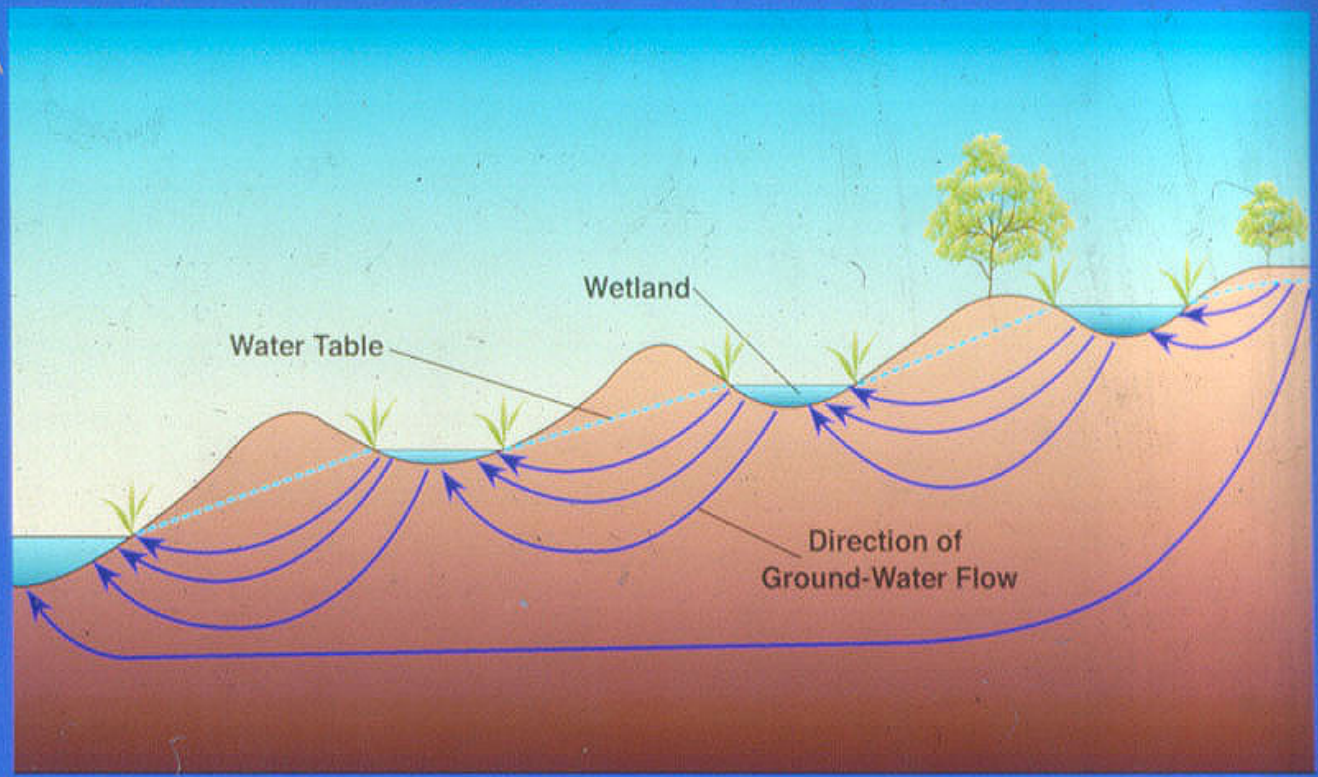
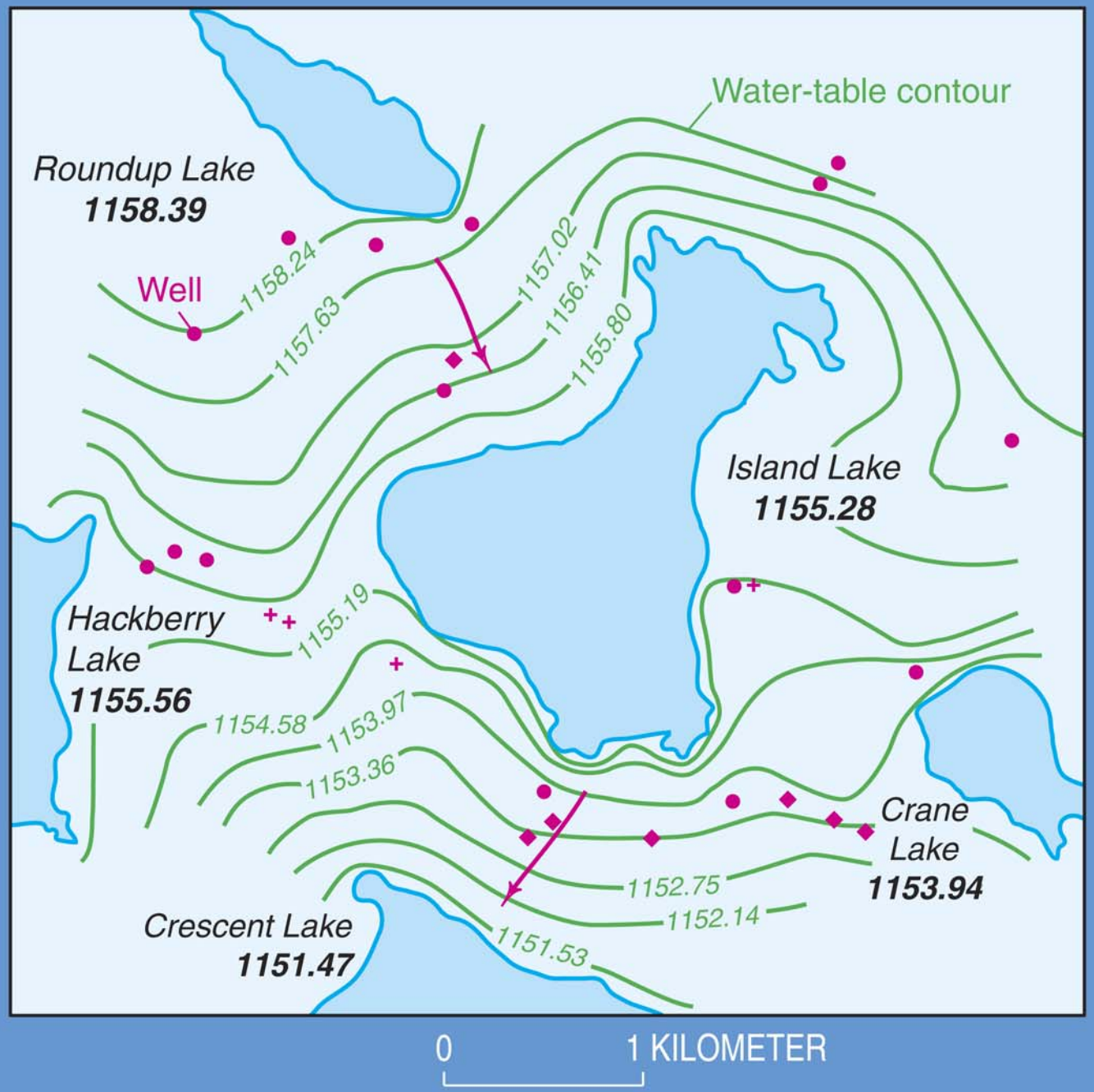
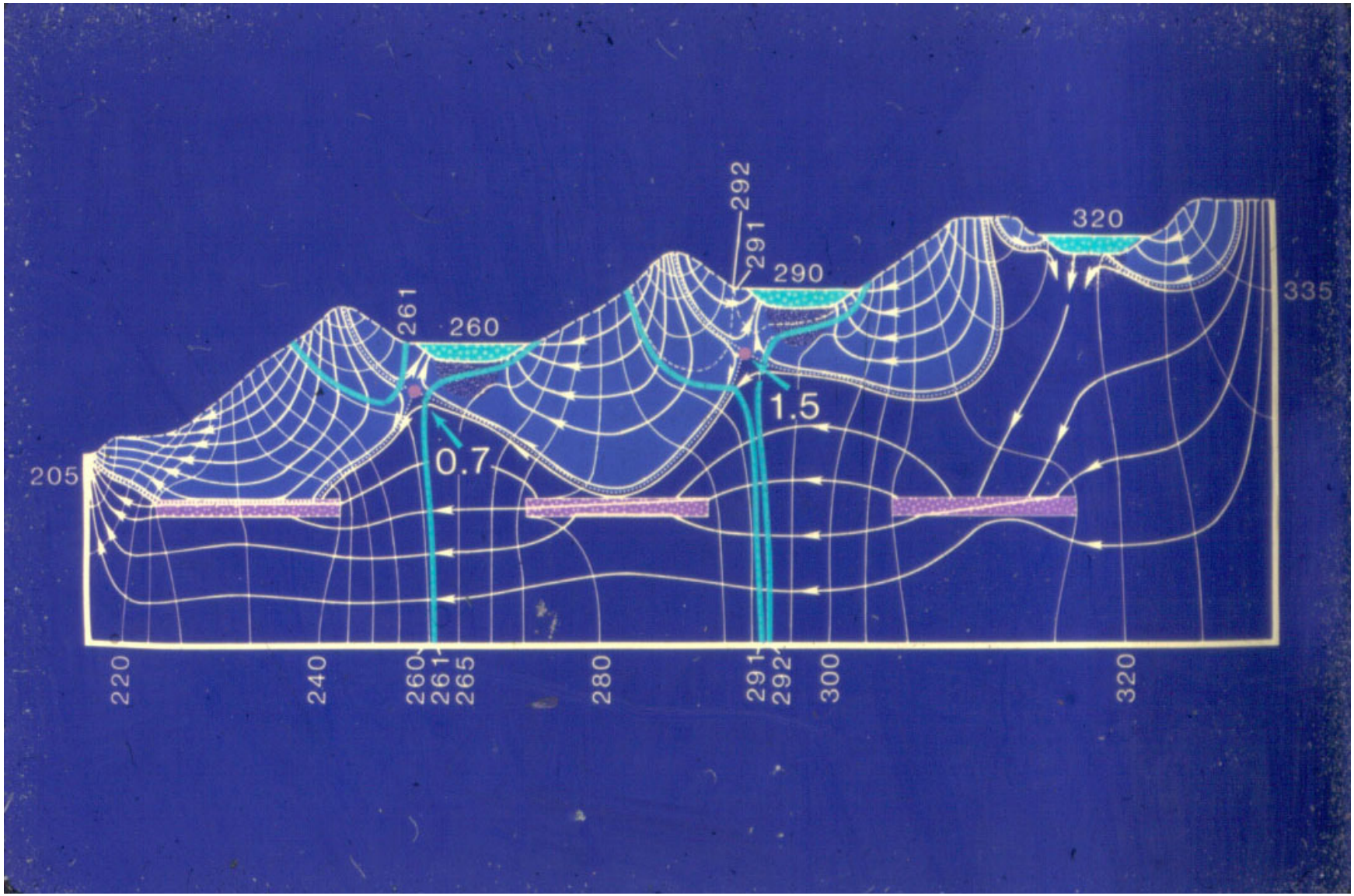
The Aquatic Systems Continuum

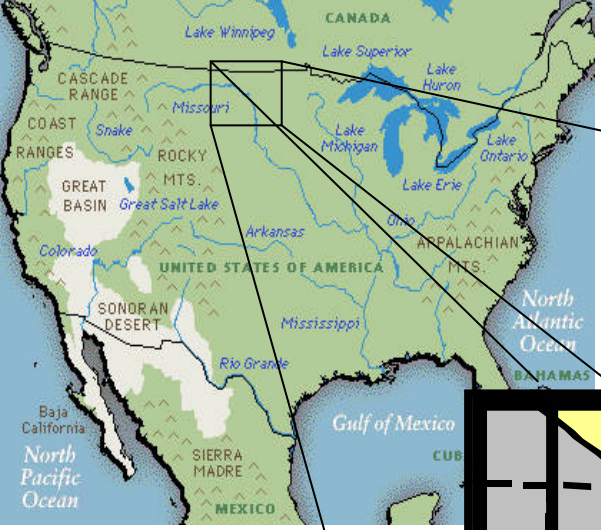
Linking ground water, surface water, and atmospheric water

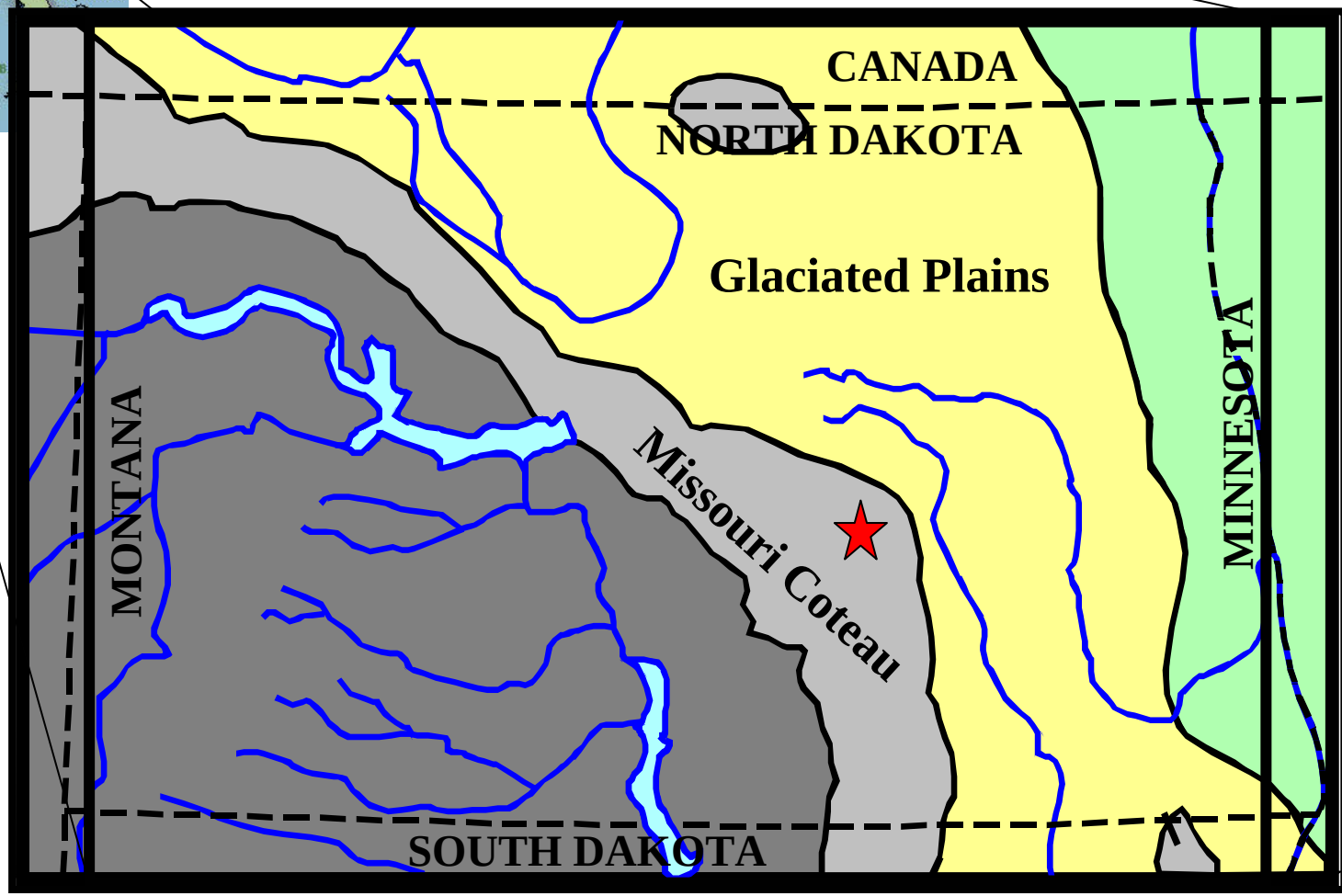
Thomas C. Winter
U.S. Geological Survey


Wetland
Water Table
Direction of
Ground-Water Flow


Water-table contour
Roundup Lake
1158.39
Well
1158.24
1157.63
1157.02
1156.41
1155.80
Island Lake
1155.28
Hackberry
Lake
1155.56
1155.19
1154.58
1153.97
1153.36
Crane
Lake
1153.94
1152.75
1152.14
1151.53
Crescent Lake
1151.47
0
1 KILOMETER


292
291
290
320
335
261
260
1.5
0.7
205
220
240
260
261
265
280
291
292
300
320





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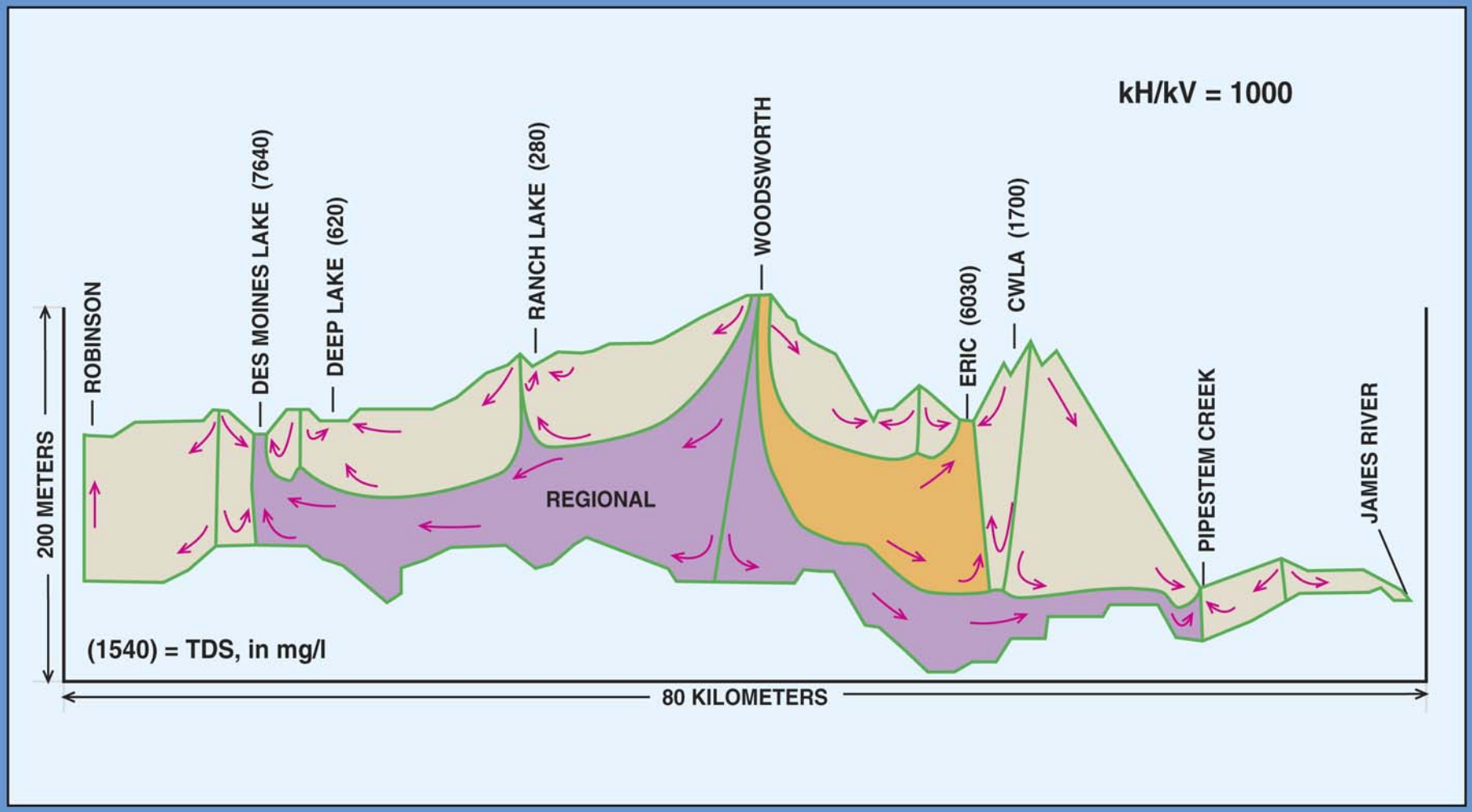
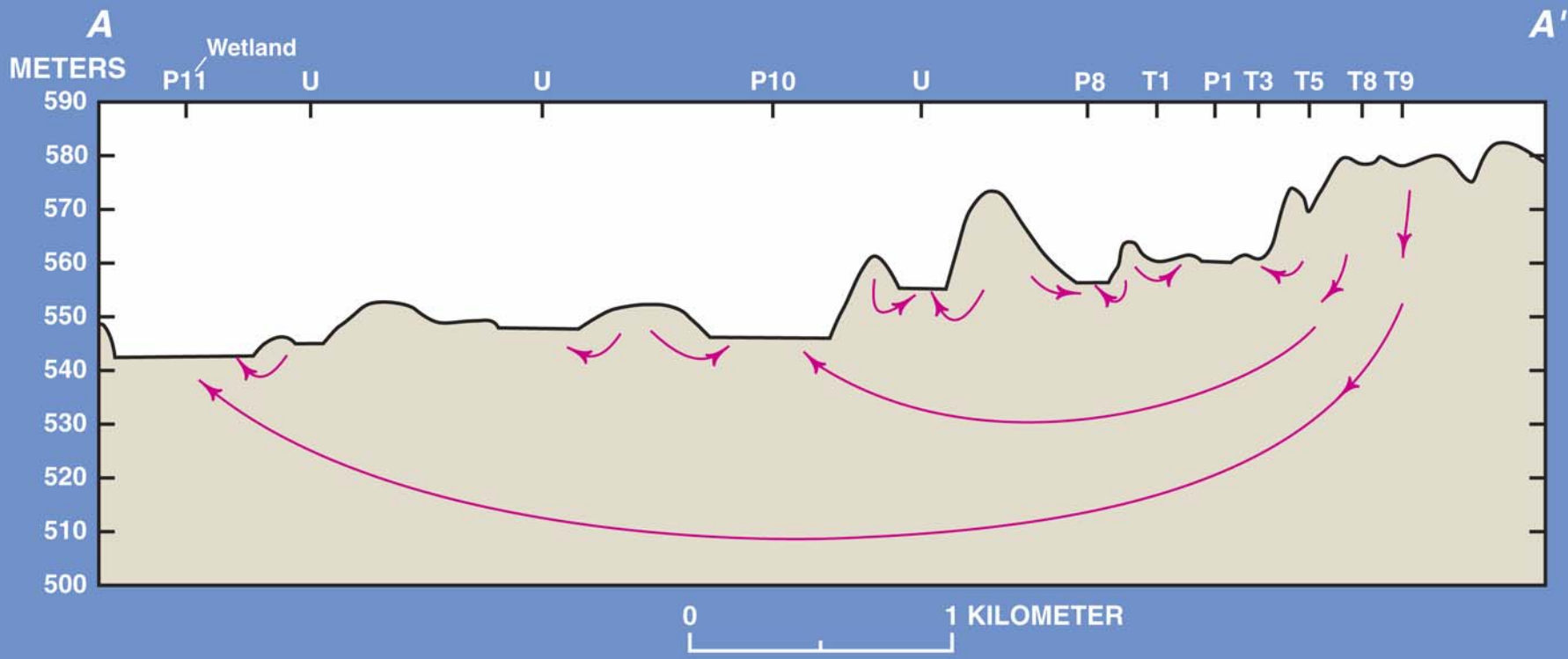
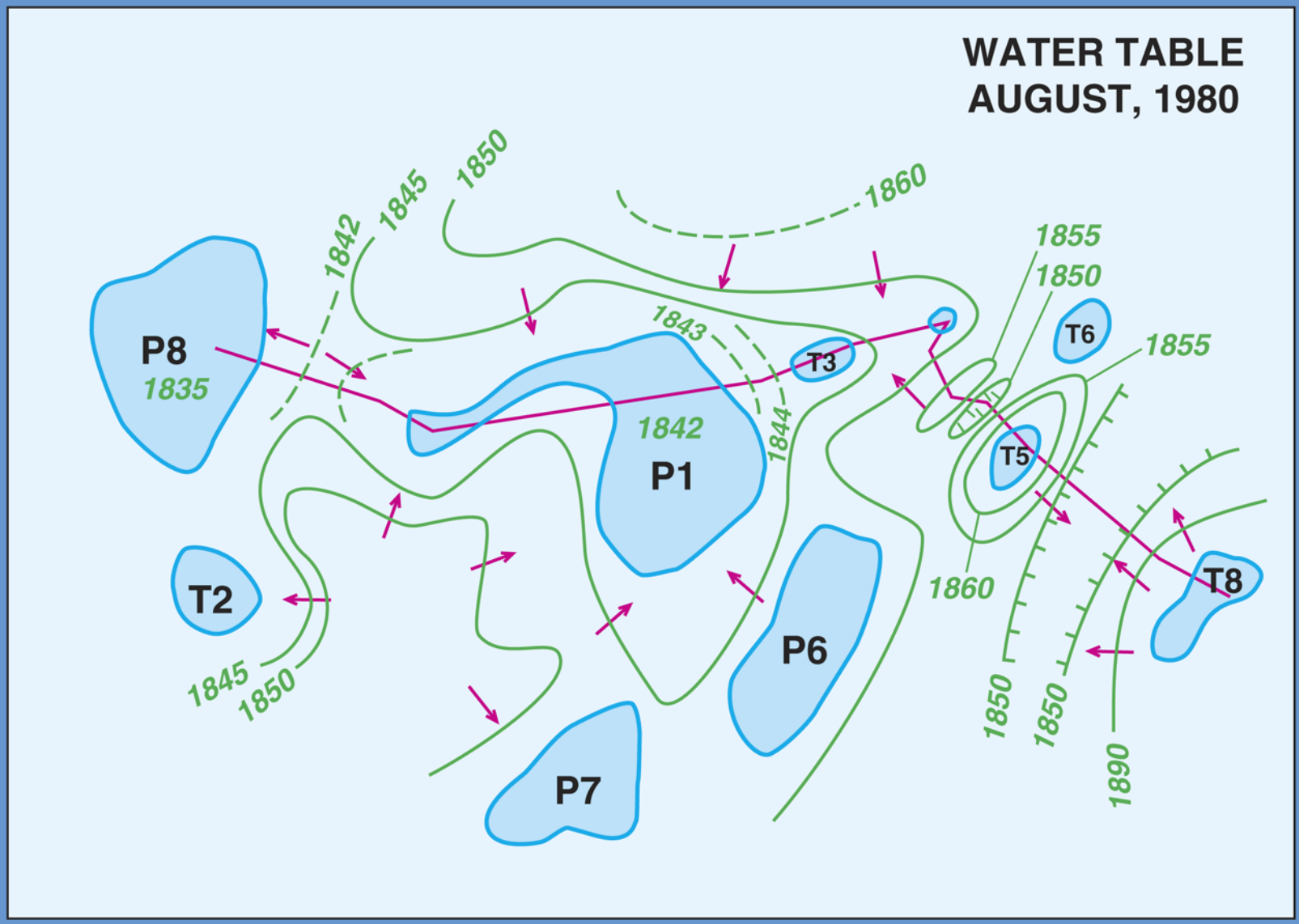
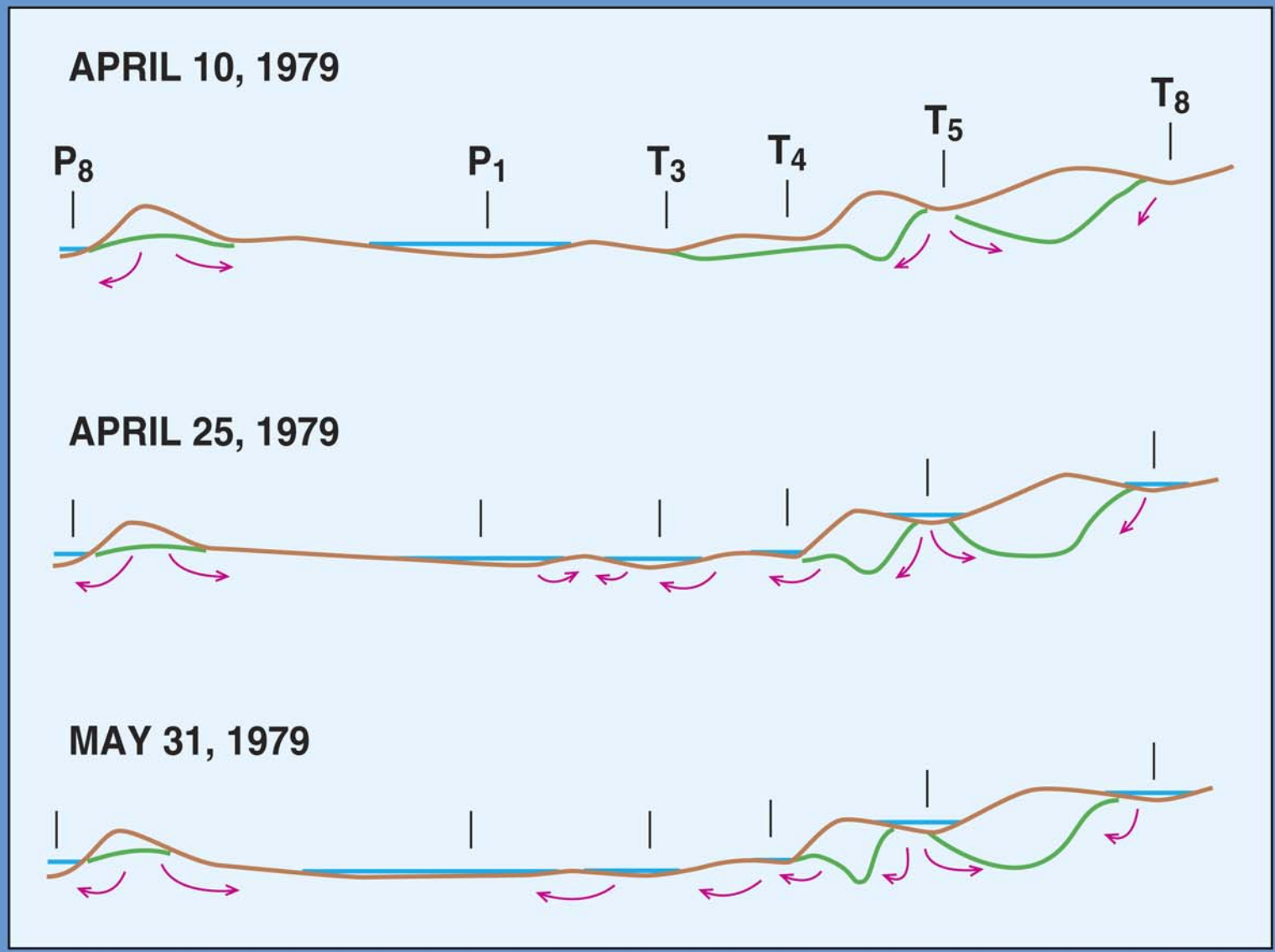
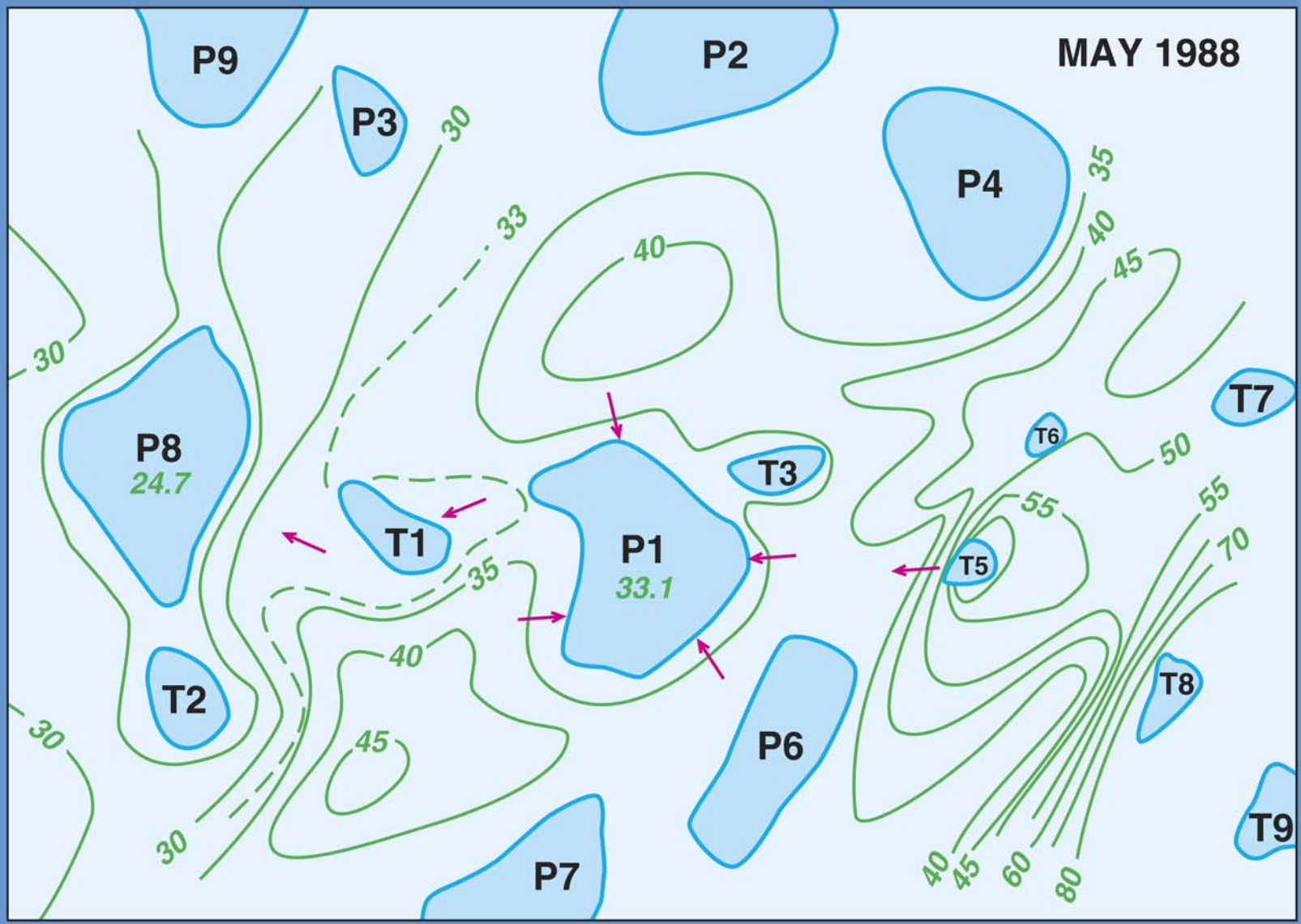
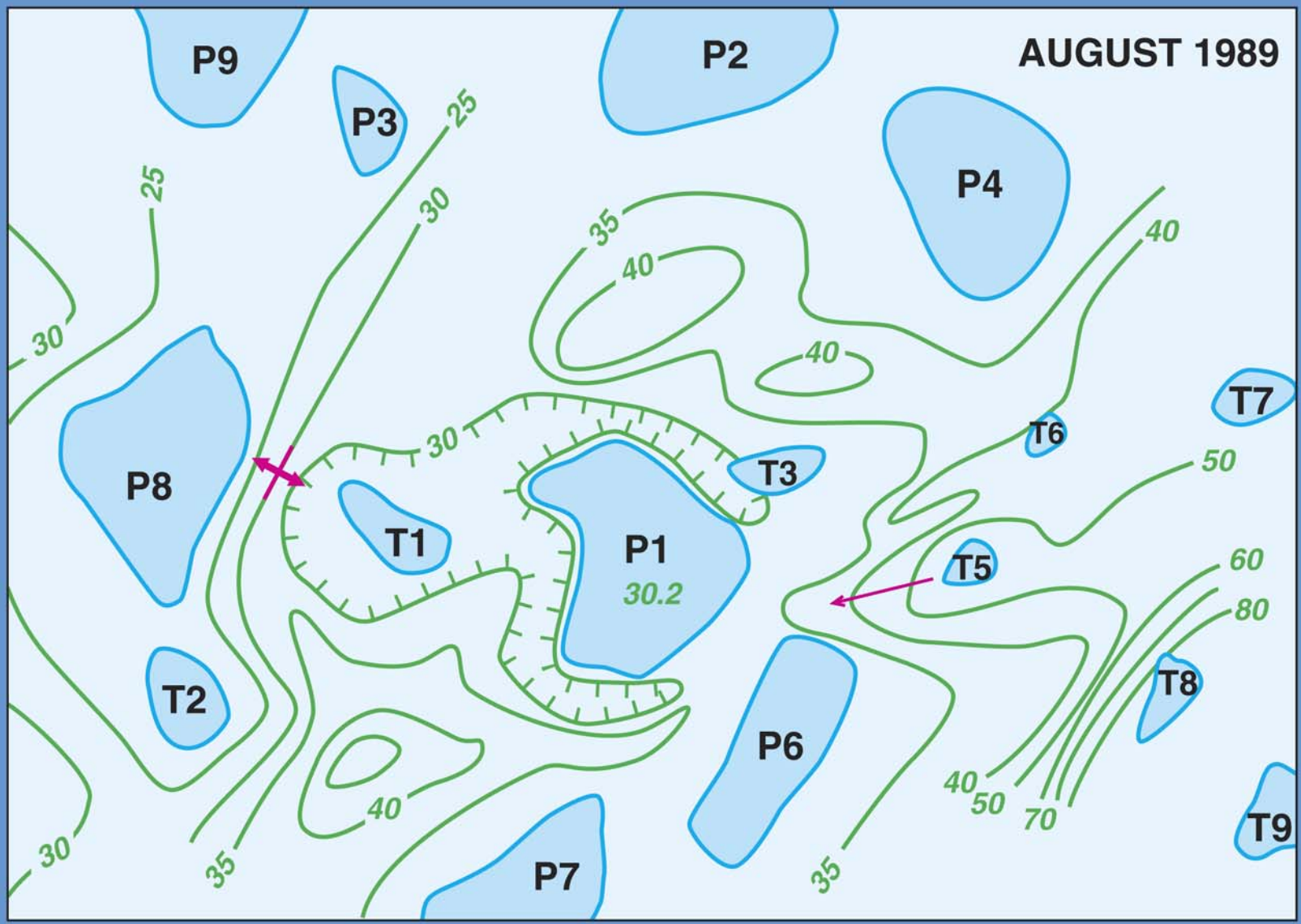

kH/kV = 1000
ROBINSON
DES MOINES LAKE (7640)
DEEP LAKE (620)
RANCH LAKE (280)
WOODSWORTH
ERIC (6030)
CWLA (1700)
PIPESTEM CREEK
JAMES RIVER
REGIONAL
200 METERS
(1540) = TDS, in mg/l
80 KILOMETERS

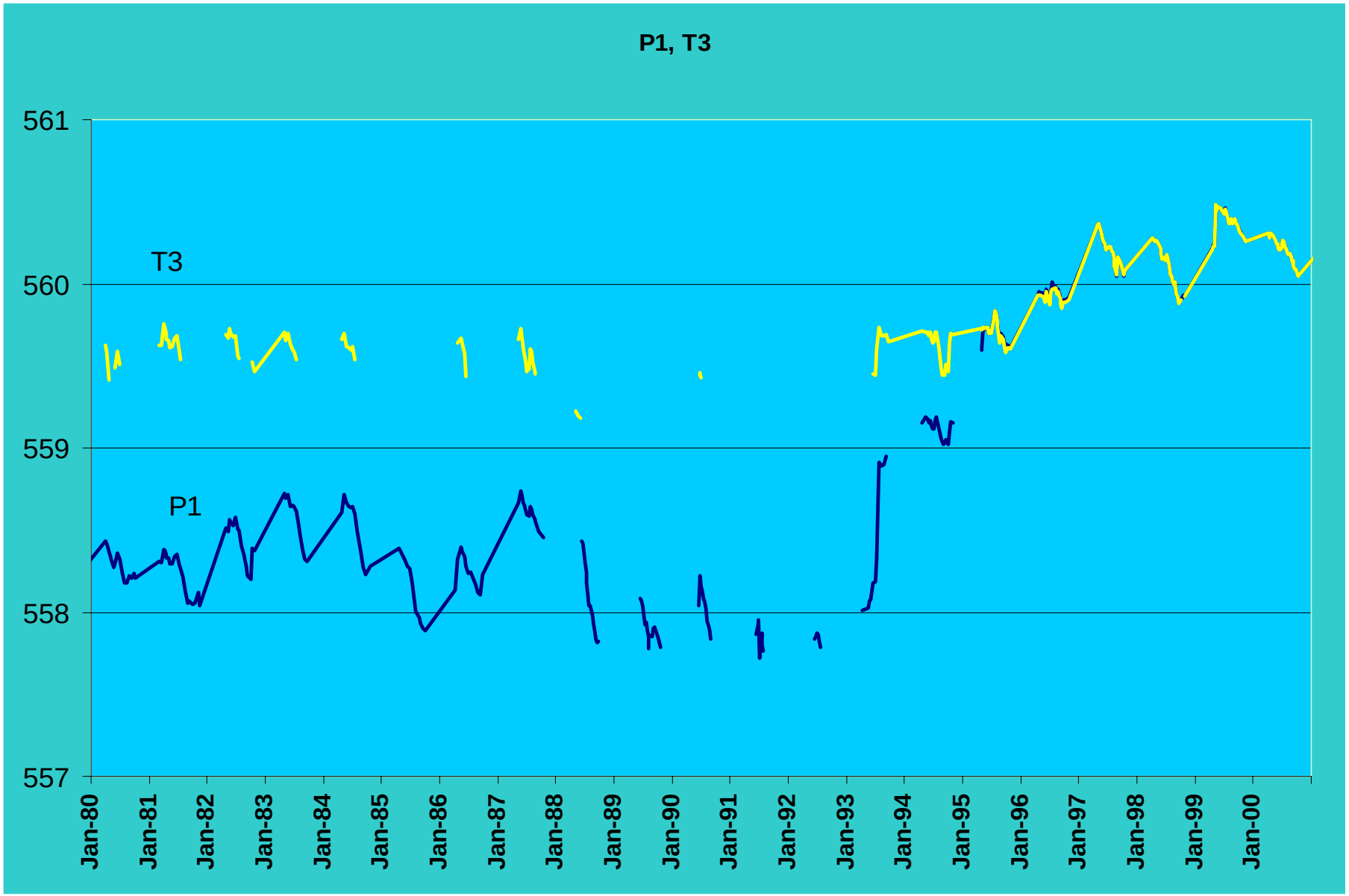

A
A'
METERS
Wetland
P11
U
U
P10
U
P8
T1
P1
T3
T5
T8
T9
590
580
570
560
550
540
530
520
510
500
0
1 KILOMETER

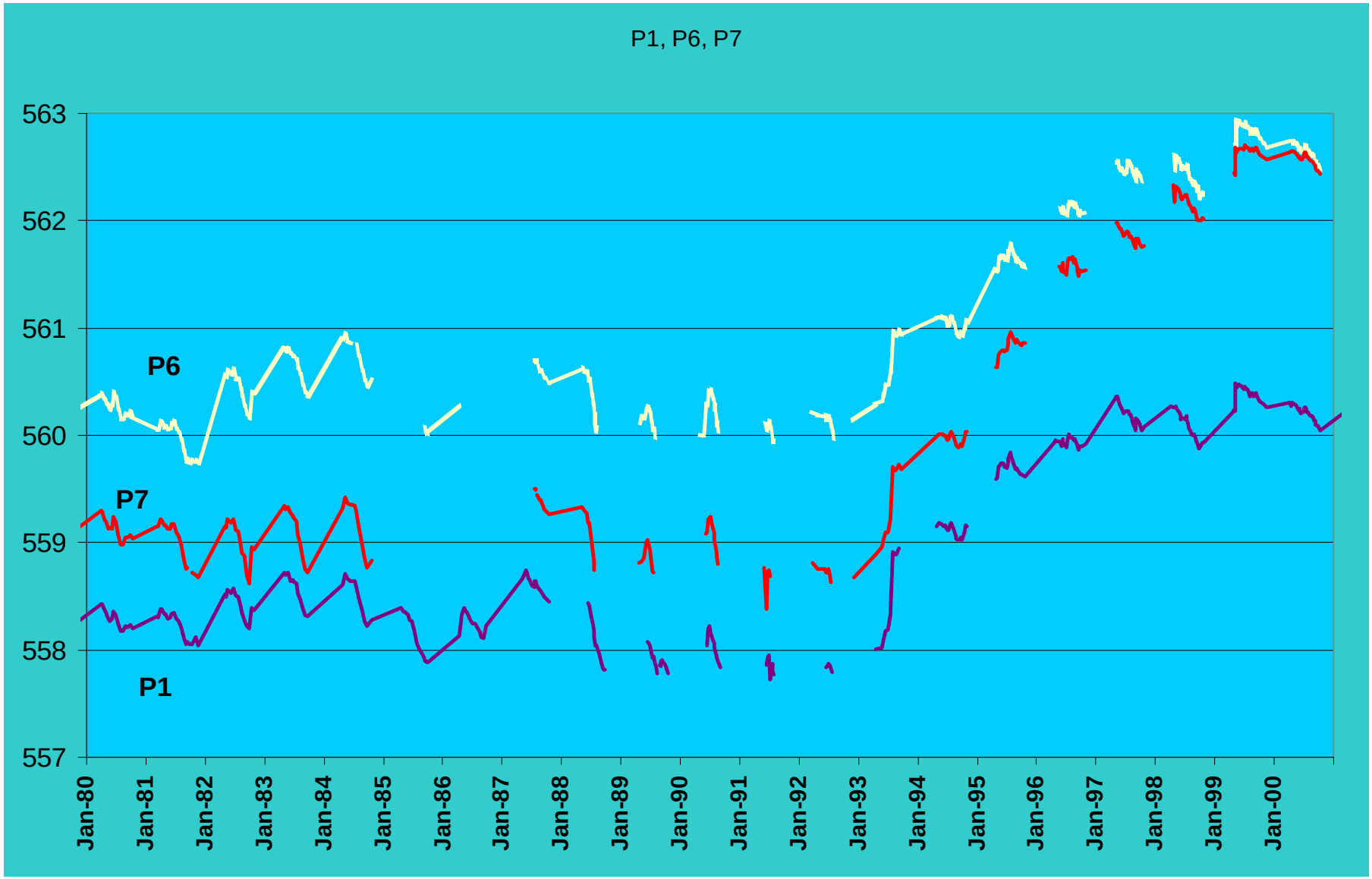

WATER TABLE
AUGUST, 1980
1842
1845
1850
1860
1855
1850
1855
1843
1844
1842
1860
1850
1850
1890
1845
1850
1835
P8
P1
P6
P7
T2
T3
T5
T6
T8


APRIL 10, 1979
P8
P1
T3
T4
T5
T8
APRIL 25, 1979
MAY 31, 1979

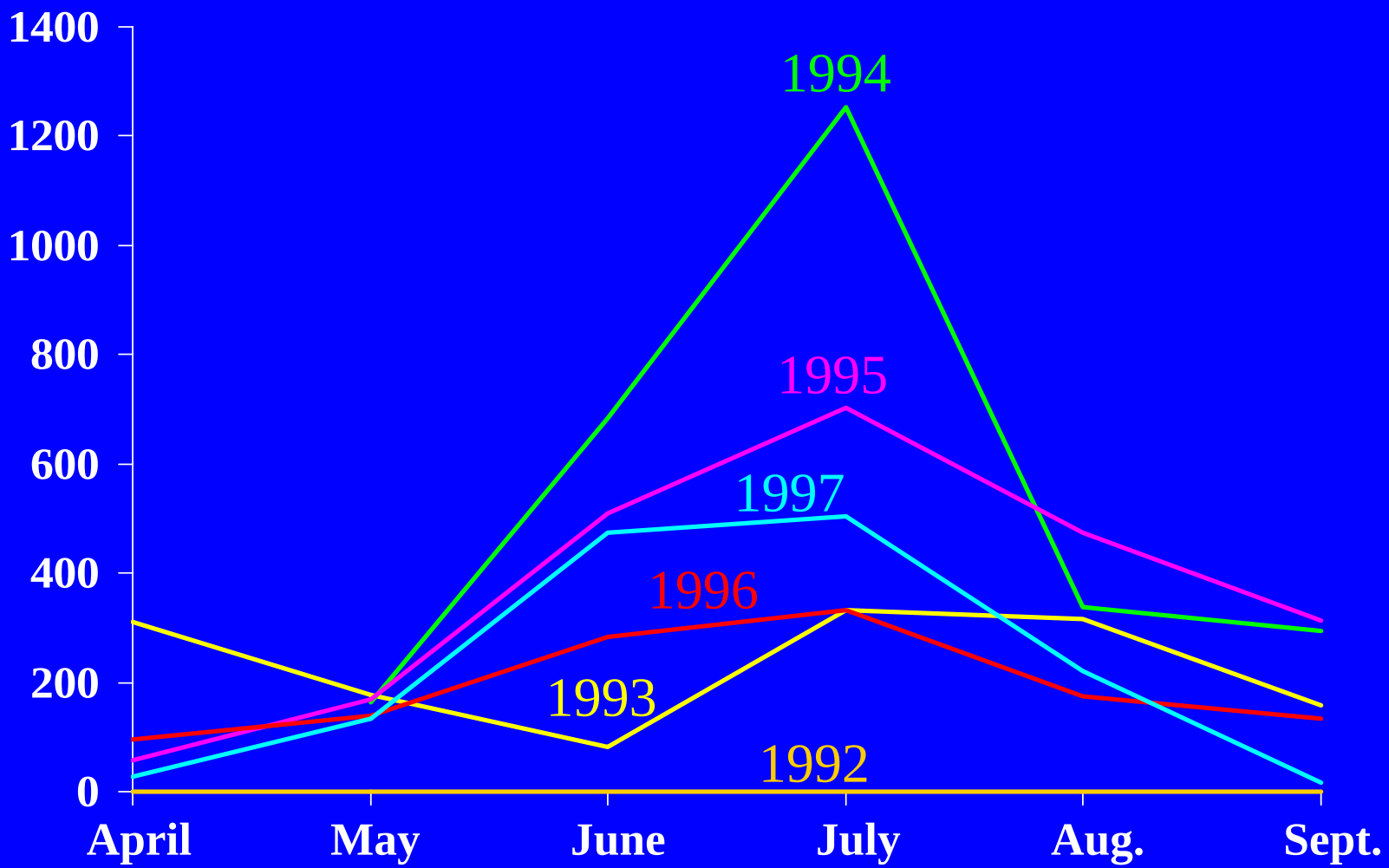

MAY 1988
P9
P2
P3
P4
P8
24.7
P1
33.1
T1
T2
T3
T4
T5
T6
T7
T8
T9
P6
P7
30
33
40
35
45
50
55
70
60
80


AUGUST 1989
P9
P2
P3
P4
P8
P1
30.2
P6
P7
T1
T2
T3
T5
T6
T7
T8
T9
25
30
35
40
50
60
70
80


P1, T3
561
560
559
558
557
T3
P1
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00


P1, P6, P7
563
562
561
560
559
558
557
P6
P7
P1
Jan-80
Jan-81
Jan-82
Jan-83
Jan-84
Jan-85
Jan-86
Jan-87
Jan-88
Jan-89
Jan-90
Jan-91
Jan-92
Jan-93
Jan-94
Jan-95
Jan-96
Jan-97
Jan-98
Jan-99
Jan-00

Invertebrate Biomass (grams x 100)



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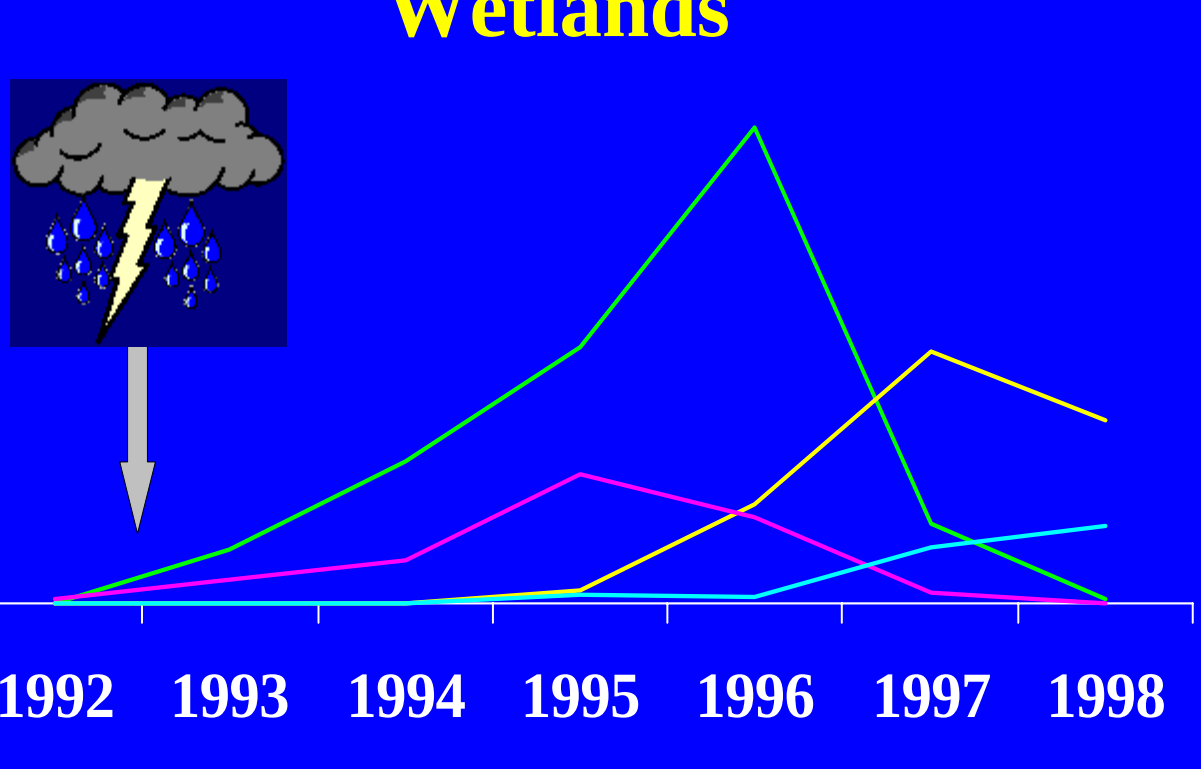
Tiger Salamander Captures in Cottonwood Lake Study Area Wetlands



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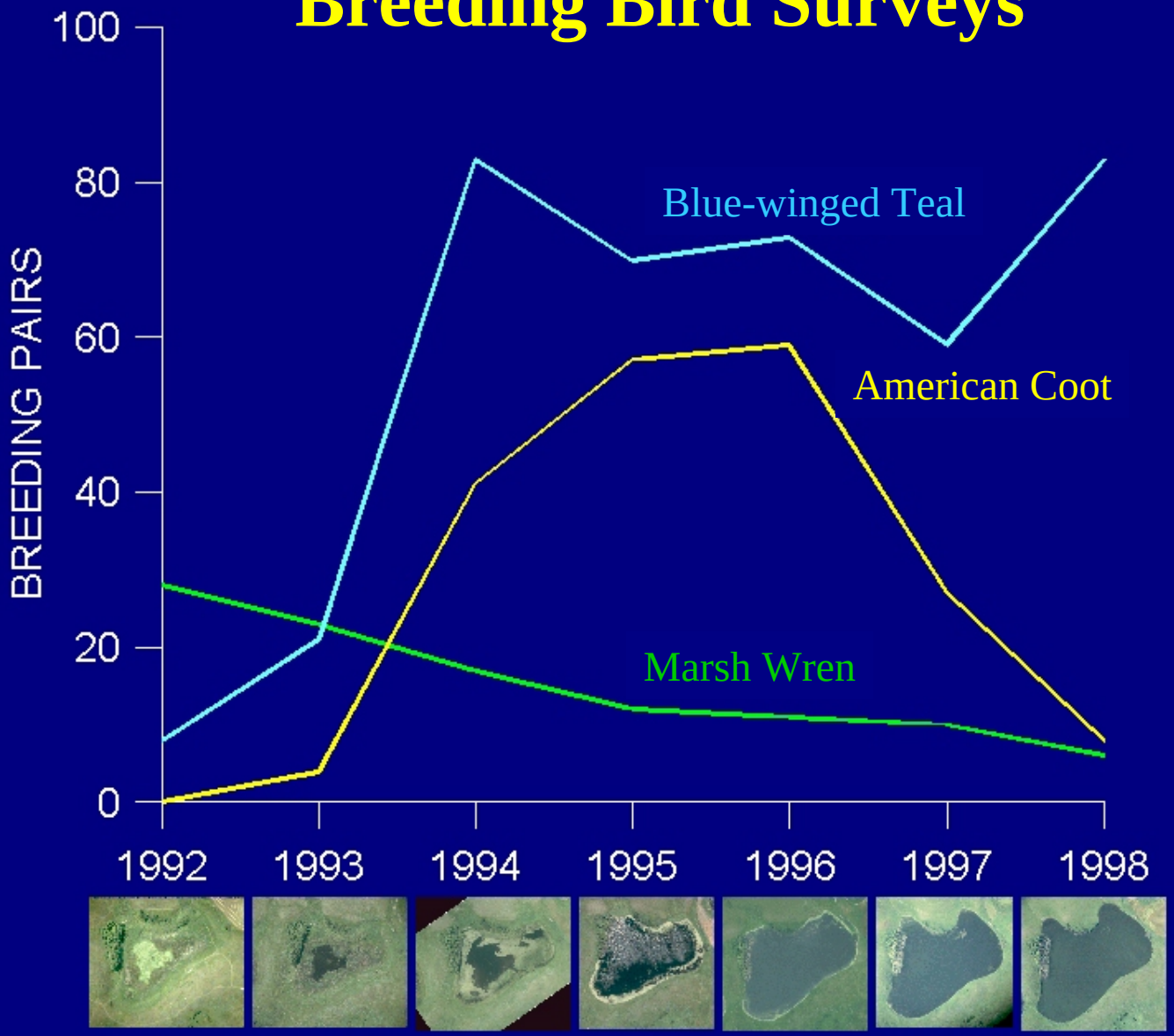
Breeding Bird Surveys



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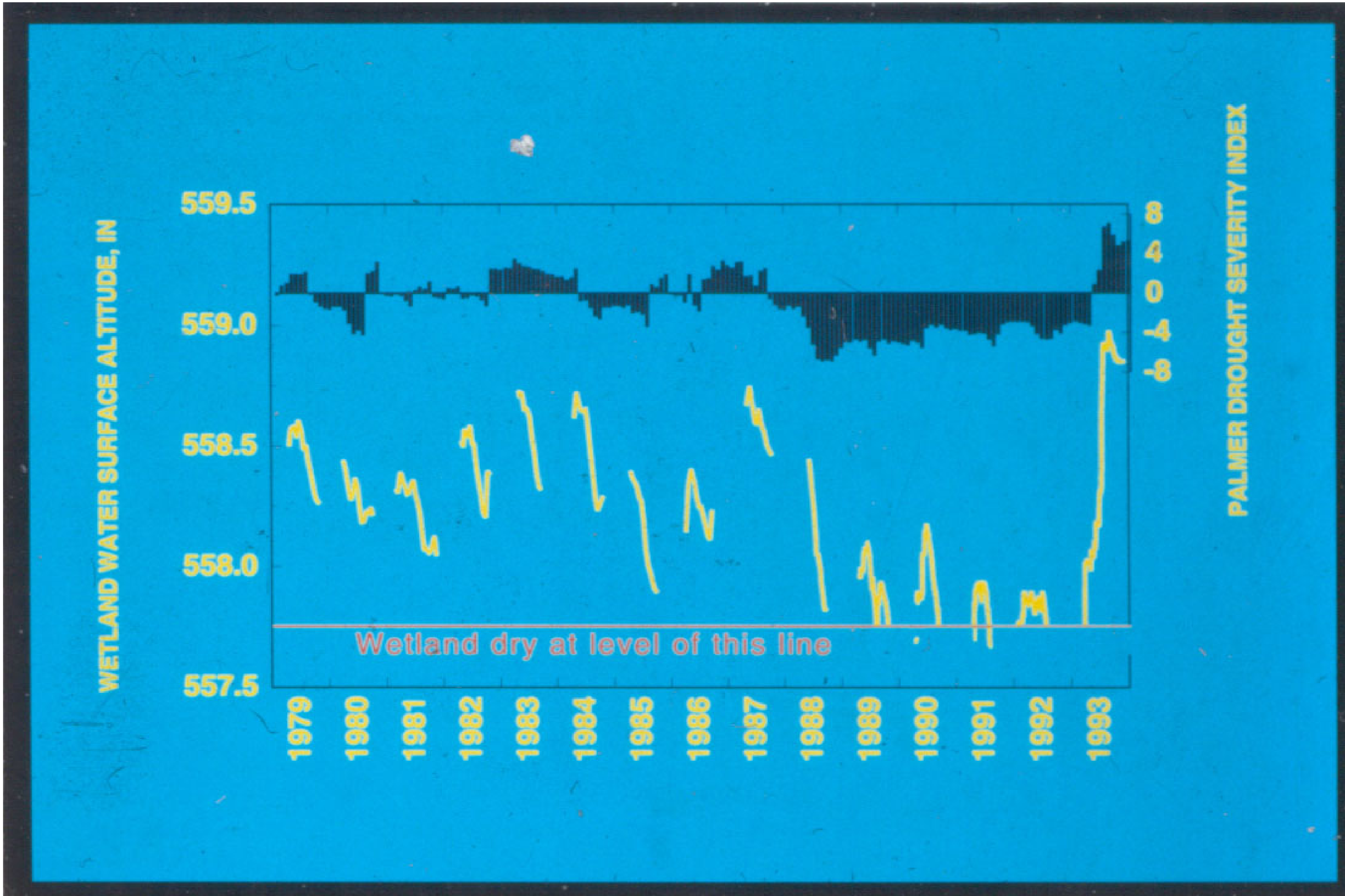
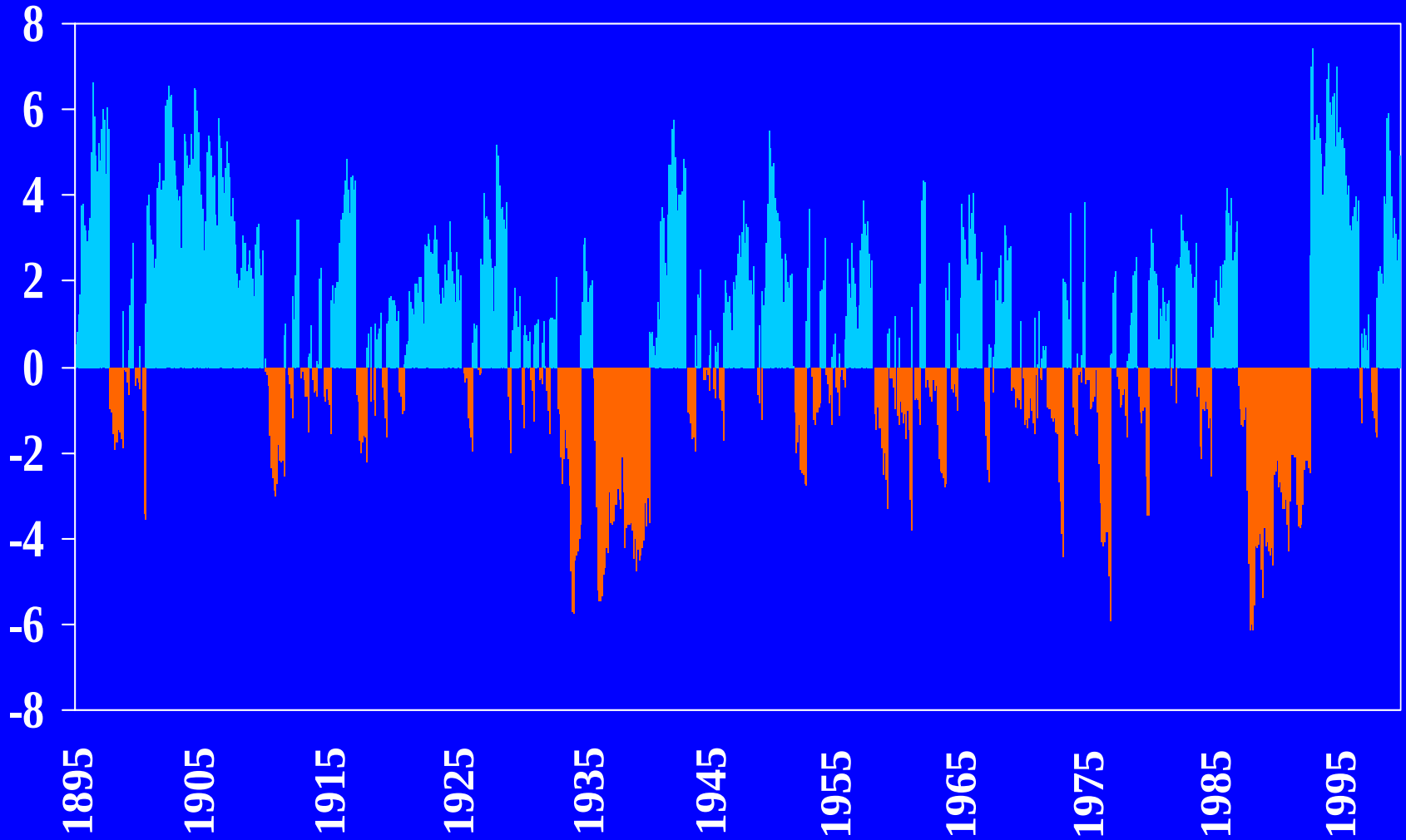


WETLAND WATER SURFACE ALTITUDE, IN
559.5
559.0
558.5
558.0
557.5
PALMER DROUGHT SEVERITY INDEX
8
4
0
-4
-8
Wetland dry at level of this line
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993

Palmer Drought Severity Index, Division 5, ND (1895 to 2000)



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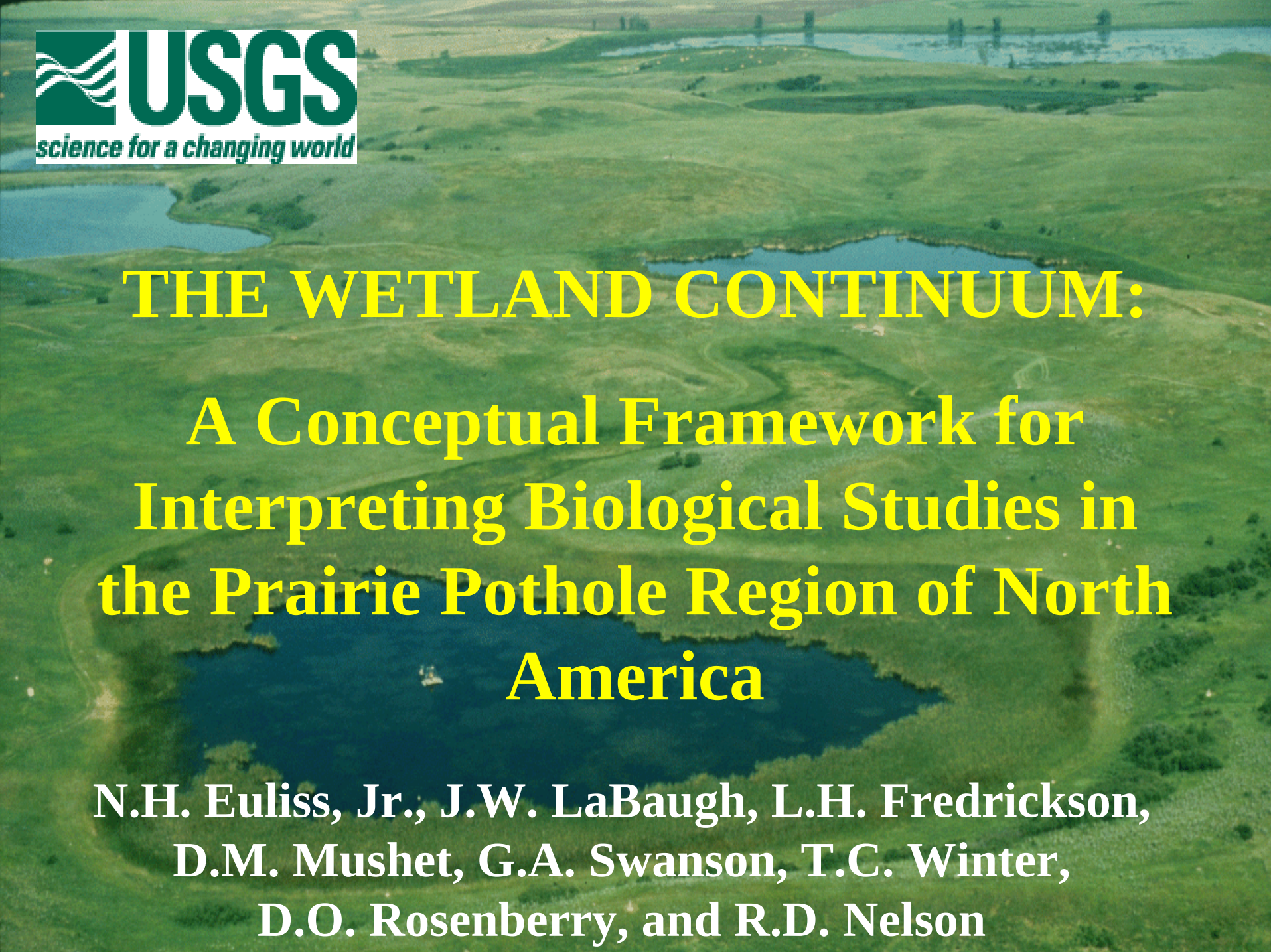
Hydrological, chemical, and biological characteristics of a prairie pothole wetland complex under highly variable climate conditions: The Cottonwood Lake area, east-central North Dakota

U.S. Geological Survey Professional Paper 1675
2003



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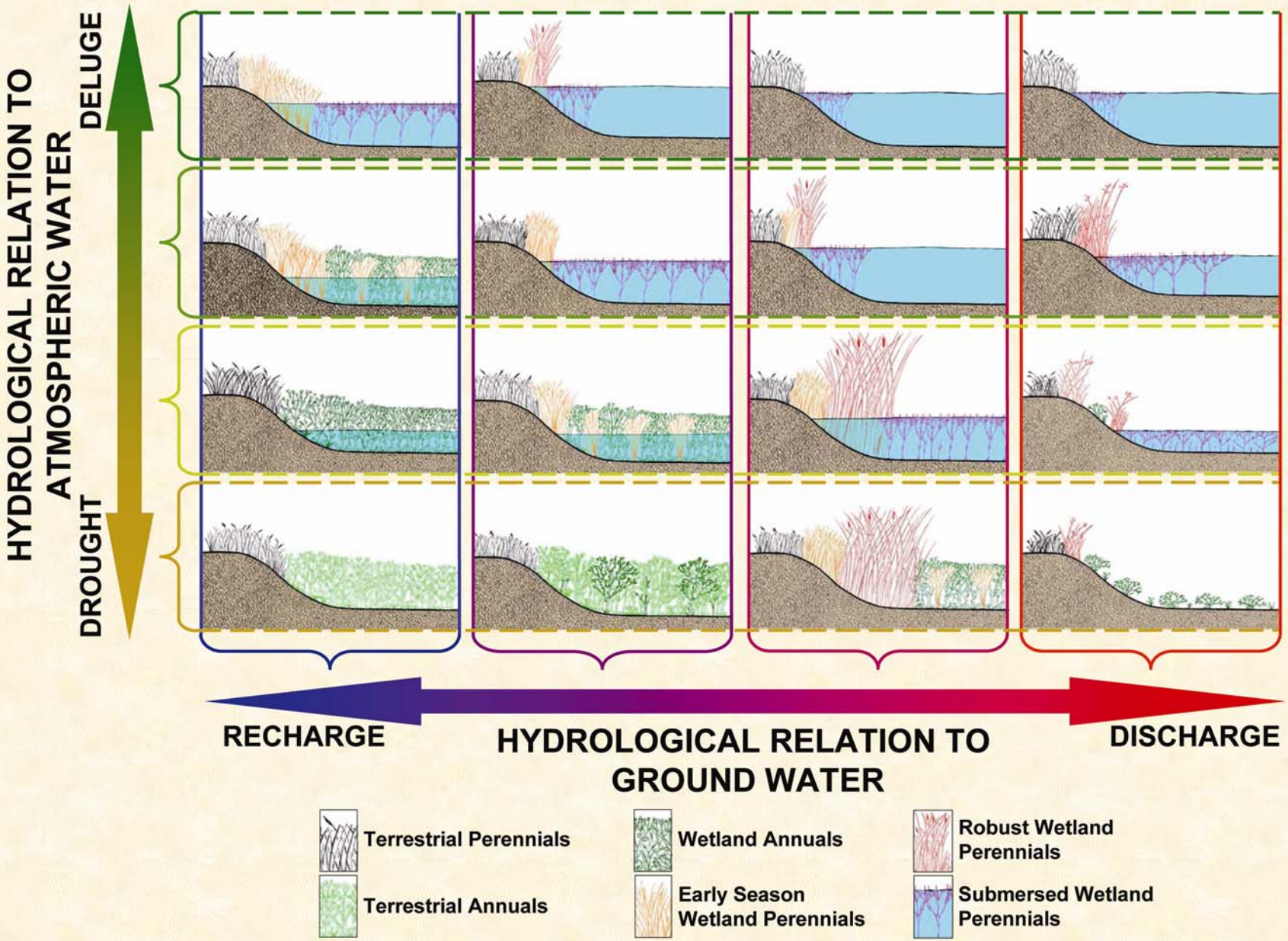
science for a changing world

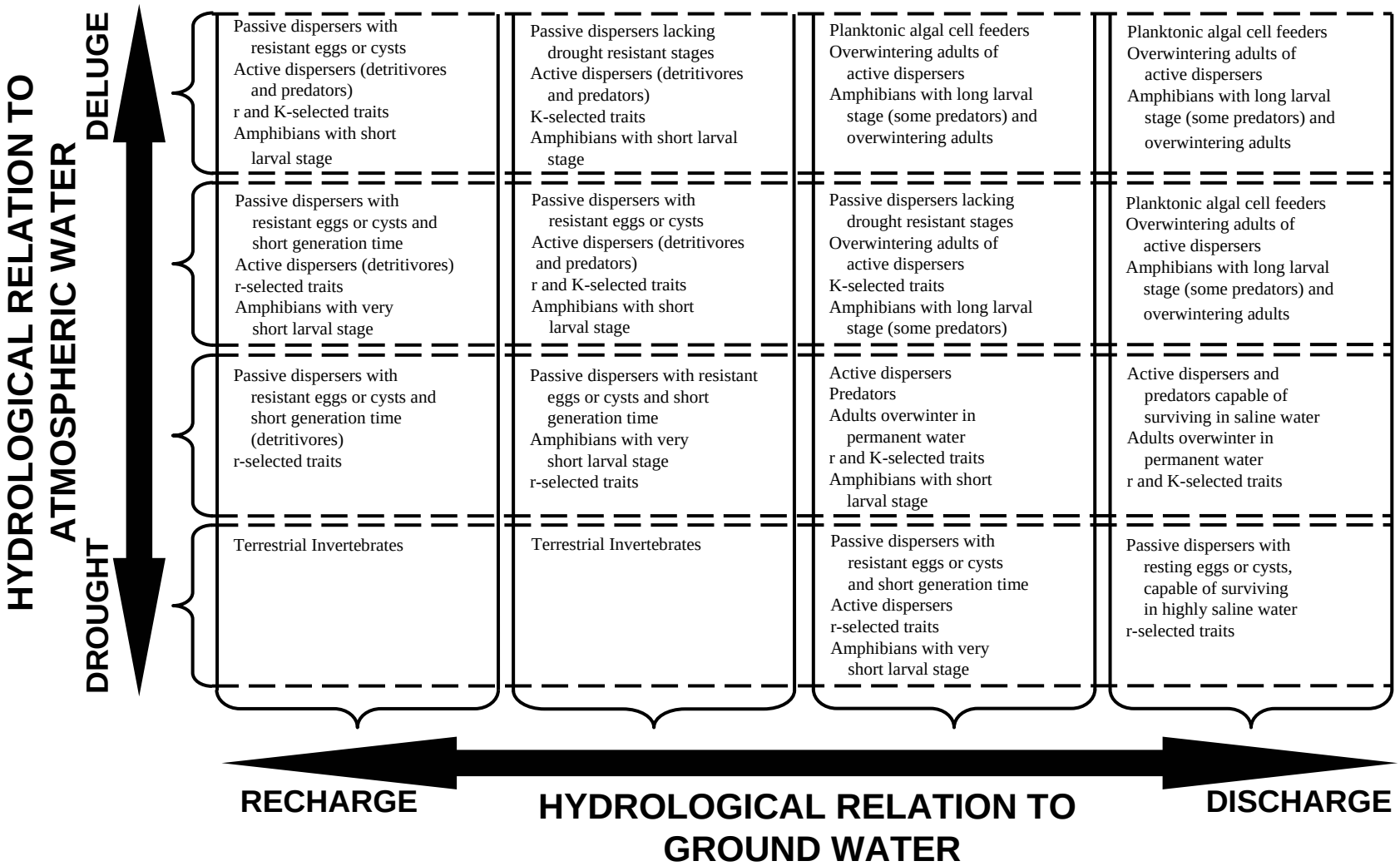
THE WETLAND CONTINUUM:

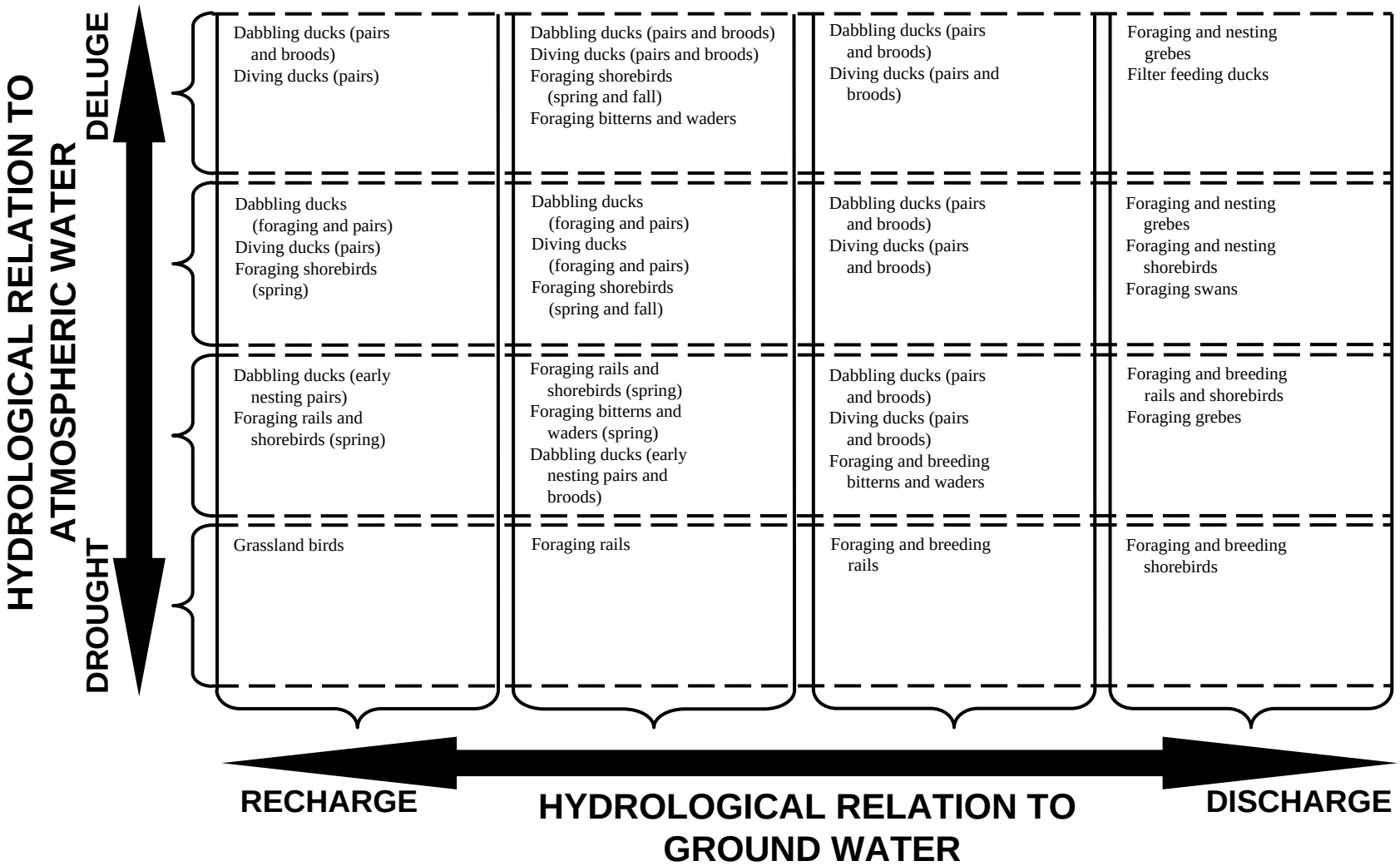
A Conceptual Framework for Interpreting Biological Studies in the Prairie Pothole Region of North America

N.H. Euliss, Jr., J.W. LaBaugh, L.H. Fredrickson, D.M. Mushet, G.A. Swanson, T.C. Winter, D.O. Rosenberry, and R.D. Nelson

THE WETLAND CONTINUUM




HYDROLOGICAL RELATION TO ATMOSPHERIC WATER
DELUGE
DROUGHT
Passive dispersers with resistant eggs or cysts
Active dispersers (detritivores and predators)
r and K-selected traits
Amphibians with short larval stage
Passive dispersers lacking drought resistant stages
Active dispersers (detritivores and predators)
K-selected traits
Amphibians with short larval stage
Planktonic algal cell feeders
Overwintering adults of active dispersers
Amphibians with long larval stage (some predators) and overwintering adults
Planktonic algal cell feeders
Overwintering adults of active dispersers
Amphibians with long larval stage (some predators) and overwintering adults
Passive dispersers with resistant eggs or cysts and short generation time
Active dispersers (detritivores)
r-selected traits
Amphibians with very short larval stage
Passive dispersers with resistant eggs or cysts
Active dispersers (detritivores and predators)
r and K-selected traits
Amphibians with short larval stage
Passive dispersers lacking drought resistant stages
Overwintering adults of active dispersers
K-selected traits
Amphibians with long larval stage (some predators)
Planktonic algal cell feeders
Overwintering adults of active dispersers
Amphibians with long larval stage (some predators) and overwintering adults
Passive dispersers with resistant eggs or cysts and short generation time (detritivores)
r-selected traits
Passive dispersers with resistant eggs or cysts and short generation time
Amphibians with very short larval stage
r-selected traits
Active dispersers
Predators
Adults overwinter in permanent water
r and K-selected traits
Amphibians with short larval stage
Active dispersers and predators capable of surviving in saline water
Adults overwinter in permanent water
r and K-selected traits
Terrestrial Invertebrates
Terrestrial Invertebrates
Passive dispersers with resistant eggs or cysts and short generation time
Active dispersers
r-selected traits
Amphibians with very short larval stage
Passive dispersers with resting eggs or cysts, capable of surviving in highly saline water
r-selected traits
RECHARGE
HYDROLOGICAL RELATION TO GROUND WATER
DISCHARGE


HYDROLOGICAL RELATION TO ATMOSPHERIC WATER
DELUGE
DROUGHT
Dabbling ducks (pairs and broods)
Diving ducks (pairs)
Dabbling ducks (pairs and broods)
Diving ducks (pairs and broods)
Foraging shorebirds (spring and fall)
Foraging bitterns and waders
Dabbling ducks (pairs and broods)
Diving ducks (pairs and broods)
Foraging and nesting grebes
Filter feeding ducks
Dabbling ducks (foraging and pairs)
Diving ducks (pairs)
Foraging shorebirds (spring)
Dabbling ducks (foraging and pairs)
Diving ducks (foraging and pairs)
Foraging shorebirds (spring and fall)
Dabbling ducks (pairs and broods)
Diving ducks (pairs and broods)
Foraging and nesting grebes
Foraging and nesting shorebirds
Foraging swans
Dabbling ducks (early nesting pairs)
Foraging rails and shorebirds (spring)
Foraging rails and shorebirds (spring)
Foraging bitterns and waders (spring)
Dabbling ducks (early nesting pairs and broods)
Dabbling ducks (pairs and broods)
Diving ducks (pairs and broods)
Foraging and breeding bitterns and waders
Foraging and breeding rails and shorebirds
Foraging grebes
Grassland birds
Foraging rails
Foraging and breeding rails
Foraging and breeding shorebirds
RECHARGE
HYDROLOGICAL RELATION TO GROUND WATER
DISCHARGE

The presence of seed banks and egg banks are important to the functioning of these types of ecosystems, and to the wetland continuum concept

The wetland continuum: A conceptual framework for interpreting biological studies

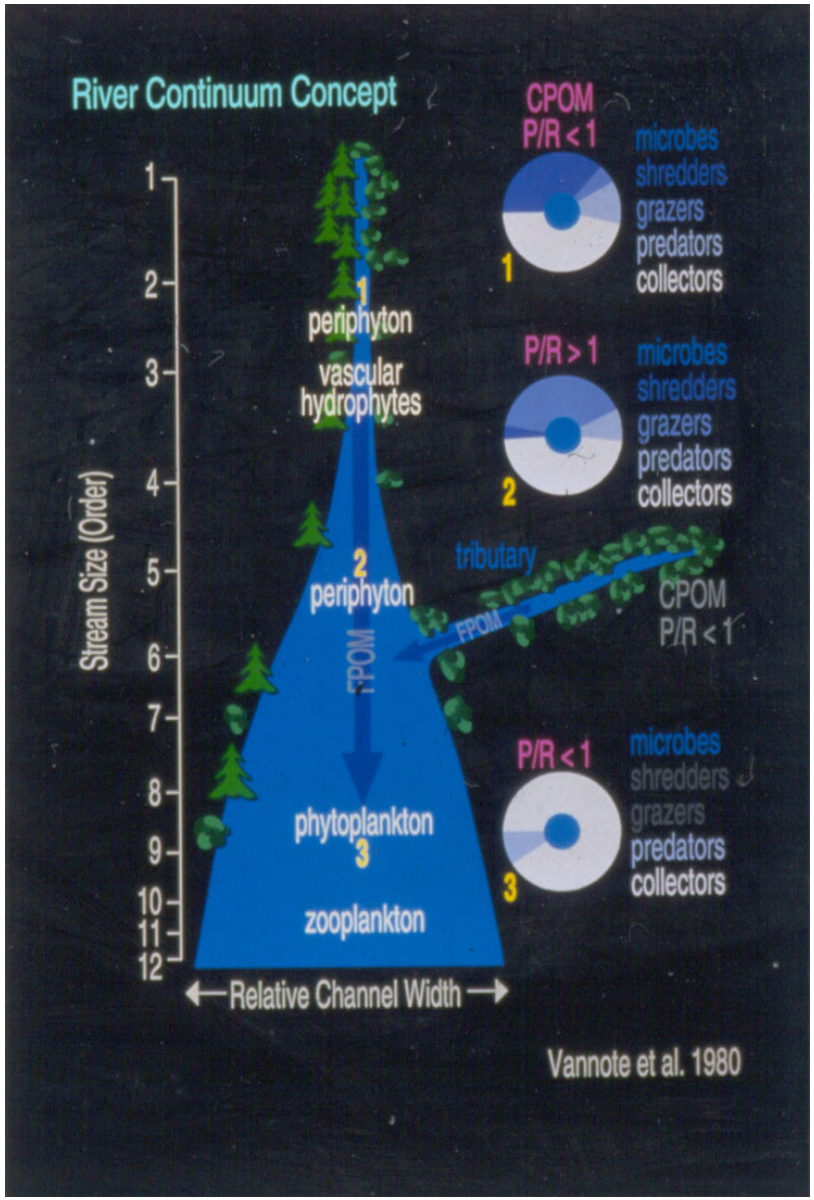
Euliss, LaBaugh, Fredrickson, Mushet, Laubhan, Swanson, Winter, Rosenberry, Nelson

Wetlands, in press

The River Continuum Concept

Vannote, Minshall, Cummins, Sedell, Cushing, 1980,
Canadian Journal of Fisheries and Aquatic Science

Slide 1

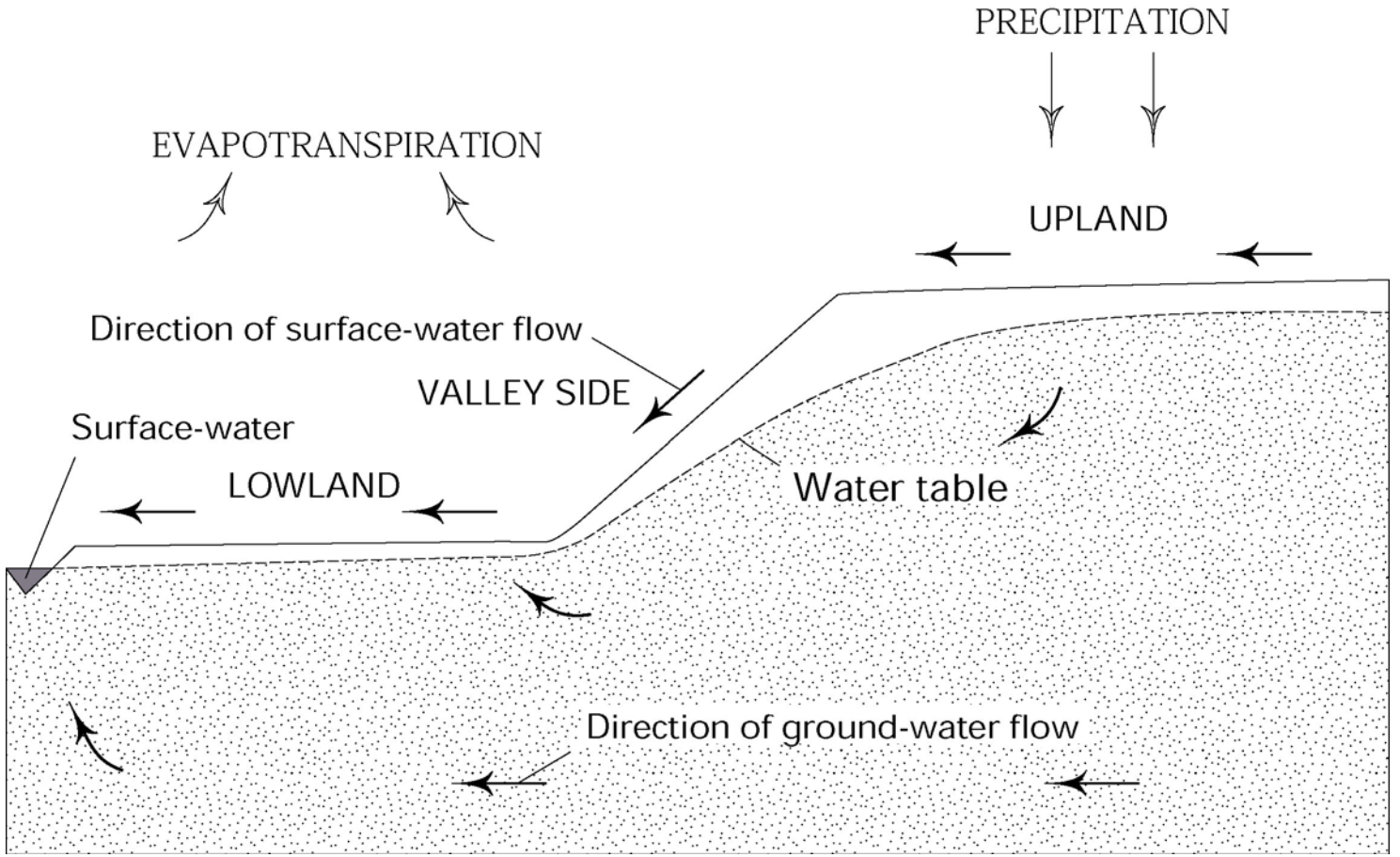

River Continuum Concept
CPOM
P/R < 1
microbes
shredders
grazers
predators
collectors
1
periphyton
vascular
hydrophytes
P/R > 1
microbes
shredders
grazers
predators
collectors
2
tributary
2
periphyton
FPOM
CPOM
P/R < 1
FPOM
P/R < 1
microbes
shredders
grazers
predators
collectors
3
phytoplankton
3
zooplankton
Stream Size (Order)
1
2
3
4
5
6
7
8
9
10
11
12
Relative Channel Width
Vannote et al. 1980

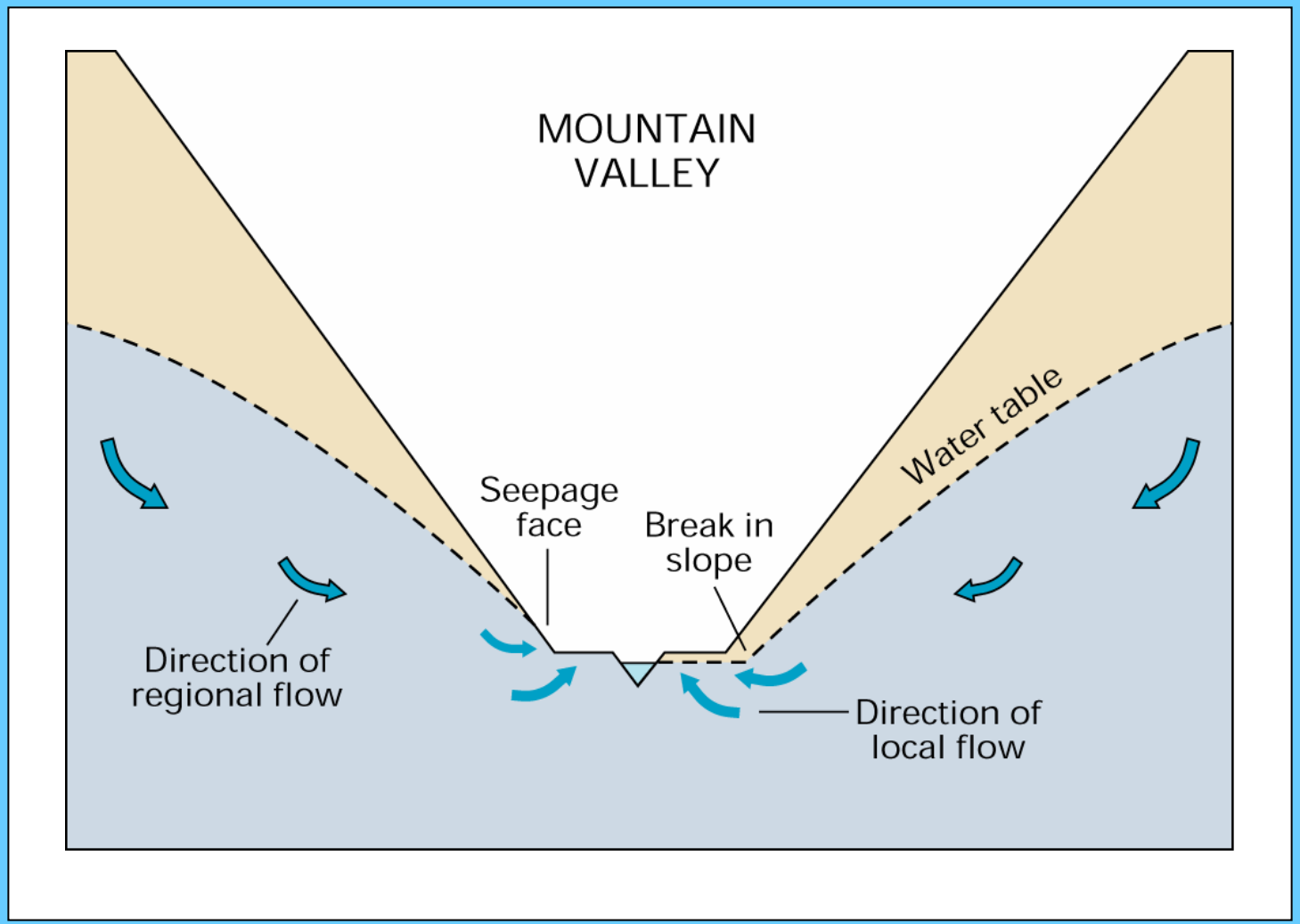
The Concept of Hydrologic Landscapes

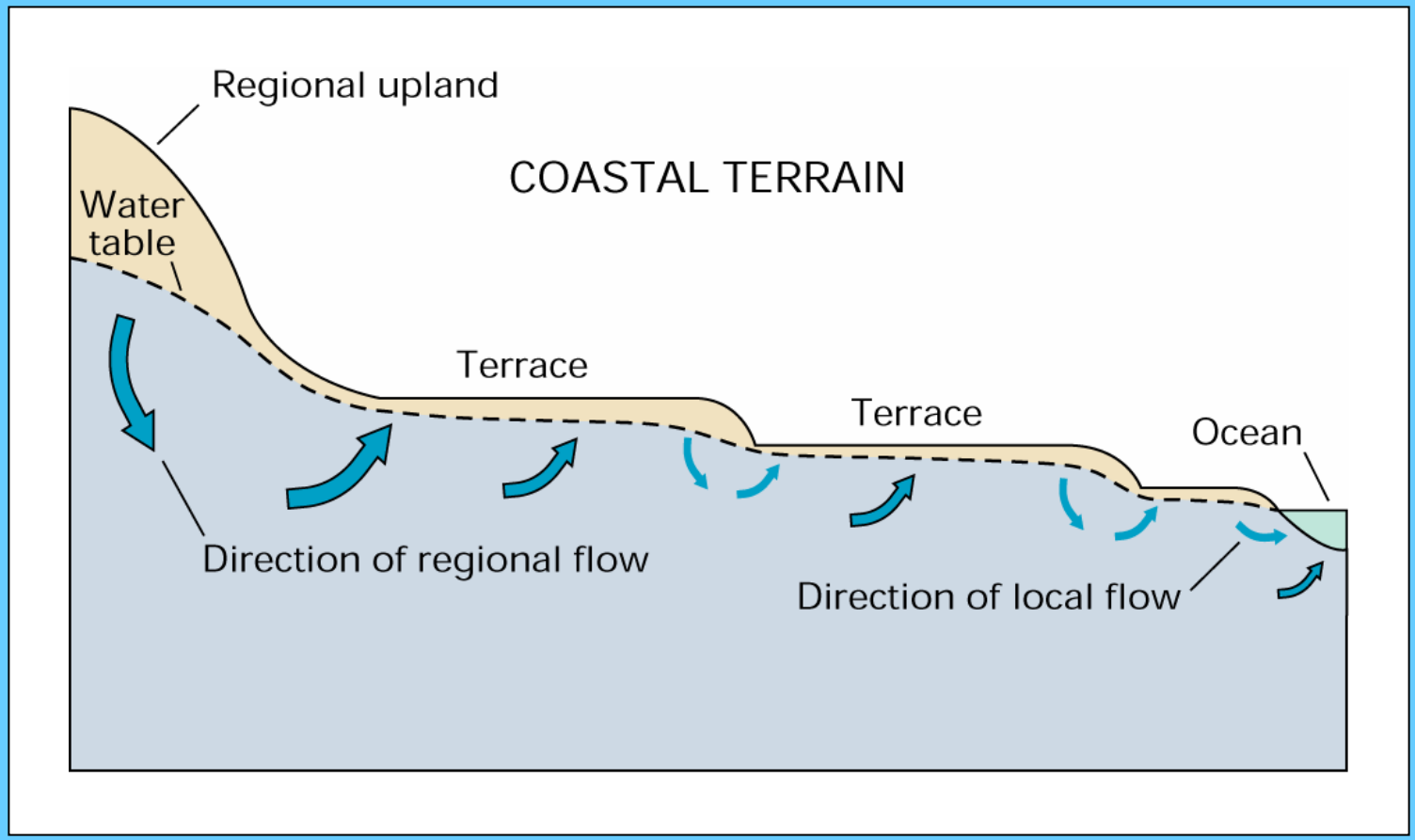
Winter, 2001,
Jour. Amer. Water Resour. Assn.

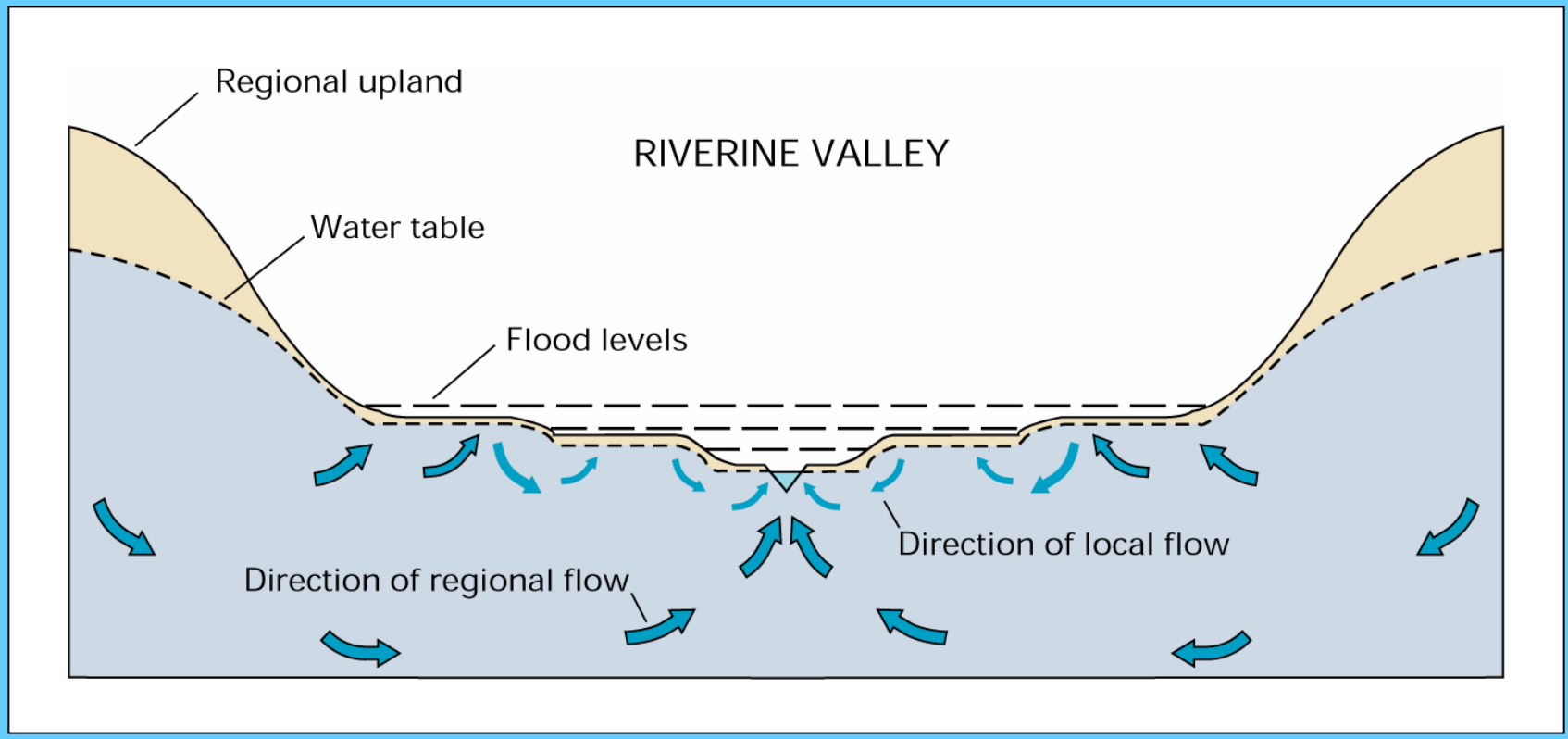
Hydrologic landscapes:

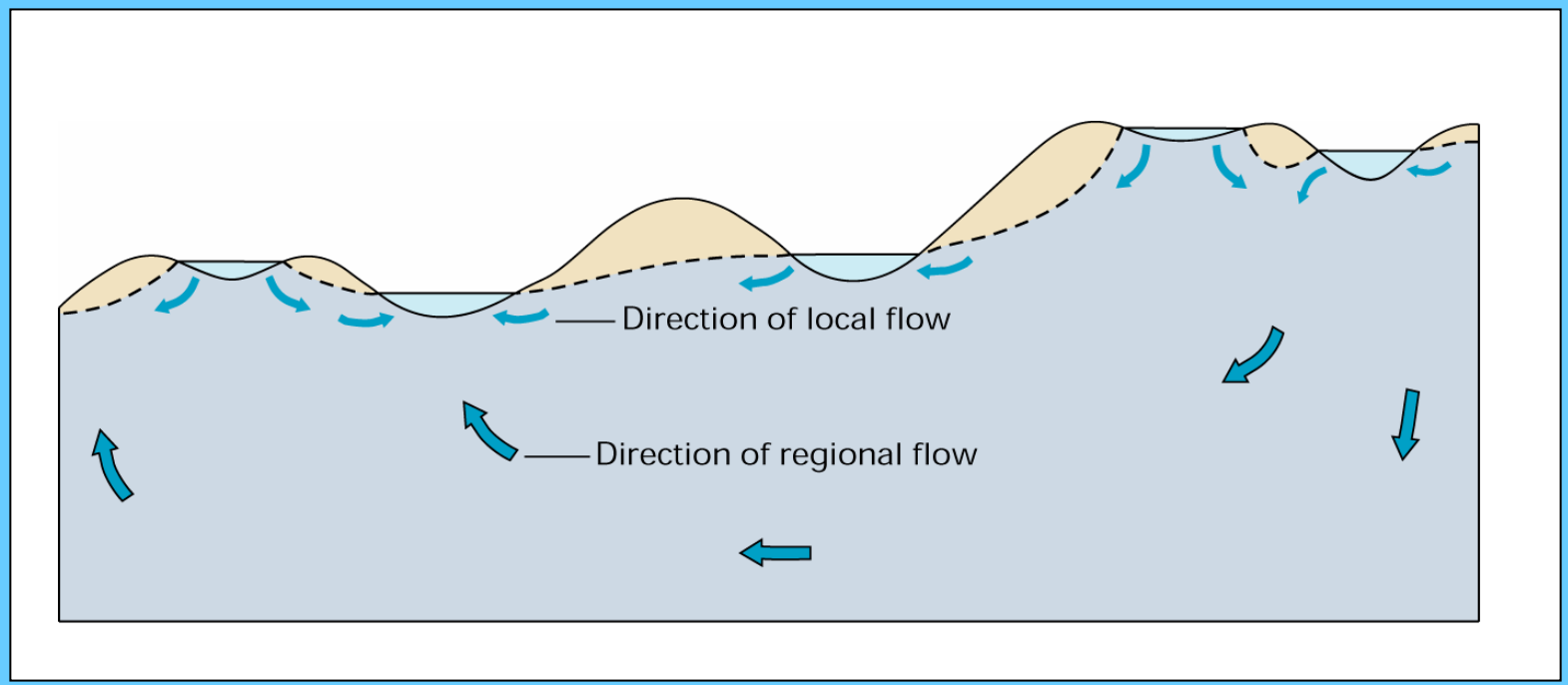
A combination of natural factors (hydroclimate, aquifer, soils, and topography) expected to affect hydrologic transport processes




MOUNTAIN
VALLEY
Water table
Seepage
face
Break in
slope
Direction of
regional flow
Direction of
local flow

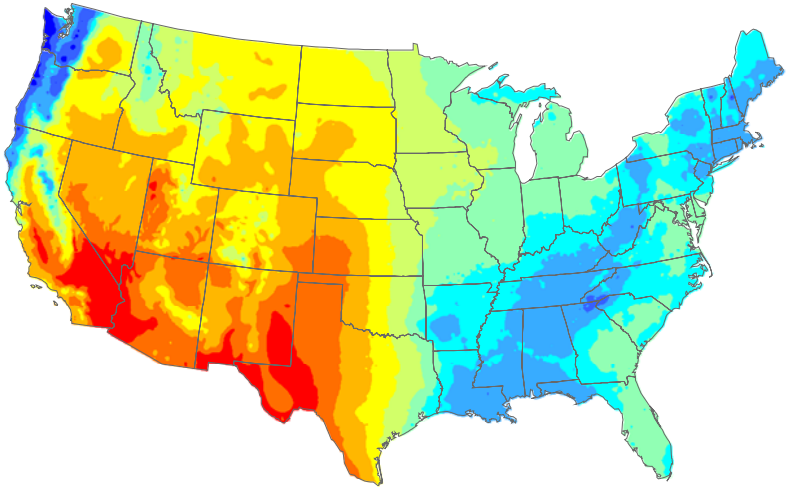

Regional upland
COASTAL TERRAIN
Water table
Terrace
Terrace
Ocean
Direction of regional flow
Direction of local flow


Regional upland
RIVERINE VALLEY
Water table
Flood levels
Direction of local flow
Direction of regional flow

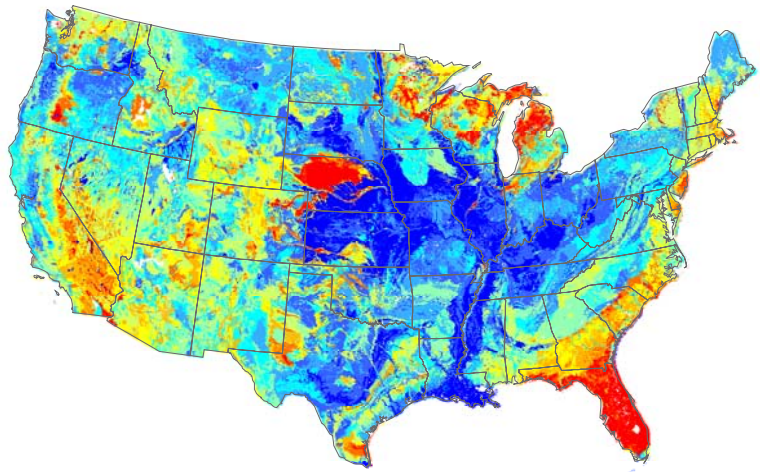

Direction of local flow
Direction of regional flow

Factors used to define hydrologic landscape regions

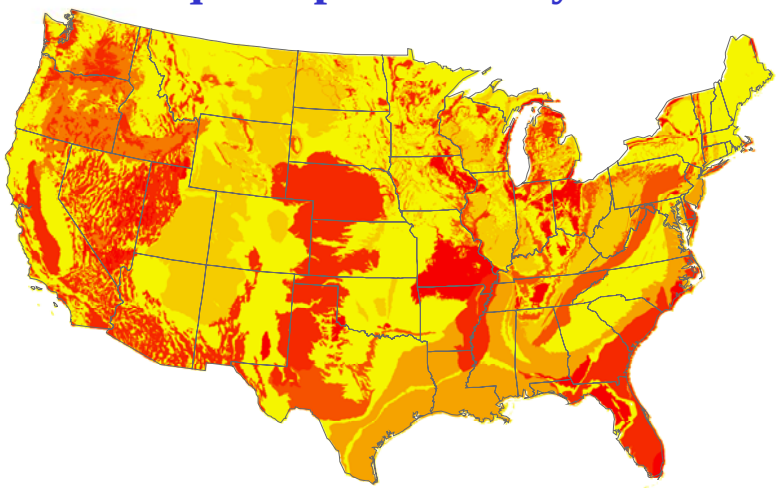
Precip – Potential evapotranspiration



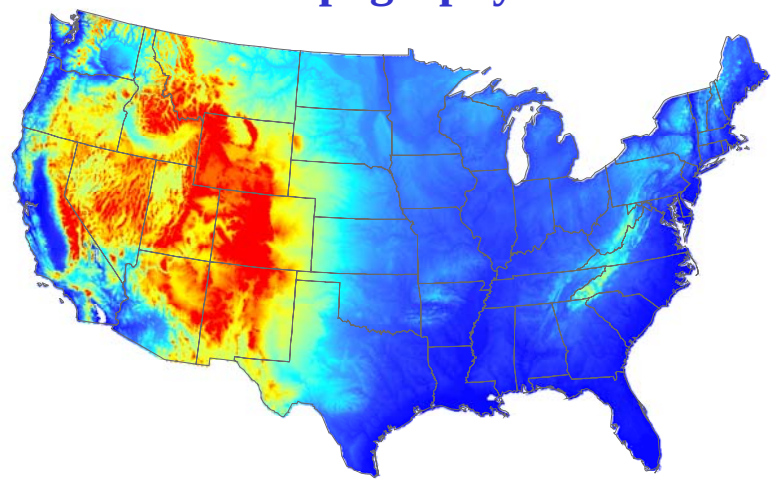
Percent sand



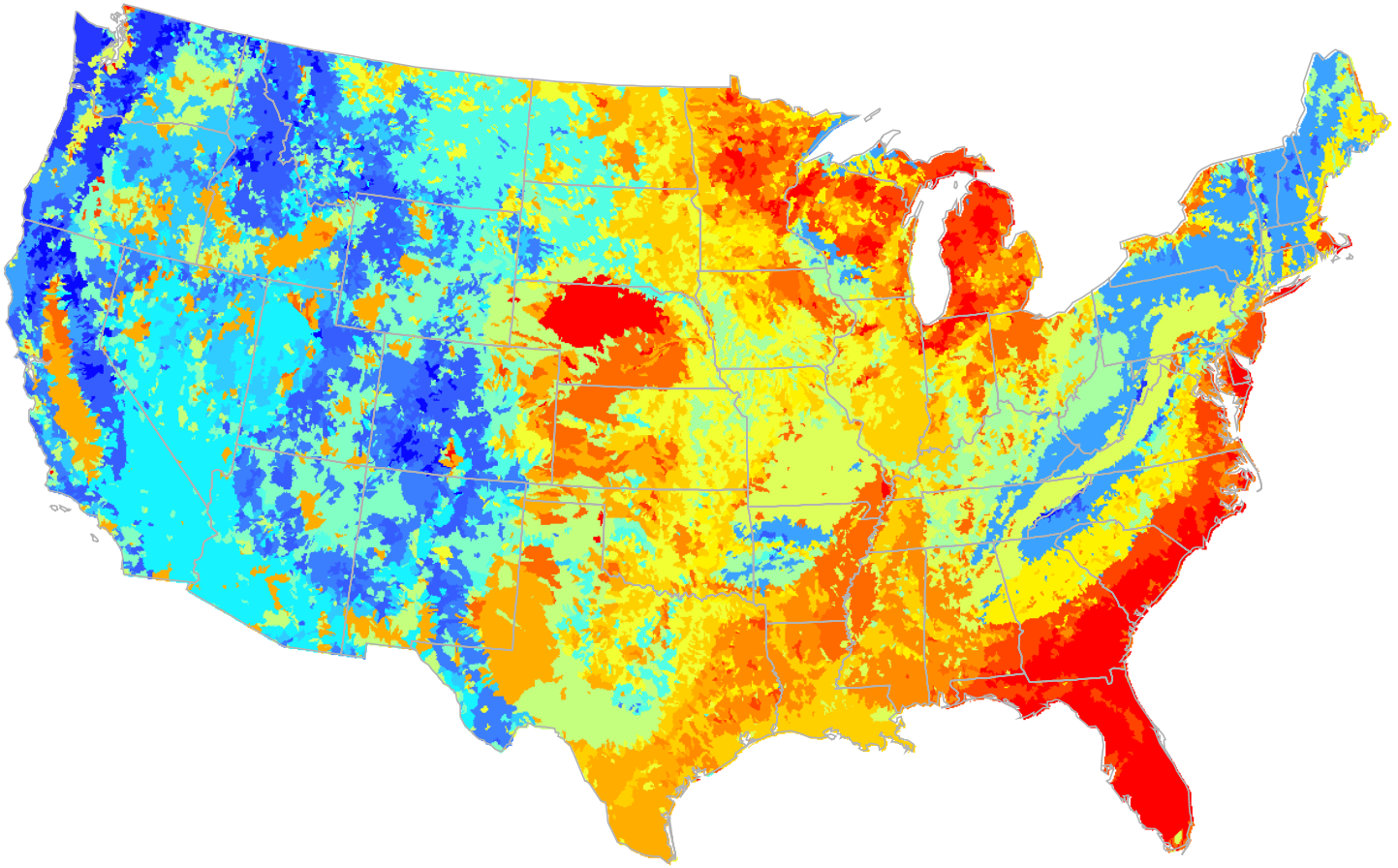
Aquifer permeability



Topography



Hydrologic landscape regions



- A statistical clustering (20) of the factors that define hydrologic landscapes
- Among-region variability in the factors is maximized and within-region variability is minimized

Delineation and evaluation of hydrologic-landscape regions in the United States using GIS tools and multivariate statistical analyses

Wolock, Winter, McMahon

Environmental Management, in press

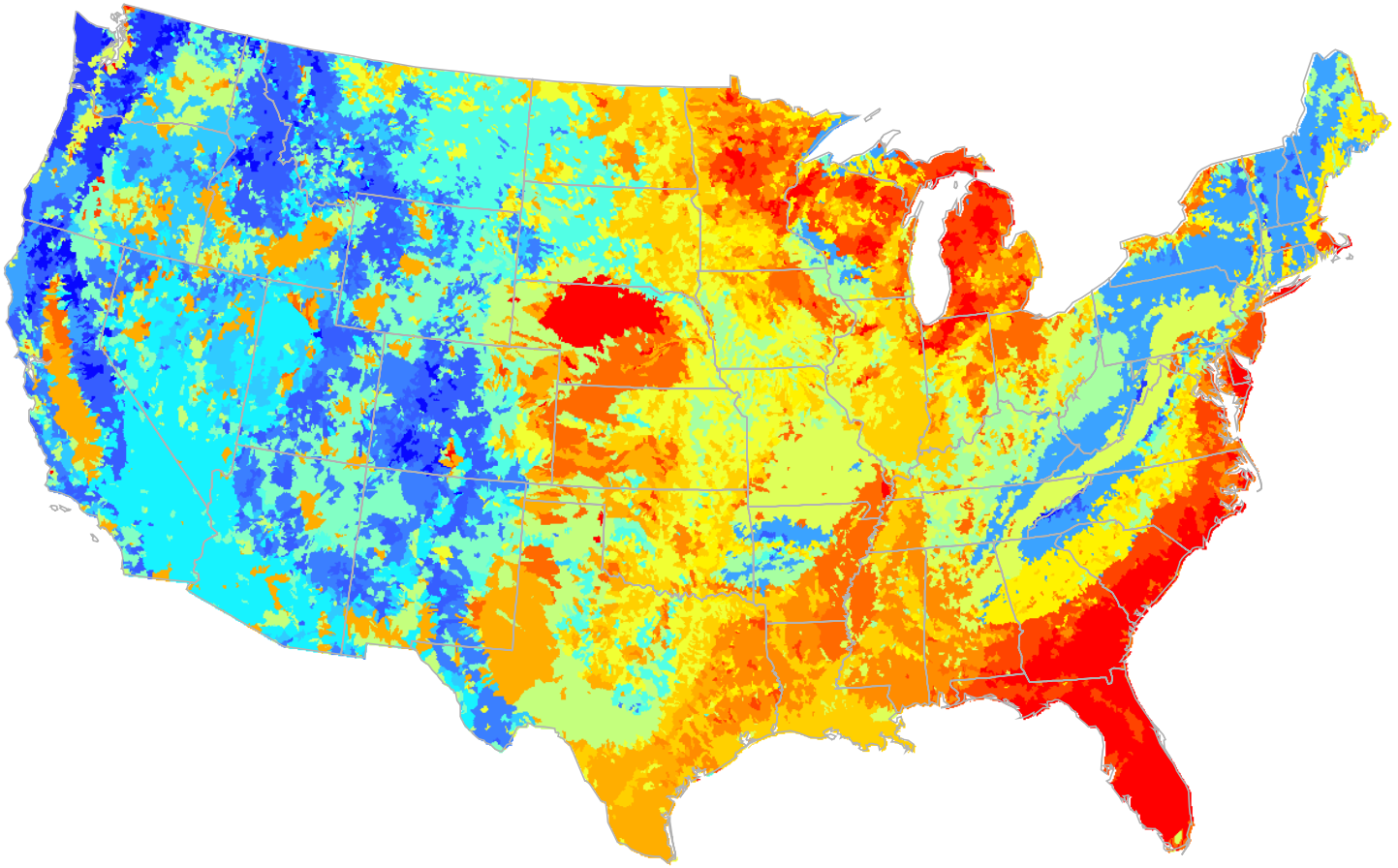
Landscape 1 – variably wet plains, having highly permeable surface deposits and highly permeable bedrock

The flat and highly permeable land surface in this landscape results in ground water being the dominant component of the hydrologic system. Recharge to local and regional ground-water flow systems is high and surface runoff is minimal. A major water issue in this landscape is likely to be contamination of both local and regional ground water. The extensive ground-water systems should help buffer aquatic systems against climate variability. This landscape is likely to have extensive irrigation.

Landscape 6 – Wet plains having poorly permeable surface and poorly permeable bedrock

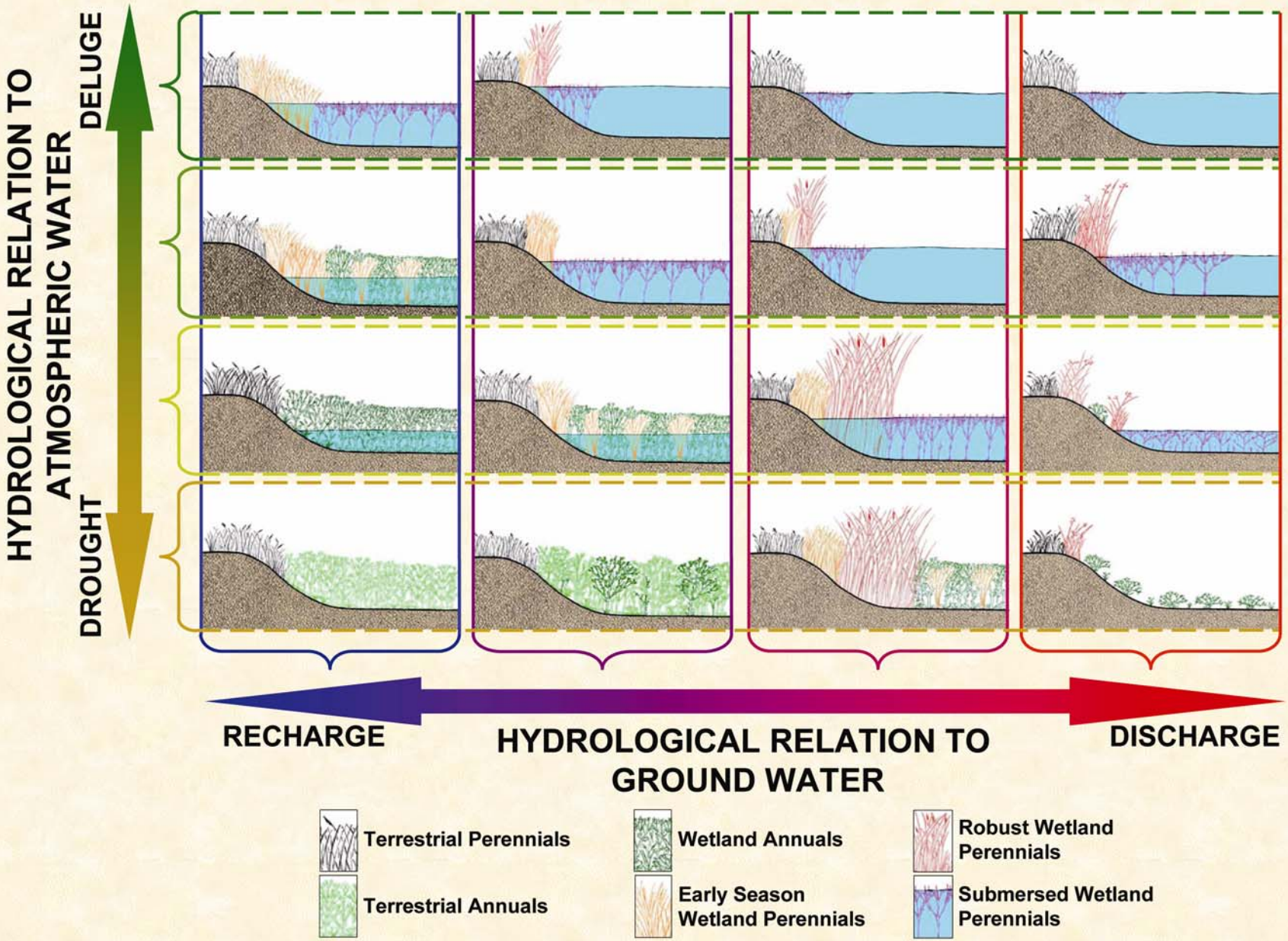
The poorly permeable surface deposits in this landscape results in surface water being the dominant component of the hydrologic system. Recharge to ground water is limited. Major water issues in this landscape are likely to be surface water contamination and flooding because of the flat land surface. The minimal influence of ground water buffering is likely to make aquatic systems greatly affected by climate variability. This landscape is likely to have extensive tile drains.

Hydrologic landscape regions

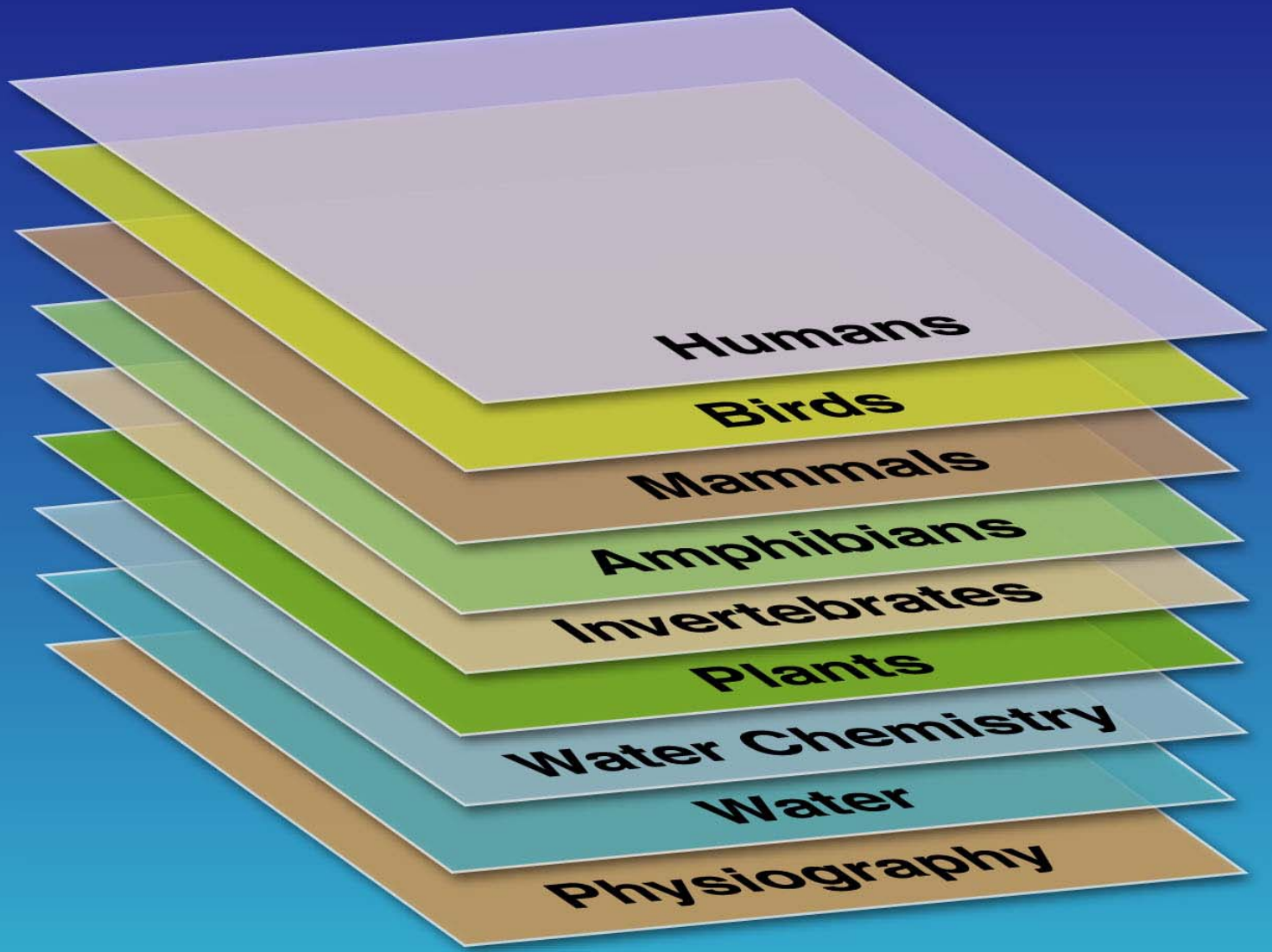


- A statistical clustering (20) of the factors that define hydrologic landscapes
- Among-region variability in the factors is maximized and within-region variability is minimized

THE WETLAND CONTINUUM



The Aquatic System Continuum



This information suggests that we characterize aquatic ecosystems; ie., their structure and function, in the context of their position within water and geochemical flow paths in the various hydrologic landscapes. In addition, to capture their response to climate variability, we must monitor the ecosystems over time.

With respect to streams, they occur in all landscapes and many cross hydrologic landscapes. Streams interact with ground water differently in different hydrologic landscapes. These interactions need to be factored into the river continuum concept in order for it to be useful for describing aquatic system continuums for streams.

The Aquatic Systems Continuum

A conceptual framework for setting research priorities, long-term monitoring, environmental management, and assessing and predicting the effect of climate variability and human activities on aquatic ecosystems