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EPA

TMDL Case Study

Denver Metro — The South Platte River Segment 15

Key Features: Revision of TMDLs to meet Water Quality Standards

Project Name: Denver Metro — The South Platte River Segment 15
Location: EPA Region VIII/Denver, Colorado
Scope/Size: River, drainage area 380 mi^2
Land Type: Smooth to irregular plains
Type of Activity: Urban
Pollutant(s): Toxic ammonia (NH_3), BOD/DO, toxics, metals
TMDL Development: PS, NPS, Toxics
Data Sources: Site-specific data from NPDES permittee and localities
Data Mechanisms: STREAMDO and Colorado Ammonia Model
Monitoring Plan: Yes
Control Measures: NPDES permit

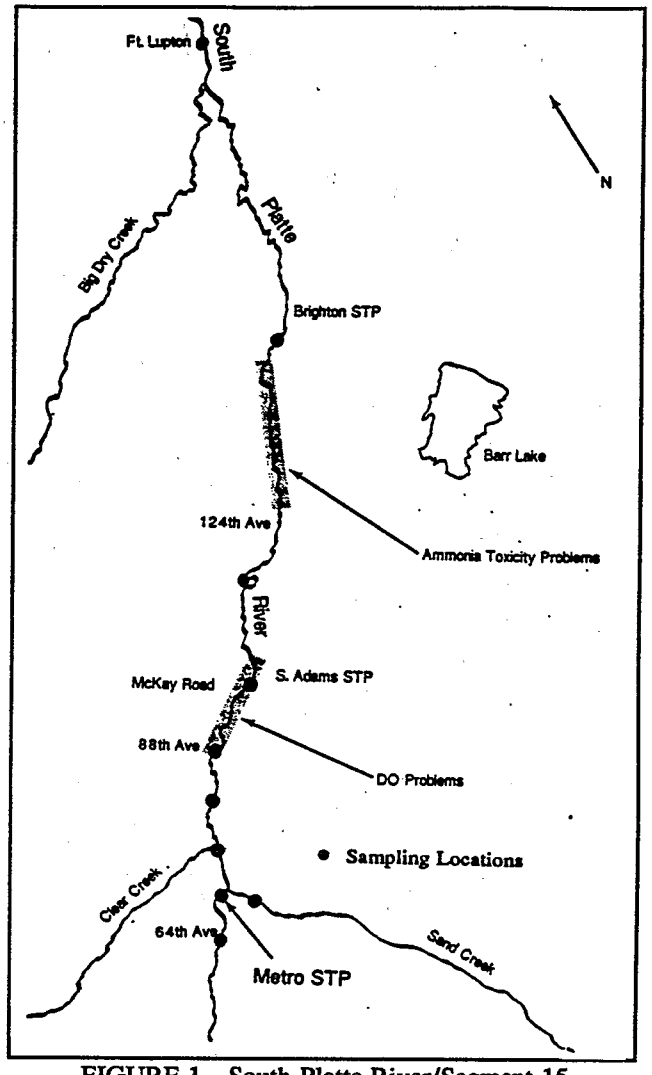

FIGURE 1. South Platte River/Segment 15

Summary: In 1986, low dissolved oxygen (DO) and the presence of toxic ammonia, other toxics, and metals convinced the Colorado Water Quality Control Commission to identify Segment 15 of the South Platte River as water quality impaired and a high priority for TMDL development. EPA Region VIII developed TMDLs for the segment after assuming authority to issue the NPDES permit for the Denver Metro Wastewater Reclamation District's Central Facility. Although numerous point sources discharge to the river upstream from Segment 15 and nonpoint source pollution was also known to contribute to its pollutant load, these were considered insignificant when compared with the discharge from the Central Facility at low flow. Almost the entire flow of the South Platte is diverted immediately above Metro's discharge. Using the extensive data that were key to identifying the water quality problems in this segment of the South Platte, TMDL development proceeded for metals, nitrates, nitrites, and ammonia. Ammonia was of primary concern because it contributed to both un-ionized ammonia toxicity and DO problems. Wasteload allocations based on the TMDLs were incorporated into the Central Facility's NPDES permit when it came up for renewal in 1986. Unfortunately, water quality data gathered since then indicate that DO continues to be below required concentrations in sections of Segment 15. As a result, the Region is now working to revise the TMDLs for those parameters that affect DO so that the DO standard will be achieved throughout the reach. The revised TMDLs may include "non-chemical" components, such as habitat restoration.

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BACKGROUND

Programmatic Issues

The Metro Wastewater Reclamation District (Metro District) provides wastewater treatment for a major portion of metropolitan Denver and portions of surrounding Adams, Arapahoe, and Jefferson Counties. It consists of 20 municipalities and service districts that are "Member Municipalities," 23 "special connectors," and 17 "connectors to connectors," discharging approximately 210 million gallons per day (mgd) into the South Platte River near Sand Creek (Figure 1). The river below this discharge is considered to be effluent dominated because estimated background flow is only about 20 mgd.

The Colorado Department of Health is delegated to issue permits in the State of Colorado. EPA Region VIII assumed authority to issue an NPDES permit for the Denver Metro municipal facility in 1986, however, because of the facility's consistent violations under the Clean Water Act (CWA). When excessive nutrients, low dissolved oxygen (DO), and the presence of toxic ammonia, other toxics, and metals convinced the Colorado Water Quality Control Commission (WQCC) to target Segment 15 of the South Platte River as a high priority for TMDL development, the Region established TMDLs to address these water quality problems. Wasteload allocations (WLAs) were incorporated into Denver Metro's NPDES permit. Metro District was the major cause of water quality impairment.

TMDL development begins with a thorough evaluation of available data and information. The Region evaluated the WLA that had already been established for Denver Metro by the Department of Health. It was deemed insufficient. The Region also considered the quality and abundance of available data to determine whether the data were adequate to calculate a TMDL and allocate pollutant loads for each parameter with a reasonable assurance that water quality standards would be met. The data appeared sufficient, and TMDLs were promulgated. A new NPDES permit, with limits based on the TMDLs calculated for each pollutant of concern, was issued to the Denver Metro facility in December 1986 (USEPA, 1986).

NOTE: Had there been substantial uncertainty that any TMDL would result in the attainment of water quality standards, a phased approach to TMDL development could have been chosen. Under this approach, a formal monitoring plan is adopted as part of the TMDL to assess attainment of standards and to support revision of the TMDL if standards are not attained.

Denver Metro—the NPDES permittee—installed pollution controls and collected data over the next 4 years so that the effectiveness of these controls could be evaluated. A review of the data in 1990 revealed that past problems with chlorine toxicity and ammonia toxicity appeared to have been resolved by upgrades of the Central Facility. The data also indicated that low DO concentrations continued to be a problem. Water quality standards had not yet been attained. (The DO profile along this segment of the river is shown in Figure 2.) This information forced a reassessment of the TMDLs for those parameters that affect DO in the stream, followed by a decision by the Region to update those TMDLs. The possibility of developing new, phased TMDLs that incorporate non-chemical parameters is currently being discussed because, while water quality problems are largely the result of various point source discharges, habitat degradation is a significant exacerbating factor.

To facilitate development of the new TMDLs, the State and EPA Region VIII are working closely with Metro District to collect and interpret additional data, as well as to model water quality. EPA's Office of Water is also continuing to review new approaches, technology, and tools to better assist in implementing the TMDL process (USEPA, 1991b). Metro District is funding the monitoring, modeling, and site-specific criteria development for the TMDLs.

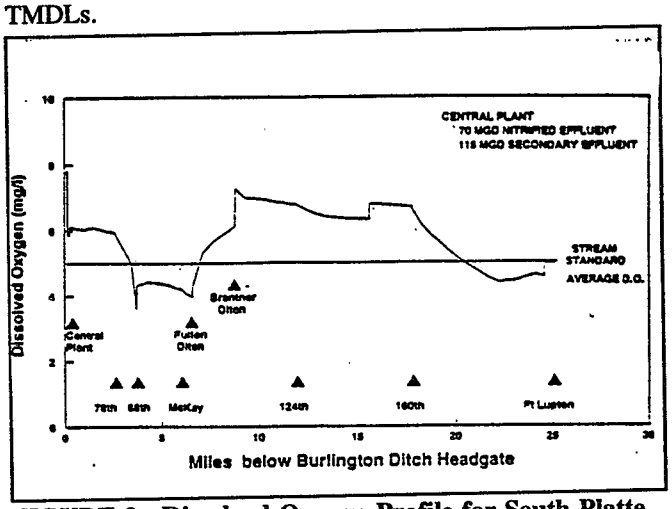

FIGURE 2. Dissolved Oxygen Profile for South Platte River Segment 15 (Camp, Dresser & McKee, 1992)

The Resource

The South Platte River originates in the center of Colorado and flows generally northeast for 270 miles to Nebraska. Approximately 65 percent of the population of Colorado is concentrated in a 30-mile-wide strip along the South Platte River, beginning 18 miles south of Denver and extending 80 miles northward. The land type in the watershed is mainly smooth western high plains. Natural vegetation on the plains tends toward gana, or buffalo grass. The soil types typical of this area are dry Mollisols (Omernik, 1987). The Denver area receives approximately 12 to 16 inches of annual rainfall, and annual natural runoff in the

area ranges from 0.1 to 1 inch (USGS, 1985). Runoff from urbanized areas, however, is greater. Low-flow conditions are most common from July to October, and high flows generally occur during the spring (May to June).

Segment 15 of the South Platte River, shown in Figure 1, flows north from the Denver metropolitan area to Fort Lupton, Colorado. This segment of the river extends 26 miles and its drainage area is approximately 380 square miles.

Upstream of Clear Creek, Segment 15 is characterized by heavy commercial and industrial land uses. Along Segment 15 itself there are active gravel mines, flooded gravel mines, pasture lands, and agricultural lands. Erosion control, which has extensively modified the upstream channel of Segment 15, has negatively affected the riparian zone, river hydrology, and assimilative capacity of the river. Dewatering flows from gravel-mining operations along the river contribute sediments and also affect the river hydrology. DO problems tend to occur in large ponded areas, which are a result of in-stream gravel mining and small dams built for irrigation withdrawal and utility line protection. Low species diversity throughout segments of the South Platte indicates that poor water quality and habitat degradation are impairing the health of aquatic communities.

Figure 1 illustrates the major pollution sources and quality-impaired areas along Segment 15. The location of point source inflows, nonpoint source loadings, irrigation return flows, tributary flows, and water supply withdrawals along the segment are indicated in Figure 3.

The WQCC has classified Segment 15 for the following uses: (1) Class 2 warm water aquatic life, (2) Class 2 recreation, (3) water supply, and (4) agricultural use. Table 1 presents the water quality standards that were in effect at the time of TMDL development so that the river reach would support these uses. It is possible that in the future the WQCC will adopt more stringent standards for un-ionized ammonia and a tiered standard for DO. Effluent limits for phosphorus are not currently in effect for Metro District's Central Facility. In addition, the State and EPA are investigating the development of site-specific standards for DO in the South Platte River. Changes in water quality standards could require TMDL revision.

ASSESSING AND CHARACTERIZING THE PROBLEM

Targeting and Prioritizing

Although each State decides how to prioritize impaired waters for TMDL development, the CWA provides that the severity of pollution and the intended uses of a waterbody be considered. EPA policy guidelines (USEPA, 1991a) suggest additional criteria. TMDL development for Segment 15 of the South Platte River was targeted and assigned a high priority because (1) available data indicated water quality was impaired, and (2) there was an urgent need to reissue the Metro Facility's NPDES permit.

Monitoring and Data Bases

Denver Metro conducted voluntary ambient monitoring at various points along Segment 15 for many years prior to 1986 in order to assess the water quality impacts of its discharges to the river. This information provided the first indication that there was a DO problem in sections of the reach, prompting EPA Region VIII to initiate more intensive water quality monitoring. EPA and the State conducted a joint data collection effort for approximately 6 months in 1985. The monitoring revealed that, in addition to low DO, the problems included chlorine and ammonia toxicity, as well as high concentrations of various metals.

The data from Denver Metro's ambient monitoring, the EPA/State intensive monitoring efforts, the water quality records from the South Adams County Water and Sanitation District and the City of Brighton, and effluent chemistry data from wastewater treatment facilities on Segment 15 were combined to form a fairly complete data base, with a period of record beginning in 1980, for numerous water quality parameters. This data base was very useful in characterizing water quality trends in Segment 15 over time and in completing TMDL analyses for the pollutants of concern.

After 1986, Denver Metro's ambient monitoring program was formally modified to provide more complete water quality data and information. Weekly water quality data are now collected at designated sampling locations along the South Platte River, including Segment 15, and in certain tributaries. In addition, Denver Metro collects a series of 24-hour (diel) water quality samples two times each year. Diel data can greatly increase the accuracy of a water quality model when used to calibrate for diel variations in DO and other parameters. This monitoring program was initially outlined in the 1986 EPA-issued NPDES permit for the Central Facility and has been sustained through annual CWA section 308 letters to Denver Metro.

The current data base is particularly valuable because of its long period of record, broad spatial coverage, and consistency in sampling and analytical methods. It is quite useful for (1) determining whether water quality standards are being met, (2) indicating water quality trends, and (3) providing better information to revise established TMDLs, if necessary. In addition, the expanded data base better supports water quality modeling efforts.

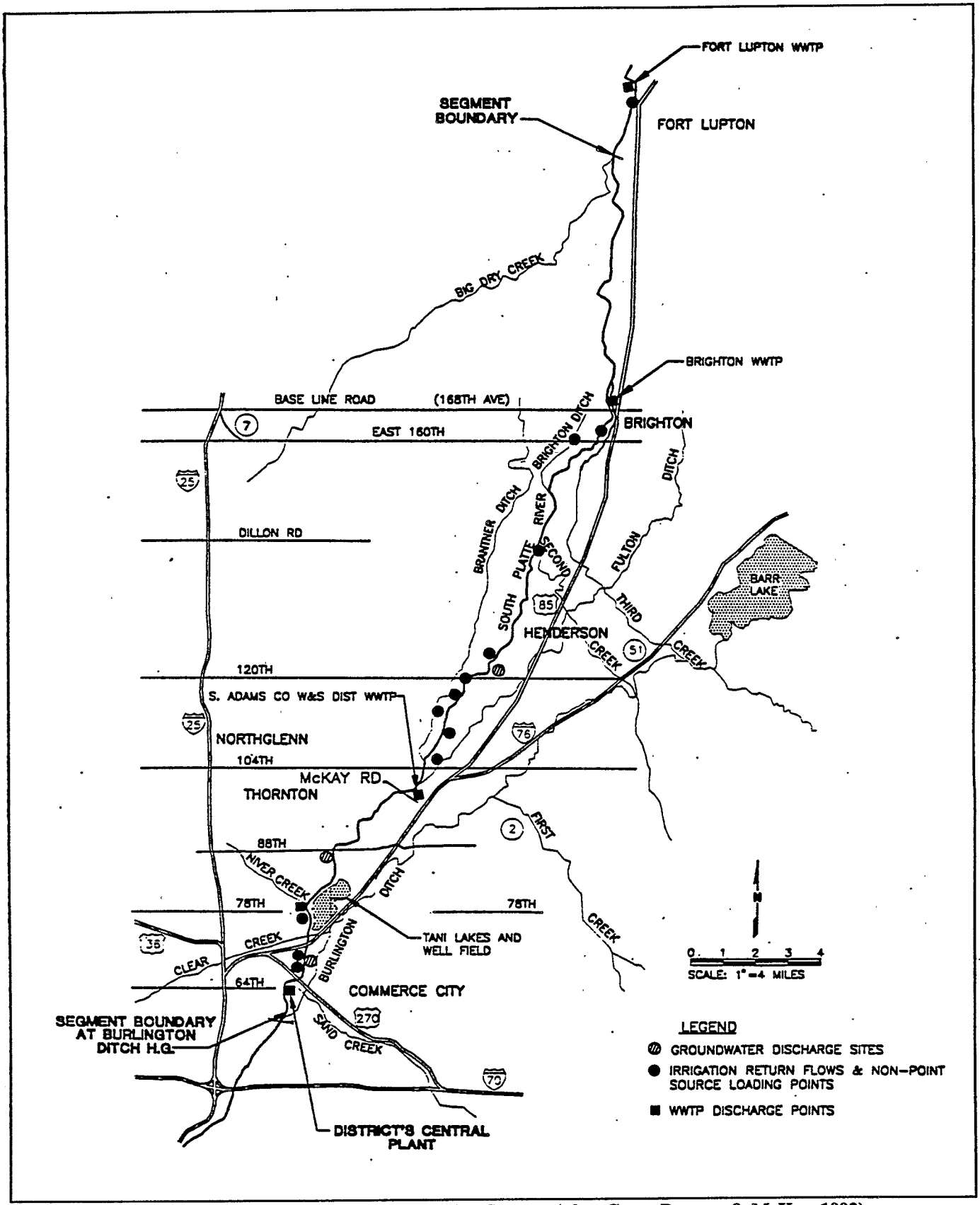

FIGURE 3. Segment 15 Pollution Loading Sources (after Camp Dresser & McKee, 1992)

TMDL DEVELOPMENT — 1986

Determining the Load/Waste Load Allocation Scheme

The objective of a TMDL is to allocate allowable loads among all of the pollutant sources throughout a watershed so that appropriate control measures can be implemented and water quality standards achieved. To do this, EPA Region VIII followed five distinct steps.

The first step taken to develop the TMDLs for Denver Metro was selecting the pollutants to consider. Water quality data for Segment 15 of the South Platte were reviewed to identify existing water quality problems and their probable causes. In 1986, Denver Metro concentrated on ammonia and chlorine toxicity, DO problems, and metals. Ammonia was of particular concern because it contributed to the un-ionized ammonia toxicity and DO problems in Segment 15 of the river (B. Zander, correspondence, May 23, 1991).

The second step taken was to estimate the maximum allowable loading of the pollutant(s) of concern that would not violate water quality standards. The critical flow condition that resulted in the lowest dilution of pollutants was identified as the 7Q10 (the 7-day consecutive low flow, reoccurring every 10 years).

Next, all point and nonpoint sources to Segment 15 were identified and their contributions estimated. Point source discharges along the South Platte and its tributaries include publicly owned treatment works and industrial dischargers (see Figure 4). The Denver Metro District's Central Facility, at the head of Segment 15, is the largest discharger in the area with a design capacity of 185 mgd (287 cfs). The South Adams County Waste and Sanitation District wastewater facility and the wastewater facility for the City of Brighton have design capacities of only 4.3 mgd (6.7 cfs) and 2.6 mgd (4.1 cfs), respectively. Various industrial discharges to the river are also relatively small. Nonpoint source pollution contributions, including ground water inflow, were also estimated. When compared with the discharge from Metro's Central Facility at low flow, however, these other loadings were considered much less significant. For this reason, TMDL development was centered around this facility and the other pollutant sources were considered to be background.

Predictive analysis of pollutants in Segment 15 of the South Platte and determination of total allowable loads were performed using the model and mass balance equations developed for the second step. WLAs for point sources and load allocations for nonpoint sources were developed and are shown in Table 1. The margin of safety (MOS), which is required when calculating a TMDL, was incorporated through the conservative assumptions used during TMDL development. If these conservative assumptions had been deemed insufficient, an additional MOS would have been added as a separate component of the TMDL.

The final step was to determine the limits to be placed on individual pollution sources so that the total loading for each pollutant would be within the specified TMDL. Because the Central Facility was identified as the most significant source of pollutants to Segment 15, the facility was required to upgrade to advanced wastewater treatment. The other municipal facilities in Segment 15 are required to treat only to secondary levels. Best management practices to control nonpoint sources were not recommended.

The WLAs for the Central Facility were incorporated into its NPDES permit. The TMDLs required the Denver Metro Facility to be very near water quality standards at the end of the pipe for many pollutants (e.g., metals and other inorganics) because of the low dilution during critical conditions.

Modeling

To predict stream response to various pollutant loading scenarios, the staff of EPA Region VIII developed STREAMDO, a steady state, one-dimensional water quality model. STREAMDO was used for Section 15 of the South Platte to model dissolved oxygen and un-ionized ammonia. There were numerous advantages to using this model. It was accepted by the regulatory authorities, was not overly complex, and was easily modified and understood. Also, it ran on Lotus 1-2-3, a common spreadsheet software package.

Features of the STREAMDO model included a mass balance approach; subdivision of stream segments; and representative equations for physical, biological, and chemical processes. To determine allowable concentrations for effluent parameters other than biological oxygen demand and ammonia, modelers used a simple mass balance calculation.

STREAMDO was calibrated and verified in 1986 using available historical water quality data. The model coefficients and inputs used to calculate TMDLs for Segment 15 were also based on these data. The TMDLs are presented in Table 1.

FOLLOW-UP

Monitoring

Reporting requirements in the NPDES permit and letters from EPA issued under CWA section 308 required the Central Facility to collect ambient water quality,

TABLE 1. Total Maximum Daily Loads for the South Platte River at the Points of Discharge for Denver Metro

PARAMETER		WASTE LOAD ALLOCATION[a] (e.g., Permit Limit)	LOAD ALLOCATION[a] (Background)	TMDL (lb/day)	WATER QUALITY STANDARD[c] (µg/L)
Arsenic (Total)	lb/day (µg/L)	91.0 (52.0)	5.0 (30.0)	96.0	50.0
Cadmium	lb/day (µg/L)	1.8 (1.0)	0.1 (1.0)	1.9	1.0
Chromium (Hex)	lb/day (µg/L)	47.0 (27.0)	1.0 (8.0)	48.0	25.0
Chromium (Tri)	lb/day (µg/L)	95.0 (54.0)	1.0 (12.0)	96.0	50.0
Copper	lb/day (µg/L)	46.0 (26.0)	2.0 (18.0)	48.0	25.0
Lead	lb/day (µg/L)	46.0 (26.0)	2.0 (14.0)	48.0	25.0
Manganese (Diss)	lb/day (µg/L)	280.0 (160.0)	27.0 (160.0)	307.0	160.0
Mercury	lb/day (µg/L)	0.09 (0.05)	0.01 (0.05)	0.1	0.05
Nickel	lb/day (µg/L)	189.0 (108.0)	3.0 (11.0)	192.0	100.0
Selenium (total)	lb/day (µg/L)	18.0 (10.0)	1.0 (10.0)	19.0	10.0
Silver	lb/day (µg/L)	0.2 (0.10)	0.02 (0.1)	0.2	0.1
Zinc	lb/day (µg/L)	252.0 (144.0)	17.0 (99.0)	269.0	140.0
Nitrite	1000 lb/day (mg/L)[b]	1.8 (1.0)	----------	1.9	1.0 (mg/L)
Nitrate	1000 lb/day (mg/L)[b]	18.0 (10.0)	----------	19.0	10.0 (mg/L)
Ammonia	1000 lb/day (mg/L)	June-Sept. 10.5 (6.0) Oct. 15.8 (9.0) Nov.-Dec. 22.8 (13.0) Jan. 35.0 (20.0) Feb.-Mar. 22.8 (13.0) Apr.-May 15.8 (9.0)	0.5 (3.0) 0.5 (3.0) 0.5 (3.0) 0.5 (3.0) 0.5 (3.0) 0.5 (3.0)	11.0 16.3 23.3 36.0 23.3 16.3	0.1 (mg/L)
Dissolved Oxygen May 1 - July 14 July 15 - Apr. 30	 mg/L mg/L				 5.0 (mg/L) 4.5 (mg/L)
pH	s.u.				6.5 - 9.0 (s.u.)
Total Residual Chlorine	mg/L				0.003 (mg/L)

Based on 210-mgd effluent flow and 20-mgd background flow in the South Platte River.
[a]The load allocation includes loadings from all PSs and NPSs upstream from the permittee's discharge (ΣWLA+ΣLA+MOS=TMDL).
[b]Nitrite and nitrate limits are based on meeting State water quality standards at the end of the pipe.
[c]Site-specific water quality standards in place at the time this TMDL was set.

hydrologic, and biological data to ensure that the facility was complying with its permit, to monitor water quality trends, and to evaluate whether the TMDLs adequately protect water quality and the aquatic community. This monitoring has shown that, while the ammonia toxicity problem appears to have been resolved, low DO concentrations persist in specific sections of Segment 15. This finding has forced EPA to re-evaluate the TMDLs established in 1986 for pollutants that exert an oxygen demand.

Modeling

STREAMDO was used for this re-evaluation using the additional data from the follow-up monitoring. The Colorado Ammonia Model was also incorporated to produce the Segment 15 Water Quality Model (Camp Dresser & McKee, Inc., 1992). This latest round of DO modeling for the South Platte shows that benthic oxygen demand plays a key role in causing excursions below the standard. As a result, more field work is planned to further

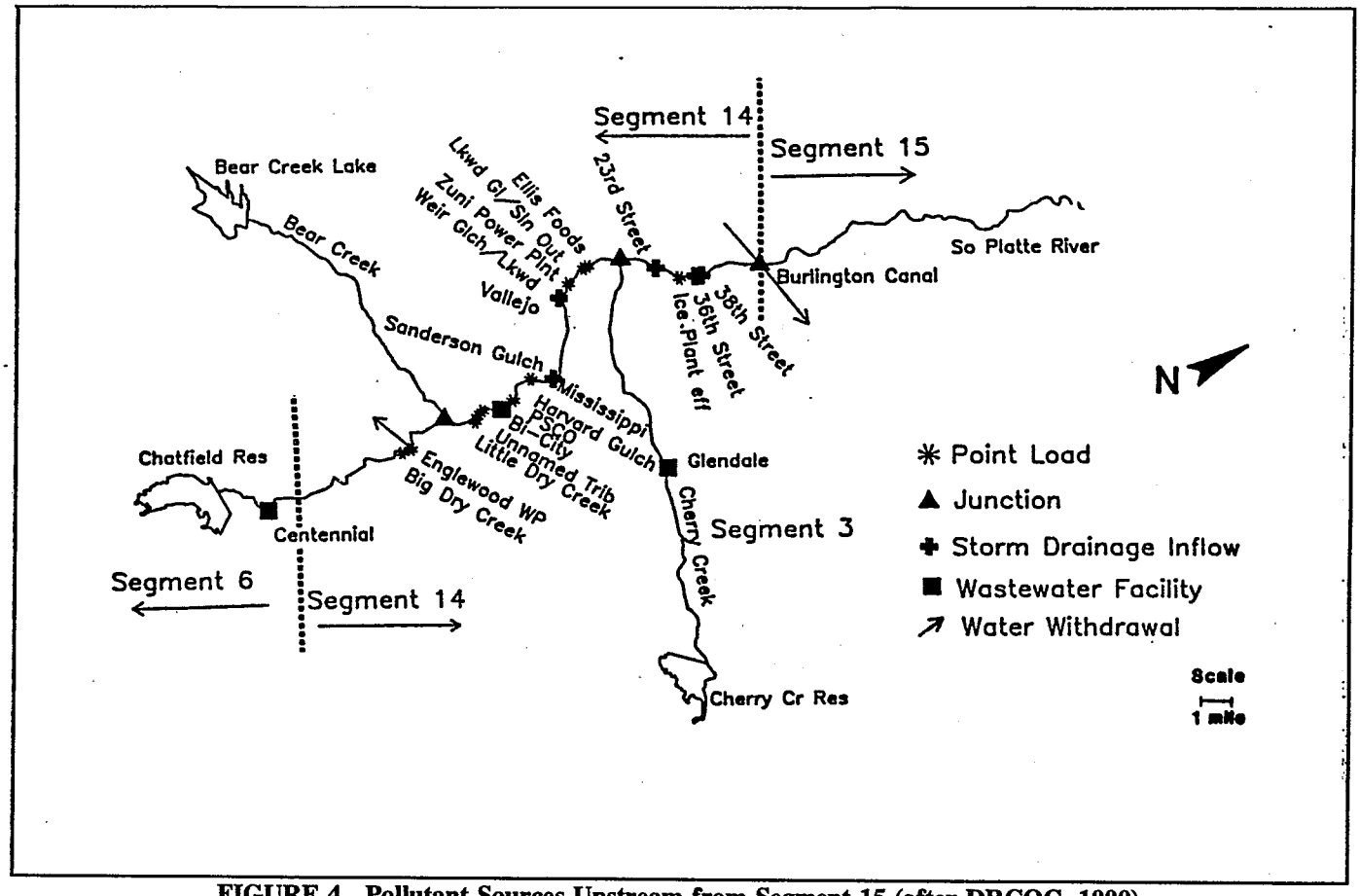

FIGURE 4. Pollutant Sources Upstream from Segment 15 (after DRCOG, 1990)

characterize the link between the quality of Denver Metro's effluent and the benthic oxygen demand. The water quality model, as well as certain TMDLs, will be updated based on information collected this year on the benthic processes.

Although it is anticipated that the TMDLs for several pollutants will change, Metro District has been required to conduct engineering studies on alternative solutions to the DO problem. One solution may involve additional nitrification/denitrification of the effluent of the South Complex of the Central Facility; although the Segment 15 Model indicated this will not necessarily alleviate the DO problem in Segment 15. Modeling also indicated that ponding above the 88th Avenue bridge and at the Fulton Ditch diversion is a major cause of oxygen depletion in the river. As a result, several nontraditional solutions are being examined. Channel restoration to improve natural stream aeration is one possibility. By restoring the river's natural cross-section—alternating riffles and pools to improve reaeration and increase velocities—it is thought that the benthic layer will have much less influence on DO. According to the model, a variety of combinations of improvements at the Denver Metro treatment facility, physical habitat improvements, and artificial reaeration may achieve the specified in-stream DO targets. The artificial reaeration involves an off-channel facility in which water is pumped over a cascade structure in a park setting.

Alternative Pollution Controls

The alternative methods to increase DO along Segment 15 of the South Platte River are currently being ranked and costed by the discharger. The alternatives and their associated costs are presented in Table 2.

Ranking of the alternatives is based on four criteria: (1) implementability and relative magnitude of activity; (2) operatability and reliability; (3) environmental comparability; and (4) public support. Implementability and relative magnitude rates each alternative on the likelihood that the alternative will actually be implemented. At this stage of the screening process, capital and operating costs are not listed as separate criteria, but are considered qualitatively in formulating a rating for this criterion. Operatability and reliability rates each alternative on how easy or difficult it is to operate from the District's standpoint. The evaluation considers the risk that the Metro District would assume in the operation if water quality standards are not met. By necessity, multiple-jurisdiction involvement would be rated at the low end of

TABLE 2. Alternative Methods to Increase DO Concentrations and Facilitate Meeting Water Quality Standards for DO Along Segment 15 of the South Platte River

DESCRIPTION OF ALTERNATIVE	CAPITAL COST ($ Million)	ANNUAL O&M COST ($ K/Yr)
• Nitrification/denitrification facilities for Central Plant's 115-mgd South Complex	72-112[a]	2,000-4,500[a]
• Stream modification above and below 88th Ave. • Effluent dispersal to 3 ditches via ditches	32	630
• Stream modification above and below 88th Ave. • Effluent dispersal to 3 ditches via pipeline	44	480
• Stream modification above and below 88th Ave. • Artificial reaeration at 168th Ave.	32	670
• Stream modification above and below 88th Ave. • Artificial reaeration at 168th Ave. • Effluent dispersal to 2 ditches via ditches	52	1970
• Stream modification above and below 88th Ave. • Artificial reaeration at 168th Ave. • Effluent dispersal to 2 ditches via pipeline	59	840
• Stream and drop structure modification at 88th Ave. • Artificial reaeration below 88th Ave. • Artificial reaeration at 168th Ave.	56	880
• Filter all Metro effluent • Chlorination/dechlorination	102	3,950
• Stream modification above and below 88th Ave. • Nitrify South Complex effluent to 5 mg/L (NH_3-N) • Chlorination/dechlorination	114	4,636

[a] 1989 cost.

the scale. Environmental comparability ratings are based on an alternative's ability to enhance land use, surface water quality, and fish and wildlife habitat, as well as air quality considerations. Public support is the most subjective of all the criteria. Under this criterion each alternative is rated on its ability to provide additional community benefits and to garner support from a high percentage of the surrounding community.

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This case study prepared by Tetra Tech, Inc., Fairfax, VA in conjunction with USEPA, Watershed Management Section, Office of Wetlands, Oceans, and Watersheds, and Region VIII.