UPDATE
November 15, 2000

P. xi, lines 1-5, change to:

"...Illinois River in 1894-1899 was reported to be 3.68 mg N/l and additional large amounts of nitrogen not measured were stored in the then-luxuriant growth of aquatic (and other) vegetation and transported in copious, albeit, unmeasured amounts of organic debris. In view of the many uncertain adjustments that have to be made in comparing these historical data with recent data, we can not conclude that the Lower Illinois River was any more N rich in the 1990s than it was in the 1890s."

P.9, line 15, add:

"Travelling further up the Illinois river, Schoolcraft described the water of Lake Peoria as 'beautifully clear', the Vermilion River as 'a fine clear stream', the Au Sables River as 'pellucid', and he mentions 'small streams of clear water' in depicting the prairie environment. However, we discuss later (page 71) the difficulties in trying to interpret 19th century descriptions of clear water, which in the context of secchi depths was subjectively different from what people living in the 20th century would call clear water."

P. 29, line 1, add:

"In summary, microbiologists are acquiring a new and more life-like view of the underground. The geosphere provides waters of the deep subsurface with ingredients necessary to support life, including fixed forms of nitrogen (Chalk and Keeney, 1971; Stevenson, 1972; Power et al., 1974; Reeder and Berg, 1977; Strathouse et al., 1980; Heaton et al., 1983; Hendrey et al., 1984; Spitzy, 1988; Ranganathan, 1993; Simpkins and Parkin, 1993; Parkin and Simpkins, 1995).

"In Illinois — a Corn Belt state whose ground waters are reported to suffer from NO_3-N contamination — the average concentration of NH_4-N in ground water is greater than NO_3-N. Unlike NO_3-N, concentration of NH_4-N increases with depth and is correlated with the products of mineral weathering (Warner, 2000). Researchers in the United States and Canada have conclusively shown that uncontaminated ground waters convert reduced geologic NH_4-N to oxidized NO_3-N. In such cases values of NO_3-N range from 0.2 to 2,000 mg NO_3-N/l (Chalk and Keeney, 1971; Power et al., 1974; Reeder and Berg, 1977; Strathouse et al., 1980; Hendrey et al., 1984). Illinois State Water Survey data (Holm, 1995) suggest that it is possible that oxidation of geologic nitrogen may be responsible for pockets of >10 mg NO_3-N/l in the relatively deep ground waters of the Mahomet aquifer of Illinois.

"Sources of N in the geosphere must be taken into account when conducting N mass-balance studies."

P. 30, line 1, add:

"But this is not supported by the historic record. During the 1940s in Illinois nearly 6,000 well samples from private water supplies of all types from all sections of the state showed that 20 percent had >10 mg NO_3 N/l. In counties in central Illinois more than 40 percent had >10 mg NO_3 N/l and more than 20 percent had > 100 mg NO_3 N/l (Weart, 1948). These water supplies were reported to show no correlation with animal and/or human wastes. In 1970 Illinois State Water Survey scientists acknowledged the earlier high nitrate ground water values and added, 'the records show this happened long before commercial, nitrogen fertilizer usage became significant' (Harmeson and Larson, 1970). The standing-nitrogen-cycle paradigm cannot explain such phenomena.

"Similarly, in the Canadian Prairie Provinces >10 mg NO_3-N/l were found in up to 25% of wells tested and frequencies today are generally no higher than levels measured earlier back to the 1940s (Harker et al., 1997), e.g.

"'The same degree of contamination was reported in the 1940s, so nitrate levels may not be increasing under current agricultural practice' (Fairchild et al., 2000).

"Survey of well water around agriculture in Central Canada (Ontario) found that:

"'The share of wells with nitrate levels more than 10 milligrams per litre recorded in 1991-1992 did not differ significantly from that reported in 1950-1954. Surveys carried out between these dates indicated that about 5 to 20% of drinking water wells had levels greater than the Canadian drinking water guideline. These results suggest that agricultural activity over the past 50 years has not significantly changed the amount of nitrate added to groundwater' (Fairchild et al., 2000).

"In summary the widespread and intensive use of chemical-N fertilizers in the latter half of the 20th century appears not to have increased ground-water nitrate concentrations for much of the Canadian breadbasket."

P. 46, line 3, add:

"A review of the literature reported, 'In waterlogged soils amended with 1 % straw, or less, nitrogen fixation rates up to 150 kg ha^{-1} a^{-1} were achieved; with 5 to 20 % straw and waterlogged conditions 500 to 1000 kg ha^{-1} a^{-1} were fixed. The responsible organism was *Clostridium butyricum* and Meiklejohn (1967) also found that the number of clostridia increased considerably when approximately 678 to 1356 kg/ha of compost was added to the soil' (Stewart, 1969).

"That addition of readily-available carbohydrates to terrestrial soils also greatly increases the numbers of N-fixing bacteria, as well as other N-cycle bacteria, has been long known, as can be seen in reviews from the early 20th century (e.g., Wakesman, 1924; Pieters, 1927). Some of the N fixed will be lost to the hydrosphere and atmosphere and, therefore, amounts of N retained in aquatic and wetland sediments will be less than the amounts fixed in them."

P. 50, line 50, add:

"The flush of such fertilizing elements into the aquatic environment also stimulate the growth of vascular aquatic vegetation in whose root zones and on whose aquatic surfaces nitrogen-fixing bacteria and algae flourish (Holm et al., 1969; Stewart, 1969; Allen, 1971; Yoshida and Ancajas, 1971; Goering and Parker, 1972; Patriquin and Knowles, 1972; Head and Carpenter, 1975; Hough and Wetzel, 1975; Jones et al., 1979; Blotnick et al., 1980; Baker and Orr, 1986; DeLaune et al., 1986)."

P. 53, line 30, change to:

"...oxides of N that are lost to the atmosphere. This is shown by the review of Woodmansee and Wallach (1981) who generalize the world literature into their figure 5, which shows the enhanced gaseous-N volatilization losses that fire induces through nitrification and denitrification."

P. 53, line 48, add:

"The experiments and review of the world's literature by Anderson et al. (1988), which support the earlier review of Woodmansee and Wallach (1981), is, in turn, supported by the later review of Levine et al. (1996), who continue to report that 'burning also enhances the biogenic emissions of NO and N_2O (Anderson et al., 1988; Levine et al., 1988; Johansson, Rodhe, and Sanhueza, 1988; Levine et al., 1990).'"

P. 58, line 30, add:

"Boughey et al. (1964) found that the almost universal burning of African grasslands prior to planting of crops appears to have the benefit of destroying plant allelopathic toxins that suppress nitrifying soil bacteria."

P. 62, line 4, add:

"Additional N was probably also mobilized by urine, because urea, like NH_4-N, dissolves organic matter from soils (Kelly, 1981). Whereas organic-N was not measured in the cow urine-leaching experiments of Stout et al. (1997), Managhan and Barraclough (1993) did measure organic-C mobilized from soil in their cow urine experiments. Cow urine initially mobilized about 1,000 mg soil C/l above reference soil-water C concentration, decreasing to 300 mg C/l above reference concentration after 3 days and about 50 mg C/l above reference concentration after 13 days. Assuming a C:N ration of 10, the amounts of soil organic N solubilized by urine can be estimated."

P.72 , line 32, add:

"Palmer (1903) reports that 'The presence of chlorine in water in amounts exceeding the normal quantity generally indicates that the water has been polluted by animal matters...' For example, Palmer reports the average concentration of chlorine at Averyville, north of Peoria, to be 30.2 mg/l in 1897-1899. At Grafton, Palmer reports the average concentration of chlorine in the Illinois River in 1899-1902 to be 12.6 mg/l. For the same years, Palmer reports the average concentration of chlorine in the Mississippi River at Grafton to be 2.92 mg/l. With an average concentration of TN of 1.59 mg N/l, the Mississippi River could also be classified as eutrophic according to the trophic criteria suggested by USEPA (USEPA, 2000b), even though it had a low chlorine concentration. In comparison, Palmer reports the average concentration of TN in Lake Michigan in 1899-1900 to be about 0.4 mg N/l, which according to the trophic criteria suggested by USEPA (USEPA, 2000a) would represent oligotrophic conditions. The average concentration of chlorine in Lake Michigan was reported to be about 3.2 mg/l, about the same as in the Mississippi River and only slightly less than in the Spoon River.

"Palmer also reports an average concentration of TN in the Kankakee River at Wilmington (1896-1900) of 2.86 mg N/l. Average chlorine concentration was reported to be 2.88 mg/l. He reports that 'The organic matters contained in the waters of this stream are almost entirely of vegetable origin, for no considerable amount of sewage is discharged into it, that of Kankakee (population 13,995) about 35 miles from the mouth and 25 miles above the point of collection, being the most important.' Palmer reports that 'there is a considerable diminution in the proportions of nitrates during the warm summer months, this diminution doubtless being in part the result of growth of vegetation in the flowing waters of the stream, in part the result of assimilation of nitrates by the vegetation of the headwaters in the Kankakee marshes, which during this portion of the year constitute the chief source of supply.' 'The higher nitrates during the high water season are in part due also to the leaching of nitrates from the soil by the run-off and the discharges from the tile drains, which occur chiefly during the seasons of lower temperature and greater precipitation.' Again, this is evidence of hypertrophic conditions well before the use of artificial nitrogen fertilizer."

P. 73, delete lines 27-33: "About 0.42 mg/l...of 4.82 mg N/l."

P. 75, delete lines 5-20:

P.89, line 31 add:

"The nitrogen loads at Kampsville shown in Figure 20 are unadjusted for the weir. Palmer (1903, Appendix) reports that the quantities of organic-N in the river at Kampsville '... were in the high water season not less than six and possibly as much as twelve times as great as the quantities contained in the water of the Des Plaines at Joliet, which comprises that of the Upper Des Plaines, the Chicago Main Drainage Canal or Sanitary Canal, and the Illinois and Michigan Canal.' This range reflects the uncertainty in calculating nitrogen loads at Kampsville due to the influence of the weir on flow. Palmer recognizes that some organic-N was transformed into inorganic-N and that the river purified itself to some extent. He also reported that 'The enormous quantities of nitrates found in the water at Averyville and Kampsville during March and April, the freshet season, are in the main derived from the leaching of surface soils by the run off and the discharges of tile drains.' The great diminution in the concentration of chlorine at Averyville and Kampsville in spring is further evidence of the non-animal and non-point sources of the spring freshet waters.

"Goolsby et al. (1999) report that rates of nitrogen mineralization in soils can be greater than 40,000 kg N/km^2/yr in virgin cultivated land. They also report that this mineralization rate in virgin cultivated soils is 3-5 times higher than the mineralization rate measured beneath Illinois soybean and corn crops in recent years (David et al., 1997). However, Goolsby et al. do not relate the high mineralization rate in virgin cultivated soils to leaching and run-off in Illinois in the 19th century."

P. 105, line 44, add:

"Conversely, relying on the soil's natural humus-bearing store of nitrogen, farmers lose control over the leaching of NO_3-N. This is now becoming recognized as a possible down-side of organic farming. It is now recommended not to build up soil organic matter to the degree that it can meet corn's peak season nitrogen demand, because this much soil organic matter presents a NO_3-N leaching problem during the dormant season (e.g., Pang and Letey, 2000)."

P. 108, line 10, add:

"Overall, 'Approximately 23% of the state was wetland prior to European settlement....there are only an estimated 870,000 acres of the original 8.2 million acres of natural wetlands remaining within the state' (Illinois Department of Natural Resources, 2000)."

P. 117, line 8, add:

"Overall, the effect of draining and leveeing has reduced Illinois wetlands and its lush, N-rich vegetation from an estimated 8.2 million acres to 870,000 acres (Illinois Department of Natural Resources, 2000). The Wetlands Initiative (Wetland Matters, 1999) cites the loss of the critical nitrogen-removing capacity of wetlands as an important cause of the historical increase in nitrate concentration in the Illinois River from <1.5 mg N/l at the end of the 19th century to average concentrations >5.0 mg N/l in recent years. Kofoid (1903) reports that in the 1890s Thompson's Lake was supplied with water mainly from the Illinois River, but had an average concentration of total nitrogen about 1.5 mg N/l less than the Illinois River. This could be an indication of assimilation, denitrification, and burial of N in this backwater lake. The Wetlands Initiative reports that restoring only 407,000 acres of wetlands in Illinois (about 5% of the 1780 wetlands), primarily on flood prone bottomland throughout the watershed, would remove 101,000 tons (80%) of today's nitrate load from the Illinois River."

"Assuming that all 2 million acres of wetland drained in the entire MRB in 1900 were drained exclusively in Illinois, this would leave 6.2 million acres of wetland to take up and transform soluble N from the drainage of the remaining 28.8 million acres of land in Illinois. Given that the concentration of TN in the lower Illinois River was about 24 percent less in the 1890ss than the 1990s, and assuming this 24 percent difference holds for flux of TN in Illinois' surface waters — now estimated at about 0.5 billion lbs/yr (David and Gentry, 2000a, b) — then these wetlands would have to be transforming only 4.1 lb N/acre/yr (4.6 Kg N/ha/yr) from the non-wetland areas to account for the difference between amounts of N in solution in the 1890s versus the 1990s. Put another way, the 6.2 million acres of wetlands would needed to have transformed only 19.1 lb N per acre (21.4 kg N/ha/yr) of wetland to produce a lush 6.2 million acre crop of N-rich aquatic and wetland vegetation every year to account for the difference in total N in solution between 1890s and 1990s surface water."

P.121, line 43 add :

"David et al. (1997) is reported to be one of only a few detailed studies 'to have linked field N budgets, NO_3^- loss in tile drained watersheds and surface water NO_3^- loads' (David et al., 1997) The study characterizes the tile-drained portions of east-central Illinois and the Upper Embarras watershed as homogeneous. From this David et al. apply field nitrogen budgets and averaged NO_3^- losses in two tile-drained watersheds draining into the Embarras River to determine, among other things, how much of the Embarras NO_3^- came from these heavily fertilized fields. The data show that the nitrate yield from the watershed that received almost 50% more fertilizer than the other watershed had a nitrate yield about 25 % less. David et al. also report that 'Even if fertilization were reduced or eliminated, the overall disturbance from agricultural production in the Embarras River watershed would still lead to high NO_3^- concentrations and export, depending on the timing of precipitation events.'

"Porter (2000), in a study of algal and macroinvertebrate responses to nonpoint source pollution relative to natural factors in the Corn Belt in 1997, concludes that 'Nutrient concentrations and the abundance of algae during low-flow conditions were not related directly to rates of fertilizer application or the number of livestock in Midwestern stream basins; however, rates of stream metabolism (P_{max} and R_{max}) increased significantly with indicators of agricultural intensity.' Porter finds that algal-nutrient relations were more of a function of landscape characteristics, hydrology, and rainfall-runoff characteristics than agricultural land use, which is relatively homogeneous throughout the region. Porter recommends that 'Improved understanding of natural factors and algal-nutrient relations that contribute to chemical and biological indicators of eutrophication in lotic systems could enhance the development of water quality criteria within and among ecoregions in the U.S. (e.g., Level III; Omernik 1986).' "

P.127, lines 34-37, delete:

"Concentration of measured TN.....before declining." Replace with:

"The concentration of TN at Havana was reported to be 3.68 mg N/l in the 1890s (Table 11), a period of drought. Although there are few measurements of TN in the Lower Illinois River in more recent years, the concentration of TN can be estimated. The concentration of TN in Peoria Lake in March-October 1967 is reported by Evans and Wang (1970) to be 8.85 mg N/l: nitrate-N was 4.33, ammonia-N 1.15, and organic-N was 3.37 mg N/l. The concentrations of ammonia-N at Havana and Meredosia in 1967-1971 were 1.39 and 1.0 mg N/l respectively (Healy and Toler, 1978). [Note the ammonia-N value reported by Harmeson et al. (1973) for Meredosia using a different method of chemical analysis was 0.57 mg N/l.] These values decrease to 0.49 and 0.28 mg N/l in 1972-1974 (Healy and Toler, 1978). The concentration of TN at Valley City in 1975-1982, according to data in STORET, was 5.50 mg N/l: ammonia-N 0.41, organic-N 1.21, and NO_2+NO_3-N 3.98 mg N/l. The concentration of TN at La Grange in 1993-1998 using grab samples was 4.82 mg N/l: ammonia-N 0.16, organic-N 0.89, and NO_2-N+NO_3-N 3.77 mg N/l (USGS, La Crosse, WI, 1999).

"Using these data and the measured 1967-1971 NO_3-N concentration of 6.2 mg N/l at Meredosia (Harmeson et al., 1973), we estimate the concentration of TN at Meredosia in 1967-

1971 to have been about 9.5 mg N/l: ammonia-N 1.0, organic-N 2.2, and NO_2+NO_3-N 6.3 mg N/l.

“Valley City (river mile 60) is downstream from Havana (river mile 120) and Meredosia (river mile 71). As N concentration can decreases downstream, possible adjustments need to be made when comparing Havana and Valley City data. Average concentration of TN at Havana in 1897-1899 was 3.3 mg N/l and at Kampsville (river mile 32) 2.6 mg N/l (Palmer, 1903). Given these limited data, it is not possible to provide a precise adjustment for TN concentrations. Perhaps an upward adjustment of the Valley City TN data of ~0.4 mg N/l is reasonable when comparing them with Havana data.

“However, there seems to be little difference in NO_3-N concentrations along the lower Illinois River. In 1897-1900 the concentration of NO_3-N at Havana was 1.20 mg N/l and at Kampsville 1.17 mg N/l. Average concentration of NO_3-N at Meredosia in 1975-1976 was 4.3 mg N/l and at Valley City 4.2 mg N/l (STORET). In 1990-998 the average concentration of NO_3-N at Havana was 4.36 mg N/l and at Valley City 4.40 mg N/l.

“Returning to the difference in climatic conditions between the 1890s and the 1990s, we must adjust the Havana data in order to compare them with the recent Valley City and La Grange data. Average annual state-wide precipitation in 1894-1899 was 35.5 in and in 1993-1998 it was 41.4 in (personal communication, Jim Angel, ISWS, September 22, 2000). There were also differences in the seasonal distribution of precipitation: in 1894-1899 average April-June precipitation was 10.6 in, and in 1993-1998 it was 15.1 in. In recent decades, higher rainfall generally has been associated with higher concentrations of TN in the MRB (Goolsby et al., 1999). However, we do not have an extensive data base to determine the relationships between climatic and landscape conditions in the 19th century and precipitation-runoff-TN concentrations.

“In 1921-1922, the concentration of TN near Pearl (river mile 43) was reported to be 2.85 mg N/l (Hoskins et al., 1927), although the representativeness of the 13-month sample is unknown. Hoskins concludes that ‘.. in 1921 the total volume of pollution contributed by Chicago to the Illinois River was about two and three-fourths times as great as the amount added just prior to the opening of the main drainage canal, and that since the opening of the canal in 1900 this pollution has just about doubled in total volume. However, the amounts of diluting water withdrawn from Lake Michigan have been gradually increased during this interval, so that the net effect has been to actually reduce rather than to increase the total nitrogen and oxygen consumed content as measured in terms of concentration.’

“The concentrations of TN in the Kankakee and Spoon Rivers in 1921-1922 were reported by Hoskins et al. to be 3.30 and 3.54 mg-N-l respectively. These values are higher than the values of 2.86 mg N/l reported by Palmer (1903) for the Kankakee and 2.59 mg N/l reported by Kofoid (1903) for the Spoon in 1896-1900.

“The Hoskins et al. data also show a very marked seasonal cycle in the concentration of both TN and NO_2+NO_3-N in the major tributaries to the Illinois River. The concentrations of TN in the Kankakee, Des Plaines, Fox, Vermilion, Mackinaw, and Spoon Rivers in 1921-1922 peaked in December and the monthly average in these tributaries was 6.7 mg N/l. The concentration of

TN in all these rivers was lowest in summer (June-August) and averaged 1.54 mg N/l in the lowest months. The concentration of NO_2+NO_3-N in these rivers peaked in December and averaged 5.14 mg N/l. The concentration of NO_2+NO_3-N in all these rivers was lowest in August and averaged 0.05 mg N/l. The amplitude of the seasonal cycle of NO_2+NO_3-N in these tributaries in 1921-1922 was thus considerably greater than the average amplitude for NO_2+NO_3-N in all Illinois rivers in 1996, as shown in Figure 15.

"Hoskins et al. data also show a pronounced seasonal variation of TN and NO_3+NO_2-N concentrations in the Lower Illinois River. At river mile 26, the monthly concentration of TN peaked at 5.3 mg N/l in January and reached a monthly minimum of 1.23 mg N/l in June. The monthly concentration of NO_2+NO_3-N peaked at 3.20 mg N/l in December and reached a monthly minimum of 0.70 mg N/l in June.

"The average monthly concentration of TN in the above six tributaries for the 12 months August 1921-July 1922 was 3.6 mg N/l, which was about 23 % higher than the concentration in the Illinois River at river mile 26.

"Yet other adjustments must be made when comparing TN concentrations in the 1890s and 1990s. Extensive areas of wetlands and aquatic vegetation that existed in the Illinois River Basin in the 1890s no longer exist. As wetlands and aquatic vegetation generally reduce the measured concentration of TN in rivers, the concentration of TN at Havana in the1890s needs to be adjusted upwards when comparing it with the measured concentrations in the Lower Illinois River in the 1990s. Goolsby et al., 1999 (p.70), for example, report that 'Nitrogen transported in particles larger than about 2 millimeters escape collection in water samples and thus is not measured and is not included in the yield estimates.'

"Further complicating the comparison of historical N data over time are the different sampling protocols and analytical techniques that have been used, the construction of levees, and other factors.

"The reported concentration of TN at Havana in 1894-1899 was 3.7 mg N/l and at La Grange in 1993-1998 it was 4.8 mg N/l. In view of the uncertain adjustments that have to be made in comparing these historical data with recent data, we can not conclude that the Lower Illinois River was any more N rich in the 1990s than it was in the 1890s.

P. 131, replace Figure 30 with the revised Figure 30 (page 9 of Update)..

P. 133, lines 29-30, delete "- flow and methods ..... 5.5 mg N/l" and add:

"In view of the many uncertain adjustments that have to be made in comparing these historical data with recent data, we can not conclude that the Lower Illinois River was any more N rich in the 1990s than it was in the 1890s."

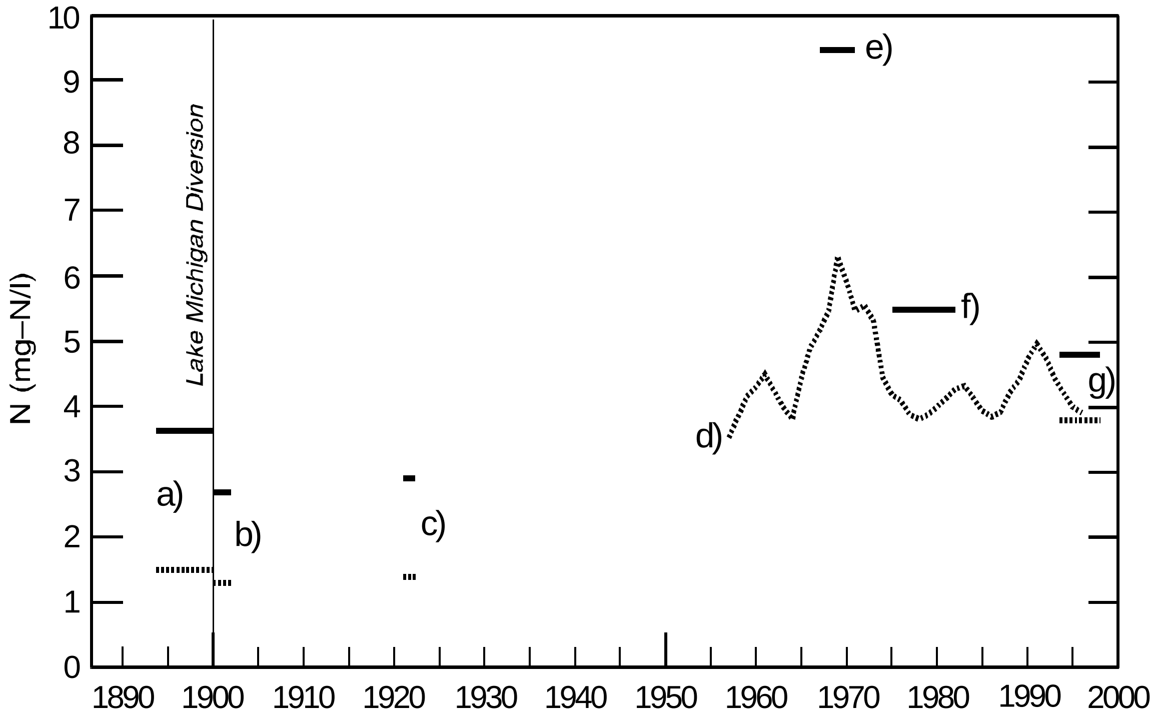

Figure 30. Concentration of nitrogen in the Lower Illinois River, 1894-1998.

TN (ammonia-N+organic-N+NO_2-N+NO_3-N) is shown with solid lines.
NO_2-N+NO_3-N is shown with dashed lines.

a) Havana, 1894-1899 (Kofoid, 1903 and Palmer, 1903).
b) Havana, 1900 and Kampsville, 1900-1902 (Palmer, 1903).
c) River mile 43, 1921-1922 (Hoskins et al., 1927).
d) Meredosia, 1955-1971 (Harmeson and Larson, 1969; Harmeson and Larson, 1970; Harmeson et al., 1973), 1971-1976 (STORET); Valley City 1975-1998 (STORET) - 5-year moving averages 1957-1996.
e) Meredosia 1967-1971 NO_3-N concentration of 6.2 mg N/l at Meredosia (Harmeson et al., 1973), plus 1.0 mg/l ammonia-N (Healy and Toler, 1978), plus estimates of 0.1 mg/l NO_2-N, and 2.2 mg N/l organic-N (see text).
f) Valley City, 1975-1982 (STORET).
g) La Grange, 1993-1998 (USGS, LTRMP, La Crosse, WI, 1999).

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