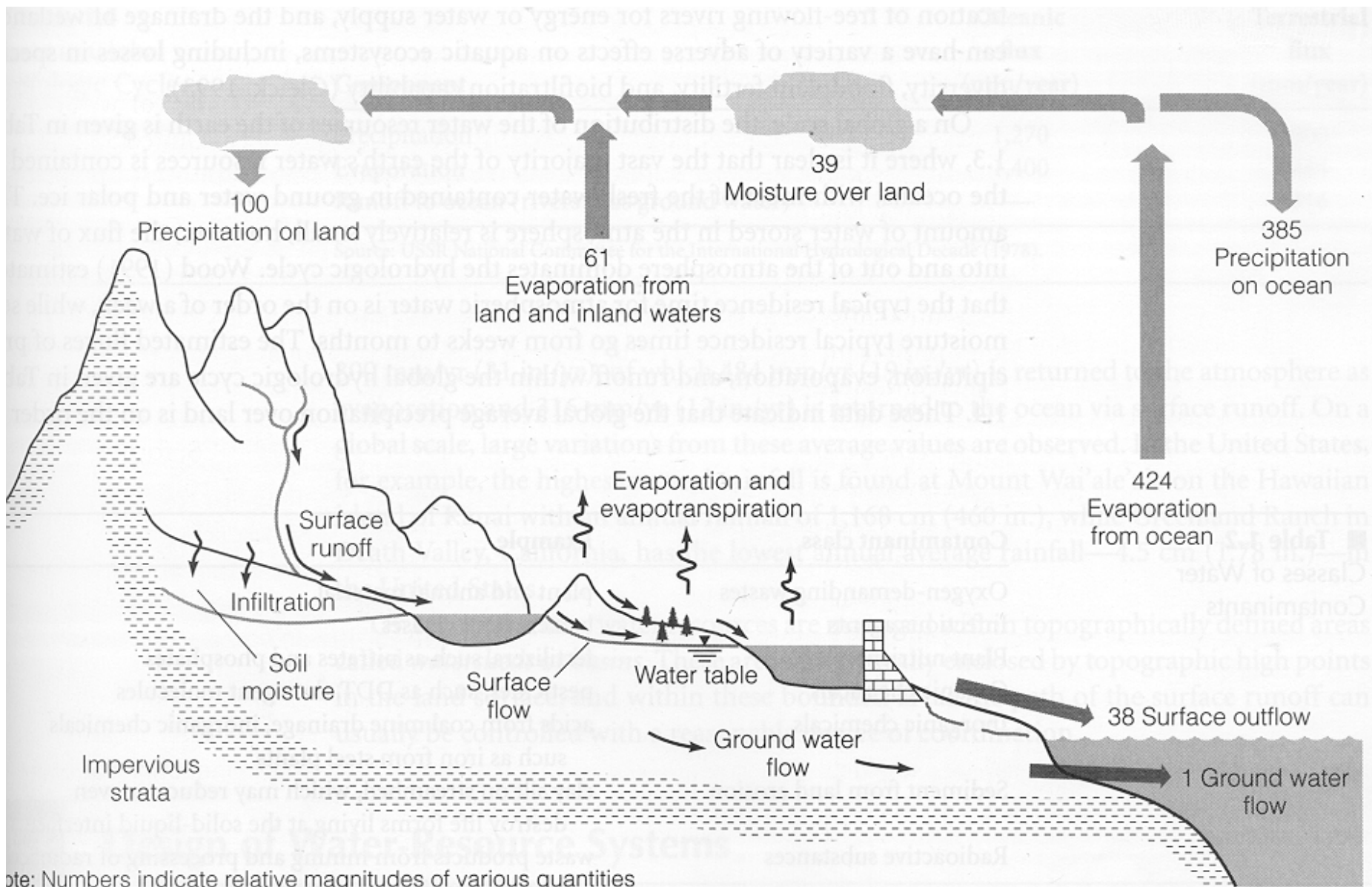
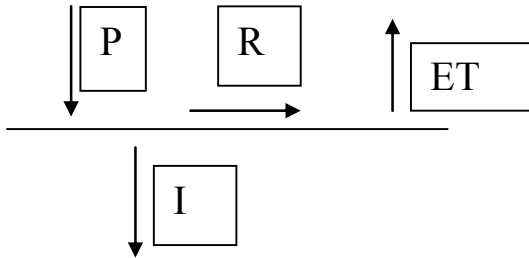


Figure 1.1 ■ Hydrologic Cycle

Source: *Applied Hydrology*. Ven Te Chow, David R. Maidment, Larry W. Mays. Copyright © 1988 The McGraw-Hill Companies.

$$P = R + I + ET$$



Normal Year Brandywine Creek

$$P = 42 \text{ in.}$$

$$R = 7 \text{ in.}$$

$$I = 14 \text{ in.}$$

$$ET = 21 \text{ in.}$$

Drought Year Brandywine Creek

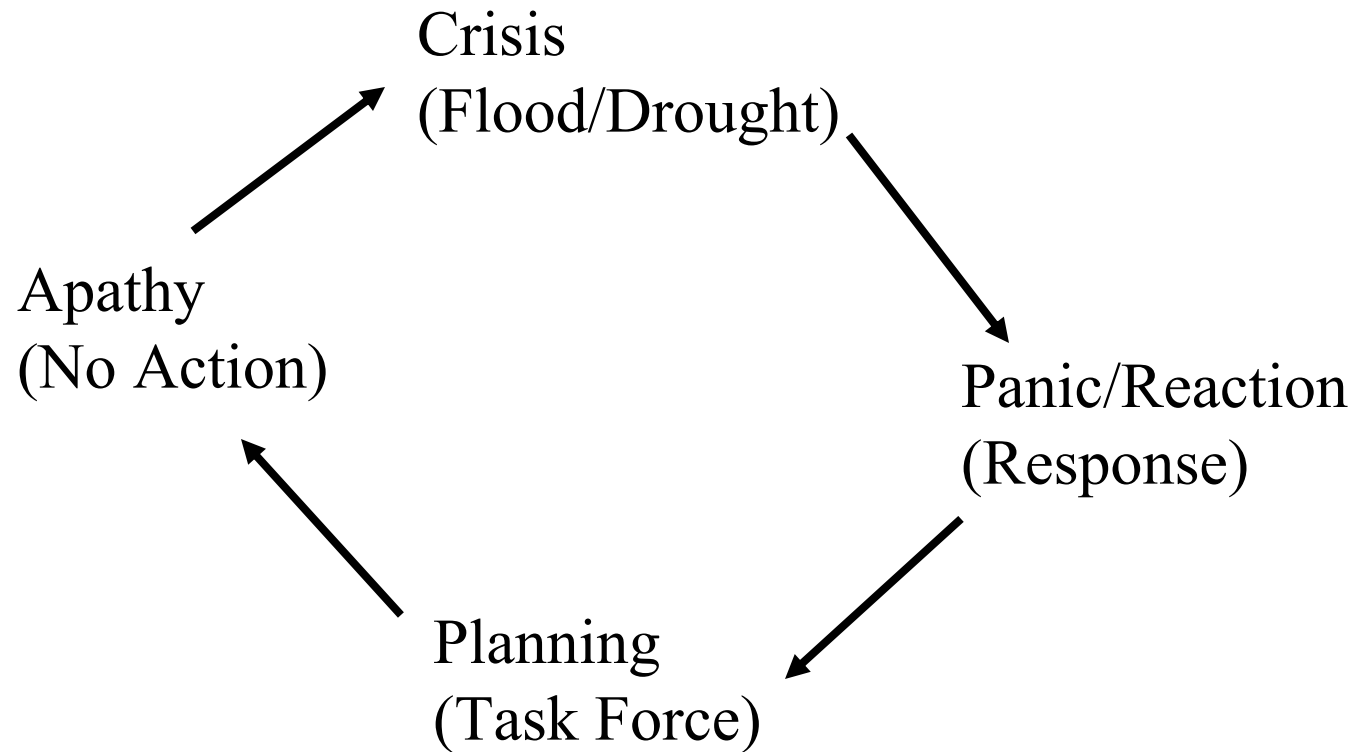
$$P = 28 \text{ in.}$$

$$R = 3 \text{ in.}$$

$$I = 4 \text{ in.}$$

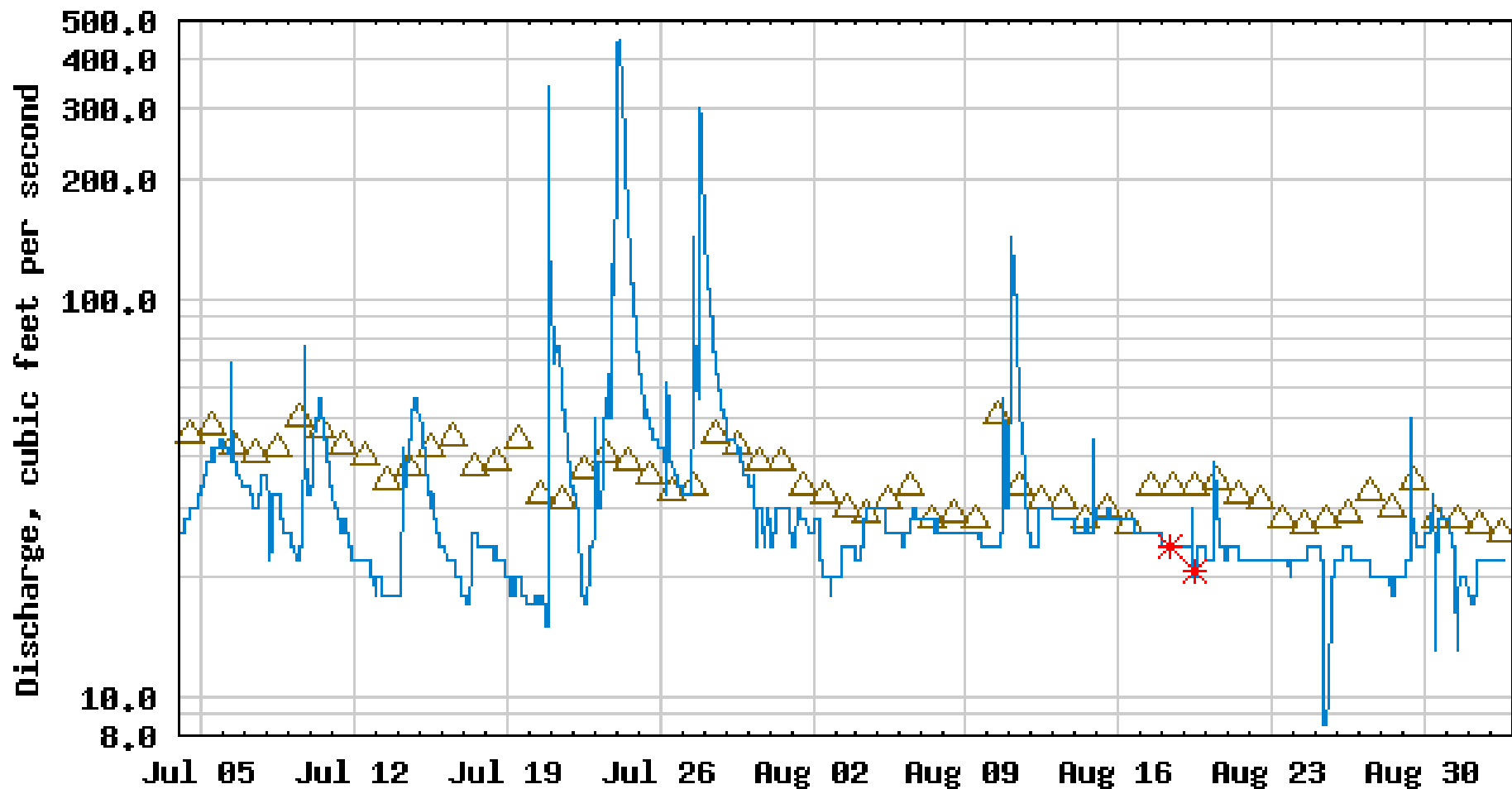
$$ET = 21 \text{ in.}$$

# Hydro-Illogical Cycle





## USGS 01478650 WHITE CLAY CREEK AT NEWARK, DE

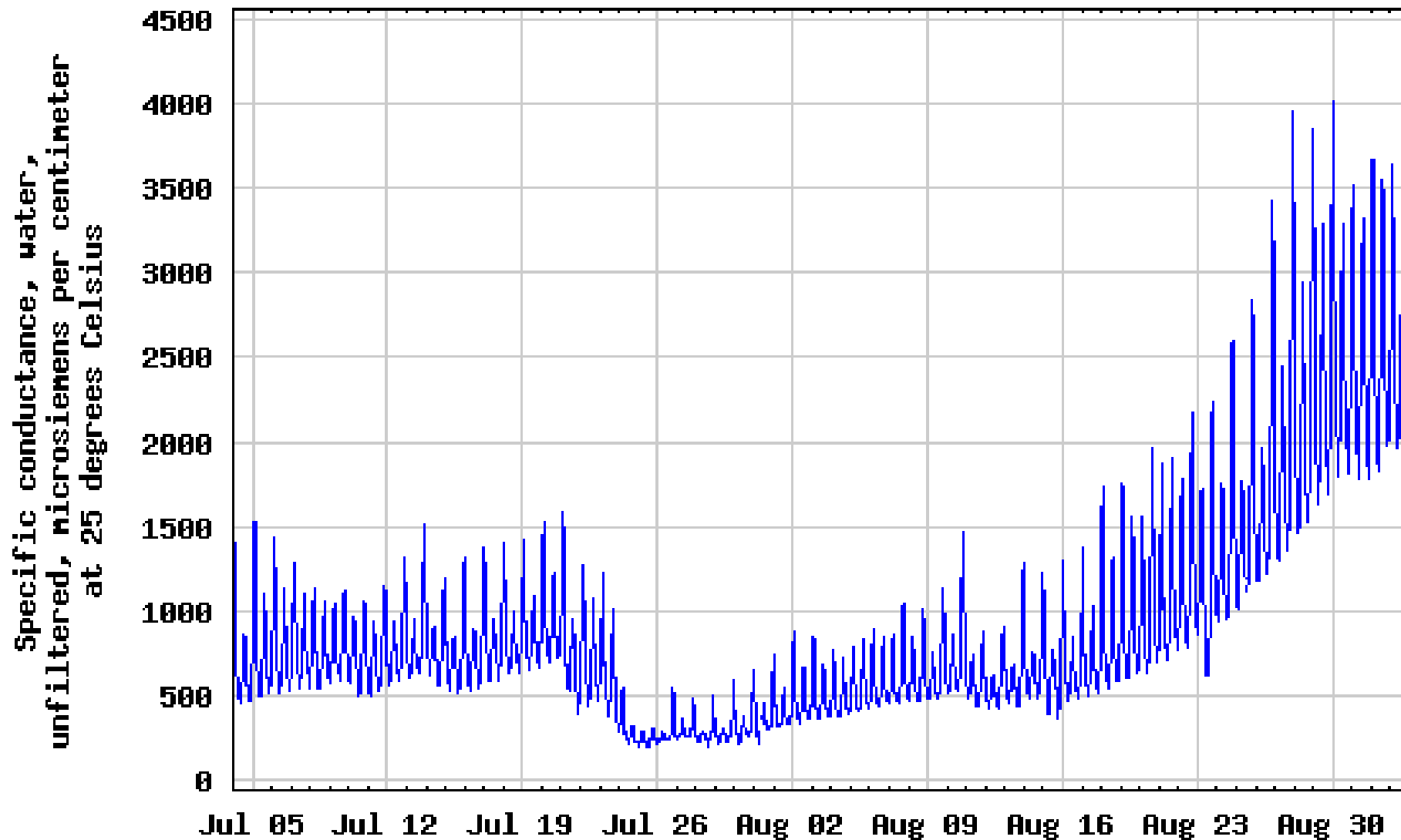


---- Provisional Data Subject to Revision ----

- △ Median daily statistic (14 years)
- \* Measured discharge
- Discharge

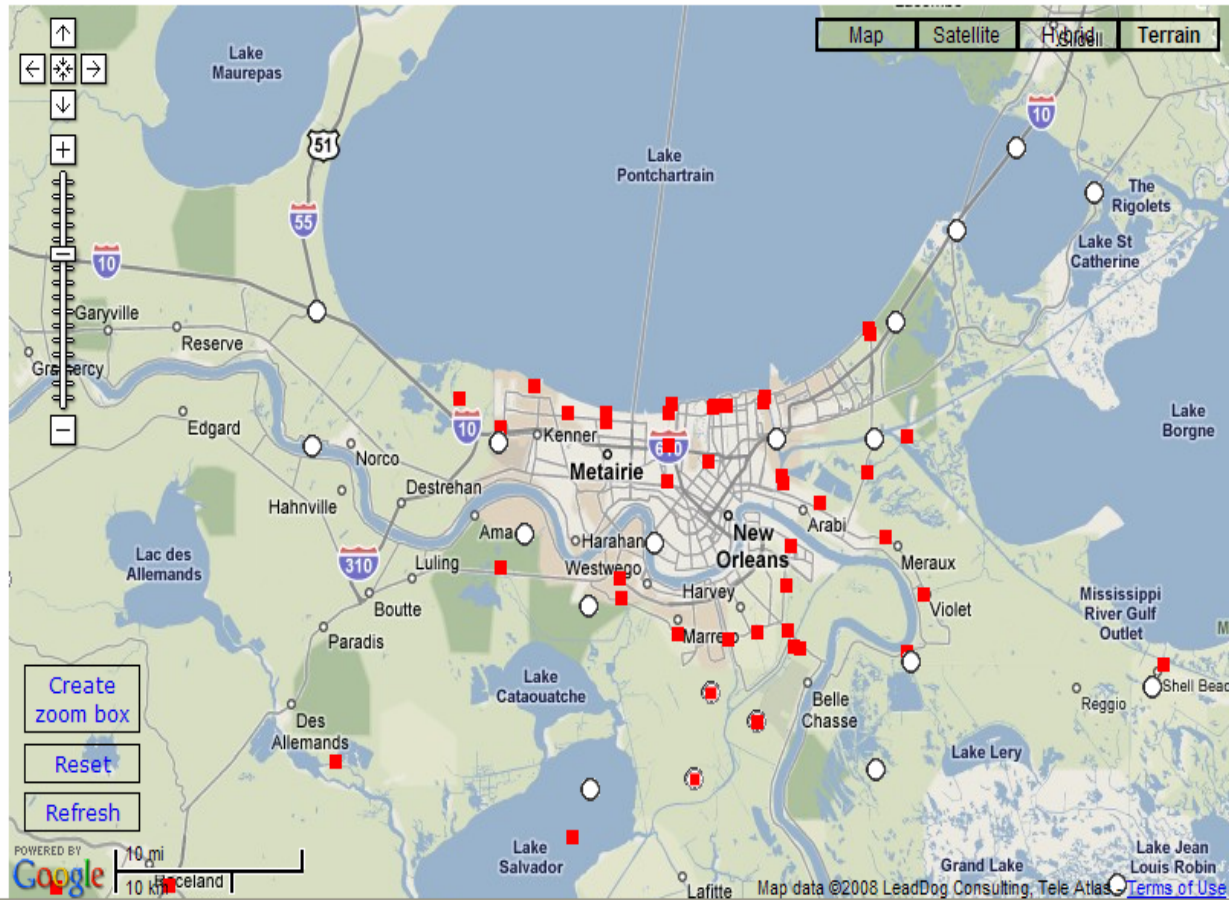


## USGS 01480065 CHRISTINA RIVER AT NEWPORT, DE



---- Provisional Data Subject to Revision ----

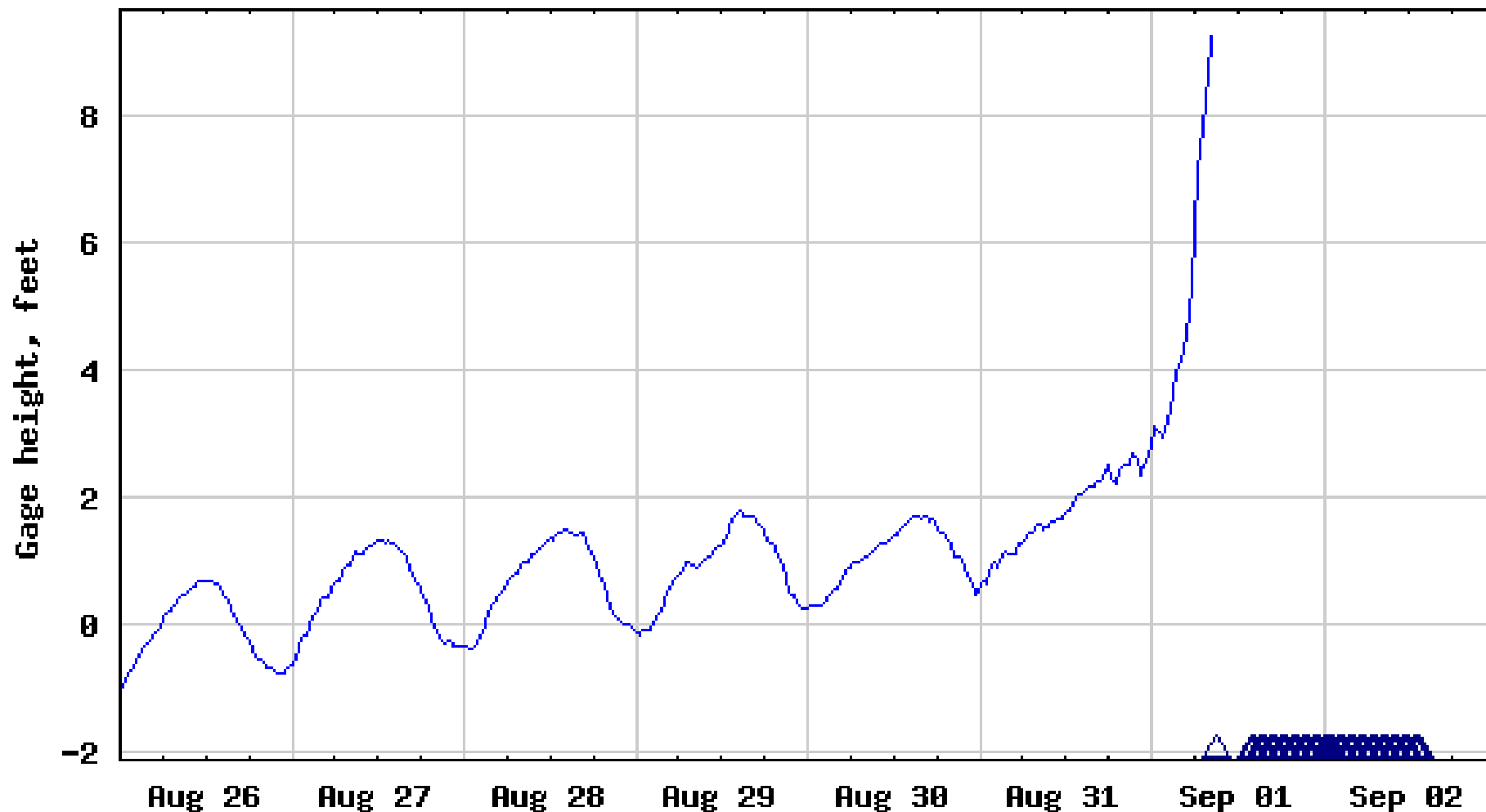
# WaterWatch -- Hurricane Gustav Hydrologic Impacts Map



Done



# USGS 0738023321 Industrial Canal at I-10 at New Orleans, LA



----- Provisional Data Subject to Revision -----

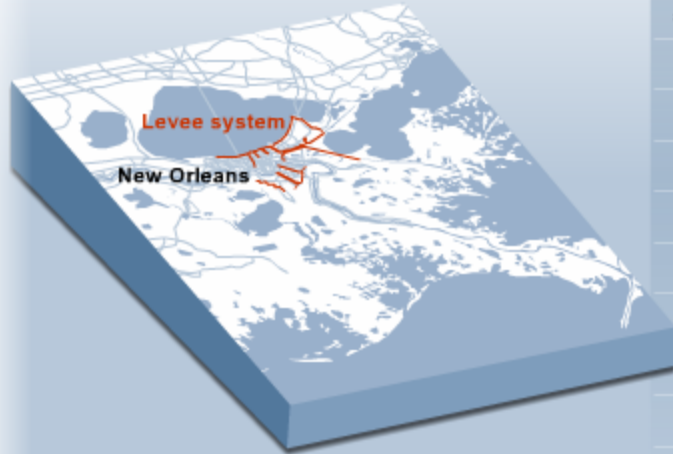
— Gage height

△ Flood damage

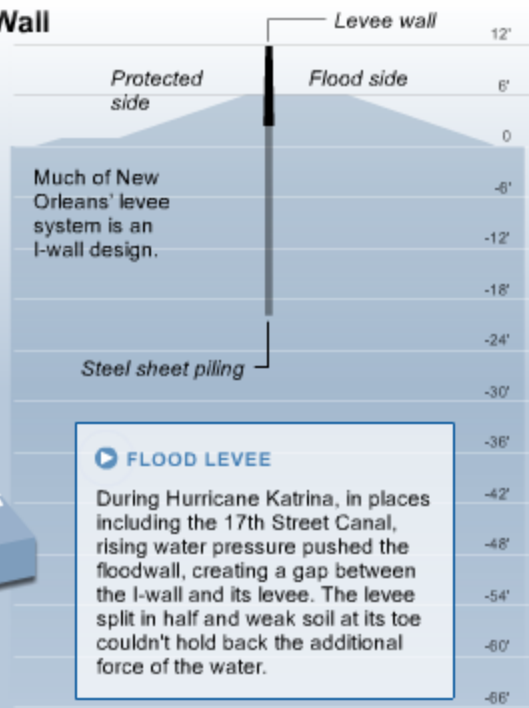


# I-Wall vs. T-Wall: design compared

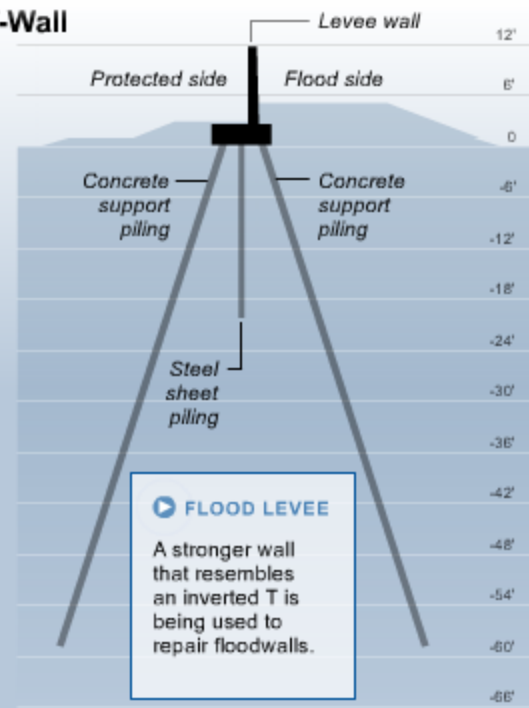
A multiagency report details what went wrong at more than 50 sites in the levee system that caused New Orleans to flood.



## I-Wall

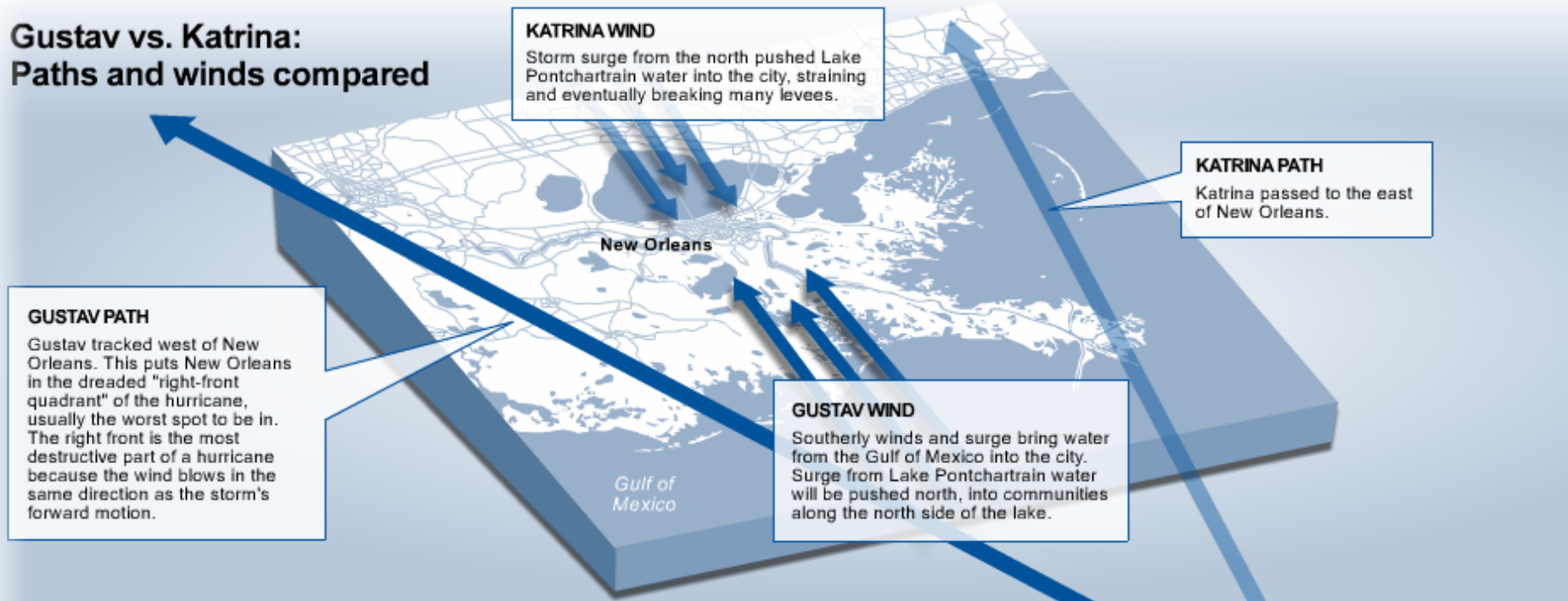


## T-Wall





## Gustav vs. Katrina: Paths and winds compared



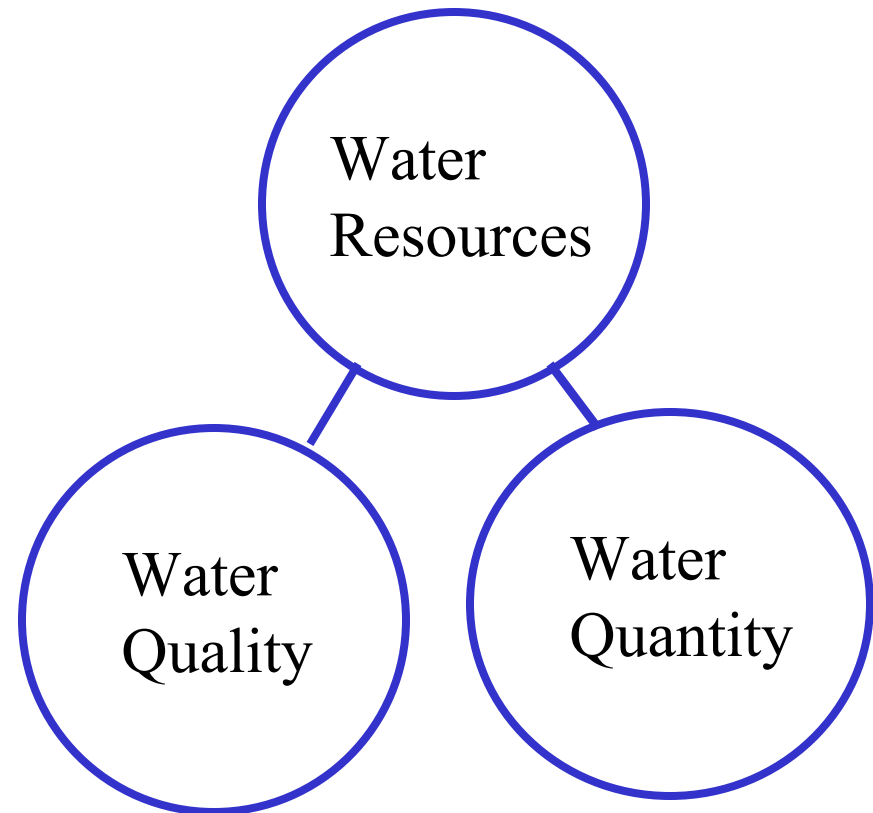
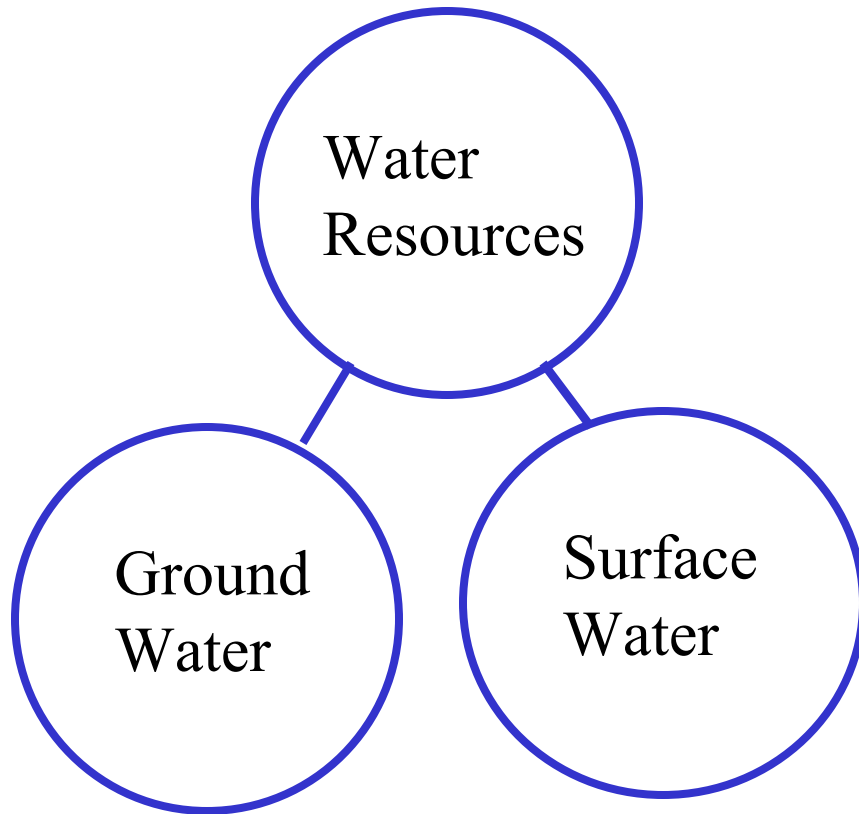
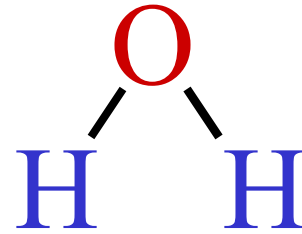
$$P = \gamma h$$

$\gamma$  = density of water (62.4 pcf)  
 $h$  = depth (ft)

$$H = UF^{0.5}/1760$$

$H$  = wave height (m)  
 $F$  = wind fetch (m)  
 $U$  = wind speed (m/s)

$$F_x = \gamma h^2/2$$



# The Origins of Watersheds

- **Derivation** - from *wasserscheide*, German for “water parting”
- **Definition** - The region draining into a river, lake or body of water (American Heritage)
- **Delineation** - John Wesley Powell lost job at USGS for proposed link between political jurisdictions and watersheds (1878).

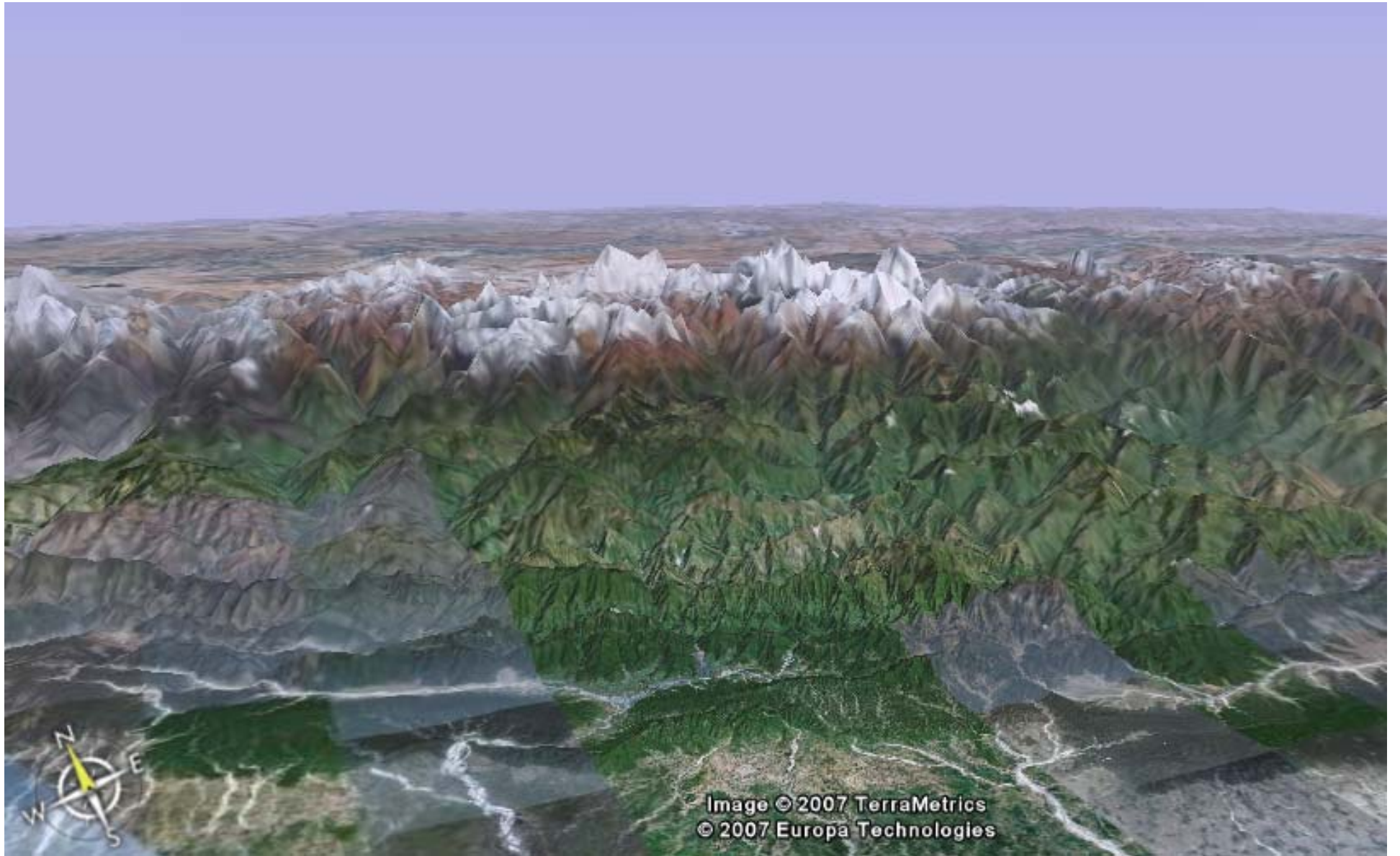


Image © 2007 TerraMetrics  
© 2007 Europa Technologies





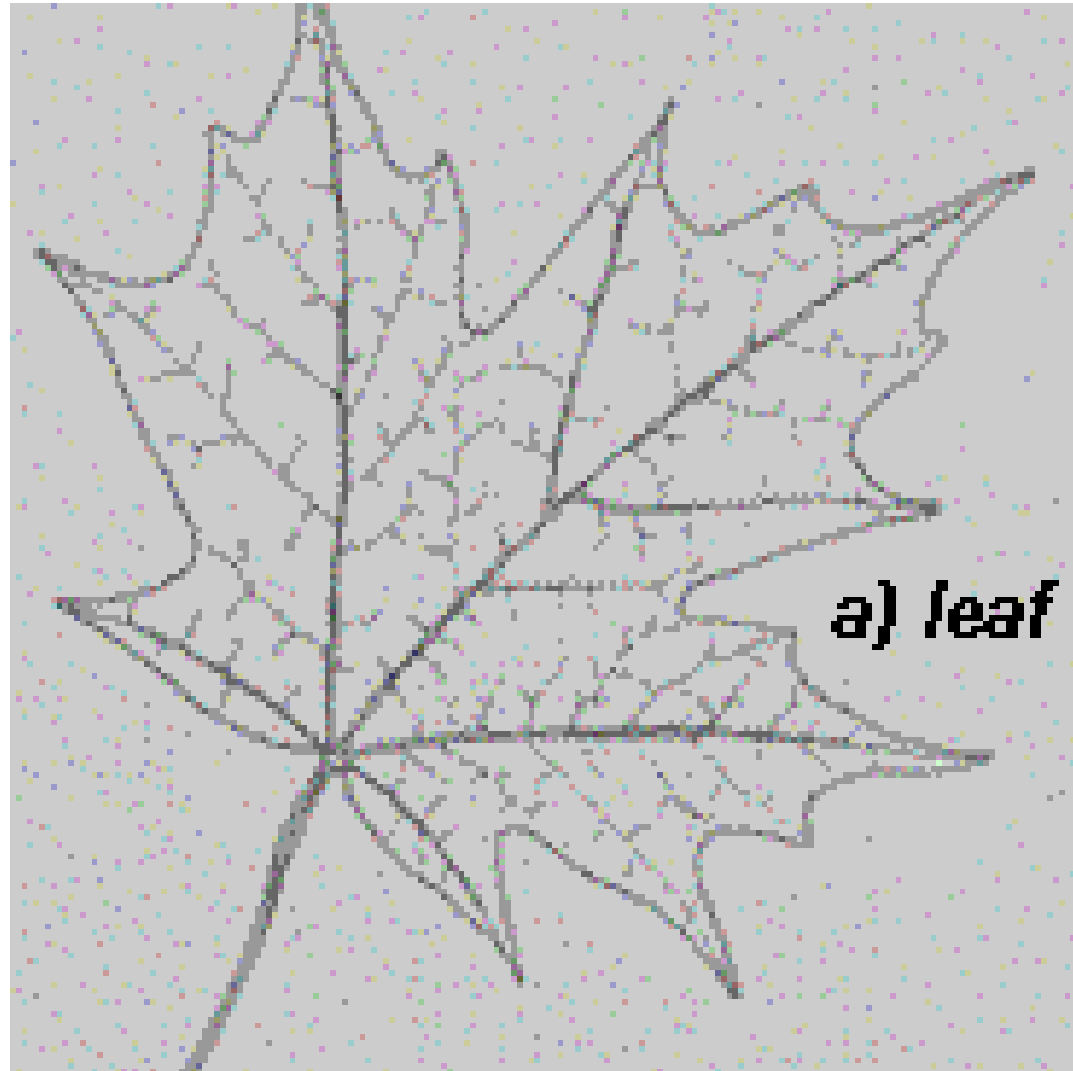
Image © 2007 TerraMetrics  
Image © 2007 State of New Jersey

© 2005 Google

Pointer 39°41'01.69" N 75°44'56.03" W elev 118 ft

Streaming ||||| 100%

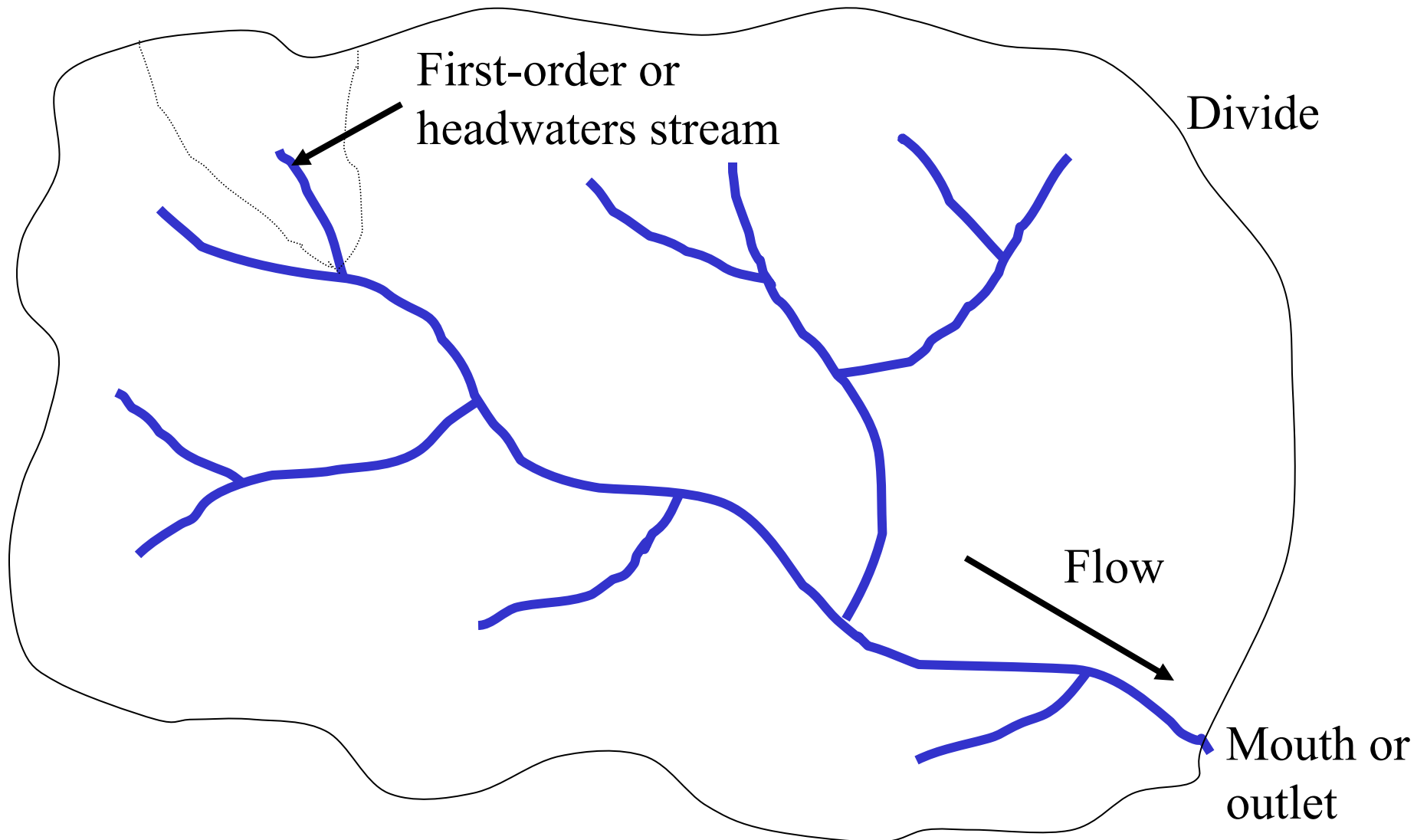
Eye alt 2161 f





# A Drainage Network

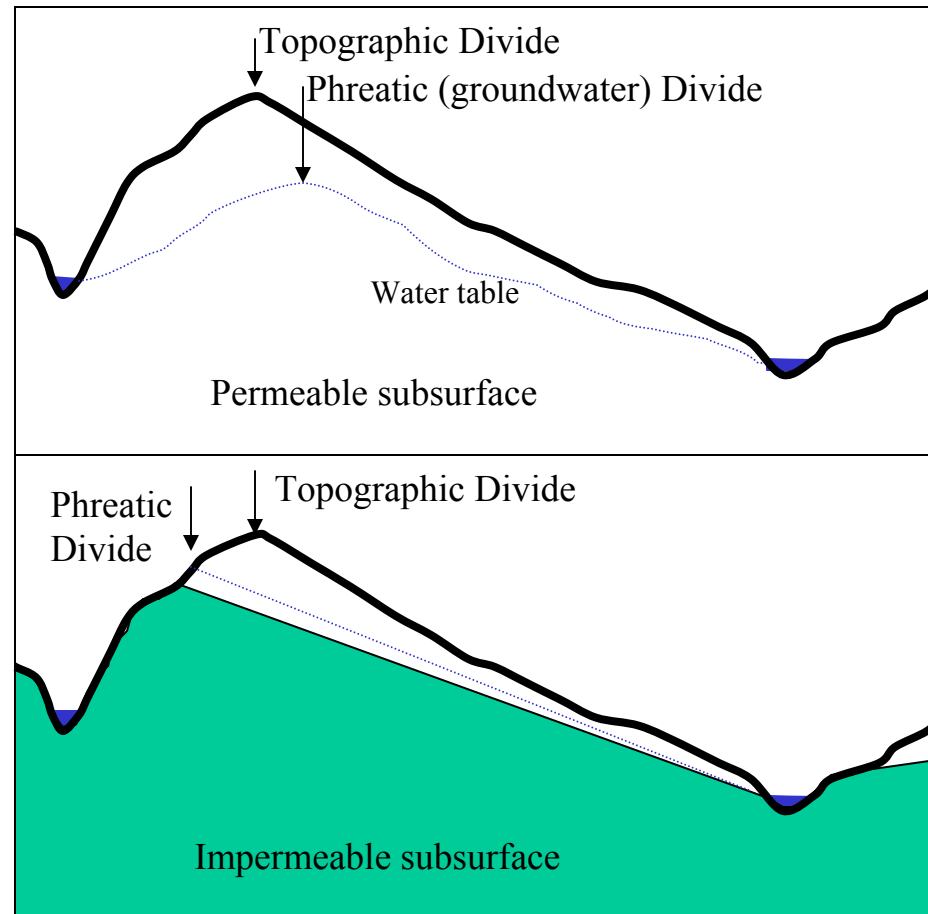
Streams and rivers form a network of channels connecting down from the headwaters to the mouth or outlet of the watershed.



# Different Divides

Caution: there are both surface (topographic) and sub-surface (phreatic or hydrogeological) divides. The latter may change seasonally.

Mapped using  
stereo air photos  
or contour maps.



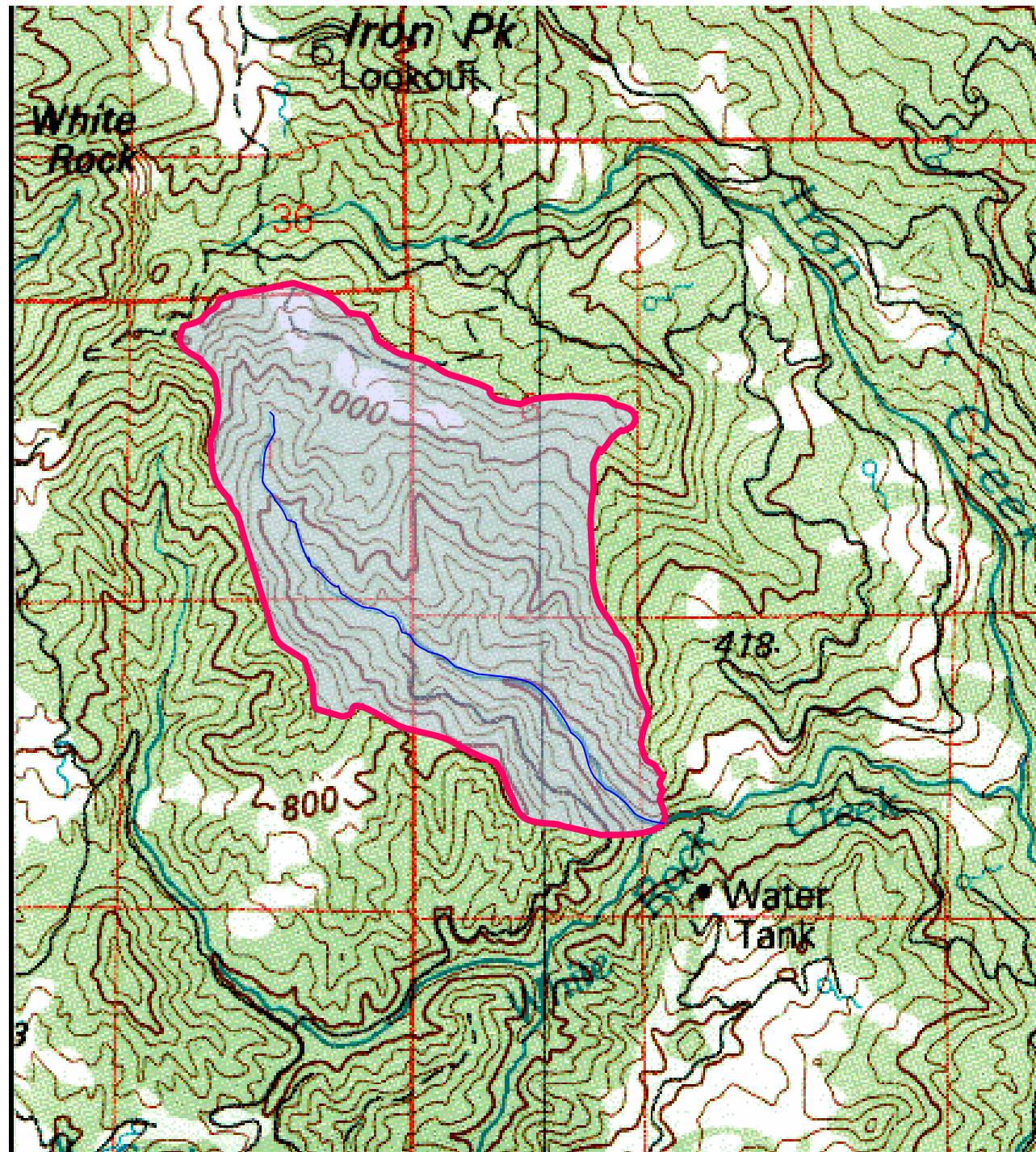
Mapped using  
geological tech,  
such as structural  
mapping, tracers,  
test drilling, etc.

# Identifying A Watershed

Un-named  
Tributary of  
White Rock Creek

COMPLETED  
EXERCISE

Source:  
Iron Peak  
Eel River  
from  
Outdoors on Disk  
CD Rom



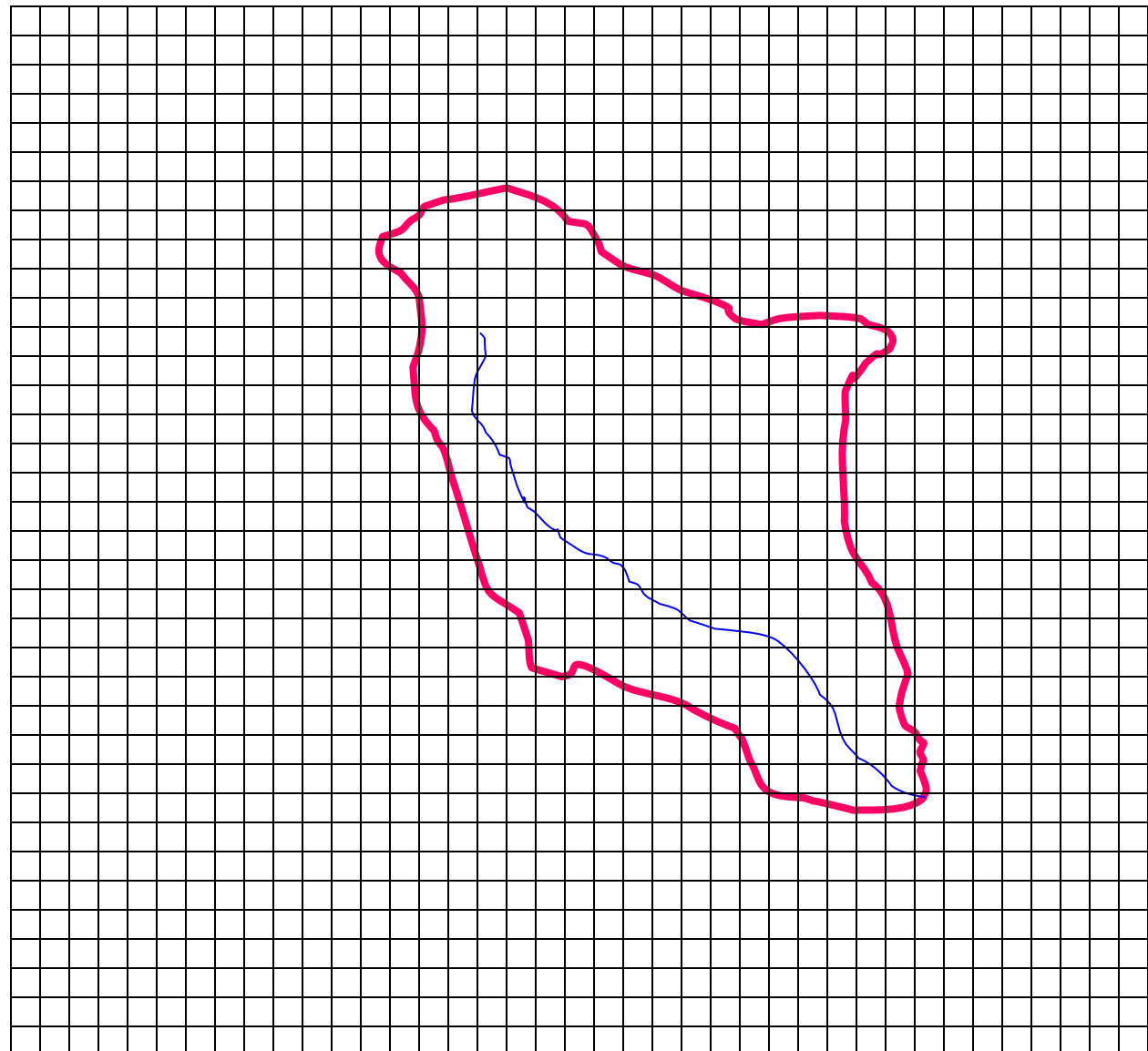
## Identifying A Watershed

Area =  $N * k^2$  where  $N$  = number of squares and  
 $k$  = length of square (e.g. if 1:250,000 Scale,  
1mm square has a  $k$  of 250m)

Un-named  
Tributary of  
White Rock Creek

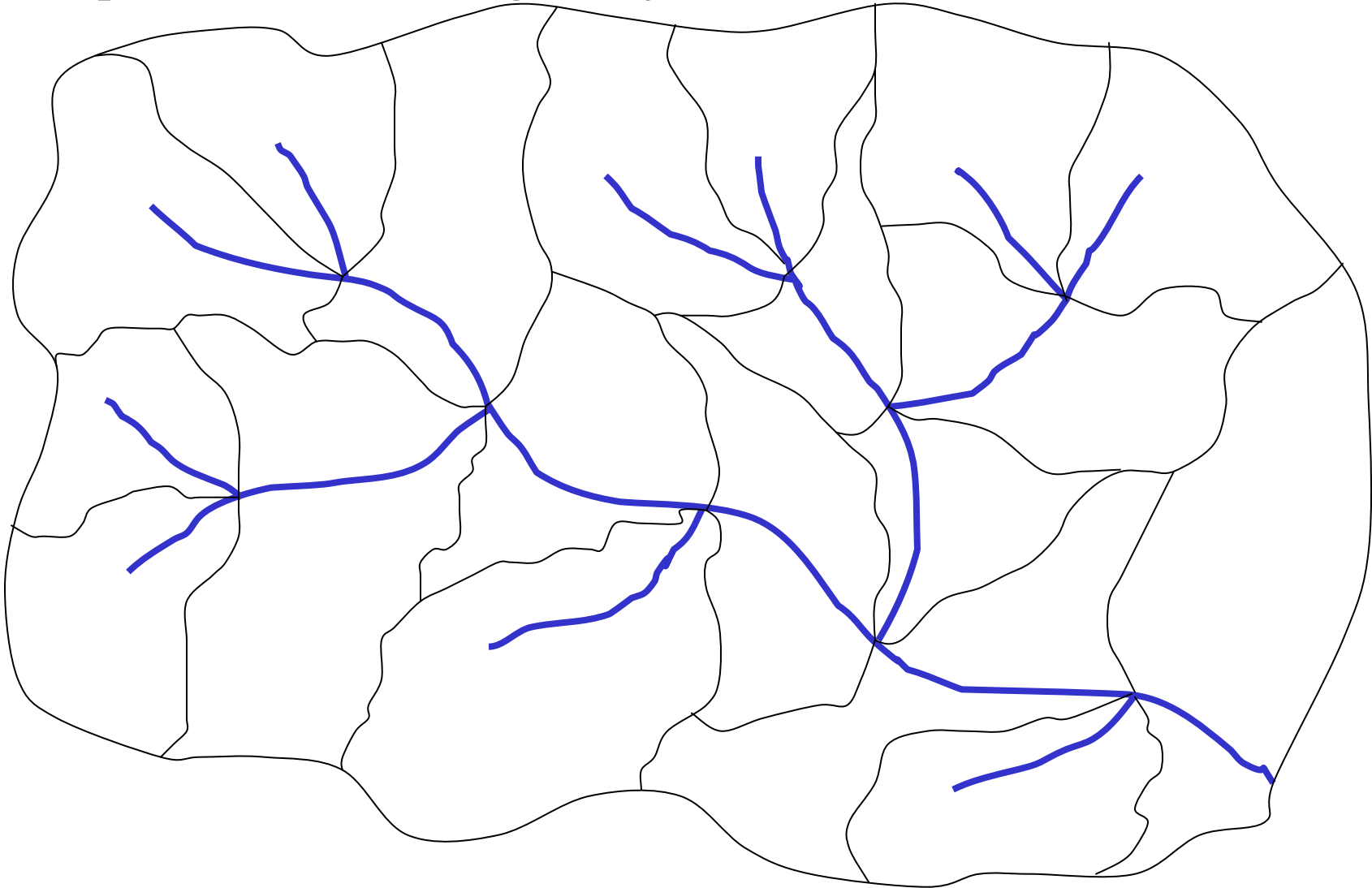
COUNT NO.  
SQUARES  
WITHIN  
WATERSHED

Source:  
Iron Peak  
Eel River  
from  
Outdoors on Disk  
CD Rom



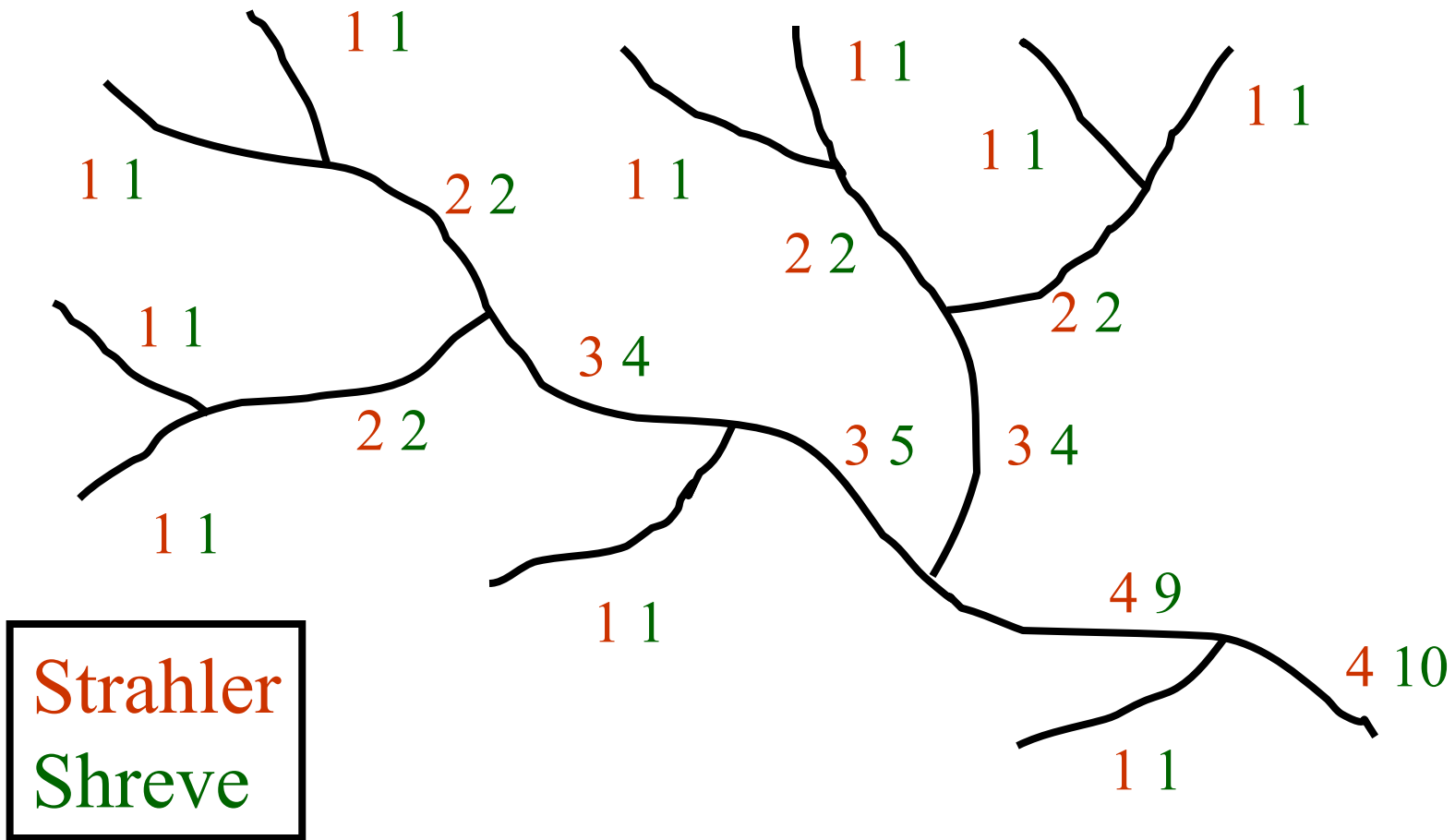
# Sub-watershed Ordering

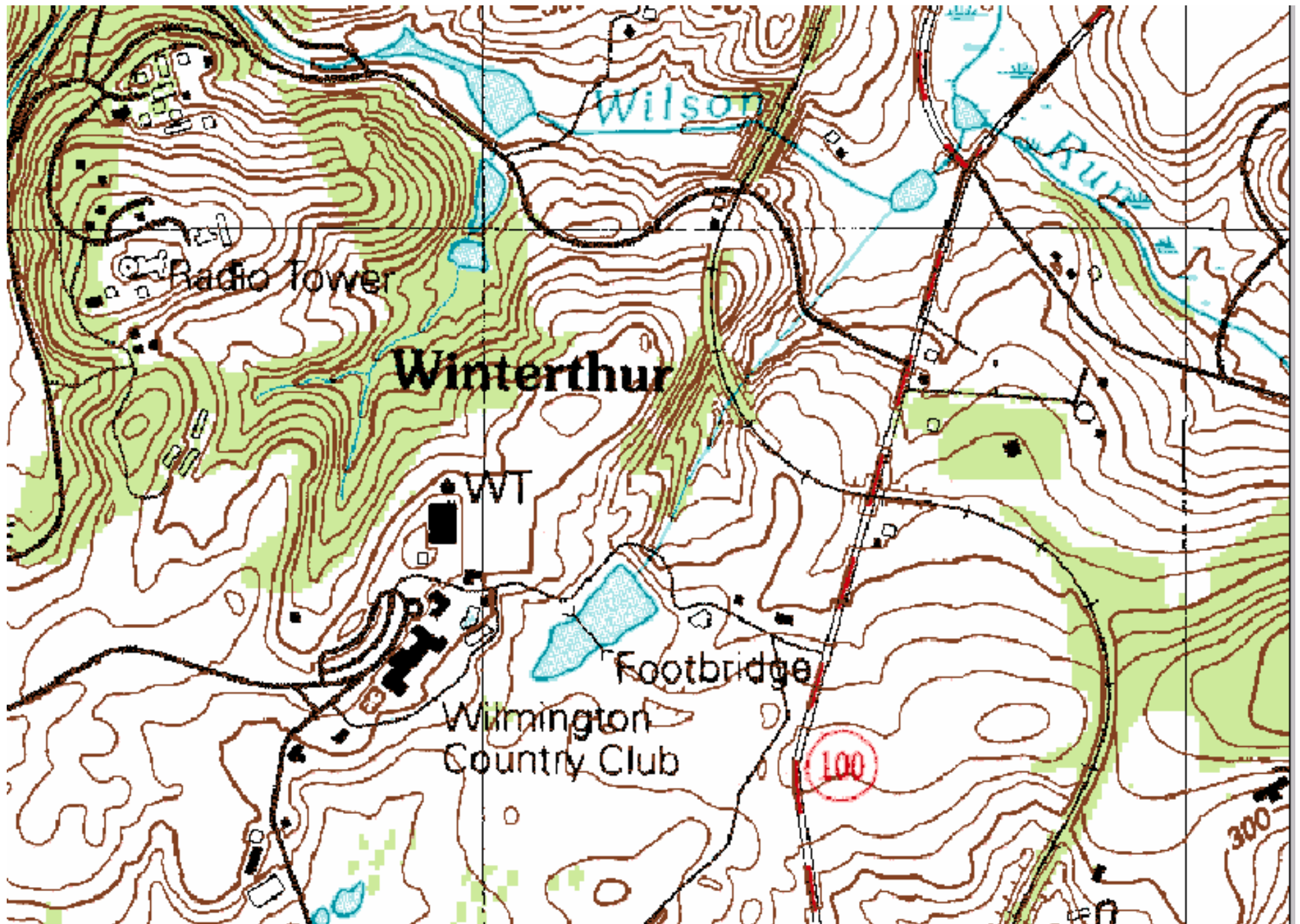
At each confluence (bifurcation), specific contributing areas can be identified (sub-watersheds) from which water will coalesce to that particular stream segment junction.



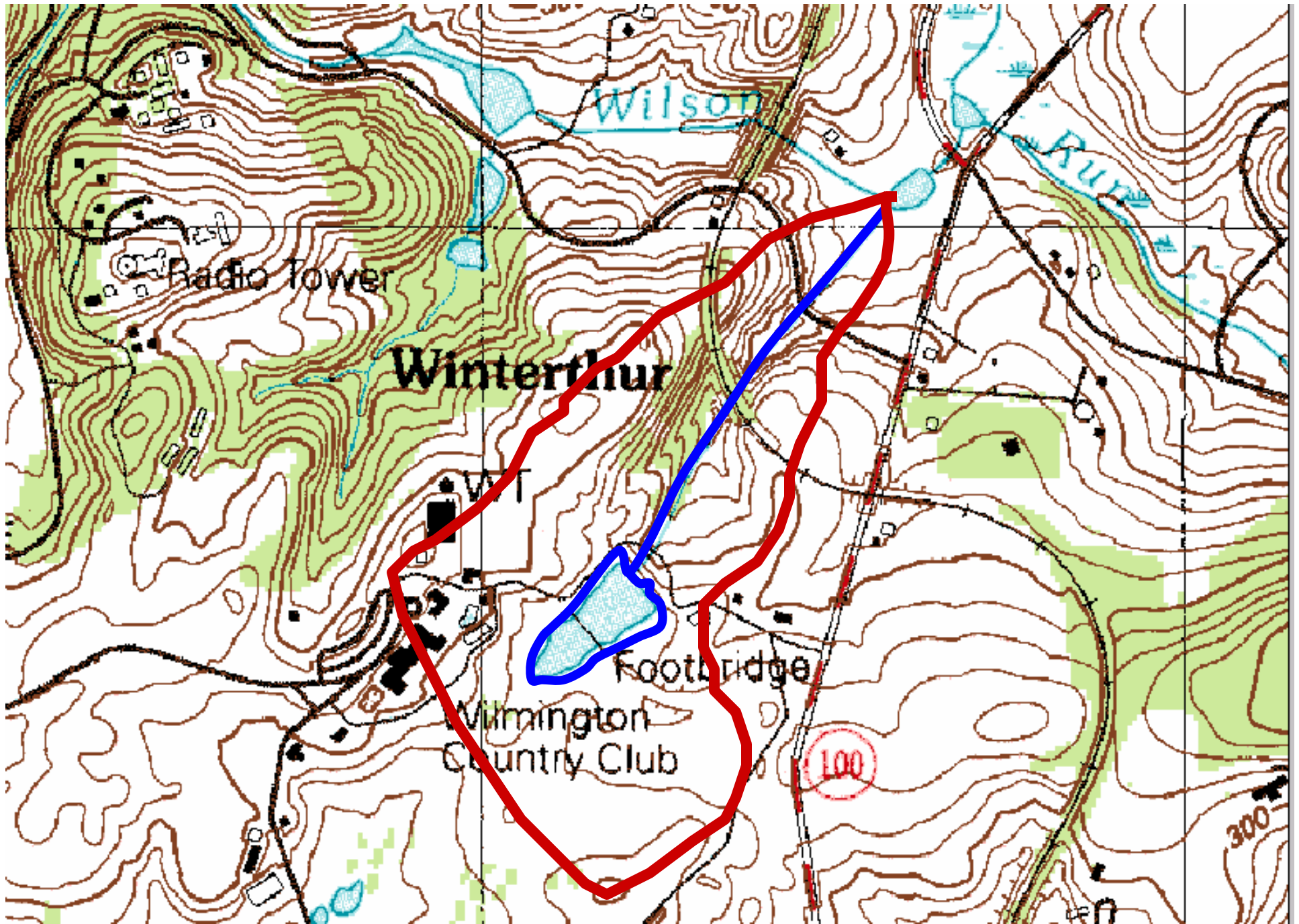
# Stream (sub-watershed) Ordering

A variety of different numbering techniques exist, each with merits and de-merits, the two most widely-adopted being:

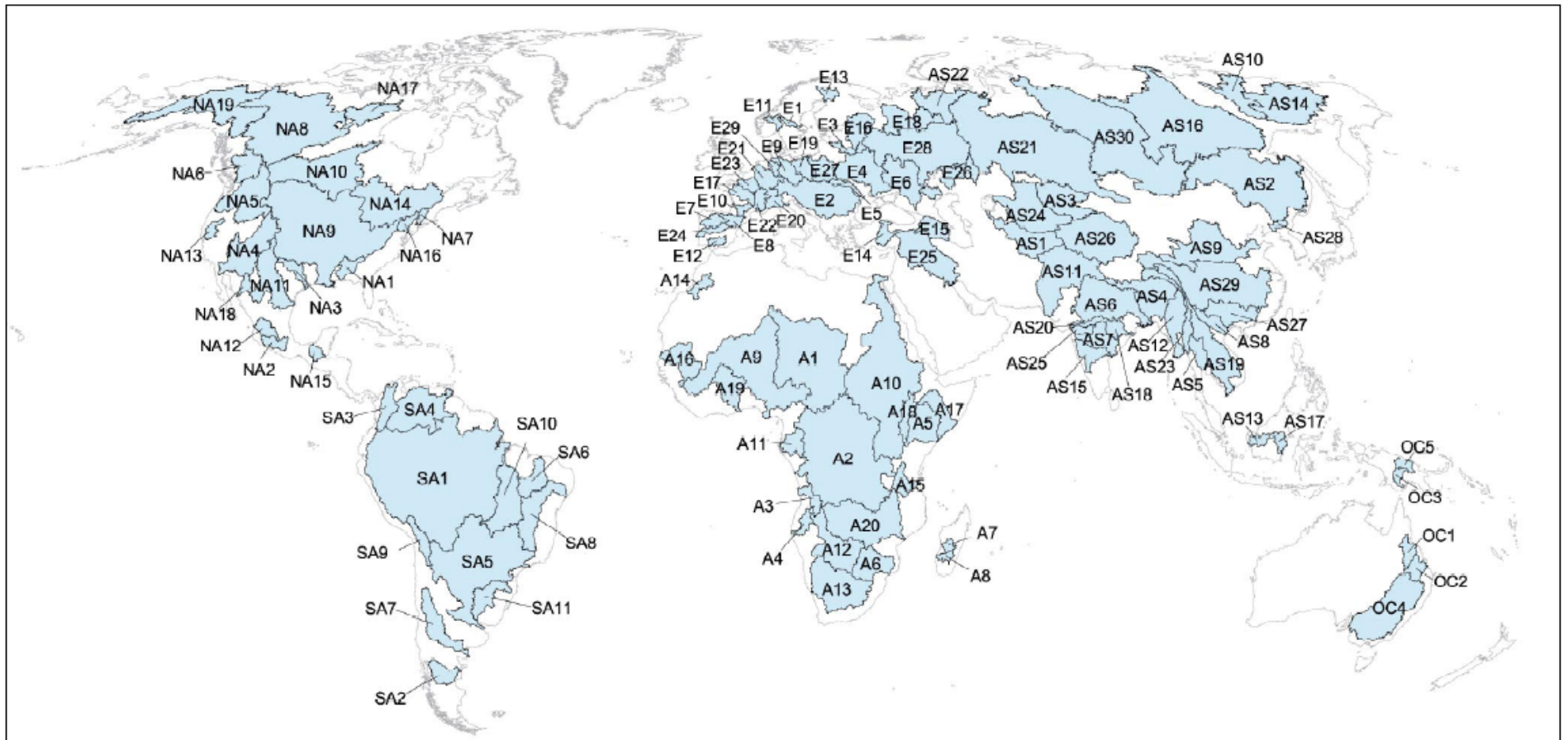












**Africa**

A01 Lake Chad  
A02 Congo  
A03 Cuanza  
A04 Cunene  
A05 Jubba  
A06 Limpopo  
A07 Mangoky  
A08 Mania  
A09 Niger  
A10 Nile  
A11 Ogooue  
A12 Okavango  
A13 Orange  
A14 Oued Draa  
A15 Rufiji  
A16 Senegal  
A17 Shaballe  
A18 Turkana  
A19 Volta  
A20 Zambezi

**Europe**

E01 Dalalven  
E02 Danube  
E03 Daugava  
E04 Dnieper  
E05 Dniester (Nistru)  
E06 Don  
E07 Duero  
E08 Ebro  
E09 Elbe  
E10 Garonne  
E11 Glomma-Laagen  
E12 Guadalquivir  
E13 Kemijoki  
E14 Kizilirmak  
E15 Kura-Araks  
E16 Lake Ladoga  
E17 Loire  
E18 North Dvina  
E19 Oder  
E20 Po  
E21 Rhine & Maas  
E22 Rhone  
E23 Seine  
E24 Tagus  
E25 Tigris &  
Euphrates  
E26 Ural  
E27 Vistula  
E28 Volga  
E29 Weser

**Asia**

AS01 Amu Darya  
AS02 Amur  
AS03 Lake Balkhash  
AS04 Brahmaputra  
AS05 Chao Phraya  
AS06 Ganges  
AS07 Godavari  
AS08 Hong  
(Red River)  
AS09 Huang He  
(Yellow River)  
AS10 Indigirka  
AS11 Indus  
AS12 Irrawaddy  
AS13 Kapuas  
AS14 Kolyma  
AS15 Krishna  
AS16 Lena  
AS17 Mahakam  
AS18 Mahanadi  
AS19 Mekong  
AS20 Narmada  
AS21 Ob  
AS22 Pechora  
AS23 Salween  
AS24 Syr Darya  
AS25 Tapti  
AS26 Tarim  
AS27 Xun Jiang  
AS28 Yalu Jiang  
AS29 Yangtze  
AS30 Yenisey

**North & Central America**

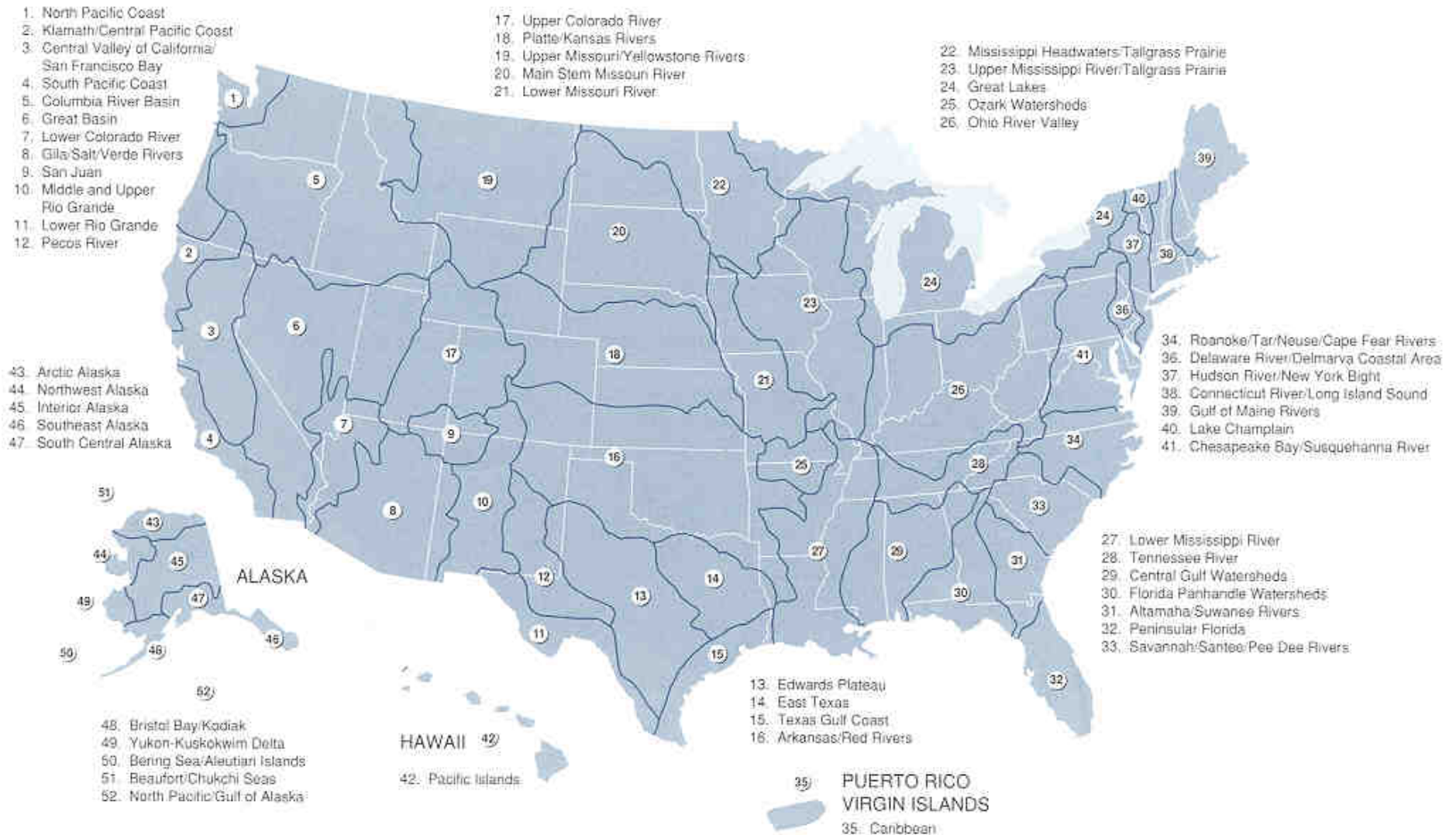
NA01 Alabama & Tombigbee  
NA02 Balsas  
NA03 Brazos  
NA04 Colorado  
NA05 Columbia  
NA06 Fraser  
NA07 Hudson  
NA08 Mackenzie  
NA09 Mississippi  
NA10 Nelson  
NA11 Rio Grande  
NA12 Rio Grande de Santiago  
NA13 Sacramento  
NA14 Saint Lawrence  
NA15 San Pedro & Usumacinta  
NA16 Susquehanna  
NA17 Thelon  
NA18 Yaqui  
NA19 Yukon

**South America**

SA01 Amazon  
SA02 Chubut  
SA03 Magdalena  
SA04 Orinoco  
SA05 Parana  
SA06 Parnaiba  
SA07 Rio Colorado  
SA08 Sao Francisco  
SA09 Lake Titicaca &  
Salar de Uyuni  
SA10 Tocantins  
SA11 Uruguay

**Oceania**

OC01 Burdekin-Belyando  
OC02 Dawson  
OC03 Fly  
OC04 Murray-Darling  
OC05 Sepik



# The United Watersheds of America





# Welcome to the UNIVERSITY OF DELAWARE Rain Garden

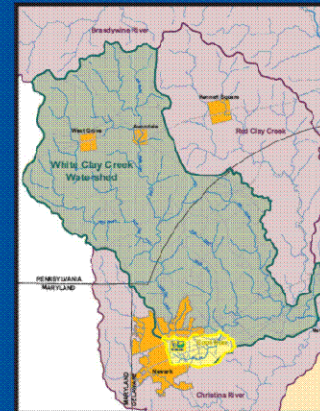
### Delaware River Basin



### Christina River Basin



### White Clay Creek Watershed



### Cool Run Watershed



### UD Rain Garden



The UD Rain Garden, although small in stature, is part of a complex watershed system, ranging in increasing scale from the small Cool Run tributary, to the White Clay Creek watershed, to the Christina Basin, and finally to the Delaware River Basin. The UD Rain Garden is situated in the headwaters of Cool Run, a small, ephemeral stream that flows south past the Perkins Student Center and then under the Amtrak railroad tracks to the UD Agricultural Farm on its way to join White Clay Creek. As the UD campus developed, the stream has been manipulated and rerouted, sometimes into an underground pipe, as illustrated by the dashed blue line.

White Clay Creek, Delaware's only National Wild and Scenic River, is the first to be designated on a watershed basis instead of a single-river-segment basis. The 108-square-mile White Clay Creek watershed is an important source of drinking water for Newark's residents and is one of only six trout streams in Delaware. It is one of the four major streams in a larger watershed called the Christina River Basin. The White Clay Creek and sister watersheds Brandywine Creek, Red Clay Creek, and Christina River originate upstream in Pennsylvania before flowing through New Castle County, Delaware, on their way to the Delaware River. The Christina River Basin is, in turn, part of a larger watershed, the five-state Delaware River Basin, which includes parts of Maryland, Delaware, New Jersey, New York, and Pennsylvania.

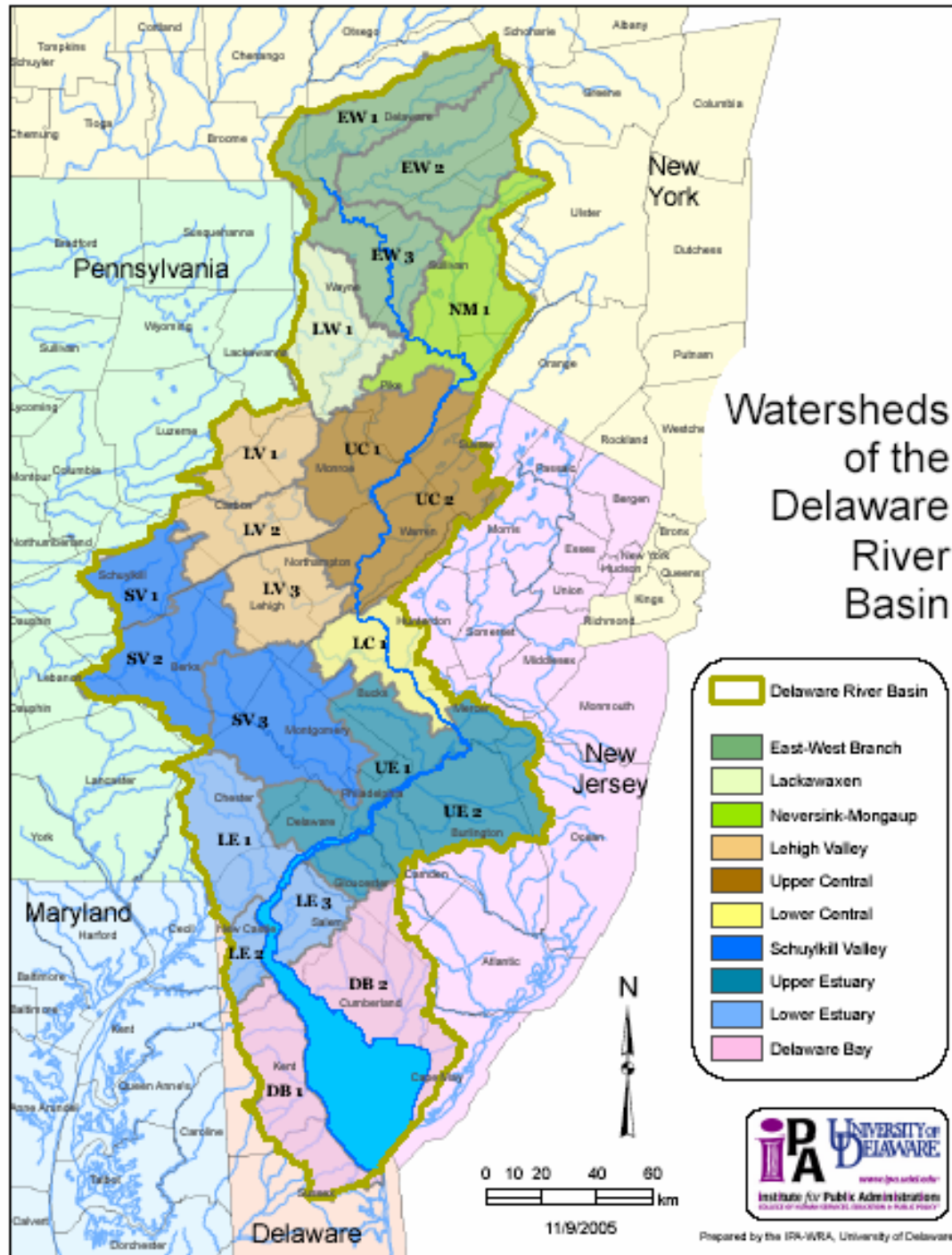
## Delaware River Basin



“Watersheds form the natural hydrogeological planning units for water, land, and ecosystems management”.

“Watersheds know no political boundaries”.



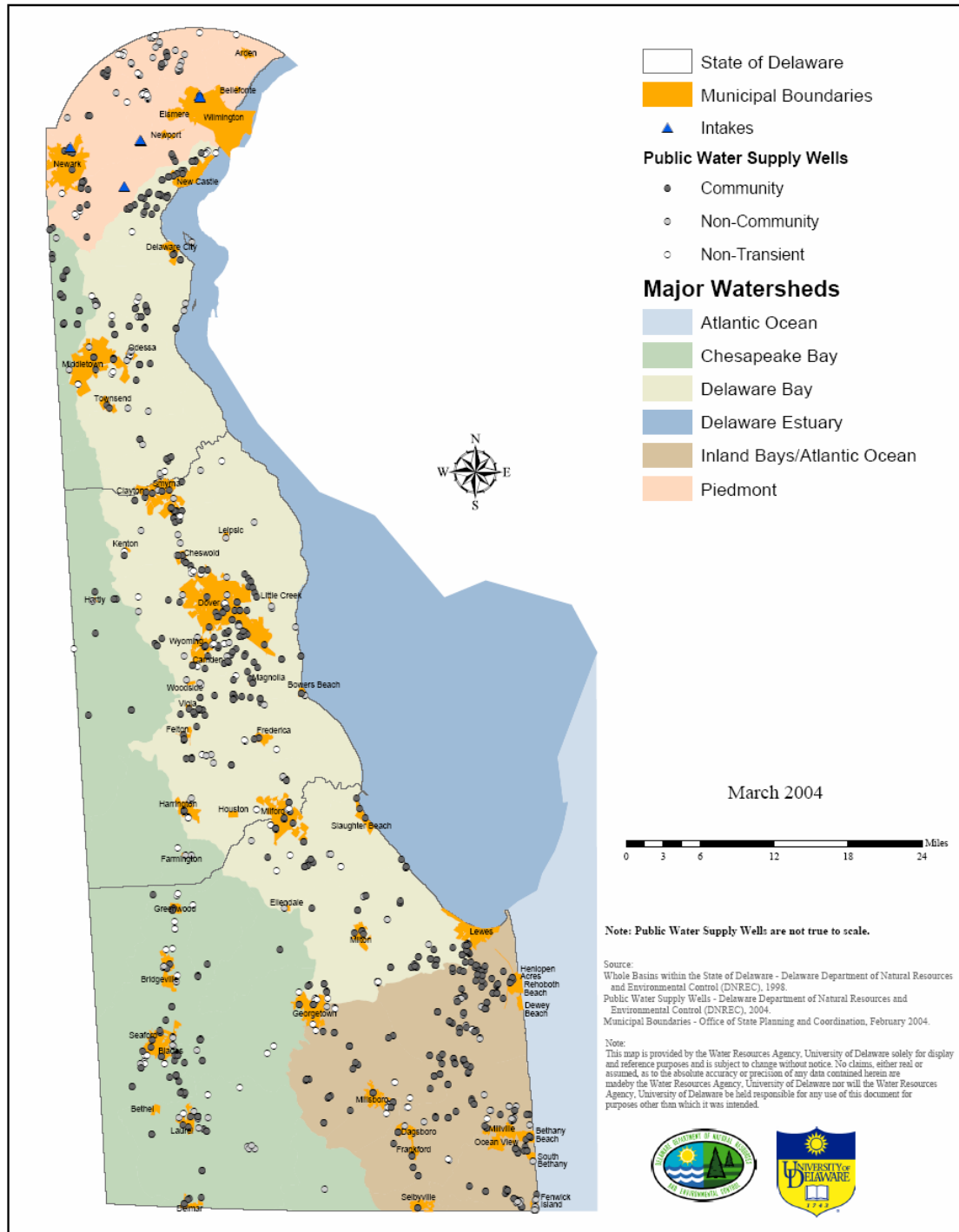


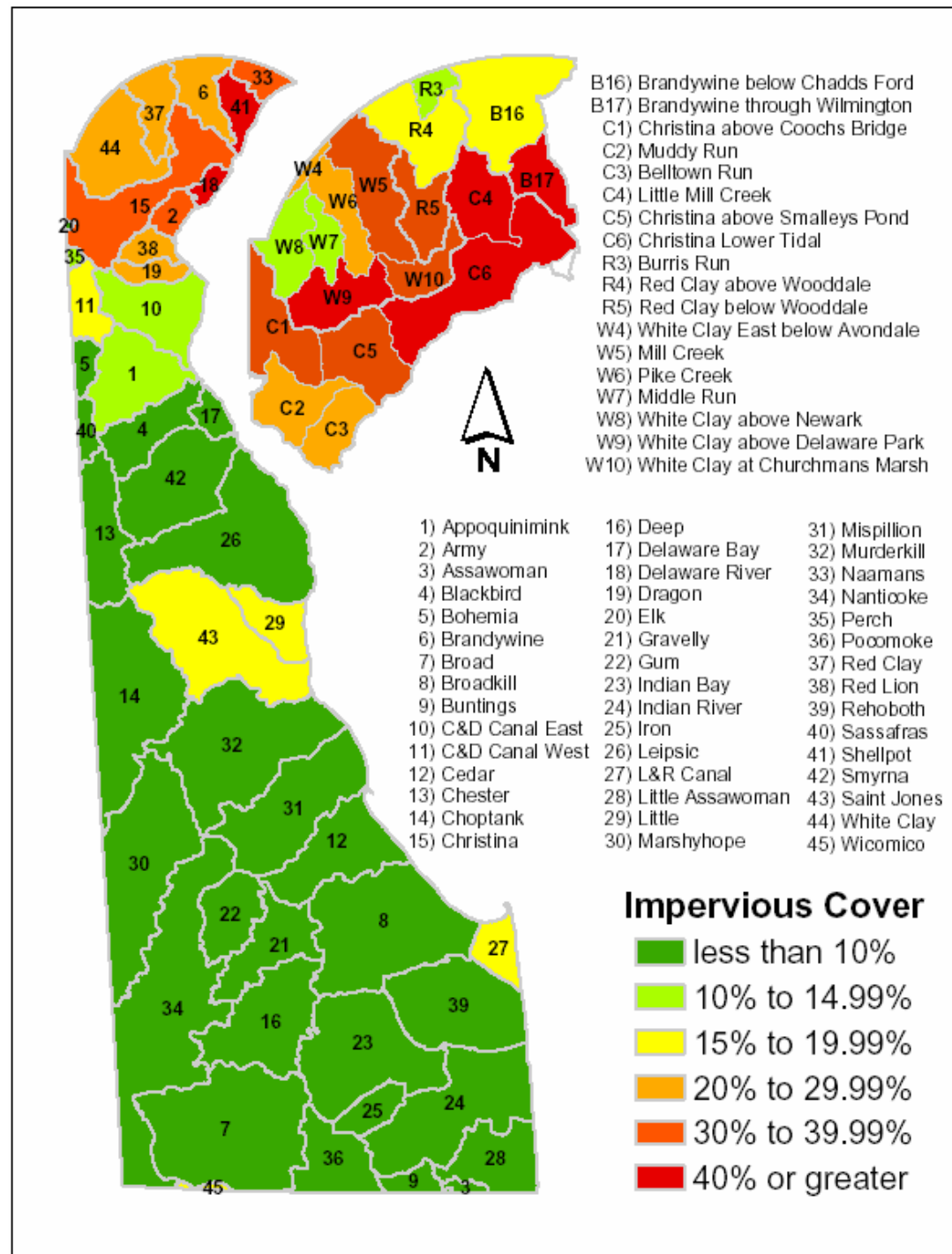
# Watersheds of the Delaware River Basin

- Delaware River Basin
- East-West Branch
- Lackawaxen
- Neversink-Mongaup
- Lehigh Valley
- Upper Central
- Lower Central
- Schuykill Valley
- Upper Estuary
- Lower Estuary
- Delaware Bay



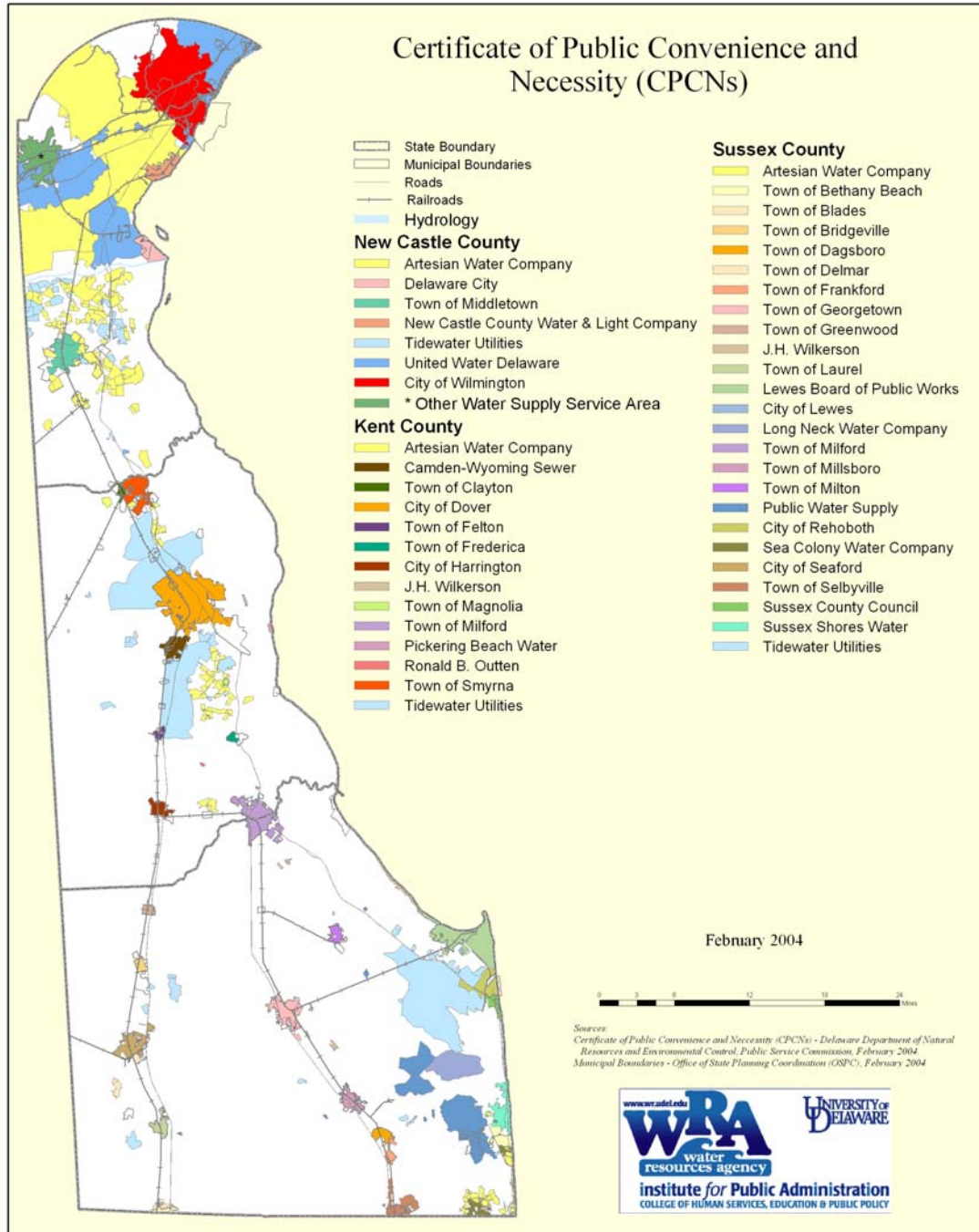
Prepared by the IRA-WRA, University of Delaware



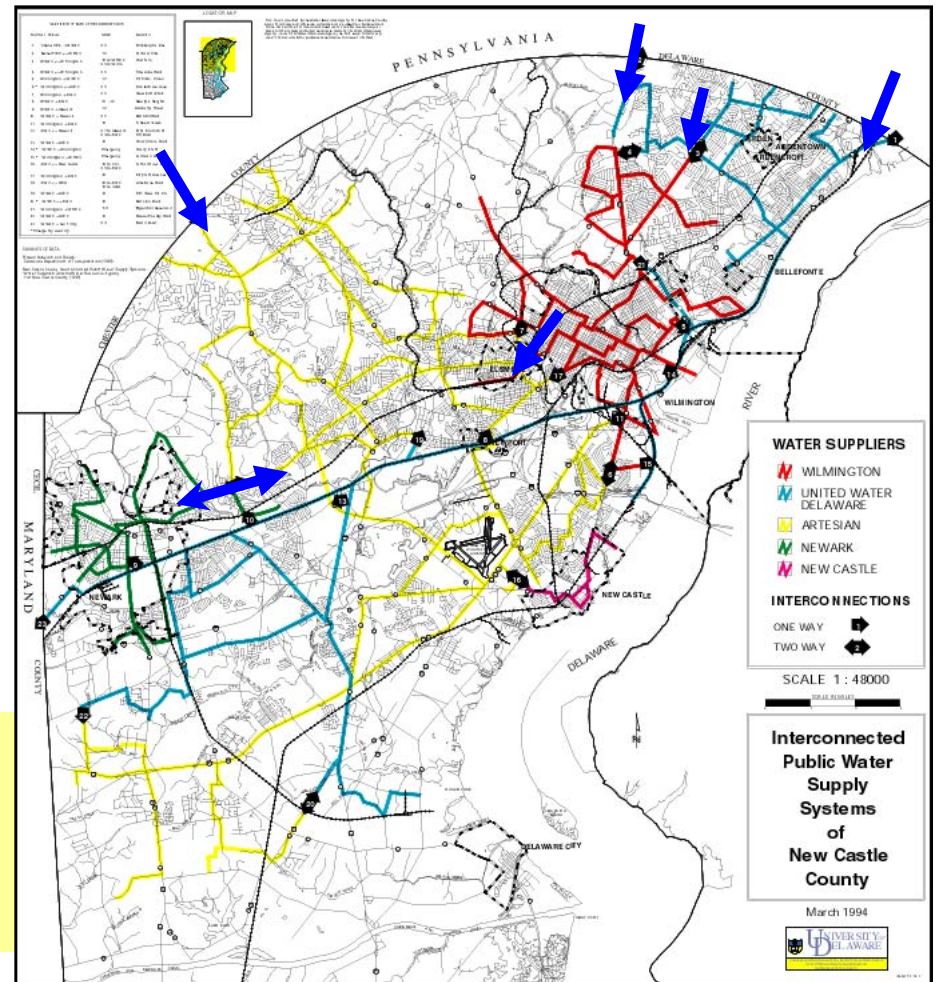
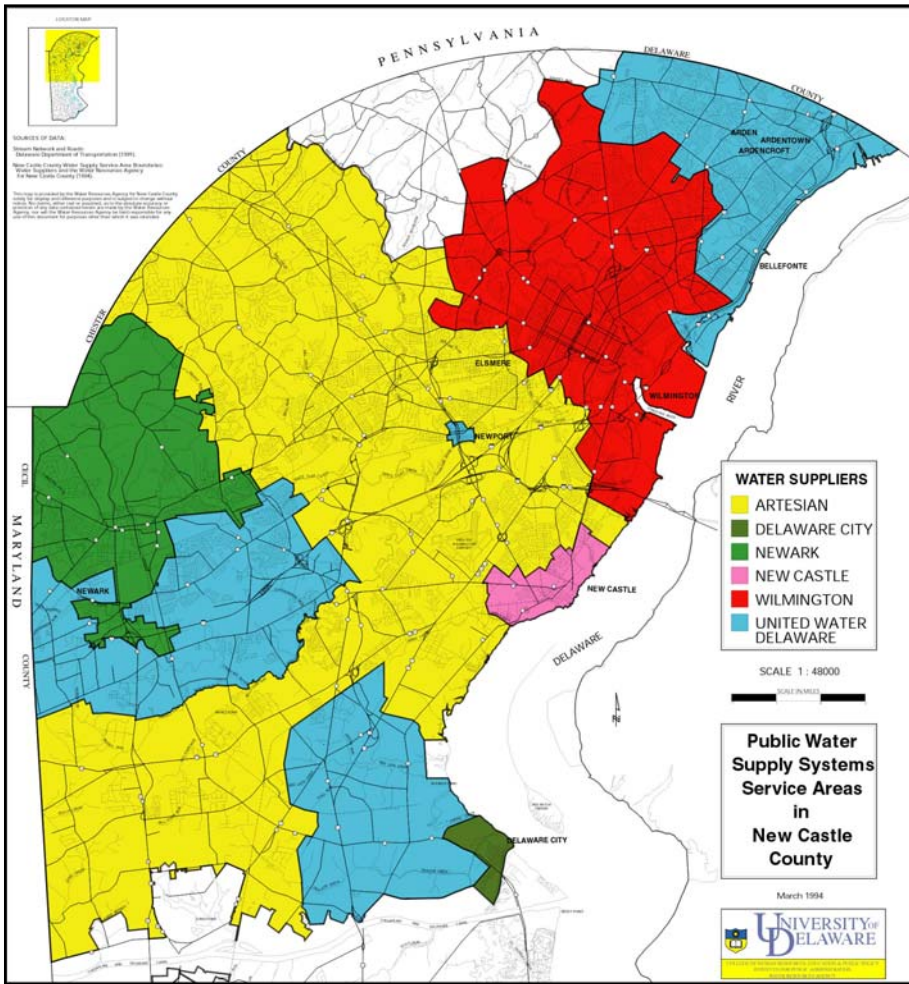




# Certificate of Public Convenience and Necessity (CPCNs)



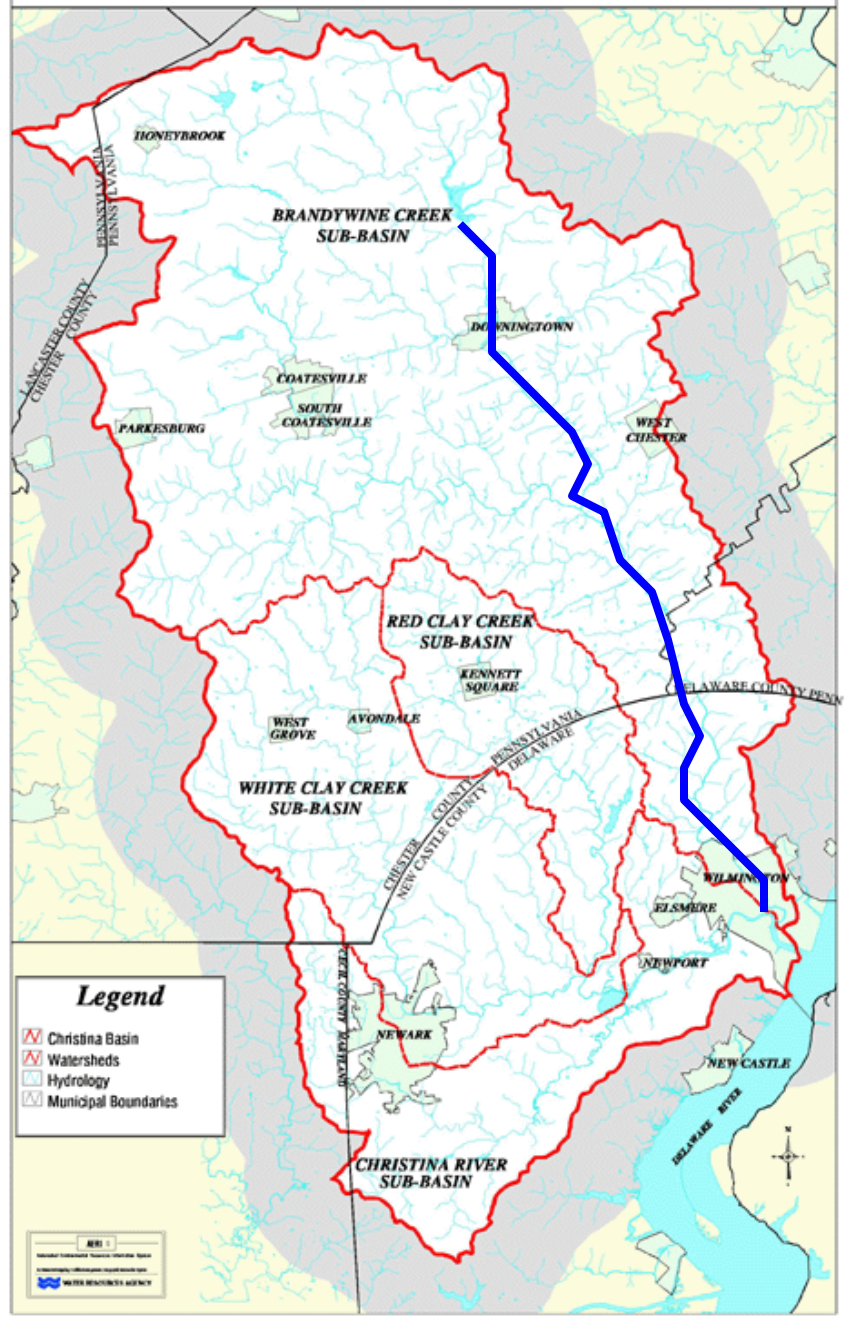
# New Castle County Public Water Supply System Service Areas



# New Castle County Public Water Supply System Interconnections



# Christina Basin Water Quality Management Strategy *Base Map*

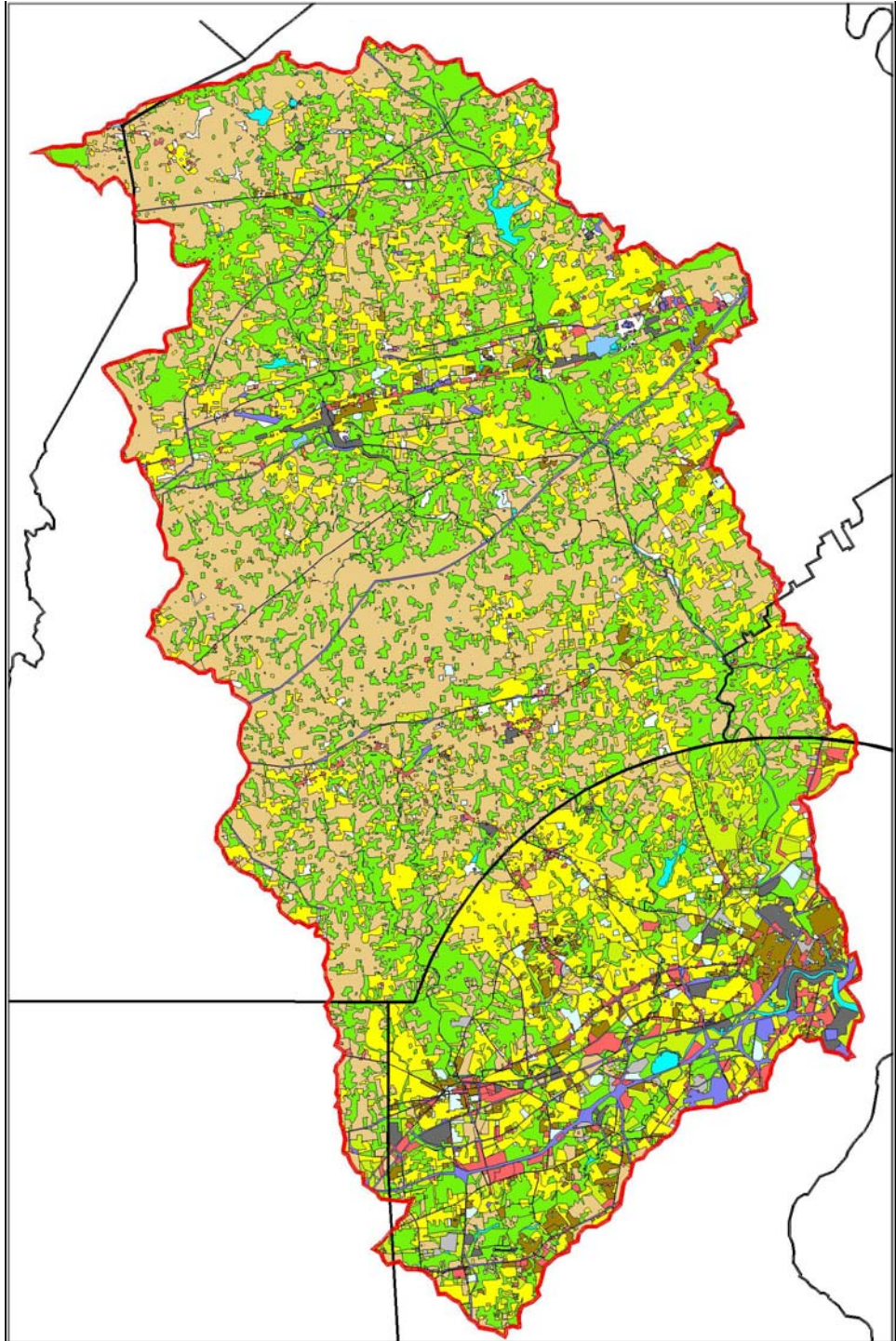


a Basin



Newark Reservoir September 2003





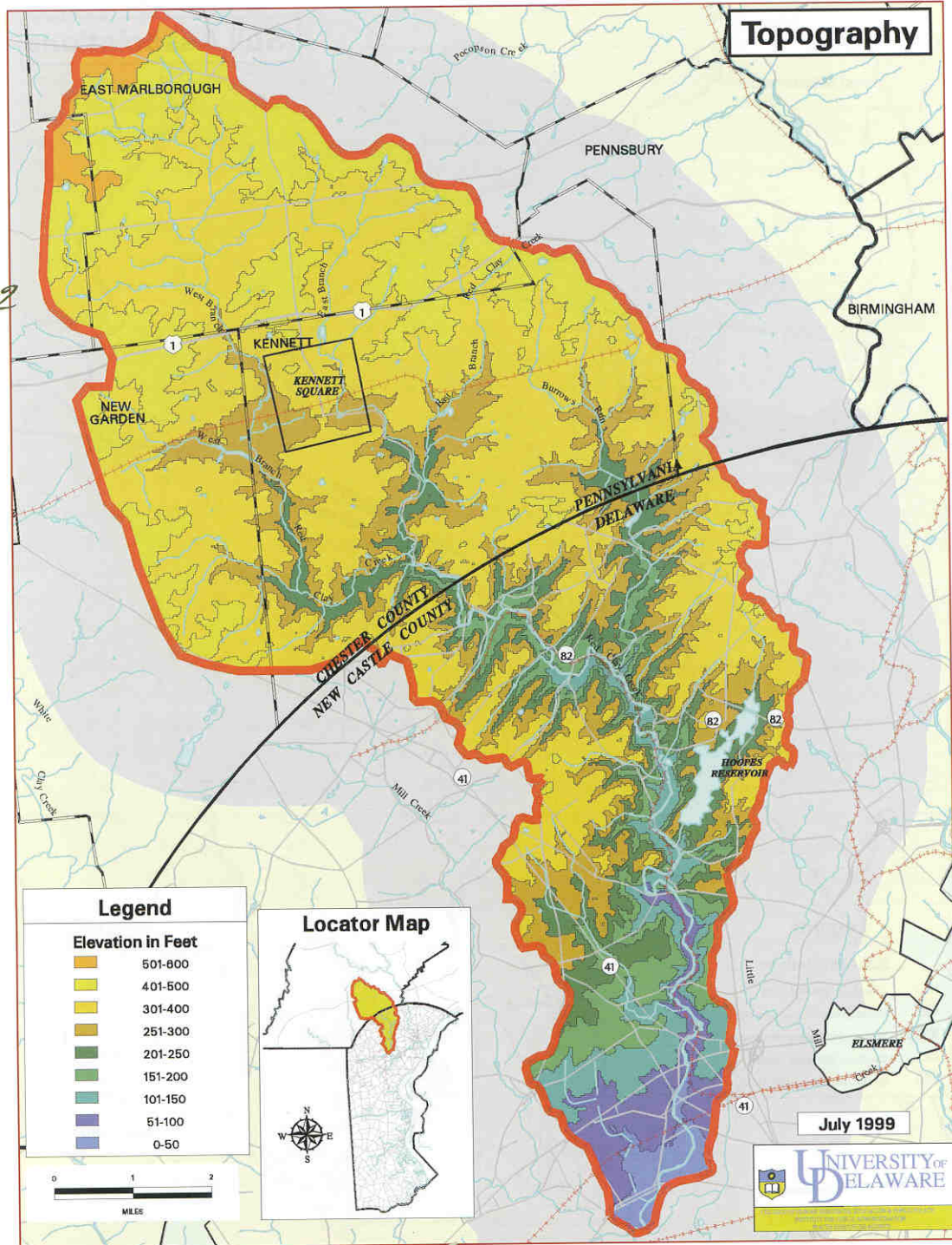




Newark  
Reservoir



# Topography









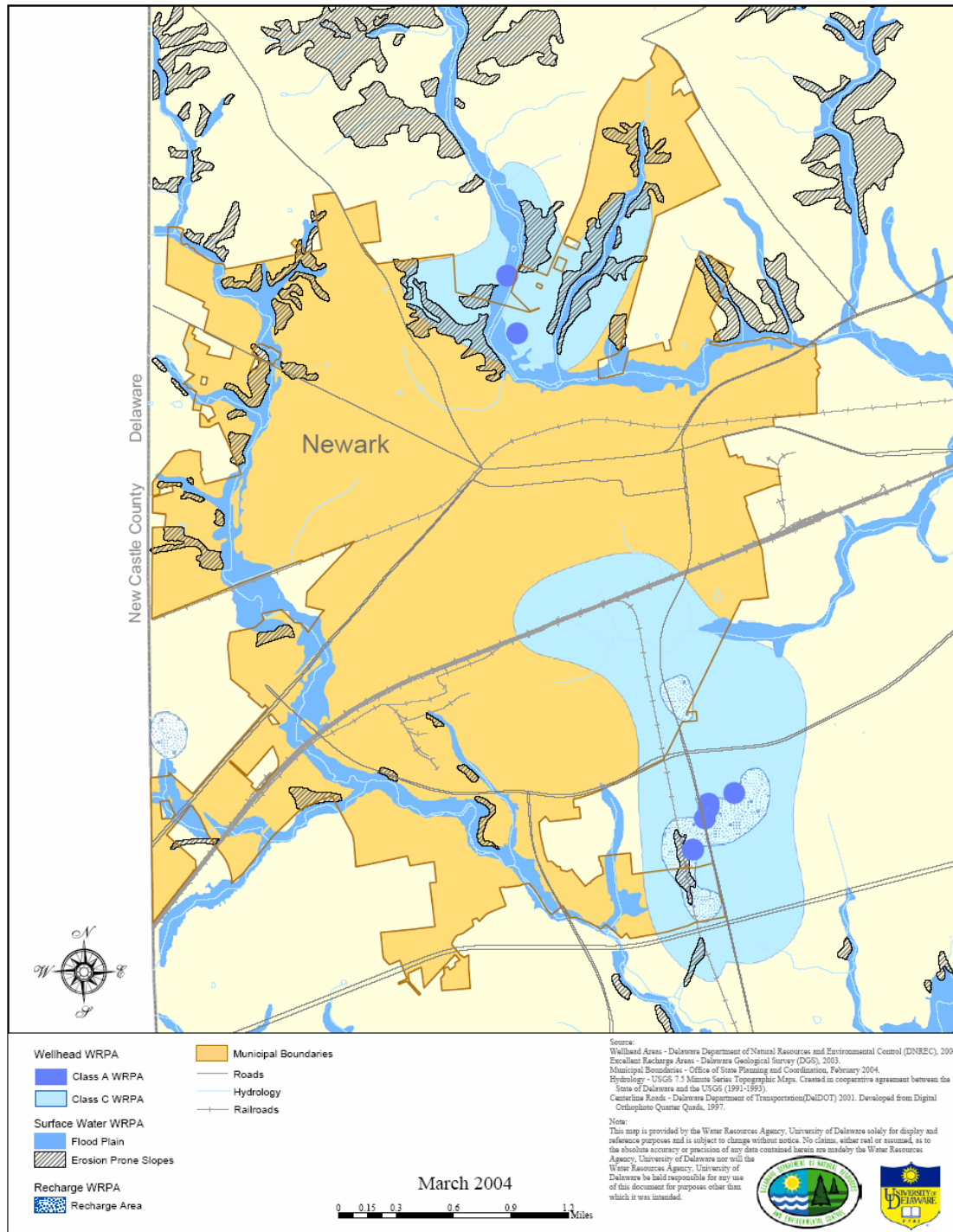






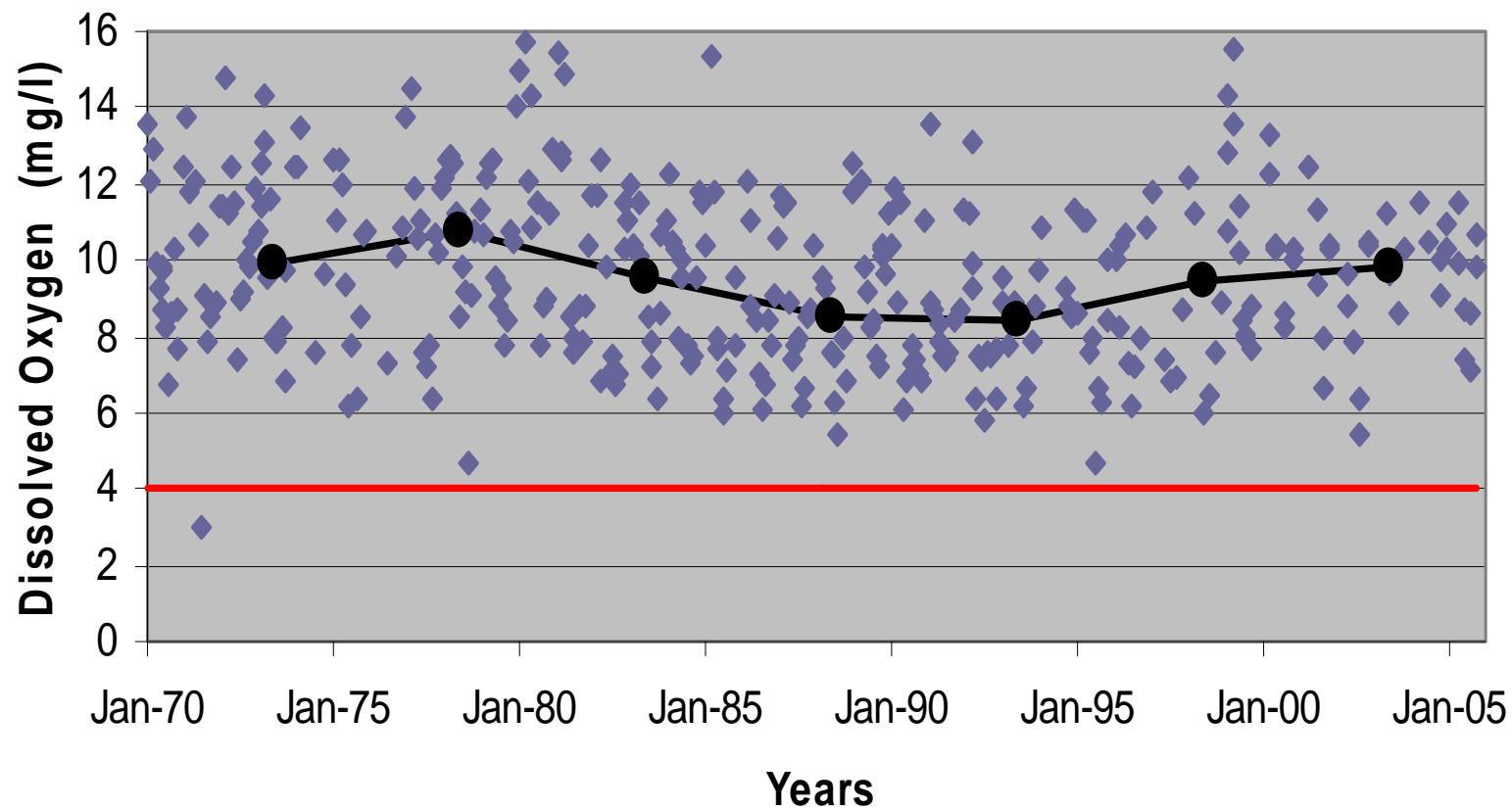






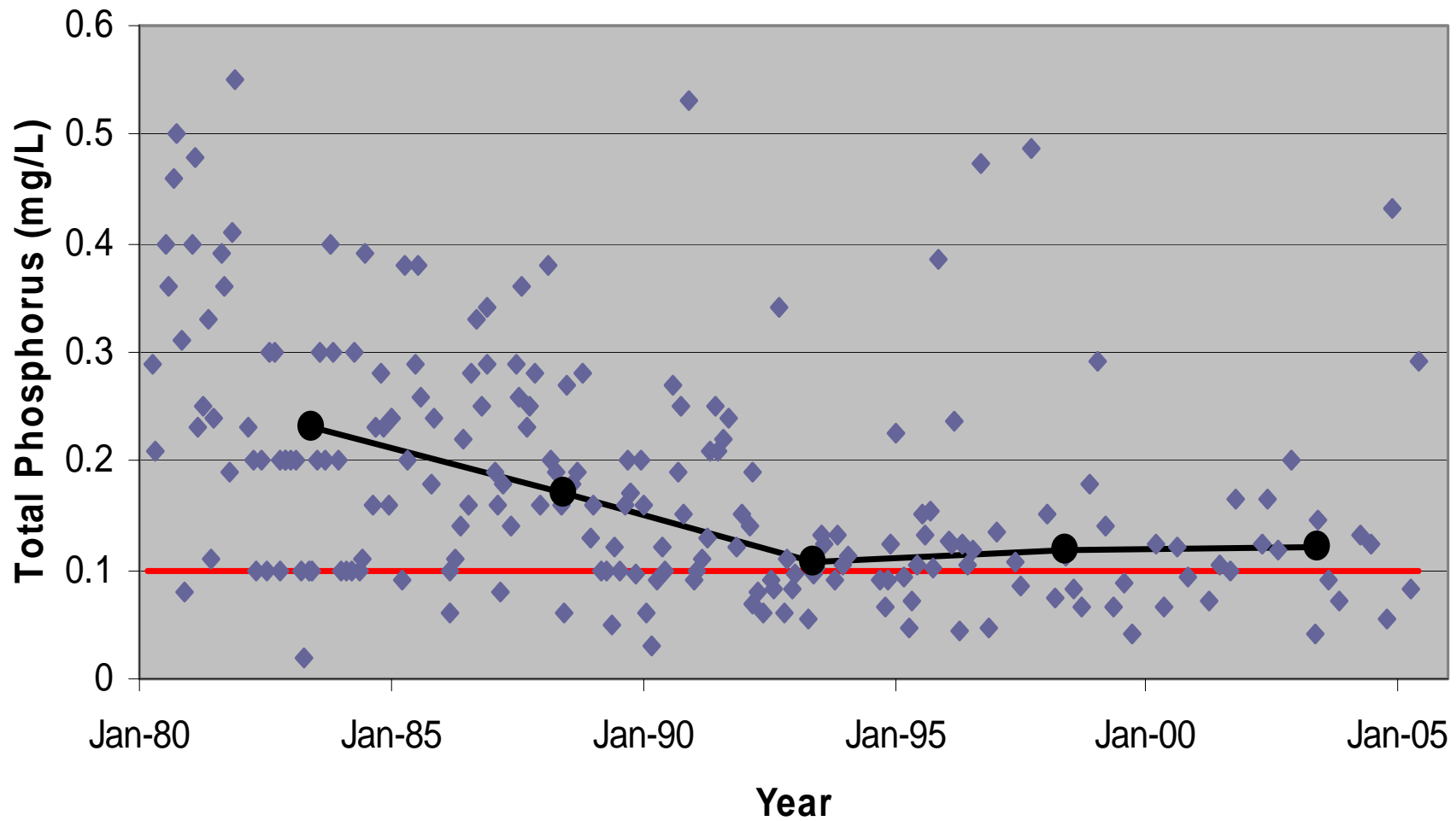
# Dissolved Oxygen, Brandywine River above Wilmington, LE1

Smith Bridge, Station 104051



◆ Dissolved Oxygen — DE WQ Standard —●— 5-yr Median

# Total Phosphorus, Brandywine River above Wilmington, LE1 Smith Bridge, Station 104051

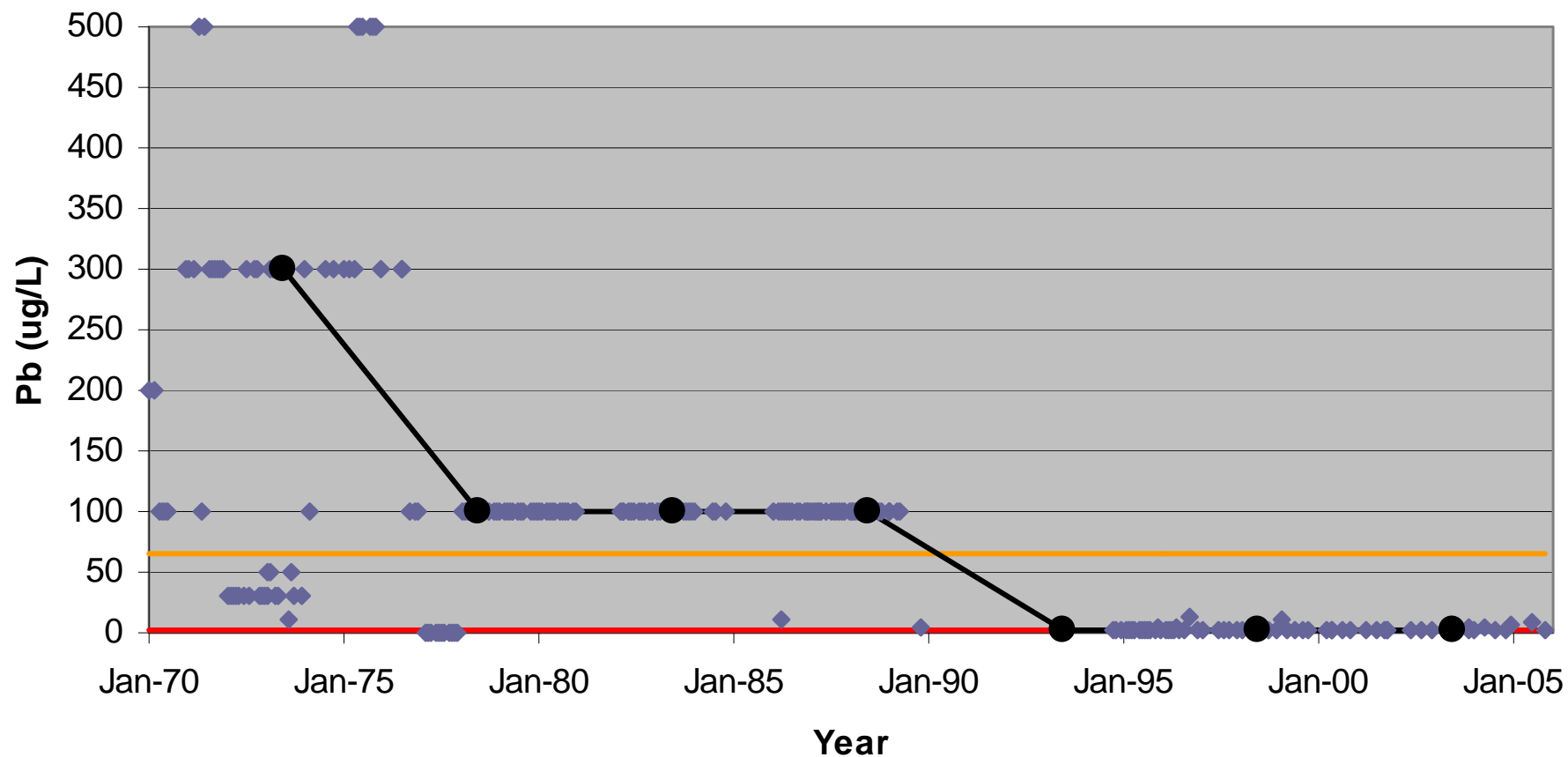


◆ Total Phosphorus — DE WQ Standard —●— 5-yr Median

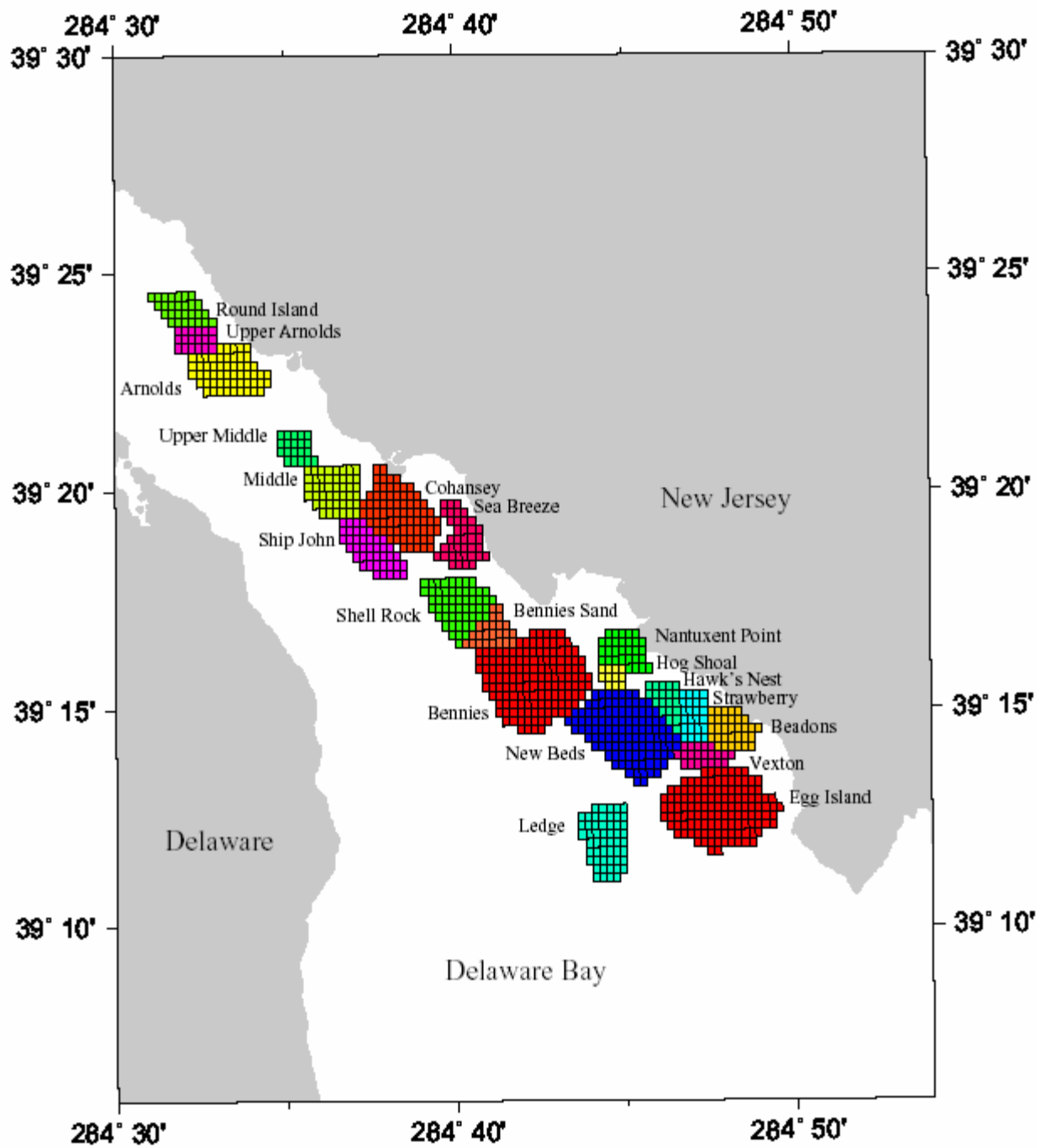


# Lead, Brandywine River at Wilmington, LE1

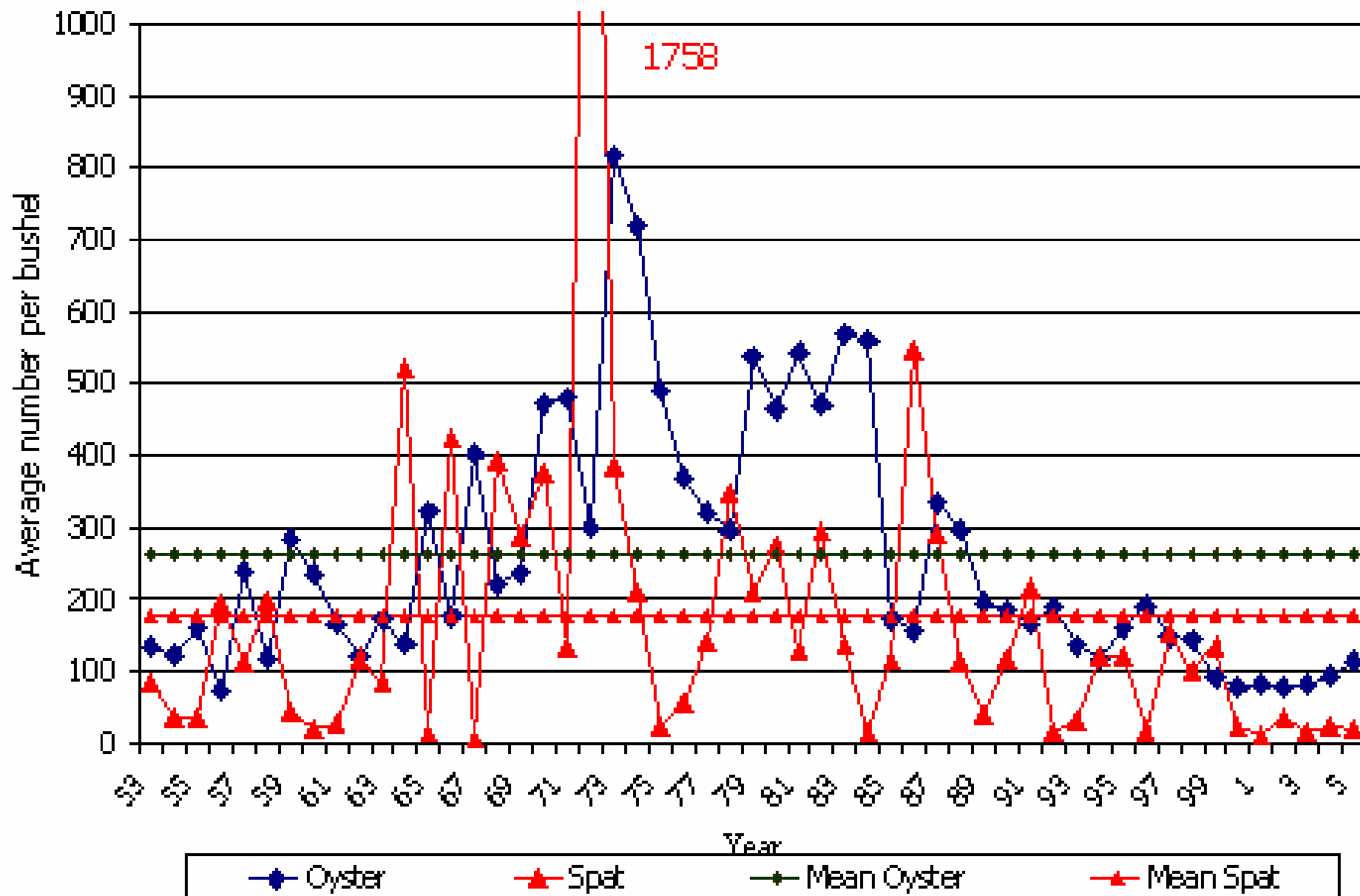
Foot Bridge, Station 104011

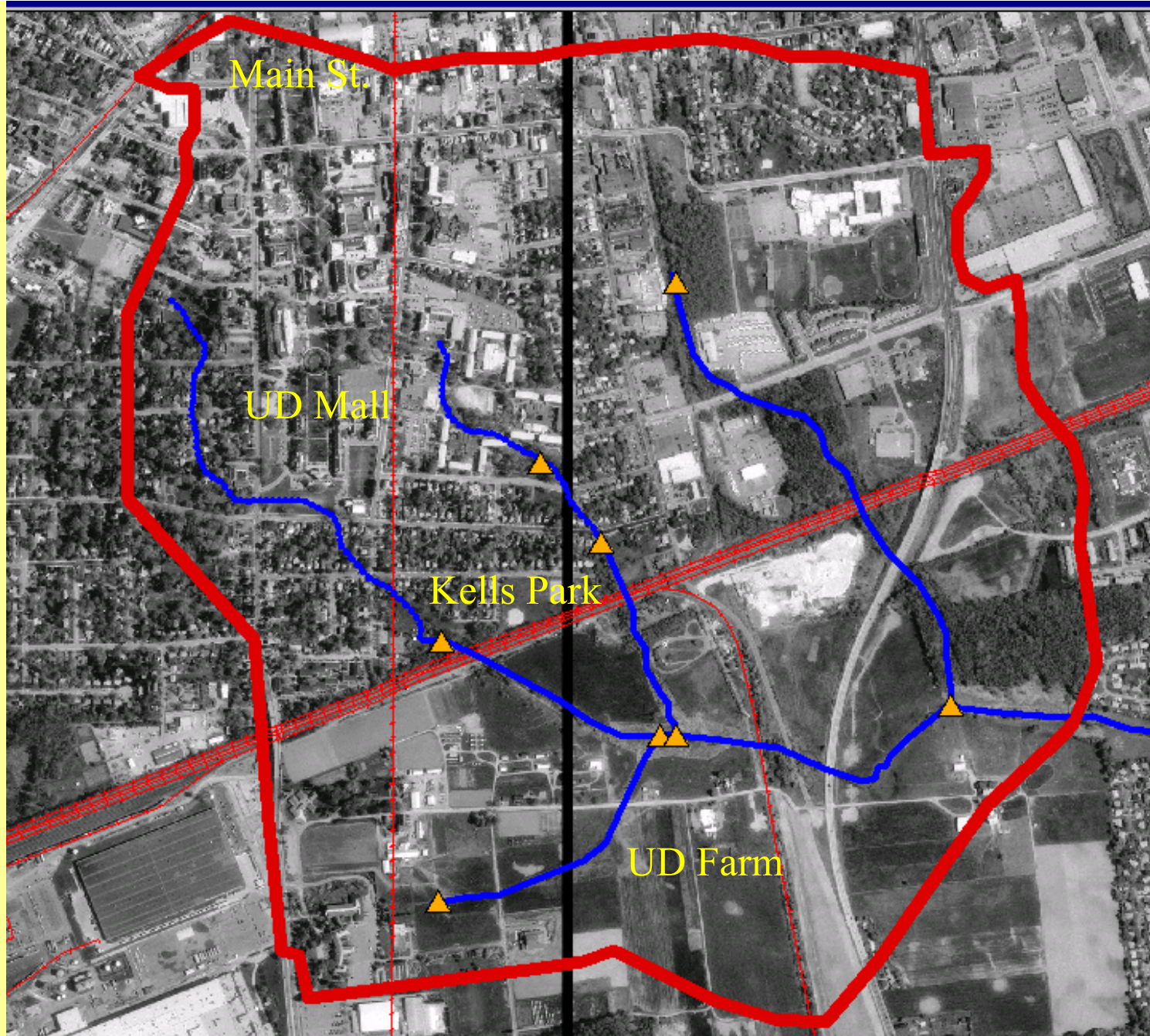


◆ Lead — Chronic WQ Standard (2.5 ug/L) — Acute WQ Standard (65 ug/L) —●— 5-yr Median



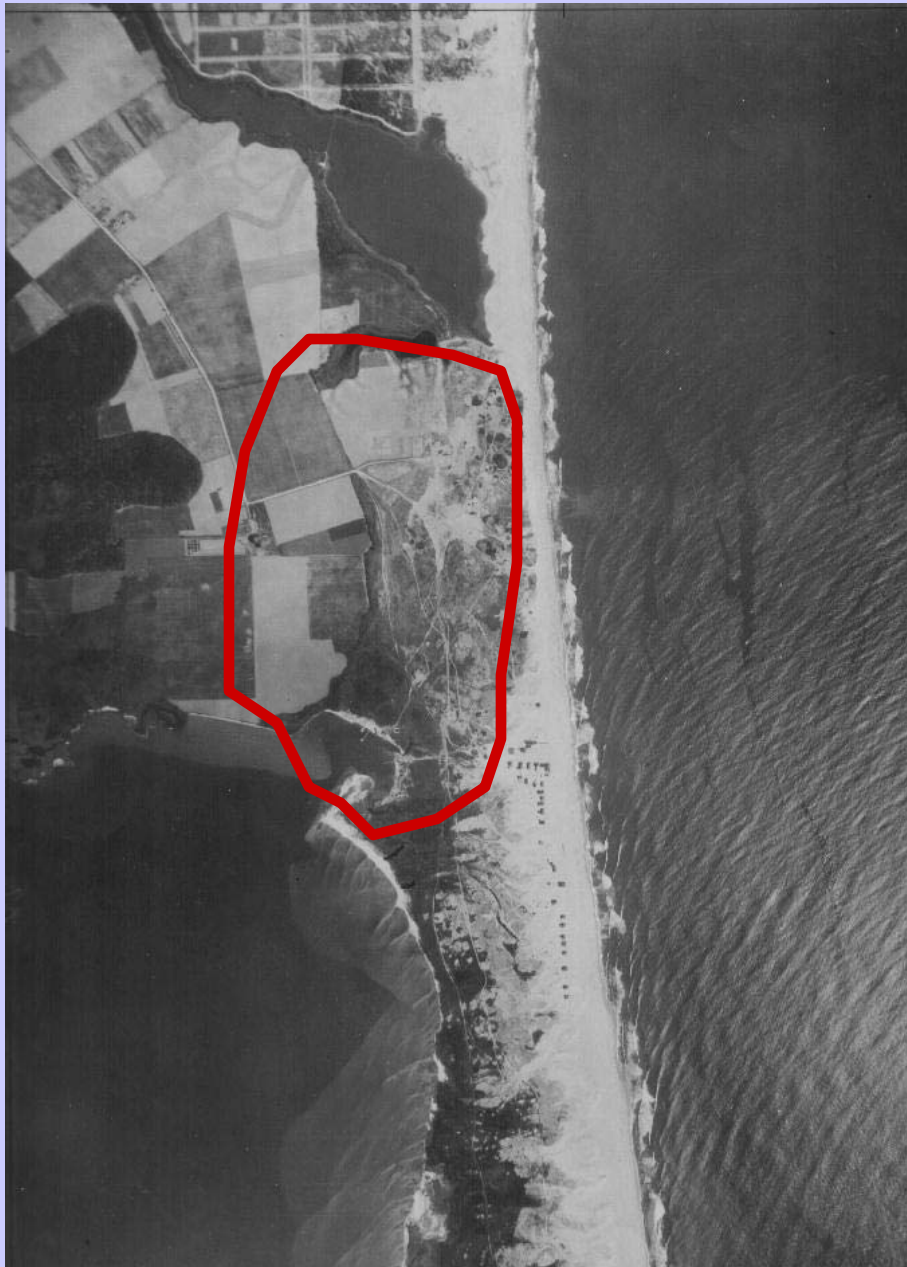
# Delaware Bay Oyster Seed Beds



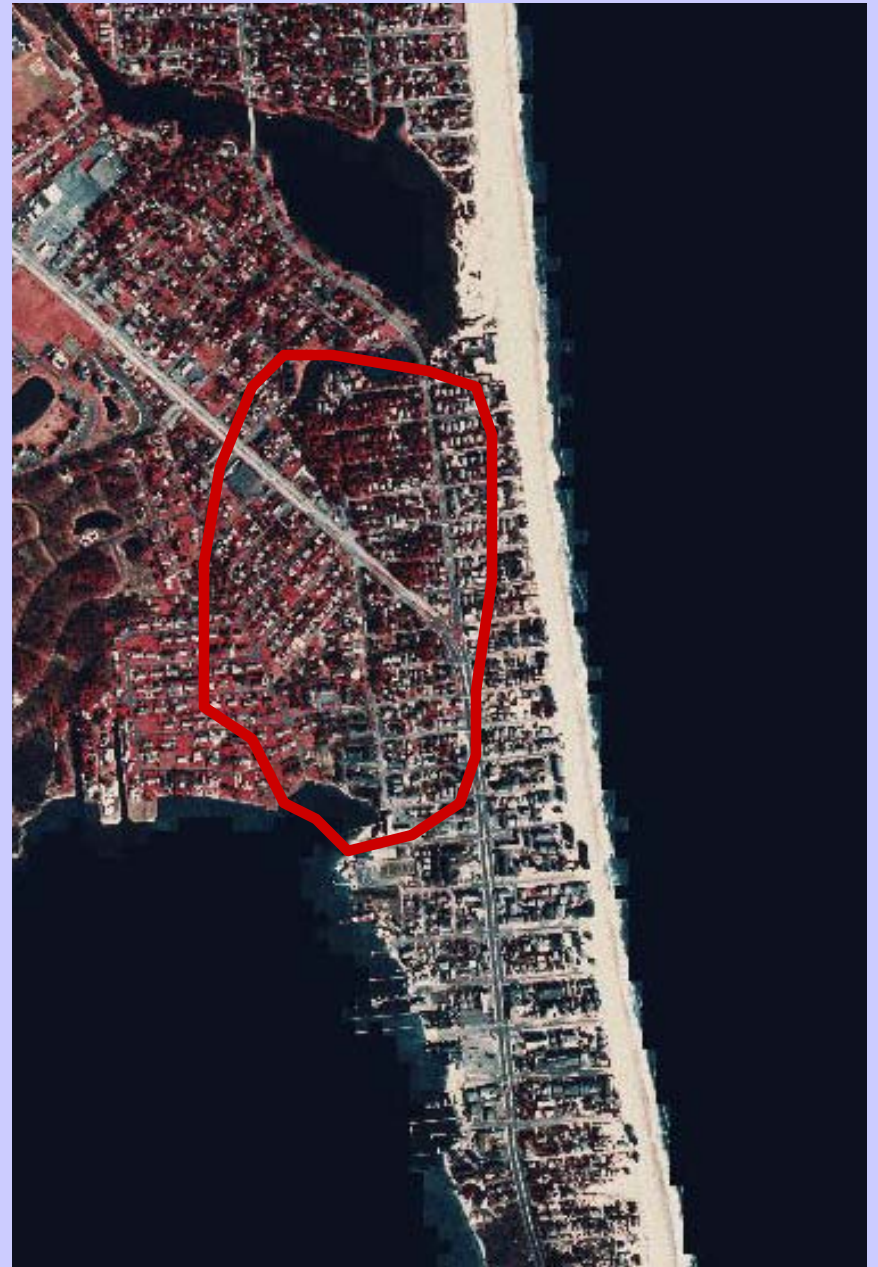


**The Coastal Plain (Southern) Experimental Watershed**





**1926**



**1992**

# Water Use

## Inside

Sustenance -	8 gallons
Showers -	50 gallons every 10 minutes
Laundry -	40 gallons per load
Toilets -	5 gallons per flush
Handwash Dishes -	12 gallons per wash

## Outside

Lawns, Gardens -	600 gallons over a couple hours.
Carwash -	100 gallons with a hose.
Wash Sidewalks -	50 gallons in 10 minutes.



## Cost of Essential Fluids

<u>Fluid</u>	<u>\$/gal.</u>
Tap Water	0.002 - 0.005
Gasoline	1.59
Ginger Ale	2.60
Milk	3.00
Bottled Water	4.00
Beer	10.60

# Water Laws (con't.)

- National Environmental Policy Act of 1969
- Federal Water Pollution Control Amendments of 1972
- Clean Water Act of 1977
  - Section 404
  - Section 401
  - Section 208
  - Section 303d

# Federal Water Agencies

- U.S. Geological Survey
- NOAA National Climatic Data Center
- U.S. Bureau of Reclamation
- U.S. Environmental Protection Agency
- U.S. Natural Resources Conservation Service
- U.S. Army Corps of Engineers

# State Water Agencies

- Delaware DNREC
  - Division of Water Resources
  - Division of Soil and Water Conservation
  - Division of Air and Waste Mgmt.
  - Division of Fish and Wildlife
- Delaware Dept. of Transportation
- Delaware State Fire Marshall's Office
- DE Public Service Commission

# Municipal/County/State Regulations

- Water Supply (NCC Certification)
- Wastewater Management
- Floodplain Management
- Stormwater Management
- Dam Safety
- Groundwater





