U.S. Geological Survey
Mail Stop 406, DFC
Lakewood, CO 80225
December 16, 1999

Gulf of Mexico Hypoxia Working Group
National Atmospheric and Oceanic Administration
National Centers for Coastal Ocean Science
Room 9127, East West Highway
Silver Spring, MD 20910

Colleagues:

The following material is being submitted in response to public comments suggesting that total nitrogen concentrations in the lower Mississippi River were higher at the beginning of this century than they are today. This response is based largely on published data presented in reports by Palmer (ca. 1903), Leighton (1907), Dole et al.(1909), Goolsby et al (1999), Howarth et al. (1996, 1998), and Maybeck (1982).

To provide a basis for determining long-term changes in nitrogen concentrations in the Mississippi Basin, an estimate of mean nitrogen concentrations in the basin before European settlement ("pristine" conditions) was developed for all major nitrogen species. This estimate is given in table 1 at the end of this document. The mean dissolved inorganic nitrogen (DIN) concentration, nitrate + nitrite + ammonium, was estimated to be about 0.115 mg/L, and the mean total dissolved nitrogen (organic + DIN) was estimated to be 0.375 mg/L (Maybeck, 1982). From these estimates the mean dissolved organic nitrogen (DON) was calculated to be about 0.26 mg/L. Particulate organic nitrogen (PON) concentration was calculated from the pre-development annual sediment flux from the Mississippi-Atchafalaya Basin to the Gulf (400 million metric tons per year; Meade, 1995), the estimated N content of the sediment (0.15%), and a mean annual streamflow of 21,990 cubic meters per second (table 2.2 in Goolsby et al., 1999). From this calculation, the PON concentration was estimated to be 0.86 mg/L. The pre-development total nitrogen (TN) concentration was then calculated from the sum of the DIN + DON + PON to be 1.24 mg/L. Other TN estimates from the literature range from 0.79 to 1.15 mg/L (see table 1). Thus, our TN estimate of 1.24 mg/l may be a little high.

Published data were used to develop estimates of mean annual concentrations of all major nitrogen species during the period 1897-1906 for 4 locations in the Mississippi Basin. The locations are 1) the Lower Illinois River, 2) Mississippi River near Grafton, IL (below Illinois River and above Missouri River), 3) Lower Missouri River, and 4) Lower Mississippi River. These estimates, based on data published in Palmer (ca. 1903), Leighton (1907), and Dole, (1909), are shown in table 2. Mean nitrogen concentrations at these 4 sites for 1980-98 (Goolsby, et al., 1999) are also shown in table 2 for comparison.

The concentrations of DIN, DON, and PON are shown in graphic form in figures 1-4 for the four locations. Estimates are shown for three periods in the history of the basin– pristine, 1897-1906, and the present (1980-98).

Results presented in tables 1-2 and figures 1-4 show that concentrations of total nitrogen

increased significantly at 3 of the 4 sites during the past 100 years. Essentially all of the increase can be attributed to nitrate, which has increased 2 to more than 5 fold. The exception to this is the lower Missouri River where total N decreased slightly, even though the DIN concentration more than doubled. All of the decrease in total N in the Missouri River can be attributed to a large reduction in the suspended sediment and PON flux from the Missouri Basin. Sediment discharge from the Missouri River has decreased more than 50% since the 1950s due to construction of several large reservoirs. The reservoirs trap large amounts of sediment and particulate forms of nitrogen (PON) and other nutrients. The sediment flux from the Mississippi Basin to the Gulf of Mexico has also decreased by about 50% since the 1950s (Meade, 1995). As a result, the PON flux to the Gulf has also decreased by about 50%.

In summary, we found no data that would indicate the total nitrogen flux to the Gulf was higher in the past than it is at the present time. PON flux to the Gulf was higher before construction of the Missouri River reservoirs than it is today. However, the decrease in PON flux has been more than offset by an increase in nitrate and DIN flux.

References

Clark, G.M., Mueller, D.K., and Mast, M.A., in press, Concentrations and yields of nitrogen and phosphorus in streams draining relatively undeveloped basins of the United States, 1990-95, Jour. Am. Water Res. Assoc.

Dole, R.B. 1909. The quality of surface waters in the United States: Part I. -- Analysis of waters east of the one hundredth meridian. U.S. Geological Survey Water-Supply Paper 236. Washington, DC: Government Printing Office. 123 p.

Goolsby, D.A., Battaglin, W.A., Lawrence, G.B., Artz, R.S., Aulenbach, B.T., Hooper, R.P., Keeney, D.R., and Stensland, G.J., 1999. Flux and Sources of Nutrients in the Mississippi-Atchafalaya River Basin: Topic 3 Report for the integrated Assessment on Hypoxia in the Gulf of Mexico. NOAA Coastal Ocean Program Decision Analysis Series No. 17. NOAA Coastal Ocean Office, Silver Spring, MD, 129 p. Also available at URL: http://wwwrcolka.cr.usgs.gov/midconherb/hypoxia.html

Howarth, R.W., G. Billen, D. Swaney, A. Townsend, N. Jaworski, K. Lajtha, J.A. Downing, R. Elmgren, N Caraco, T. Jordan, F. Berendse, J. Freney, V. Kudeyarov, P. Murdoch, and Z. Zhao-Liang. 1996. Regional nitrogen budgets and riverine N & P fluxes for the drainages to the North Atlantic Ocean: Natural and human influences. Biogeochemistry 35:75-139.

Howarth, R.W. 1998. An assessment of human influences on fluxes of nitrogen from the terrestrial landscape to the estuaries and continental shelves of the North Atlantic Ocean. Nutrient Cycling in Agroecosystems p. 213-223.

Leighton, M.O., 1907, Pollution of the Illinois River by Chicago Sewage, U.S. Geological Survey WSP 194, 369 p. (this report cites data presented in the Palmer report and other sources).

Lewis, W.M., 1986, Nitrogen and phosphorus runoff losses from nutrient-poor tropical forest. Ecology v67, p1275-1282.

Maybeck, Michael, 1982, Carbon, Nitrogen, and Phosphorus Transport by World Rivers. American Journal of Science, v282, April, 1982, p 401-500.

Meade, R.H. 1995. Contaminants in the Mississippi River. U.S. Geological Survey Circular 1133. 140 p.

Palmer, Arthur W., ca. 1903, Chemical Survey of the Waters of Illinois: Report for the years 1897-1902, University of Illinois, 254 p.

Donald A Goolsby

Don Goolsby
U.S. Geological Survey

Table 1. – Estimates of Nitrogen Concentrations in the Mississippi River Basin prior to European Settlement (Pristine conditions).

Nitrogen species	mg/L	Reference of source
Nitrate	0.10	Maybeck (1982). Ave. for unpolluted major world rivers
	0.09	Clark, et al., (in press) median for 82 relatively undeveloped U.S. watersheds
Ammonium	0.015	Maybeck (1982)
Dissolved inorganic N	0.115	Calculated from Maybeck (1982)
Total dissolved N	0.375	Maybeck (1982)
Dissolved organic N	0.26	Calculated (from Maybeck, 1982)
Particulate organic N	0.86	Calculated from estimated pre-development sediment flux of 400 x 10^6 t/y (Meade, 1995); N content of sediment of 0.15%; 1980-96 mean annual streamflow of 21,990 m^3/s.
Total organic N	1.12	Calculated from dissolved and particulate organic N
Total N	1.24	Calculated from total dissolved N and particulate organic N
Other estimates of total N	0.93	Howarth et al., 1996 (from Maybeck 1982)
	0.08-1.15	Howarth et al., 1996 (from Lewis, 1986)
	0.79	Howarth et al., (1998) for mean discharge=17,313 m^3/s; basin area=3.23 x 10^6 km^2
	0.26	Clark, et al. (in press); small watersheds throughout the United States

Table 2. - Historical and Recent Data on Nitrogen Concentrations in the Mississippi River Basin (Results in milligrams per liter as N).

Location	Number of Samples	Organic N			Inorganic N			Total N[2]
		Total	DON[1]	PON[1]	Nitrate-N	NH_4-N	DIN	
Lower Illinois River								
1897-1902	weekly	1.01	0.59	0.42	1.25	0.38	1.63	2.64
1980-98	189	1.22	0.45	0.60	4.09	0.14	4.23	5.46
Upper Mississippi River near Grafton (below Illinois R. & above Missouri R.)								
1899-1900	70	1.10	0.48	0.62	0.59	0.13	0.72	1.82
1980-98	120	1.27	0.81	0.63	2.63	0.11	2.74	4.01
Lower Missouri River								
1899-1900	63	1.83	0.30	1.53	0.51	0.06	0.57	2.40
1980-98	186	1.03	0.51	0.69	1.23	0.05	1.28	2.24
Lower Mississippi								
1905-06	52	1.16[a]	0.40[b]	0.76[c]	0.56	0.1[d]	0.66	1.82
1980-98	104	0.92	0.52	0.38	1.45	0.06	1.51	2.40

[1]DON and PON not analyzed on all samples in 1980-98, thus DON + PON does not equal total organic N for this time period.

[2]Total N calculated as the sum of total organic N + DIN.

[a]Calculated as the sum of DON + PON.

[b]Estimated from DON concentrations in upper Mississippi River and Lower Missouri River.

[c]Estimated as 2 times the average 1980-98 PON concentration.

[d]Estimated from NH_4 concentrations in the upper Mississippi and Lower Missouri River.

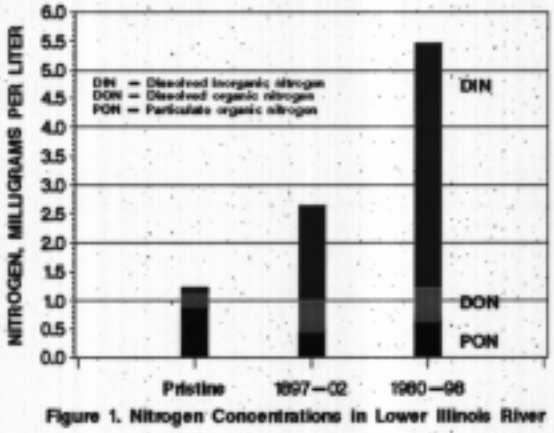

Figure 1. Nitrogen Concentrations in Lower Illinois River

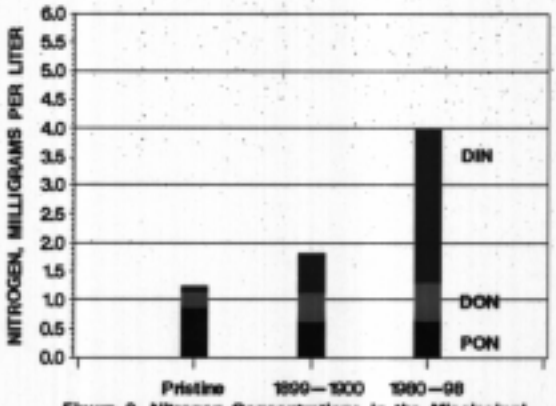

Figure 2. Nitrogen Concentrations in the Mississippi River near Grafton Illinois

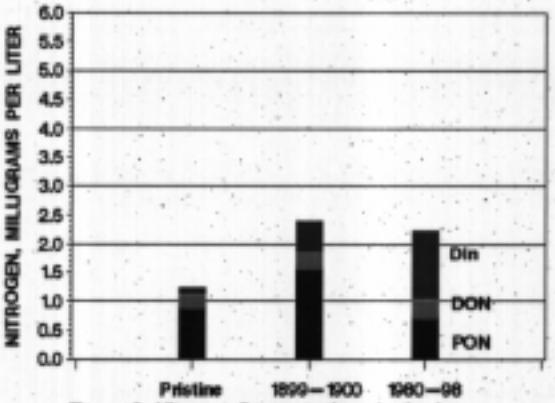

Figure 3. Nitrogen Concentrations in the Lower Missouri River

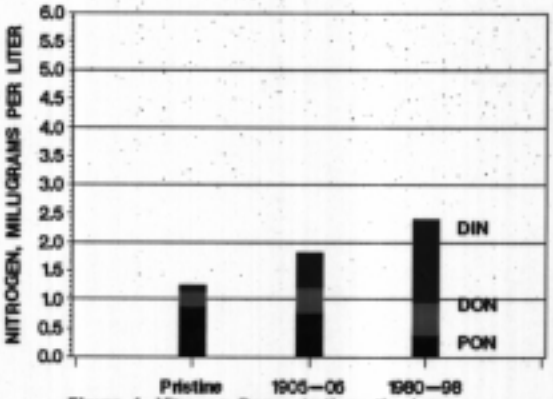

Figure 4. Nitrogen Concentrations the Lower Mississippi River