US Army Corps
of Engineers

Detroit District

Long-term Sediment Delivery - St. Joseph River

EASTMAN SPRINGS.
BENTON HARBOR, MICH.
1889.
LOOKING NORTH WEST.

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Study Objectives

- Application of SWAT model to examine sediment yield over last 175 years and examine trapping efficiency of federal harbor

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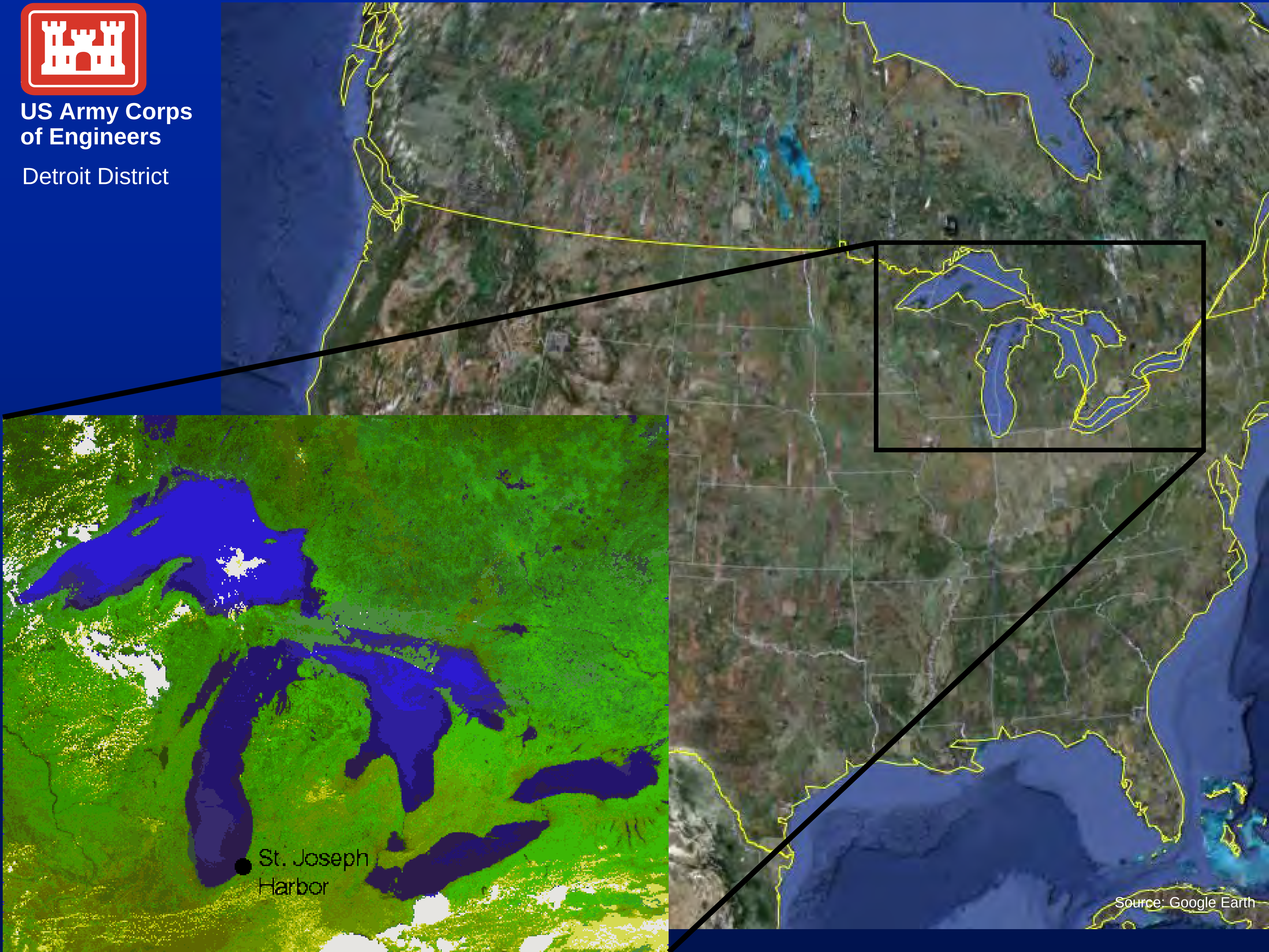
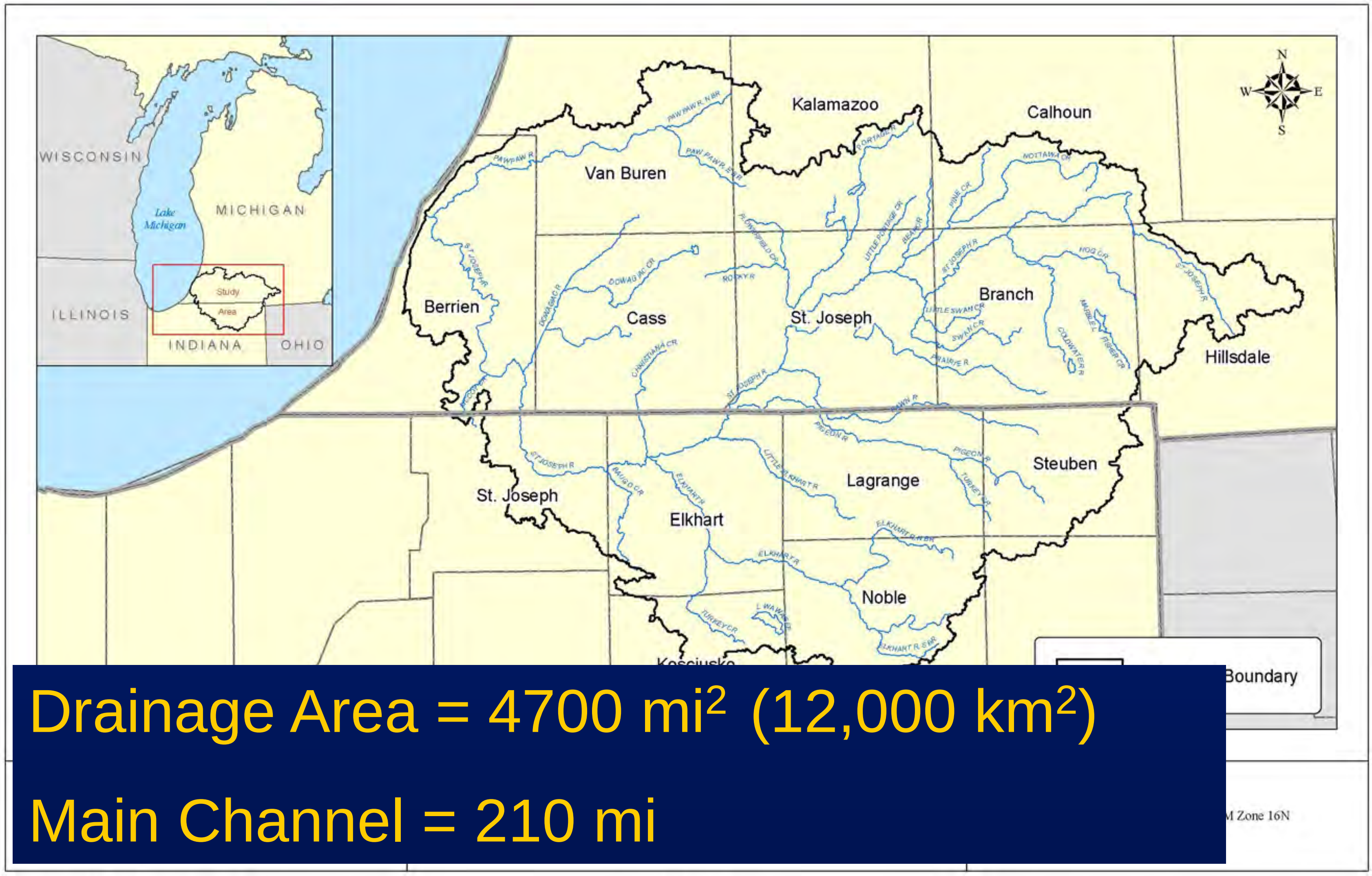

St. Joseph Harbor

Source: Google Earth

Watershed Location and Drainage Area

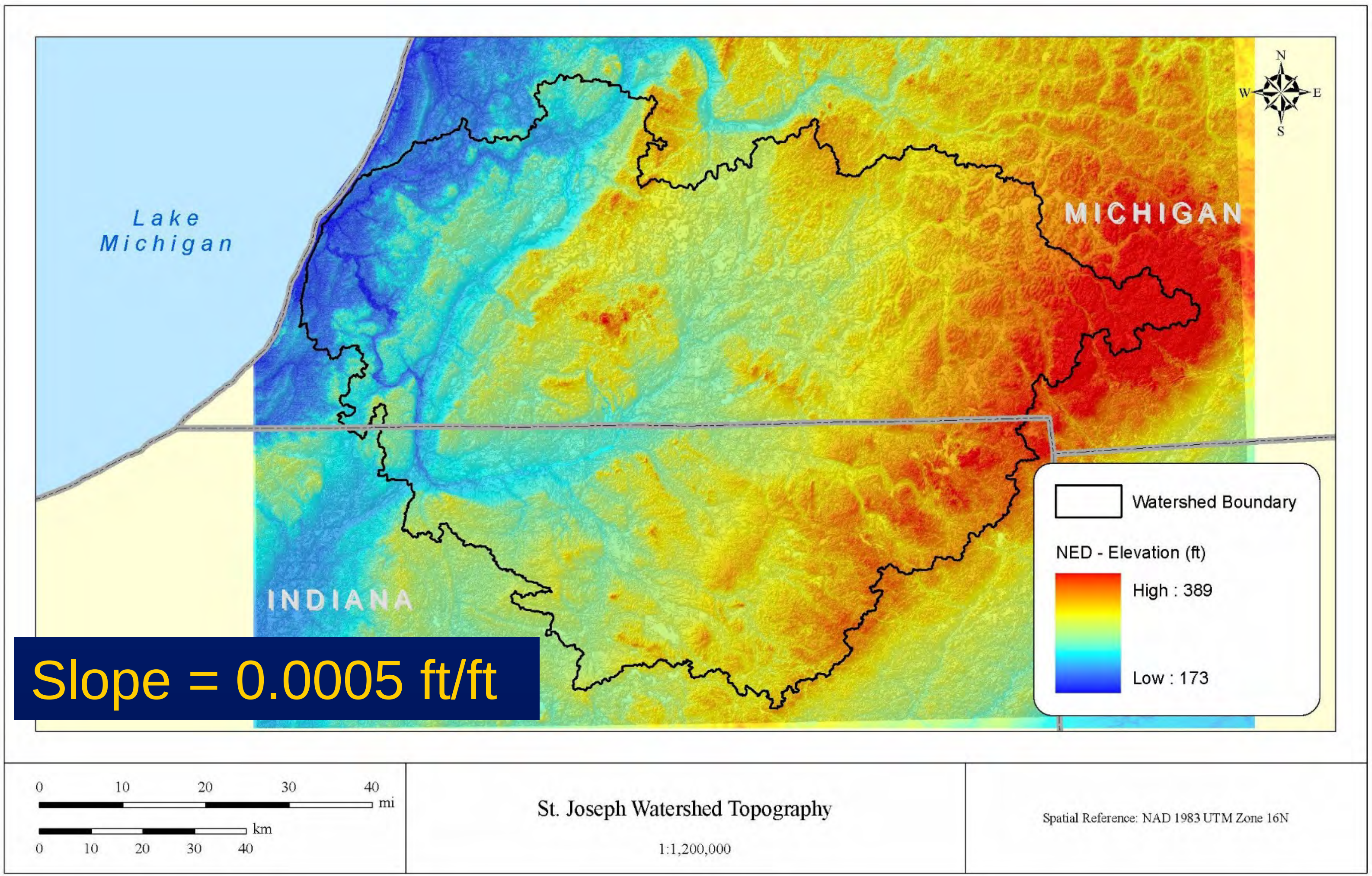

WISCONSIN
MICHIGAN
Lake Michigan
Study Area
ILLINOIS
INDIANA
OHIO
N
W
E
S
Kalamazoo
Calhoun
Van Buren
Berrien
Cass
St. Joseph
Branch
Hillsdale
St. Joseph
Elkhart
Lagrange
Steuben
Noble
Kosciusko
Boundary
M Zone 16N

Drainage Area = 4700 mi^2 (12,000 km^2)

Main Channel = 210 mi

Source: USACE, Detroit

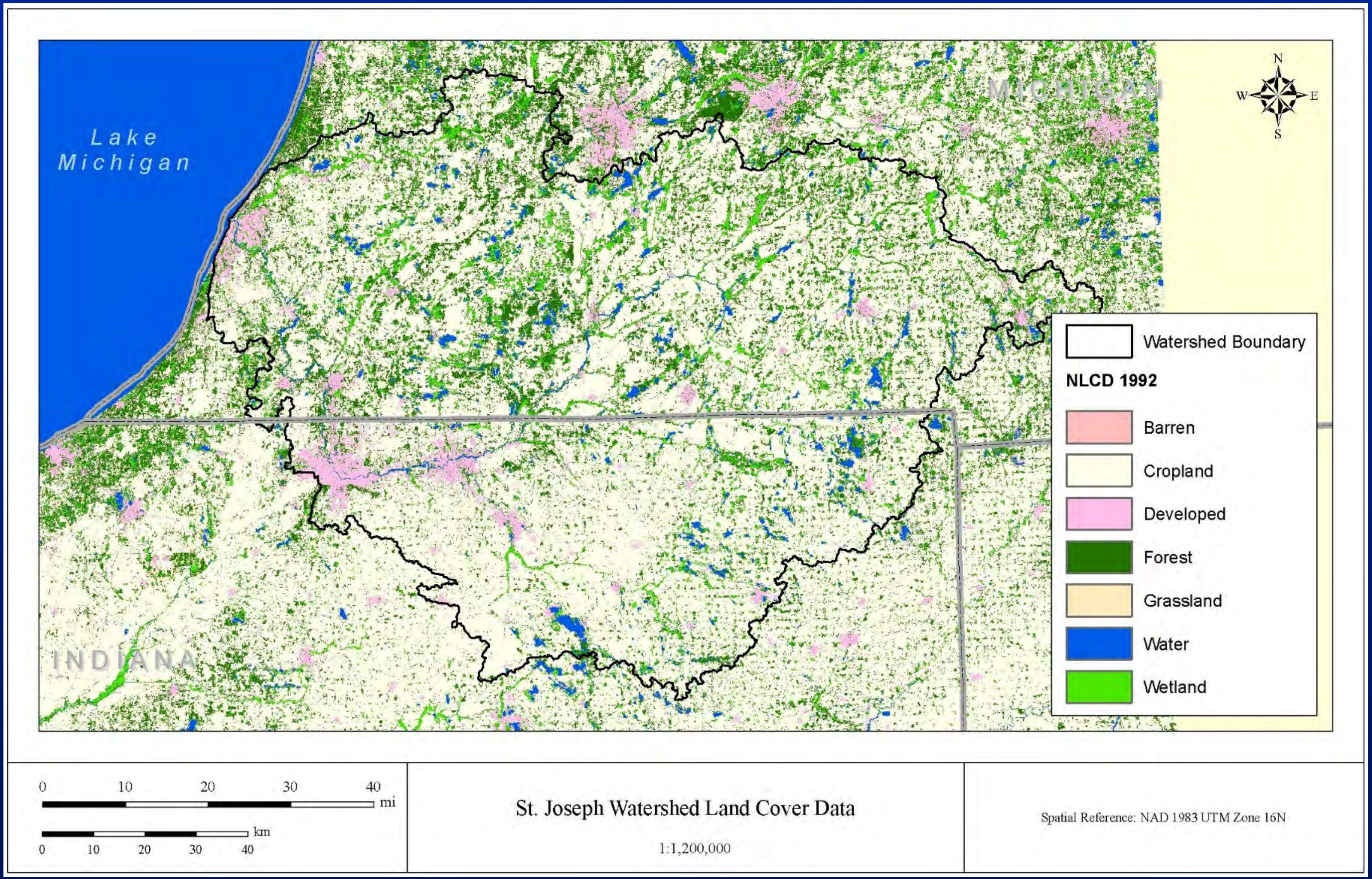
Watershed Topography


Lake Michigan
MICHIGAN
INDIANA
N
W
E
S
Watershed Boundary
NED - Elevation (ft)
High : 389
Low : 173
0 10 20 30 40 mi
0 10 20 30 40 km
St. Joseph Watershed Topography
1:1,200,000
Spatial Reference: NAD 1983 UTM Zone 16N

Slope = 0.0005 ft/ft

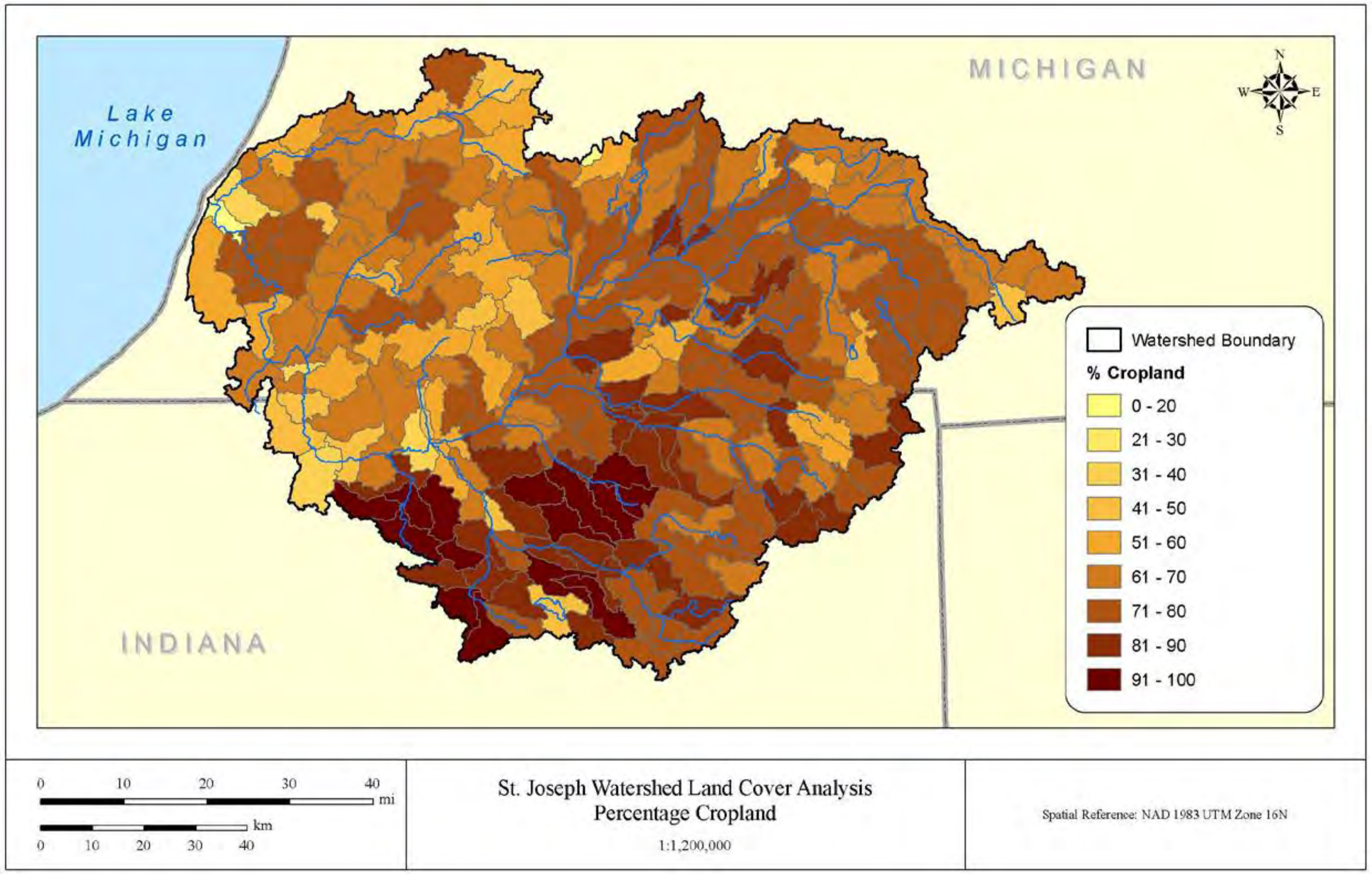
Source: USACE, Detroit

Land Cover -1992


Lake Michigan
MICHIGAN
INDIANA
N
W
E
S
Watershed Boundary
NLCD 1992
Barren
Cropland
Developed
Forest
Grassland
Water
Wetland
0 10 20 30 40 mi
0 10 20 30 40 km
St. Joseph Watershed Land Cover Data
1:1,200,000
Spatial Reference: NAD 1983 UTM Zone 16N

Source: USACE, Detroit

Distribution of Cropland


Lake Michigan
MICHIGAN
INDIANA
N
W
E
S
Watershed Boundary
% Cropland
0 - 20
21 - 30
31 - 40
41 - 50
51 - 60
61 - 70
71 - 80
81 - 90
91 - 100
0
10
20
30
40
mi
km
0
10
20
30
40
St. Joseph Watershed Land Cover Analysis
Percentage Cropland
1:1,200,000
Spatial Reference: NAD 1983 UTM Zone 16N

Source: USACE, Detroit

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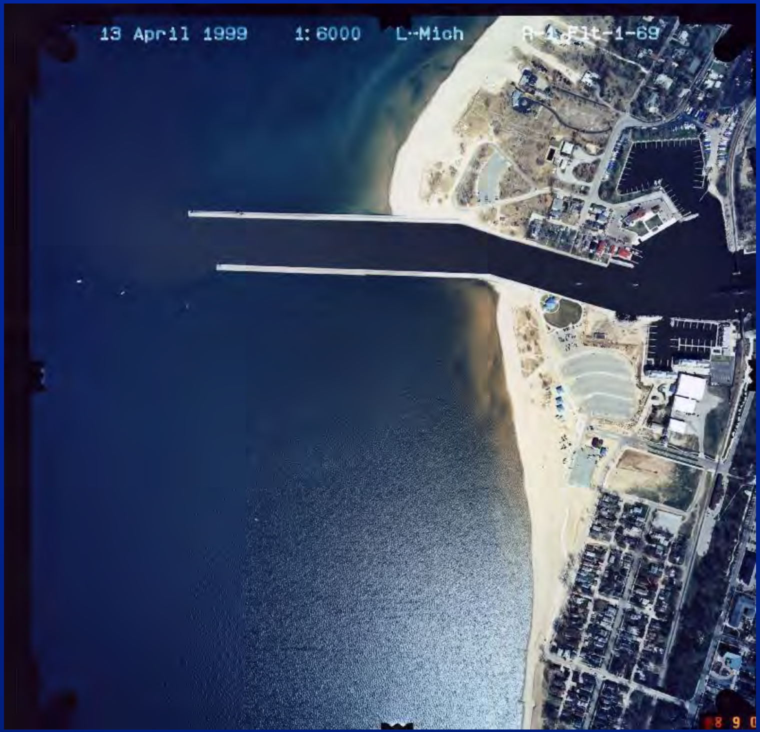
Present St. Joseph Harbor


13 April 1999
1:6000
L-Mich
Flt-1-69

5. 22. 2001 16:43

Source: USACE, Detroit

7. 12. 2001 11:07

Temporal Changes to Sediment Supply

Model sediment yield over last 175 years and examine trapping efficiency of federal harbor and incorporate the following land use changes:

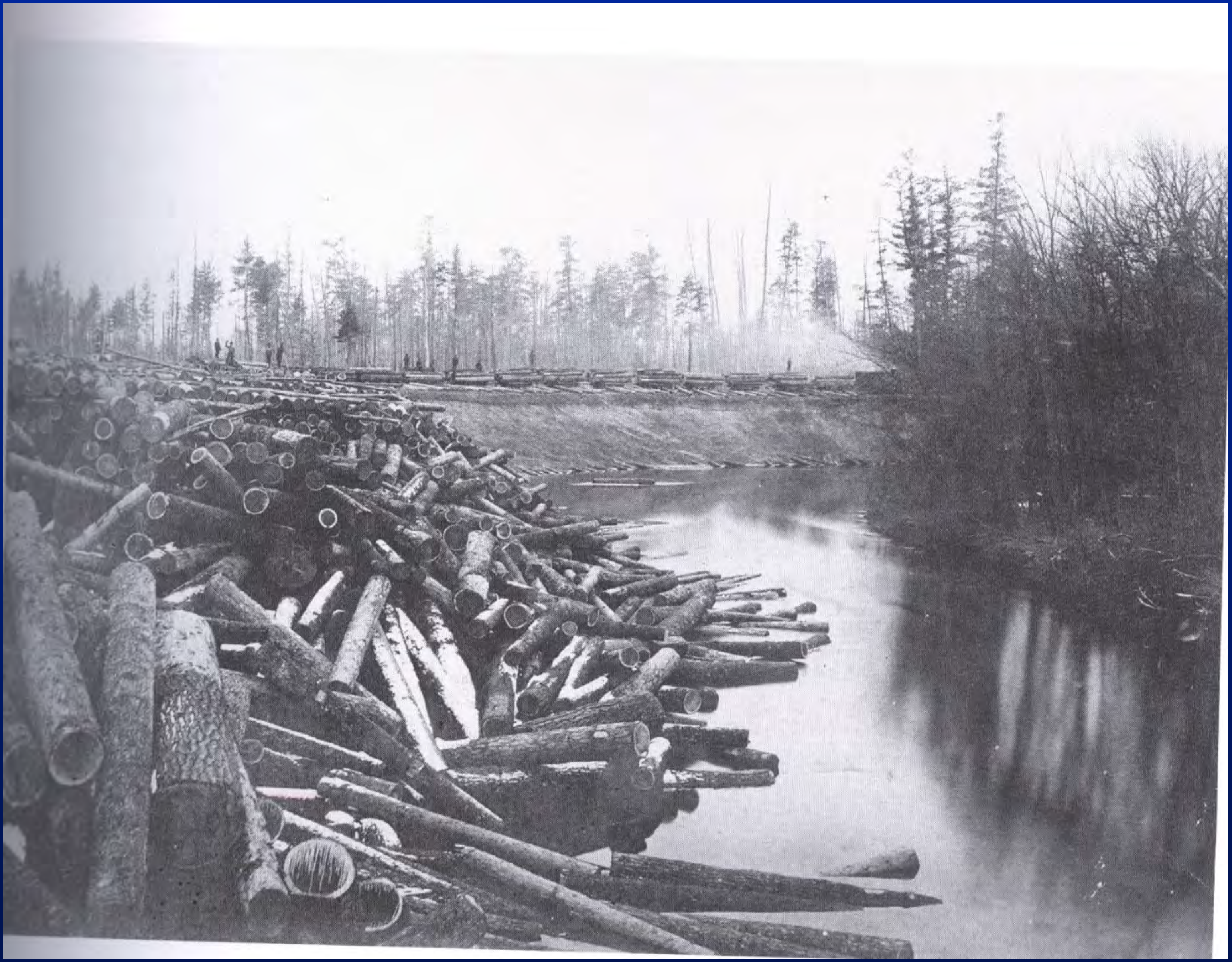
< 1840 – very little human impact

1850 - Intense logging begins

> 1850 – watershed converted to ag use.

> 1850 – dams built to support logging and agriculture

Logging and Sediment



From Dickmann and Leefers, 2003

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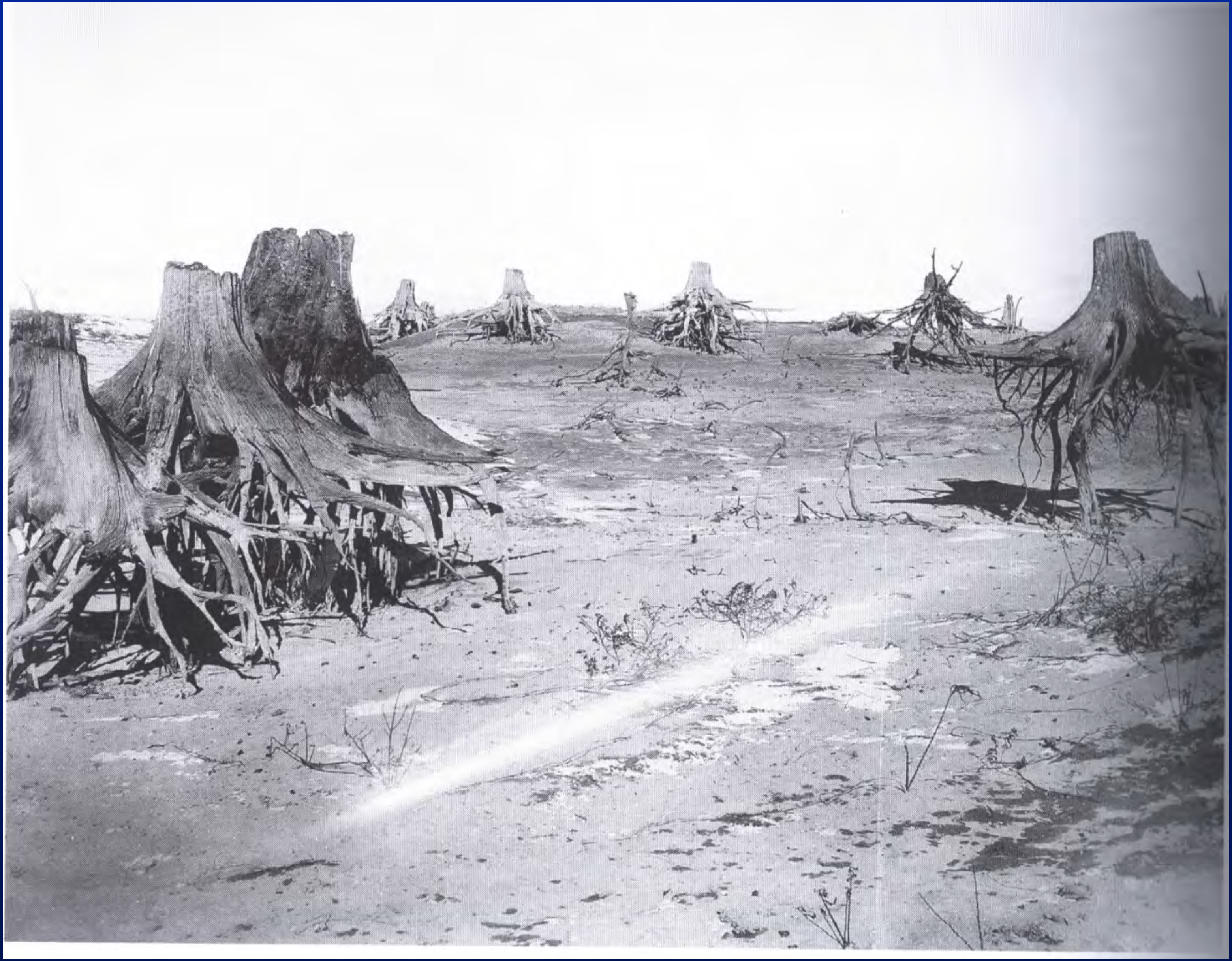
Logging and Sediment

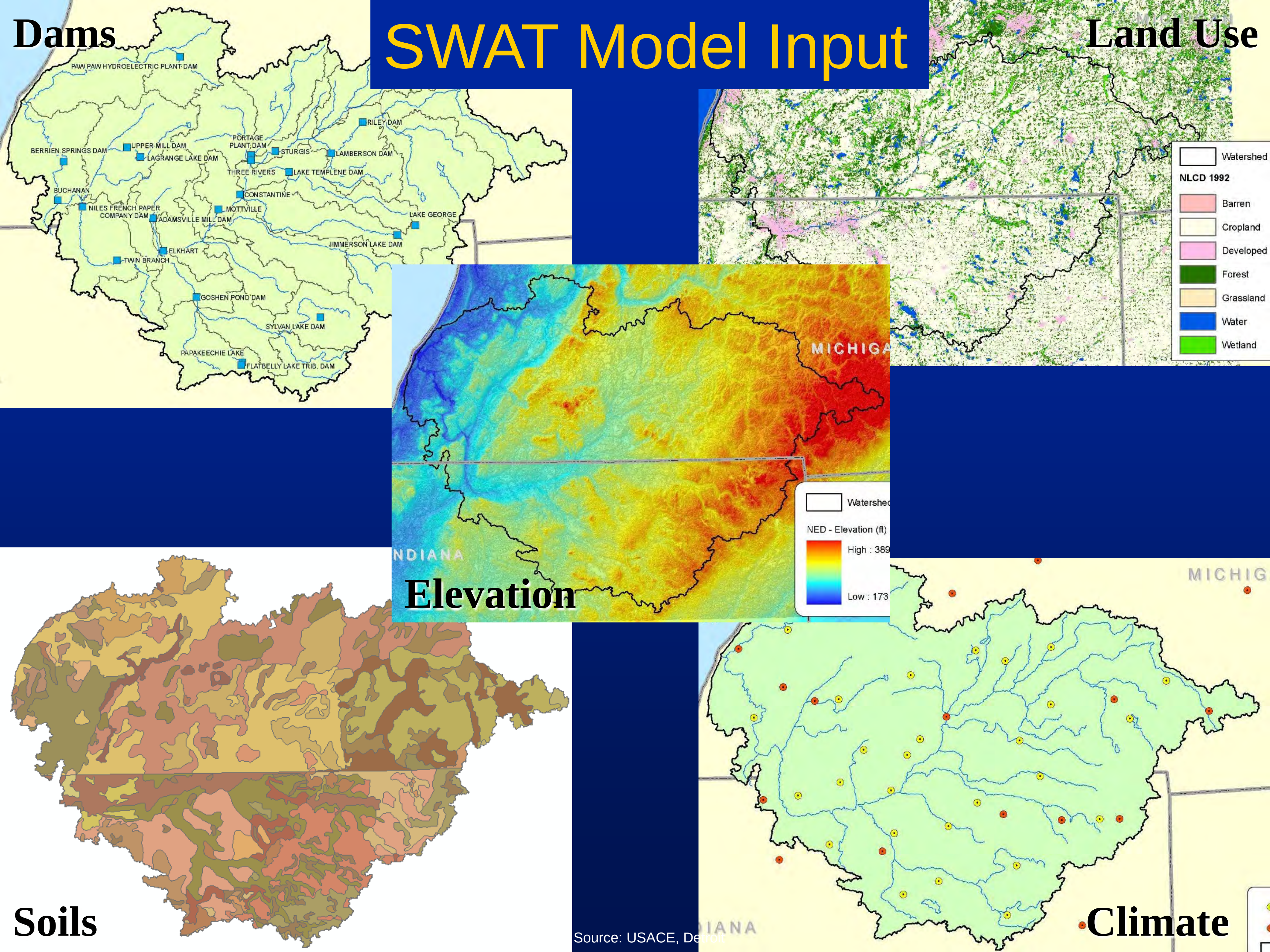


From Dickmann and Leefers, 2003

Models Applied

Acronym	Model Name	Agency	Processes
SWAT	Soil Water Assessment Tool	USDA / EPA	Hydrology Soil Erosion Sediment Delivery
GSSHA	Gridded Surface-Subsurface Hydrologic Analysis	USACE	Hydrology (1-D River Hydrodynamics) Sediment Transport Sediment Yield Sediment Delivery
RMA2-SED2D	RMA2-SED2D	USACE-WES	2-D River Hydrodynamics; Sediment Erosion, Transport and Deposition

SWAT Model Input



Dams

Land Use

Elevation

Soils

Climate

PAW PAW HYDROELECTRIC PLANT DAM
RILEY DAM
BERRIEN SPRINGS DAM
UPPER MILL DAM
LAGRANGE LAKE DAM
PORTAGE PLANT DAM
STURGIS
LAMBERSON DAM
THREE RIVERS
LAKE TEMPLENE DAM
BUCHANAN
CONSTANTINE
NILES FRENCH PAPER COMPANY DAM
MOTTVILLE
ADAMSVILLE MILL DAM
LAKE GEORGE
JIMMERSON LAKE DAM
ELKHART
TWIN BRANCH
GOSHEN POND DAM
SYLVAN LAKE DAM
PAPAKEECHIE LAKE
FLATBELLY LAKE TRIB. DAM
Watershed
NLCD 1992
Barren
Cropland
Developed
Forest
Grassland
Water
Wetland
MICHIGA
NDIANA
Watershed
NED - Elevation (ft)
High : 389
Low : 173
MICHIG
IANA

Source: USACE, De

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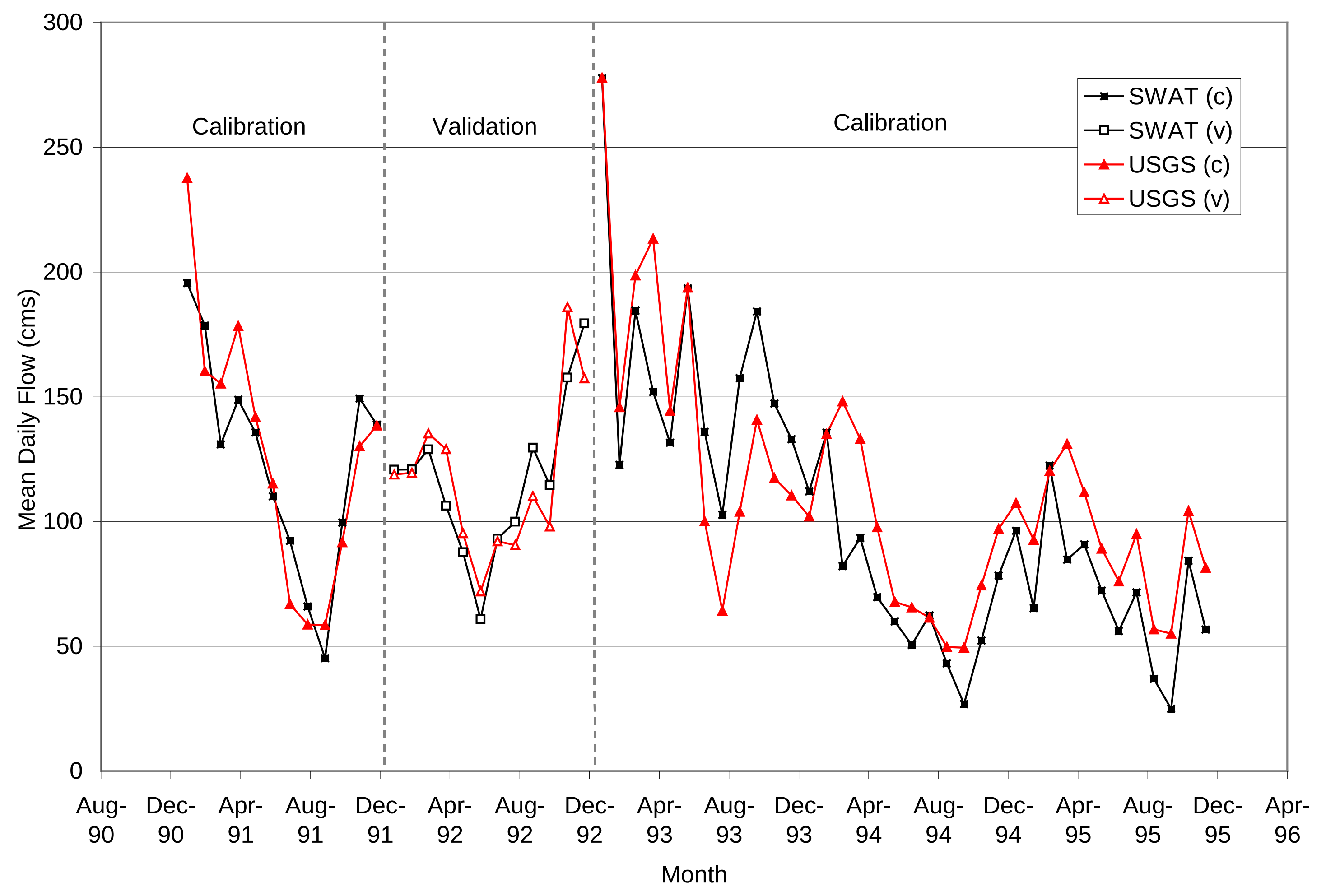
SWAT Calibration/Validation



Source: USACE, Detroit

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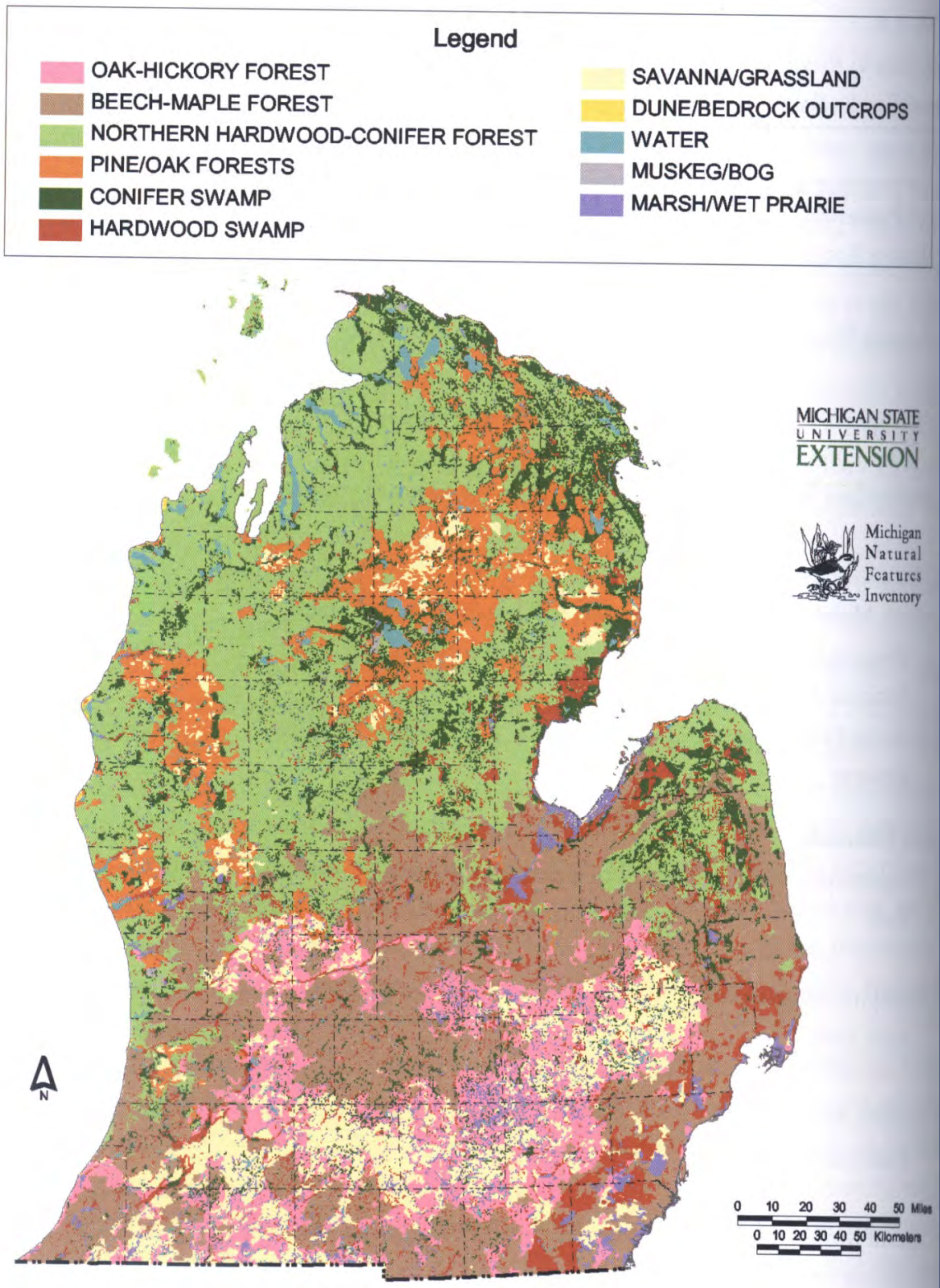
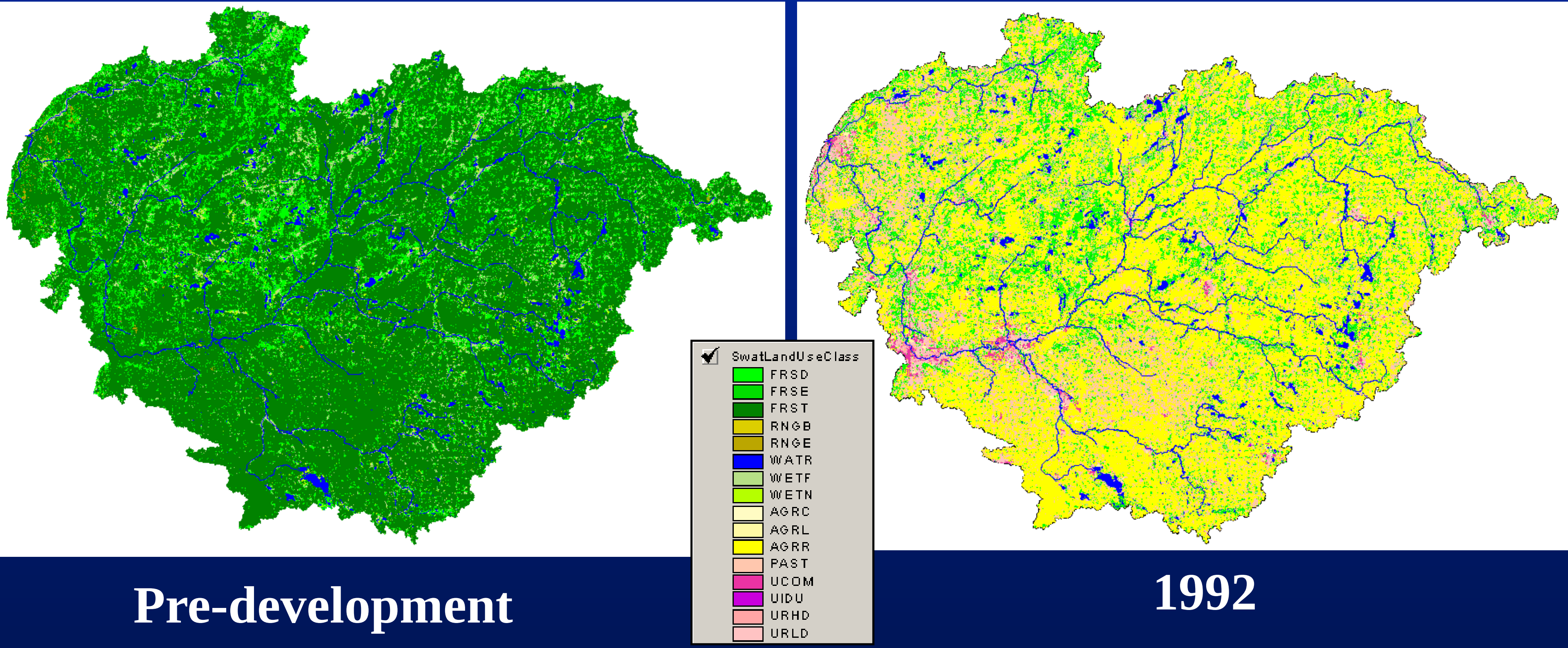
Pre-European Settlement Landcover


Legend
OAK-HICKORY FOREST
BEECH-MAPLE FOREST
NORTHERN HARDWOOD-CONIFER FOREST
PINE/OAK FORESTS
CONIFER SWAMP
HARDWOOD SWAMP
SAVANNA/GRASSLAND
DUNE/BEDROCK OUTCROPS
WATER
MUSKEG/BOG
MARSH/WET PRAIRIE
MICHIGAN STATE UNIVERSITY EXTENSION
Michigan Natural Features Inventory
N
0 10 20 30 40 50 Miles
0 10 20 30 40 50 Kilometers

In Dickmann and Leefers, 2003

Land Cover Change

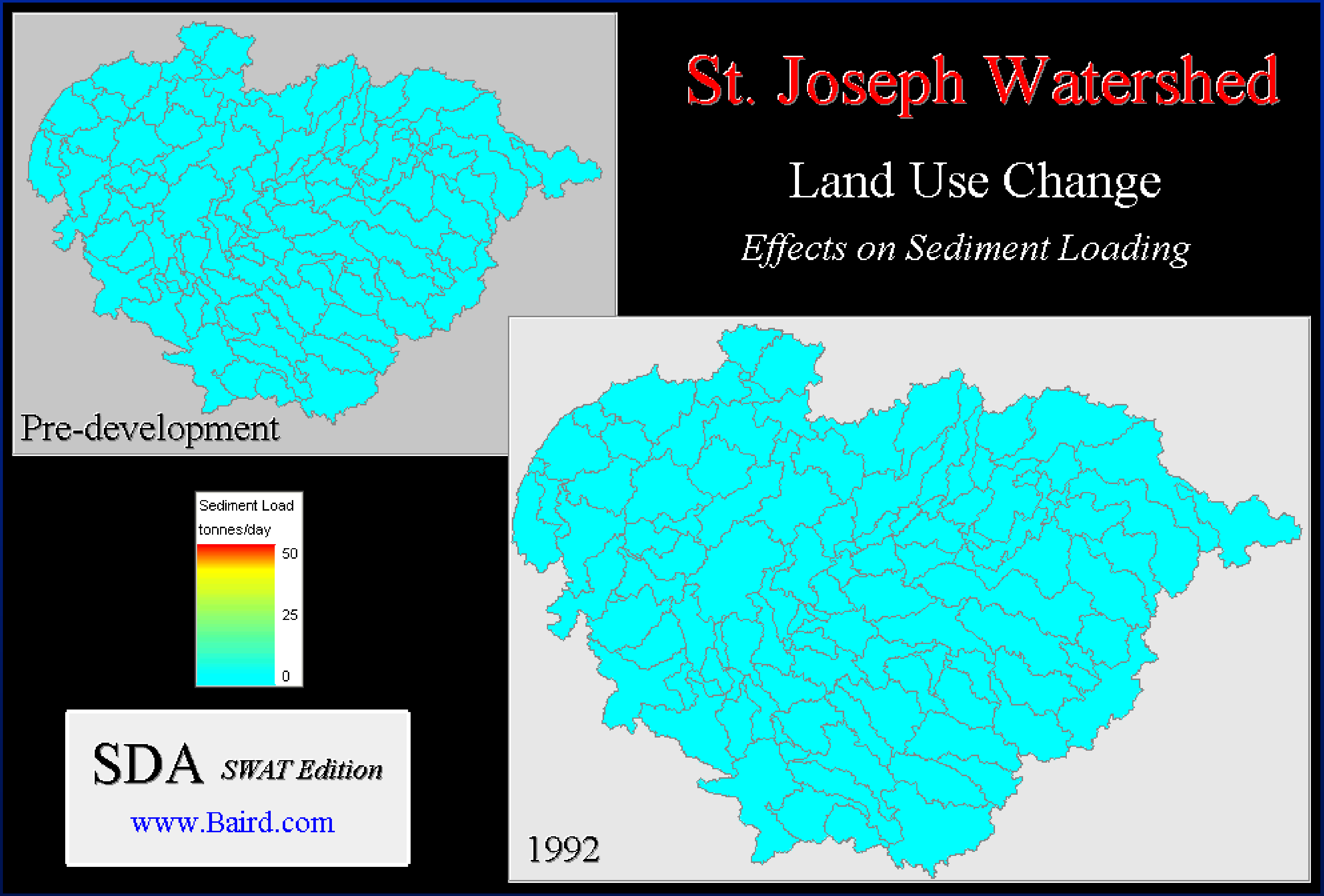

SwatLandUseClass
FRSD
FRSE
FRST
RNGB
RNGE
WATR
WETF
WETN
AGRC
AGRL
AGRR
PAST
UCOM
UIDU
URHD
URLD

Pre-development

1992

Source: USACE, Detroit

Land Cover Change



St. Joseph Watershed

Land Use Change

Effects on Sediment Loading

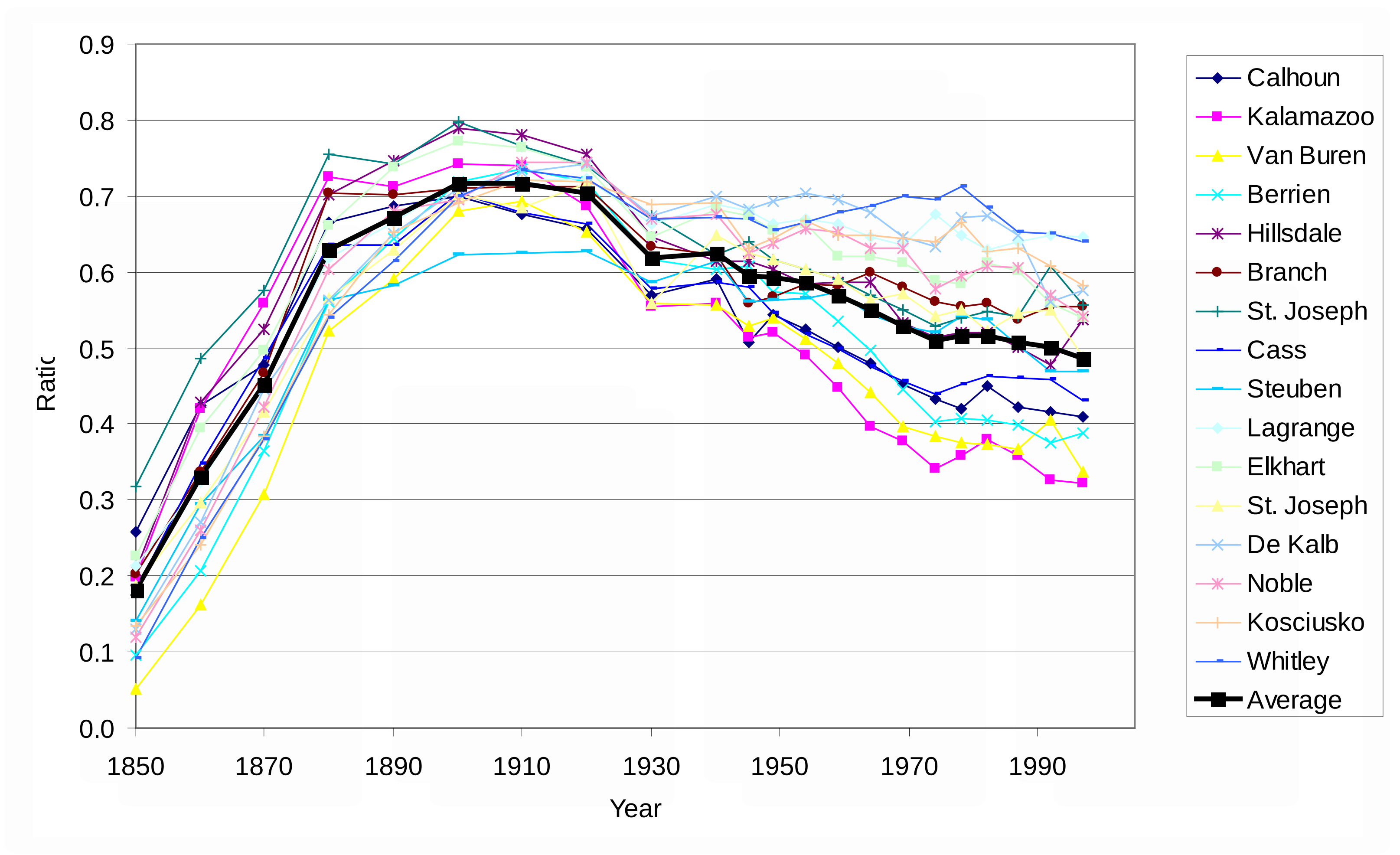
Pre-development
1992
Sediment Load
tonnes/day
50
25
0
SDA SWAT Edition
www.Baird.com

Source: USACE, Detroit

SWAT Land Cover Change Results

Year	Model Condition	Total Soil Erosion in the Watershed (m^3 per year)
1830	Pre-Development	55,000
1992	Present Land Use	676,000

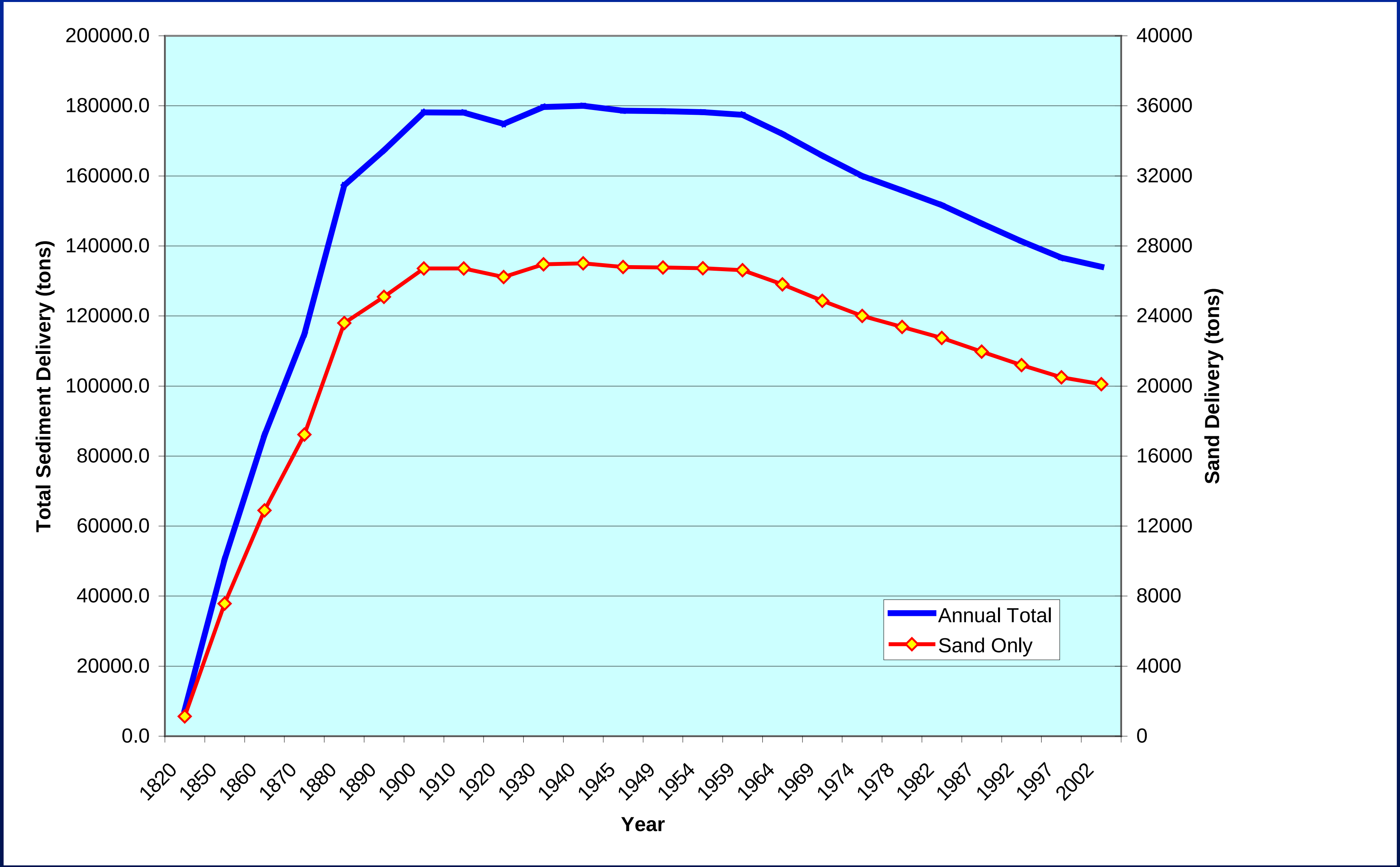
Improved Farmland by County



Source: USACE, Detroit

US Army Corps of Engineers
Detroit District

Sediment Delivery Estimates

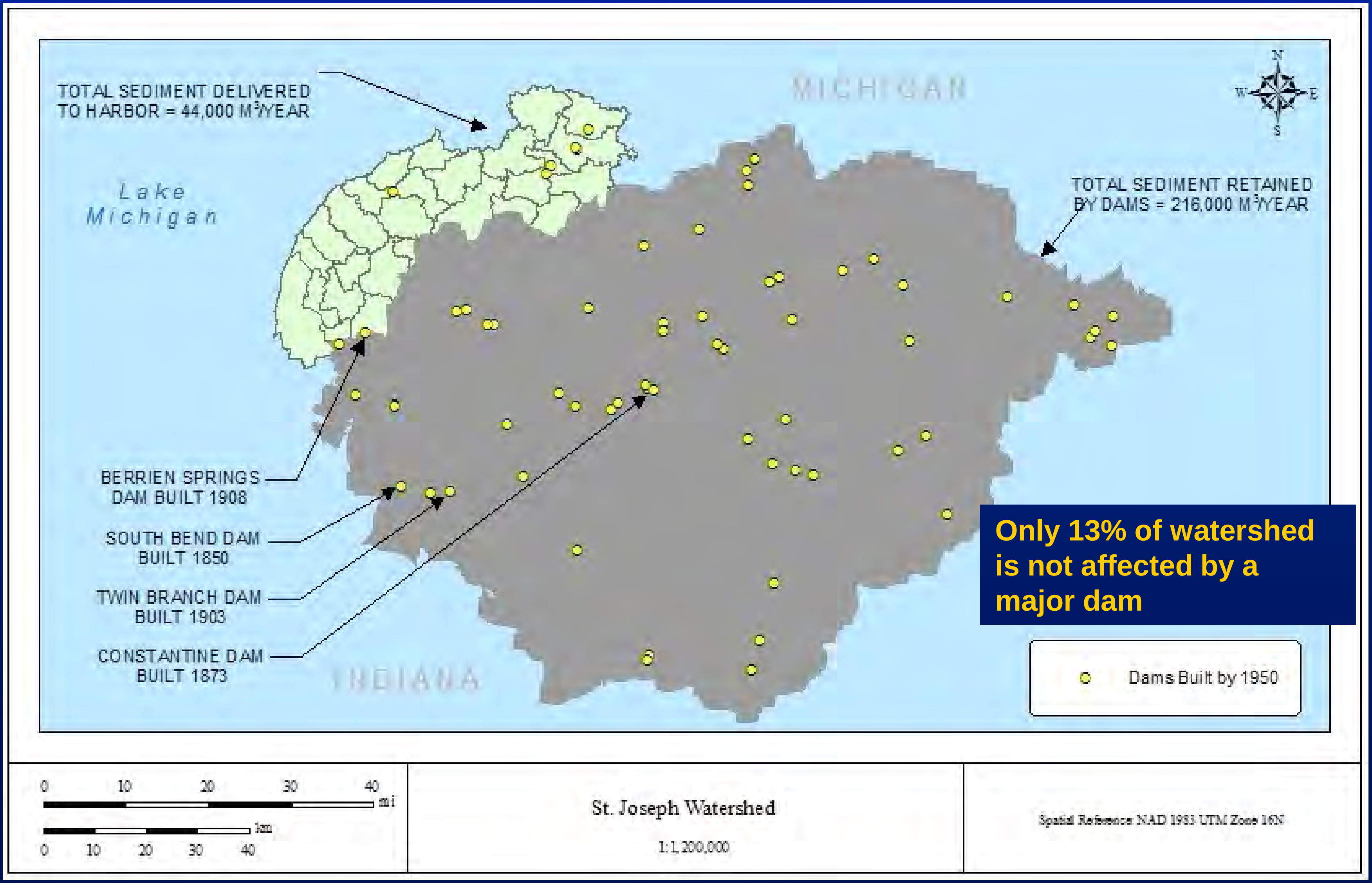


Source: USACE, Detroit

Influence of Dams

- St. Joseph Watershed: 65 major dams and 125 minor dams constructed since 1850s
- Dams intercept most coarse sediment
- 87% of watershed upstream from major dams
- SWAT used to determine likely effect of dams on sediment supply to the harbor

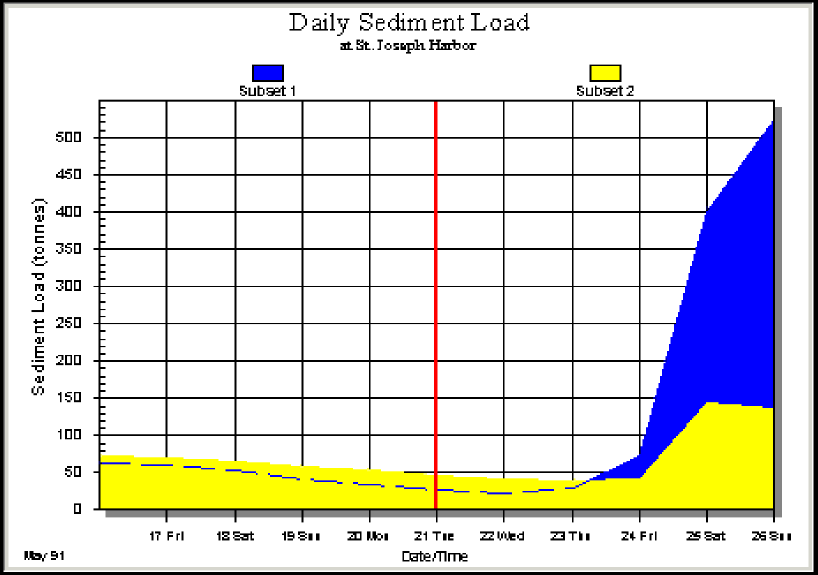
Influence of Dams


TOTAL SEDIMENT DELIVERED TO HARBOR = 44,000 M³/YEAR
MICHIGAN
Lake Michigan
TOTAL SEDIMENT RETAINED BY DAMS = 216,000 M³/YEAR
N
W
E
S
BERRIEN SPRINGS DAM BUILT 1908
SOUTH BEND DAM BUILT 1850
TWIN BRANCH DAM BUILT 1903
CONSTANTINE DAM BUILT 1873
INDIANA
Dams Built by 1950
0 10 20 30 40 mi
0 10 20 30 40 km
St. Joseph Watershed
1:1,200,000
Spatial Reference NAD 1983 UTM Zone 16N

Only 13% of watershed is not affected by a major dam

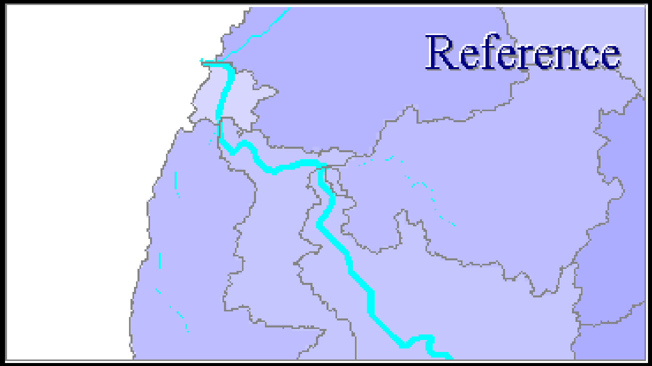
Source: USACE, Detroit

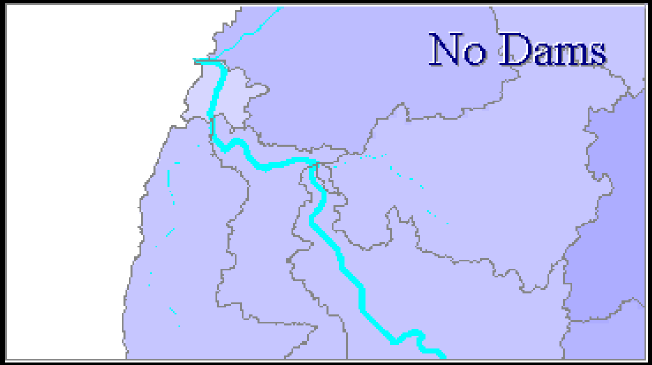
SWAT: Dam Scenario Results



SDA *SWAT Edition*

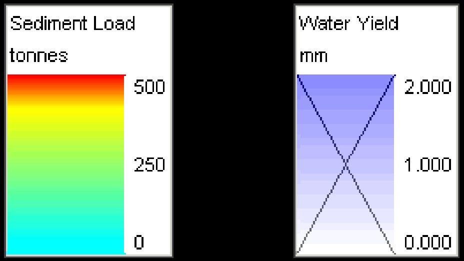
www.Baird.com





Effect of Dams

on Sediment Delivery to St. Joseph Harbor

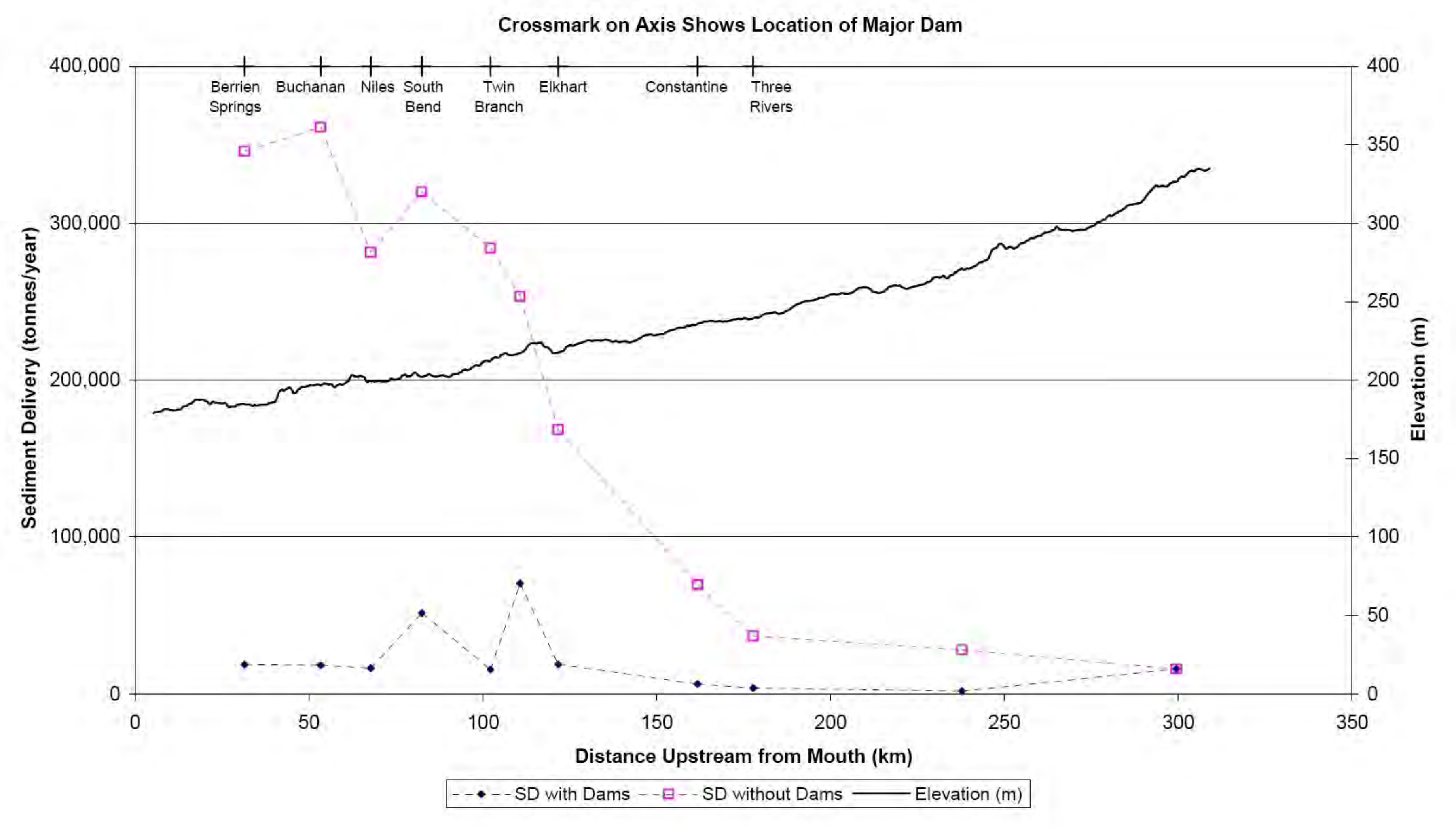

Sediment Load
tonnes
500
250
0
Water Yield
mm
2.000
1.000
0.000

Source: USACE, Detroit

US Army Corps of Engineers

Detroit District

Influence of Dams



Source: USACE, Detroit

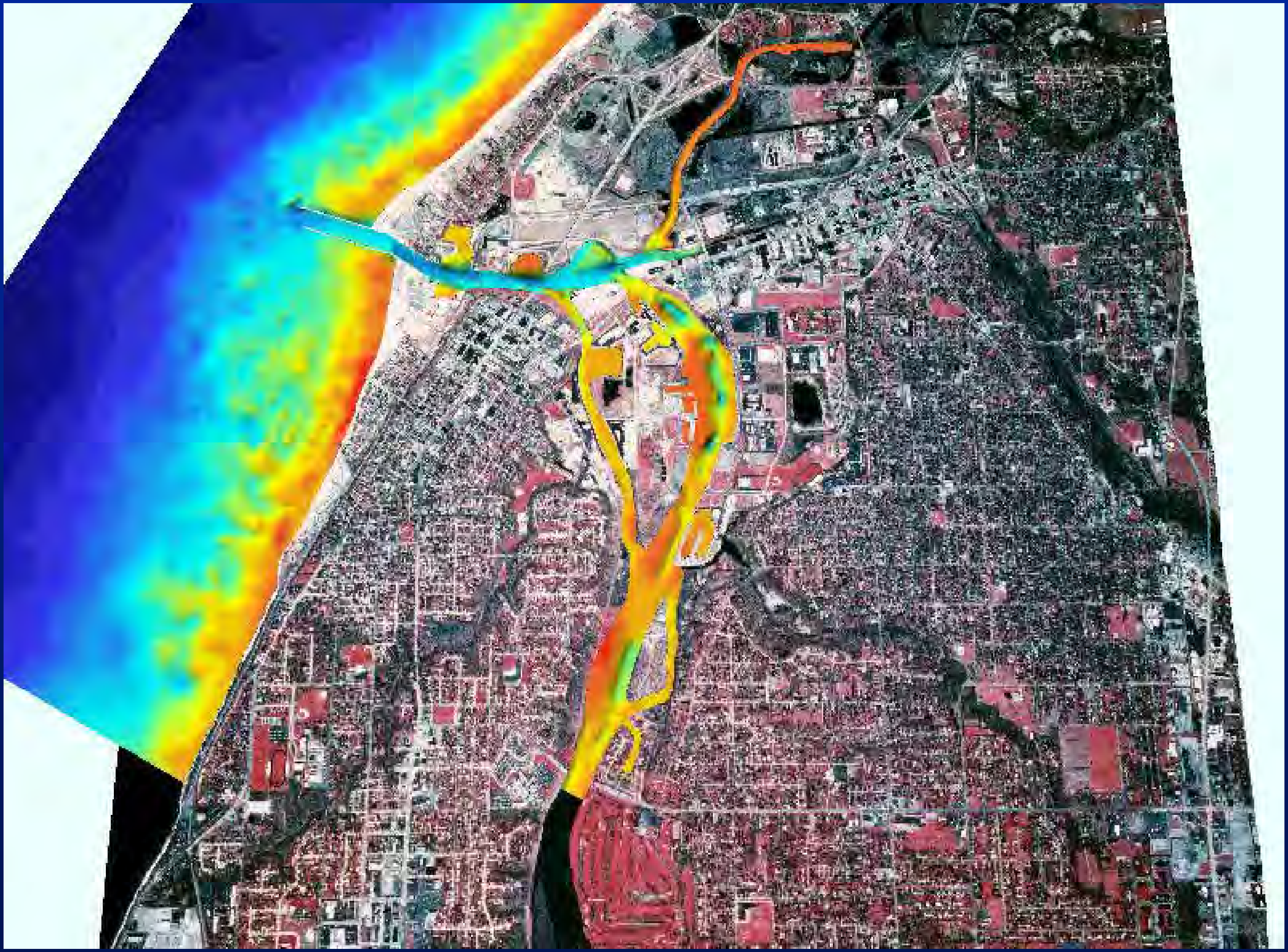
Influence of Dams

Year	Model Conditions	Total Soil Erosion in the Watershed (m^3 per year)	Total Sediment at Mouth of Paw Paw (m^3 per year)	Total Sediment at Harbor Mouth (m^3 per year)
1992	Reference Condition	675,000	11,000	44,000
1992	No dams or reservoirs	675,000	11,000	216,000

(44,000 m^3 = 57,000 yd^3)

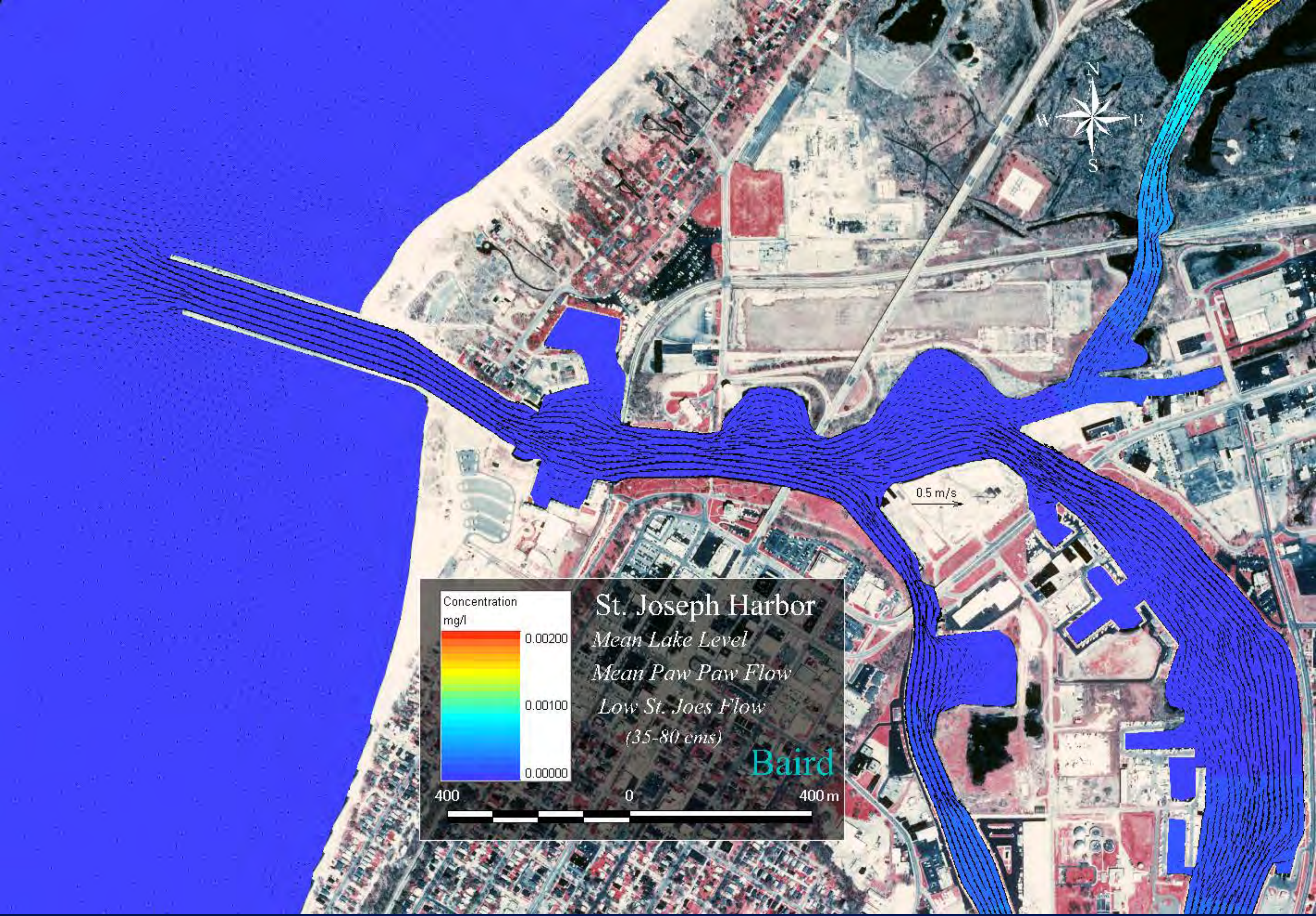
Sediment Transport Modeling

Harbor Trapping

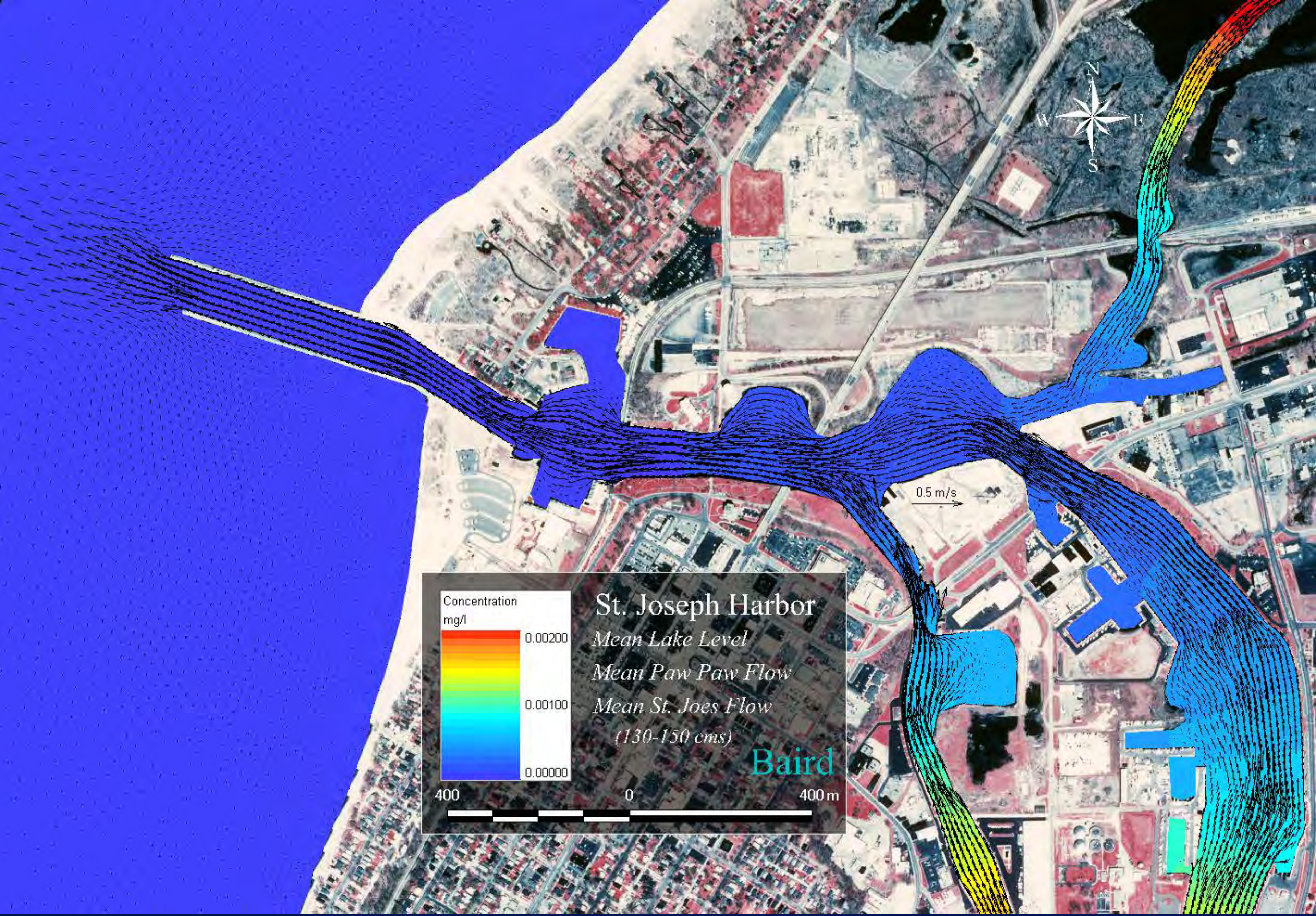


3 mile u/s, 1 mile offshore

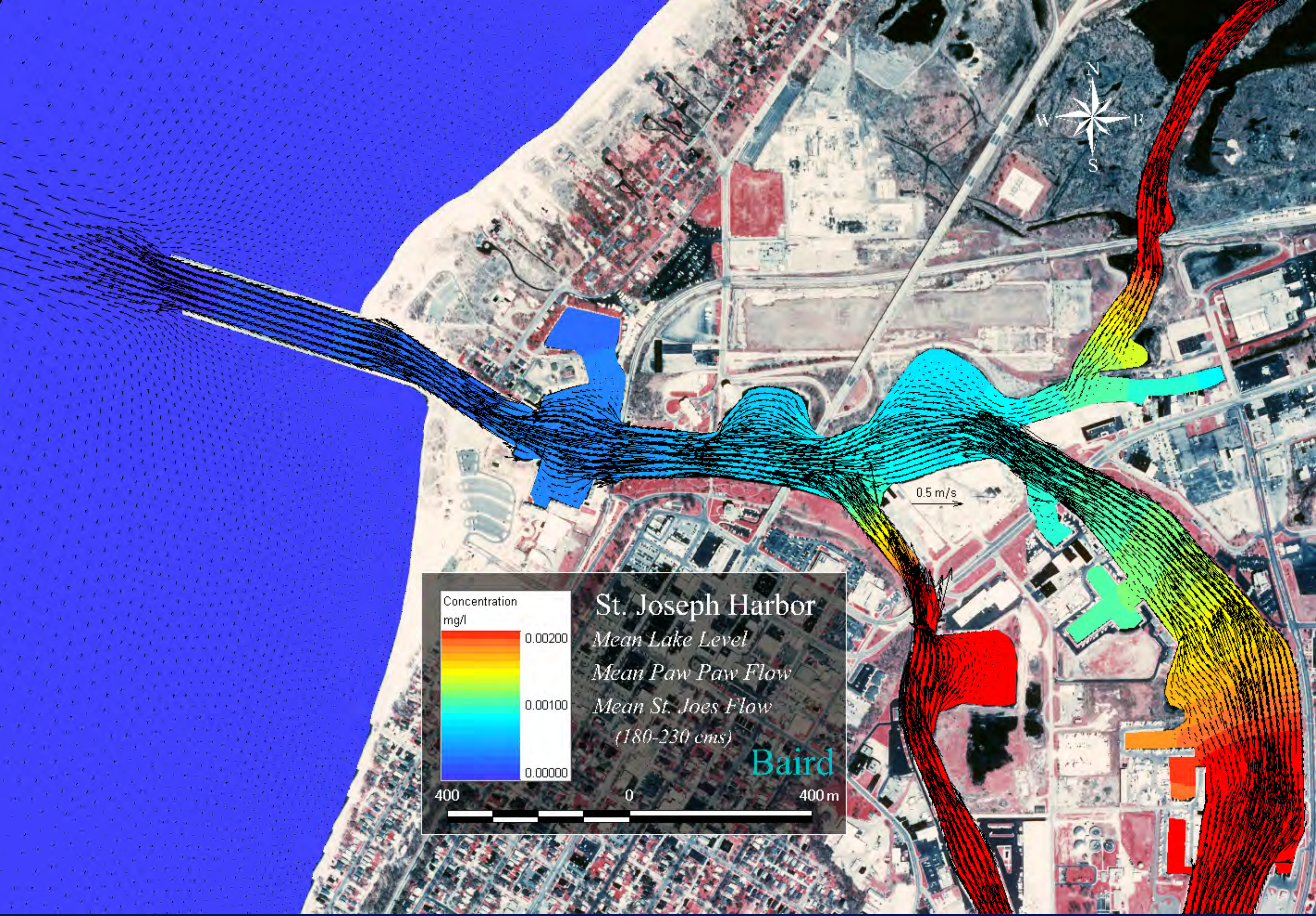
Source: USACE, Detroit


N
W
E
S
0.5 m/s
Concentration
mg/l
0.00200
0.00100
0.00000
St. Joseph Harbor
Mean Lake Level
Mean Paw Paw Flow
Low St. Joes Flow
(35-80 cms)
Baird
400
0
400 m

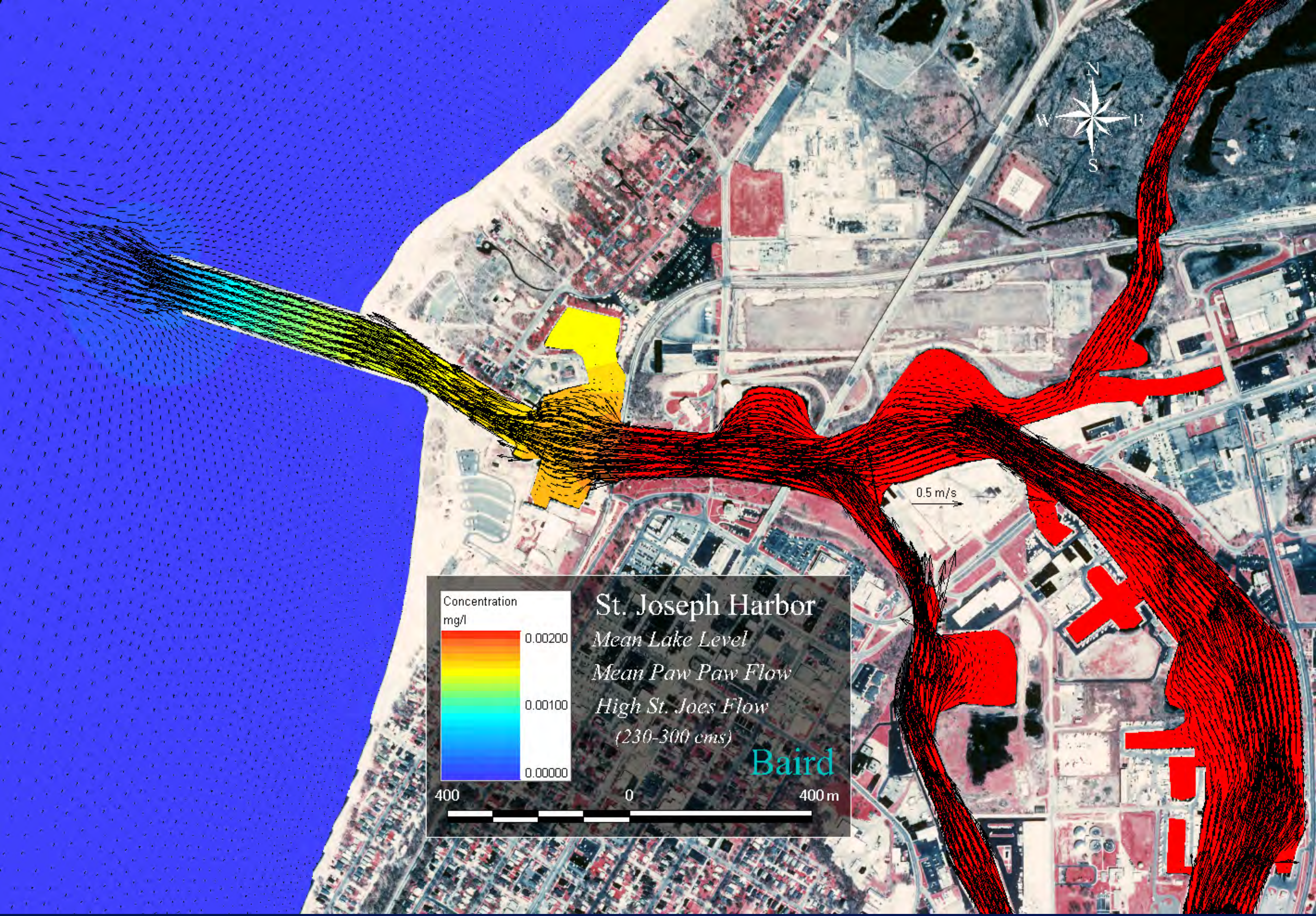
Source: USACE, Detroit


N
W
E
S
0.5 m/s
Concentration
mg/l
0.00200
0.00100
0.00000
St. Joseph Harbor
Mean Lake Level
Mean Paw Paw Flow
Mean St. Joes Flow
(130-150 cms)
Baird
400
0
400 m

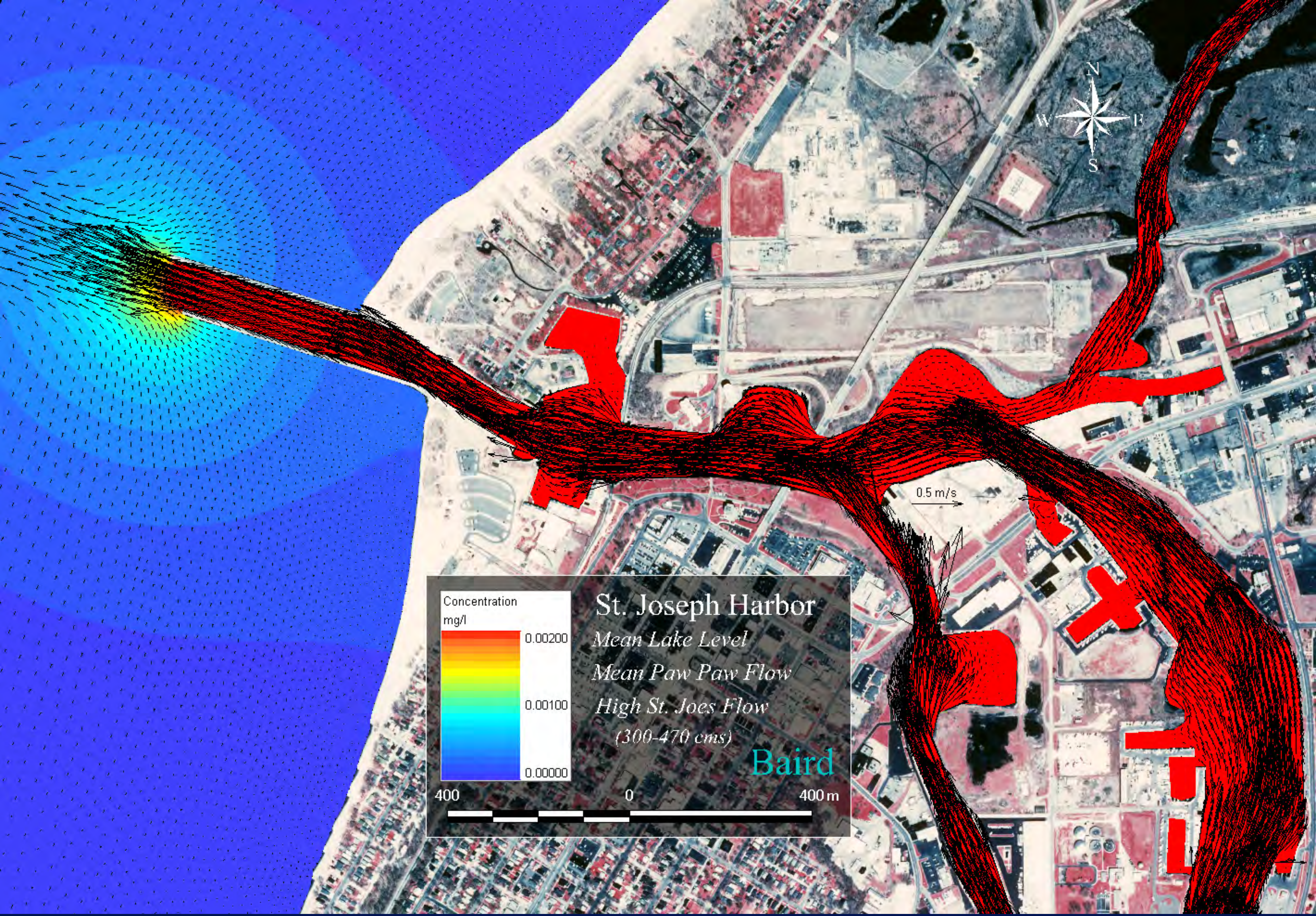
Source: USACE, Detroit


N
W
E
S
0.5 m/s
Concentration
mg/l
0.00200
0.00100
0.00000
St. Joseph Harbor
Mean Lake Level
Mean Paw Paw Flow
Mean St. Joes Flow
(180-230 cms)
Baird
400
0
400 m

Source: USACE, Detroit


N
W
E
S
0.5 m/s
Concentration
mg/l
0.00200
0.00100
0.00000
St. Joseph Harbor
Mean Lake Level
Mean Paw Paw Flow
High St. Joes Flow
(230-300 cms)
Baird
400
0
400 m

Source: USACE, Detroit


N
W
E
S
0.5 m/s
Concentration
mg/l
0.00200
0.00100
0.00000
St. Joseph Harbor
Mean Lake Level
Mean Paw Paw Flow
High St. Joes Flow
(300-470 cms)
Baird
400
0
400 m

Source: USACE, Detroit

RMA2 Results

2002 bathymetry - no dredging (present condition)

Time Period	Duration (Years)	% Leaving Inner Harbor	% Deposited in Inner Harbor
Oct 1930- Sept 2003	73	45%	55%
Jan 1980 - Dec 2000	21	48%	52%
Jan 1978 - Dec 1997	20	48%	52%
Jan 1988 - Dec 1997	10	33%	67%

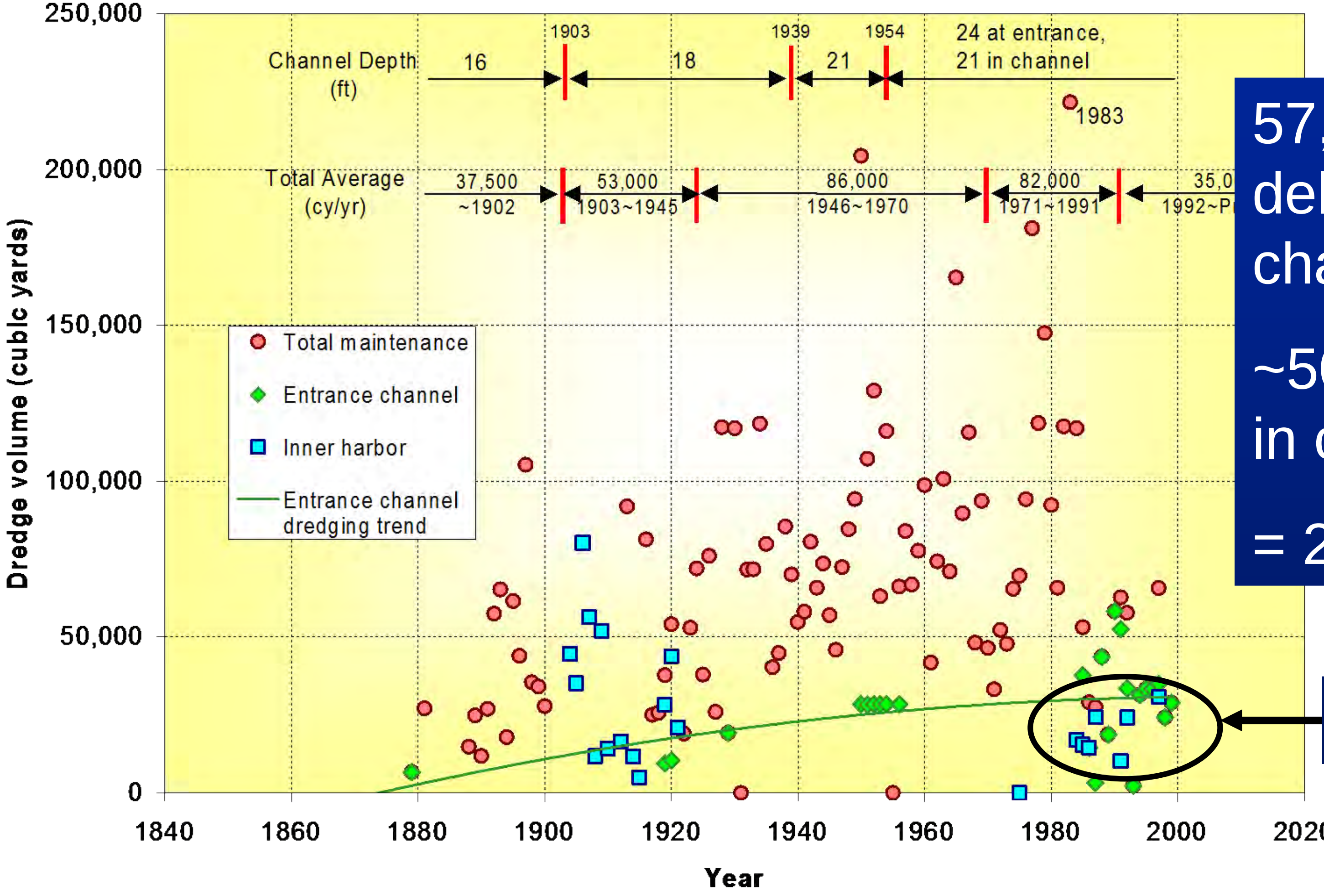
2002 bathymetry - inner harbor dredged to 20 feet

Time Period	Duration (Years)	% Leaving Inner Harbor	% Deposited in Inner Harbor
Oct 1930- Sept 2003	73	46%	54%
Jan 1980 - Dec 2000	21	50%	50%
Jan 1978 - Dec 1997	20	50%	50%
Jan 1988 - Dec 1997	10	34%	66%

1907 bathymetry

Time Period	Duration (Years)	% Leaving Inner Harbor	% Deposited in Inner Harbor
Oct 1930- Sept 2003	73	54%	46%
Jan 1980 - Dec 2000	21	57%	43%
Jan 1978 - Dec 1997	20	57%	43%
Jan 1988 - Dec 1997	10	44%	56%

Harbor Dredging Records



57,000 cy delivered to channel

~50% remains in channel

= 28,500 cy

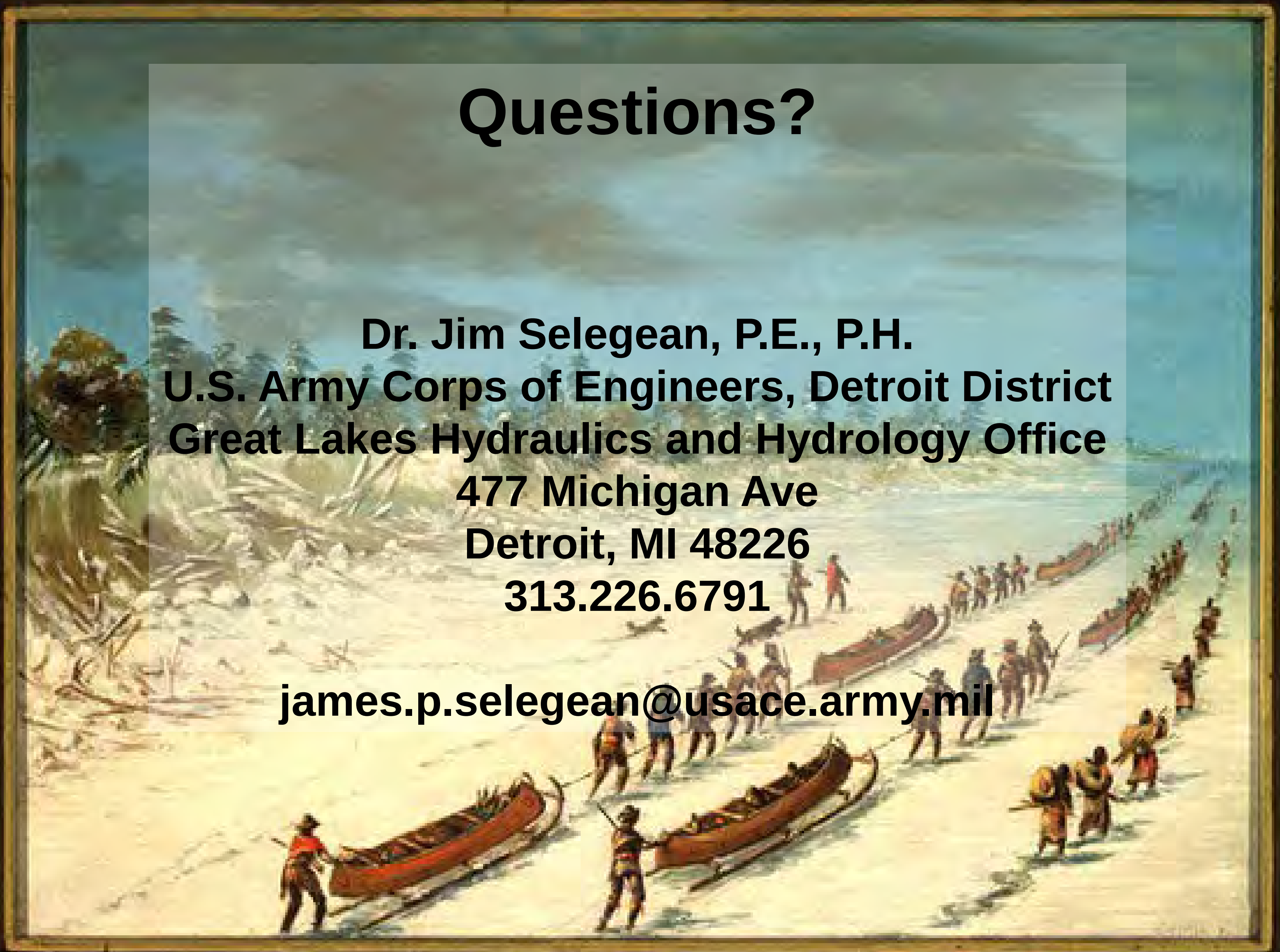
23,000 cy

Source: USACE, Detroit

Conclusions

- Present sediment production is an order of magnitude greater than during Pre-European settlement of the watershed (675,000 m^3/yr vs. 55,000 m^3/yr).
- Dams are presently storing 80% of sediment delivered to the stream.
- The effect of land-use changes is offset by the addition of dams

Questions?



Dr. Jim Selegean, P.E., P.H.
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Detroit, MI 48226
313.226.6791

james.p.selegean@usace.army.mil

LaSalle at St. Joseph in 1681 by George Catlin