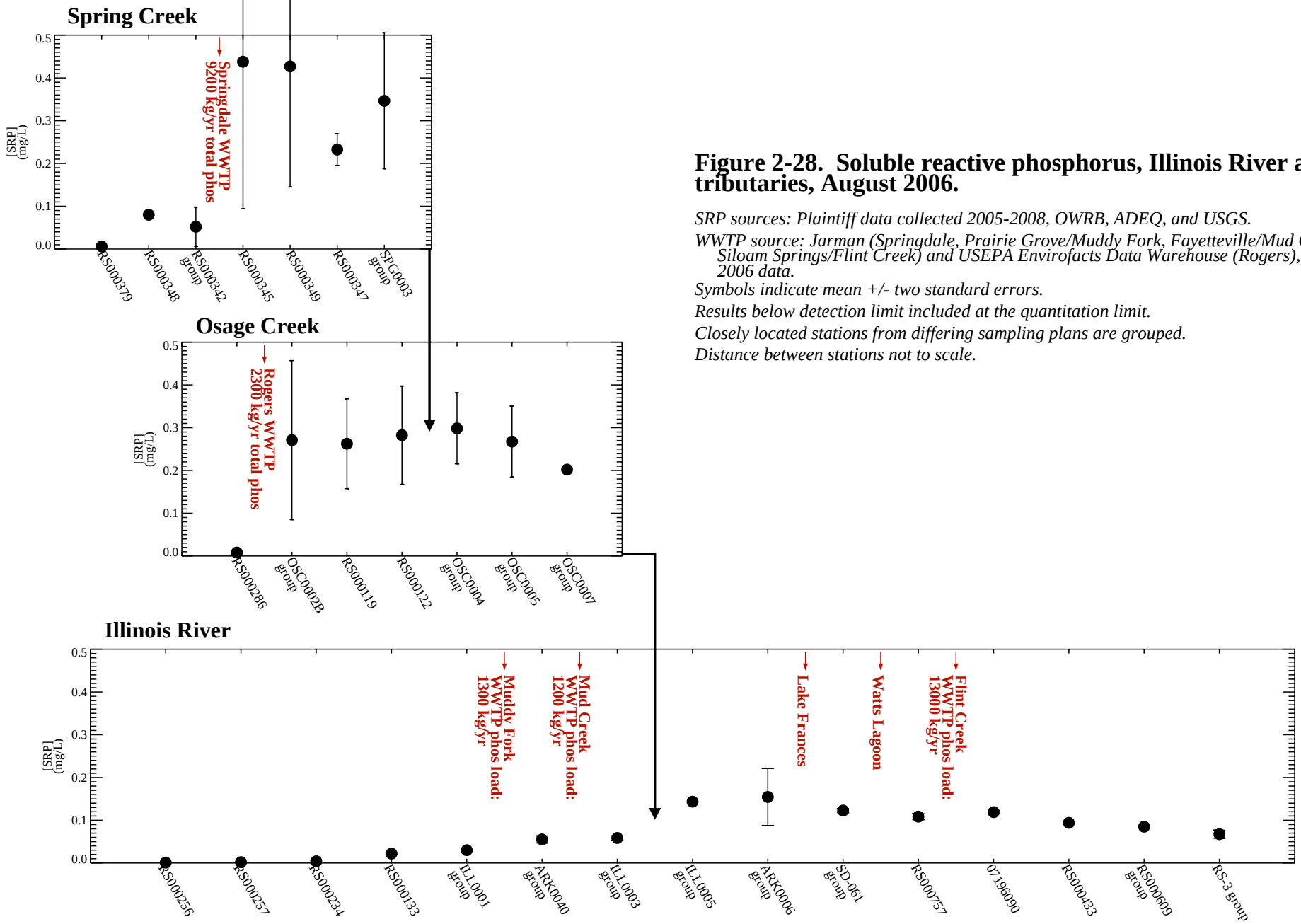


Figure 2-28. Soluble reactive phosphorus, Illinois River and tributaries, August 2006.

SRP sources: Plaintiff data collected 2005-2008, OWRB, ADEQ, and USGS.

WWTP source: Jarman (Springdale, Prairie Grove/Muddy Fork, Fayetteville/Mud Creek, Siloam Springs/Flint Creek) and USEPA Envirofacts Data Warehouse (Rogers), 2006 data.

Symbols indicate mean +/- two standard errors.

Results below detection limit included at the quantitation limit.

Closely located stations from differing sampling plans are grouped.

Distance between stations not to scale.

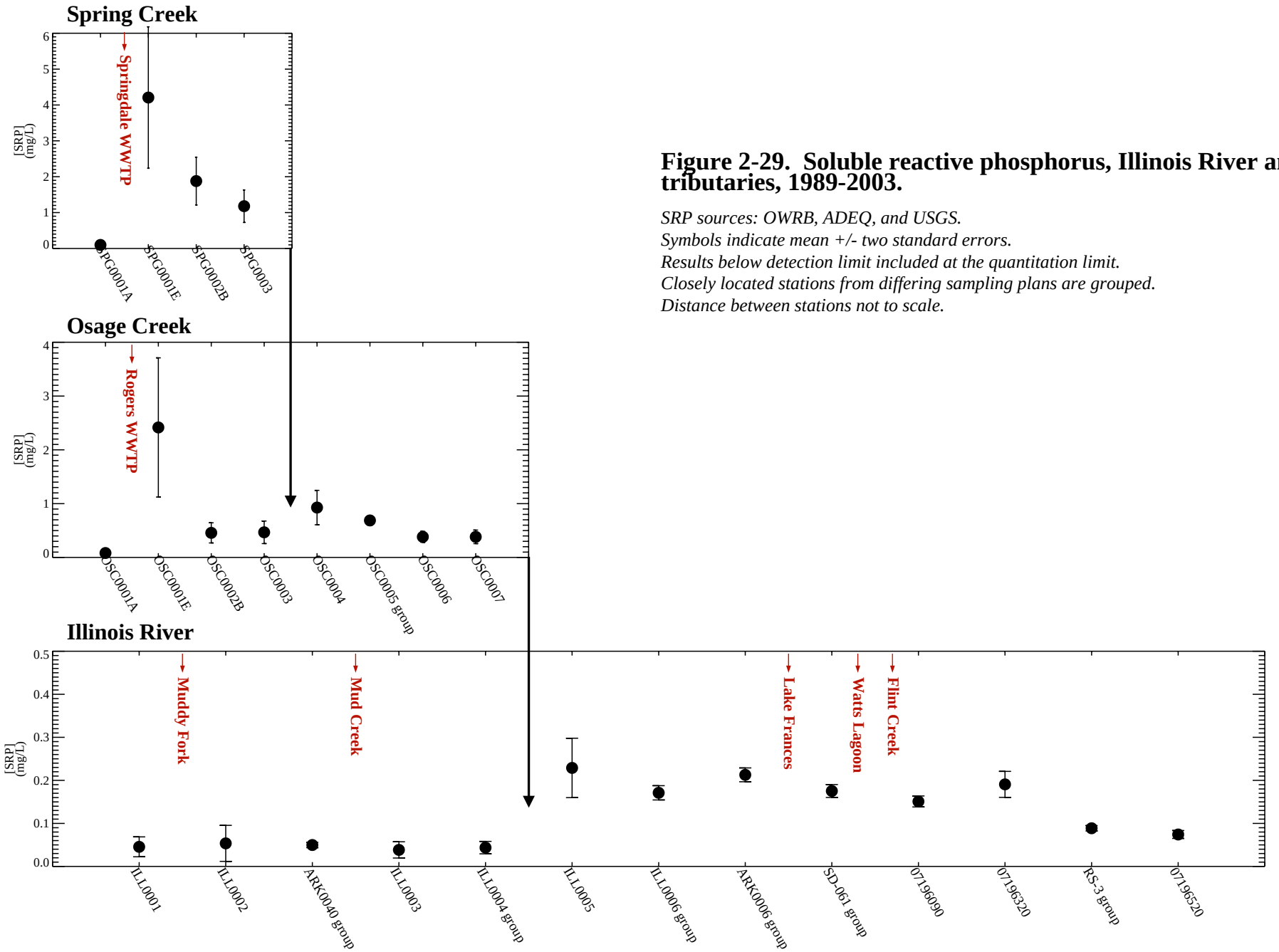


Figure 2-29. Soluble reactive phosphorus, Illinois River and tributaries, 1989-2003.

SRP sources: OWRB, ADEQ, and USGS.
Symbols indicate mean +/- two standard errors.
Results below detection limit included at the quantitation limit.
Closely located stations from differing sampling plans are grouped.
Distance between stations not to scale.

PAL - D:\OIChln\Analyses\IDL_decks\puppyosageill_pre04.pro
Thu Jan 22 14:36:29 2009

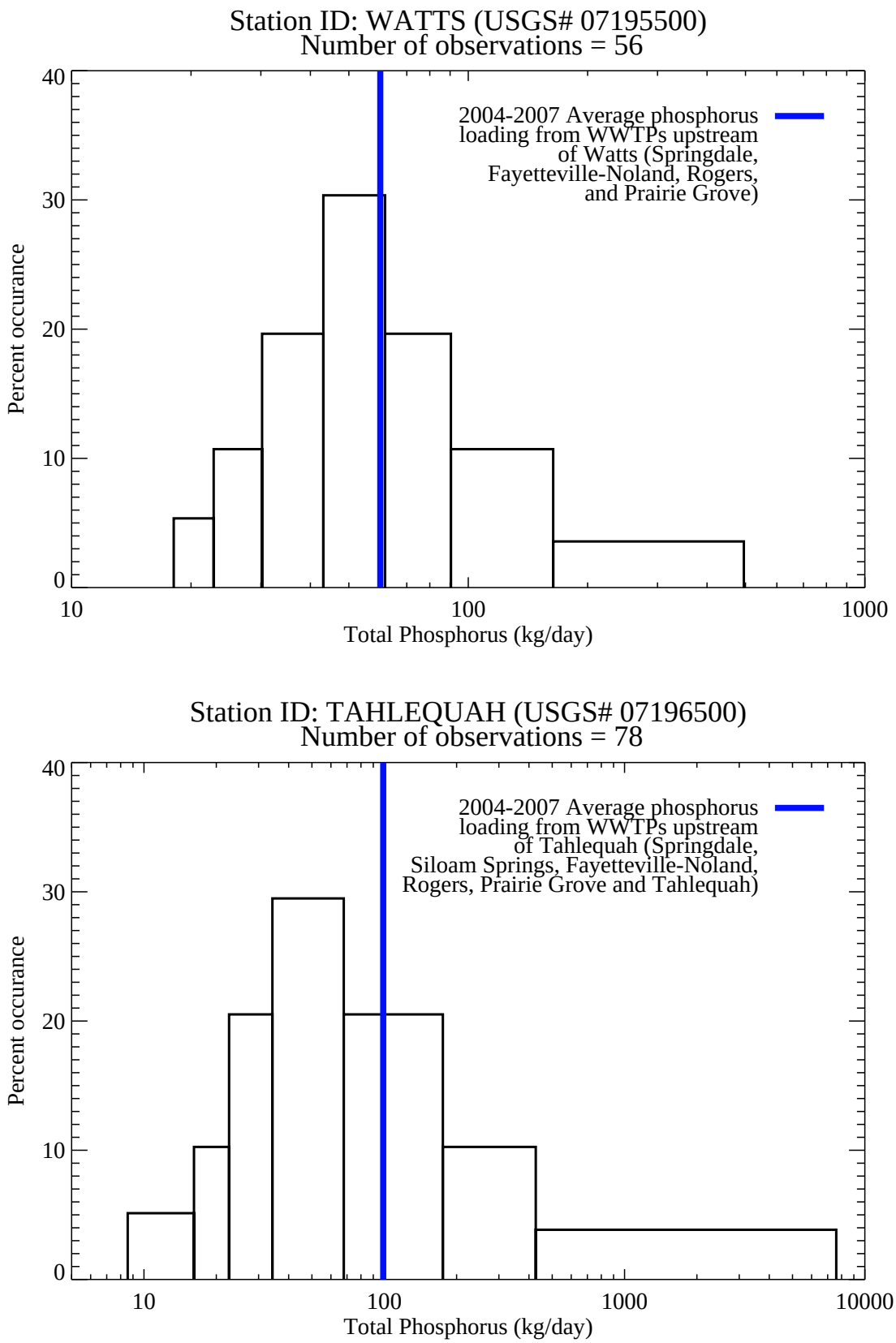


Figure 2-30. Frequency of calculated loads for total phosphorus under base flow condition, 2004-2007.

WWTP loads from Jarman 2008.
River loads calculated for days that had measured flow (USGS) and phosphorus concentration data (Plaintiff's data collected 2005-2007, OWRB, ADEQ and USGS).

QEA\JKC - D:\Jobs\OICiln\Analysis\Phosphorus\Plot_base_flow_loads_20081125.pro
Fri Jan 23 10:34:24 2009

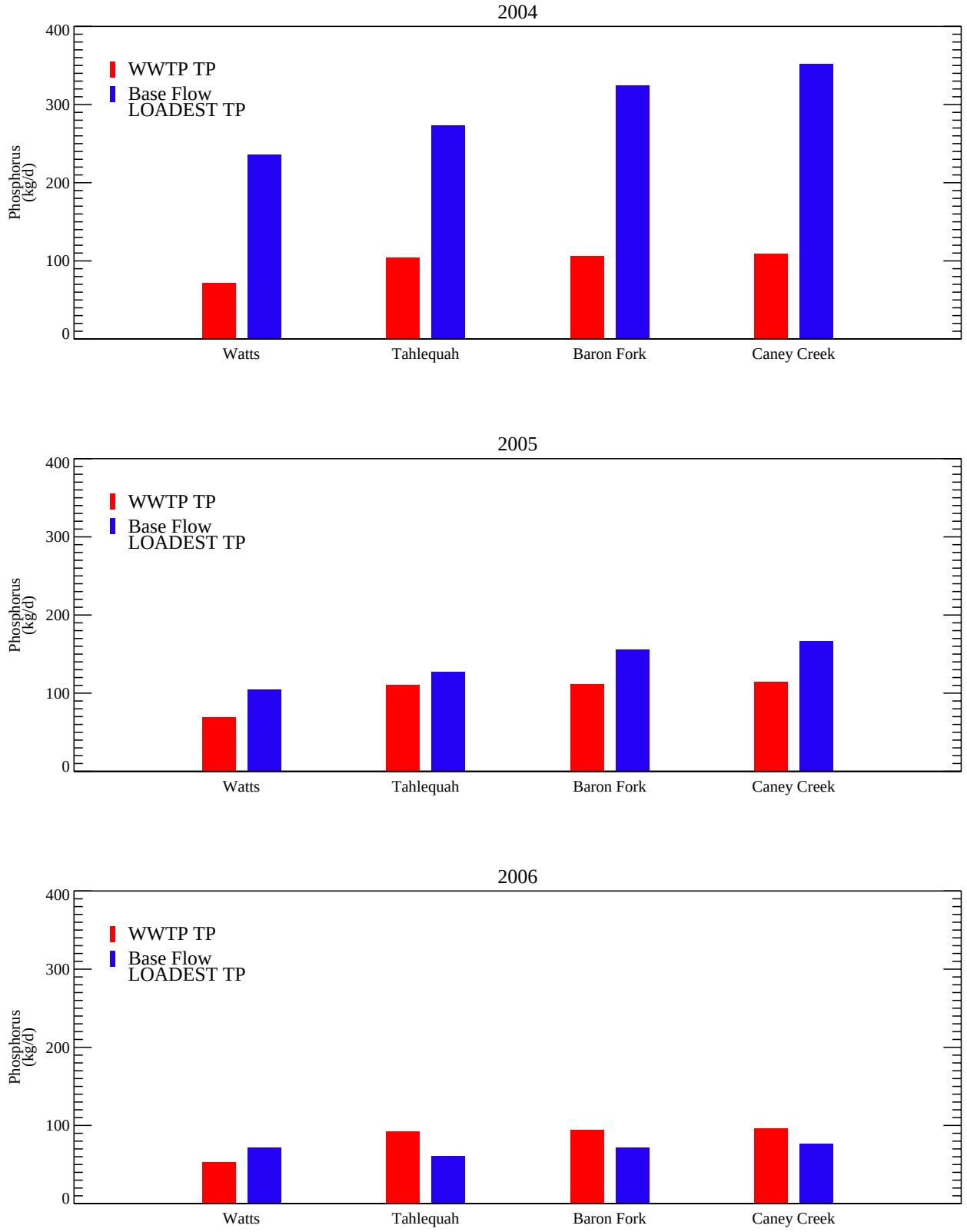


Figure 2-31. Average daily phosphorus loads along Illinois River.

Locations: USGS stations at Watts and Tahlequah; points of confluence of Baron Fork and Caney Creek with Illinois River.
Values plotted at each location are cumulative loads till that point on the river.
LOADEST calibrated for 2004-2008.
Data sources in text.

RN - D:\OICiln\Analysis\tp_srp_wwtp_barplot.pro
Fri Jan 23 12:40:04 2009

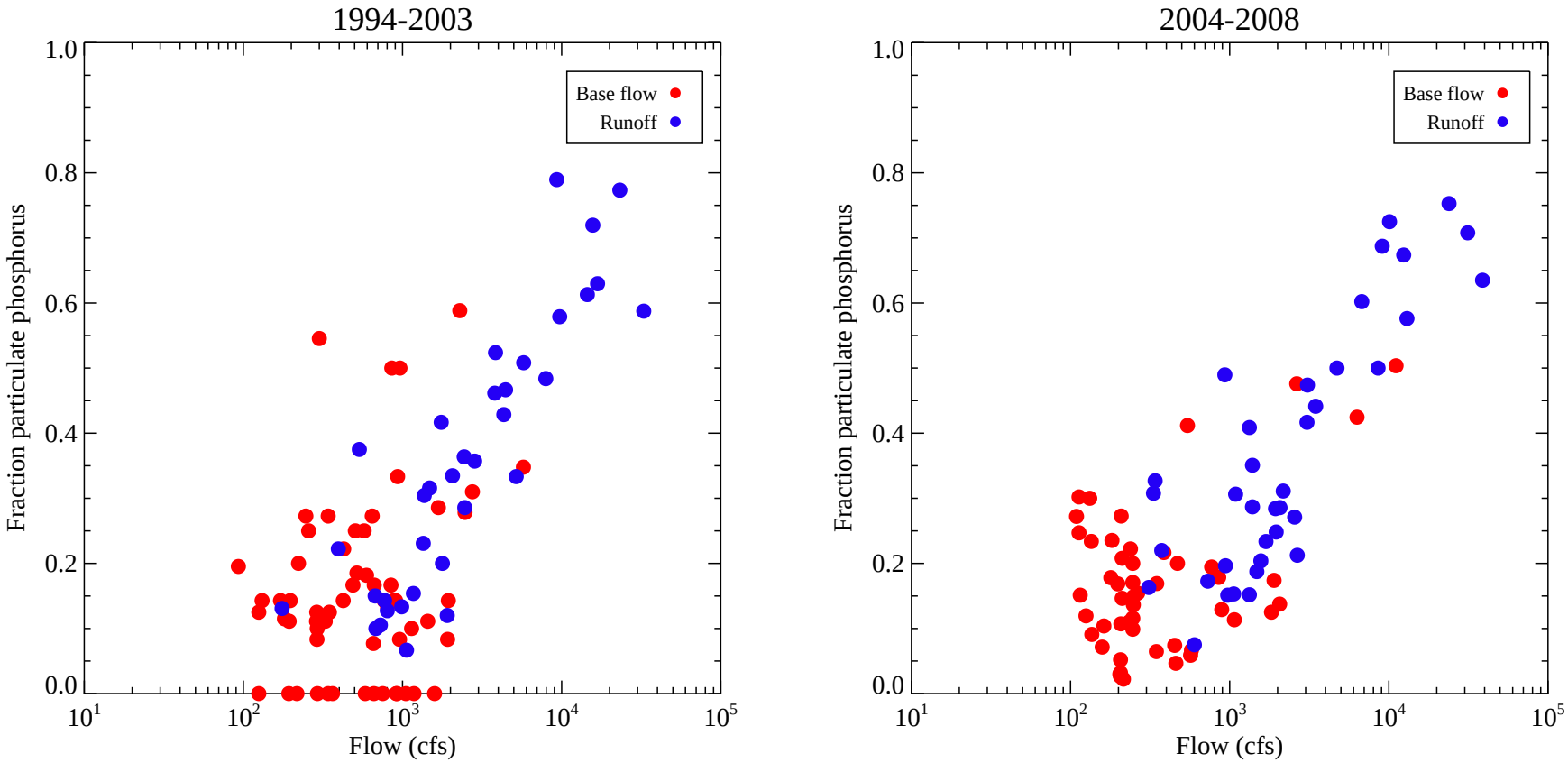


Figure 2-32. Fraction particulate phosphorus as a function of flow at Tahlequah.
Data: Plaintiff's Database 2004-2008, USGS 1994-2008.

RN - D:\OICiln\Analysis\pp_rating_curve.pro
Fri Jan 23 12:40:34 2009

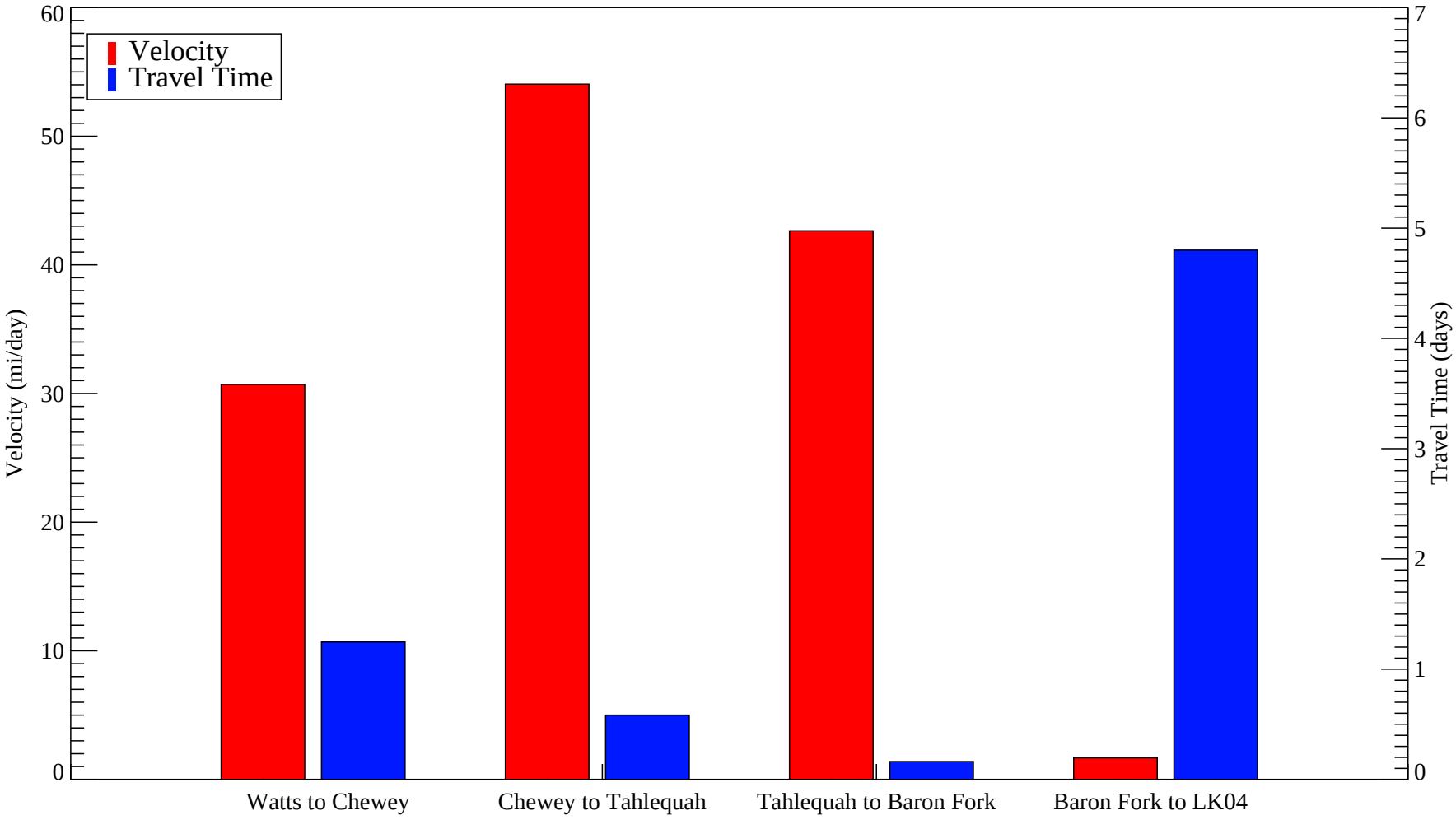
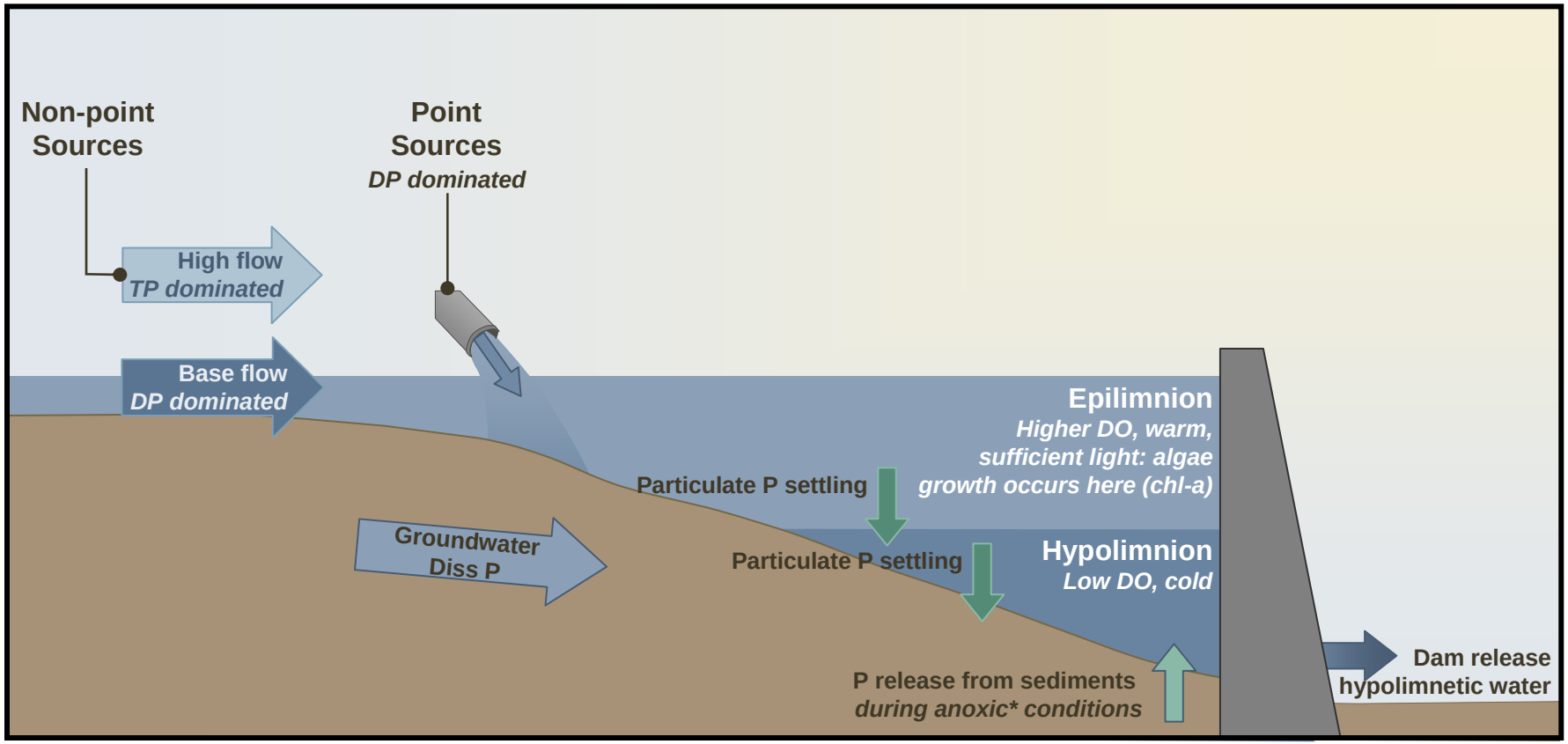


Figure 2-33. Travel times and velocities along the Illinois River under average summer flows conditions.
Data: USGS, Google Maps, GIS: 2004 and 2005 ESRI Data & Maps.



** Anoxic = no DO in the water*

Figure 2-34. Schematic of reservoir phosphorus sources and summer-time stratification.

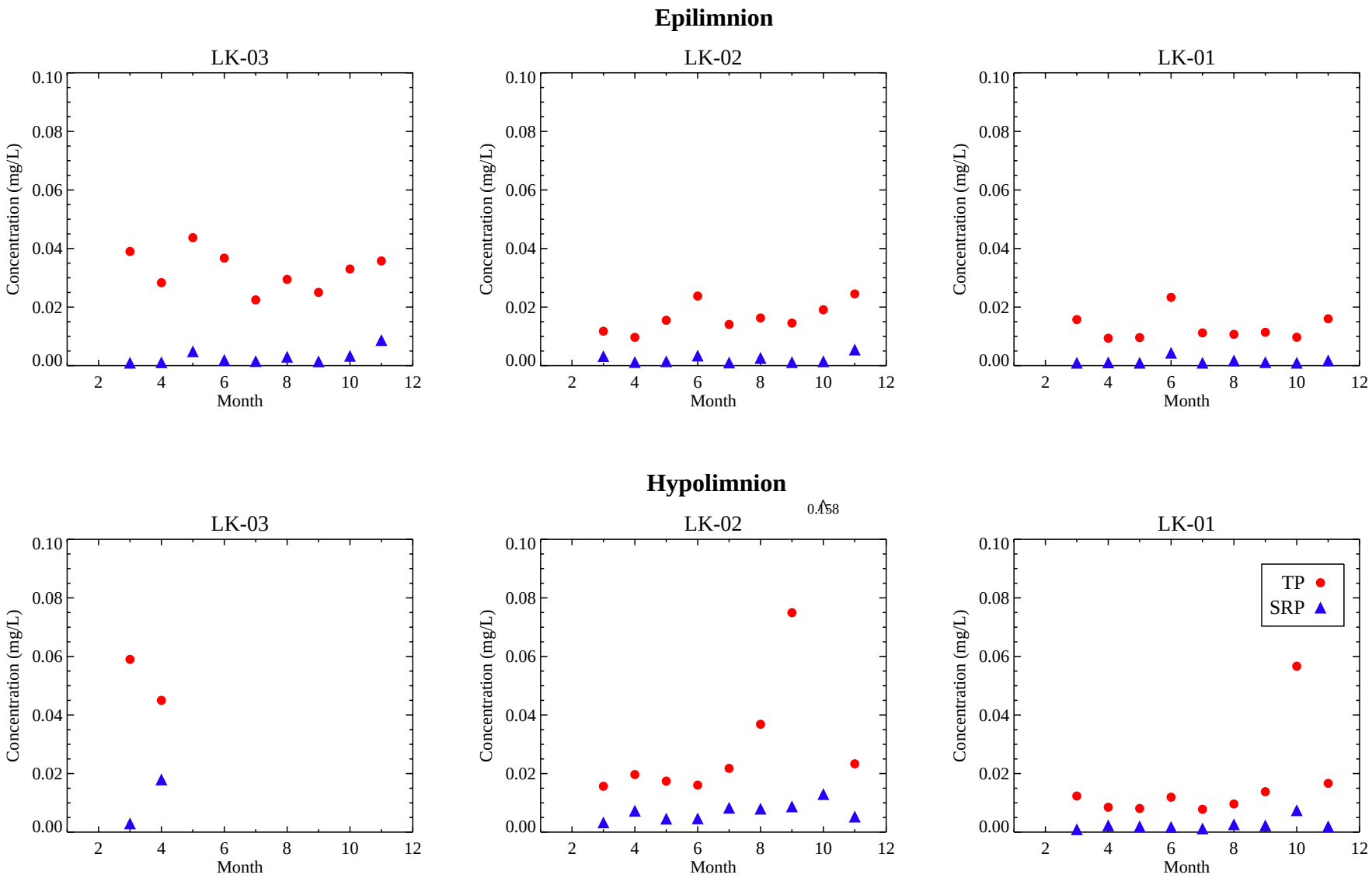


Figure 2-35. Monthly-averaged total phosphorus and SRP at three stations on Lake Tenkiller.

Epilimnion is <10 m depth, and hypolimnion is >=10 m depth. Data source: Plaintiff data collected 2005-2008. Includes only method SM18-4500PF. Non-detects included at detection limit.

PAL - D:\OIClln\Analyses\IDL_decks\tp_srp_monthlyavg_PAL.pro
Thu Jan 22 14:29:32 2009

^

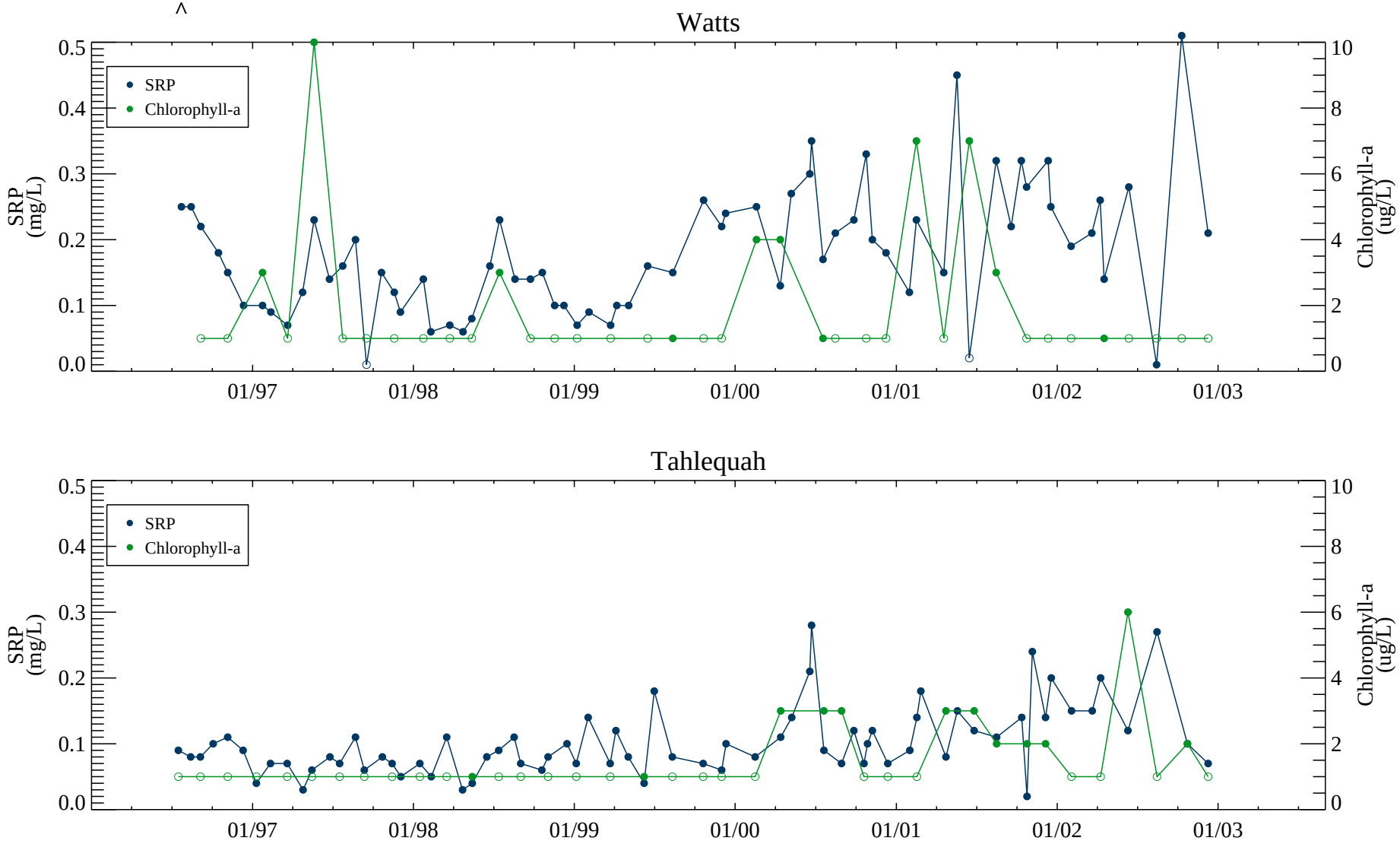


Figure 3-1. SRP and chlorophyll-a concentrations versus time at Watts and Tahlequah.

Watts data from USGS station 07195500. Tahlequah data from USGS station 07196500.
Chlorophyll-a data from USGS parameter 32211 (chlorophyll-a, phytoplankton, spectrophotometric acid method).
Non-detects included at detection limit and indicated by open symbols.

PAL - D:\OIChln\Analyses\IDL_decks\chlor_tp_temporal_wattstahlequah.pro
Thu Jan 22 14:43:29 2009

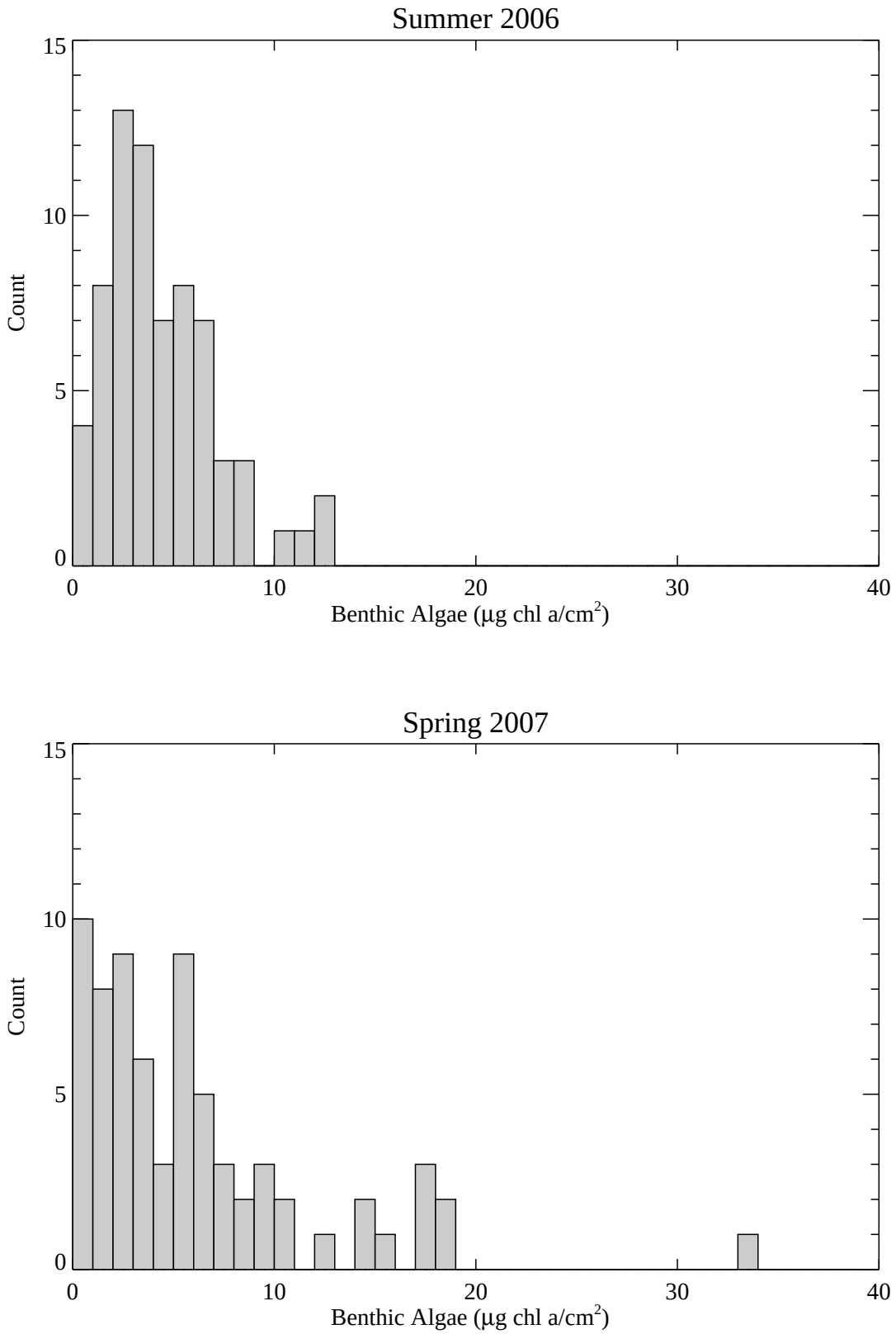
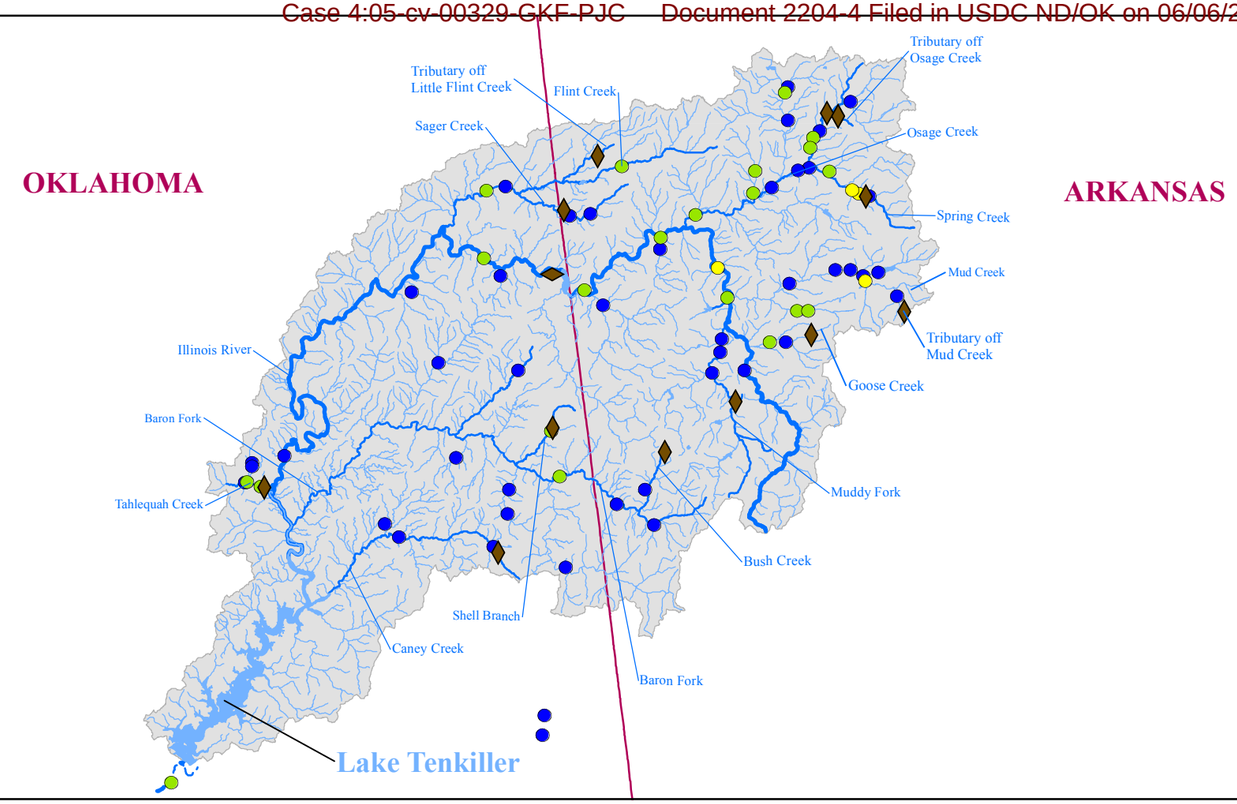


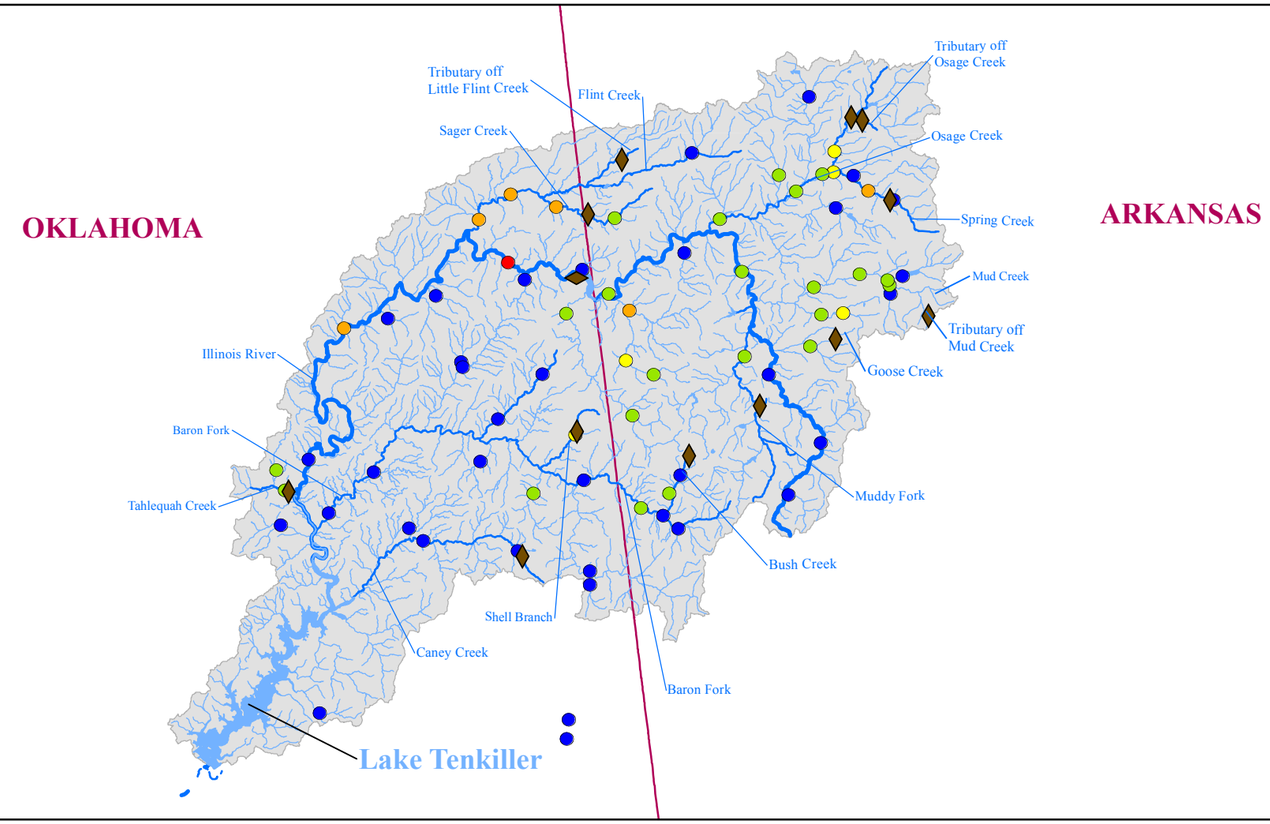
Figure 3-2. Count of benthic algae algal biomass at stations sampled in Summer 2006 and Spring 2007.

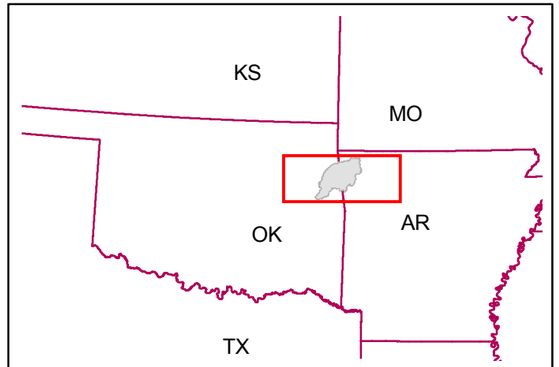
Data has been confirmed with reasonable confidence by GEI Consultants during data discovery; data based on samples collected by Stevenson.

Summer 2006



Spring 2007





Locator Map

Legend

Outfall Locations*

- NPDES Discharge
- Land Application Only

Algal Biomass
(ug chl-a/cm2)

- 0 - 5
- 5 - 10
- 10 - 15
- 15 - 20
- > 20
- Major Tributaries
- Illinois River Watershed

*Jarman, 2008.
Data source: Figure 2.2.1, Stevenson.

Figure 3-3.
Benthic algae biomass at stations sampled in Summer 2006 and Spring 2007.

OICiln:114

January 2009

CALL - \\Frodo\D_Drive\QEA_Syracuse\Jobs\OICiln\GIS\Projects\Chicken\All_locs_Algae.mxd

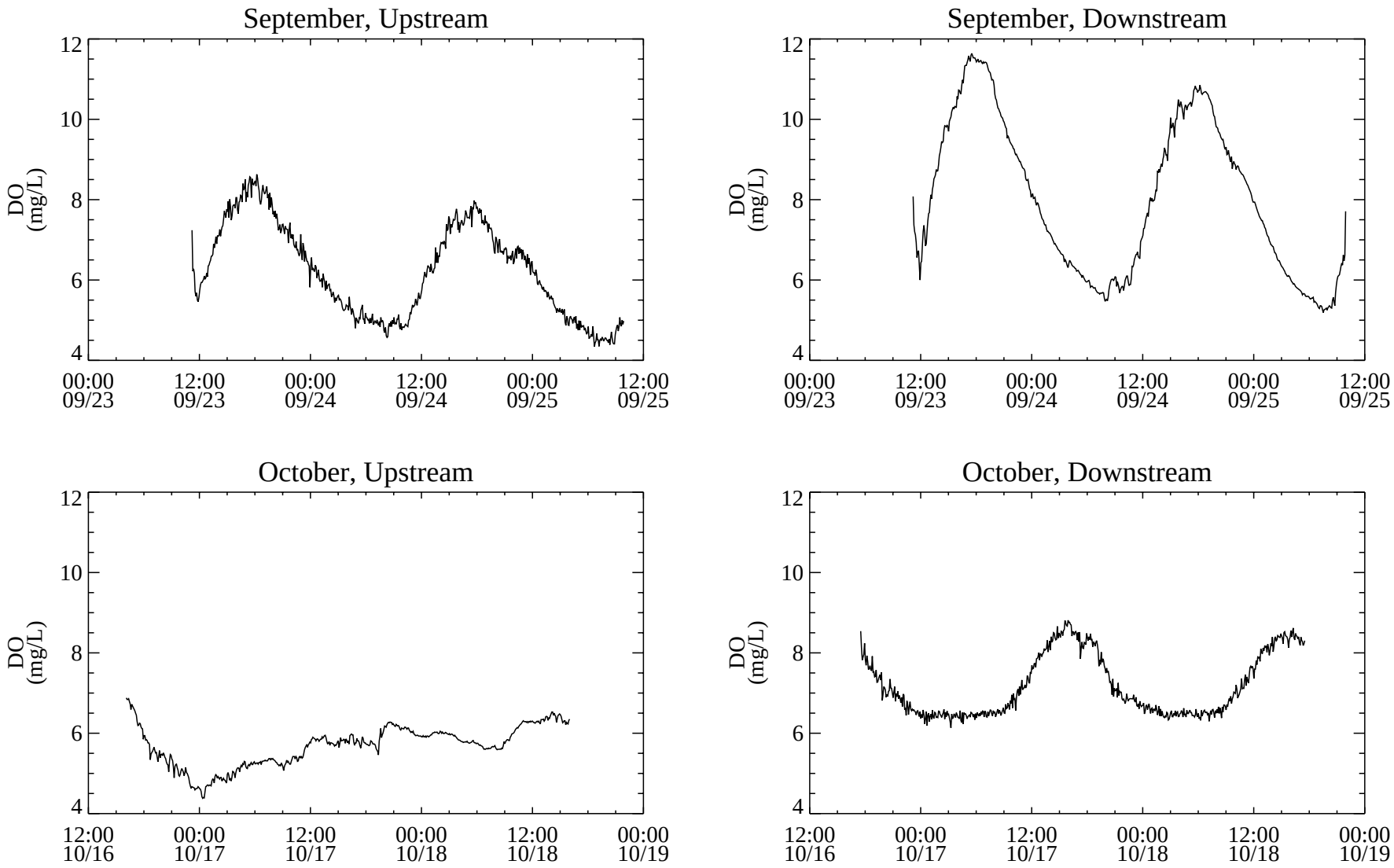


Figure 3-4a. Dissolved oxygen, Prairie Grove WWTP. River slope = 1 ft / 1000 ft.

Data collected in 2003 by U.S. EPA Region 6 water quality and biological assessment of Illinois River and King River basins. Upstream measurements taken ~4800 ft upstream of outfall. Downstream measurements taken ~9300 ft downstream of outfall.

PAL - D:\OICiln\Analyses\IDL_decks\wwtpdoplot_station.pro
Thu Jan 22 14:52:49 2009

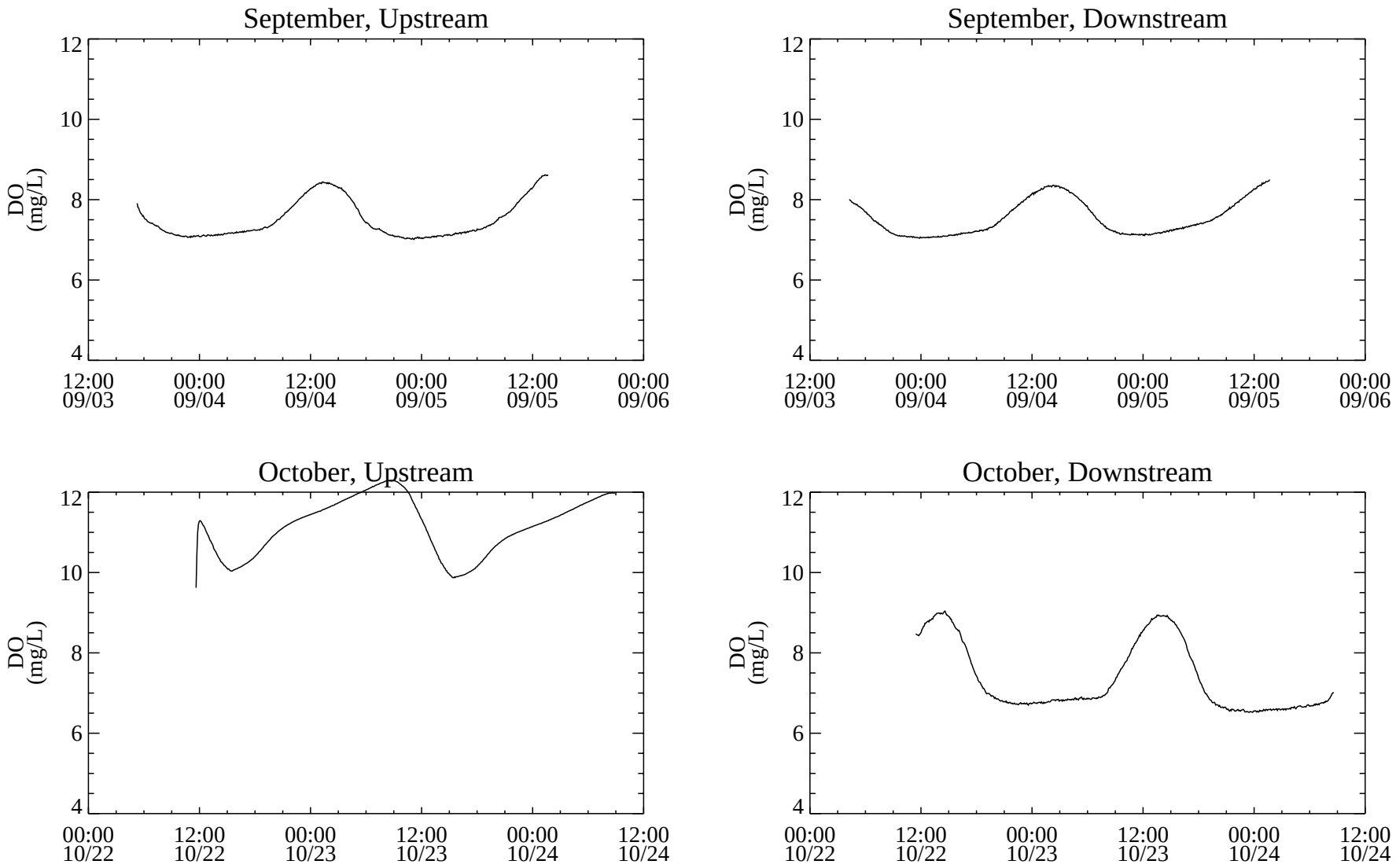


Figure 3-4b. Dissolved oxygen, Rogers WWTP. River slope = 2 ft / 1000 ft.

Data collected in 2003 by U.S. EPA Region 6 water quality and biological assessment of Illinois River and King River basins. Upstream measurements taken ~850 ft upstream of outfall. Downstream measurements taken ~2500 ft downstream of outfall.

PAL - D:\OICiln\Analyses\IDL_decks\wwtpdoplot_station.pro
Thu Jan 22 14:52:50 2009

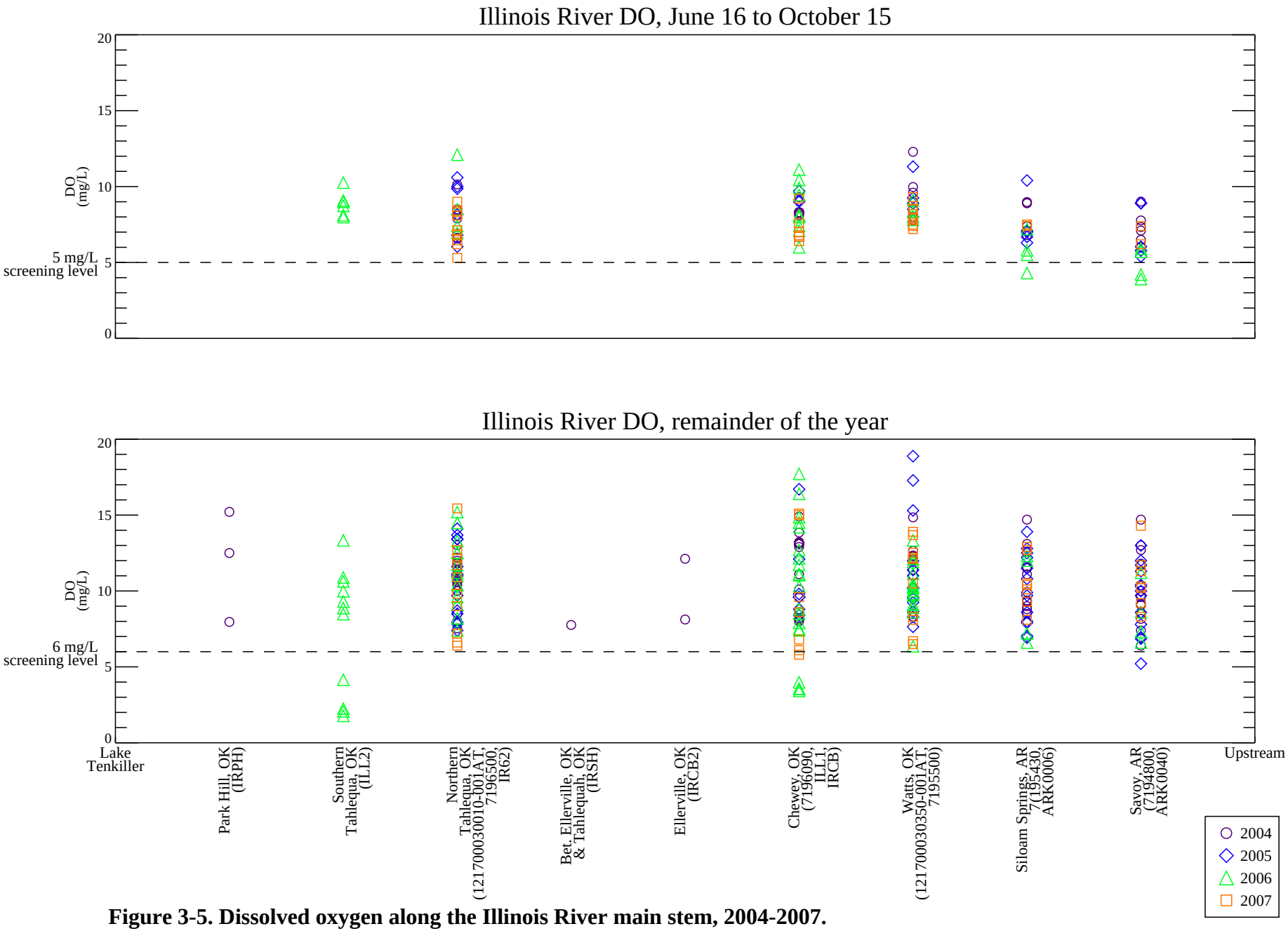
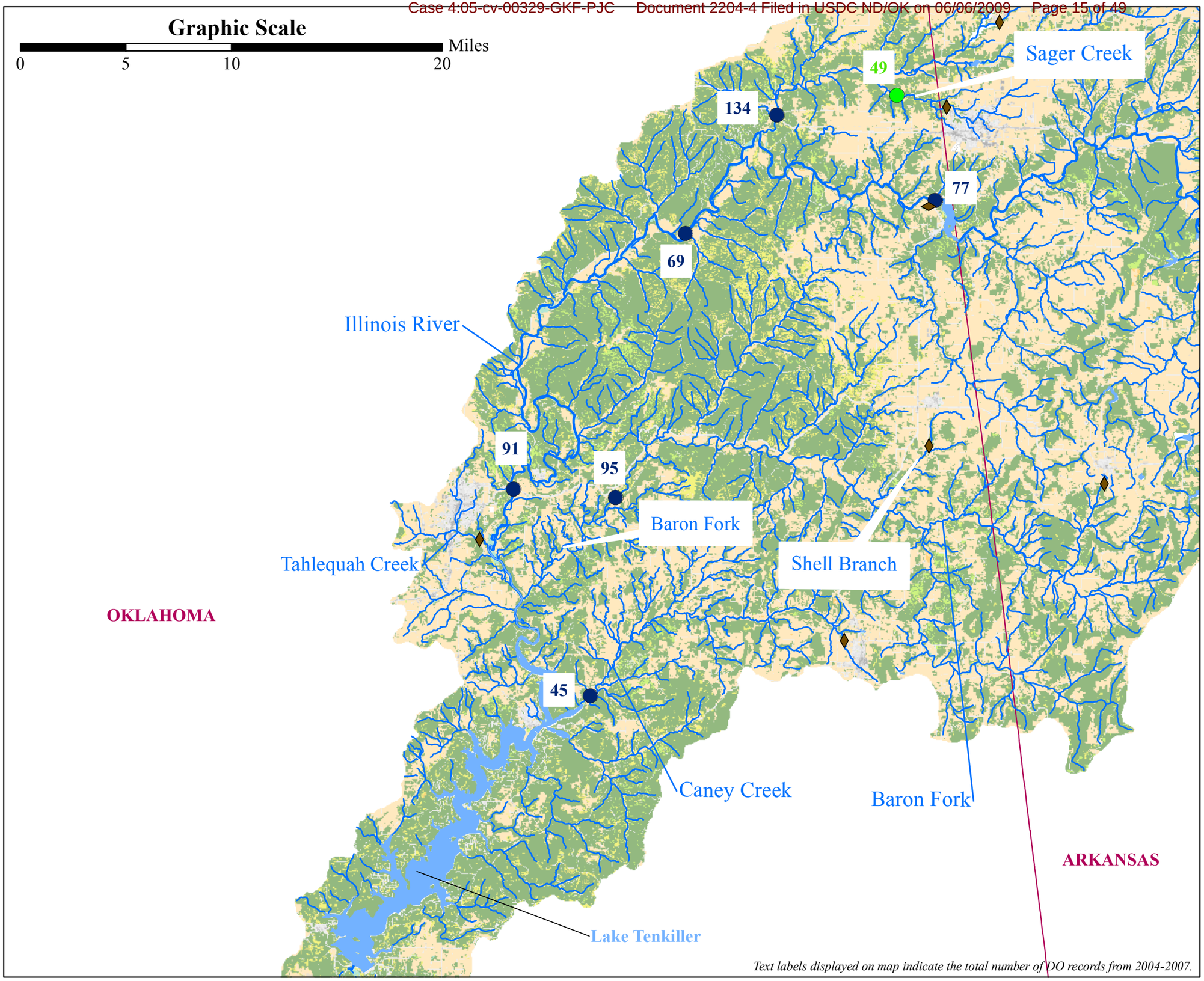


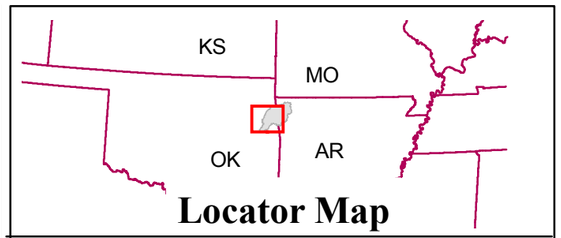
Figure 3-5. Dissolved oxygen along the Illinois River main stem, 2004-2007.

Data sources: Arkansas Dept. of Environmental Quality, Cherokee Nation (Oklahoma), Oklahoma Dept. of Environmental Quality, OWRB, USGS

SJRH - D:\OICiln\DO_New\IllinoisR_DO_spat.pro
Wed Jan 21 15:53:16 2009



Text labels displayed on map indicate the total number of DO records from 2004-2007.



Legend

Outfall Locations

- NPDES Discharge
- Land Application Only

Dissolved oxygen*

- 0 years with > 10% below screening level
- 1 year with > 10% below screening level
- 2 years with > 10% below screening level
- 3 years with > 10% below screening level
- 4 years with > 10% below screening level
- Lakes
- Major Tributaries and Tributaries with Outfall Locations

Landuse

- Developed, Open Space
- Developed, Low Intensity
- Developed, Medium Intensity
- Developed, High Intensity
- Barren Land
- Deciduous Forest
- Evergreen Forest
- Mixed Forest
- Scrub/Shrub
- Grassland/Herbaceous
- Pasture/Hay
- Cultivated Crops
- Woody Wetlands
- Emergent Herbaceous Wetlands

**These values represent the number of years that a given station exceeded the standard and for rivers and streams only.*

Notes:

1) This analysis is based on habitat specific DO screening levels:

a) For warm water habitat 4.0 mg/L between June 16 and October 15 and 5.0 mg/L for the rest of the year.

b) For cold water habitat 5.0 mg/L between June 16 and October 15 and 6.0 mg/L for the rest of the year.

2) Data sources: ADEQ, OWRB, USGS, Storet, Storet-Modern and Plaintiffs' data collected 2005 - 2007.

3) To assure sufficient data for determining frequency of exceedance, all sampling stations which meet the following criteria are shown:

- 8 or more DO records per year in at least 2 years from 2004-2007

- 1 or more DO records per quarter (3-month period) for at least 3 quarters each year.

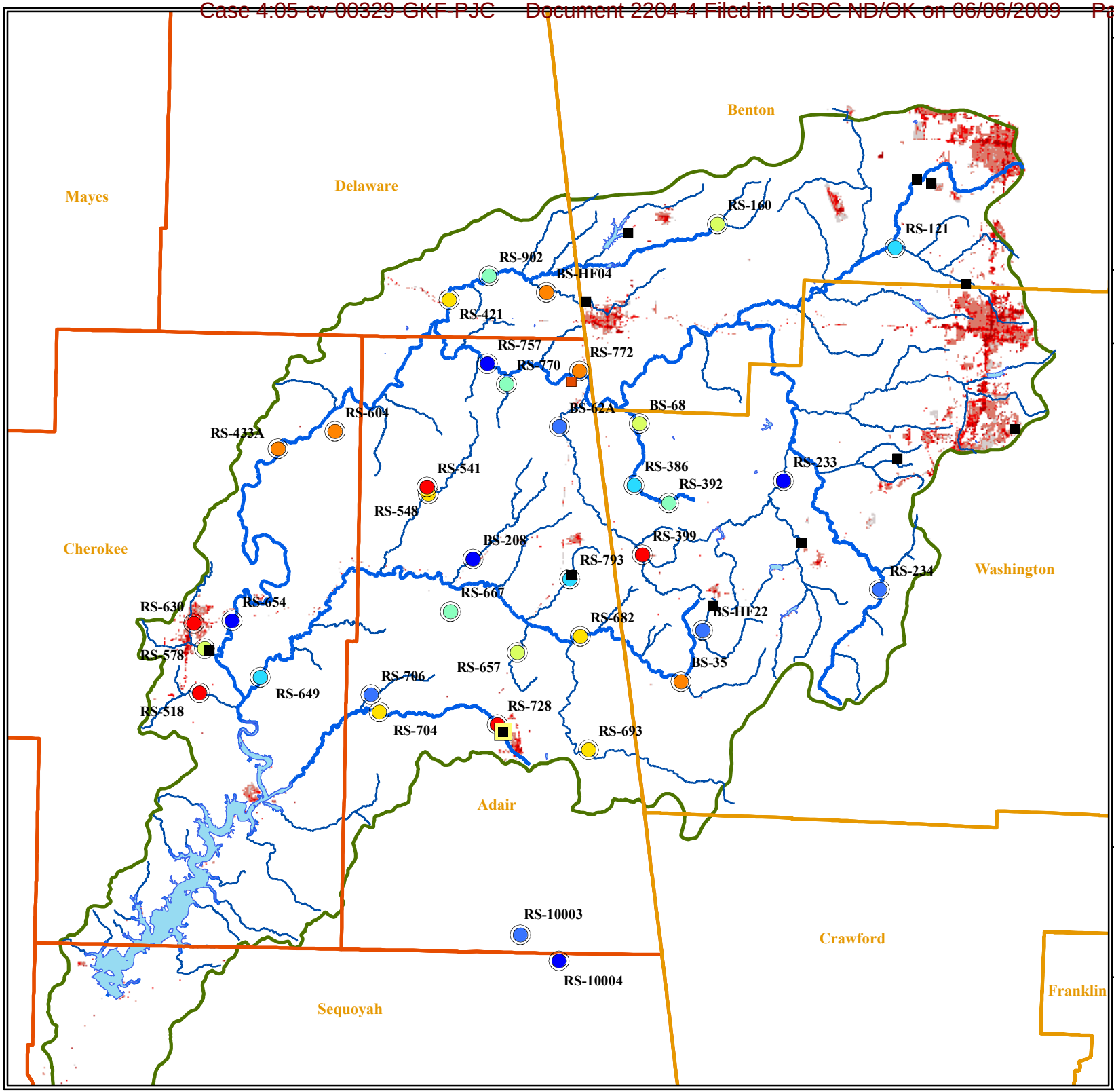
4) Outfall locations are from Jarman, 2008.

5) Landuse data source: NLCD 2001.

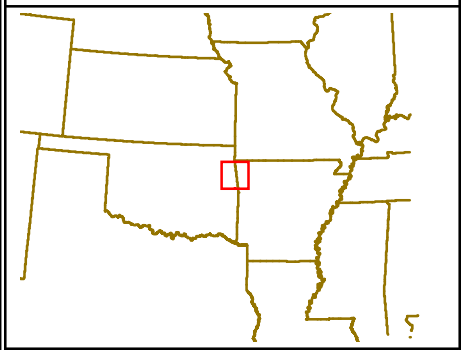
Figure 3-6. Dissolved oxygen exceedances in rivers and streams for the Illinois River Watershed, 2004-2007.

OICiln:114

January 2009



LOCATOR



SCALE

0 2.5 5 7.5 10 Miles

LEGEND

Shannon-Weiner Diversity Index*

- 1.01 - 1.12
- 1.12 - 1.52
- 1.52 - 1.62
- 1.62 - 1.69
- 1.69 - 1.74
- 1.74 - 1.95
- 1.95 - 2.11
- 2.11 - 2.58

Counties

- Arkansas
- Oklahoma

NLCD Landcover

- urban, vacant
- urban, low
- urban, medium
- urban, high

WWTP Locations

- NPDES Discharge
- Land Application

- Waterbodies
- Major streams
- Smaller streams
- Watershed

Approximate WWTP Location

** Includes 2007 Plaintiff's data only.*

Figure 3-7. Illinois River fish: Shannon-Weiner diversity index values.

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OICiln:115 January 2009

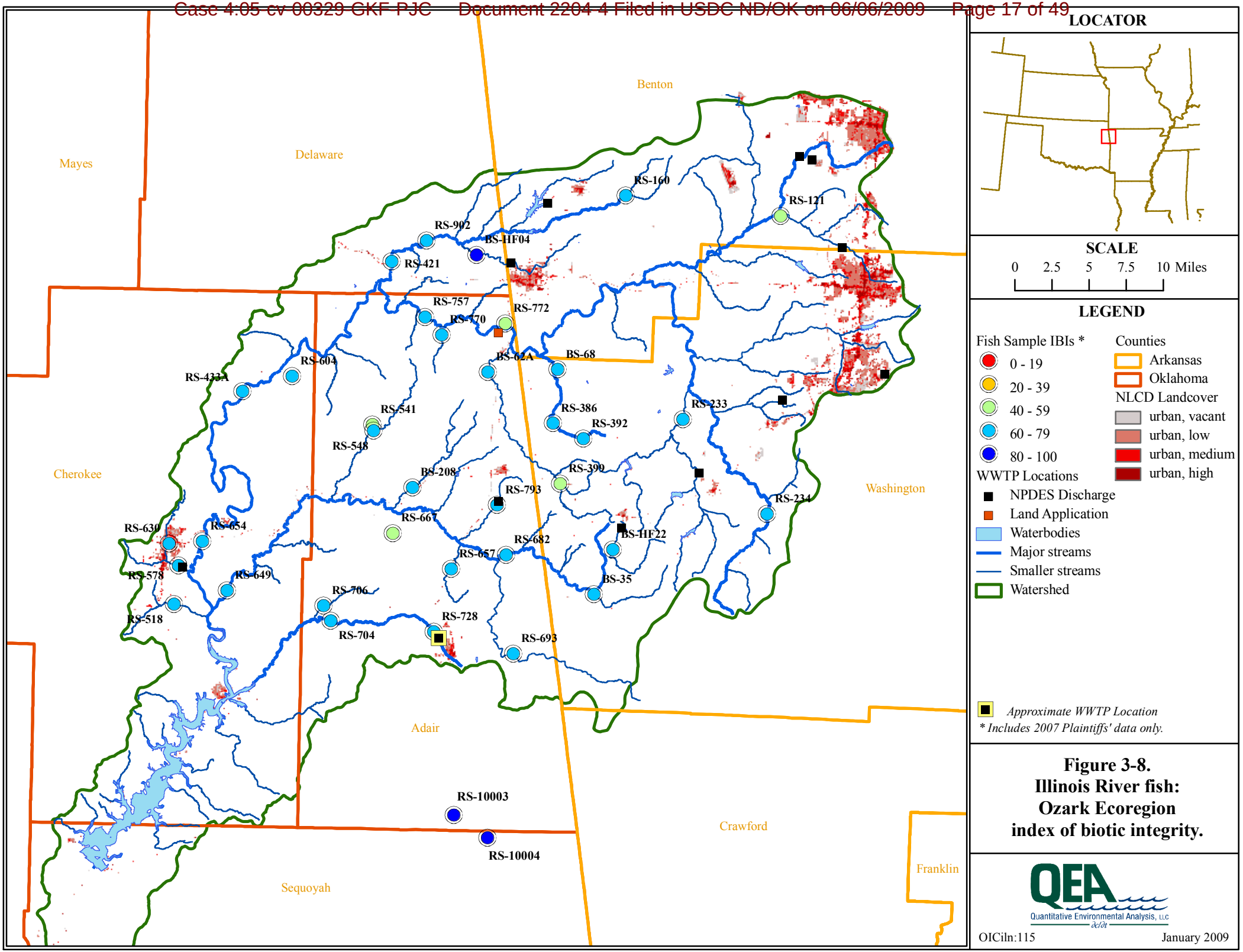

Figure 3-8.
Illinois River fish:
Ozark Ecoregion
index of biotic integrity.

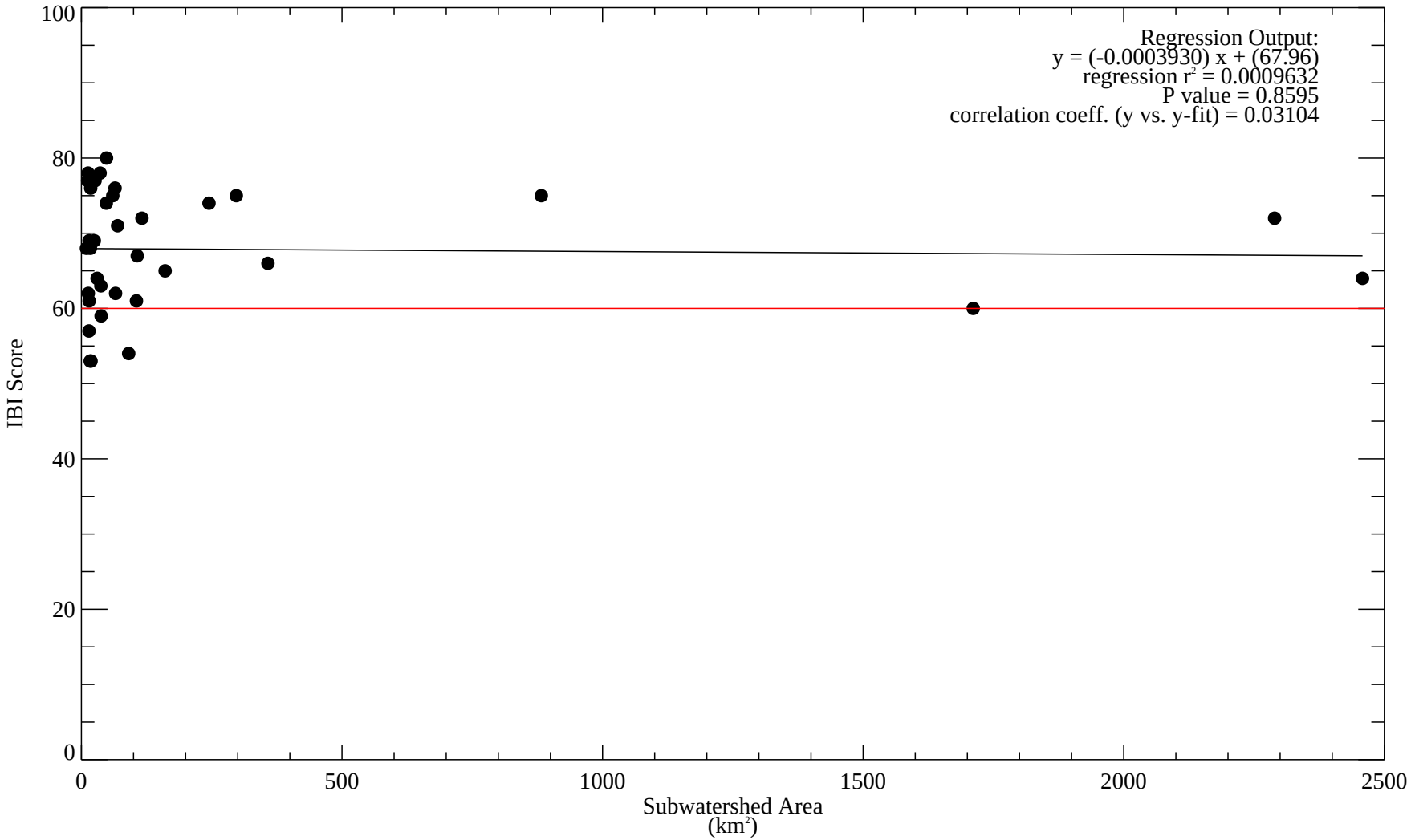

Figure 3-9. IBI score vs. sub-watershed area: 2007 Plaintiffs' data only.

Note: Subwatershed areas based on manual subdivision of NHD subwatersheds.
The horizontal red line denotes the minimum IBI score (60) for sites considered in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

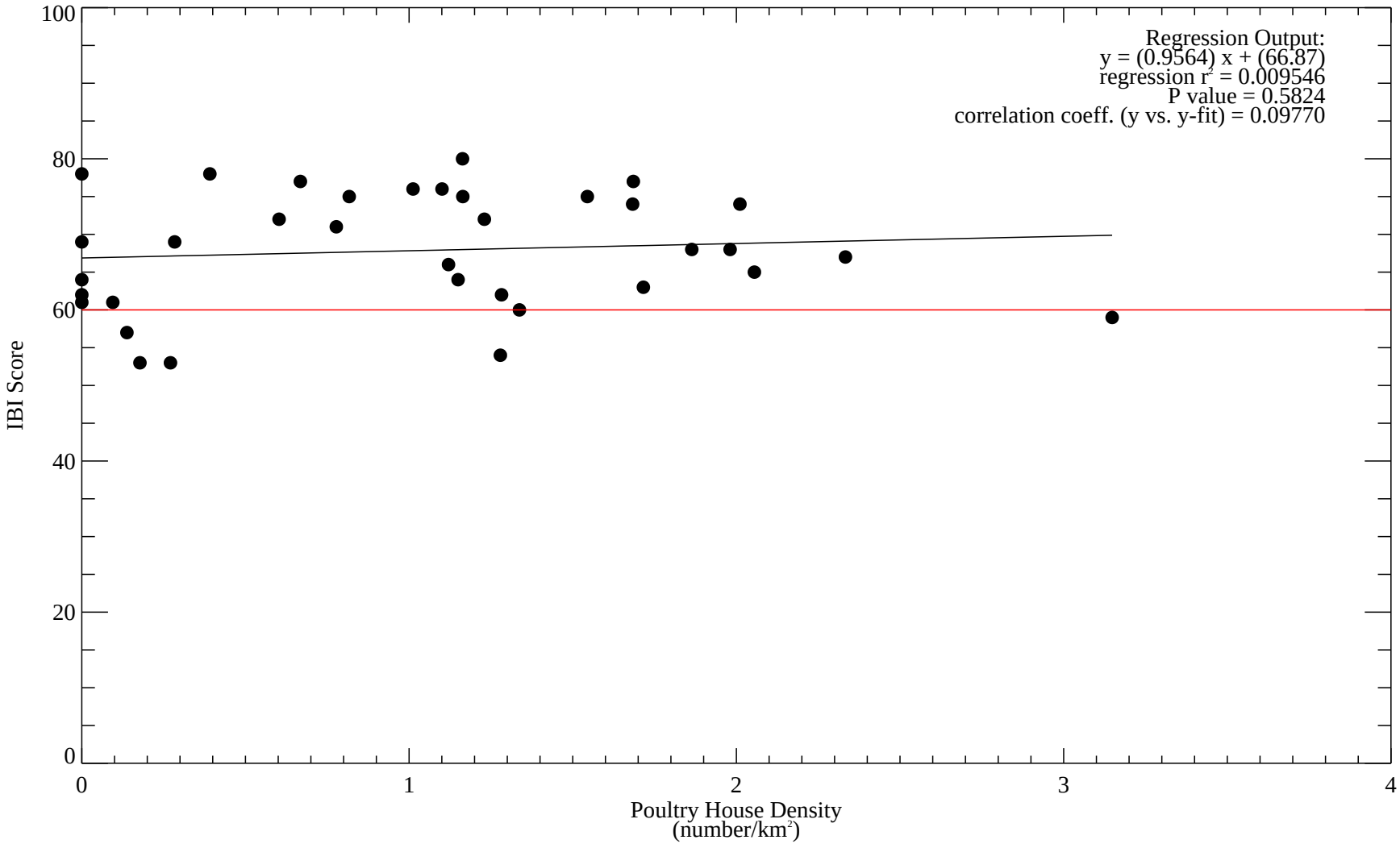

Figure 3-10. IBI score vs. poultry house density in the sub-watershed: 2007 Plaintiffs' data only.

Note: Poultry house density was determined using Prof. Fisher's data coverage.
The horizontal red line denotes the minimum IBI score (60) for sites considered in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

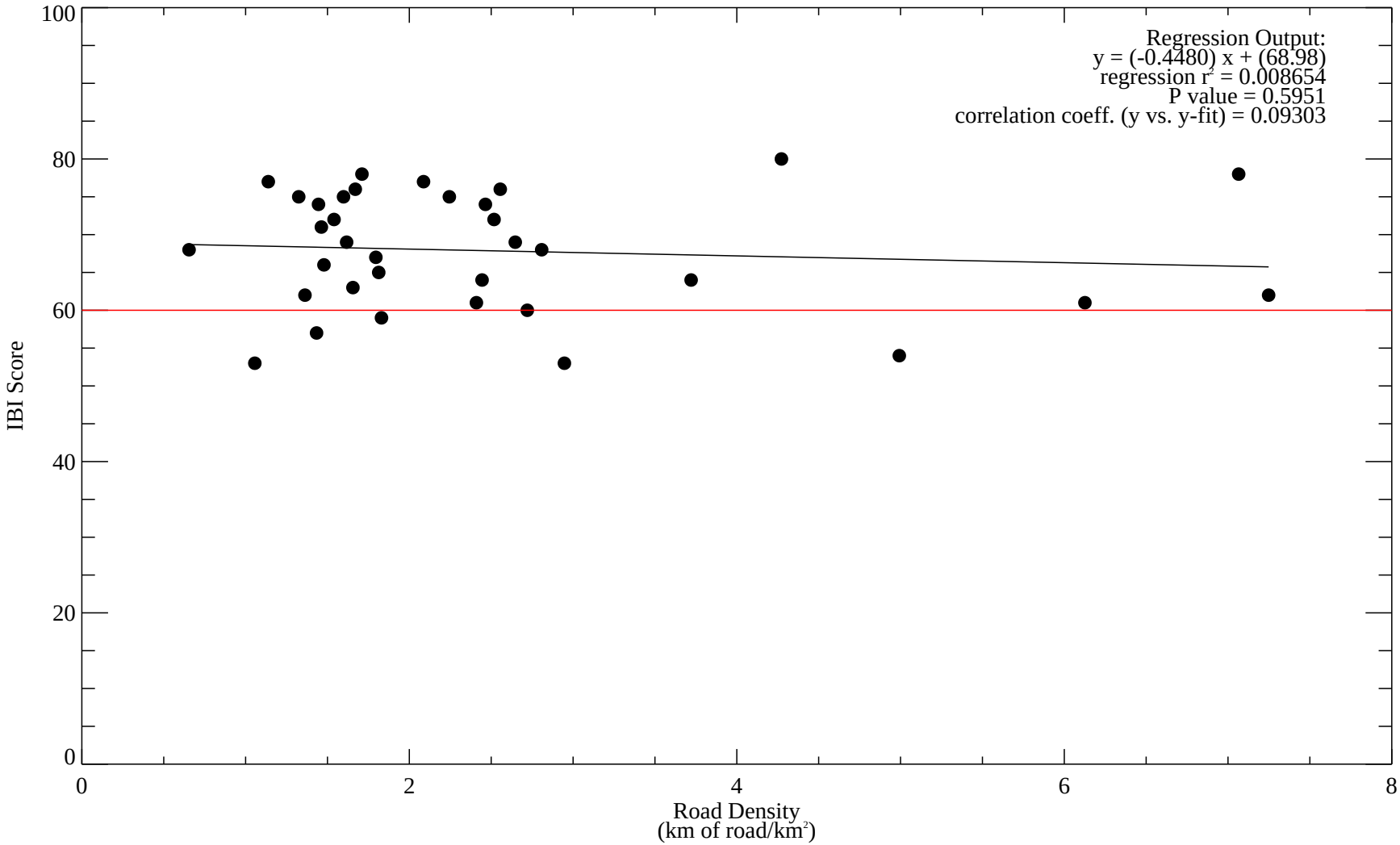

Figure 3-11. IBI score vs. road density in the sub-watershed: 2007 Plaintiffs' data only.

Note: Road density determined using the U.S. Census Bureau's 2007 road coverage.
The horizontal red line denotes the minimum IBI score (60) for sites considered in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

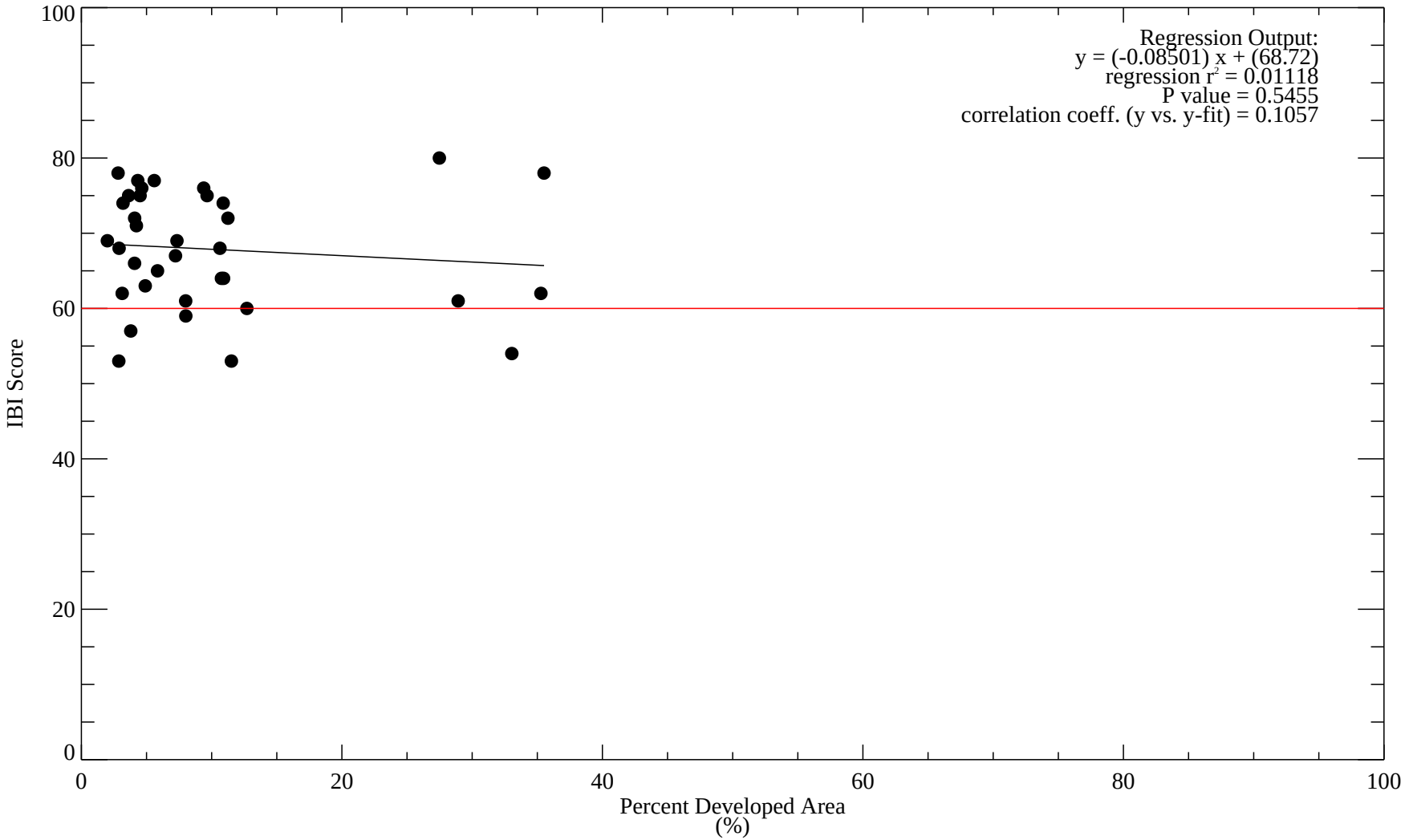

Figure 3-12. IBI score vs. percent developed area of the sub-watershed: 2007 Plaintiffs' data only.

Note: Includes roads and low, mid, and high density urban land-use classifications from the NLCD (2001). The horizontal red line denotes the minimum IBI score (60) for sites considered in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

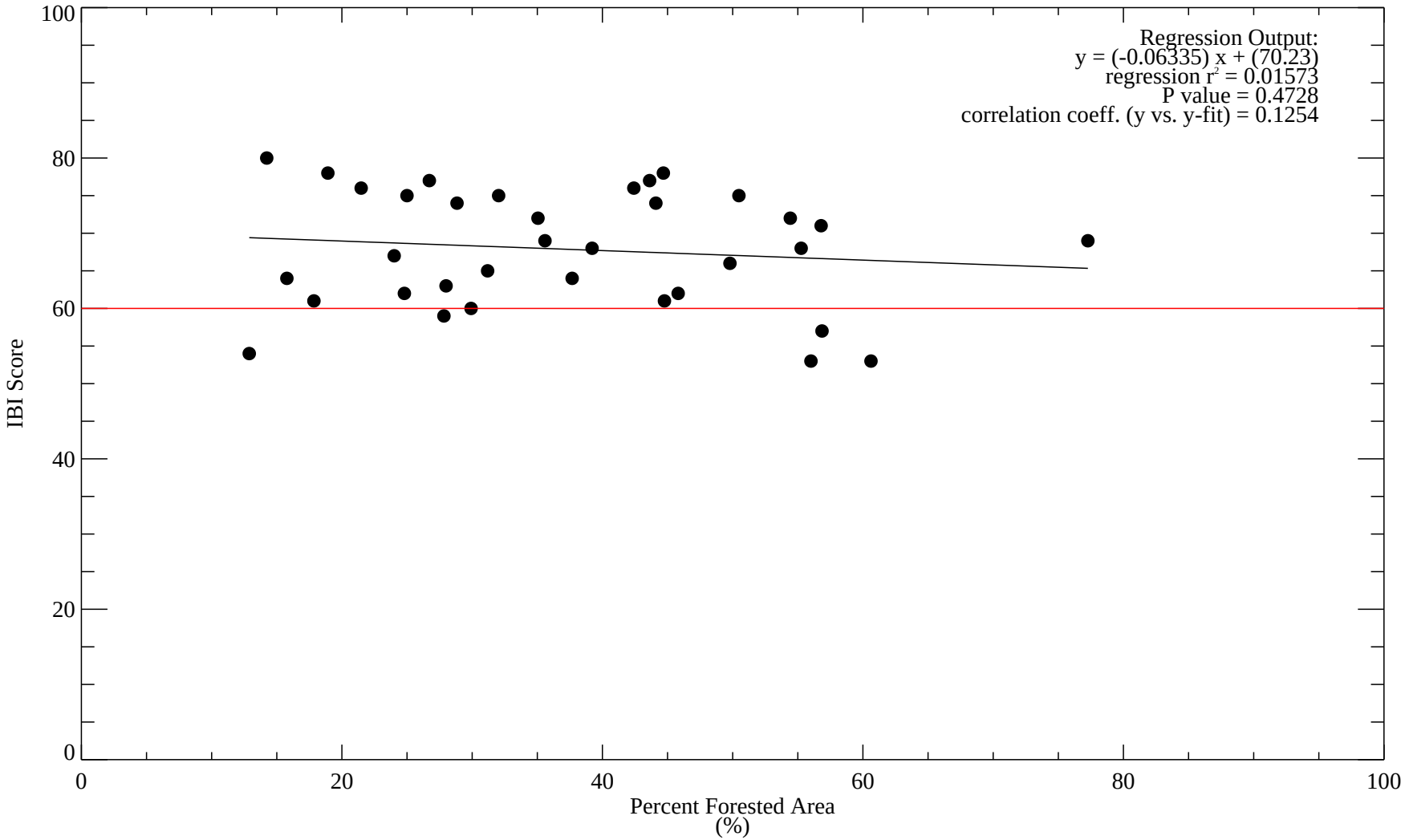

Figure 3-13. IBI score vs. percent forested area of the sub-watershed: 2007 Plaintiffs' data only.

Note: Forested area was determined from the 2001 NLCD land use data.
The horizontal red line denotes the minimum IBI score (60) for sites considered in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

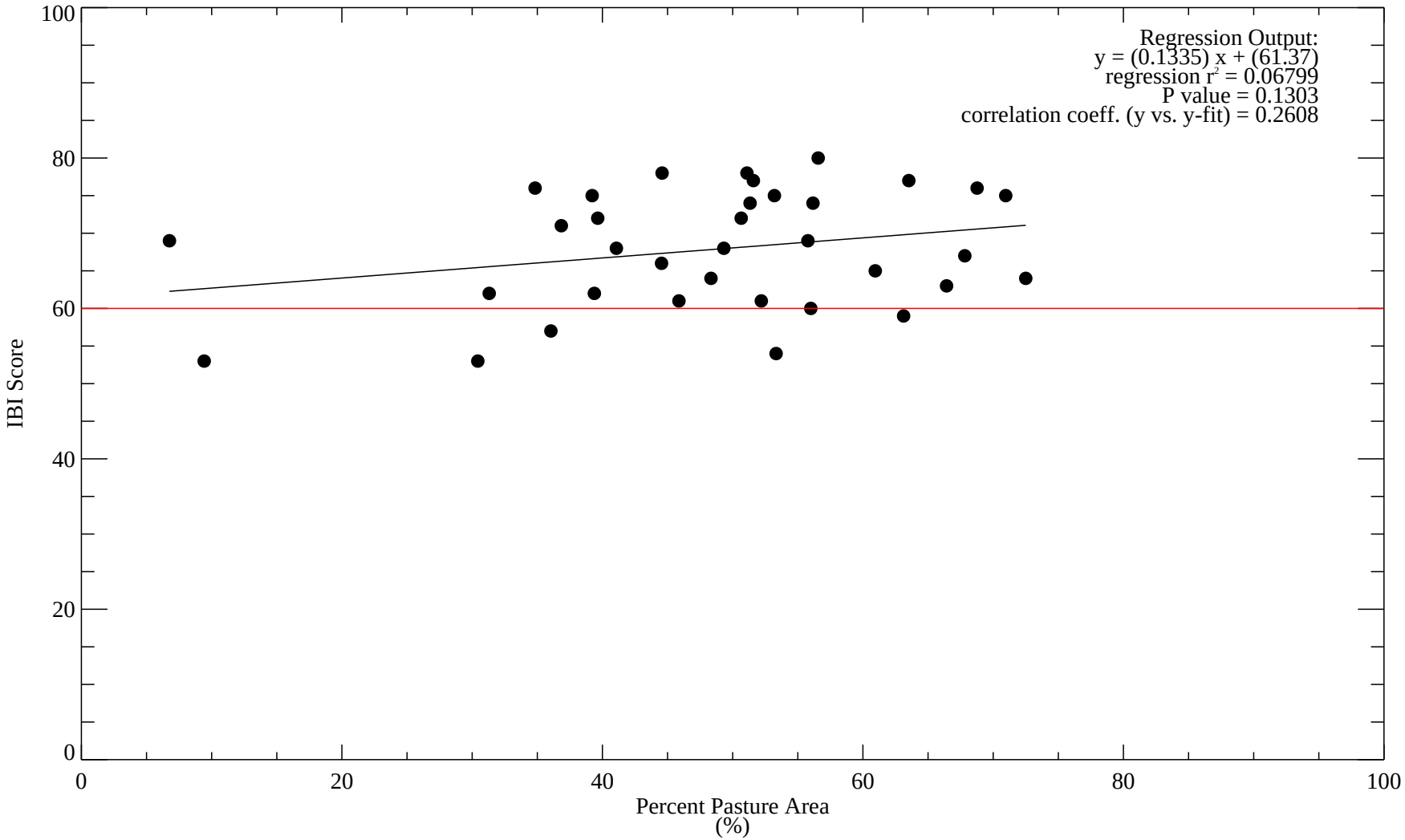

Figure 3-14. IBI score vs. percent pasture area of the sub-watershed: 2007 Plaintiffs' data only.

Note: Pasture area was determined from the 2001 NLCD land use data.
The horizontal red line denotes the minimum IBI score (60) for sites in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

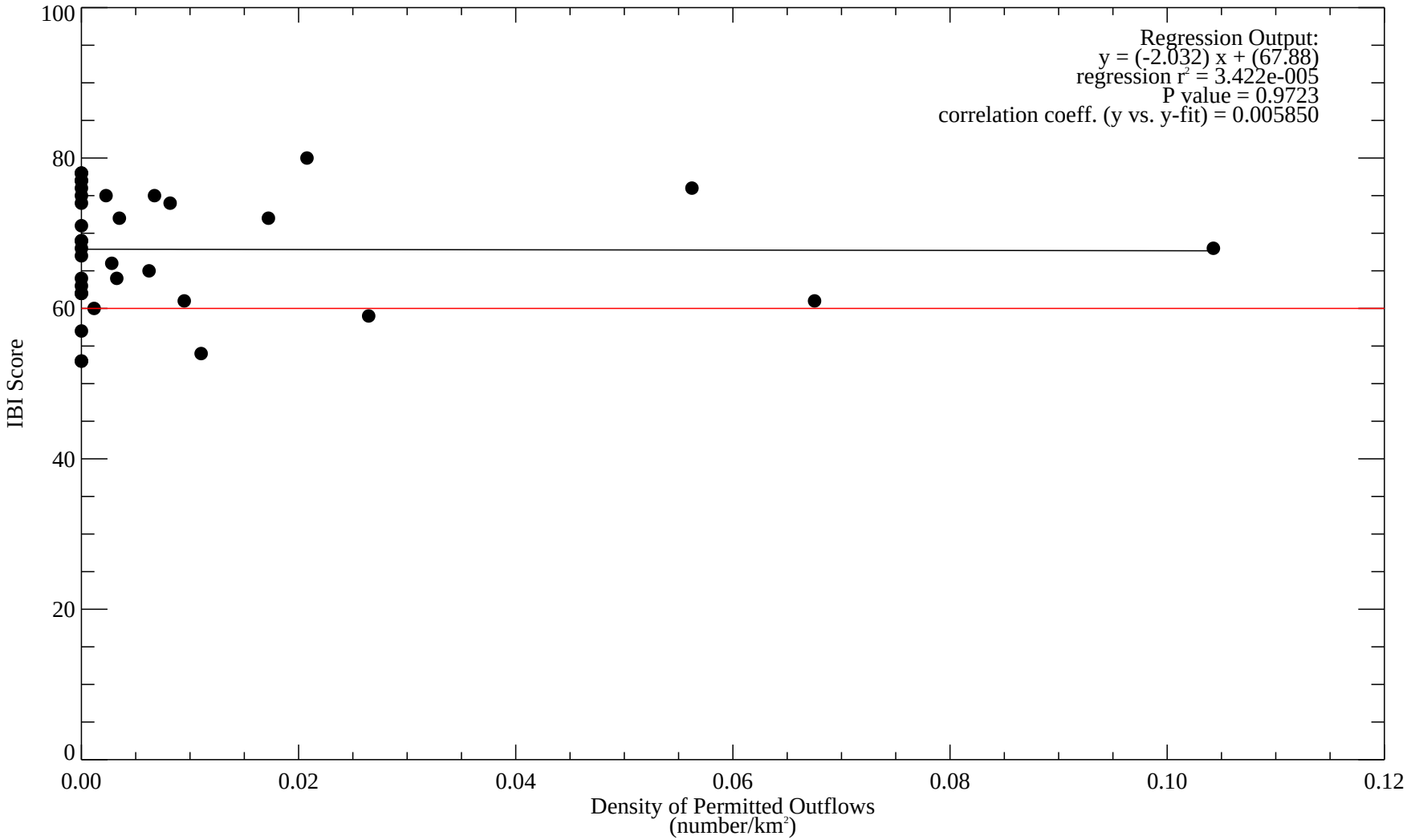

Figure 3-15. IBI score vs. the density of permitted outflows in the sub-watershed: 2007 Plaintiffs' data only.

Note: Waste-water treatment plants with current discharge data in EPA's PCS system are included.
The horizontal red line denotes the minimum IBI score (60) for sites in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

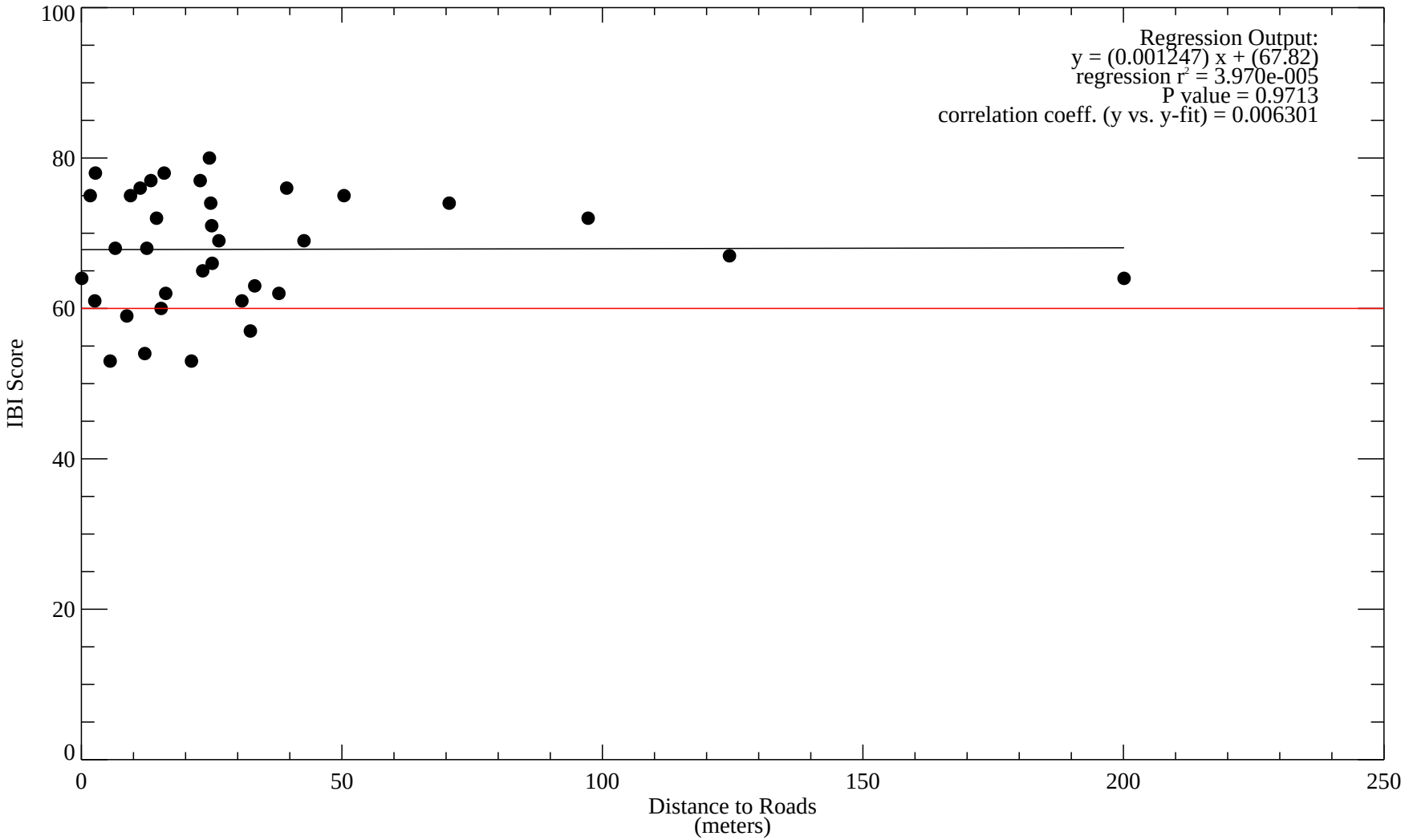

Figure 3-16. IBI score vs. distance to the nearest road: 2007 Plaintiffs' data only.

Note: Road proximity determined using the U.S. Census Bureau's 2007 road coverage. The horizontal red line denotes the minimum IBI score (60) for sites in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

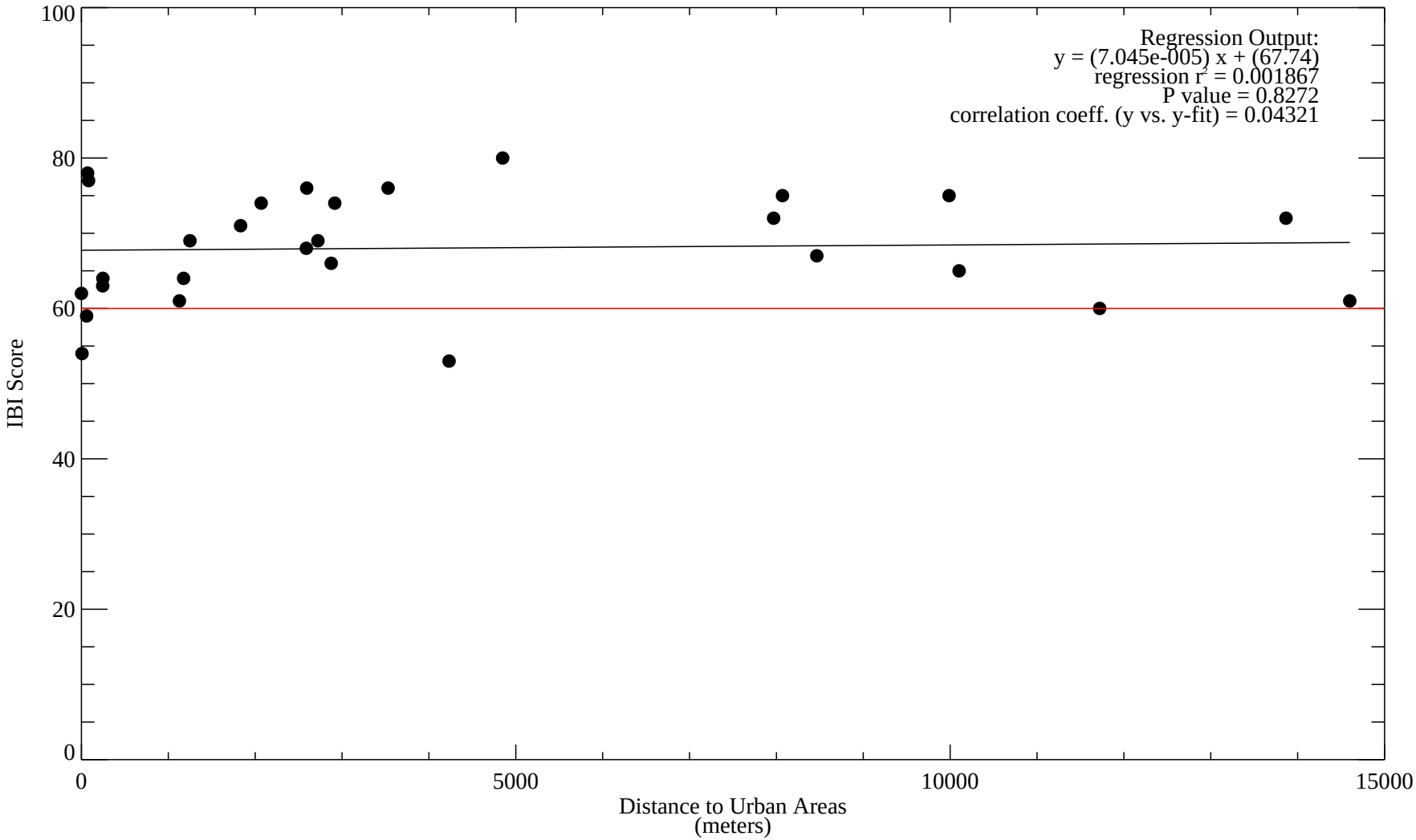

Figure 3-17. IBI score vs. distance to the nearest urban land-use classification: 2007 Plaintiffs' data only.

Note: Urban land-use includes low, mid, and high density urban land-use classifications from the NLCD (2001). The horizontal red line denotes the minimum IBI score (60) for sites in good condition.

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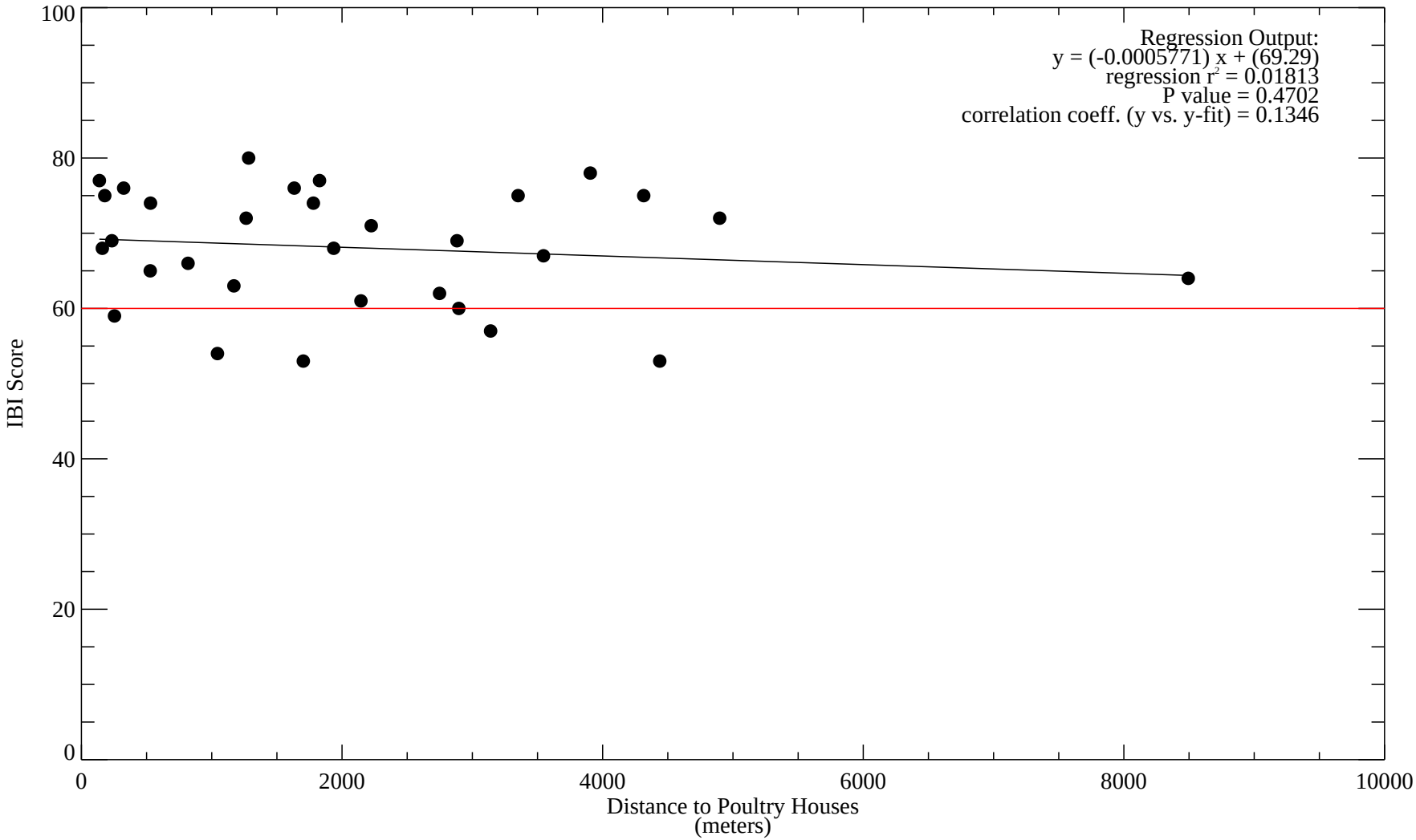


Figure 3-18. IBI score vs. distance to the nearest poultry house: 2007 Plaintiffs' data only.

Note: Poultry house proximity was determined using Prof. Fisher's data coverage.
The horizontal red line denotes the minimum IBI score (60) for sites in good condition.

NDK - Z:\OICiln\Analysis\Fisheries\illinoisriver_ibi_plots.pro
Fri Jan 16 13:41:02 2009

No depths or time for RS-3 samples.
Assumed to be at surface. Averaged data.

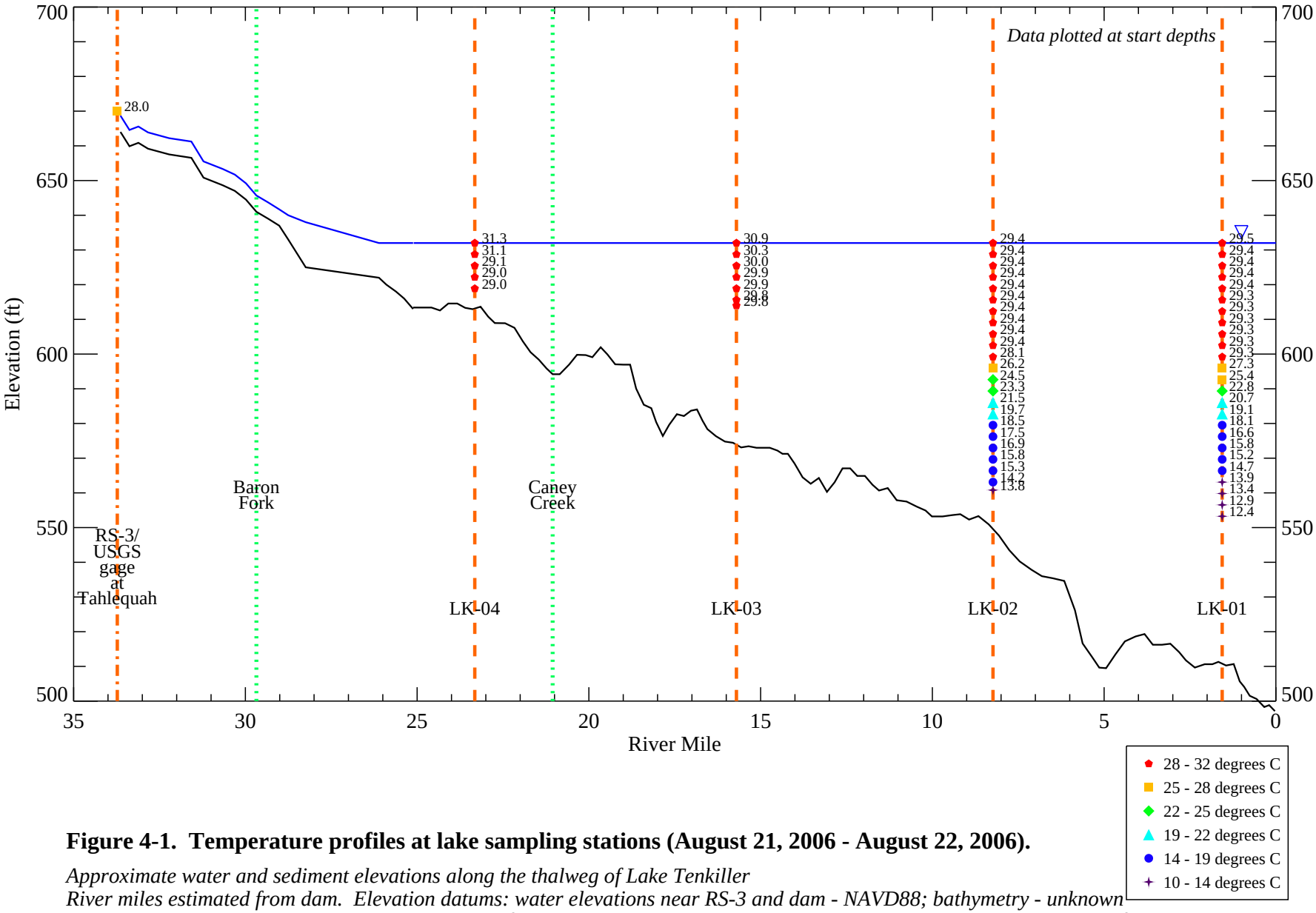
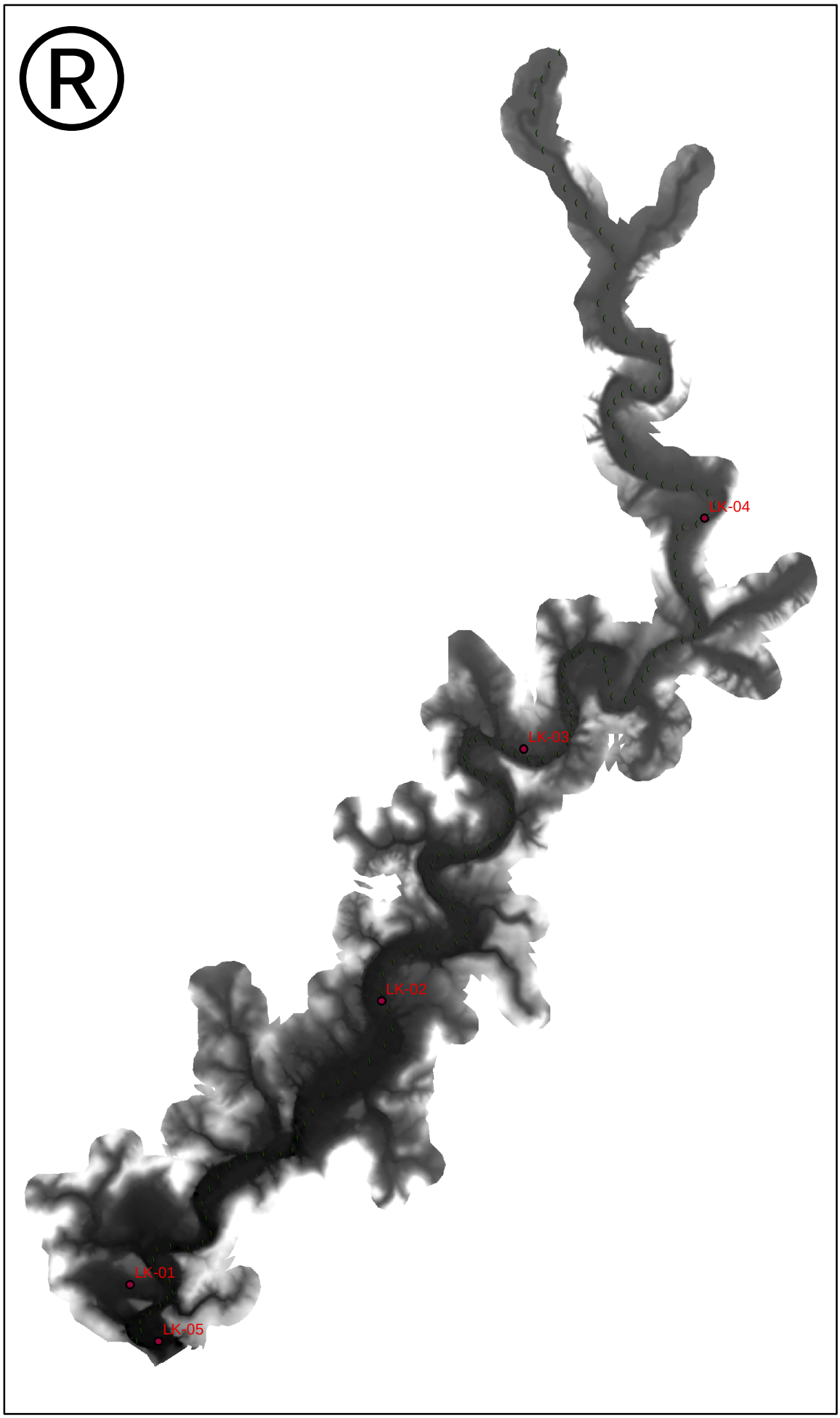


Figure 4-1. Temperature profiles at lake sampling stations (August 21, 2006 - August 22, 2006).

Approximate water and sediment elevations along the thalweg of Lake Tenkiller
River miles estimated from dam. Elevation datums: water elevations near RS-3 and dam - NAVD88; bathymetry - unknown
Data sources: gage height corresponding to 1300 cfs at Tahlequah (near RS-3) - USGS; normal pool height - Army Corp of Engineers
Plaintiff's Database 2005-2007; data elevations estimated from normal pool elevation

ec - D:\OICiln\Analysis\bathymetry\bathy_spatial_chla_temp_P.pro
Thu Jan 15 18:01:36 2009



0 0.5 1 2 Miles

Legend

Thalweg

Sampling Locations

Elevation (m)

High : 314

Low : 140

Illinois River Project

Figure 4-2.

Lake Tenkiller sampling locations and bathymetry.

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OICiln:114 January 2009

\\Emily\d_drive\OICiln\Analysis\bathymetry\GIS\bathy_SURFERgrd_20090107.mxd

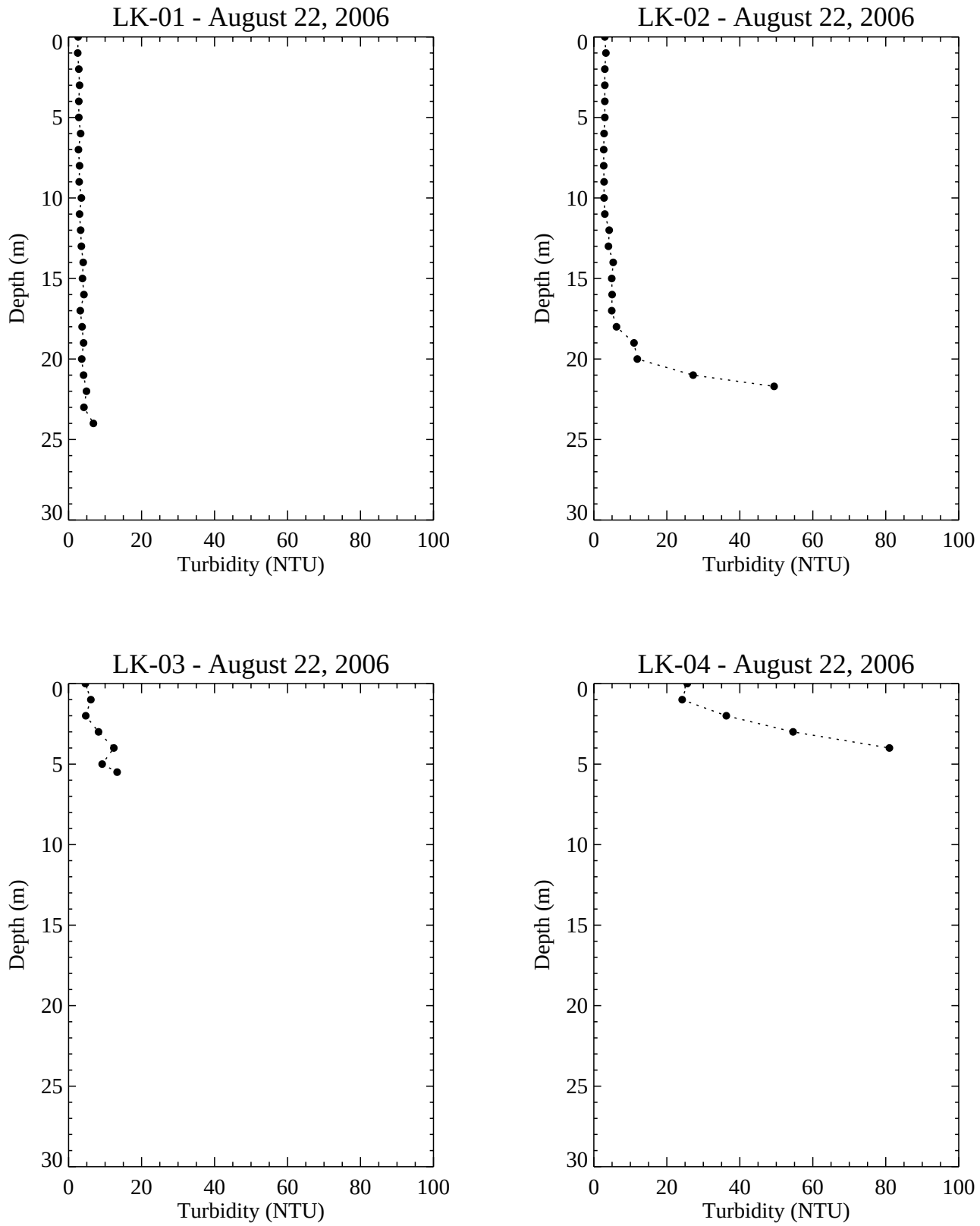

Figure 4-3. Vertical depth profiles of turbidity on August 22, 2006.

Data source: Plaintiff data collected 2005 - 2008.

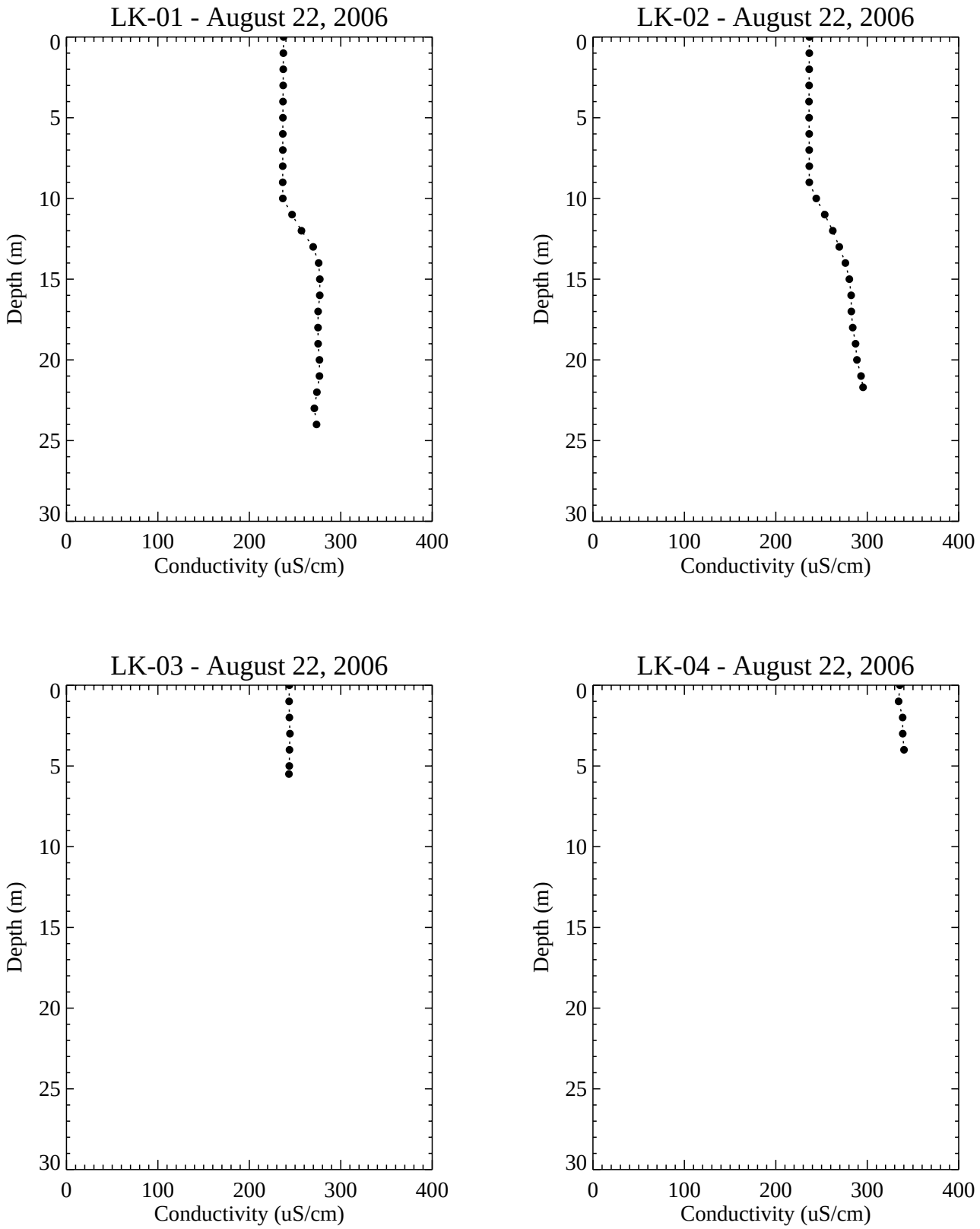

Figure 4-4. Vertical depth profiles of conductivity on August 22, 2006.

Data source: Plaintiff data collected 2005 - 2008.

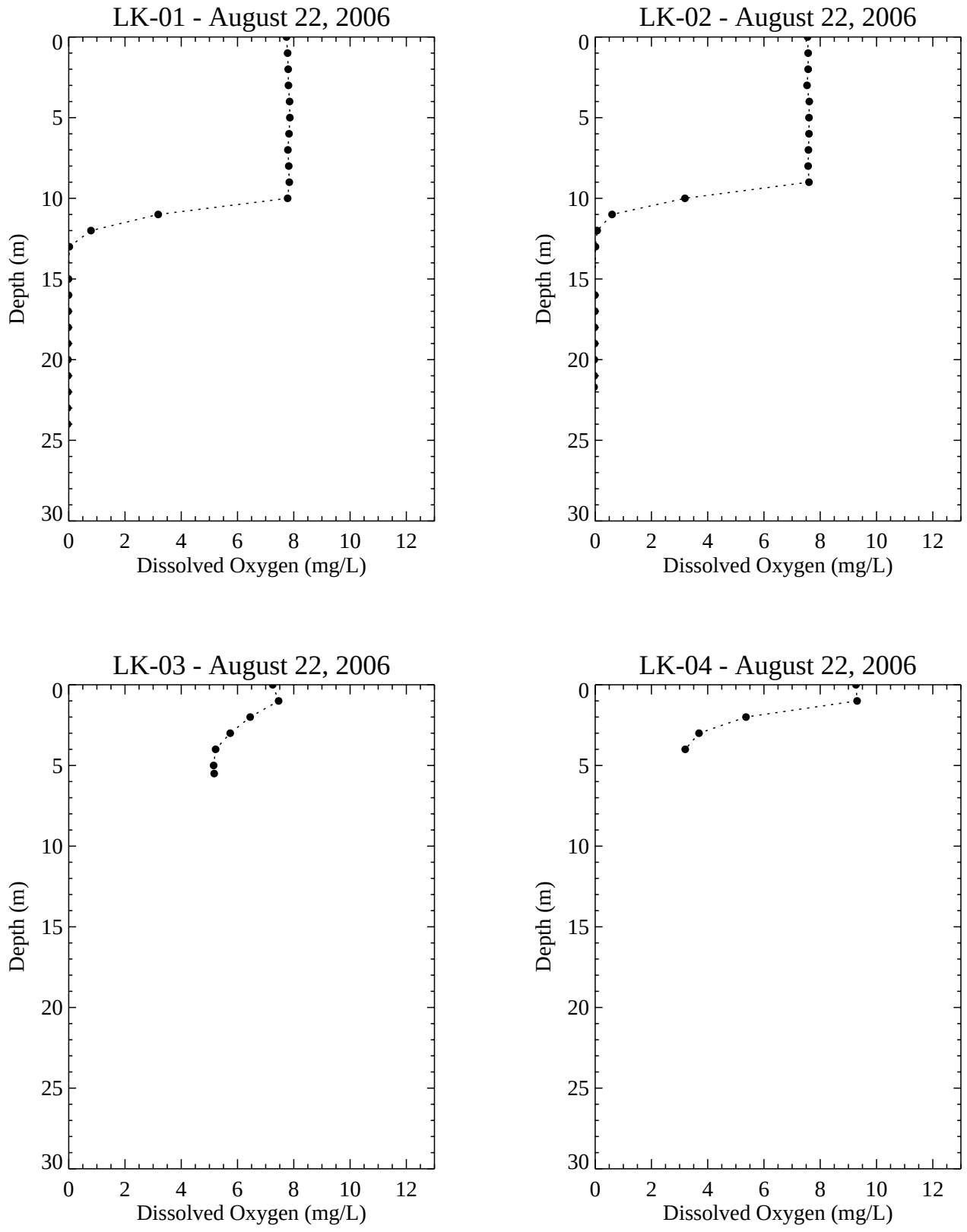

Figure 4-5. Vertical depth profiles of dissolved oxygen on August 22, 2006.

Data source: Plaintiff data collected 2005 - 2008.

DRAFT

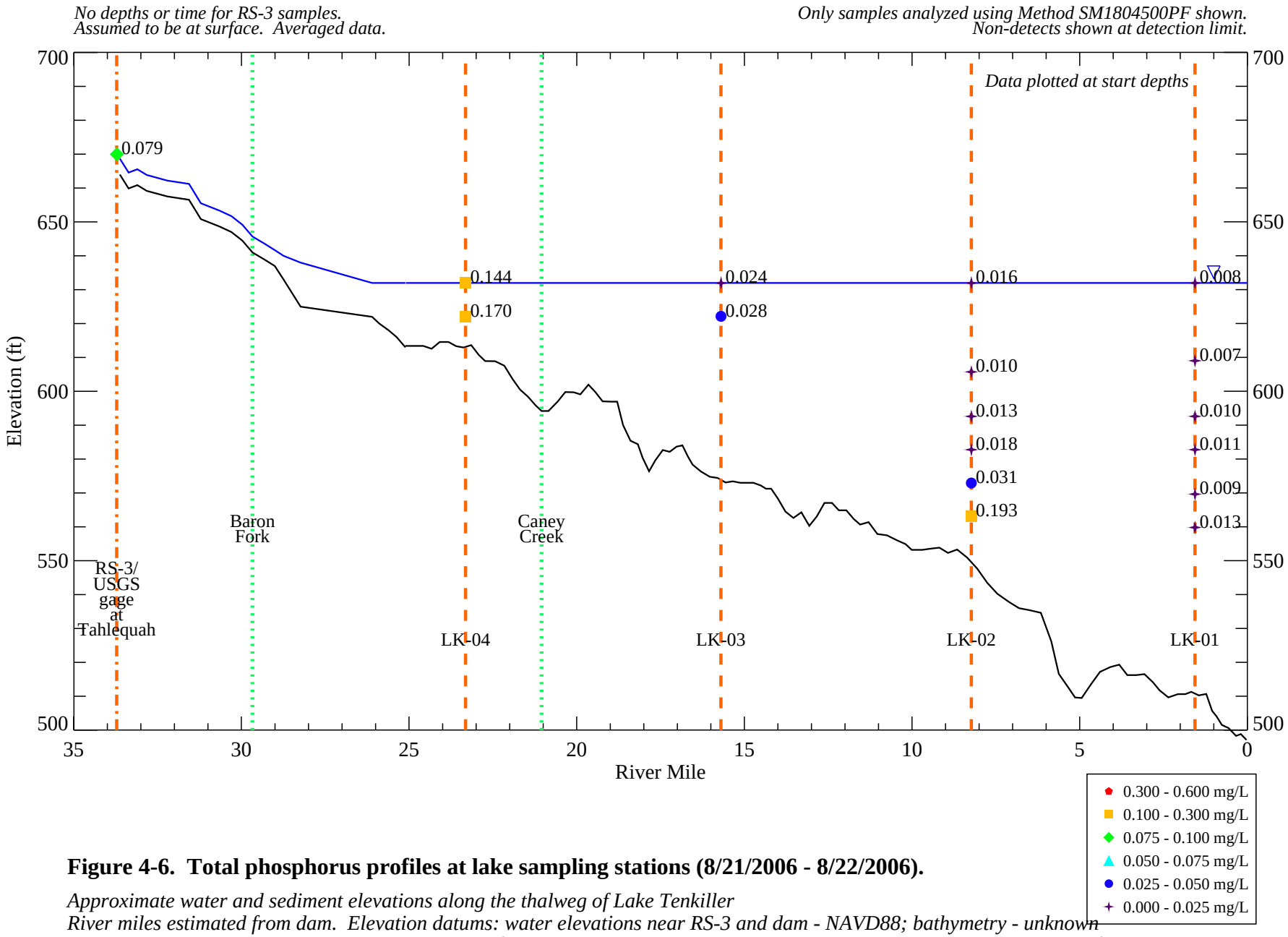

Figure 4-6. Total phosphorus profiles at lake sampling stations (8/21/2006 - 8/22/2006).

Approximate water and sediment elevations along the thalweg of Lake Tenkiller
River miles estimated from dam. Elevation datums: water elevations near RS-3 and dam - NAVD88; bathymetry - unknown
Data sources: gage height corresponding to 1300 cfs at Tahlequah (near RS-3) - USGS; normal pool height - Army Corp of Engineers
Plaintiff's Database 2005-2007; data elevations estimated from normal pool elevation

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PRIVILEGED AND CONFIDENTIAL
ATTORNEY WORK PRODUCT
PREPARED AT REQUEST OF COUNSEL

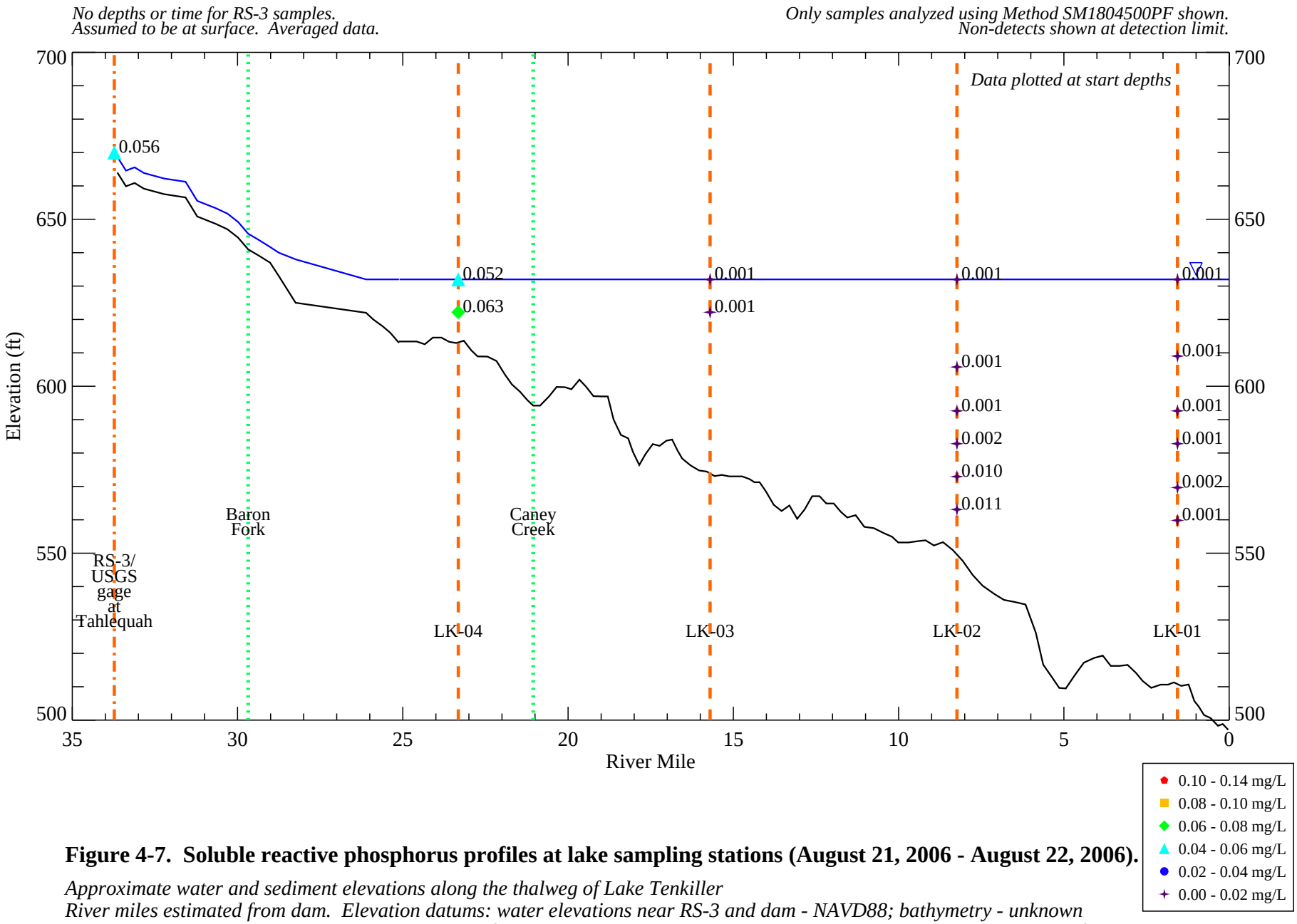

Figure 4-7. Soluble reactive phosphorus profiles at lake sampling stations (August 21, 2006 - August 22, 2006).

Approximate water and sediment elevations along the thalweg of Lake Tenkiller
River miles estimated from dam. Elevation datums: water elevations near RS-3 and dam - NAVD88; bathymetry - unknown
Data sources: gage height corresponding to 1300 cfs at Tahlequah (near RS-3) - USGS; normal pool height - Army Corp of Engineers
Plaintiff's Database 2005-2007; data elevations estimated from normal pool elevation

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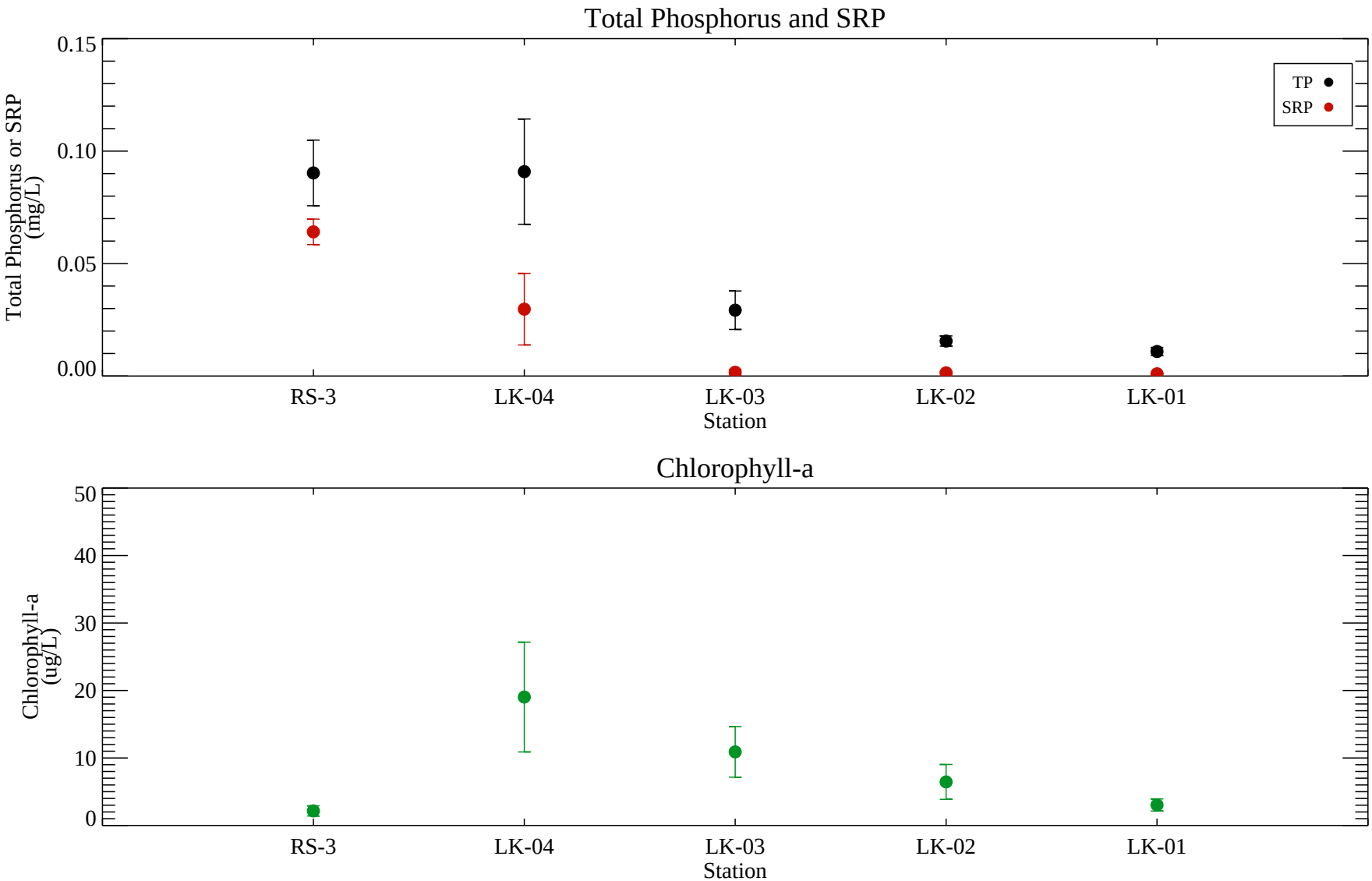

Figure 4-8. Spatial distribution of summer total phosphorus, SRP, and chlorophyll-a in Lake Tenkiller (2006).

Data source: Plaintiff data collected 2005 - 2008. Only surface samples considered at lake stations. Error bars are at +/- 2 standard errors. Only method SM18-4500PF for TP, SRP considered. Non-detects assigned detection limit values. RS-3 includes data from the collocated station RS000654.

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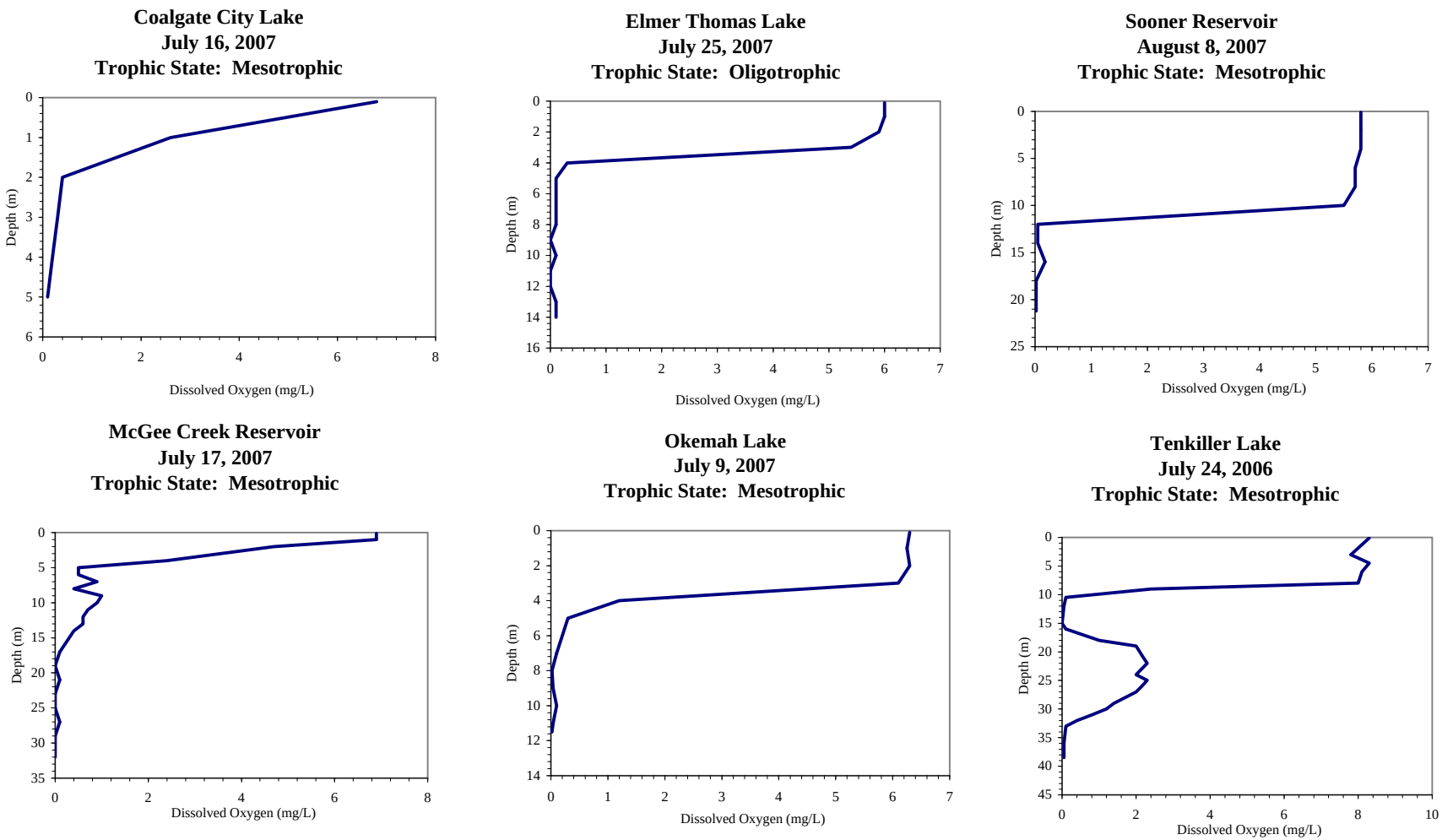
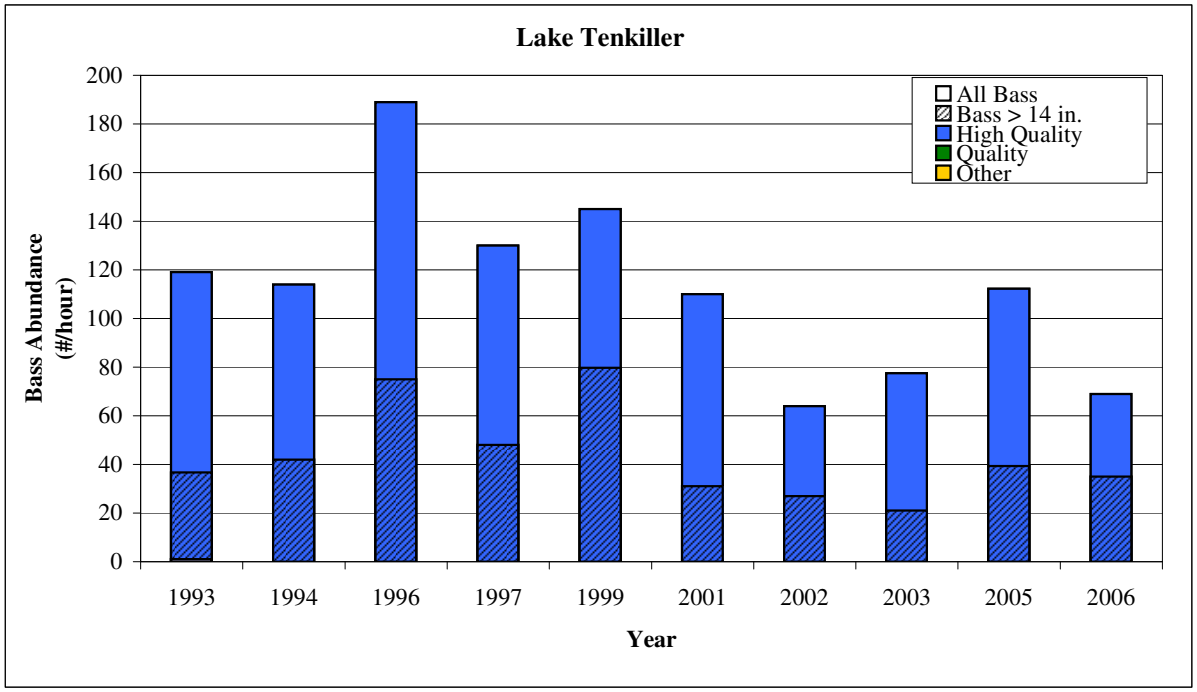


Figure 4-9. Dissolved oxygen profiles for various Oklahoma reservoirs in summers 2006 and 2007.
Data source: 2007 Beneficial Use Monitoring Program Report



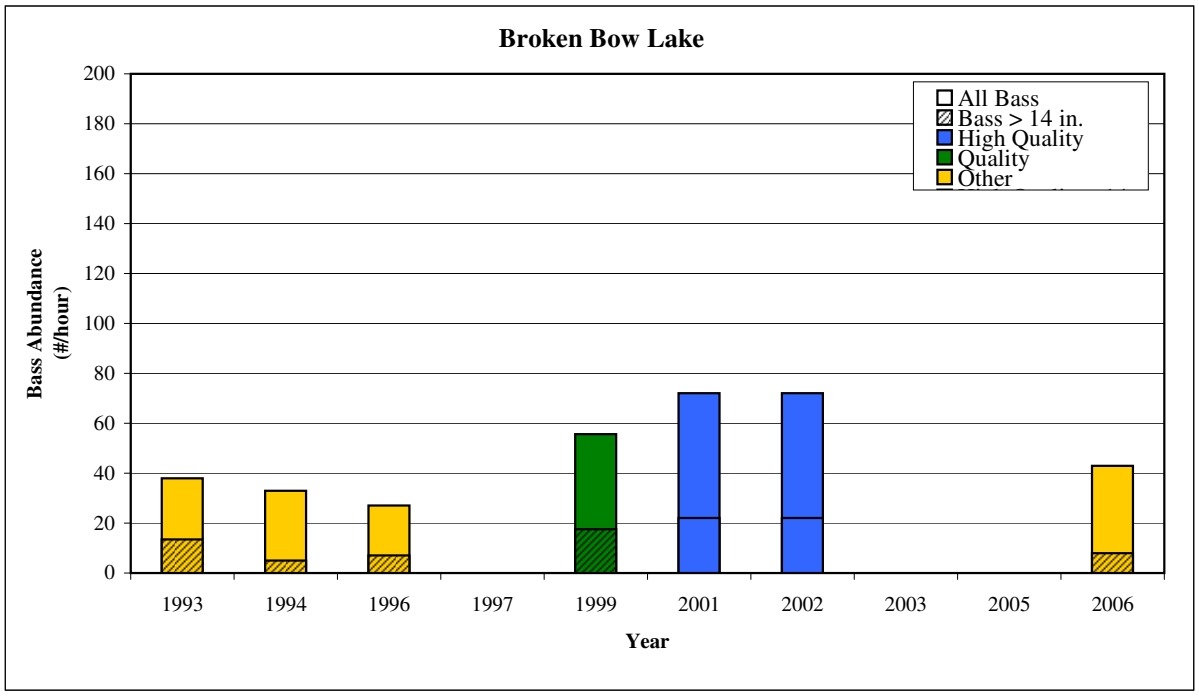


Figure 4-10. Comparison of Oklahoma Department of Wildlife Conservation spring largemouth bass electrofishing surveys 1993-2006 in Lake Tenkiller and Broken Bow Lake.[1]

[1] *Data downloaded from www.wildlifedepartment.com on 6/12/08.*

High Quality Fishery: 60 or more bass per hour of electrofishing with 15 or more bass at least 14 inches in length.

Quality Fishery: 40 or more bass per hour of electrofishing with 10 or more bass at least 14 inches in length.

Note: missing years indicate no fish collection in the lake for that year; fish collections not conducted in Broken Bow in 1997, 2003, or 2005

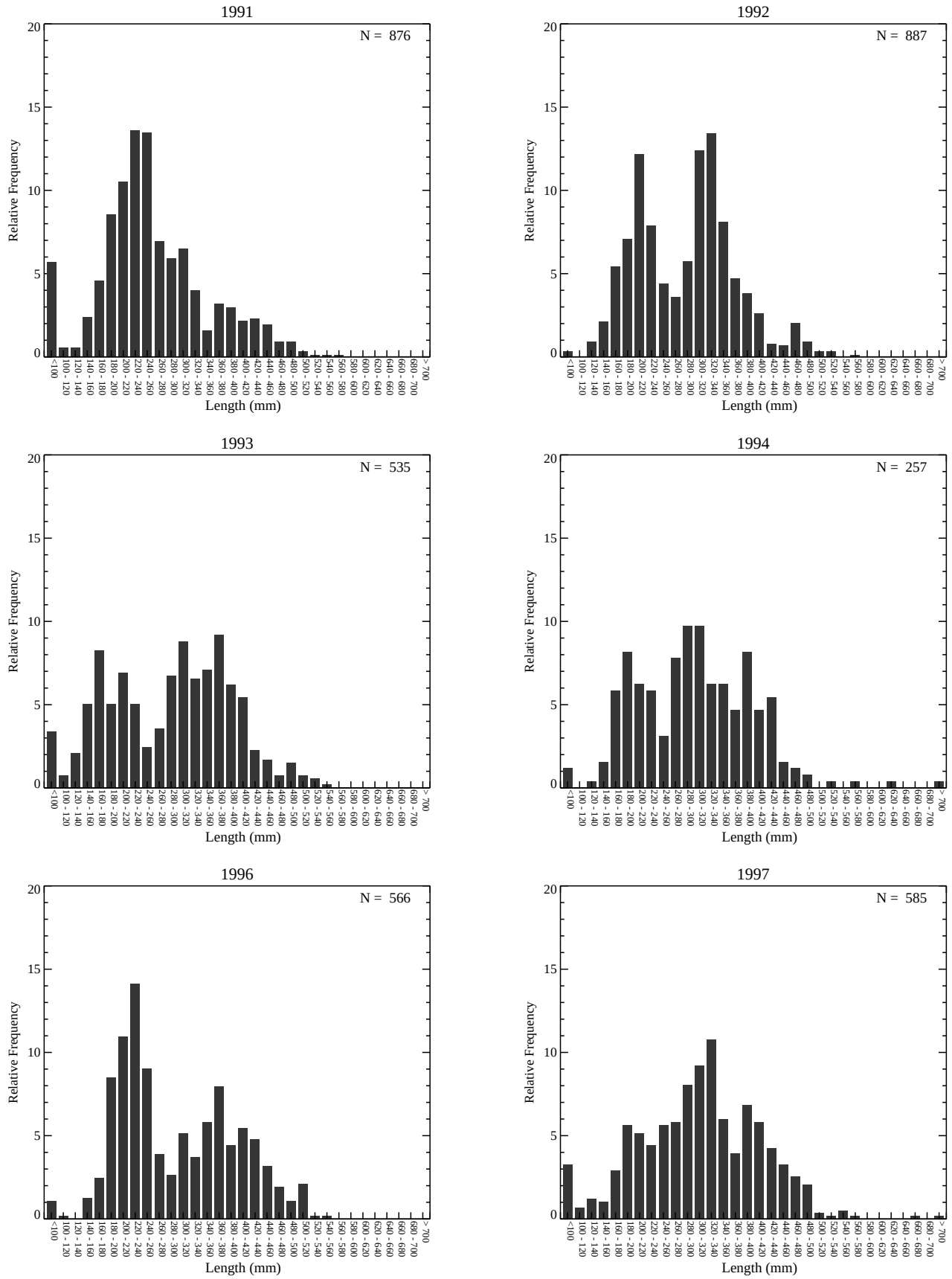


Figure 4-11. Length frequency in spring of largemouth bass in Lake Tenkiller.

Data source: Oklahoma Department of Wildlife Conservation - bass electrofishing.

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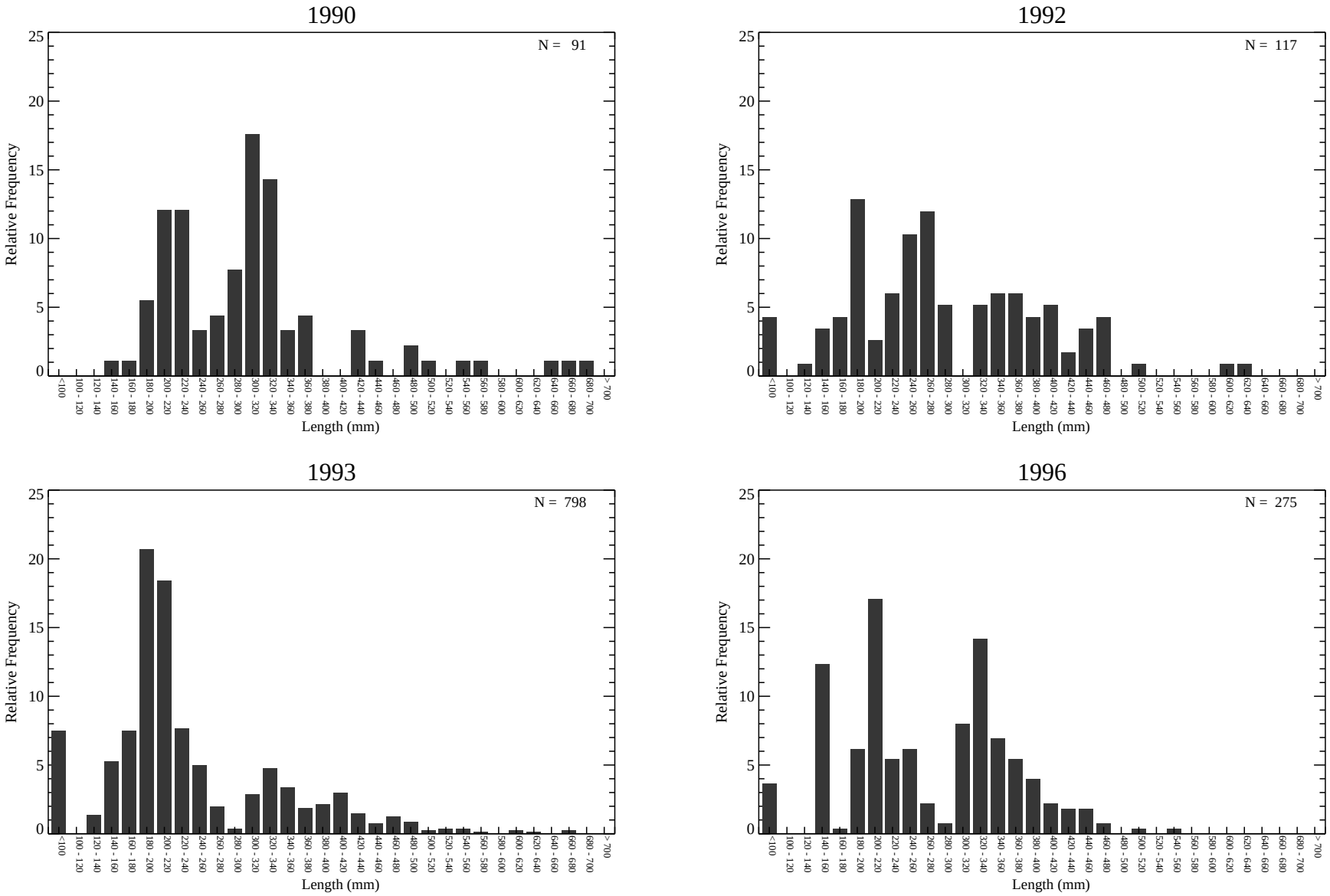

Figure 4-12. Length frequency of white bass in Lake Tenkiller (all zones).

Note: Data source is Oklahoma Department of Wildlife Conservation - gillnetting (1993 is research netting).

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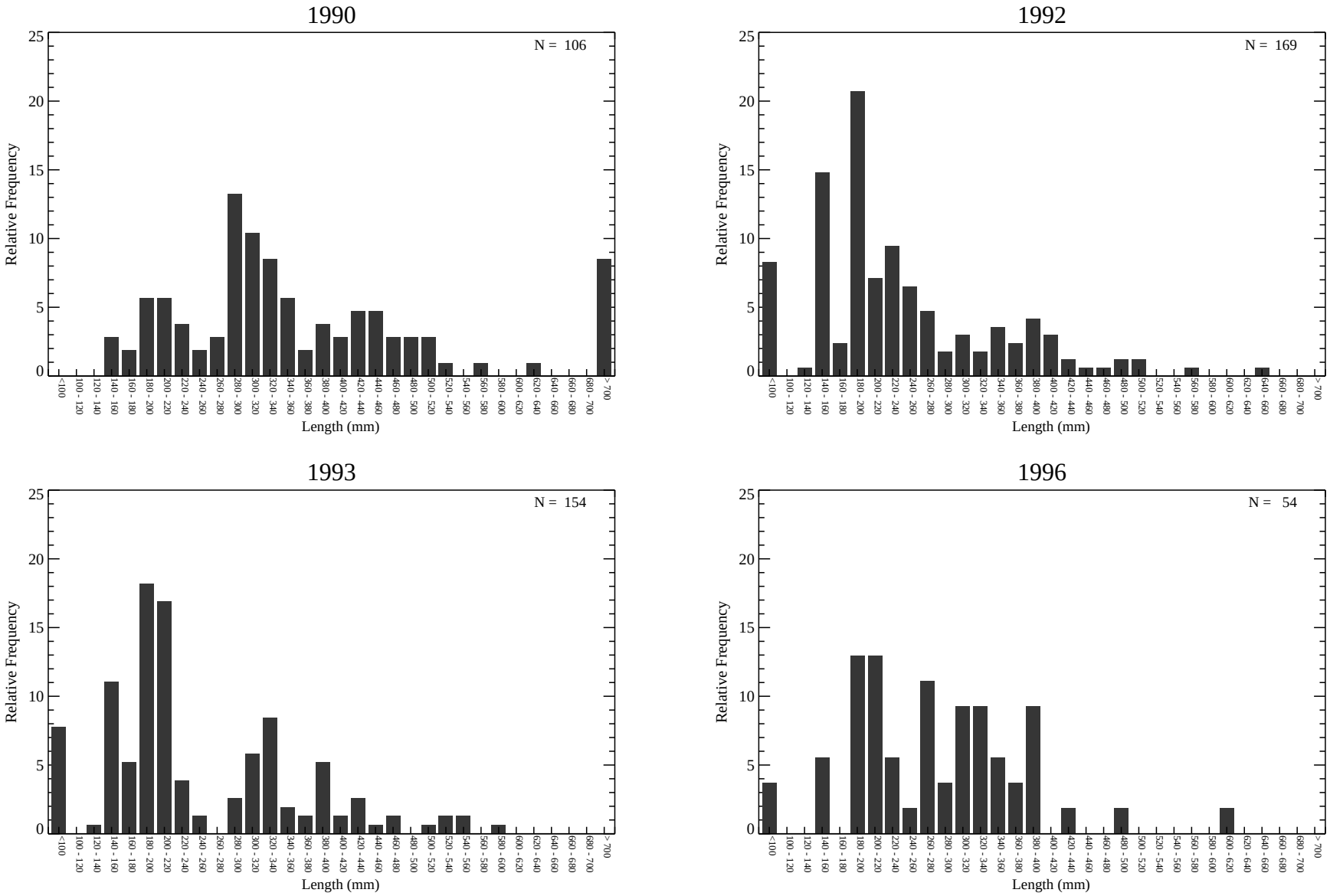

Figure 4-13. Length frequency of channel catfish in Lake Tenkiller (all zones).

Note: Data source is Oklahoma Department of Wildlife Conservation - gillnetting (1993 is research netting).

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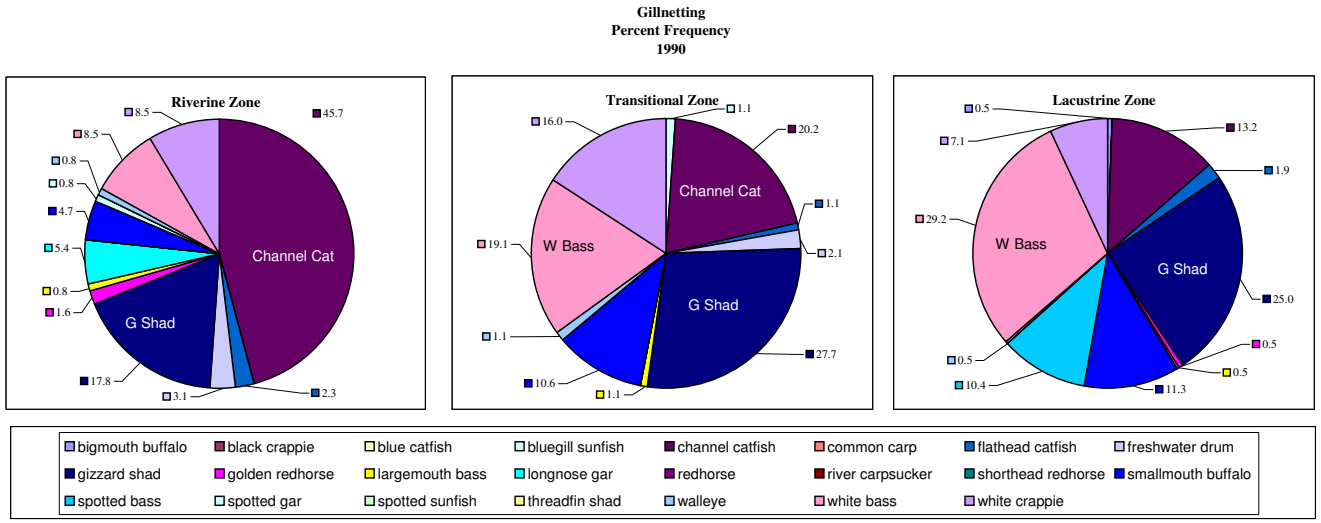

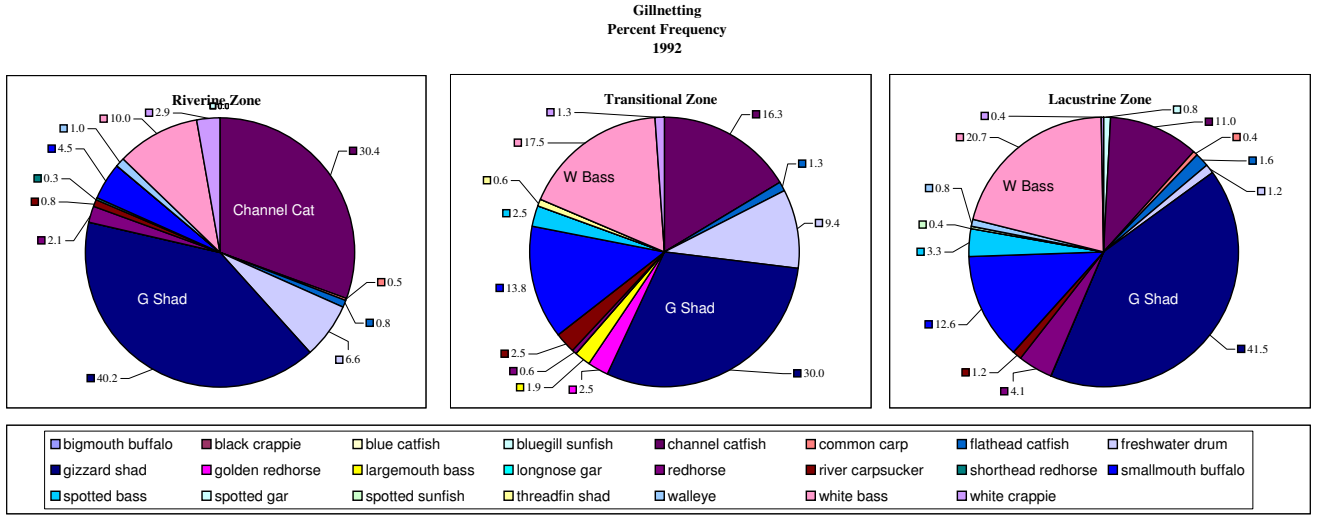

Figure 4-14. Percent frequency of fish species in Lake Tenkiller based on ODWC gillnetting data: 1990 and 1992.

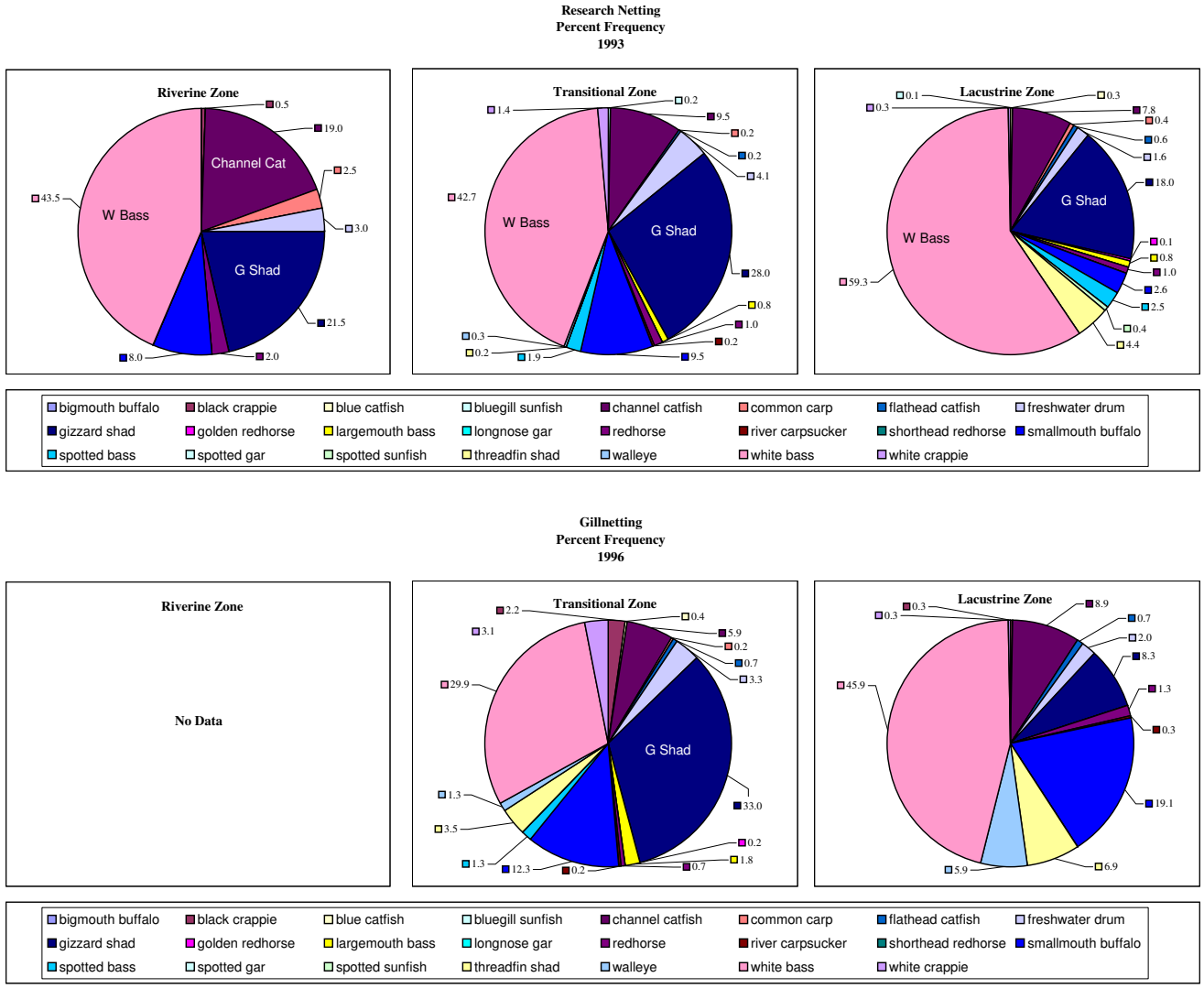

Figure 4-15. Percent frequency of fish species in Lake Tenkiller based on ODWC gillnetting data: 1993 and 1996.

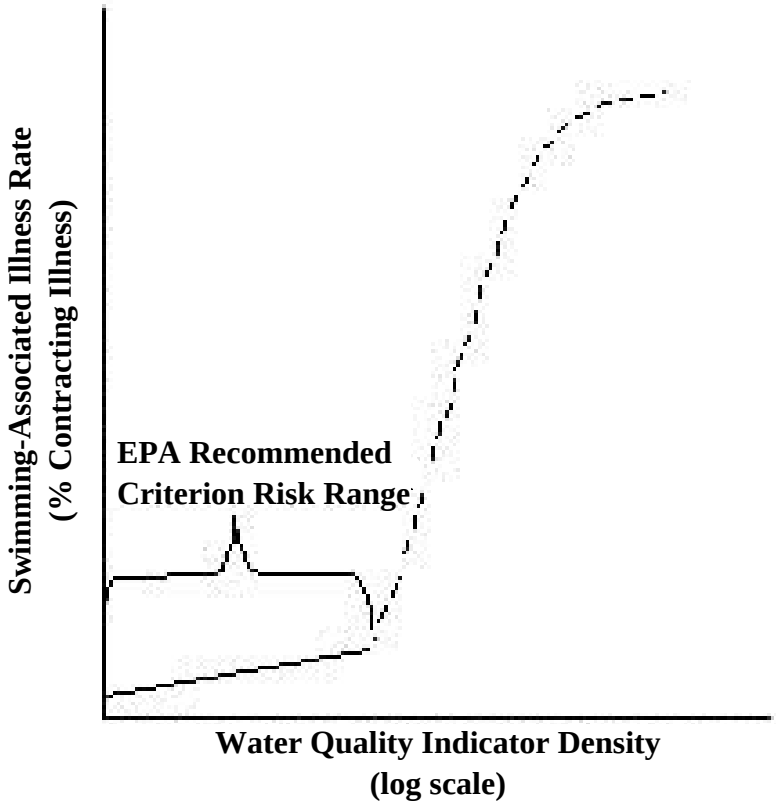

Figure 5-1. EPA conceptual relationship between illness rates and bacterial indicator density. Reproduced from USEPA (2004).

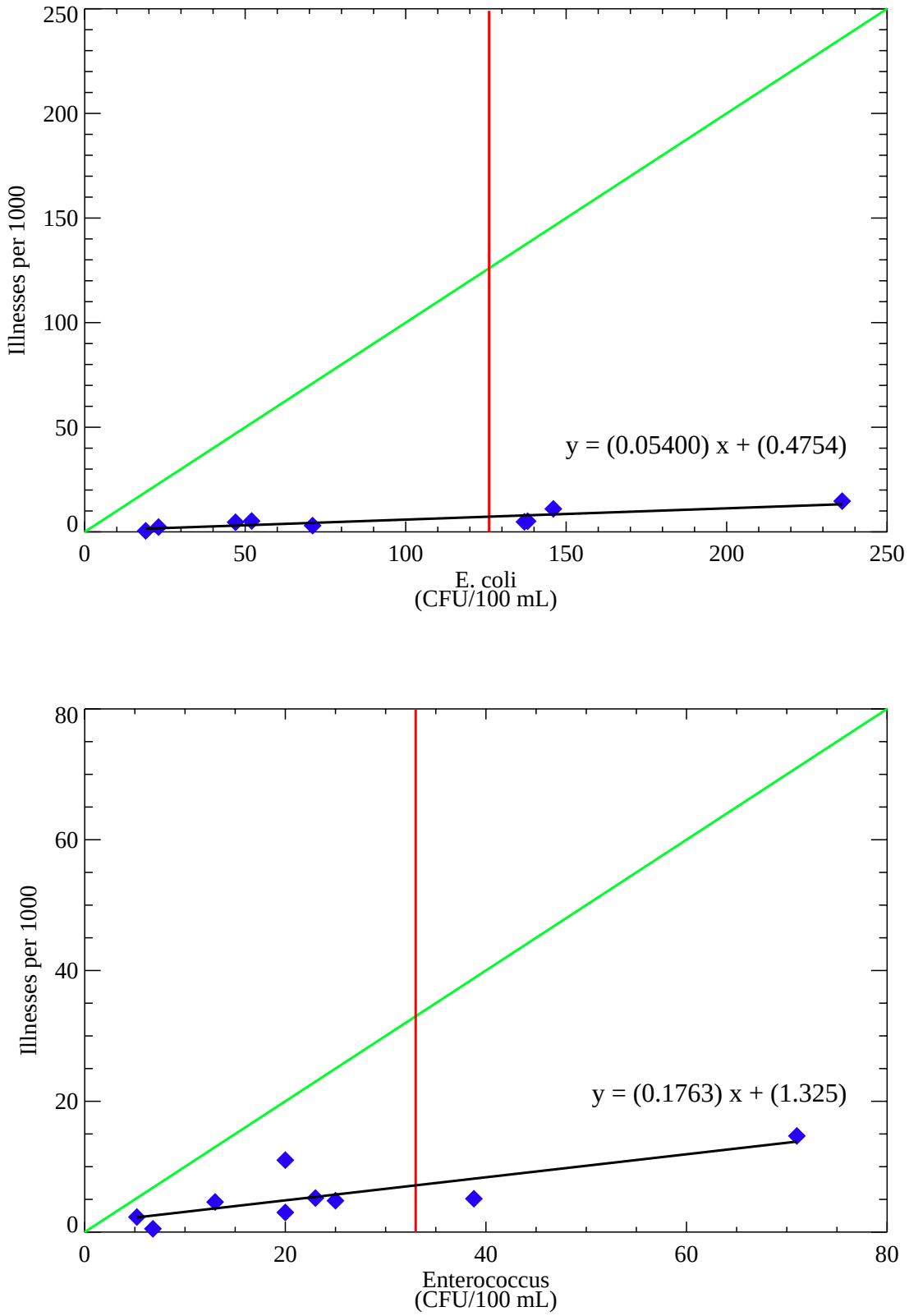

Figure 5-2. Epidemiological data used to set current USEPA water quality criteria.

Data points (blue diamonds), and water quality criteria thresholds (red vertical lines) are taken from Table 3 of USEPA (1986). The 1:1 line for bacteria density vs. illness rate per 1000 is shown in green. The equation for linear regression is presented next to the regression line.

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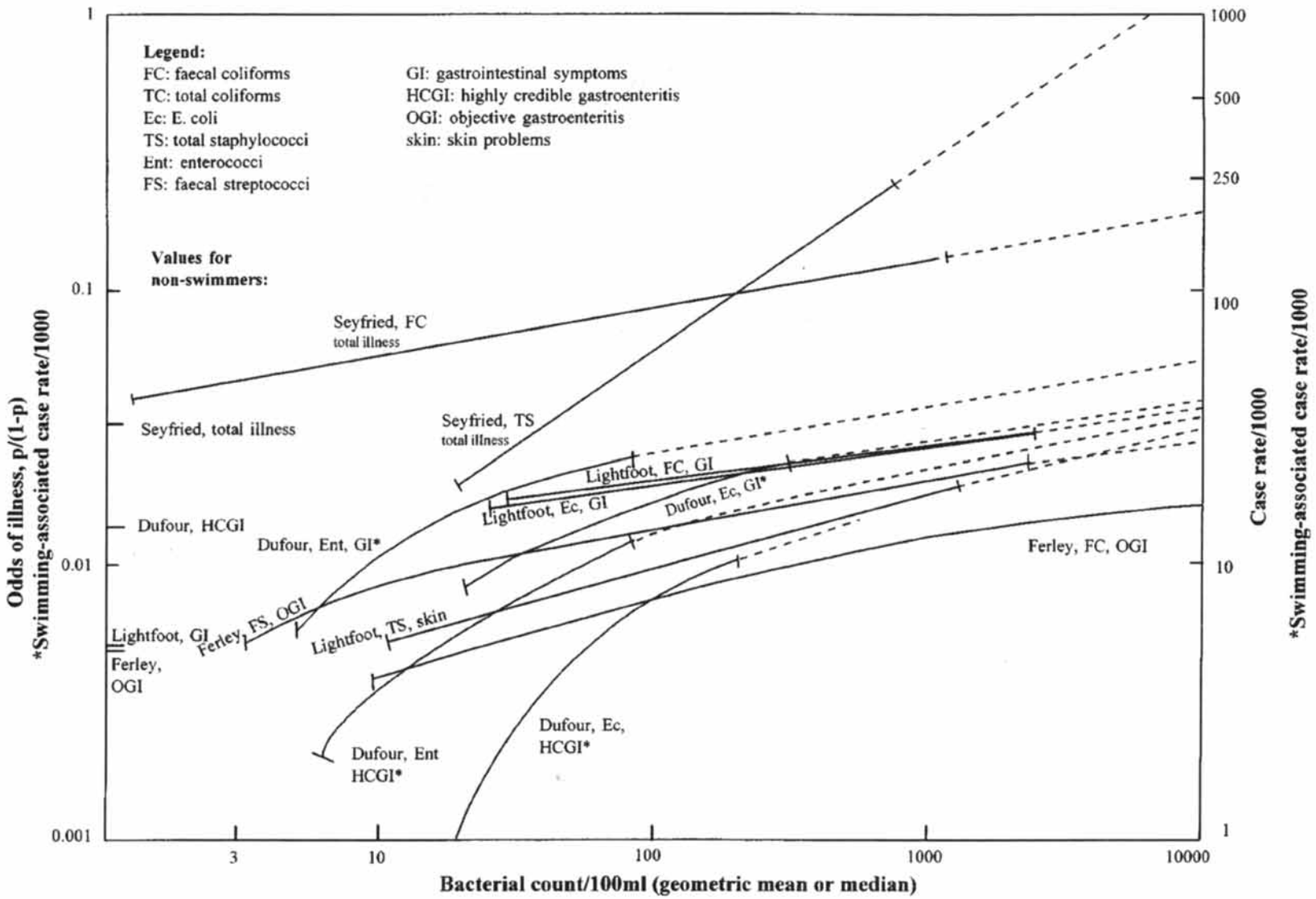


Figure 5-3. Relationship between illness risk for swimmers and indicator bacteria count in multiple freshwater epidemiological studies. Reproduced from Prüss 1998.

KS

Oolagahl Lake

Lake O the Cherokees

Keystone Lake

Tenkiller Lake

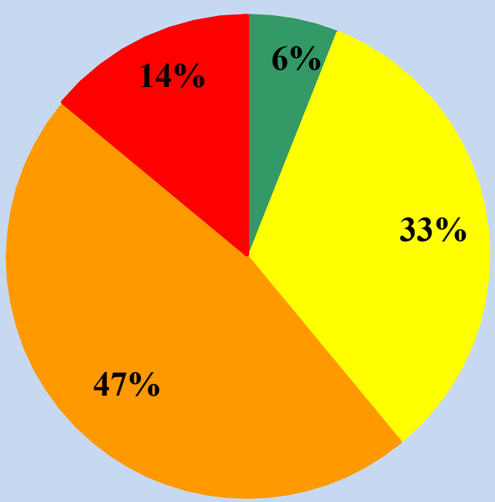
Eufaula Lake

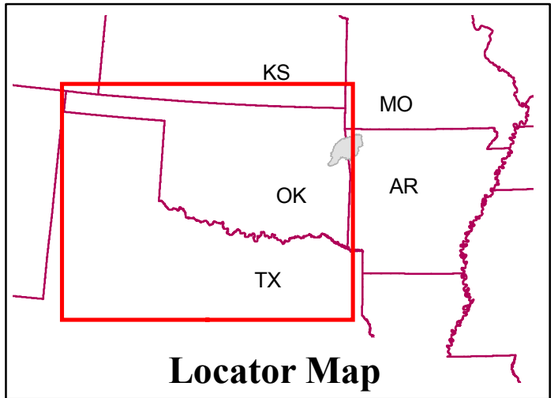
Hugo Lake

Pine Creek Lake

Broken Bow Lake

TX





Locator Map

Legend

Trophic State Index

- Oligotrophic (<=40)
- Mesotrophic (41 - 50)
- Eutrophic (51 - 60)
- Hypereutrophic (>= 61)
- Rivers
- Lakes
- Illinois River Watershed

**This map was replicated from the 2007 BUMP. The TSI values represent the most recent data and were taken from the Lake Monitoring and Results Discussion of the report. Coordinates for Wayne Wallace could not be found and is not displayed on this map.*

Figure 6-1.
2004-2007 BUMP (OWRB) sample lakes in Oklahoma.

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January 2009

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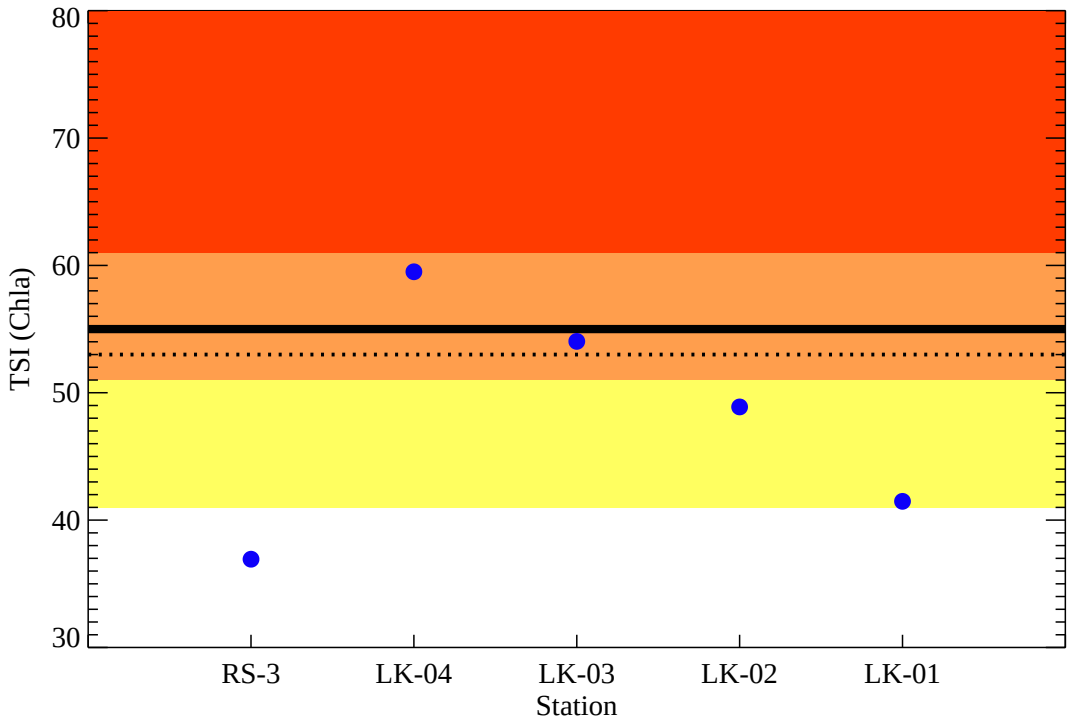

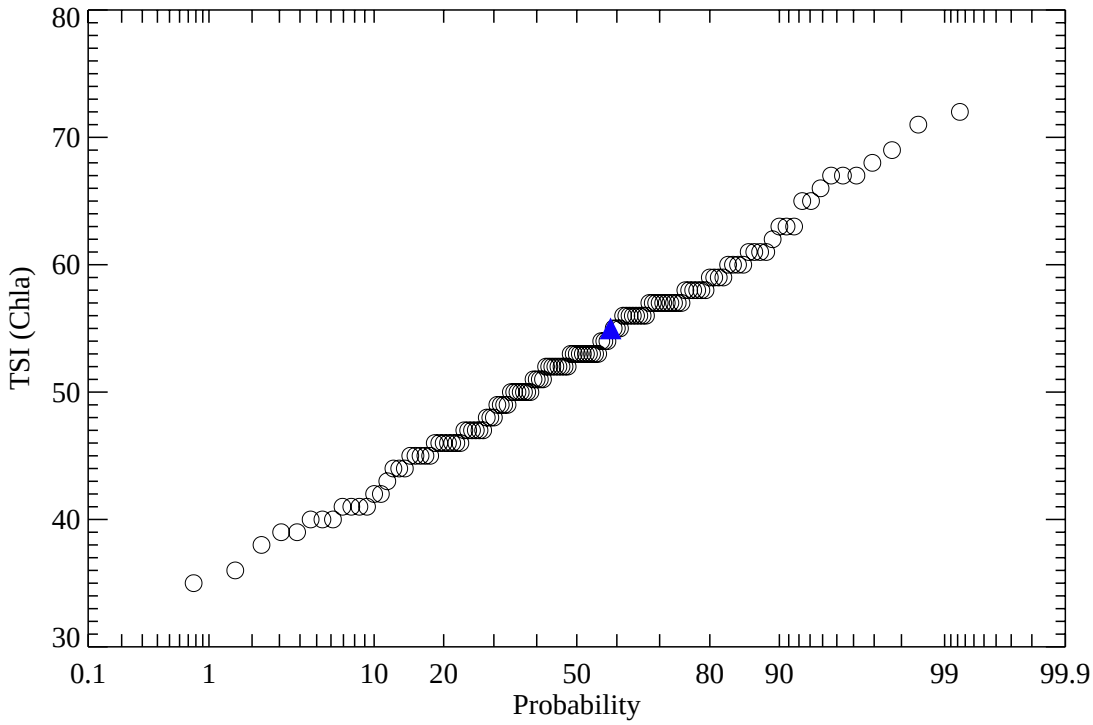

Figure 6-2. Spatial and probability distribution of summer TSI (chlorophyll-a).

Tenkiller data in the first panel comprise surface samples from summer 2006.
Points in the second panel are all BUMP TSI measurements in Oklahoma.
The blue point in the second panel represents TSI of Lake Tenkiller.
TSI = 9.81 ln Chlorophyll a (ug/L) + 30.6.
Data: OWRB - BUMP (2007), Plaintiff's Database 2004-2008.

- Mesotrophic range
- Eutrophic range
- Hypereutrophic range
- Mean BUMP TSI
- BUMP value at Tenkiller (55)

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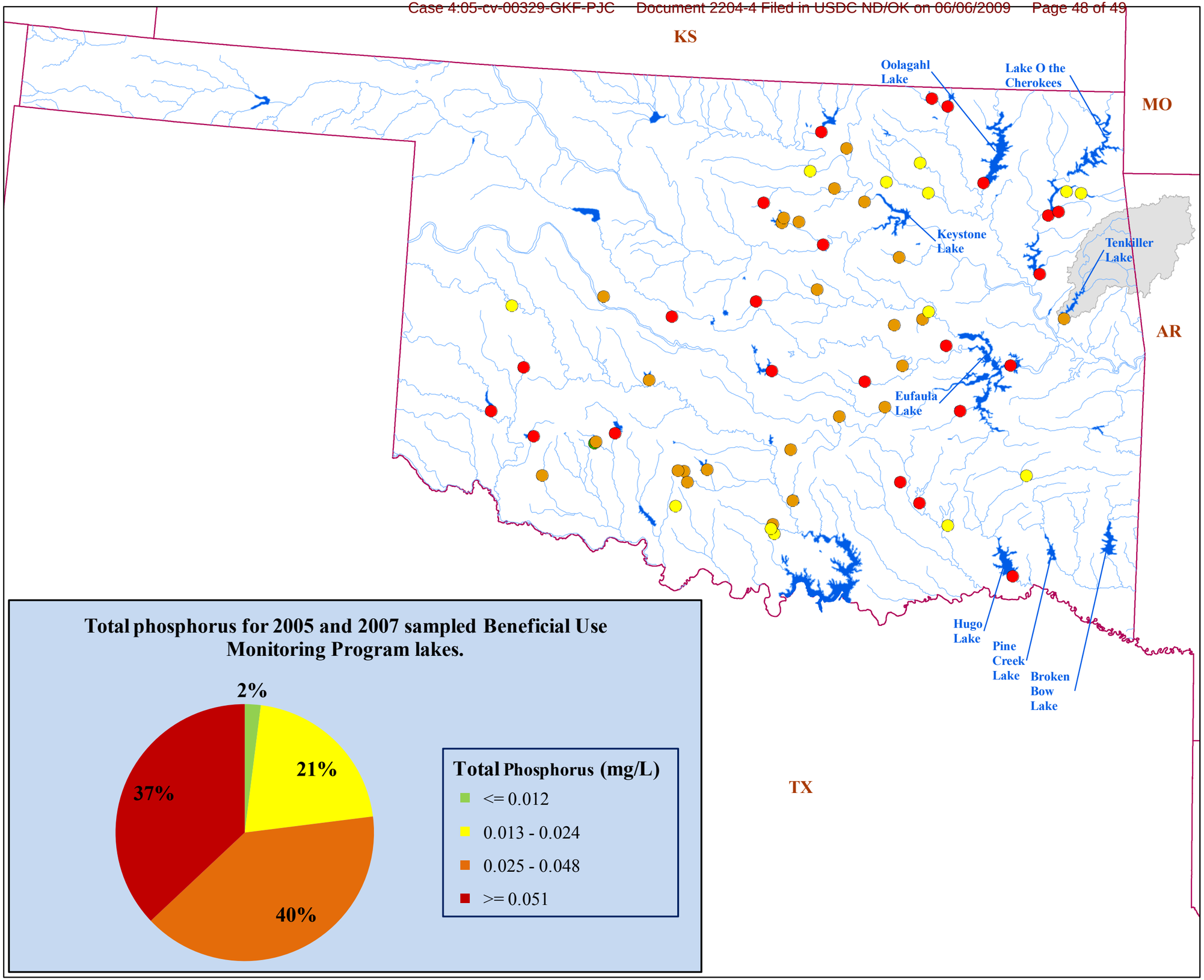
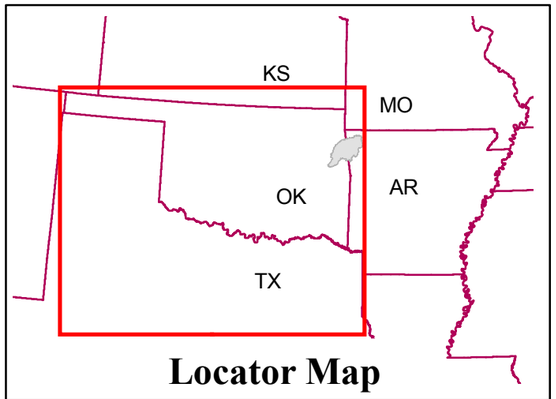
Wed Jan 21 11:45:50 2009





Legend

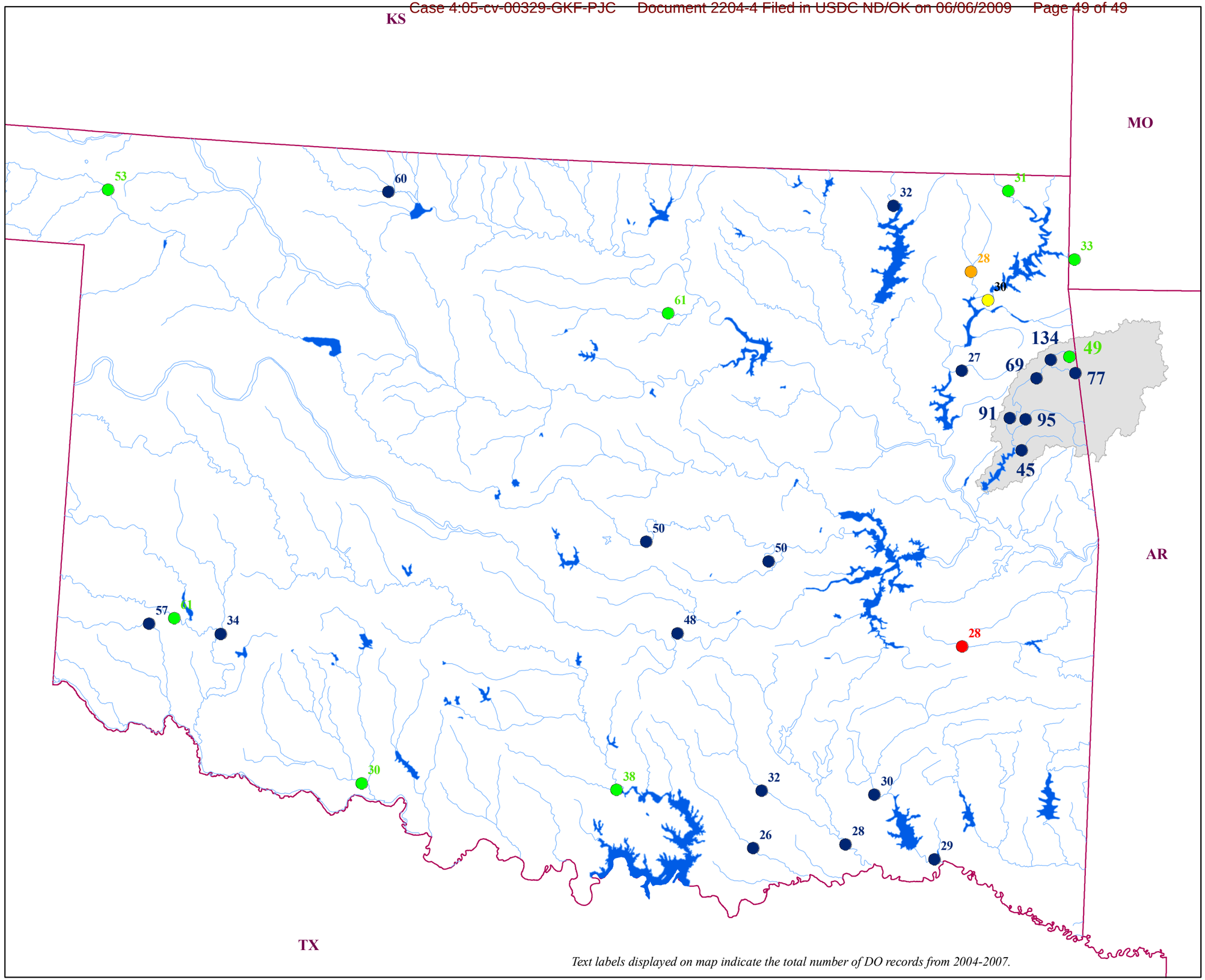
Total Phosphorus* (mg/L)

- <= 0.012
- 0.013 - 0.024
- 0.025 - 0.048
- >= 0.051
- Rivers
- Lakes
- Illinois River Watershed

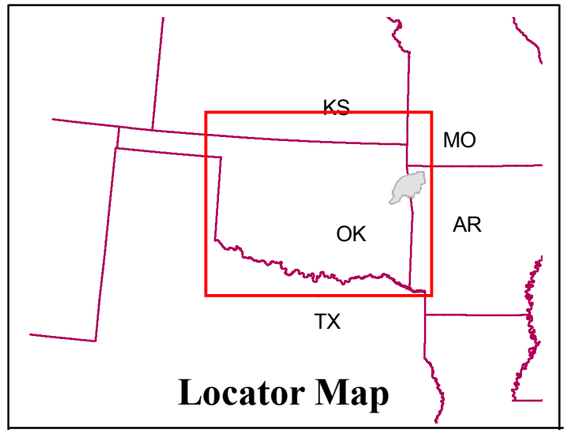
**This map was created from data in the 2005 and 2007 BUMP. The Total phosphorus (calculated from TSI values) values represent the most recent data and were taken from the Lake Monitoring and Results Discussion of the report (Table 5). Coordinates for Wayne Wallace could not be found and is not displayed on this map.*

Figure 6-3. Total phosphorus for 2005 and 2007 BUMP (OWRB) sampled lakes in Oklahoma.

OICiln:114 January 2009



Text labels displayed on map indicate the total number of DO records from 2004-2007.



Locator Map

Legend

Dissolved oxygen*

- 0 years with > 10% below screening level
- 1 year with > 10% below screening level
- 2 years with > 10% below screening level
- 3 years with > 10% below screening level
- 4 years with > 10% below screening level
- Rivers
- Lakes
- Illinois River Watershed

These values represent the number of years that a given station exceeded the standard and for streams and rivers only.

Notes:

1) This analysis is based on habitat specific DO screening levels:

a) For warm water habitat 4.0 mg/L between June 16 and October 15 and 5.0 mg/L for the rest of the year.

b) For cold water habitat 5.0 mg/L between June 16 and October 15 and 6.0 mg/L for the rest of the year.

2) Data sources: ADEQ, OWRB, USGS, Storet, Storet-Modern and Plaintiffs' data collected 2005 - 2007.

3) To assure sufficient data for determining frequency of exceedance, all sampling stations which meet the following criteria are shown:

- 8 or more DO records per year in at least 2 years from 2004-2007

- 1 or more DO records per quarter (3-month period) for at least 3 quarters each year.

Figure 6-4. Dissolved oxygen exceedances for the state of Oklahoma, 2004-2007.

QEA Quantitative Environmental Analysis, LLC

OICiln:114

January 2009