

REPORT ON DIFFERENCES IN GREAT LAKES PHOSPHORUS LOAD ESTIMATES

by

Walter Rast
International Joint Commission
Great Lakes Regional Office
Windsor, Ontario

and

Dennis J. Gregor
National Water Research Institute
Canada Center for Inland Waters
Burlington, Ontario

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DISCLAIMER

The study discussed in this document was carried out as part of the efforts of the Pollution from Land Use Activities Reference Group (PLUARG), an organization of the International Joint Commission, established under the Canada-United States Great Lakes Water Quality Agreement of 1972. Findings and conclusions are those of the authors and do not necessarily reflect the views of the Reference Group or its recommendations to the Commission.

SUMMARY

A review of the 1976 Great Lakes phosphorus load estimates developed by the Pollution From Land Use Activities Reference Group (PLUARG), the Water Quality Board (WQB) and Task Group III (TG) (the bilateral technical group which developed phosphorus Target Loads for the Great Lakes as part of the Fifth Year Review of the United States - Canadian Water Quality Agreement) was conducted. The load estimates were examined to determine the sources of differences between estimates and, where possible, to explain the reasons for the differences. A summary of the sources of information used by the three groups to develop the 1976 phosphorus load estimates is presented in the following table:

INFORMATION SOURCES USED TO DEVELOP 1976 PHOSPHORUS LOAD ESTIMATES

I. Direct Municipal and Industrial Loads:

- A) PLUARG - information taken principally from the Water Quality Board, as modified by PLUARG.
- B) Water Quality Board - information prepared by the Remedial Programs Subcommittee; derived principally from data submitted by states and province.
- C) Task Group III - information taken principally from the Water Quality Board, as modified by Task Group III, principally Saginaw Bay (U.S. EPA data) and Lake Erie (U.S. Army Corps of Engineers Lake Erie Wastewater Management Study data).

II. Tributary (Monitored and Unmonitored):

- A) PLUARG - U.S. data based on PLUARG U.S. tributary loading studies, except for Lake Erie (U.S. Army Corps of Engineers Lake Erie Wastewater Management Study data); Canadian data for monitored tributaries provided by Ontario Ministry of Environment, while data for unmonitored tributaries taken from the Water Quality Board.
- B) Water Quality Board - information prepared by the Surveillance Subcommittee; derived principally from data submitted by states and province.
- C) Task Group III - information taken principally from the Water Quality Board, as modified by Task Group III, principally Saginaw Bay (U.S. EPA data) and Lake Erie (U.S. Army Corps of Engineers Lake Erie Wastewater Management Study data).

III. Atmospheric Loads:

- A) PLUARG - data based on PLUARG atmospheric studies.
- B) Water Quality Board - information prepared by the Surveillance Subcommittee; data based on Canadian studies generalized to entire Great Lakes Basin, except for Lake Michigan (study conducted for the U.S. EPA),
- C) Task Group III - information taken from the Water Quality Board.

IV. Upstream Lake Loads:

- A) PLUARG - information for Lakes Huron and Erie taken from the Water Quality Board; data for Lake Ontario based on Environment Canada Niagara River mouth studies.
- B) Water Quality Board - information for Lakes Huron and Erie taken from the Upper Lakes Reference Group; data for Lake Ontario taken from 1974 Hydrosience report to the Water Quality Board.
- C) Task Group III - information taken from Water Quality Board.

The major observations concerning the phosphorus load estimates of the three groups are highlighted in the following paragraphs.

There is little difference between the WQB and TG Lake Superior load estimates. The higher PLUARG load is due principally to a higher (but likely more accurate) atmospheric estimate.

The WQB and TG Lake Michigan estimates are similar. The lower PLUARG load is due primarily to a lower (but likely more accurate) tributary load estimate.

The PLUARG and WQB load estimates for Lake Huron are comparable. The lower TG load is accounted for principally by a lower tributary load estimate.

The phosphorus load estimates show the greatest differences for Lake Erie. The TG estimate is highest and the WQB estimate lowest, with the PLUARG load approximately midway between these two estimates. The main difference between the PLUARG and TG loads is due primarily to the U.S. direct municipal estimate, while that between the PLUARG and WQB loads is due principally to the tributary estimate. The PLUARG atmospheric load is lower than the identical WQB and TG value. The TG load is likely the more accurate of the three estimates for Lake Erie.

There is little difference between the WQB and TG Lake Ontario load estimates. The lower PLUARG estimate is due mainly to a lower (but likely more accurate) upstream lake load estimate from Lake Erie to Lake Ontario.

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I. INTRODUCTION

Pollution from Land Use Activities Reference Group (PLUARG) has presented 1976 phosphorus load estimates for the Great Lakes which are different than those reported by the Water Quality Board (WQB) and Task Group III (TG) (Task Group III was the bilateral technical group which developed proposed phosphorus Target Loads for the Great Lakes as part of the Fifth Year Review of the Water Quality Agreement). As a result, the phosphorus load estimates of PLUARG and these two groups have been re-examined to determine the sources of these differences and, where possible, to explain why these differences exist. The following material represents a summary of this evaluation.

This material was prepared for distribution to the IJC, PLUARG members, the WQB, the RAB and the RAB's Phosphorus Management Strategies Task Force, as well as other interested individuals or agencies, for their information and consideration.

It should be noted that the Great Lakes Basin Commission and Canada Centre for Inland Waters are independently compiling and analyzing in detail loadings data for portions of the basin. These two ongoing activities, not yet completed, are not included in this evaluation.

The Great Lakes 1976 phosphorus loads as reported by PLUARG¹, WQB² and TG³ are presented by country in Tables 1a-e. They are subdivided into classes as follows:(1) direct municipal-sewage treatment plants draining directly into the lakes; (2) direct industrial-industrial plants draining directly into lakes; (3) tributary total load--calculated loads at tributary mouth (includes diffuse sources as well as municipal and industrial sources draining to Great Lakes tributaries); (4) atmospheric--dry fallout and rainfall directly onto the lake surface; (5) other--urban diffuse draining directly into the lakes; (6) upstream lakes--interconnecting channel loads from upstream lakes (for Lakes Huron, Erie and Ontario); and (7) total load--sum of direct municipal and industrial, tributary total, atmospheric, urban direct and, where appropriate, upstream lake load. It is noted that PLUARG and other studies have established that phosphorus from shoreline erosion consists of chemical forms essentially unavailable for use by algae. Thus, while shoreline erosion may produce aesthetic problems by increasing turbidity in some nearshore areas (e.g., "red clay" area of U.S. Lake Superior shoreline) and can cause fish-related problems by siltation of fish spawning grounds and clogging of fish gills, etc., phosphorus from this source will have a negligible effect, relative to other sources, on trophic conditions in the Great Lakes. Consequently, phosphorus inputs from shoreline erosion were not included in the total load estimates presented in this report. Groundwater inputs of phosphorus were also not included in the loading estimates, since the magnitude of the input from this source is virtually unknown.

Tables 2a-e present the relative differences in the 1976 WQB and TG loads as compared to the PLUARG loads. For each lake, and by country, the absolute differences in the load estimates from the various point and nonpoint sources, relative to the PLUARG loads, are presented. For example, in Table 2a, the direct municipal value of +7 under the U.S. column for Task Group III indicates that the Task Group III estimate for the U.S. direct municipal input is 7 metric tons greater than PLUARG's estimate (the actual load from this source is presented in Table 1a). Tables 2a-e also present, for each source, the differences in percentages of the WQB and TG loads relative to the PLUARG loads. Thus, in Table 2a, the Task Group III direct municipal value of +18 in parentheses under the U.S. column indicates the Task Group III U.S. value is 18 percent greater than PLUARG's estimate for this source. Although interesting, these percentage values are less informative than the absolute phosphorus load differences because for this analysis it is more important to know by how many metric tons the WQB and TG estimates differ from the PLUARG estimates. For example, a 40 percent difference in a 50 metric ton estimate is many-fold less than a 10 percent difference in a 3000 metric ton load; although a smaller percentage difference, in absolute terms the latter value is clearly of greater significance relative to the total load because of its much greater magnitude. It is also noted that the word "significant" is used throughout this report to indicate that the magnitude of one number is either very large or very small compared to another number. It is not meant to connote a statistical significance.

In order to allow easier evaluation and comparison, the loads in Tables 1a-e have also been expressed graphically in Figures 1a-e.

The loading estimates presented by these three groups are based on the best data available to the groups at the time they prepared their estimates. Consequently, it must be kept in mind that these loading estimates are only as accurate as the data used to develop them. There are many potential sources of error in the collection of field data for calculation of phosphorus loads to the Great Lakes. It is unlikely, for example, that one can calculate an accurate tributary load if the sampling regime missed critical runoff events. PLUARG studies indicated that phosphorus concentrations in some tributaries varied dramatically ("event response" streams) as a function of runoff events, while concentrations in other tributaries remained fairly constant ("stable response" streams) during such events. Obviously, the phosphorus load calculated in the event response stream would be subject to much more variability than the loads in the stable response streams, if the sampling frequency in the former were not adjusted to consider precipitation and resultant runoff events.

One additional factor to be remembered is that the load estimates presented below are for the year 1976. The relative distribution of point versus nonpoint sources, as well as the total load estimates, can vary naturally from year to year and from one lake basin to the other. Consequently, the reader is advised to keep the differences in the load estimates between the three groups in perspective. A 100 metric ton difference between groups for Lake Huron, for example, amounts to

only about two percent of the total load estimated for this lake. Consequently, in an overall sense, such a difference would not be of any major significance relative to Great Lakes phosphorus management strategies. It should also be noted that many identical or nearly identical numbers in the following analysis reflect a common data base, rather than three independent similar load estimates of the same phosphorus source.

A final point to be made is that all discussions of phosphorus in this report refer to total phosphorus. There is a great deal of difficulty in determining the biological availability of phosphorus from different sources and in different chemical forms for use by algae. Further, PLUARG, the WQB and TG only reported total phosphorus loads. With further understanding of phosphorus dynamics in lake systems, it is likely that meaningful distinctions will be made in the future concerning available and unavailable components of the phosphorus loads to water bodies. However, for the purposes of this analysis, it is only possible to consider the total phosphorus loads.

II. PHOSPHORUS LOADS BY LAKE (TABLES 1a-e and Figures 1a-e):

- 1) LAKE SUPERIOR (Table 1a) - In general, the WQB and TG estimates are similar for all sources. Major differences among the three groups appear to be the atmospheric and tributary inputs. The WQB and TG estimates from these sources are identical. The PLUARG estimates for atmospheric and tributary loads are greater (by about 500 and 150 metric tons, respectively) than the WQB or TG estimates. The result is that the WQB and TG total load estimates are about 650 metric tons lower than that of PLUARG. The tributary and atmospheric loads presented by PLUARG are believed to be the best available estimates.

The WQB and TG estimates of the total load are 16 and 15 percent, respectively, below the estimates of PLUARG.

- 2) LAKE MICHIGAN (Table 1b) - The WQB and TG total load estimates are essentially identical. PLUARG's tributary estimate is about 300 metric tons below that of the WQB and TG. Since PLUARG specifically investigated tributary loadings, it is believed that the PLUARG estimate is the best available. The atmospheric estimates of the three groups are essentially identical.

Thus, the Lake Michigan total tributary load differences are reflected in the total load, PLUARG's estimate being approximately 300 metric tons, or approximately 5 percent of the total load, less than the WQB and TG estimates.

- 3) LAKE HURON (Table 1c) - The PLUARG and WQB total load estimates are similar, while the TG estimate is lower by about 500 metric tons. The PLUARG atmospheric estimates are nearly 70 metric tons greater than the WQB or TG estimates. This difference is not significant relative to the total load to Lake Huron.

The tributary load estimates of the WQB and PLUARG are nearly identical. The TG tributary estimates are lower than the PLUARG and WQB estimates by about 500 metric tons. It was noted that TG estimated that approximately 30 percent of the phosphorus entering Saginaw Bay was retained in the sediments of the Bay and did not enter the main basin of Lake Huron. While this phosphorus retention factor is important in estimating the phosphorus contribution from Saginaw Bay into the main Lake Huron basin, it was appropriately not applied by TG in calculation of the total Lake Huron phosphorus load. It is possible that the lower TG estimate results from calculation of the load for the 1976 calendar year, whereas the PLUARG estimate is based on the 1976 water year (October 1, 1975-September 31, 1976). However, further evaluation is necessary to substantiate this possibility.

Overall, the WQB and TG estimates are 1 and 12 percent lower, respectively, than the PLUARG load.

4. LAKE ERIE (Table 1d) - The Lake Erie phosphorus load estimates show the greatest absolute differences among the three groups. The direct industrial and upstream load from Lake Huron are identical for the three groups, all being taken from the WQB. The atmospheric load is identical for the WQB and TG, while PLUARG's estimate is approximately 350 metric tons less. However, the magnitude of the atmospheric load difference is insignificant when compared to the total lake load of greater than 15,000 metric tons. The TG reported the greatest tributary total load, being over 600 and 3000 metric tons greater, respectively, than the PLUARG and WQB loads. The TG and PLUARG used identical U.S. tributary loads (monitored and unmonitored). PLUARG used its own estimates for the Canadian monitored tributaries and those of the WQB for the Canadian unmonitored tributaries. Both the PLUARG and TG values suggest the WQB tributary load estimates were too low. It was in fact, noted by the WQB in their 1977 report on Great Lakes water quality⁵ that the 1976 tributary loads for Lake Erie were likely "severely underestimated".

The TG total load estimate of approximately 19,700 metric tons is about 2200 metric tons greater than the PLUARG estimate and about 4250 metric tons greater than the WQB estimate. The major differences are in the direct municipal load estimates. The tributary and atmospheric loads are the other major sources of differences in the load estimates. Overall, the PLUARG total load estimate lies between that of the TG (highest) and the WQB (lowest).

The WQB total load is about 12 percent below that of PLUARG, while the TG load is about 13 percent greater than PLUARG's estimate.

5. LAKE ONTARIO (Table 1e) - The WQB and TG total load estimates are nearly identical, while the PLUARG estimate is about 1000 metric tons less. The direct municipal load estimates for the three groups are nearly identical, have been derived primarily from the WQB. The direct industrial, and atmospheric load estimates are also similar. The TG and WQB tributary loads are identical, both being over 400 metric tons greater than the PLUARG estimate. The WQB and TG upstream load estimates from Lake Erie are identical, both having been taken from the WQB. The WQB value was in turn taken from a 1974 report prepared by Hydrosience⁶. By contrast, PLUARG upstream loads are based on nearly daily samplings at the Niagara river mouth into Lake Ontario (direct point sources to the Niagara River were subtracted from the Niagara River mouth load and considered as part of the direct municipal load to Lake Ontario). The PLUARG estimate for the upstream lake load from Lake Erie to Ontario was considerably lower than that reported by Hydrosience, suggesting the Hydrosience estimate was too high. This suggestion was subsequently substantiated by the WQB⁵ which reported a reduced 1977 upstream load of about 2800 metric tons to Lake Ontario, approximately one half of their 1976 value.

III. DISCUSSION AND ASSESSMENT OF LOADS BY SOURCE

The authors have also attempted to explain some of the differences among the three loading estimates on the basis of source (Tables 1a-e and Figure 2). Since the greatest differences, relative to the PLUARG estimates, occurred in Lakes Erie and Ontario, attention will be focused on these lakes. However, a summary of loading data by source for all lakes is also provided.

Evaluation of the PLUARG loading estimates by the authors during this analysis has resulted in some changes to the PLUARG values in Tables 1a-e. This evaluation results in only minor changes in load estimates and does not alter any conclusions already reached in the PLUARG study. These minor changes are identified in Table 3 in parentheses immediately below the published values of PLUARG¹. Explanation of these changes is presented below by source.

- 1) DIRECT MUNICIPAL - The major differences in this source occur in Lakes Erie and Ontario. The WQB estimate for Lake Erie is 73 metric tons greater than the PLUARG load, while the TG estimate is over 1200 metric tons greater, with the greatest difference in the U.S. estimates for both groups. Re-examination of the PLUARG data produced the change in the direct municipal load to Lake Erie indicated in Table 3, resulting in a closer agreement between the PLUARG and WQB load estimates. The remaining negligible difference between the PLUARG and WQB estimate is explained by PLUARG's conservative assumption that plants which had flow data, but no concentration data, were attaining the 1 mg/L effluent requirement. By contrast, the WQB omitted such plants. However, the TG estimate is still over 1200 metric tons greater than PLUARG's estimate. This larger value was provided to the TG by the U.S. Army Corps of Engineers Lake Erie Wastewater

Management Study. The Corps of Engineers data were composed of the municipal plant loads identified by the WQB, as well as additional data from plants with discharges less than one million gallons per day, producing the greater TG load estimate. Based on the more extensive municipal data base of the Corps of Engineers for Lake Erie, it is assumed their estimate is the most accurate of the three groups.

In Lake Ontario, the re-examination of the PLUARG data produced a higher Canadian direct municipal load estimate. However, the PLUARG estimate from this source remains below that of either TG or WQB, the explanation being that two plants (Whitby-Corbett Creek and Pringle Creek), classified as direct dischargers by WQB and TG, actually discharge into tributaries above a tributary water quality monitoring station and were considered as an indirect municipal source by PLUARG, resulting in the lower PLUARG Canadian direct municipal estimate. The only difference between the TG and WQB estimates is that 3 municipal plants (Kingston Township, Port Hope and Trenton), accounting for 25 metric tons, were omitted from the TG estimate.

With respect to the U.S. direct municipal loads to Lake Ontario, a number of New York plants were not included by the WQB in their loading estimates, since data concerning these plants were not available. PLUARG estimated loads for these plants using a 1 mg/L phosphorus effluent concentration (if flow data were available), whereas TG apparently used the 1975 average annual concentration (2.8 mg/L) for calculating the load from such plants. Which procedure produces a more accurate estimate requires more detailed study. It should be noted that all 3 estimates have considered municipal plants discharging directly to the Niagara River as direct dischargers to Lake Ontario.

- 2) DIRECT INDUSTRIAL - In general, the WQB and TG estimates for all the lakes are identical to, or slightly greater than, the PLUARG estimates, all being derived from essentially the same source. The greatest differences occur for Lakes Michigan and Huron. However, the magnitude of this source relative to the total loads to the lakes is generally insignificant.
- 3) TRIBUTARY TOTAL - The tributary total loads determined by PLUARG have two sources for all lakes. The Canadian data for monitored tributaries were provided by the Ontario Ministry of the Environment (OME). Some revisions of the OME data previously provided to the WQB for use in the WQB loading estimates occurred. The PLUARG estimates for Canadian unmonitored tributaries were those reported by the WQB. The PLUARG U.S. tributary data (monitored and unmonitored) were prepared by the Great Lakes Basin Commission, except for Lake Erie, where U.S. Army Corps of Engineer loading estimates were used (i.e., TG's U.S. Lake Erie loadings). It is these authors' belief that the PLUARG estimates are the best available, with the exception of Lake Erie. In this latter case, the TG load is believed to be the best overall estimate.

- 4) ATMOSPHERIC - The WQB and TG loads are identical in all lakes, being taken from the WQB. Lakes Michigan, Huron and Ontario show general agreement between the PLUARG, WQB and TG estimates. The Lake Erie WQB and TG loads are about 350 metric tons greater than the PLUARG value, a small difference when compared to the 15,000+ metric ton total lake load estimates. Both the WQB and TG atmospheric load estimates for Lake Superior are almost 500 metric tons less than the PLUARG value. Overall, PLUARG's 1976 atmospheric loads are believed to be the best available estimates.

- 5) UPSTREAM LAKE LOADS - Lakes Superior and Michigan have no upstream lake loads. The upstream lake loads to Lake Huron and Erie for PLUARG, WQB and the TG are identical, being derived from the Upper Lakes Reference Group⁴. The identical WQB and TG estimate of the Lake Ontario upstream load from Lake Erie are about 850 metric tons greater than the PLUARG value. This is due in part to the use by the WQB and TG of the 1974 upstream lake load determined by Hydrosience⁶, as discussed earlier. The PLUARG load is based on ongoing Environment Canada studies (thus it may be subject to revision), using data from almost daily measurements to determine the 1976 Niagara River load to Lake Ontario. The upstream load estimate represents the Lake Erie load to Lake Ontario, as well as all tributaries draining to the Niagara River. Inadvertently, the Welland River (which flows to the Niagara River) was also included in the tributary load estimate and was consequently counted twice in the PLUARG Lake Ontario load estimate. This correction reduces the tributary load and the total lake load by 195 metric tons (about 2 percent of the total lake load). PLUARG's upstream lake load from Lake Erie to Lake Ontario is considered to be the best available estimate.

- 6) OTHER (DIRECT URBAN) - Neither the WQB or TG explicitly reported direct urban loads. However, overall this is an insignificant phosphorus source to the Great Lakes, relative to other inputs.

In conclusion, none of the three groups have provided estimates which can be considered the most accurate for all the lakes. The PLUARG and TG estimates have probably provided improvements over the WQB estimate, from which both have drawn heavily for basic information. It is these authors' opinion that the PLUARG loads are probably better for Lakes Superior, Michigan and Ontario, while TG's estimate is probably the best for Lake Erie. The Lake Huron estimates are difficult to assess, partly because of the phenomenon of cross-loading between portions of the lake basin, which was addressed by TG, but not by PLUARG or WQB. This is a problem which requires further evaluation.

IV. TOTAL LOADS TO THE LAKES

Generally, the WQB and TG loads follow the same pattern, except for Lakes Huron and Erie (Tables 2a-e and Figure 2). The WQB and TG Lake Superior loads are essentially identical, both about 650 metric tons (about 15-16 percent) below the PLUARG estimates. The WQB and TG loads for Lake Michigan are also nearly identical, about 300 metric tons (3 percent) greater than the PLUARG load. The WQB and TG Lake Ontario loads are about 1000 metric tons (about 8-9 percent) greater than the PLUARG values. The WQB Lake Huron load is 59 metric tons (1 percent) less than the PLUARG load, while the TG load estimate is over 550 metric tons (12 percent) less than the PLUARG load.

The largest anomalies are seen with the Lake Erie load. The WQB estimate is about 2000 metric tons (12 percent) lower than the PLUARG value, while the TG estimate is about 2200 metric tons (13 percent) greater than the PLUARG load. Thus, the PLUARG load is essentially midway between the WQB and TG estimates. The differences are reflected principally in the direct municipal and tributary loads.

It is interesting to note that, in spite of numerous differences in specific source inputs, the total lake load estimates of PLUARG, the WQB and the TG appear to be basically compatible. None of the total loads are more than about ± 15 percent of the PLUARG estimate, most being considerably less. This is encouraging and tends to support the validity of the estimates. It is also noted, however, that the lake with the largest load (Erie) shows the greatest range of load estimates. Yet, the differences in the Lake Erie phosphorus load estimates are explainable. It is known that these differences have been examined and resolved informally and satisfactorily by several individuals involved with each of the three groups. It remains for these differences to be addressed formally and the results distributed through the basin community by these individuals so that the confusion surrounding the Lake Erie estimates can be eliminated. Further more detailed evaluation may subsequently be desirable, though not necessarily required, to clear up more specific anomalies in the load estimates. However, these authors feel that resolution publicly of the gross load differences for at least Lake Erie and distribution of these resolutions to the Great Lakes regulatory and implementation community is warranted.

The reader is cautioned that while similar loads produced by three independent groups may be encouraging, this does not necessarily mean that the "true" phosphorus loads to the Great Lakes have been determined. Similar load estimates could also indicate similar data sources or that all three groups made similar or off-setting errors in their estimates. However, in view of the lack of an absolute standard against which to evaluate the loads now or in the foreseeable future, it can only be assumed that similar loads by several groups constitutes the best estimate of the phosphorus loads to the Great Lakes at the present time. This is not to close the door to further refinement of phosphorus load estimates, but rather to recognize that the load estimates presented in this report essentially constitute the extent of the available 1976 phosphorus loading data.

Finally, it is the conclusion of the authors that, the best phosphorus load estimates for the Great Lakes (and they will likely always remain estimates as further refinement occurs) can only result from a coordinated collection of phosphorus loading data and a standardized and scientifically sound approach for calculating loading estimates. This is illustrated by comparison of the 1976 Lake Erie load estimates of the three groups with the Lake Erie phosphorus Target Load recommended in the 1978 Water Quality Agreement. If the WQB estimates for this lake are accurate, the Target Load can be achieved with only 1 mg/L point source effluent phosphorus control measures. However, if the PLUARG or TG estimates are accurate, then some additional degree of point source and/or nonpoint source phosphorus control measures will be necessary for the Lake Erie basin. Therefore, such a coordinated approach is past due and is necessary to advance scientific studies and to refine phosphorus management strategies for the Great Lakes.

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TABLE 1a: LAKE SUPERIOR 1976 PHOSPHORUS LOAD (metric tons)

Source	PLUARG ^a			TASK GROUP III ^b			WATER QUALITY BOARD ^c		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	39	28	67	46	31	77	31	28	59
Direct Industrial	0	102	102	2	102	104	0	102	102
Tributary Total ^d	964	1491	2455	845	1455	2300	845	1455	2300
Atmospheric	-	-	1566	-	-	1089	-	-	1089
Load from Upstream Lake	-	-	-	-	-	-	-	-	-
Other:	-	-	16	-	-	-	-	-	-
Urban Direct ^e	-	-	16	-	-	-	-	-	-
TOTAL	4207			3570			3550		

^a as reported in Reference #1

^b as reported in Reference #3

^c as reported in Reference #2

^d estimated loads at rivermouths

^e urban diffuse sources discharging directly to the Great Lakes

TABLE 1b: LAKE MICHIGAN 1976 PHOSPHORUS LOAD (metric tons)

Source	PLUARG ^a			TASK GROUP III ^b			WATER QUALITY BOARD ^c		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal			1040			1042			1040
Direct Industrial			32			45			32
Tributary Total ^d			3596			3894			3880
Atmospheric			1682			1690			1690
Load from Upstream Lake			-			-			-
Other:			-			-			-
Urban Direct ^e			-			-			-
TOTAL			6350			6671			6642

(note: all inputs into Lake Michigan are assumed to come from the U.S.)

^a as reported in Reference #1

^b as reported in Reference #3

^c as reported in Reference #2

^d estimated loads at rivermouths

^e urban diffuse sources discharging directly to the Great Lakes

TABLE 1c: LAKE HURON 1976 PHOSPHORUS LOAD (metric tons)

Source	PLUARG ^a			TASK GROUP III ^b			WATER QUALITY BOARD ^c		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	16	107	123	23	107	130	16	107	123
Direct Industrial	31	0	31	40	6	46	31	0	31
Tributary Total ^d	1954	947	2901	-	-	2398	1854	1071	2925
Atmospheric	-	-	1129	-	-	1062	-	-	1062
Load from Upstream Lake	-	-	657	-	-	657	-	-	657
Other:			16	-	-	-	-	-	-
Urban Direct ^e									
TOTAL			4857			4293			4798

^a as reported in Reference #1

^b as reported in Reference #3

^c as reported in Reference #2

^d estimated loads at rivermouths

^e urban diffuse sources discharging directly to the Great Lakes

TABLE 1d: LAKE ERIE 1976 PHOSPHORUS LOAD (metric tons)

Source	PLUARG ^a			TASK GROUP III ^b			WATER QUALITY BOARD ^c		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	5588	70	5658	6846	81	6927	5661	70	5731
Direct Industrial	111	164	275	111	164	275	111	164	275
Tributary Total ^d	7732	1911	9643	7732	2544	10,276	5603	1608	7211
Atmospheric	-	-	774	-	-	1119	-	-	1119
Load from Upstream Lake	-	-	1080	-	-	1080	-	-	1080
Other:			44			-			-
Urban Direct ^e									
TOTAL			17,474			19,677			15,416

^a as reported in Reference #1

^b as reported in Reference #3

^c as reported in Reference #2

^d estimated loads at rivermouths

^e urban diffuse sources discharging directly to the Great Lakes

TABLE 1e: LAKE ONTARIO 1976 PHOSPHORUS LOAD (metric tons)

Source	PLUARG ^a			TASK GROUP III ^b			WATER QUALITY BOARD ^c		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	968	1079	2047	1010	1129	2139	884	1155	2039
Direct Industrial	33	47	80	33	51	84	33	47	80
Tributary Total ^d	2800	1247	4047	3098	1392	4490	3098	1392	4490
Atmospheric	-	-	488	-	-	473	-	-	473
Load from Upstream Lake	-	-	4769	-	-	5613	-	-	5613
Other:									
Urban Direct ^e	-	-	324	-	-	-	-	-	-
TOTAL			11,755			12,799			12,695

^a as reported in Reference #1

^b as reported in Reference #3 cas reported in Reference #2

^d estimated loads at rivermouths

^e urban diffuse sources discharging directly to the Great Lakes

TABLE 2a: LAKE SUPERIOR DIFFERENCES IN PHOSPHORUS LOADS ^a RELATIVE TO PLUARG 1976 LOAD (metric tons)

Source ^b	TASK GROUP III			WATER QUALITY BOARD		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	+7 (+18) ^c	+3 (+11)	+10 (+15)	-8 (-20)	0 (0)	-8 (-12)
Direct Industrial	+2 (n/a)	0 (0)	+2 (+2)	0 (0)	0 (0)	0 (0)
Tributary Total	-119 (-12)	-36 (-2)	-155 (-6)	-119 (-12)	-36 (-2)	-155 (-6)
Atmospheric	-	-	-477 (-30)	-	-	-477 (-30)
Load from Upstream Lake	-	-	-	-	-	-
Other	-	-	-16 (n/a)	-	-	-16 (n/a)
Total			-637 (-15)			-557 (-16)

^a differences in Task Group III and Water Quality Board 1976 loads relative to 1976 PLUARG load

^b sources are identical to those in Tables 1a-e

^c percent difference relative to 1976 PLUARG estimate from each source

n/a = not applicable (see text)

TABLE 2b: LAKE MICHIGAN DIFFERENCES IN PHOSPHORUS LOADS ^a RELATIVE TO PLUARG 1976 LOAD (metric tons)

Source ^b	TASK GROUP III			WATER QUALITY BOARD		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal			+2 (+0.2) ^c			0 (0)
Direct Industrial			+13 (+41)			0 (0)
Tributary Total			+298 (+8)			+284 (+8)
Atmospheric			+8 (+0.5)			+8 (+0.5)
Load from Upstream Lake			-			-
Other			-			-
Total			+321 (+5)			+292 (+5)

(note: all phosphorus inputs to Lake Michigan are assumed to come from the U.S.)

^a differences in Task Group III and Water Quality Board loads relative to 1976 PLUARG load

^b sources are identical to those in Tables 1a-e

^c percent difference relative to 1976 PLUARG estimate from each source

n/a = not applicable (see text)

TABLE 2c: LAKE HURON DIFFERENCES IN PHOSPHORUS LOADS^a RELATIVE TO PLUARG 1976 LOAD (metric tons)

Source ^b	TASK GROUP III			WATER QUALITY BOARD		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	+7 (+44) ^c	0 (0)	+7 (+6)	0 (0)	0 (0)	0 (0)
Direct Industrial	+9 (+29)	+6 (n/a)	+15 (+48)	0 (0)	0 (0)	0 (0)
Tributary Total			-503 (-17)	-100 (-5)	+124 (+13)	+24 (+0.8)
Atmospheric	-	-	-67 (-6)	-	-	-67 (-6)
Load from Upstream Lake	-	-	0 (0)	-	-	0 (0)
Other	-	-	-16 (n/a)	-	-	-16 (n/a)
Total			-562 (-12)			-59 (-1)

^a differences in Task Group III and Water Quality Board 1976 loads relative to 1976 PLUARG load

^b sources are identical to those in Tables 1a-e

^c percent difference relative to 1976 PLUARG estimate from each source

n/a = not applicable (see text)

TABLE 2d: LAKE ERIE DIFFERENCES IN PHOSPHORUS LOADS ^a RELATIVE TO PLUARG 1.976 LOAD (metric tons)

Source ^b	TASK GROUP III			WATER QUALITY BOARD		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	+1258 (+22) ^c	+11 (+16)	+1269 (+22)	+73 (+1)	0 (0)	+73 (+1)
Direct Industrial	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)
Tributary Total	0 (0)	+633 (+33)	+633 (+7)	-2129 (-28)	-303 (-16)	-2432 (-25)
Atmospheric	-	-	+345 (+44)	-	-	-345 (+44)
Load from Upstream Lake	-	-	0 (0)	-	-	0 (0)
Other	-	-	-44 (n/a)	-	-	-44 (n/a)
Total			+2203 (+13)			-2058 (-12)

^a differences in Task Group III and Water Quality Board 1976 loads relative to 1976 PLUARG load

^b sources are identical to those in Tables 1a-e

^c percent difference relative to 1976 PLUARG estimate from each source

n/a = not applicable (see text)

TABLE 2e: LAKE ONTARIO DIFFERENCES IN PHOSPHORUS LOADS ^a RELATIVE TO PLUARG 1976 LOAD (metric tons)

Source ^b	TASK GROUP III			WATER QUALITY BOARD		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	+42 (+4) ^c	+50 (+5)	+92 (+4)	-84 (-9)	+76 (+7)	-8 (-0.4)
Direct Industrial	0 (0)	+4 (+8)	+4 (+5)	0 (0)	0 (0)	0 (0)
Tributary Total	+298 (+11)	+145 (+12)	+443 (+11)	+298 (+11)	+145 (+12)	+443 (+11)
Atmospheric	-	-	-15 (-3)	-	-	-15 (-3)
Load from Upstream Lake	-	-	+844 (+18)	-	-	+844 (+18)
Other	-	-	-324 (n/a)	-	-	-324 (n/a)
Total	+1044 (+9)			+940 (+8)		

^a differences in Task Group III and Water Quality Board 1976 loads relative to 1976 PLUARG load

^b sources are identical to those in Tables 1a-e

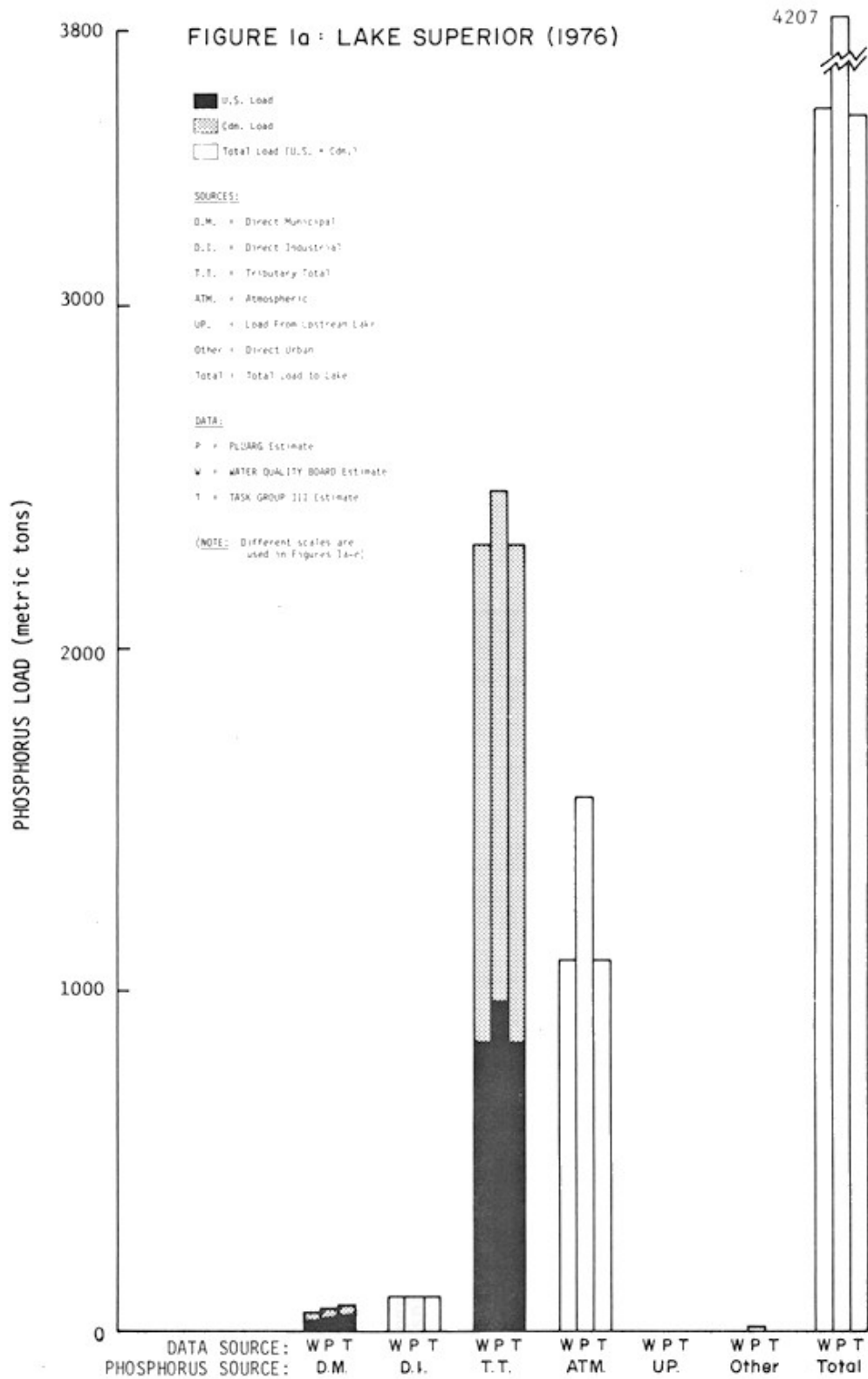
^c percent difference relative to 1976 PLUARG estimate from each source

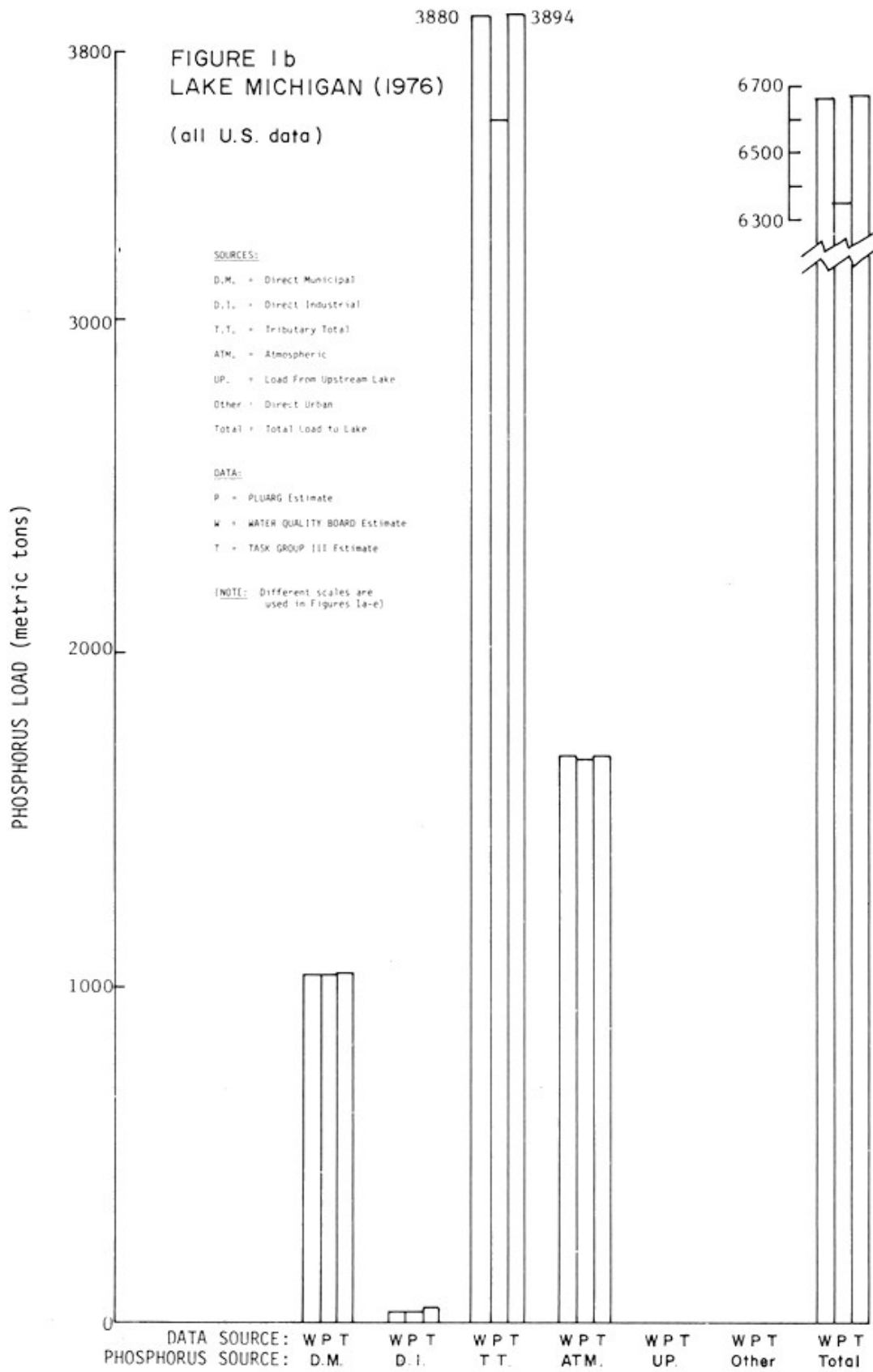
n/a = not applicable (see text)

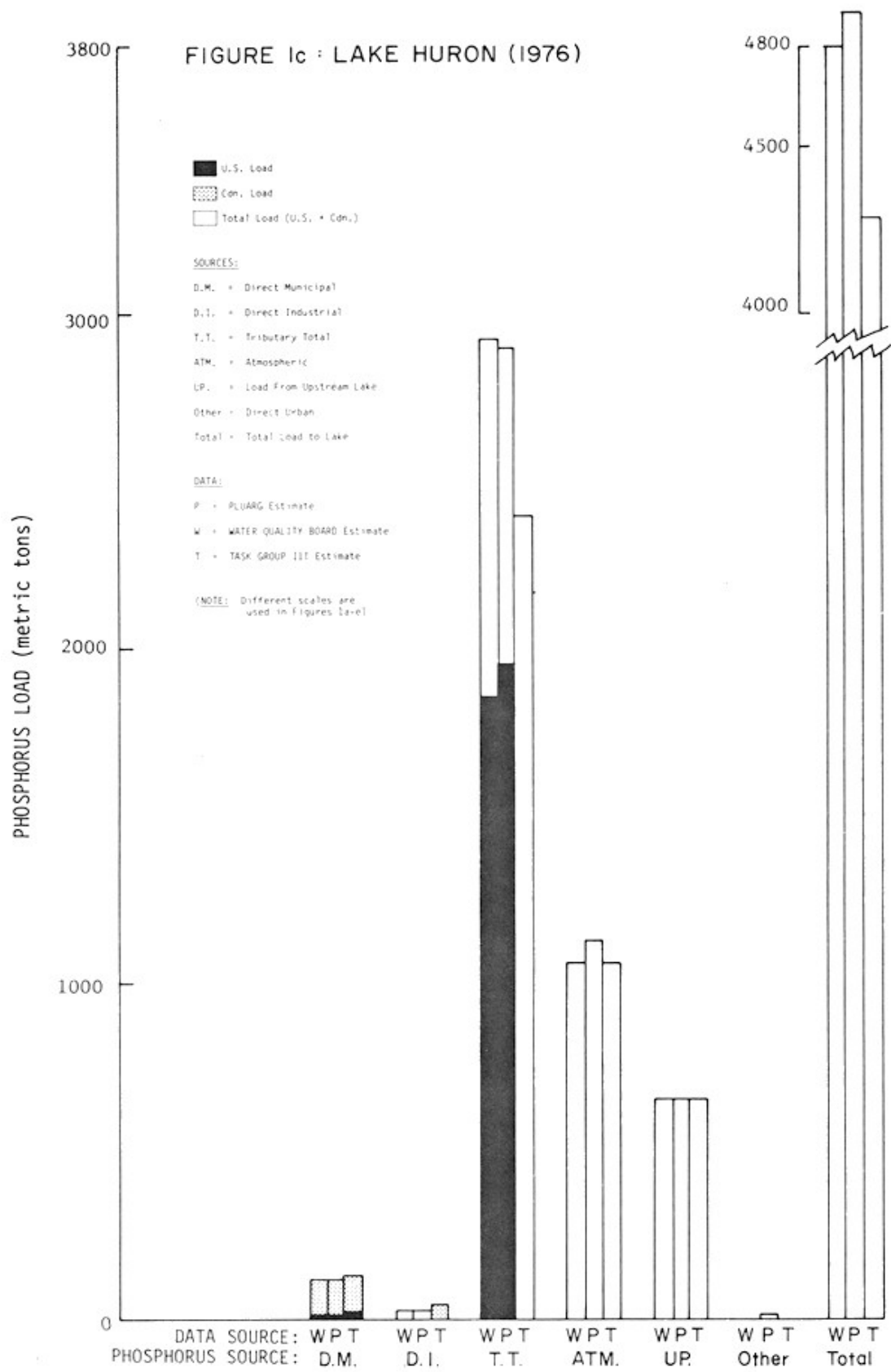
TABLE 3: REVISION OF 1976 TOTAL PHOSPHORUS LOADS REPORTED BY PLUARG (metric tons)
(revised estimates are within parentheses)

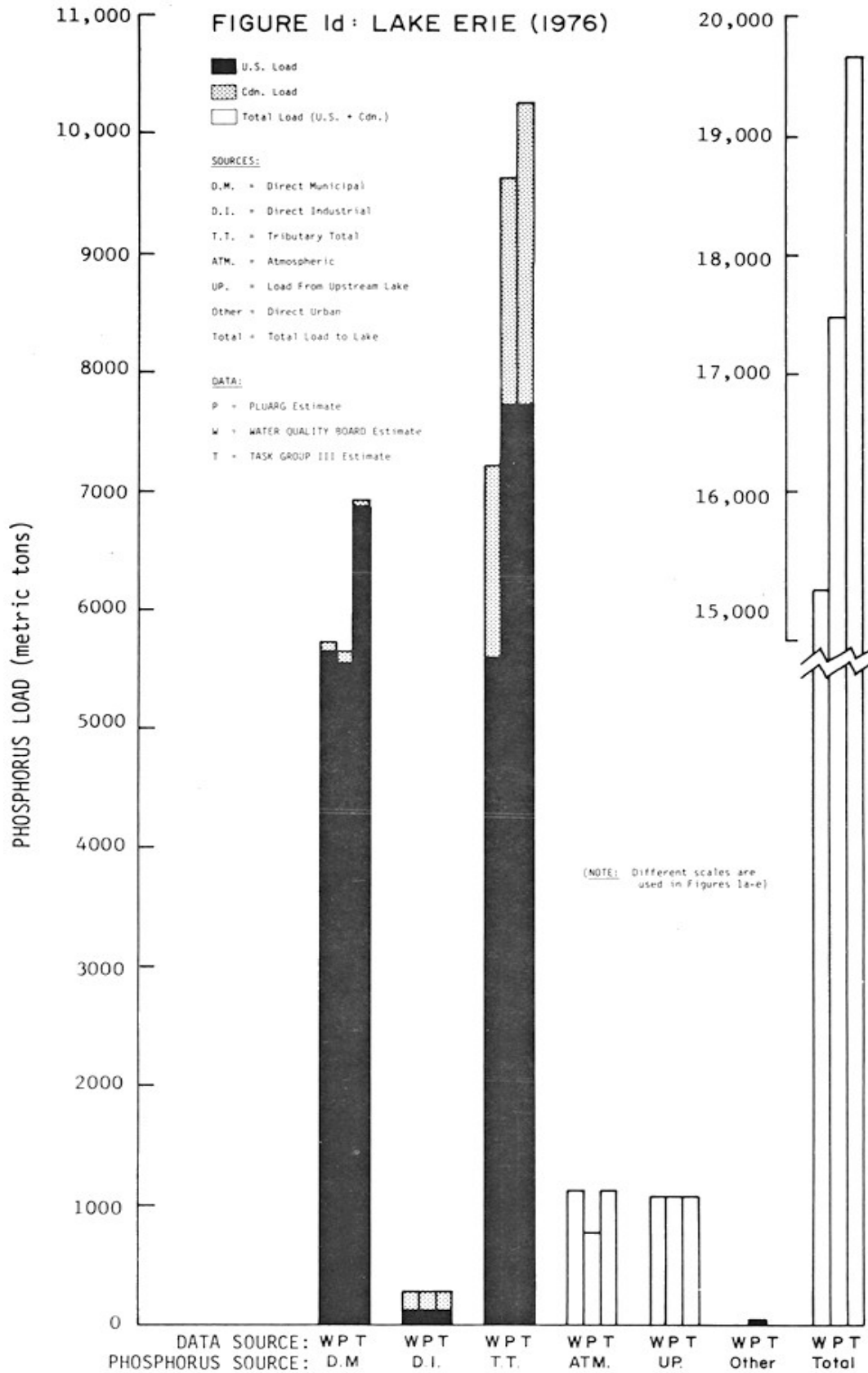
	LAKE SUPERIOR			LAKE MICHIGAN			LAKE HURON			LAKE ERIE			LAKE ONTARIO		
	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total	U.S.	Cdn.	Total
Direct Municipal	39	29	68	1,040	-	1,040	16	107	123	5,588	70	5,658	968	1,079	2,047
										(5,672)		(5,742)		(1,142)	(2,110)
Direct Industrial	0	102	102	32	-	32	31	0	31	111	164	275	33	47	80
Urban Nonpoint	*	16	16	*	-	*	*	16	16	*	44	44	*	324	324
Direct															
Tributary Total	964	491	2,455	3,596	-	3,596	1,954	947	2,901	7,732	1,911	9,643	2,800	1,247	4,047
														(1,052)	(3,852)
Atmospheric	-	-	1,566	-	-	1,682	-	-	1,129	-	-	774	-	-	488
Load from	-	-	-	-	-	-	-	-	657	-	-	1,080	-	-	4,769
Upstream Lake															
Total	-	-	4,207		-	6,350	-	-	4,857	-	-	17,474	-	-	11,755
												(17,558)			(11,623)

* included in tributary load









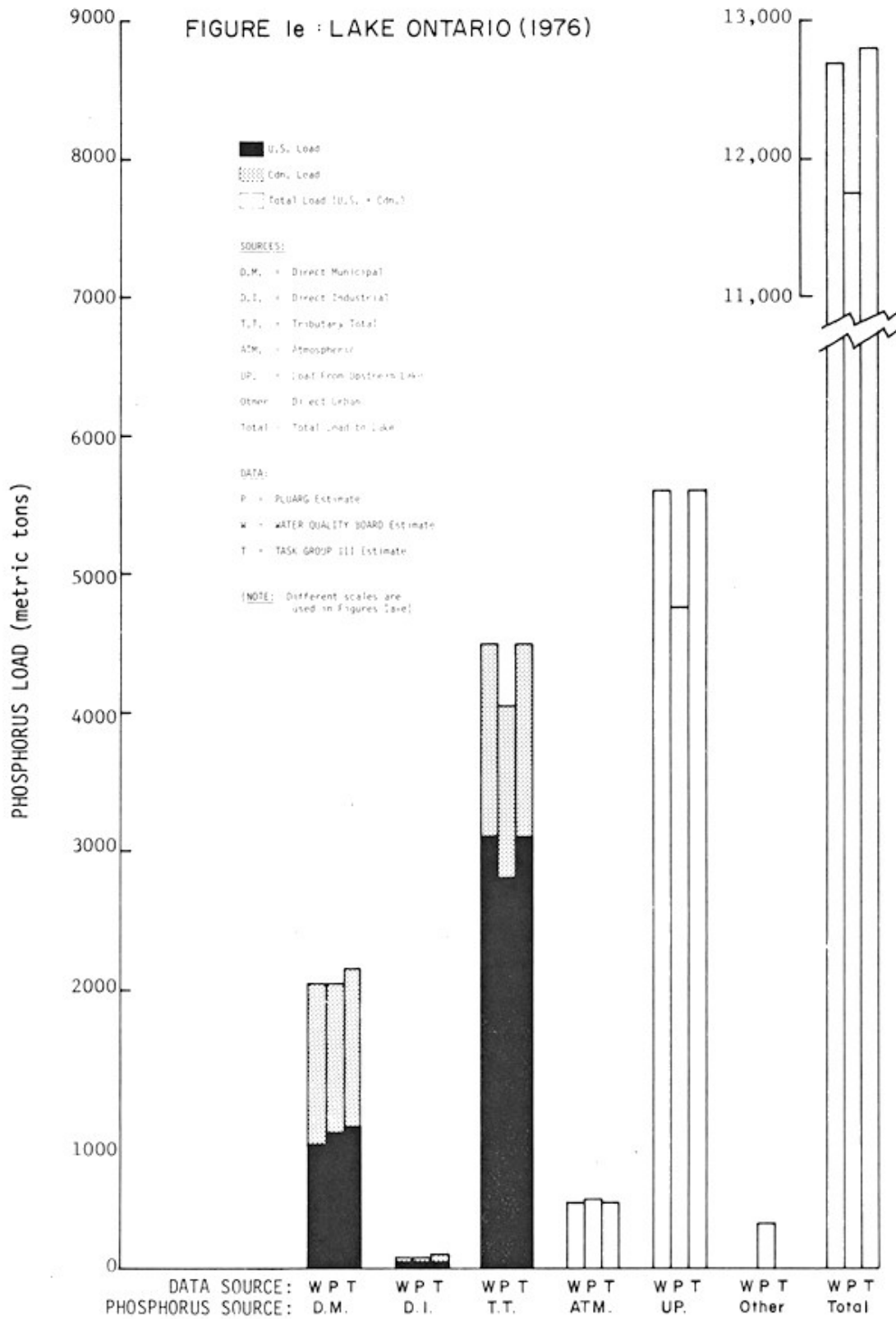


FIGURE 2.

Differences in Total Phosphorus Loads Relative to 1976 PLUARG Loads (metric tons)

