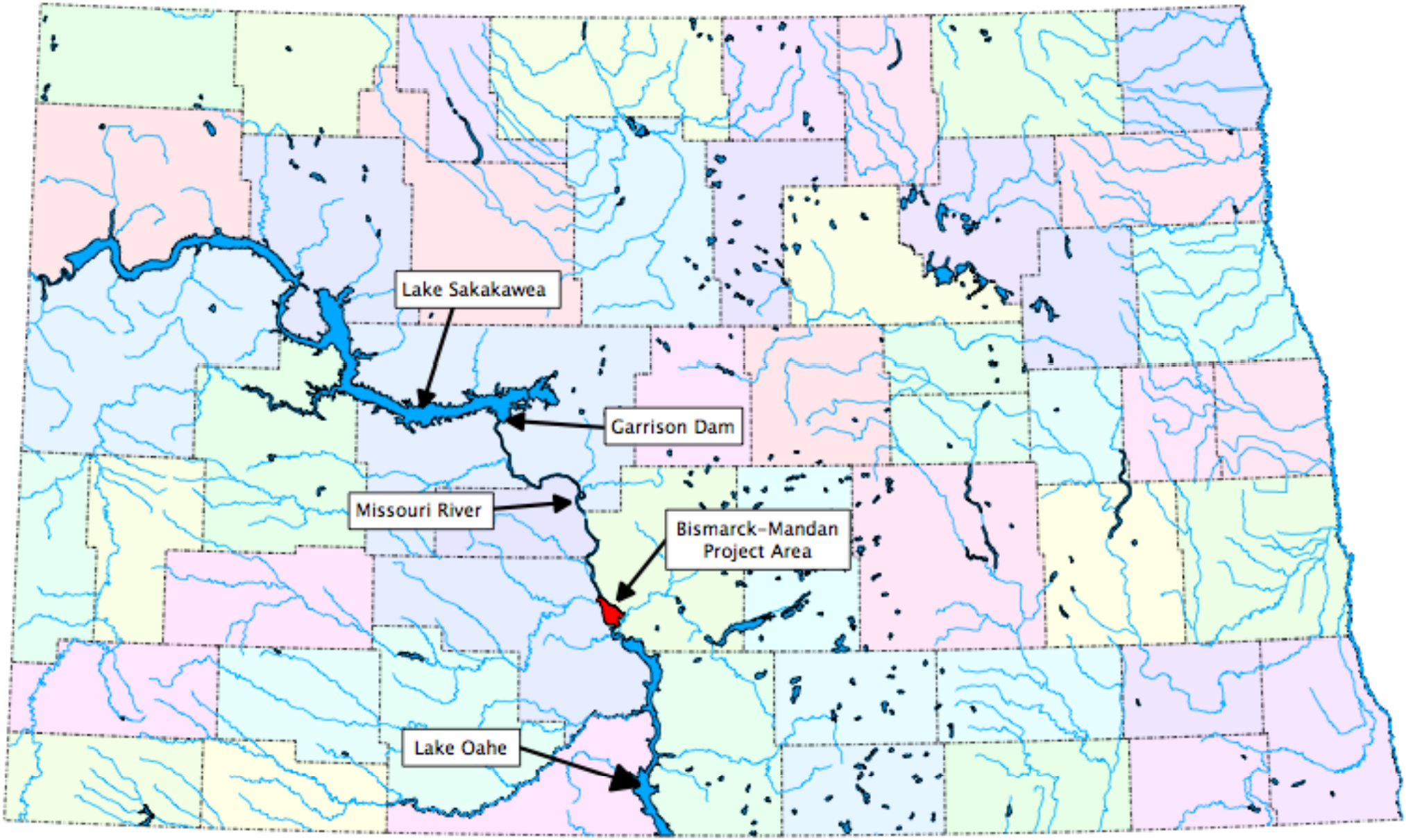
Impact of the 2011 Missouri River Flooding on Groundwater Levels in Bismarck and Mandan, North Dakota

North Dakota State Water Commission

Royce Cline

Steve Pusc

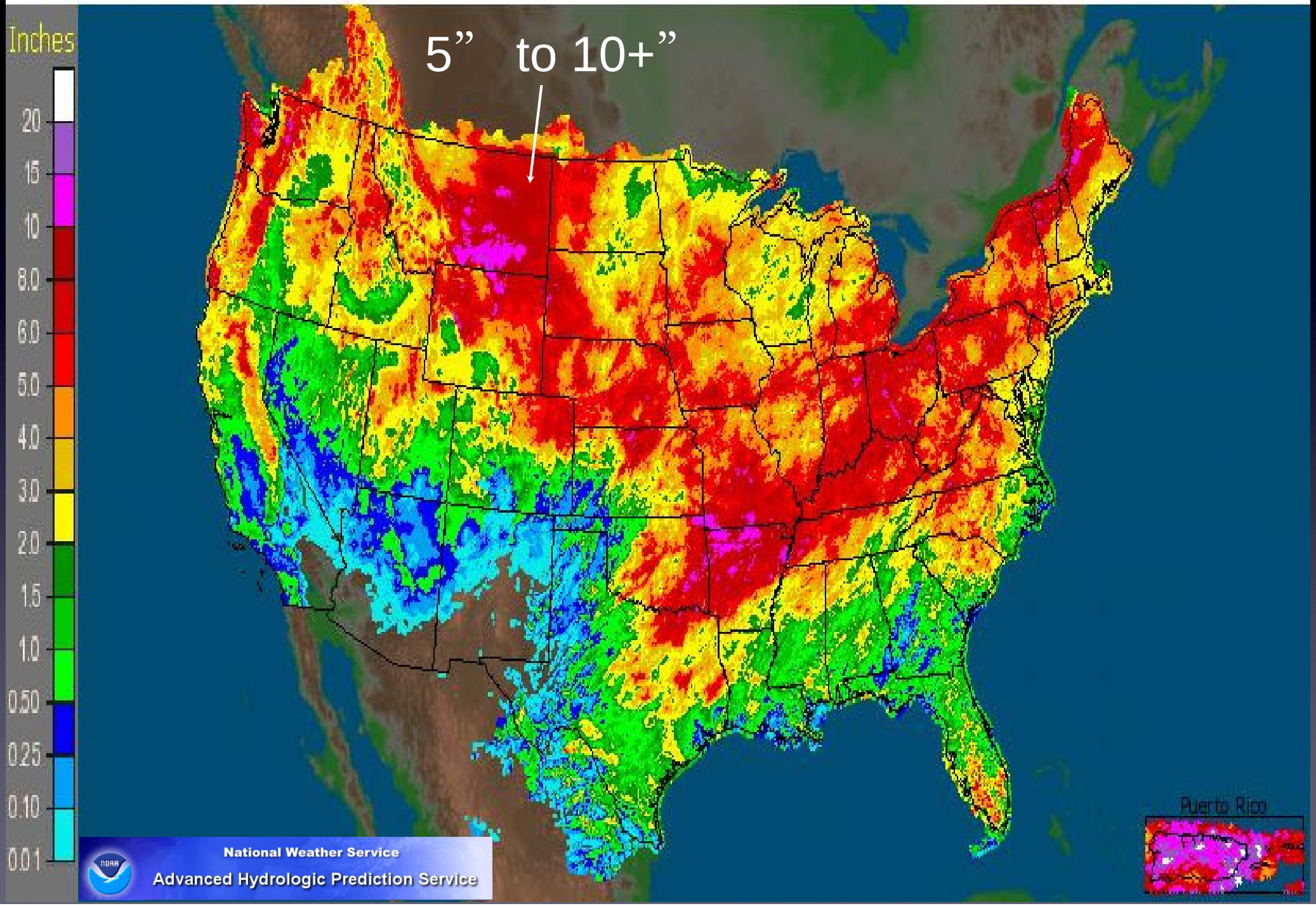
NORTH DAKOTA



Anomalously high May and June precipitaion in western North Dakota and eastern Montana led to the 2011 Missouri River flood.

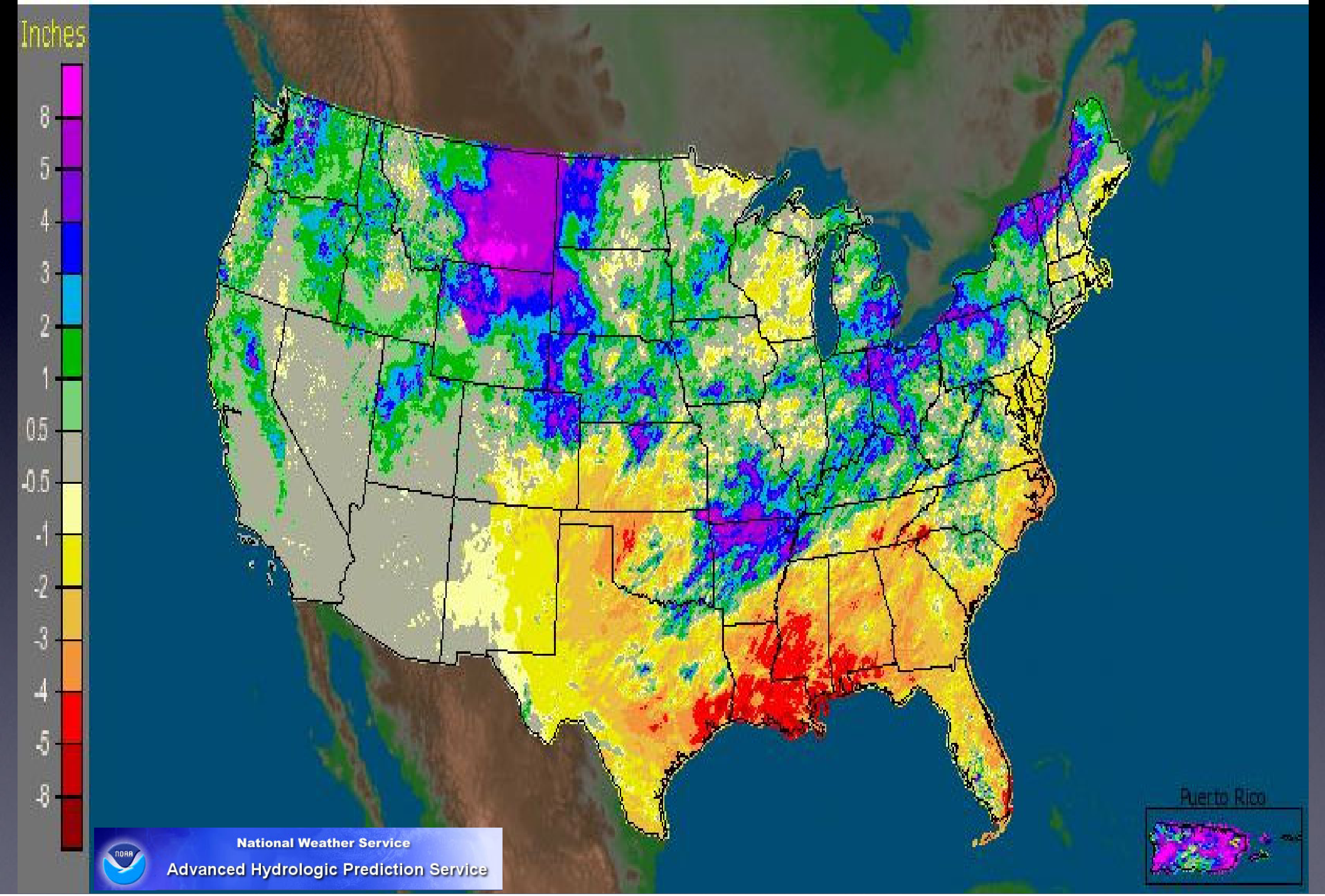
CONUS + Puerto Rico: May, 2011 Monthly Observed Precipitation

Valid at 6/1/2011 1200 UTC- Created 6/3/11 21:32 UTC



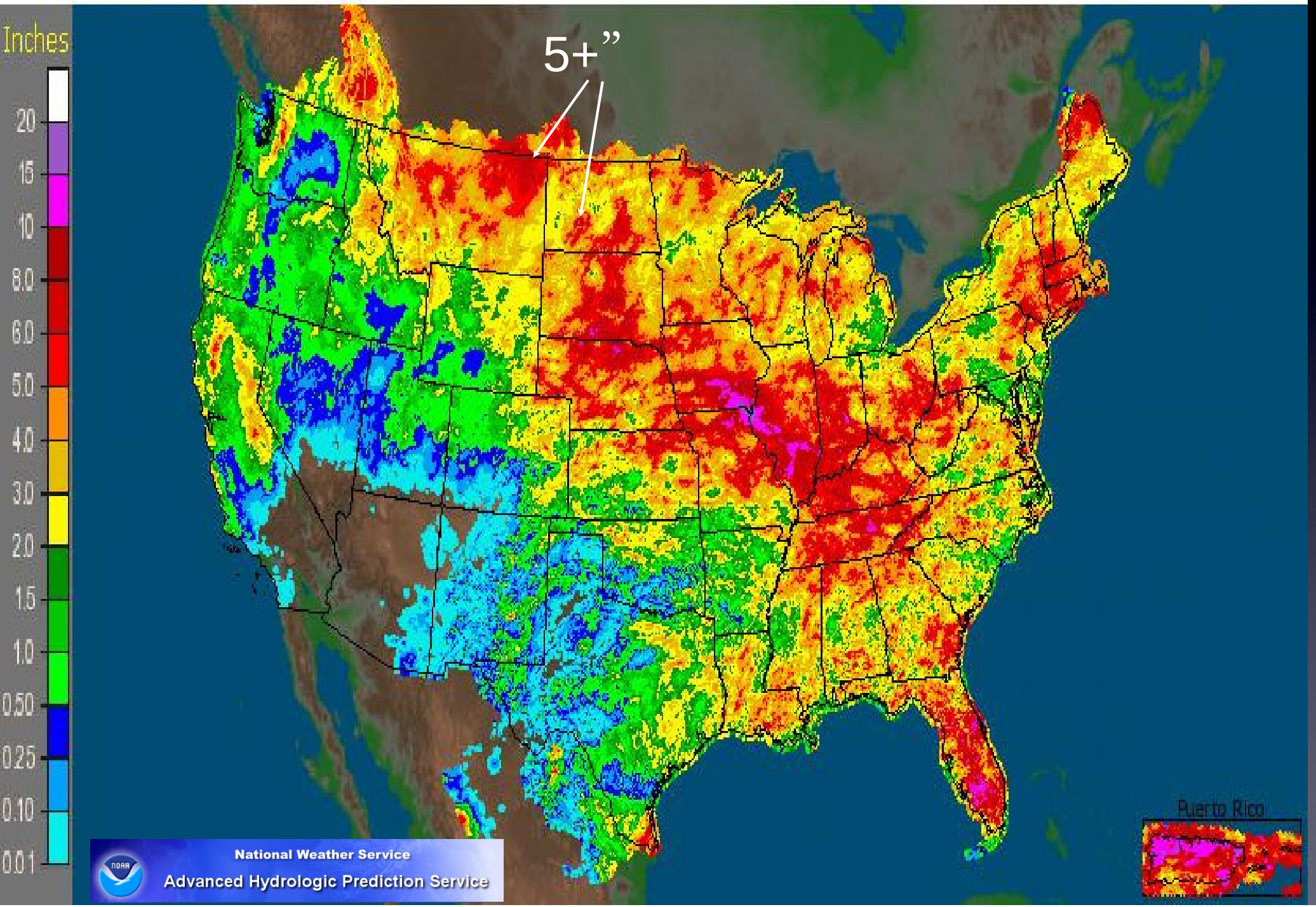
CONUS + Puerto Rico: May, 2011 Monthly Departure from Normal Precipitation

Valid at 6/1/2011 1200 UTC- Created 6/3/11 21:33 UTC



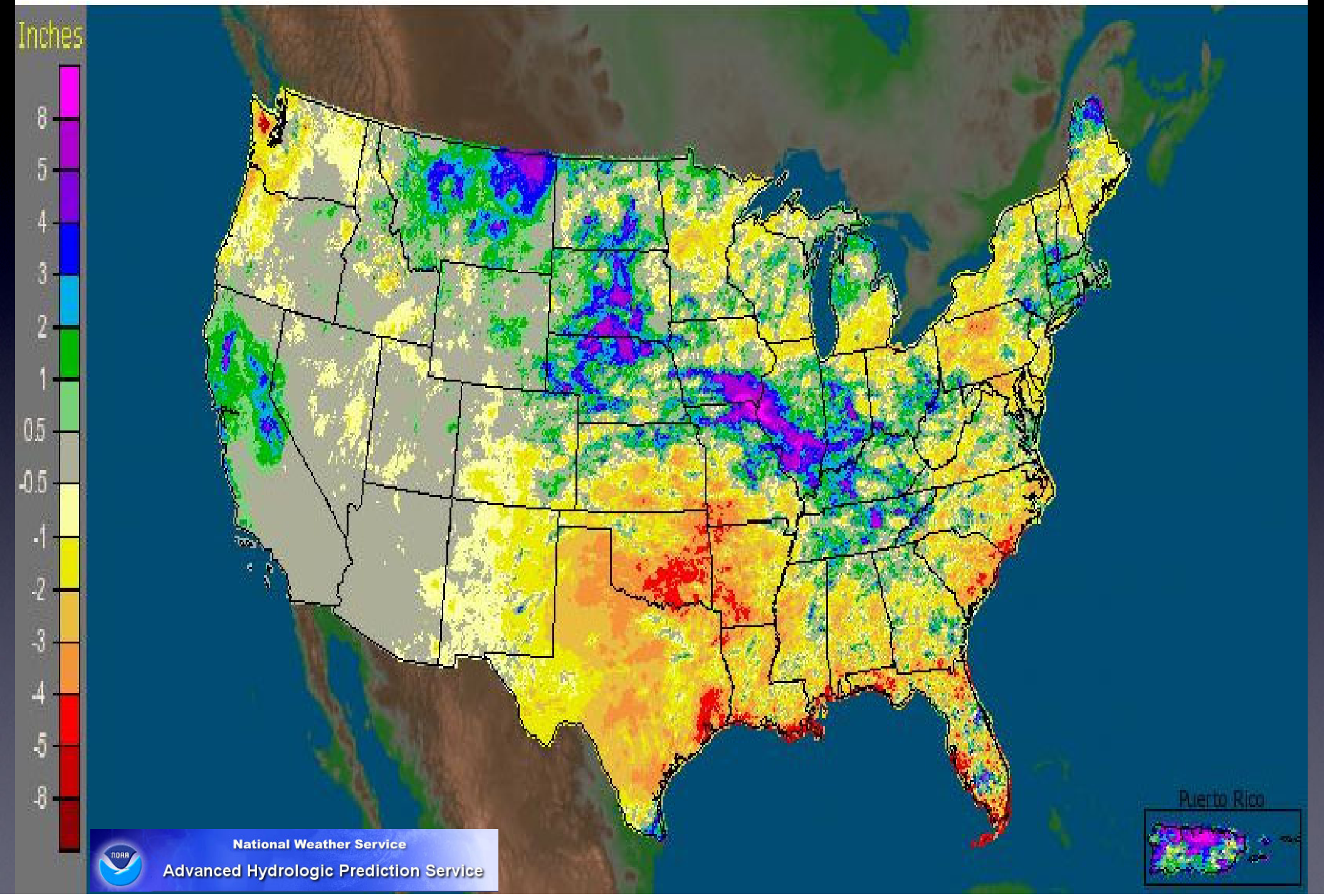
CONUS + Puerto Rico: June, 2011 Monthly Observed Precipitation

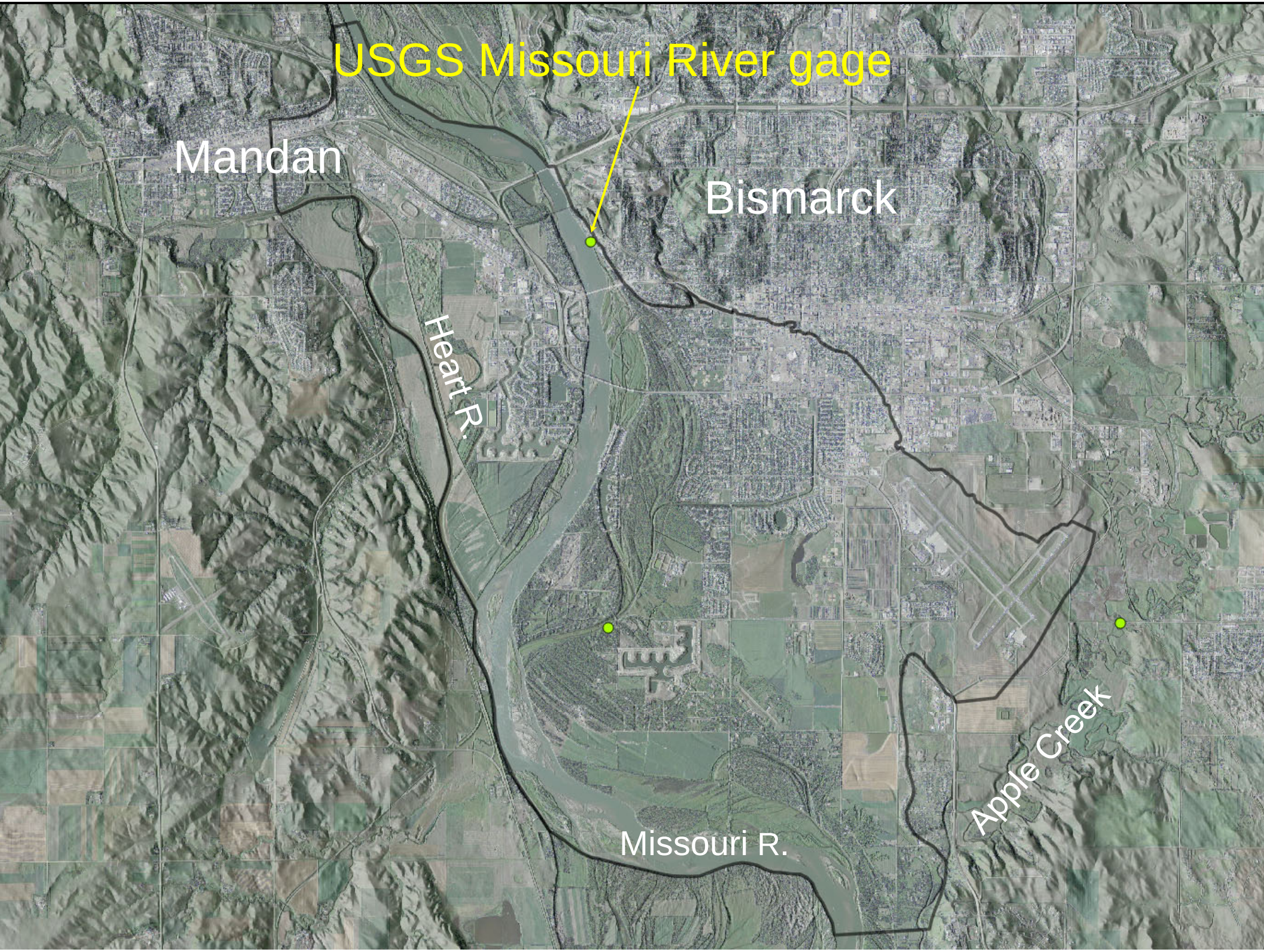
Valid at 7/1/2011 1200 UTC- Created 7/3/11 21:32 UTC



CONUS + Puerto Rico: June, 2011 Monthly Departure from Normal Precipitation

Valid at 7/1/2011 1200 UTC- Created 7/3/11 21:33 UTC




USGS Missouri River gage
Mandan
Bismarck
Heart R.
Missouri R.
Apple Creek

Floods aren’t normally a problem that involves groundwater hydrologists.

Why was this one?

Duration of the flooding!

Projected release by U.S. Army Corps of Engineers

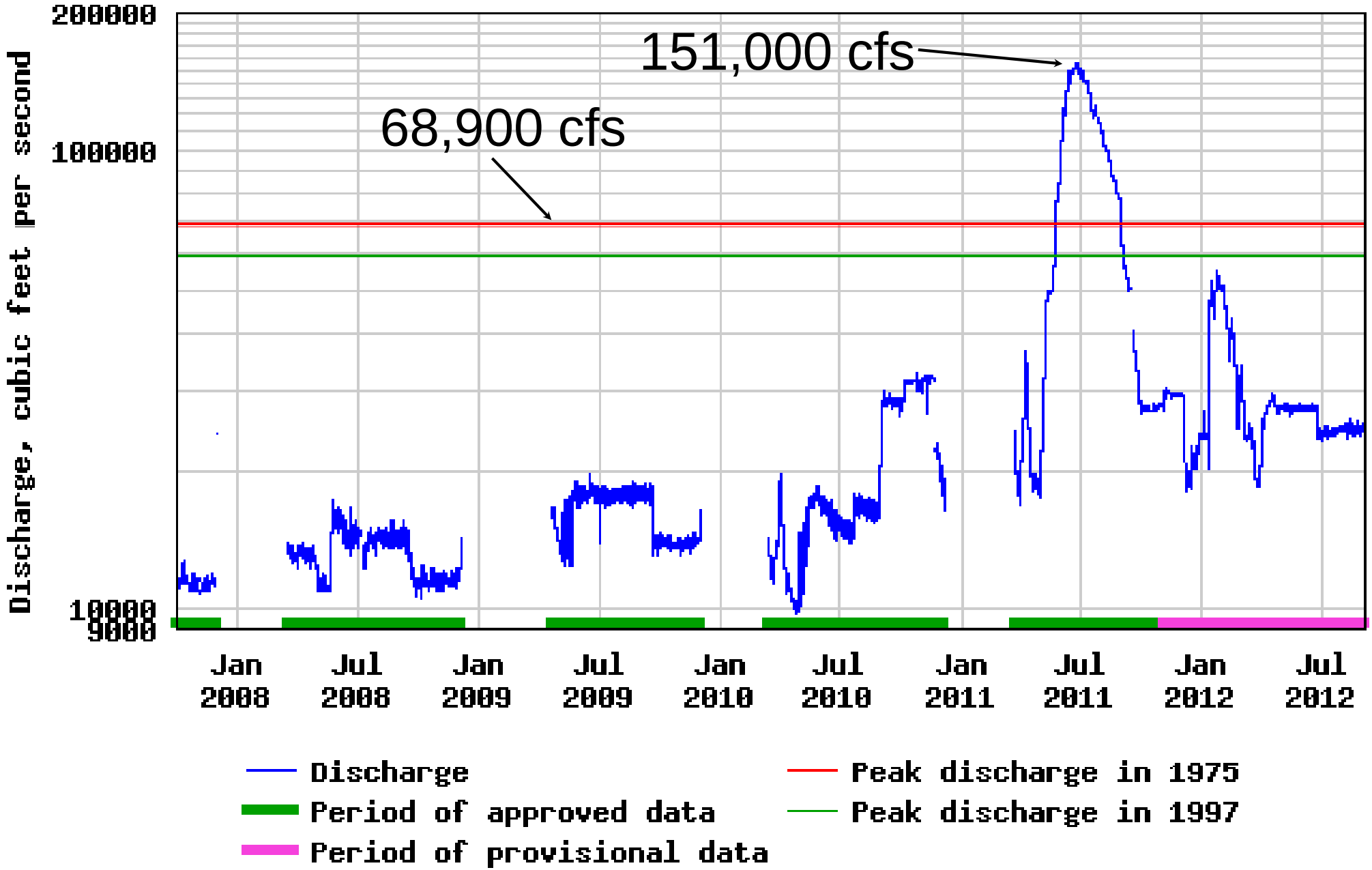
- May 23 -- 75,000 cfs
- May 24 -- 85,000 cfs
- May 26 -- 110,000 to 120,000 cfs
- May 28 -- 150,000 cfs by middle of June

Extreme Duration of the Flood

- Exceeded moderate flood stage of 16.0’ from June 2 to August 18.
- Total of 77 days.
- Exceeded major flood stage of 18.0’ from June 13 to August 2.
- Total of 50 days.
- Flood peaked at 19.25 feet on July 1.

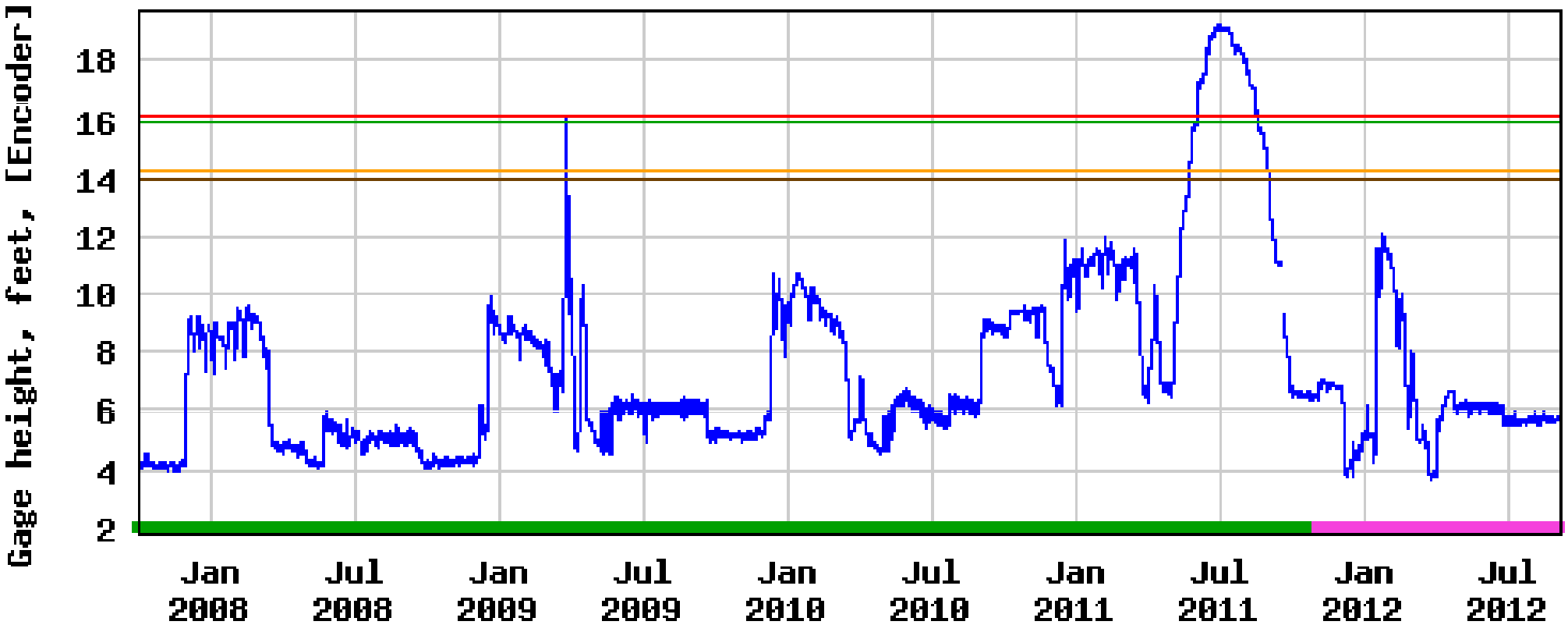
USGS

USGS 06342500 MISSOURI RIVER AT BISMARCK, ND



USGS

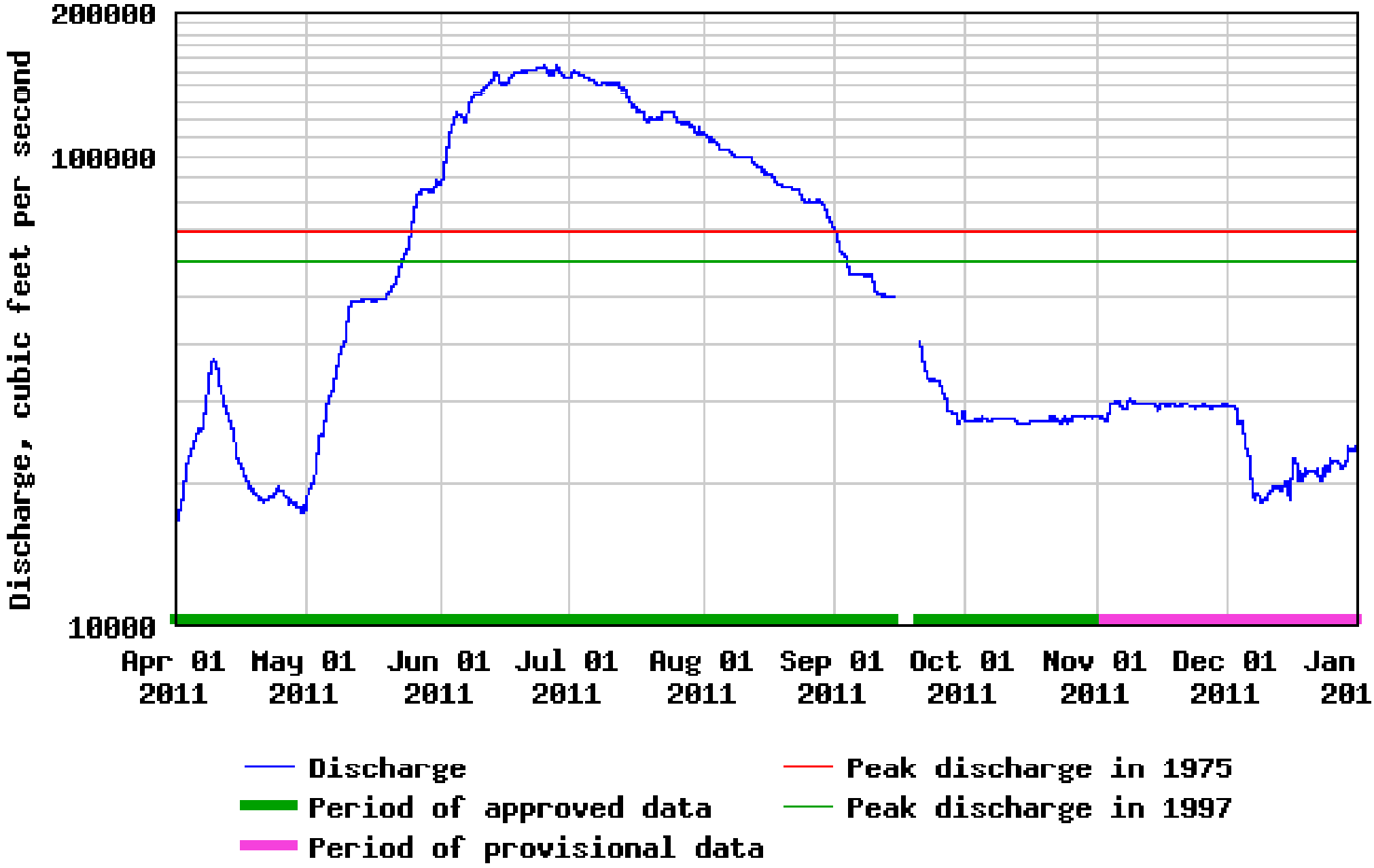
USGS 06342500 MISSOURI RIVER AT BISMARCK, ND



Flood stage
major 18.0’
moderate 16.0’

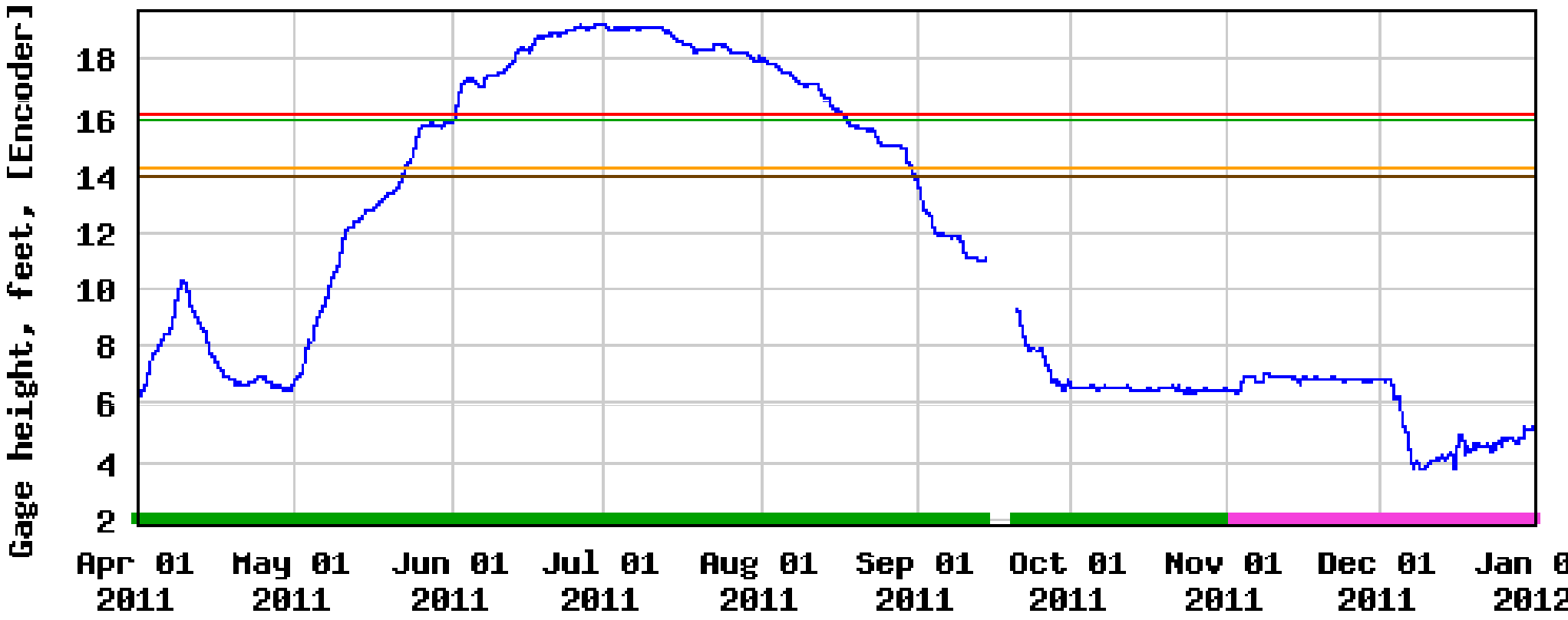
USGS

USGS 06342500 MISSOURI RIVER AT BISMARCK, ND



USGS

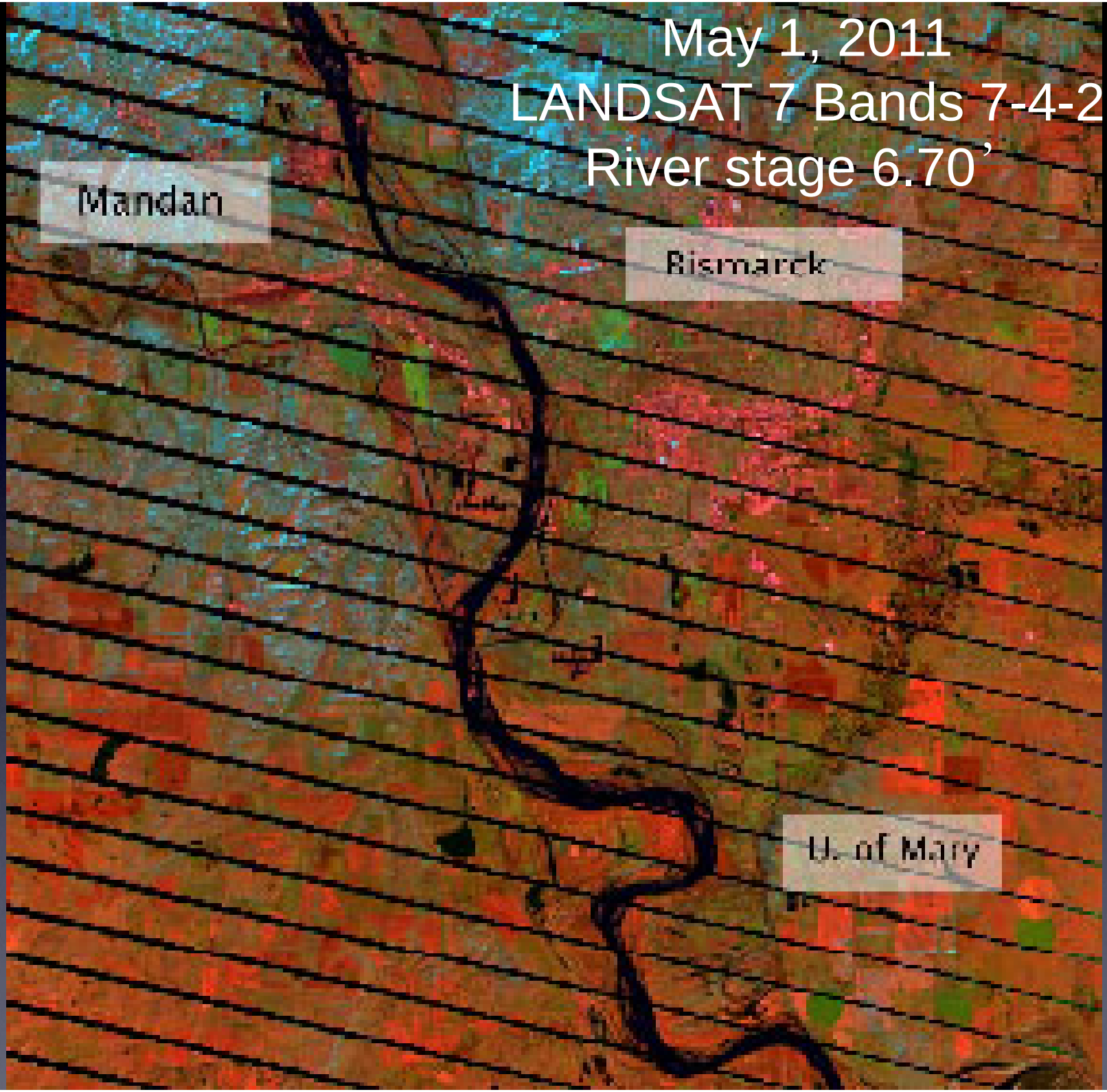
USGS 06342500 MISSOURI RIVER AT BISMARCK, ND

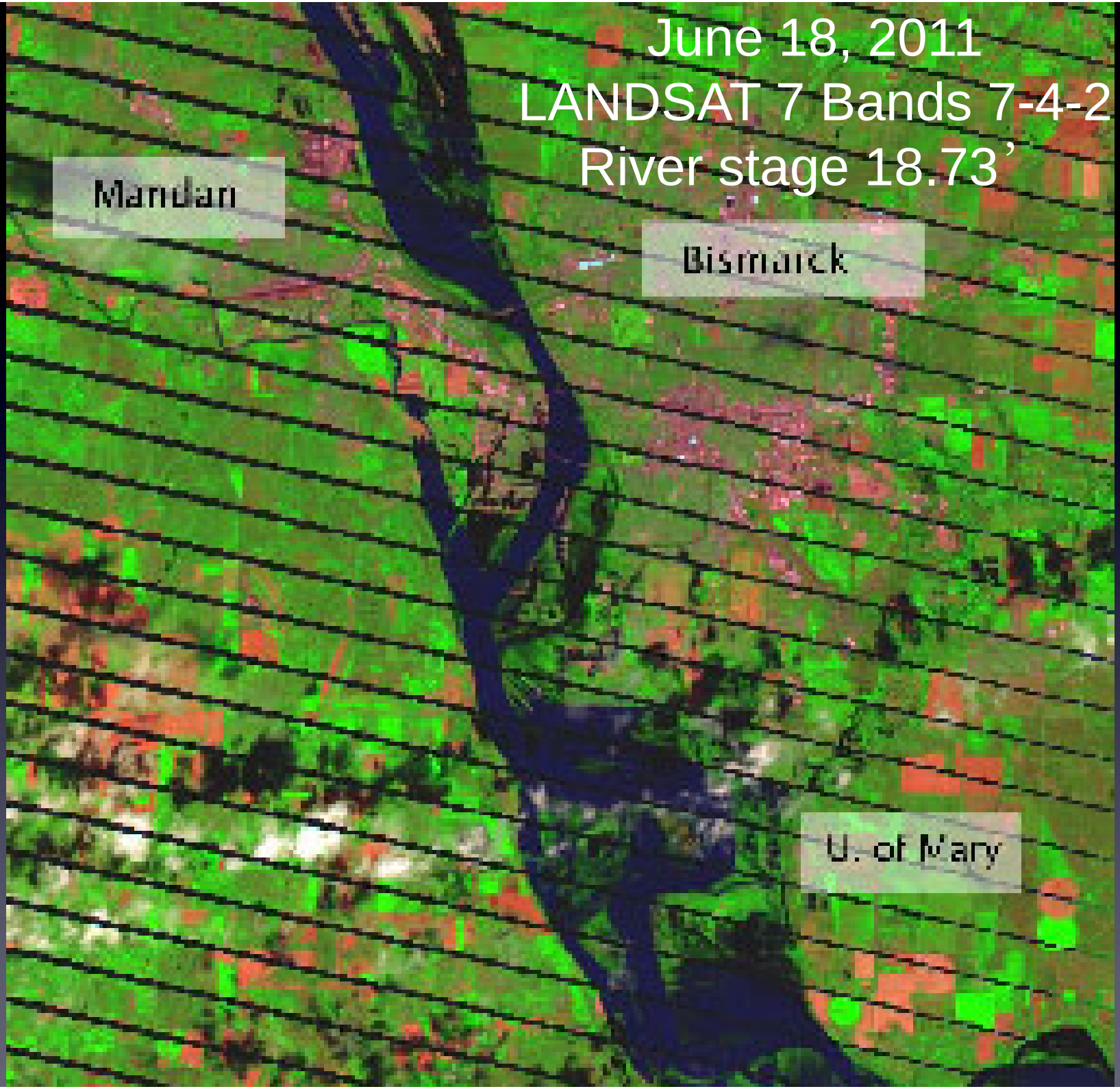


Flood stage
major 18.0’
moderate 16.0’

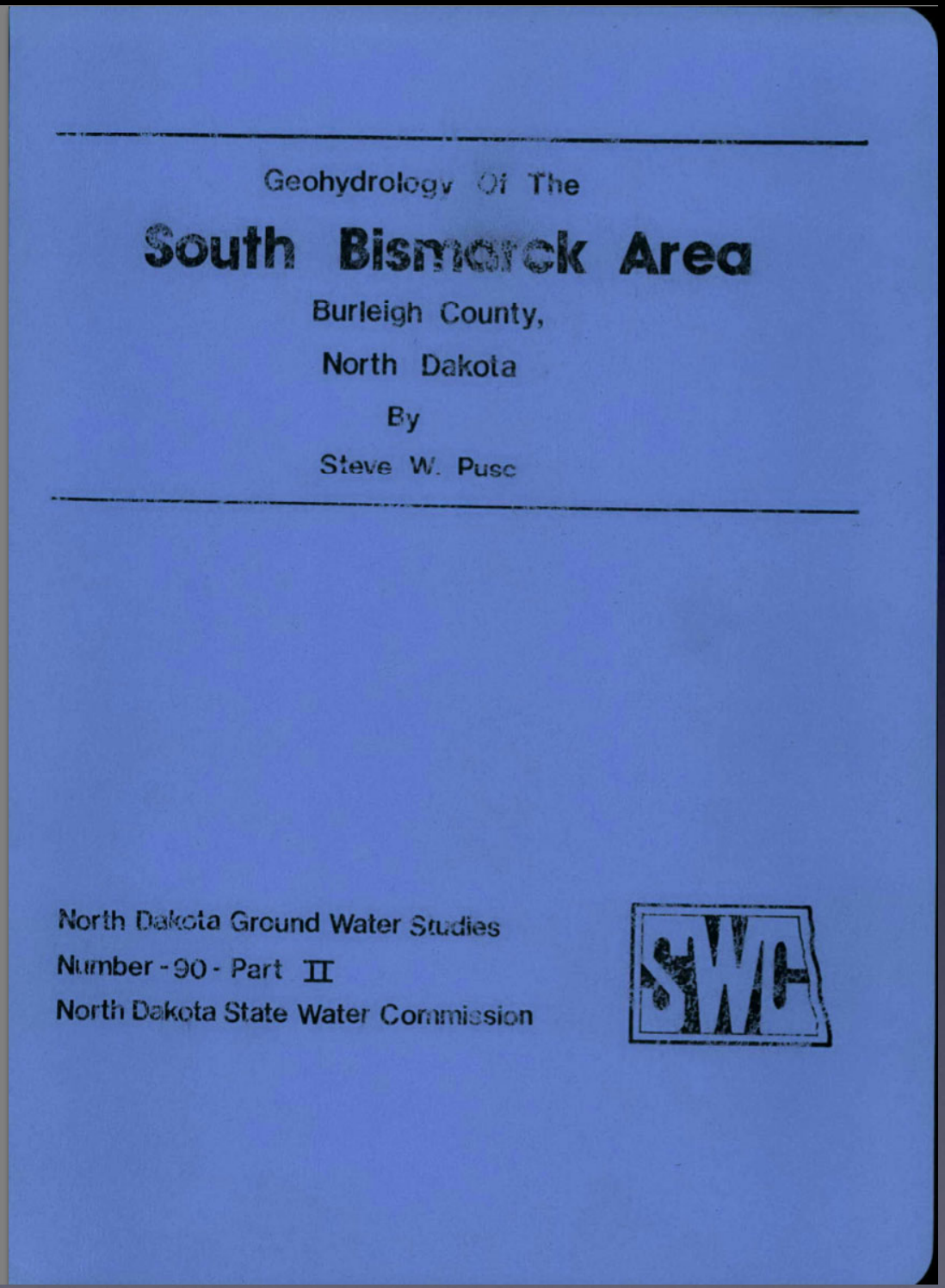
- Gage height
- Period of approved data
- Period of provisional data
- Peak gage height in 2009
- National Weather Service Flood Stage
- Peak gage height in 1975
- Peak gage height in 1997

Extent of the flooding.


May 1, 2011
LANDSAT 7 Bands 7-4-2
River stage 6.70'
Mandan
Bismarck
U. of Mary


June 18, 2011
LANDSAT 7 Bands 7-4-2
River stage 18.73’
Mandan
Bismarck
U. of Mary

Important to have good baseline data.



This 1984 report provided the foundation for the NDSWC response to the flooding.

- Described the geohydrologic framework.
- Evaluated the interrelationships between the ground water and surface water systems in the area.
- Determined the configuration of the water table and illustrate the range in depth to water in the

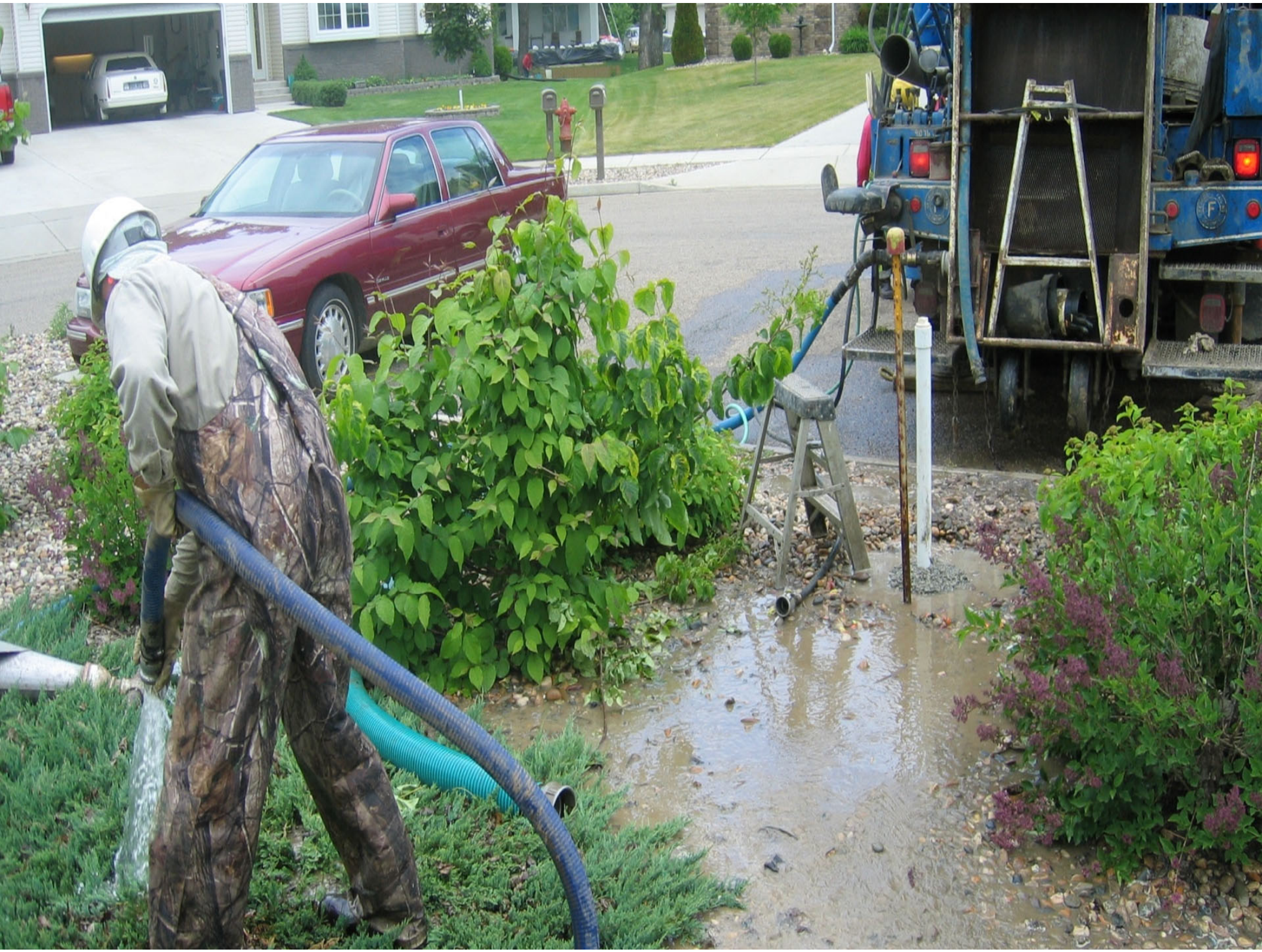
Prior Data

- Measurement of most of the observation wells installed for the South Bismarck study ceased soon after the completion of the study. In 2005, plugging these wells was considered. Fortunately Steve decided to add many of the wells that still pumped back into the NDSWC water level monitoring network. This gave us critical water level background prior to the flood.
- LIDAR for Bismarck-Mandan area was flown in 2009.
- Without the LIDAR data, useful depth to water maps would not have been possible

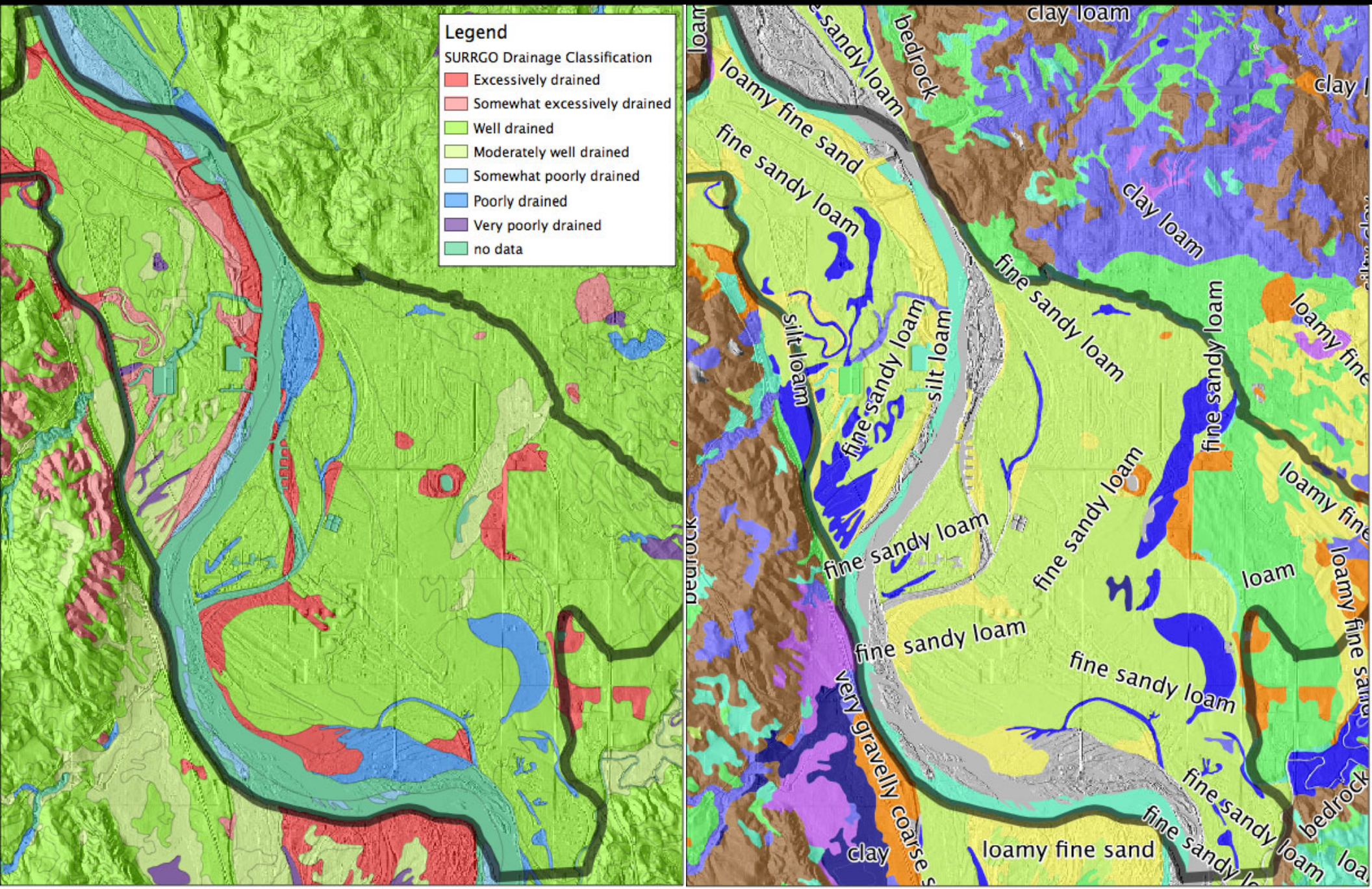

June 16, 2011
River stage 18.34 ft.

Dikes were built across the mouths of the bays and then pumped to control the water levels within the development.

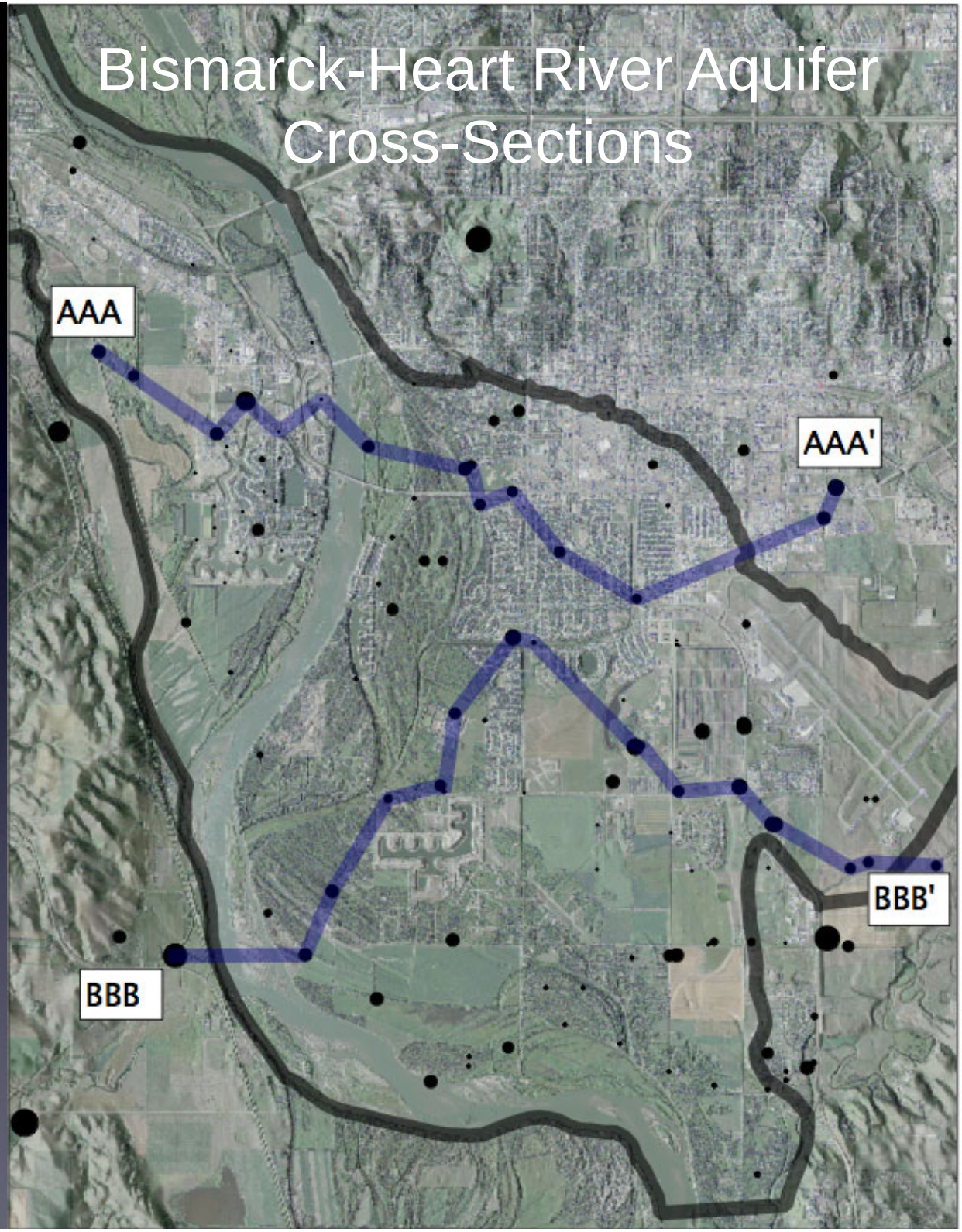
Head differential between the bays and the river was not allowed to exceed 3 feet to prevent sand boils from developing in the bottom of the bays.

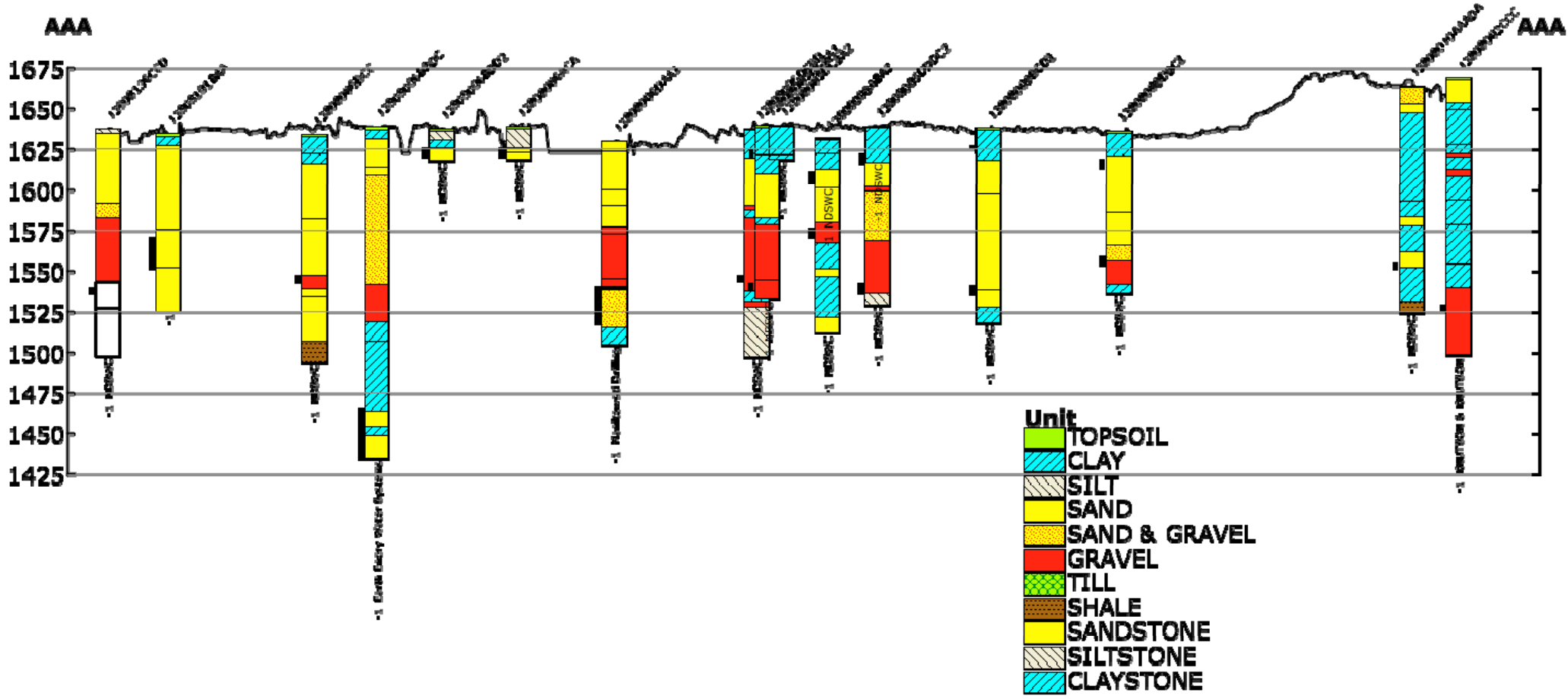


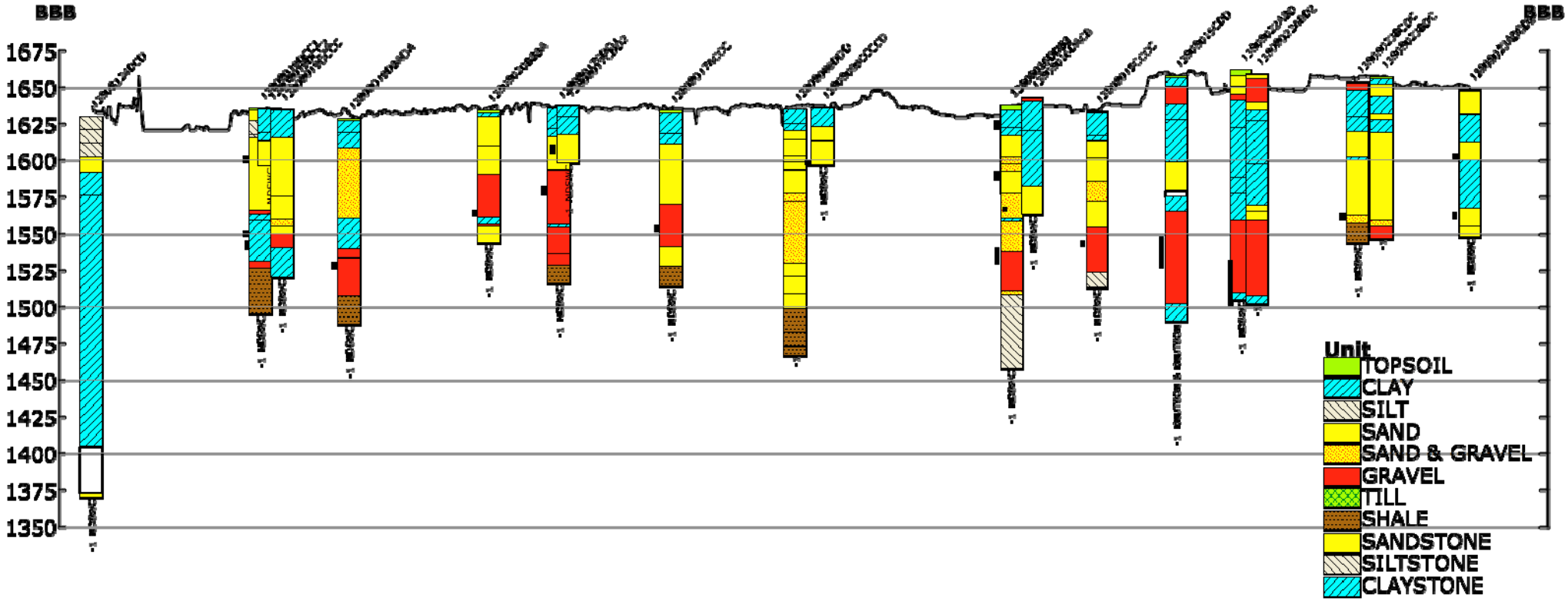
Hydrogeology


Legend
SURRGO Drainage Classification
Excessively drained
Somewhat excessively drained
Well drained
Moderately well drained
Somewhat poorly drained
Poorly drained
Very poorly drained
no data
clay loam
bedrock
loamy fine sand
fine sandy loam
silt loam
very gravelly coarse
clay
loam

Bismarck-Heart River Aquifer Cross-Sections



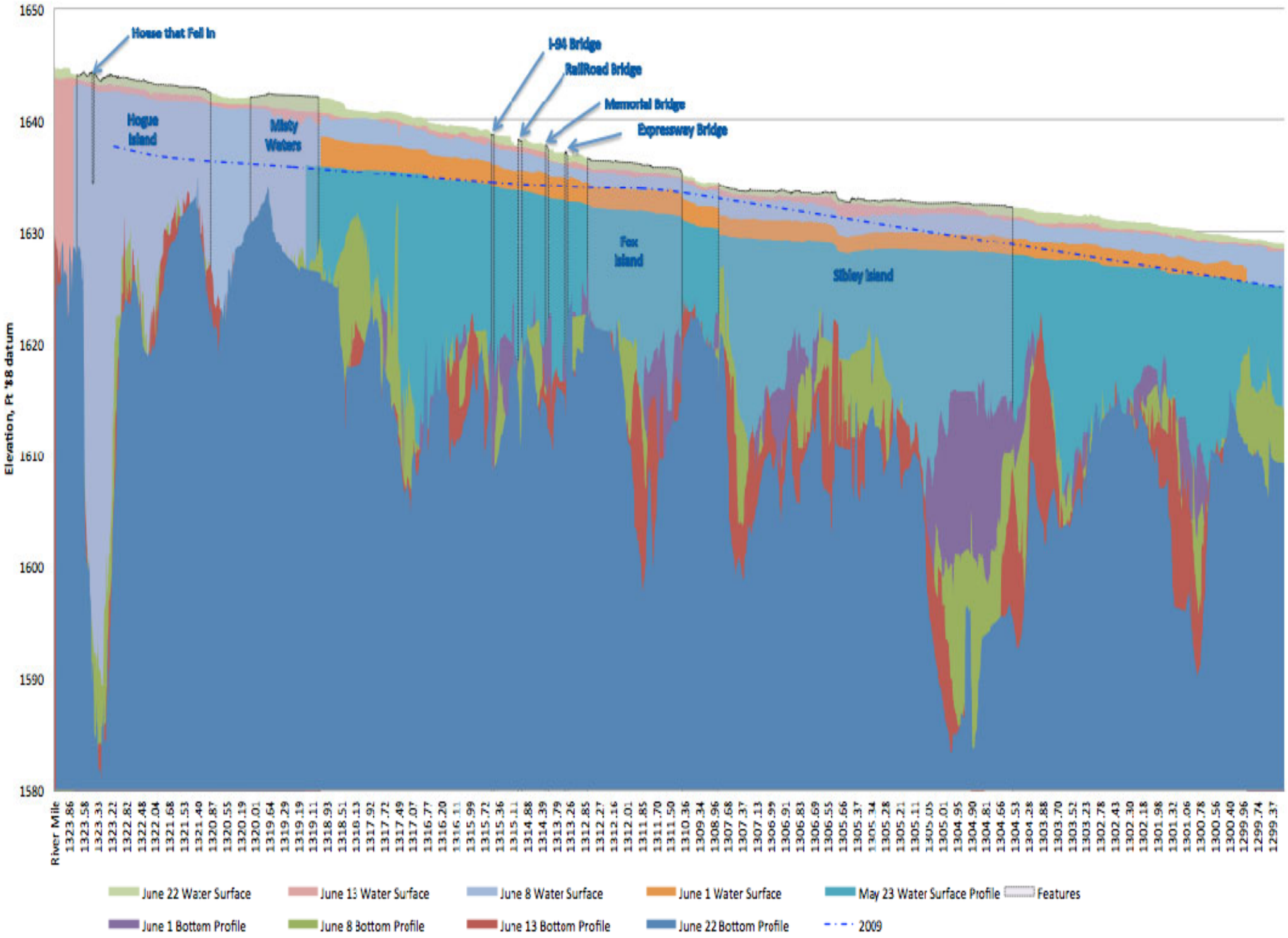

AAA
AAA
1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
1425
Unit
TOPSOIL
CLAY
SILT
SAND
SAND & GRAVEL
GRAVEL
TILL
SHALE
SANDSTONE
SILTSTONE
CLAYSTONE


BBB
BBB
1675
1650
1625
1600
1575
1550
1525
1500
1475
1450
1425
1400
1375
1350
Unit
TOPSOIL
CLAY
SILT
SAND
SAND & GRAVEL
GRAVEL
TILL
SHALE
SANDSTONE
SILTSTONE
CLAYSTONE

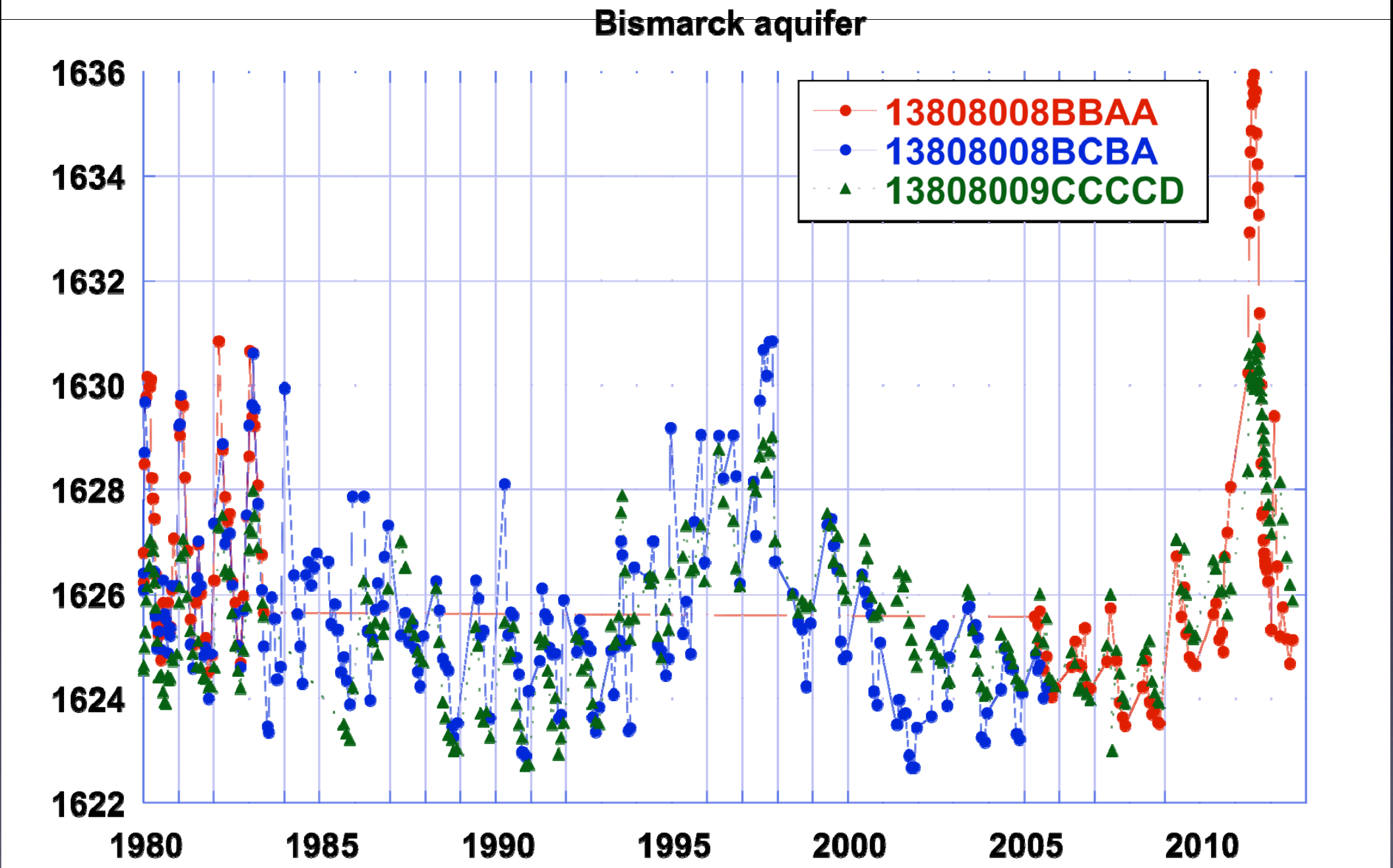
Aquifer connection to the Missouri River.

Missouri River Water/Bottom Profile through Bismarck/Mandan

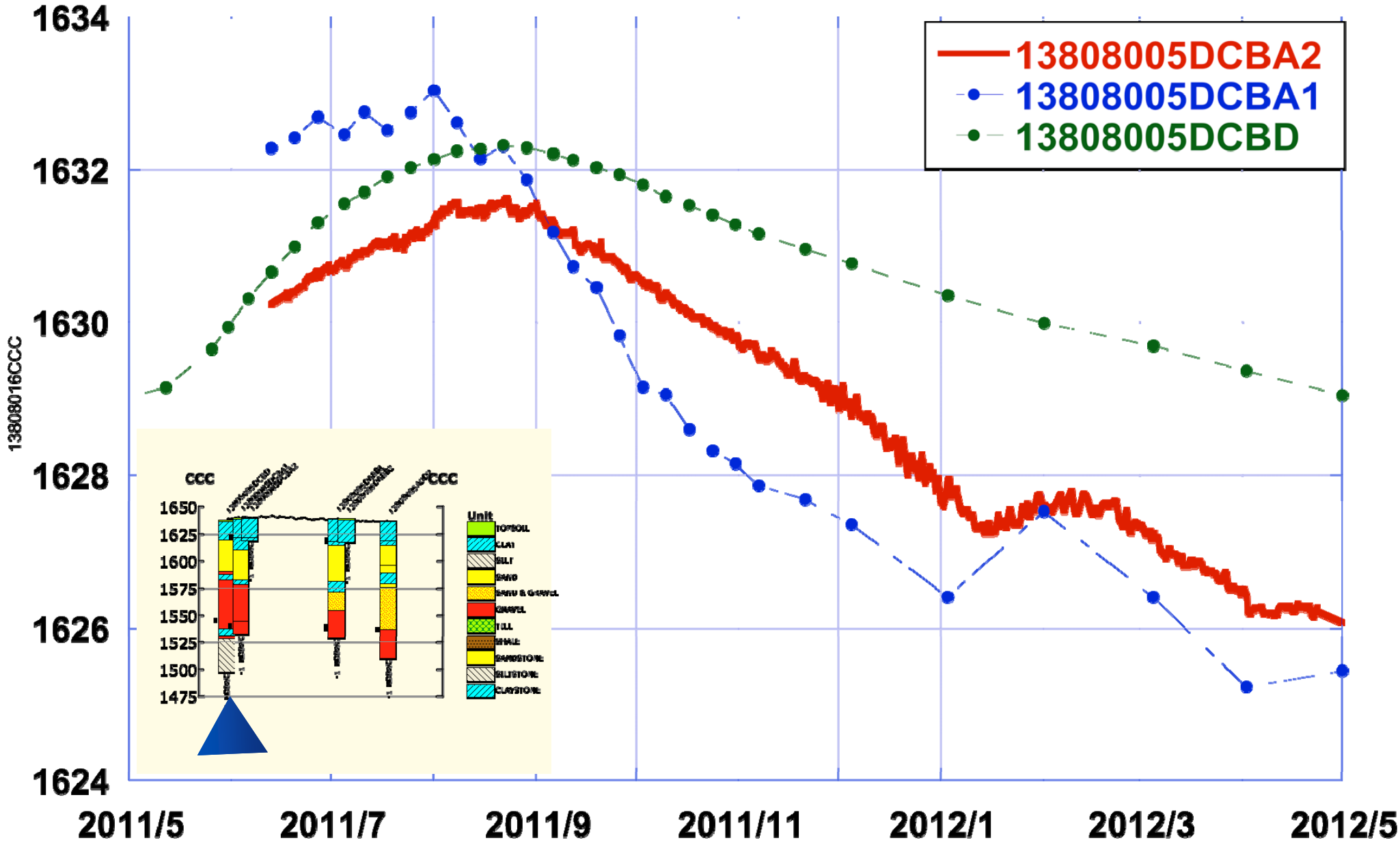
June 22, 2011

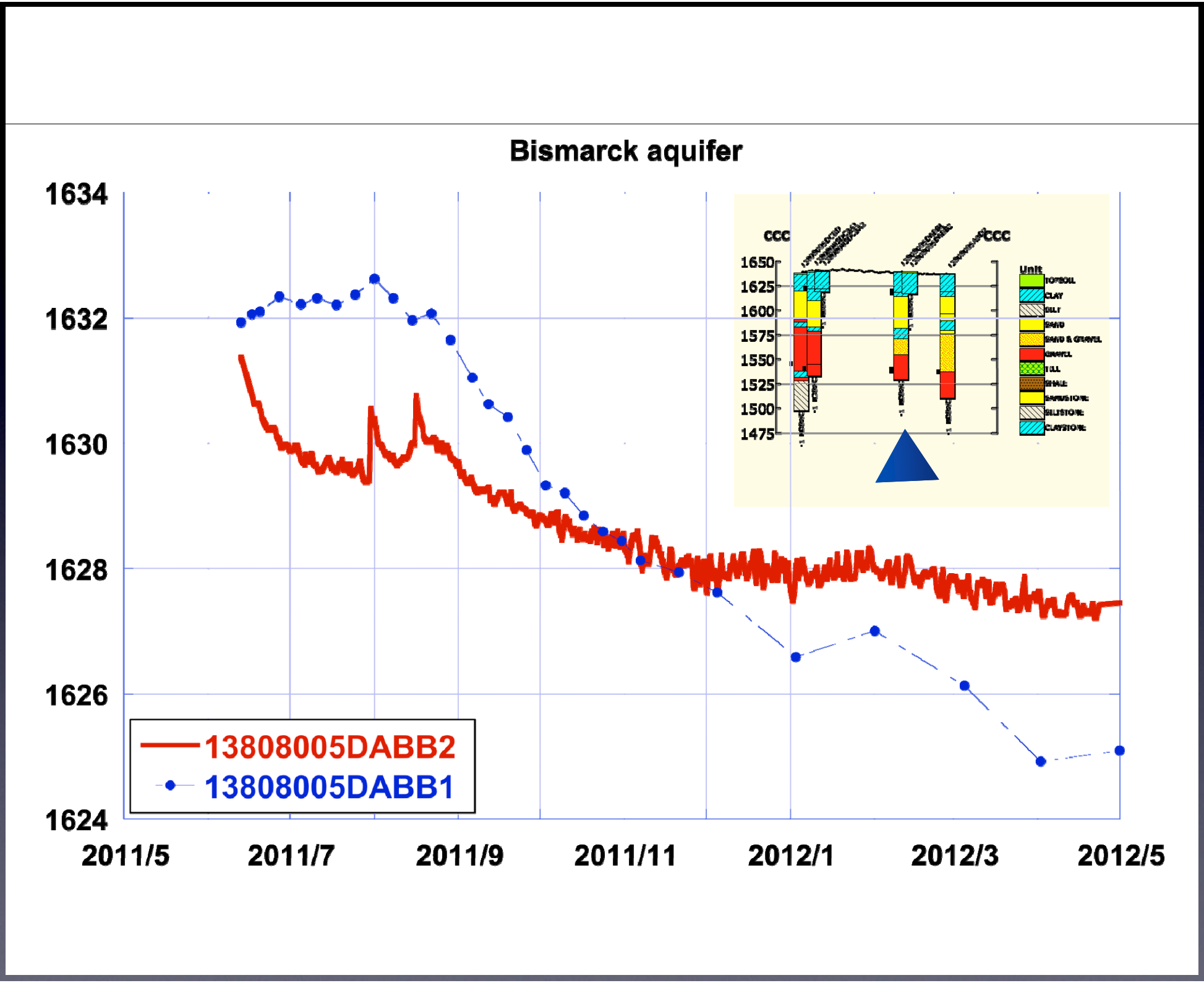


Hydrographs

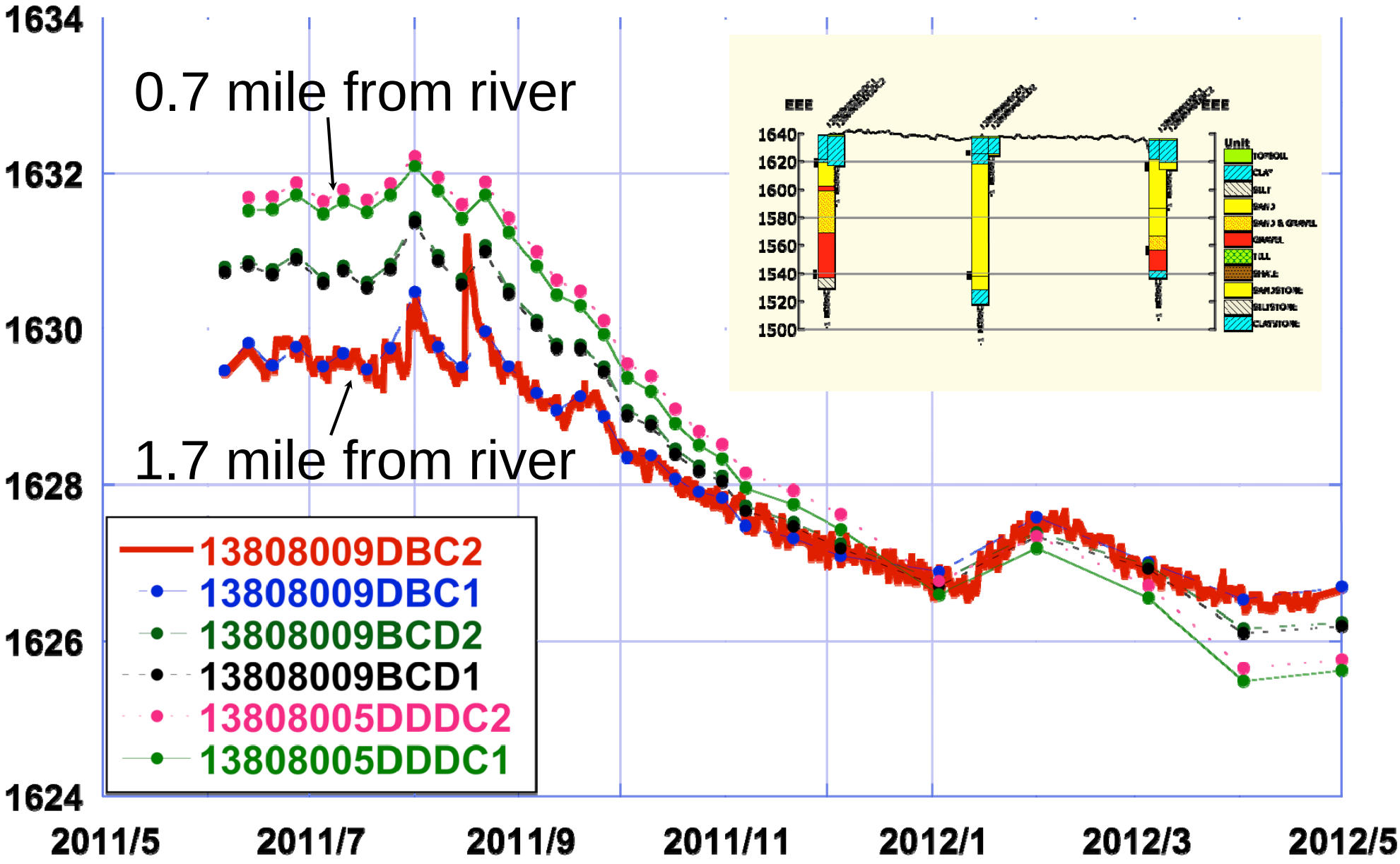

Bismarck aquifer
13808008BBAA
13808008BCBA
13808009CCCCD
1636
1634
1632
1630
1628
1626
1624
1622
1980
1985
1990
1995
2000
2005
2010

Bismarck aquifer

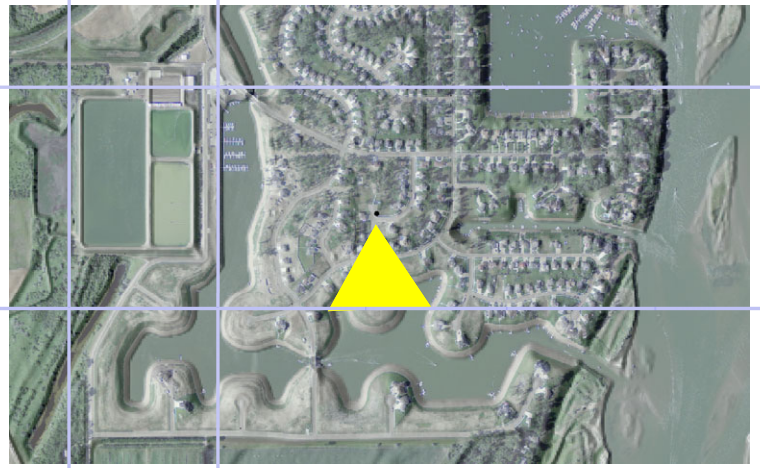


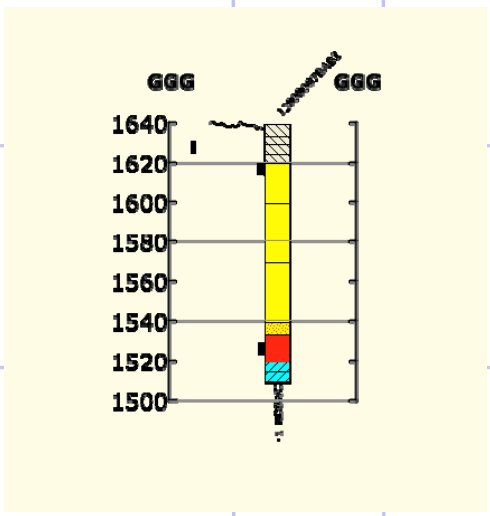

Bismarck aquifer
1634
1632
1630
1628
1626
1624
2011/5
2011/7
2011/9
2011/11
2012/1
2012/3
2012/5
13808005DABB2
13808005DABB1
CCC
CCC
1650
1625
1600
1575
1550
1525
1500
1475
Unit
TOPSOIL
CLAY
SILT
SAND
SAND & GRAVEL
GRAVEL
TILL
SHALE
SANDSTONE
SILTSTONE
CLAYSTONE

Bismarck aquifer



Heart River aquifer





Elevation (feet, NAVD88)

1633
1631
1629
1627
1625

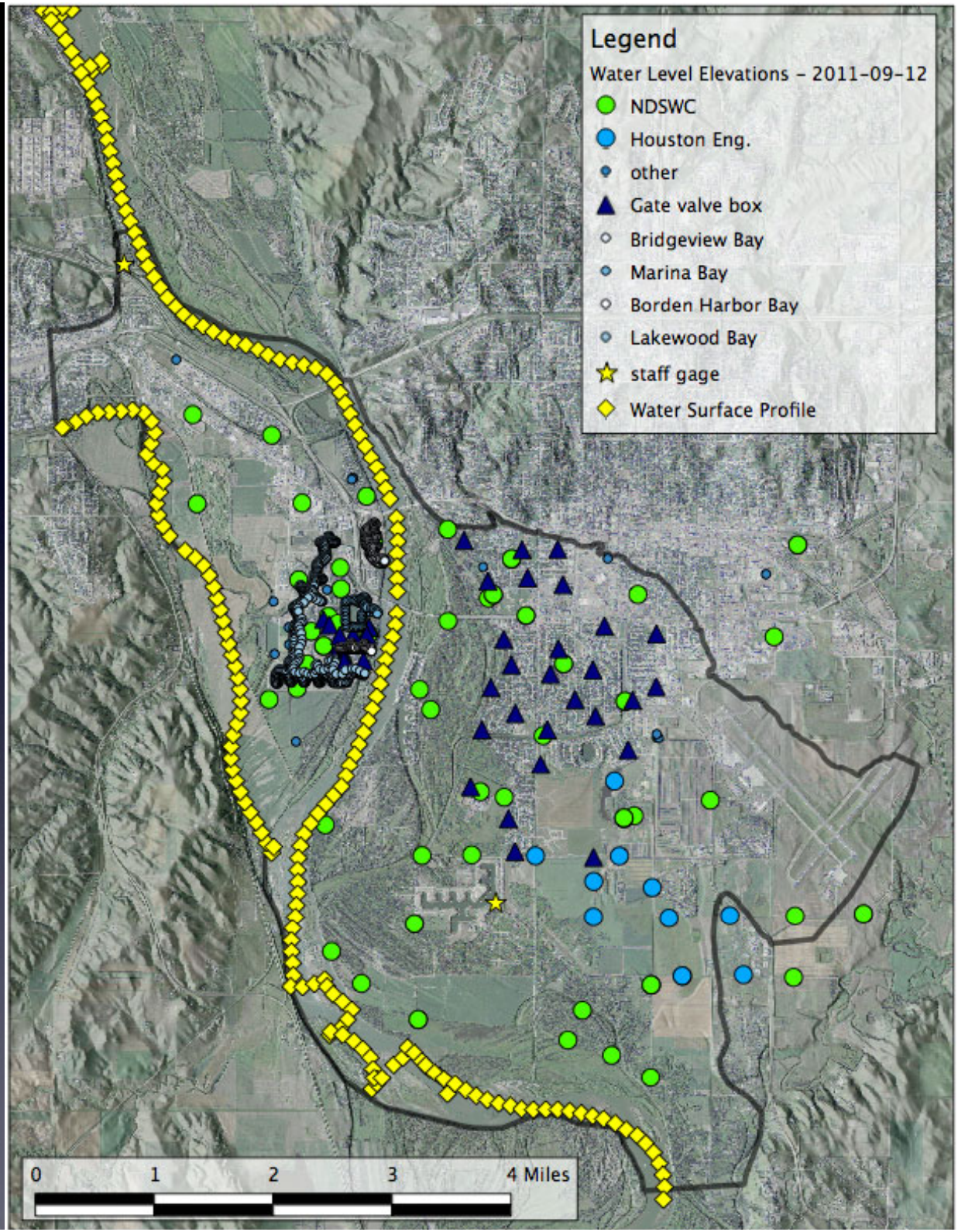
13808007BAB2
13808007BAB1

2011/5
2011/7
2011/9
2011/11
2012/1
2012/3
2012/5

Data sources:

- Geohydrology of the South Bismarck Area, Burleigh County, North Dakota, 1984. This study drilled 75 test holes and installed 68 observation wells. Prior to the flood, 31 wells at 25 sites were being monitored.
- NDSWC installed 14 obs. wells at 8 sites in South Bismarck aquifer and 17 obs. wells at 16 sites in the Heart River aquifer.
- 14 South Bismarck aquifer and 6 Heart River aquifer private and monitoring wells were located and added to the NDSWC well run.

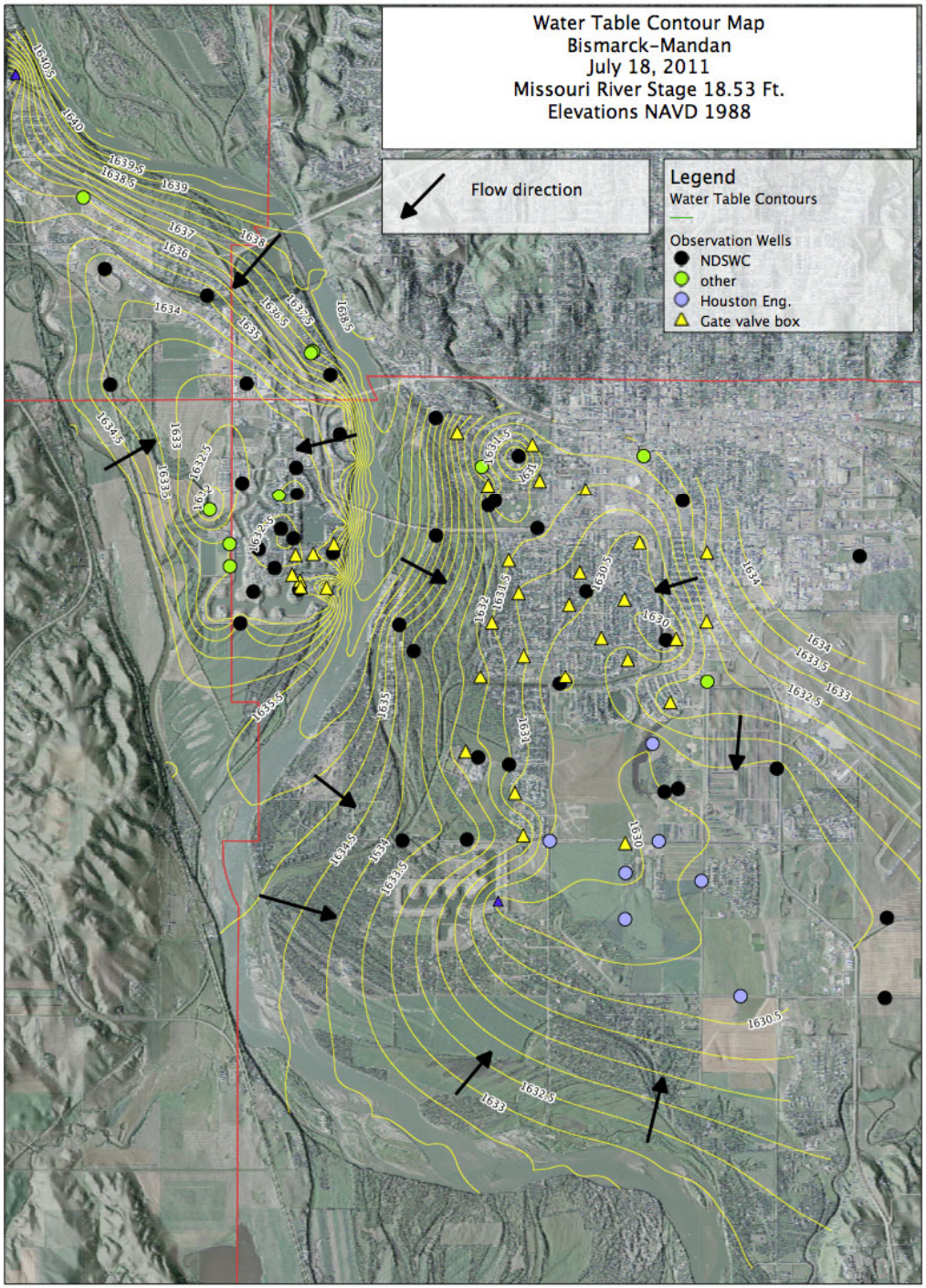
- City of Bismarck supplied water level elevations at 28 gate valve boxes and 5 surface water bodies overlying the South Bismarck aquifer.
- KLJ Engineering supplied water level elevations for 10 gate valve boxes and the 4 bays in Mandan.
- NDSWC Water Development Division supplied water level profiles for the Missouri River.

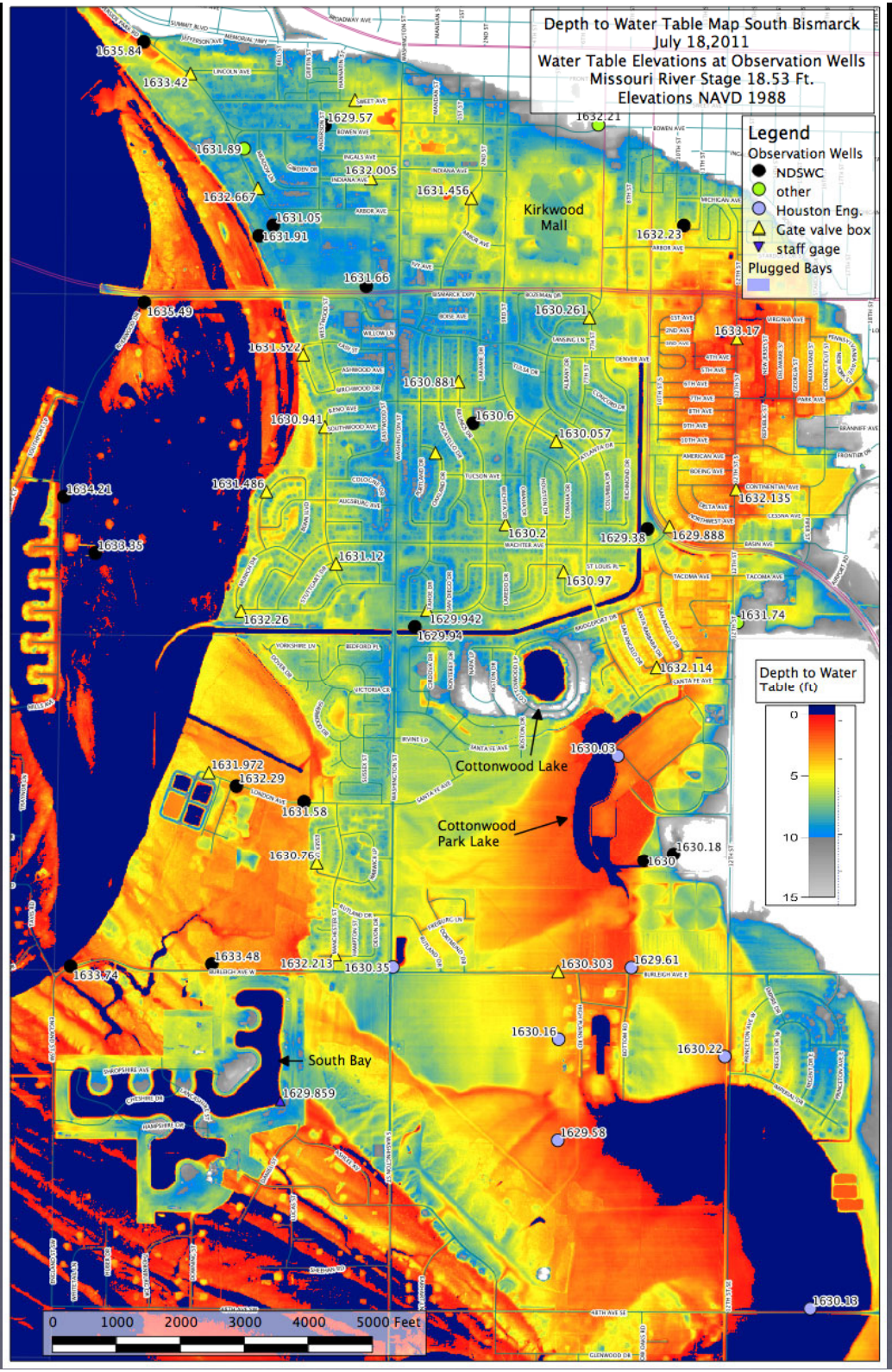

Legend
Water Level Elevations - 2011-09-12
NDSWC
Houston Eng.
other
Gate valve box
Bridgeview Bay
Marina Bay
Borden Harbor Bay
Lakewood Bay
staff gage
Water Surface Profile
0
1
2
3
4 Miles

If the river water level profile was not done on the day of the observation well measurements, it was adjusted up or down by the difference at the Bismarck gage between the time of the profile and that of the well run.

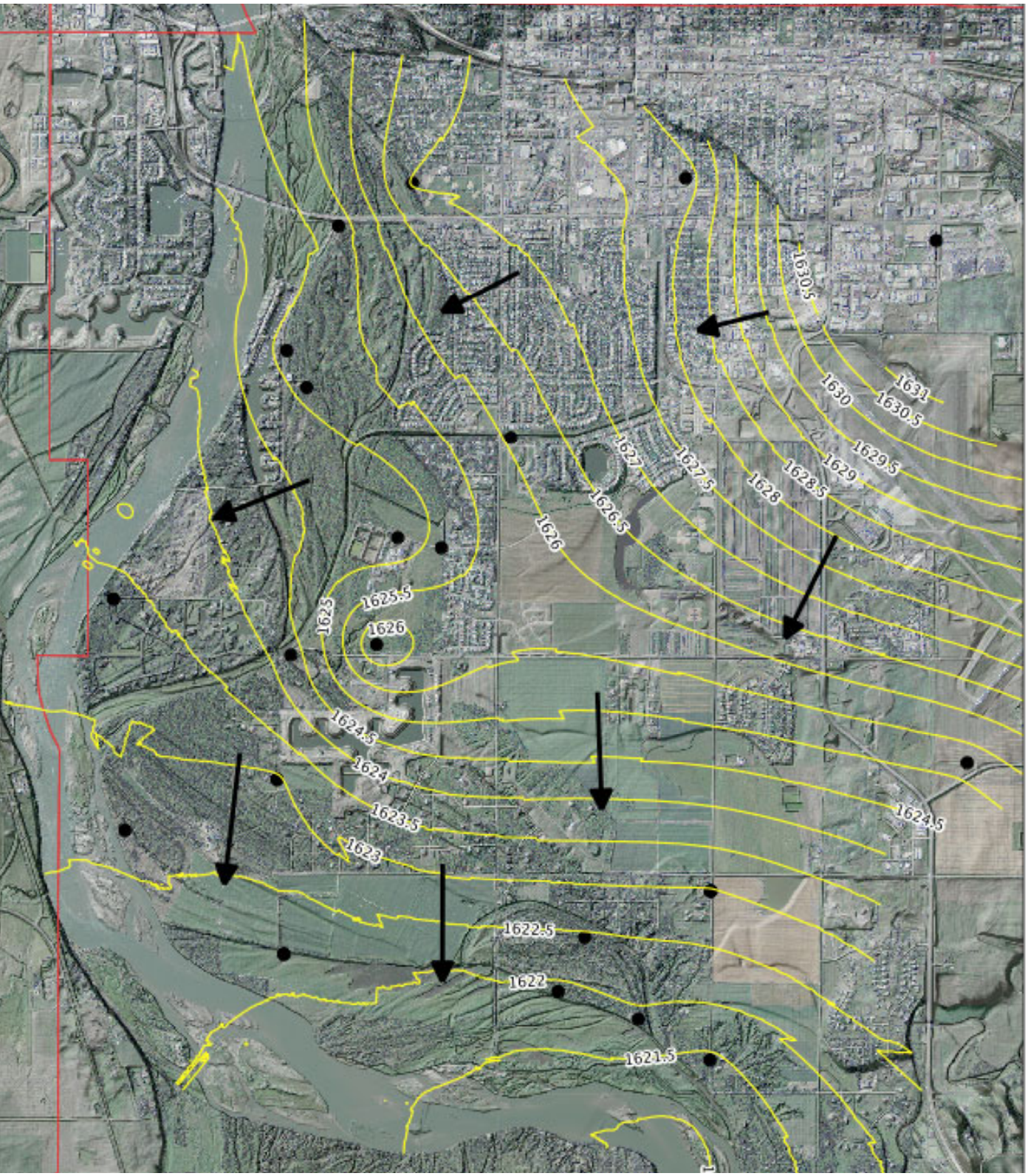
Map Preparation

- Data from the various sources was pasted into an Excel spreadsheet and exported as a text file.
- This was imported into QGIS and exported to a shapefile.
- The DBF was imported into Surfer. The grid coordinates and cell size were set to match the project LIDAR and then gridded. The grid was then clipped to the project extent.
- Depth to water grid was created by subracting the water table grid from the LIDAR DEM grid.
- The water table grid and contours, and the depth to water grid were then imported into QGIS to produce the final maps.

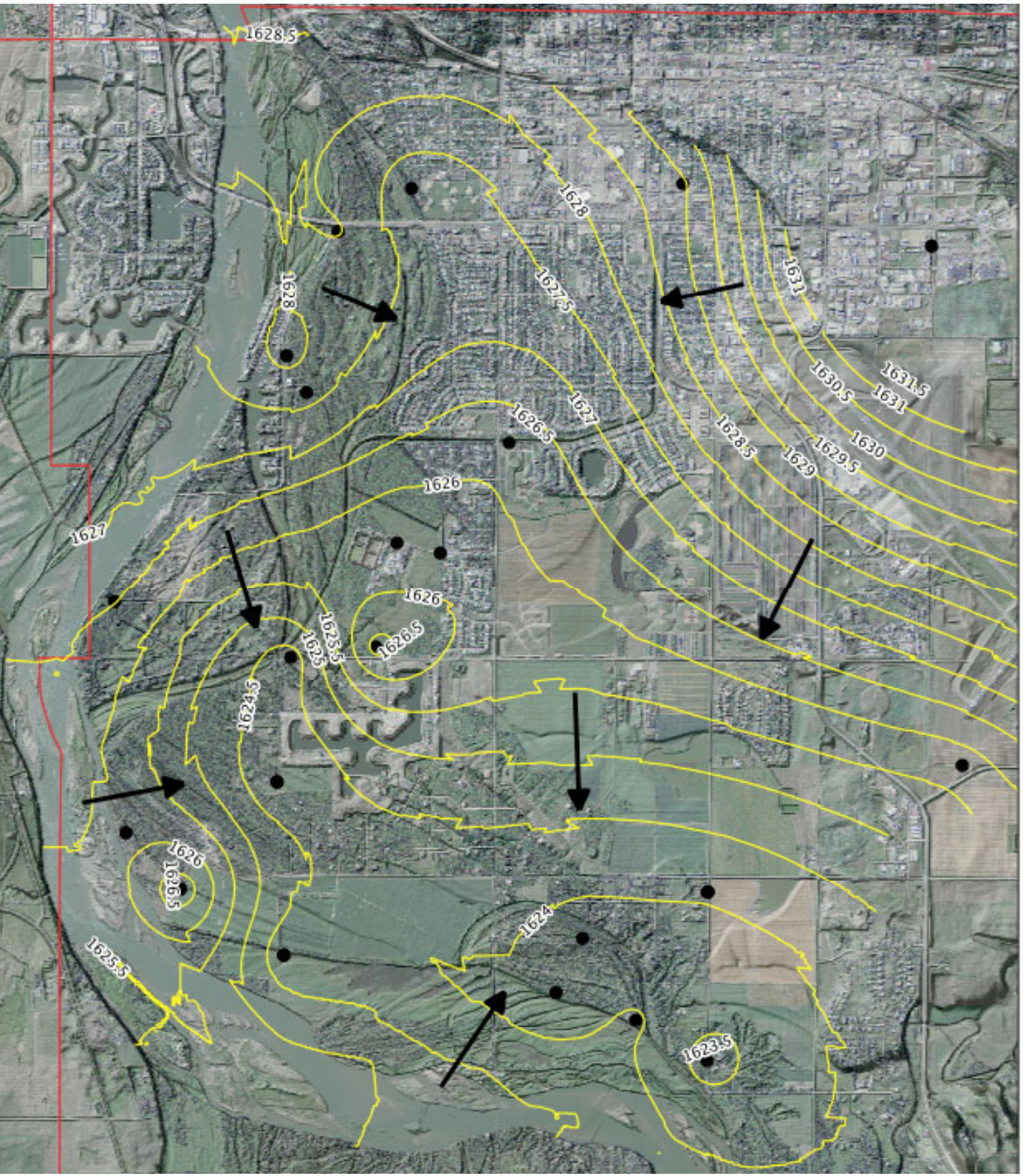

Water Table Contour Map
Bismarck-Mandan
July 18, 2011
Missouri River Stage 18.53 Ft.
Elevations NAVD 1988
Flow direction
Legend
Water Table Contours
Observation Wells
NDSWC
other
Houston Eng.
Gate valve box
1 0 1 2 3 4 Miles


Depth to Water Table Map South Bismarck
July 18,2011
Water Table Elevations at Observation Wells
Missouri River Stage 18.53 Ft.
Elevations NAVD 1988
Legend
Observation Wells
NDSWC
other
Houston Eng.
Gate valve box
staff gage
Plugged Bays
Depth to Water Table (ft)
0
5
10
15
Kirkwood Mall
Cottonwood Lake
Cottonwood Park Lake
South Bay
0 1000 2000 3000 4000 5000 Feet

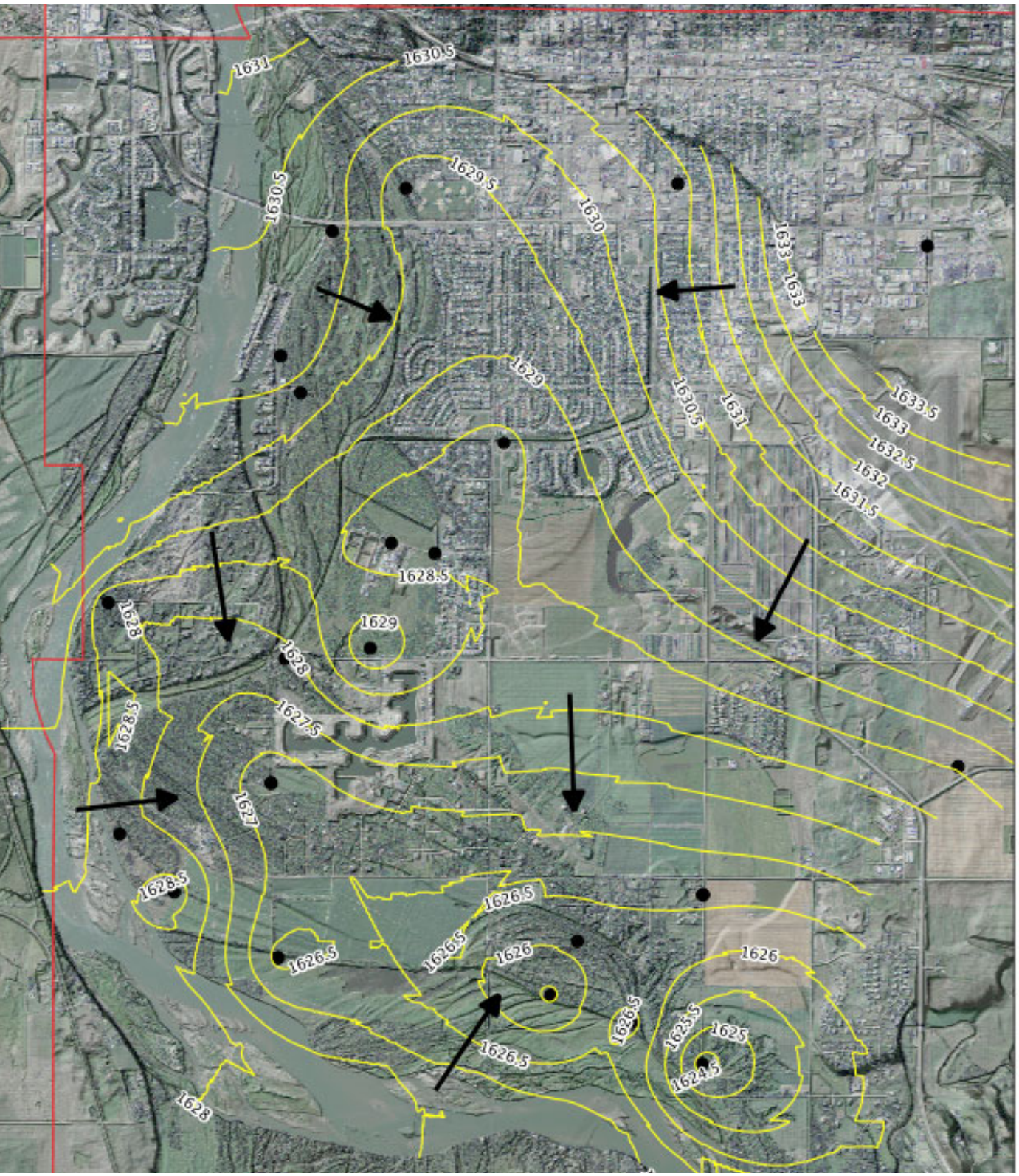
Water Table Contour Maps



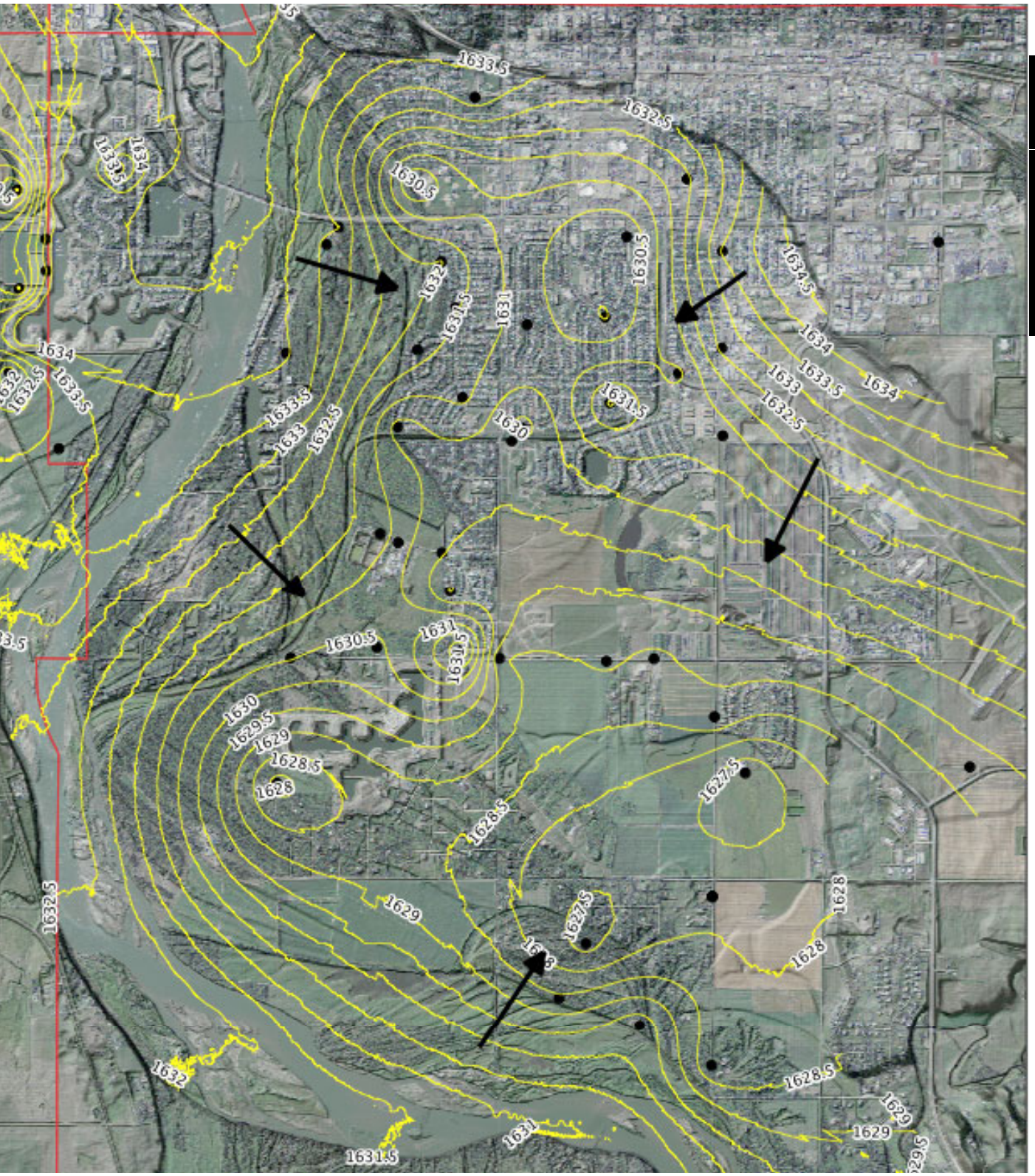
Water Table Contours 0.5 ft. August 9, 2010 River Stage 6.15 ft



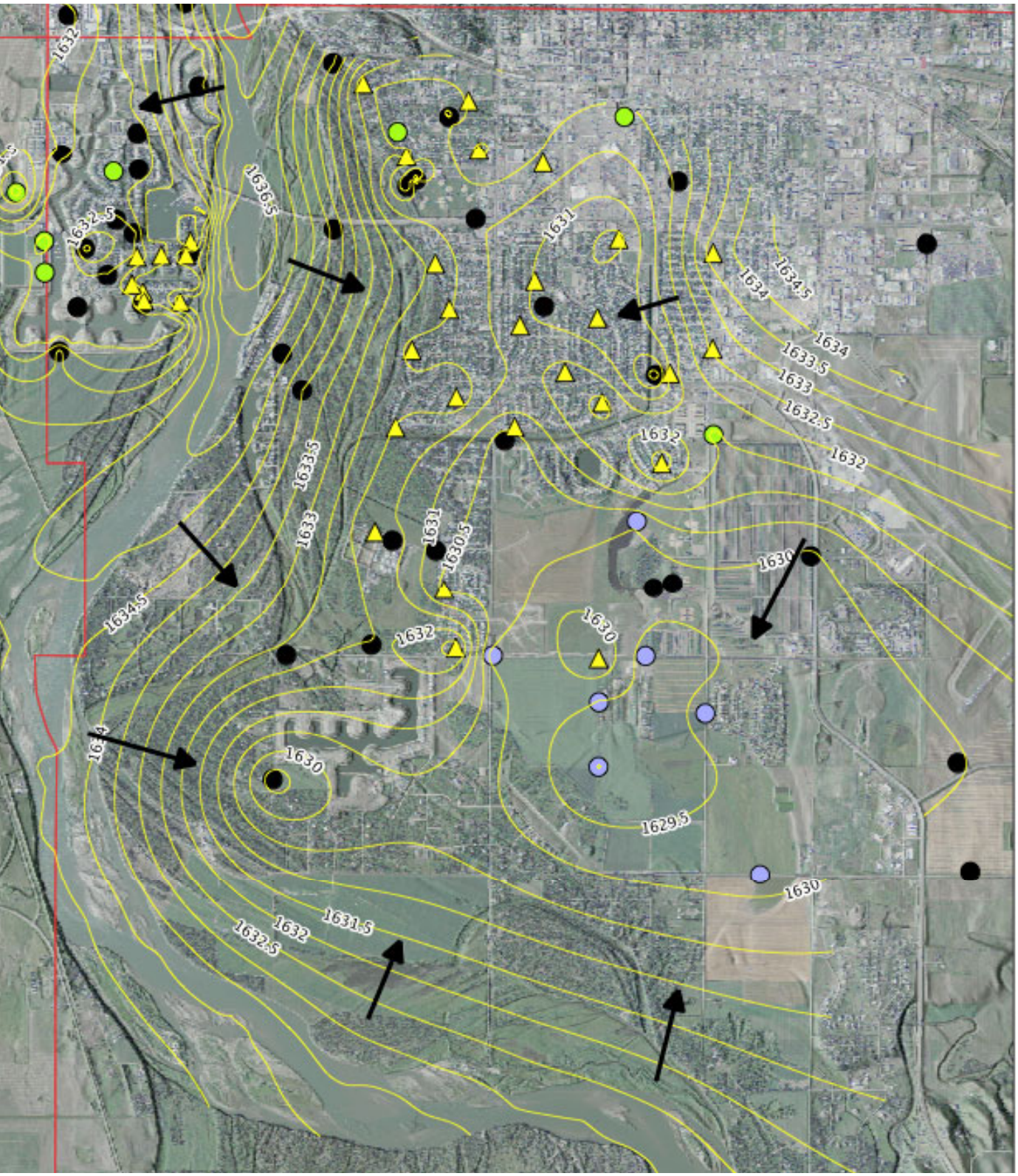
Water Table Contours 0.5 ft. November 11, 2010 River Stage 9.49 ft



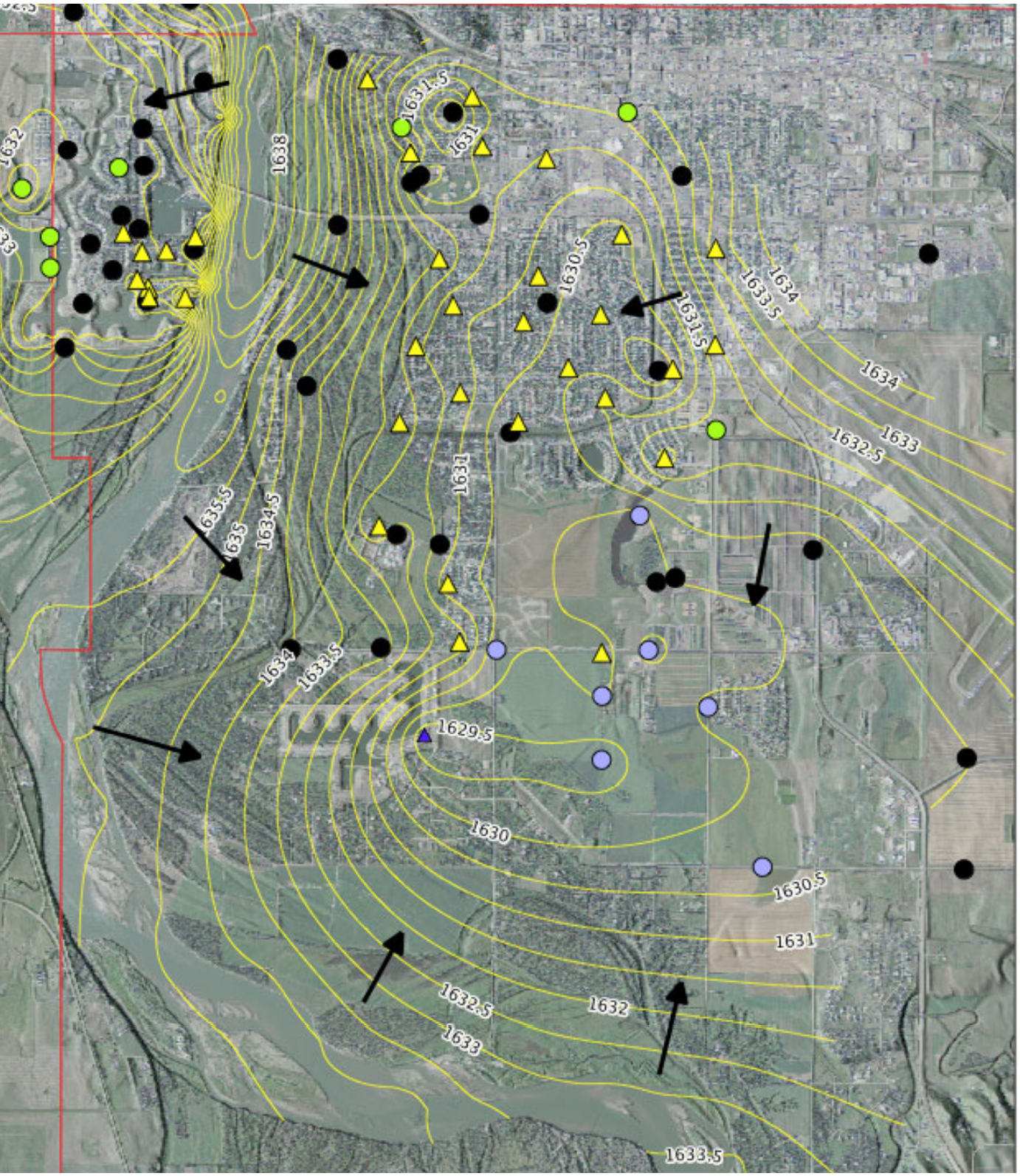
Water Table Contours 0.5 ft. May 12, 2011 River Stage 12.17 ft



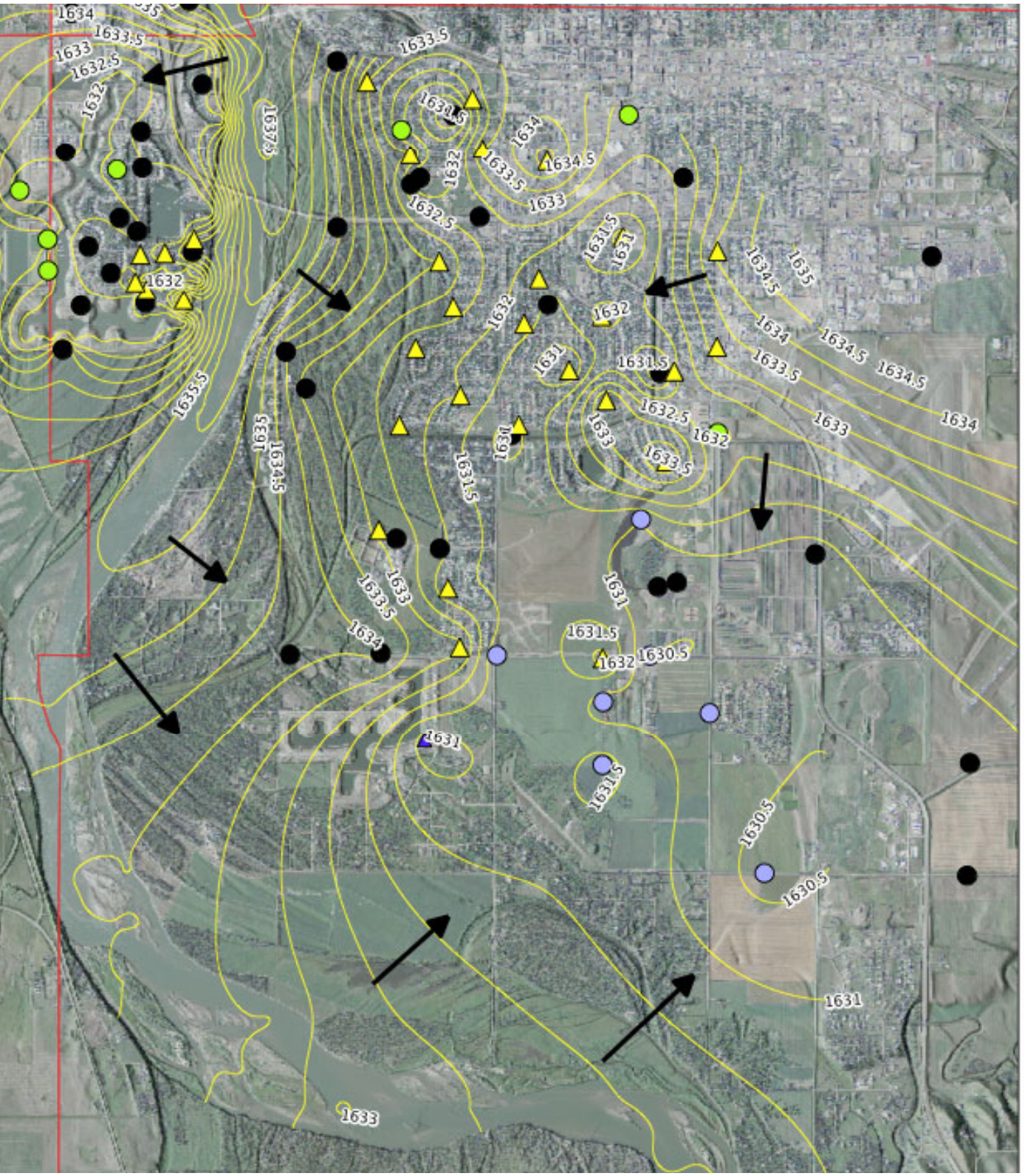
Water Table Contours 0.5 ft. May 31, 2011 River Stage 15.91 ft



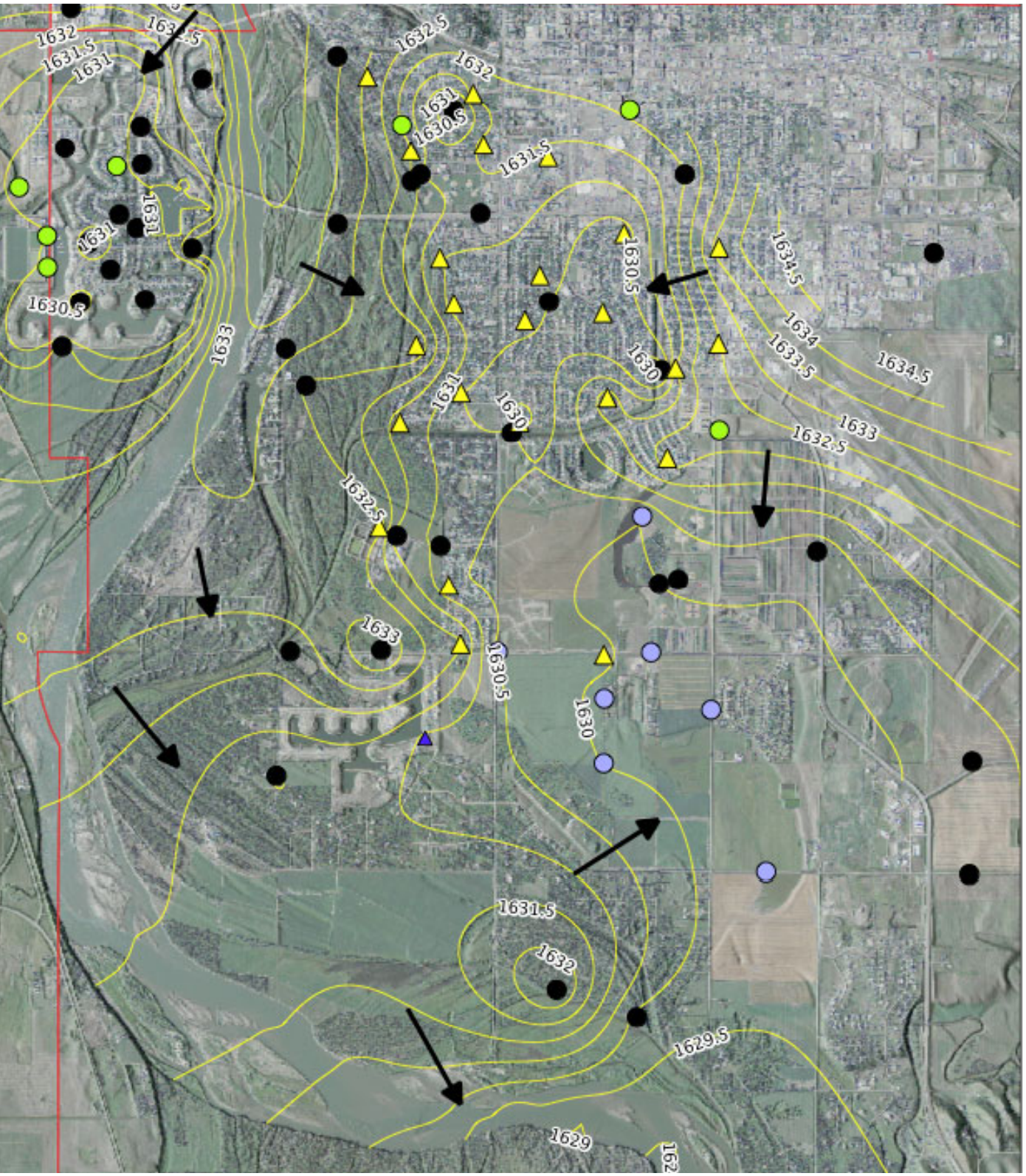
Water Table Contours 0.5 ft. June 13, 2011 River Stage 17.85 ft



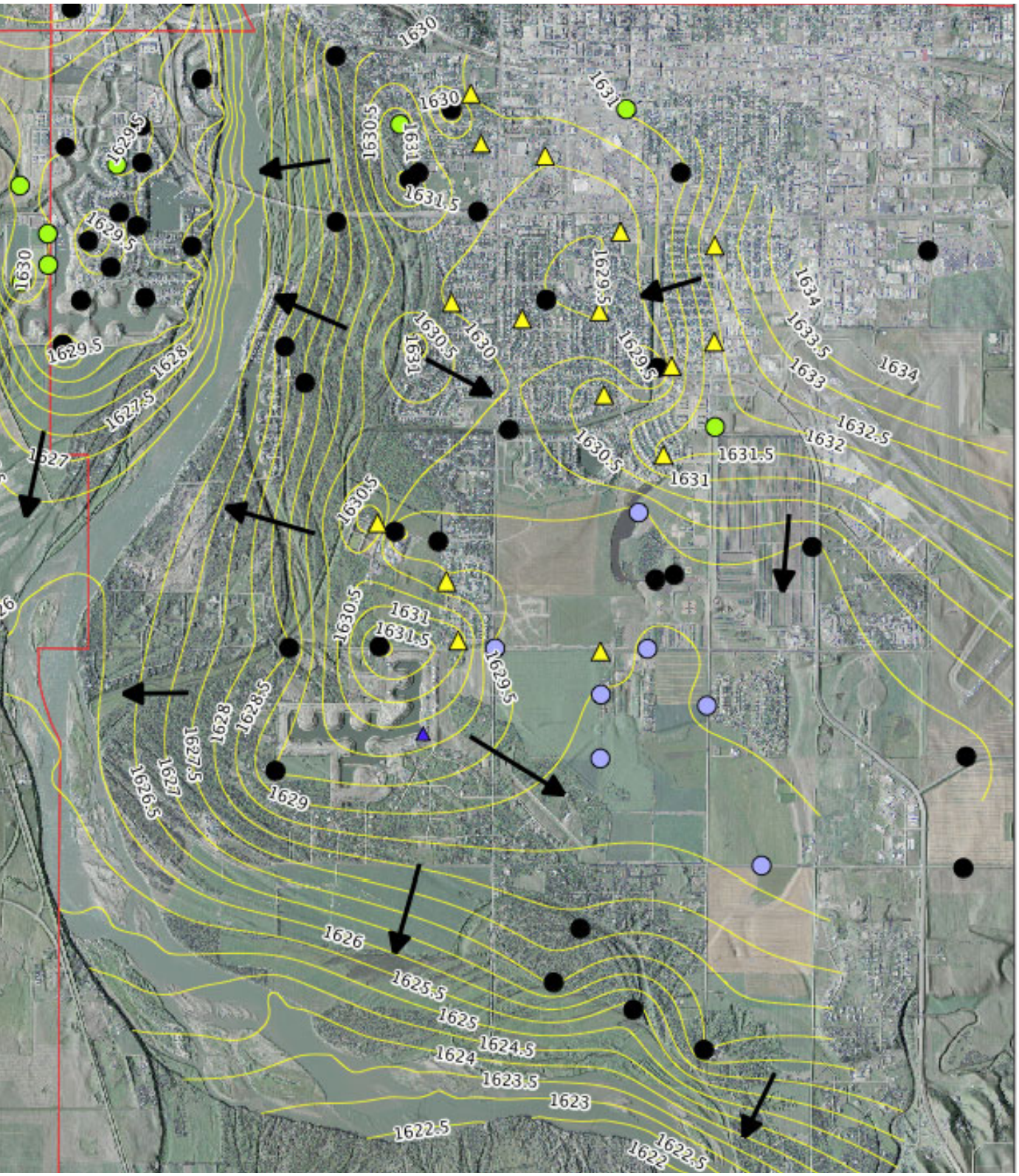
Water Table Contours 0.5 ft. July 5, 2011 River Stage 19.08 ft



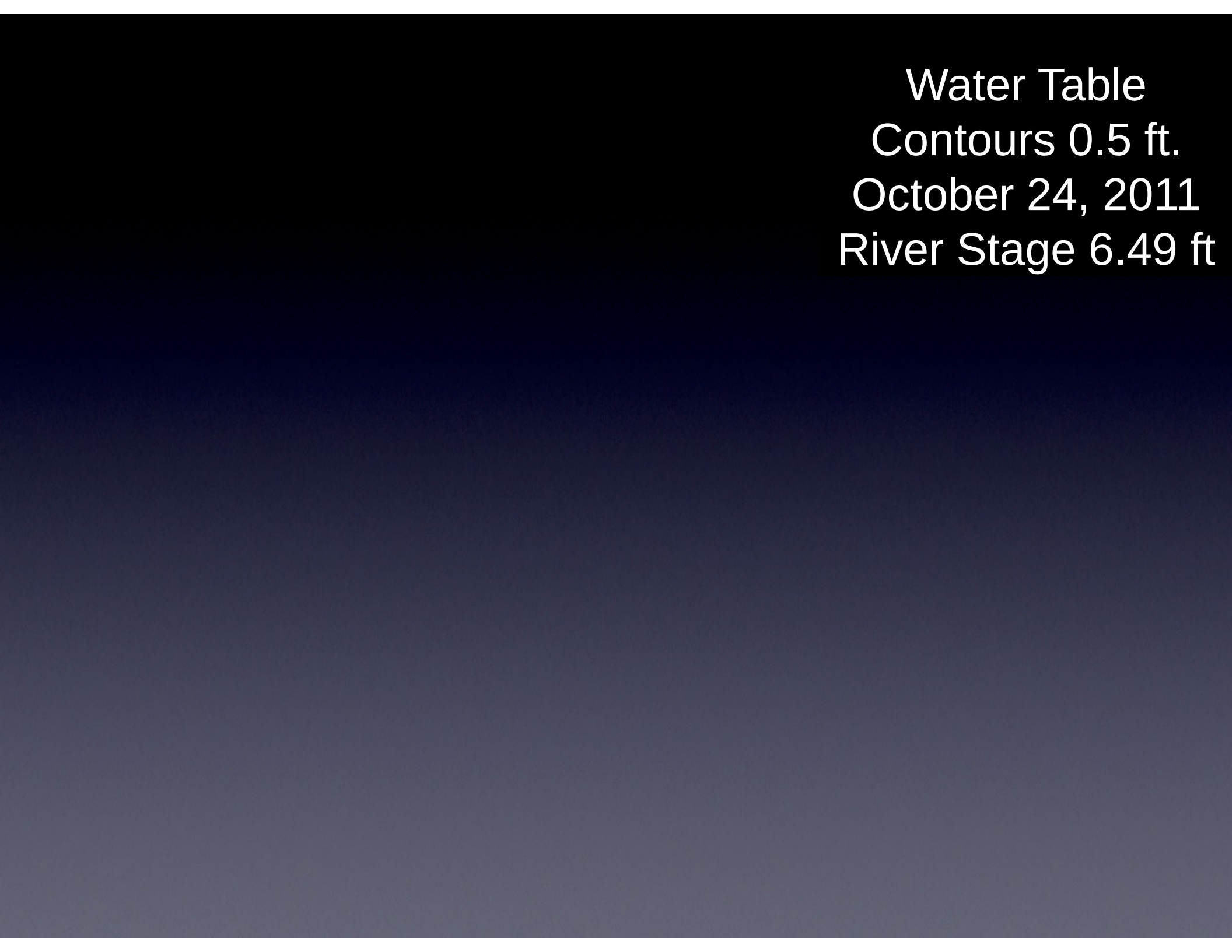
Water Table Contours 0.5 ft. August 1, 2011 River Stage 18.01 ft

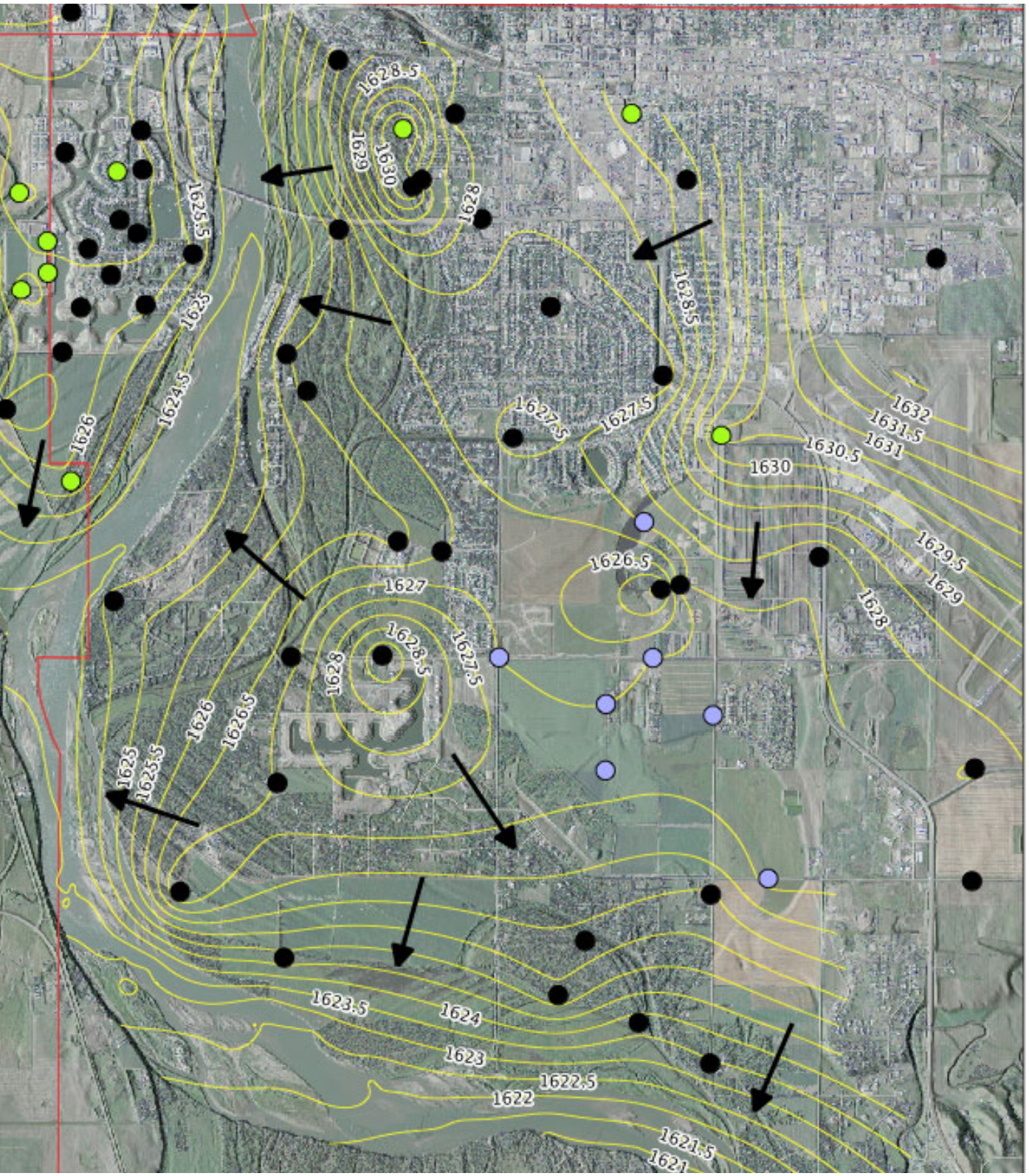


Water Table
Contours 0.5 ft.
August 29, 2011
River Stage 15.05 ft



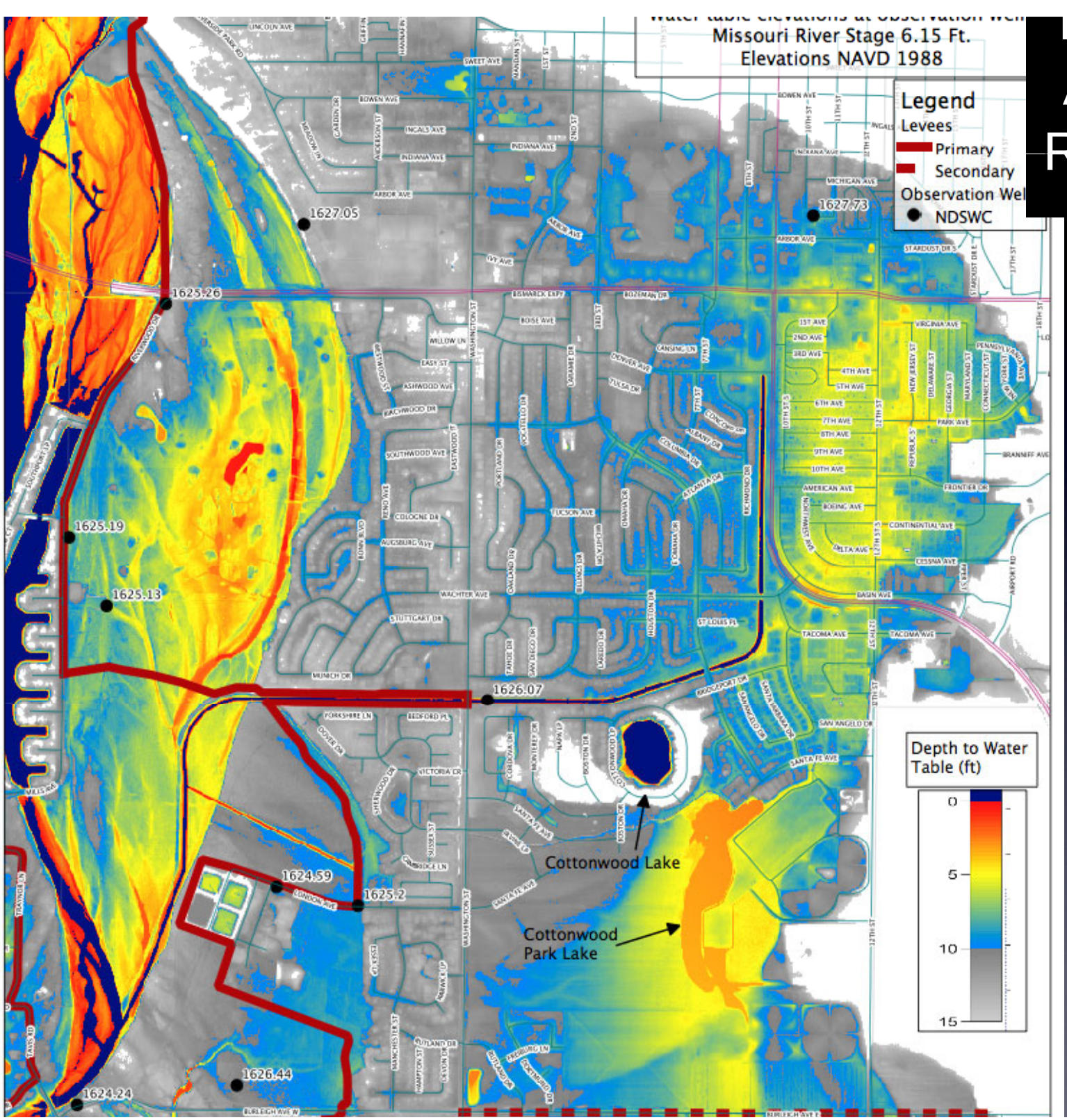
Water Table Contours 0.5 ft. September 26, 2011 River Stage 7.42 ft


Water Table
Contours 0.5 ft.
October 24, 2011
River Stage 6.49 ft

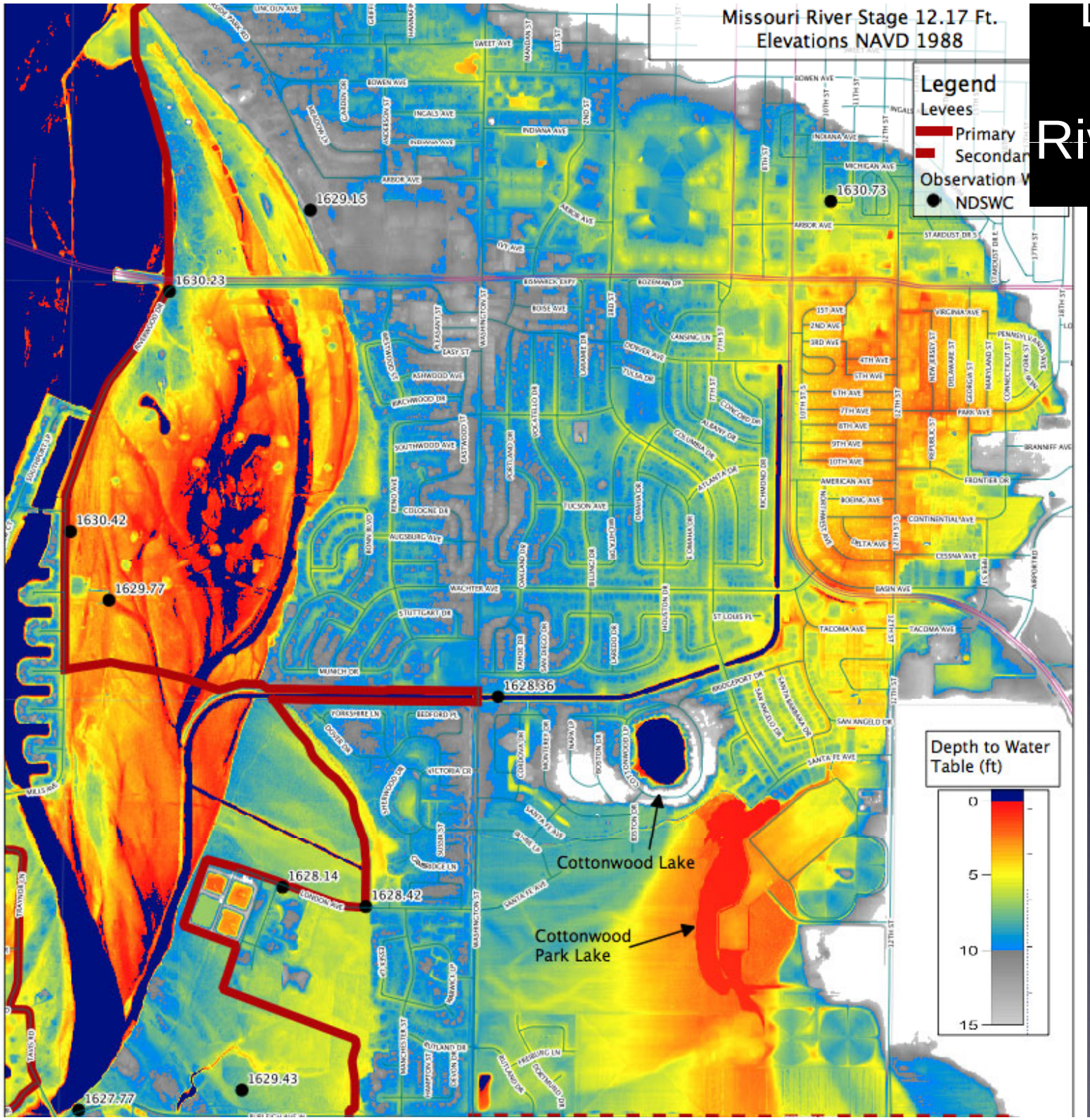


Water Table Contours 0.5 ft. December 5, 2011 River Stage 5.81 ft

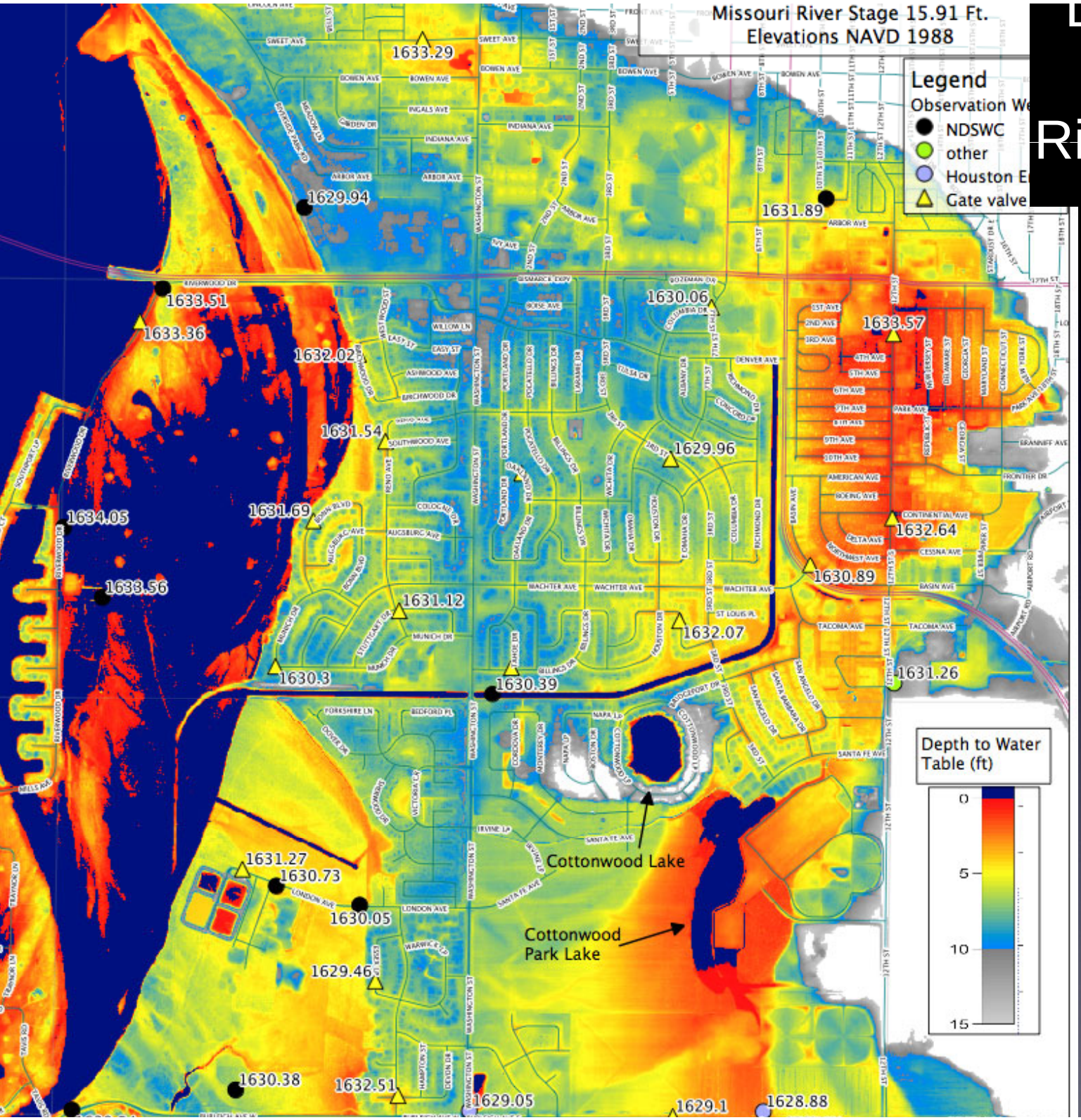
Depth to Water Maps



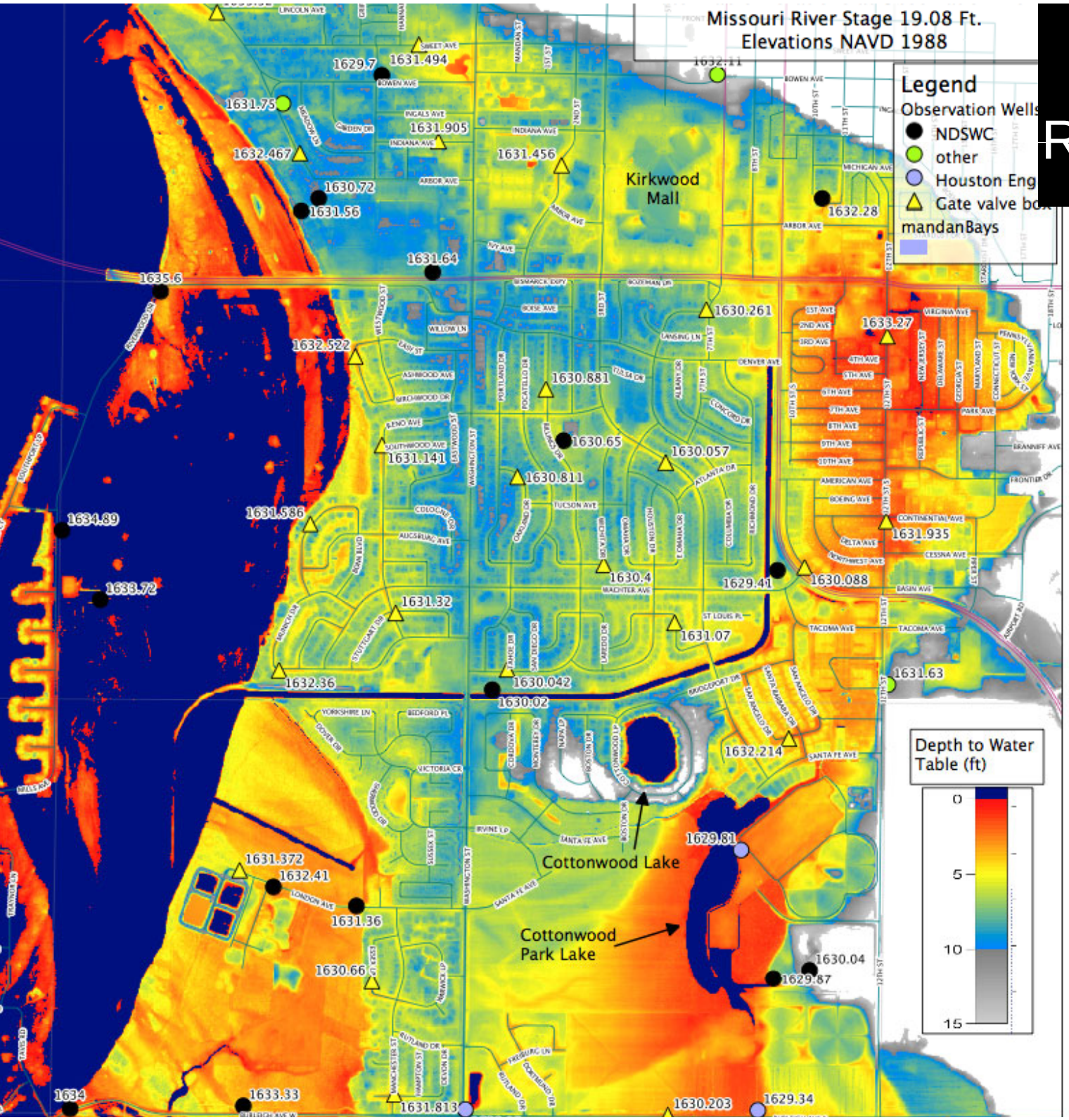
Depth to Water August 9, 2010 River Stage 6.15 ft



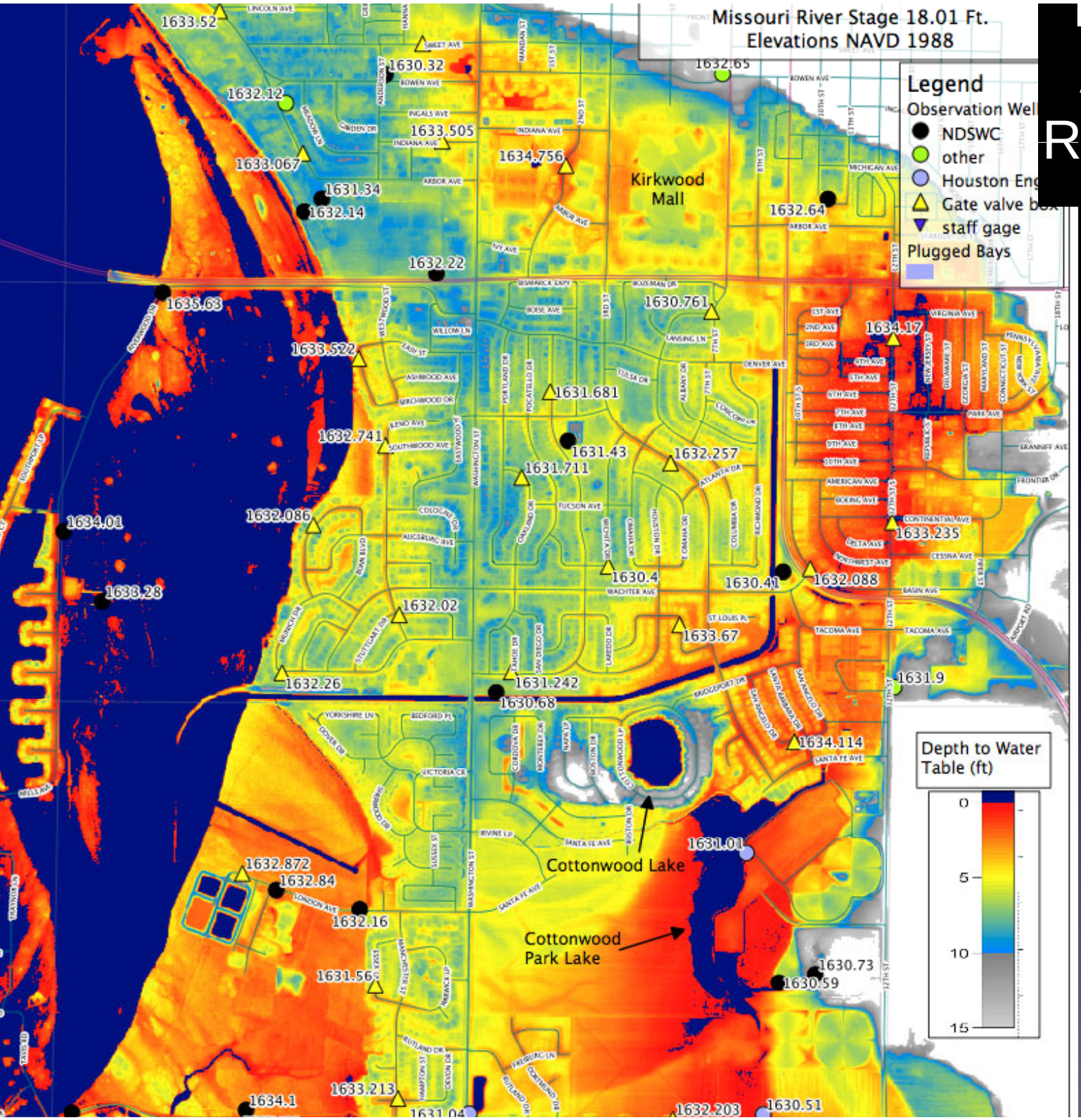
Depth to Water
May 12, 2011
River Stage 12.17
ft



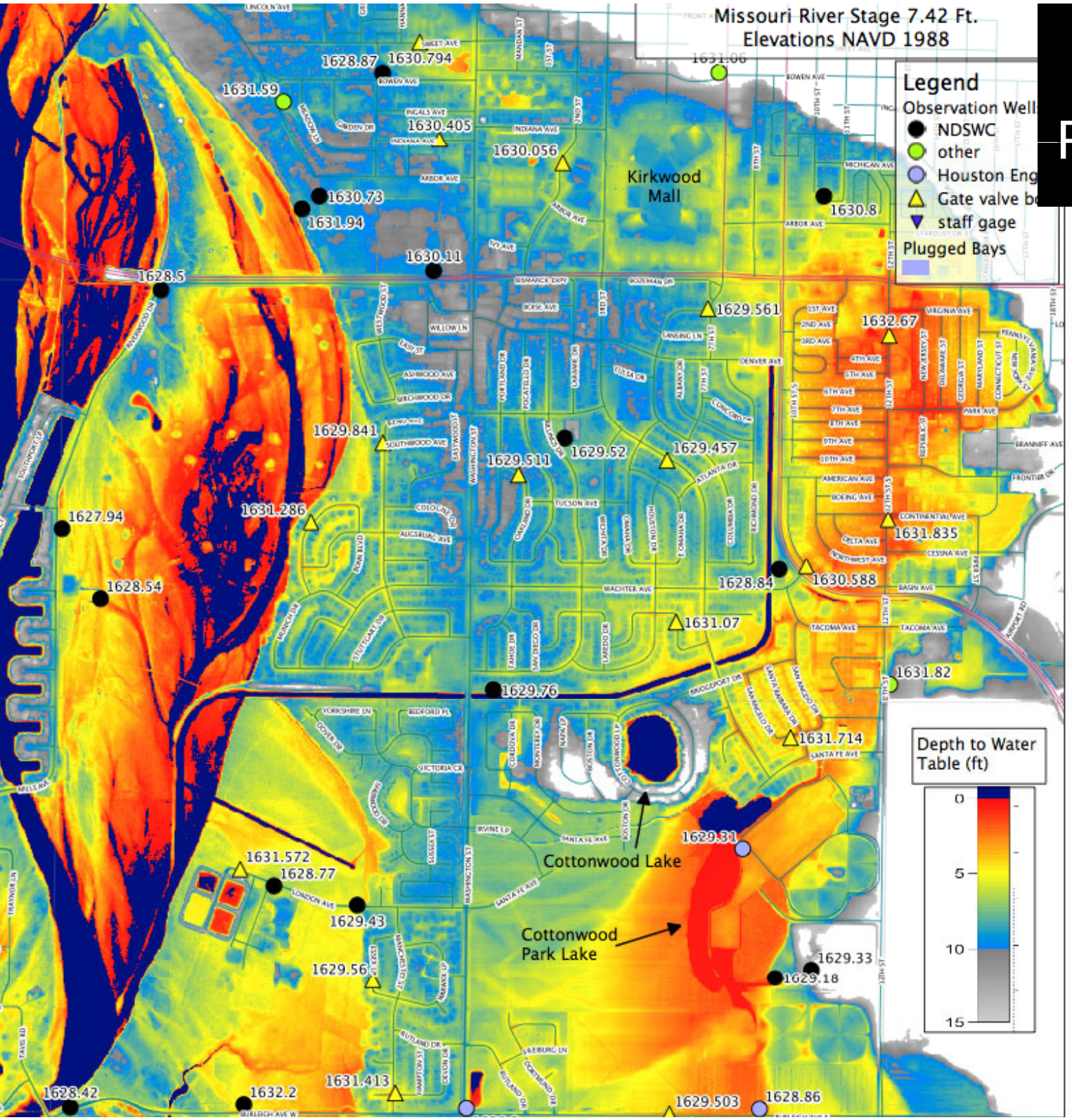
Depth to Water
May 31, 2011
River Stage 15.91 ft



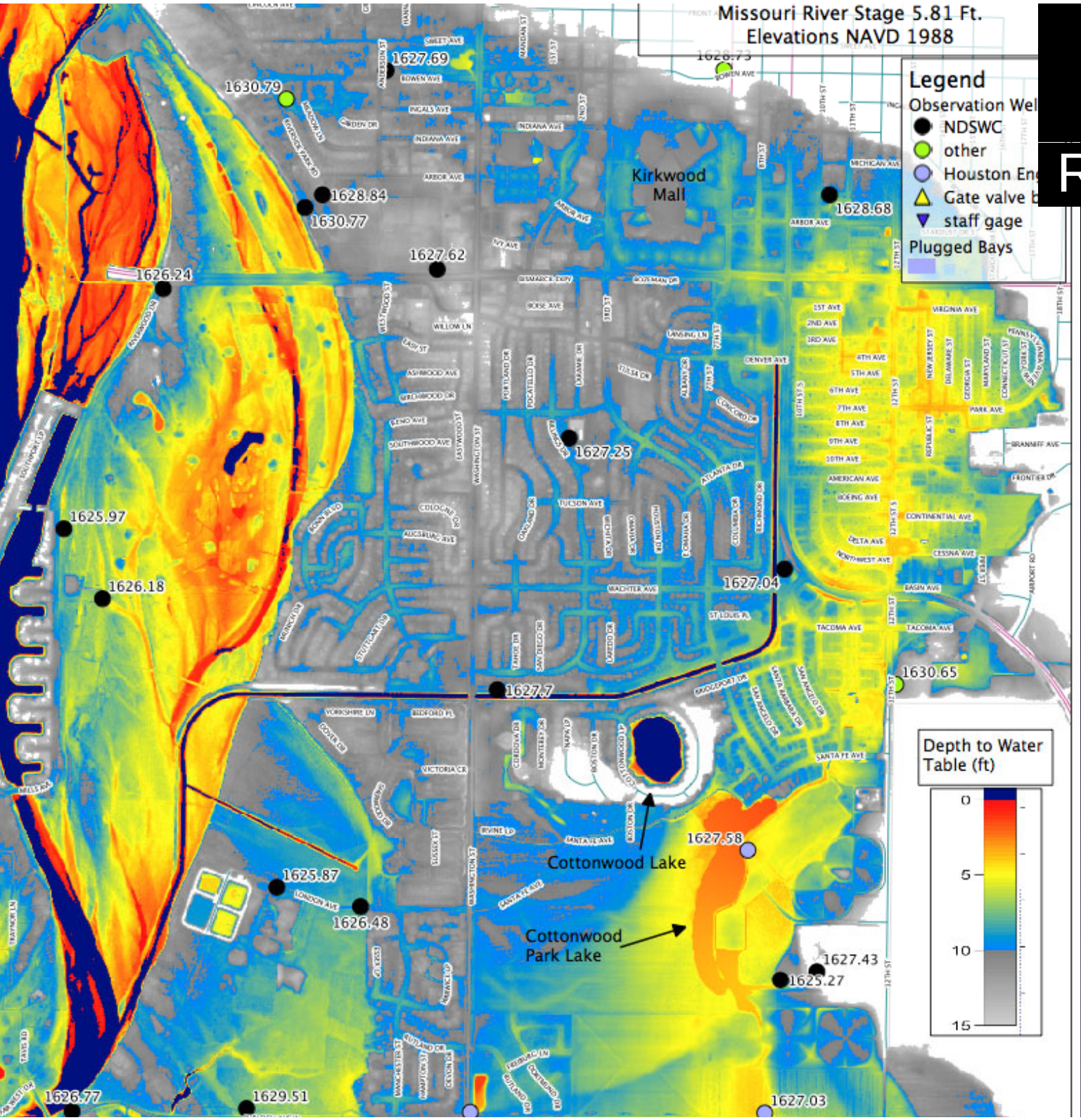
Depth To Water
July 5, 2011
River Stage 19.08
ft



Depth To Water
August 1, 2011
River Stage 18.01 ft



Depth To Water
Sept. 26, 2011
River Stage 7.42 ft



December 5, 2011 River Stage 5.81 ft

- Weekly maps were provided on the NDSWC website from June 2 through September 9 and biweekly from then until November 7. The last map was December 5.
- Water levels were measured on Mondays with the maps released on Tuesday morning. If I was late with the maps, the NDSWC got calls and emails wondering where the maps were.

THIS PRESENTATION IS DEDICATED IN MEMORY OF STEVE PUSC

March 26, 1952 – September 13, 2012

HYDROLOGIST MANAGER I

NORTH DAKOTA STATE WATER COMMISSION