

Appendix H
Pollutant Loading Changes

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Pollutant Loading Changes

From 1940 to the present day, the combination of advancing wastewater treatment technology, increased public concern, various State wastewater treatment regulations, and, finally, the 1972 CWA secondary treatment mandate resulted in an increased number of POTWs with at least secondary and, in many cases, greater than secondary levels of treatment. The total population in the United States grew rapidly in the latter half of the 20th century, increasing from around 140 million people in 1940 to about 297 million in 2004. This population growth meant POTWs not only had to upgrade their treatment processes to increase pollutant removal efficiency, but they had to accomplish it while dealing with increasing influent wastewater loads. To view the steady increase in population served by centralized collection and treatment, see Figure 3-1. This section examines trends concerning the Nation's expansion and upgrades of POTWs and analyzes how increased use of secondary and greater than secondary treatment after the 1972 CWA affected the rate of effluent BOD loading to the Nation's waterways.

This analysis focuses on CBOD₅, the BOD at 5 days that includes only the carbonaceous component of oxygen consumption, as well as BOD_u, the ultimate BOD of the carbonaceous and nitrogenous components of oxygen consumption at completion of both the carbonaceous decomposition and nitrification processes. Including both CBOD₅ and BOD_u is important because the oxygen consumed in nitrification is about 30 percent of the oxygen consumed in carbonaceous oxidation of pure organic matter (Chapra 1997).

The information sources for this analysis uses municipal wastewater inventories published by the U.S. Public Health Service from 1940 through 1968 (USPHS 1951; NCWQ 1976; USEPA 1974) and USEPA's Clean Watersheds Needs Surveys conducted since 1973. The results presented here are based on the work presented by USEPA (2000) and updated through the data reported in Appendix C of this report.

To compute influent and effluent loadings, numerous assumptions are needed related on influent concentrations, removal efficiencies and conversion factors. Major assumptions are provided in the text box to the right. Designed-based BOD₅ removal efficiencies are minimum requirements typically assigned by NPDES permits according to the treatment process and treatment plant design assumptions (Metcalf and Eddy 1991). Generally, they represent conservative estimates of BOD₅ removal efficiencies. Many modern POTWs report a higher rate of BOD₅ removal than their permitted rate. This study, however, focuses on designed-based BOD₅ removal efficiencies because it is assumed that these conservative rates would provide a more effective and consistent comparison of BOD₅ removal over the entire historical period of record used in the analysis. For more information justifying the assumptions used in these calculations or the detailed calculations themselves, see USEPA 2000.

Municipal Wastewater Inventories

- 1940–1968: U.S. Public Health Service
- 1972–2004: USEPA CWNS

Key Assumptions

- Flow rate: 165 gallons per capita per day (gpcd)
- Influent CBOD₅ concentration: 215 mg/L
- Influent TKN concentration: 30.3 mg/L
- Influent NBOD loading: 0.191 lb per capita per day
- NBOD_u = 4.57 [TKN]
- BOD_u = [CBOD_u] + [NBOD_u]
- [CBOD_u] / [CBOD₅] conversion ratios
 - Raw: 1.2
 - Less than Secondary: 1.6
 - Secondary: 2.84
 - Greater than Secondary: 2.9
- CBOD₅ removal efficiency
 - Raw: 0.0%
 - Less than Secondary: 42.5%
 - Secondary: 85.0%
 - Greater than Secondary: 92.5%

Trends in Influent Loading. Figure H-1a is a bar chart that presents a comparison of the total influent CBOD₅ and BOD_u loading from 1940 to 2004. Figures H-1b and H-1c display influent CBOD₅ and BOD_u loading data, respectively, organized by wastewater treatment type. The key observations from Figure H-1 include the following:

- Influent BOD loading to the Nation’s POTWs more than tripled from 1940 to 2004, reflecting population growth, increases in the number of facilities, and expanding service areas.
- Influent CBOD₅ loading increased from 9,508 metric tons per day in 1940 to 18,814 metric tons per day in 1968. By 2004, influent CBOD₅ loading stood at 29,925 metric tons per day, a 59 percent increase from 1968.
- Influent BOD_u loading increased from 17,532 metric tons per day in 1940 to 34,693 metric tons per day in 1968. By 2004, influent BOD_u loading stood at 55,183 metric tons per day, a 59 percent increase from 1968.
- In 1940 72 percent of influent BOD_u loading nationwide was being treated by facilities with less than secondary treatment (12,555 of 17,532 metric tons per day of BOD_u). By 1968 39 percent of influent BOD_u loading nationwide was being treated by facilities with less than secondary treatment (13,422 of 34,693 metric tons per day of BOD_u). Thirty-two years after the 1972 CWA, only 1.5 percent of influent BOD_u loading was being treated by facilities with less than secondary treatment (819 of 55,183 metric tons per day of BOD_u).

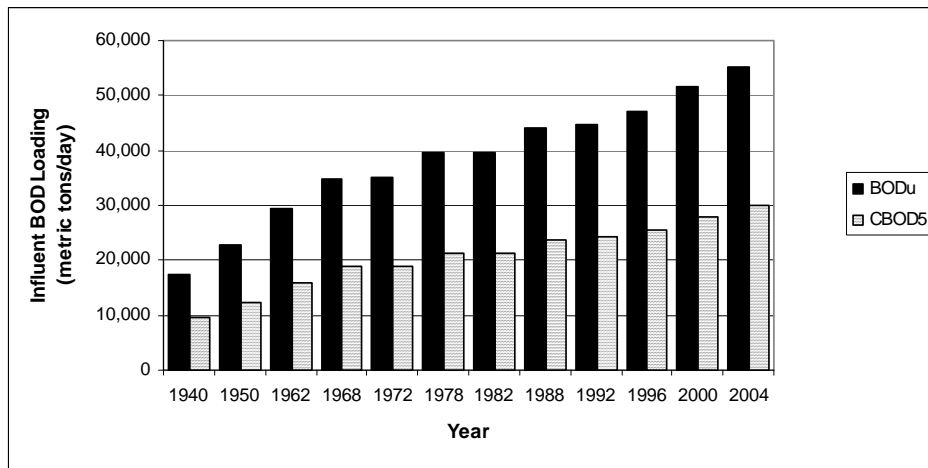


Figure H-1a. Influent loading of total BOD_u and CBOD₅ nationwide for select years between 1940 and 2004.

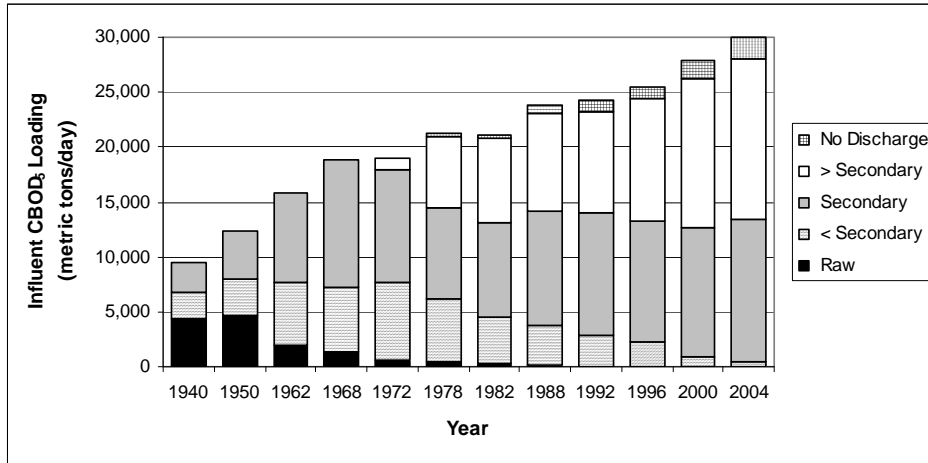


Figure H-1b. Influent loading of $CBOD_5$ to POTWs nationwide for select years between 1940 and 2004 organized by wastewater treatment type.

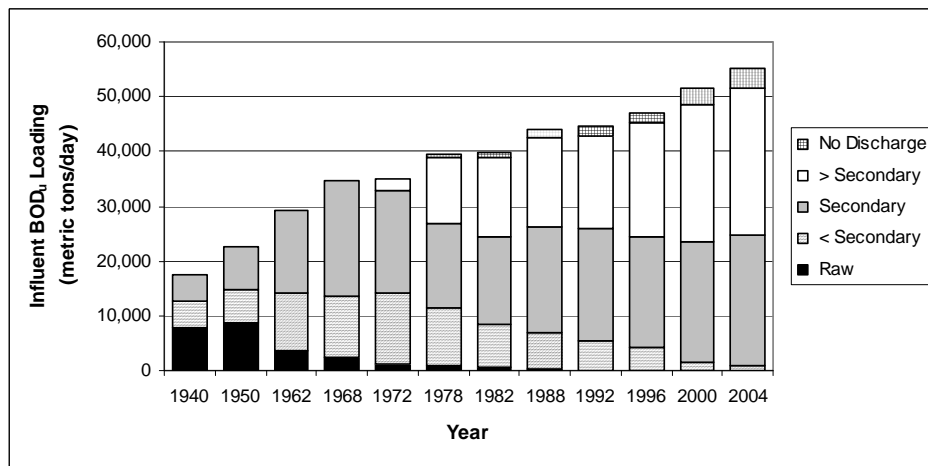


Figure H-1c. Influent loading of BOD_u to POTWs nationwide for select years between 1940 and 2004 organized by wastewater treatment type.

Trends in Effluent Loading. Figure H-2a is a bar chart that presents a comparison of the total effluent $CBOD_5$ and BOD_u loading from 1940 to 2004. Figures H-2b and H-2c display effluent $CBOD_5$ and BOD_u loading data, respectively, organized by wastewater treatment type. The key observations from Figure H-2 include the following:

- Effluent BOD loading from POTWs was significantly reduced between 1968 and 2004. In 1968, 4 years before the 1972 CWA, effluent $CBOD_5$ and BOD_u loadings were 6,932 and 21,281 metric tons per day, respectively. By 2004 $CBOD_5$ and BOD_u loadings were reduced to 3,291 and 16,499 metric tons per day, respectively. This represents a 53 percent decline in $CBOD_5$ and a 22 percent decline in BOD_u between 1968 and 2004. Notably, these declines were achieved even though influent $CBOD_5$ and BOD_u loading to POTWs each increased by 59 percent during the same time period.
- The proportion of effluent $CBOD_5$ loading attributable to raw and less than secondary wastewater treatment was reduced from about 94 percent in 1940 to 8 percent in 2004 (Figure H-2b). The

proportion of effluent BOD_u loading attributable to raw and less than secondary wastewater treatment was reduced from about 84 percent in 1940 to 4 percent in 2004 (Figure H-2(c)).

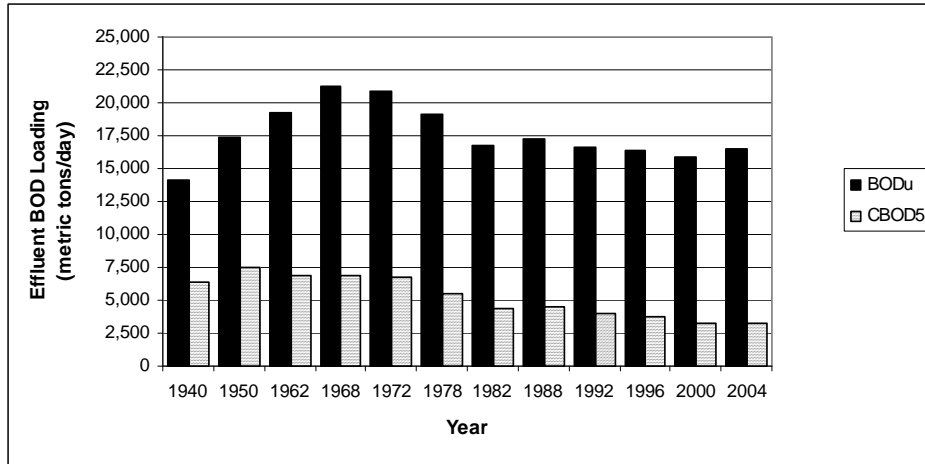


Figure H-2a. Effluent loading of total BOD_u and CBOD₅ from POTWs nationwide for select years between 1940 and 2004.

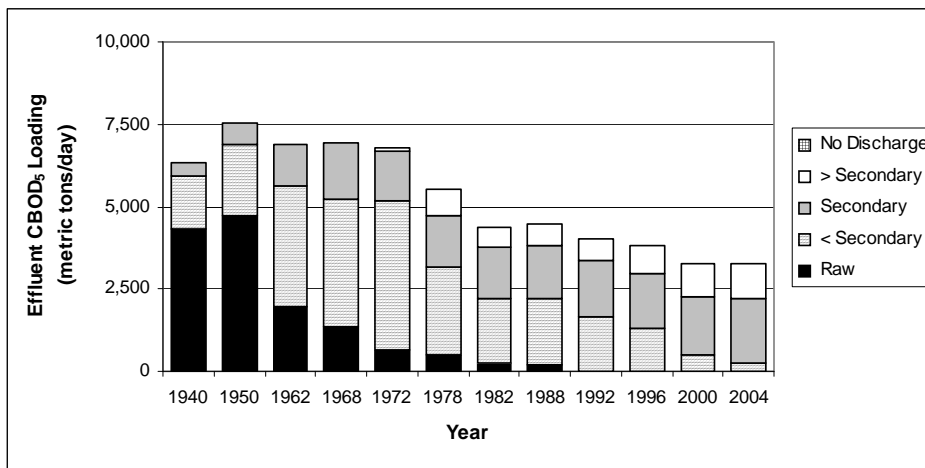


Figure H-2b. Effluent loading of CBOD₅ from POTWs nationwide for select years between 1940 and 2004 organized by wastewater treatment type.

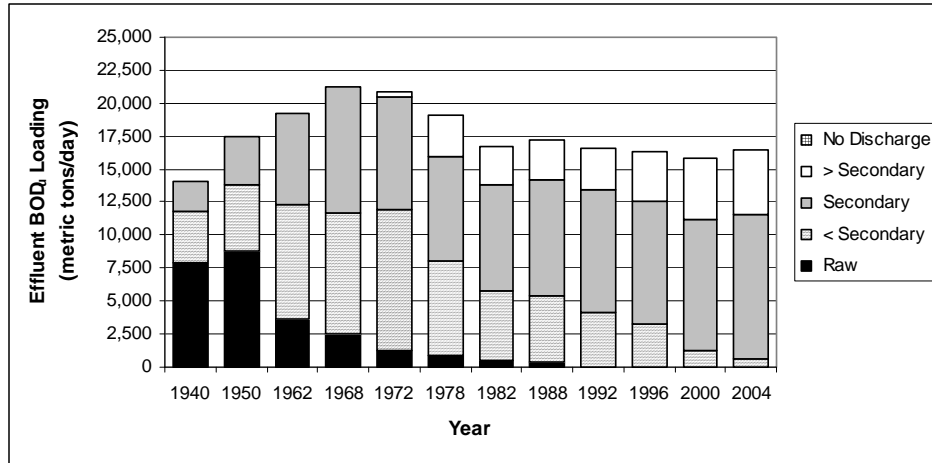


Figure H-2c. Effluent loading BOD_u from POTWs nationwide for select years between 1940 and 2004 organized by wastewater treatment type.

The analysis above indicates that tremendous progress was achieved between 1968 and 2004 in reducing effluent BOD loading from POTWs into the Nation’s waterways. Notably, this reduction occurred at the same time the number of people served by POTWs was increasing rapidly. Figures H-3 and H-4 present influent and effluent loadings together with removal efficiencies for CBOD₅ and BOD_u, respectively. Key observations from Figures H-3 and H-4 include the following:

- BOD removal efficiency nationwide significantly increased between 1940 and 2004. In 1940 the aggregate national removal efficiency stood at about 33 percent for CBOD₅ and 20 percent for BOD_u. By 1968 removal efficiencies had increased to 63 percent for CBOD₅ and 39 percent for BOD_u. By 2004 they had further increased to 89 percent for CBOD₅ and 70 percent for BOD_u.
- The BOD removal efficiency increased substantially between 1972 and 1978, the 6-year period after the passage of the CWA (from 64 to 74 percent for CBOD₅ and from 41 to 52 percent for BOD_u). Between 1978 and 2004 removal efficiency increased an additional 15 percent for CBOD₅ and 18 percent for BOD_u. Those larger increases in BOD_u removal efficiency reflect the ever-increasing role of greater than secondary POTWs over this time period.

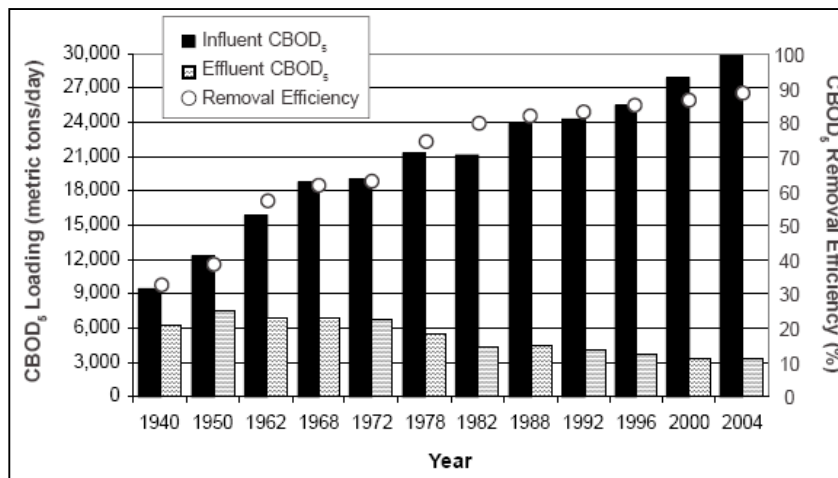


Figure H-3. Total POTW influent and effluent CBOD₅ loading and corresponding CBOD₅ removal efficiency for select years.

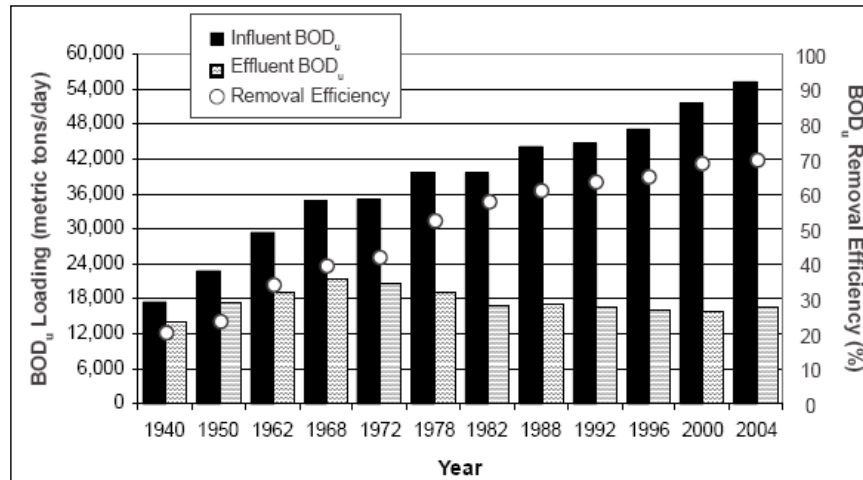


Figure H-4. Total POTW influent and effluent BOD_u loading and corresponding BOD_u removal efficiency for select years between 1940 and 2004.

Future Trends in BOD Effluent Loading. As shown in Chapter 4 (Figure 4-1), the population served by secondary treatment facilities declined sharply between 1968 (85.6 million) and 1978 (56.3 million) and then leveled off at about 82 million in the 1990s. In contrast, the number of people served by greater than secondary treatment surged between 1968 and 1978 (0.3 to 49.1 million) and then increased steadily to about 108.5 million in 2004. Unlike secondary treatment, advanced wastewater treatment enhances biological processes to incorporate nitrification (ammonia removal) and denitrification (nitrate removal), thus reducing the NBOD fraction of effluent BOD_u loading.

The data presented in the previous sections indicate that the increase in BOD removal efficiency between 1940 and 2004 resulted in significant reductions in BOD effluent loading to the Nation's waterways even though the number of people served by POTWs greatly increased. *Given that the population served by POTWs is projected to continue to increase, what might the effluent BOD loadings be in the future?*

Using the population projections provided in Appendix C (Table C-4), projections in influent and effluent BOD loading rates and BOD removal efficiencies for 2004 and corresponding projections can be made. Figure H-5 is a bar chart that extends the influent and effluent BOD_u loading totals and POTW removal efficiencies originally presented in Figure H-4 well into the 21st century by adding columns for the years 2016 and 2025 to the chart. These projections are based on the following assumptions:

- USEPA CWNS 1996 (USEPA 1997) estimates that 275 million people will be served by POTWs in the year 2016. This figure is based on middle-level population projections from the Census Bureau (USBC 1996) and the assumption that 88 percent of the population will be served by POTWs in 2016. Assuming that 88 percent of the population projected for 2025 is also served by POTWs, about 295 million people will be served by POTWs.
- Design-based BOD_u removal efficiency will increase from a nationwide average of 70 percent in 2004 to 71 percent by 2016 on the basis of projections of population served by the different categories of POTWs. This removal efficiency is assumed to remain at that level through 2025.
- Influent wastewater flow will remain a constant 165 gpcd and influent BOD_u concentration will remain a constant 396.5 mg/L for the projection period from 2004 to 2025.

Key observations from Figure H-5 include the following:

- Population growth from 2004 to 2016 will increase influent BOD_u loading nationwide to 68,030 metric tons per day, an increase of 23 percent. By 2025 influent loading will be about 73,179 metric tons per day, a 33 percent increase from 2004.
- Although the BOD_u removal efficiency is projected to increase from 70 to 71 percent by 2016, it is predicted that effluent BOD_u loadings will increase from 16,499 metric tons per day in 2004 to 19,607 metric tons per day in 2016, an increase of 19 percent.
- By 2025 the projected effluent BOD_u loading will be 21,090 metric tons per day, an increase of 28 percent from 2004.
- By 2016 the overall BOD_u removal efficiency of 71 percent and increases in population will result in a 19 percent increase of effluent loads relative to the 2004 loading rate. To maintain an effluent BOD_u loading rate comparable to 1996 conditions through 2016, the national aggregate removal efficiency would have to be increased from 71 to 77 percent. This would be equivalent to shifting the projected population served from secondary to advanced secondary and advanced wastewater treatment facilities.

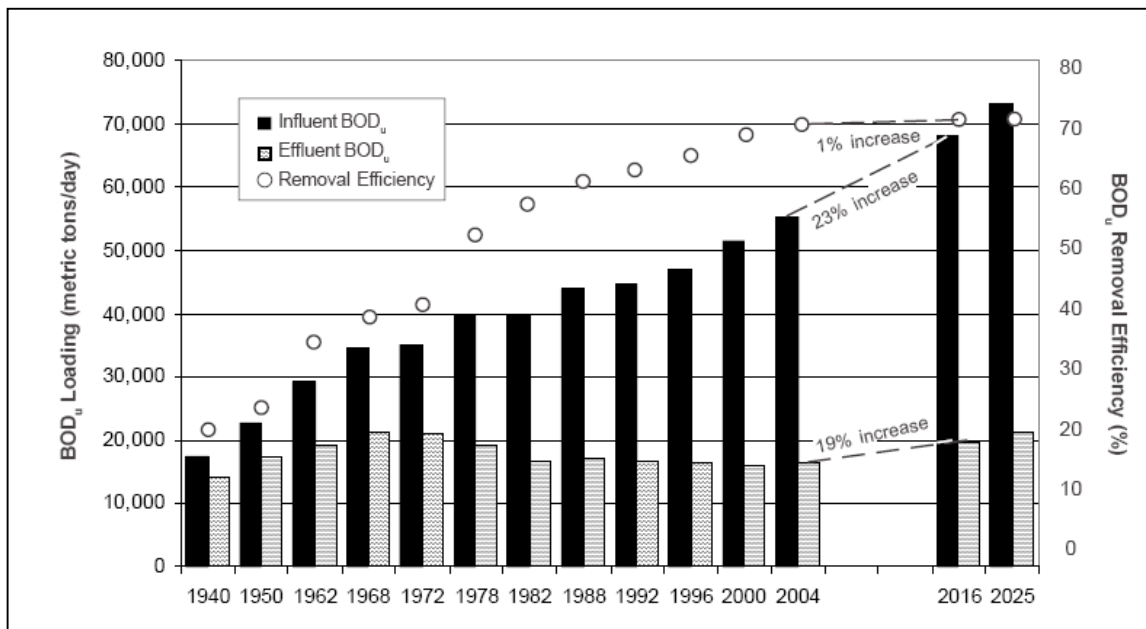


Figure H-5. POTW influent and effluent BOD_u loading and removal efficiency for select years between 1940 and 2000 and projected POTW influent and effluent BOD_u loading and removal efficiency for 2016 and 2025.

References

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