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CHERRY CREEK BASIN

WATER QUALITY AUTHORITY

1991 Annual Report

Authority Members:

Arapahoe County
Arapahoe Water and Wastewater Authority
City of Aurora
Cottonwood Water & Sanitation District
Denver Southeast Suburban Water & Sanitation District
Douglas County
City of Greenwood Village
Inverness Water & Sanitation District
Meridian Metropolitan District
Parker Water & Sanitation District
Stonegate Center Metropolitan District
Town of Castle Rock
Town of Parker

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NOTE: Portions of this report were excerpted from the "Cherry Creek Basin Annual Water Quality Monitoring Report; 1991" Advanced Sciences, Inc. 1992.

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1991 ANNUAL REPORT SUMMARY

Executive Summary

In 1984 the Colorado Water Quality Control Commission established a standard of 0.035 mg/1 phosphorus for Cherry Creek Reservoir based upon the assumption that if this standard were met chlorophyll a levels in the Reservoir would not exceed 15 ug/1, a level considered acceptable for recreational use of lake waters.

The Cherry Creek Basin Water Quality Authority ("Authority") is the 208 management agency for the Cherry Creek Basin ("Basin"). The Authority operates pursuant to special legislation, which created and authorized the Authority to undertake activities and impose controls for water quality purposes. See Section 2-8.5-101, et seq., C.R.S. The Authority also carries out special responsibilities in the Cherry Creek Basin, as provided by the Cherry Creek Control Regulation. See 5 C.C.R. 1002-19 (1985). The Authority oversees point source and nonpoint discharges in the Basin, conducting water quality monitoring, implementing plans to improve the water quality of Cherry Creek Reservoir and the upstream Basin, and has undertaken technical studies and research to define and characterize the Reservoir. This annual report is a summary of the Authority's 1991 activities pursuant to its plans to satisfy requirements of the Cherry Creek Control Regulations.

Shop Creek Drainage Water Quality Project.

The Authority, in cooperation with the City of Aurora, constructed the Shop Creek Project in 1989. The Master Plan (1985) reported that Shop Creek was a major contributor of nonpoint source phosphorus loads to the Reservoir. The Shop Creek Project consists of channel stabilization, a detention facility with infiltration followed by a series of wetlands. The Authority established three monitoring sites in 1990 to monitor the effectiveness of phosphorous removal. Those sites are upstream of the project, below the detention pond and downstream of the wetlands, and have been successfully operated for two years. The combined 1990 and 1991 monitoring results indicate the phosphorous removal efficiency of the pond to be 43 percent and that of the wetlands to be 30 percent and an overall two year removal efficiency of 60%. With only two years of data, removal efficiencies are considered preliminary.

In addition to monitoring funded by the Authority, the Urban Drainage and Flood Control District (UD&FCD) separately funded the monitoring to determine removal efficiencies of other non-point source constituents. The results of this additional monitoring are reported in Appendix A.

Baldwin Pond Water Quality Project

The Colorado Department of Transportation agreed to construct a demonstration "dry land treatment" water quality project to mitigate for water quality impacts associated with widening of State Highway 83. The Authority provided design, project review and technical assistance.

The project designed in 1991 will consist of a constructed pond of approximately 0.7 acres, with a phosphorous and sediment removal media consisting of clay soils planted with fescue grass. The soils/grass phosphorous removal and uptake system overlays a system of perforated pipes which collect the filtered water and discharges downstream of the pond.

The "dry land" system will treat run-off from a 14 acre developed subdivision and 100 acres of open space consisting of dry land vegetation. Construction is scheduled for the spring of 1992.

It is anticipated that this pilot project of "dry land treatment" may be a viable phosphorous removal technique for intermittent flow tributary streams.

NonPoint Source and Bulk Precipitation

Nonpoint source loadings to the Reservoir during 1991 were 1,620 pounds of phosphorous and 24,600 pounds of nitrogen. Bulk precipitation loadings contributed 2,030 pounds of phosphorous. The annual bulk precipitation has continually exceeded the DRCOG 1982 estimate of 690 pounds and is a major source of uncontrolled phosphorous.

Considering the critical annual phosphorous loading of 14,270 pounds, and an allocation for nonpoint sources of 10,290 pounds, the 1991 nonpoint loading of 1,620 pounds is 15.7 percent of the allowable which indicates substantial compliance with the 50% reduction criteria. Note: The original master plan and background studies projected the nonpoint source phosphorous contribution to be 20,500 pounds in the year 2000, assuming normal development.

Control Options

In 1991 the Authority continued an evaluation of the effectiveness of impeding algal growth by reducing the in-reservoir phosphorous concentration levels; average 1987 through 1991 of 0.072 mg/l phosphorous compared to the standard of 0.035 mg/l. The options reviewed were: (1) Sedimentation Ponds and Wetlands located on Cottonwood Creek and Lone Tree, Dove Creek, Windmill drainages, (2) Reservoir Dredging, and (3) Precipitation of phosphorous by alum addition. These options had been previously identified by a consultant study as being potentially effective in reducing phosphorous inflow and in-reservoir phosphorous levels.

Of the three alternatives, only one may be cost effective and technically feasible - Sedimentation Ponds and Wetlands. Controlled experiments using alums to precipitate phosphorous were conducted with the results being inconclusive due to the small scale of the experimentation and side effects which may be detrimental to aquatic life. Dredging was discarded due to the extremely high cost, $6.0 million, and the problem of sludge disposal.

The study, Camp, Dresser & McKee, November 1990, proposed sedimentation ponds and wetlands on the Cottonwood Creek Drainage, immediately upstream from the reservoir pool. Concurrent with the Authority study on Cottonwood Creek wetlands, the Urban Drainage and Flood Control District is developing a detention/water quality master plan for the entire Cottonwood drainage basin and the Lone Tree, Dove Creek, and Windmill Drainage Basins. The Authority is coordinating with Urban Drainage and other agencies on the feasibility of joint venture funding of water quality improvements in these two major drainage basins.

Data Evaluation

In 1991 the Authority contracted with Advanced Sciences, Incorporated to accumulate into a single document and onto computer discs all known data, approximately 350,000 data points, collected by the Authority and others beginning in 1982. Upon completion of the data project the Authority sponsored a seminar in Denver, Colorado inviting recognized limnologists to review the information and offer general comments concerning the overall characteristics of the reservoir, on-going monitoring programs, Best Management Practices, and the basin-wide management plan.

The Authority has contracted with the University of Missouri, principal investigator Dr. John R. Jones, to further review the data and offer monitoring and basin-wide management recommendations. As part of this contract the University of Missouri will conduct in-reservoir experiments during the summer of 1992.

Point Source Phosphorous Contributions

The Cherry Creek Control Regulation allocates 2310 pounds of phosphorous annually to the seven in-basin wastewater treatment plants. Total 1991 contributions were 2,405 pounds.

Cottonwood Water and Sanitation District reported a total contribution of 454 pounds, exceeding its allocation of 213 pounds by 241 pounds. Cottonwood is making arrangements to substantially reduce operations at its treatment plant and transfer the wastewater and associated phosphorous allocations to Arapahoe Water and Wastewater Authority for treatment and disposal; except for a small land application site at E-470 greenbelts.

Denver Southeast Suburban Water and Sanitation District had a total contribution of 1614 pounds, exceeding its allotment of 365 pounds by 1249 pounds. 1,586 pounds were contributed in the months of January, through March, 1991; before bringing its new plant into operation. For the balance of the year, April through December, the District contributed 29 pounds of phosphorous.

Parker Water and Sanitation District contributed 91 pounds; 17% of its allocation. Inverness, Stonegate and Meridian had no discharges during 1991.

1991 Monitoring Program

Following is an outline of the 1991 Monitoring Program:

1. Inflow/Outflow Monitoring

   During 1991 a total of 21 storm-runoff samples were collected at inflow sites, Cherry Creek, Shop Creek, and Cottonwood Creek. Two reservoir outflow samples were collected and analyzed.

2. Shop Creek System (Pond and Wetlands)

   A total of 26 samples from 14 storm events were collected at the Shop Creek Pond and Wetlands System. In addition 4 ambient samples (non-storm related) were collected at the pond inflow and outflow. The average phosphorous removal for the pond only was approximately 43 percent. The downstream wetlands had a removal efficiency of 30 percent, for a total system phosphorous removal of approximately 60 percent.

3. Reservoir Inflow/Outflow/Phosphorous/Nitrogen

   A total of 32 inflow/outflow samples were collected. Utilizing Reservoir inflow/outflow records of the U.S. Army Corps of Engineers, inflow was 2,320 acre-feet; whereas outflow was 1,646 acre-feet. Annualized loadings associated with these flows was 1,620 pounds of phosphorous and 24,600 pounds of nitrogen.

4. Phosphorous/Chlorophyll-a Relationship

   During the 1991 growing season (July through September) the average concentration of phosphorous was 109 ug/l with a corresponding average chlorophyll-a of 9.8 ug/l. The water quality standards established by Control Regulations are 35 ug/l for phosphorous and 15 ug/l of chlorophyll-a. During the 1991 growing season, no blooms of blue-green algae were apparent. The larger heterocystic blue-green algae, which obtain nitrogen

directly from the atmosphere, were absent during the 1991 growing season.

Conclusion

The Colorado Water Quality Control Commission adopted a phosphorus standard of 35 ug/L for Cherry Creek Reservoir to ensure compliance with a seasonal mean algal chlorophyll value of 15 ug/L. This standard was based on the assumption that algal growth in the reservoir is limited by the element phosphorus and that algal biomass will respond to increases or decreases in the phosphorus content of the waterbody (Jones and Bachmann 1976). This standard presumes that the relation between algal chlorophyll and in-lake phosphorus, as a ratio, is 0.4 (15 ug/L chl / 35 ug/L TP = 0.4). This is consistent with the then (1984) limnological research demonstrating that, on the basis of the seasonal mean, the chlorophyll-to-phosphorus ratio (Chl:TP) in most temperate lakes of moderate fertility ranges between 0.3 and 0.5.

Limnological monitoring of Cherry Creek Reservoir has documented the following conditions:

Year	Phosphorus as ug/l	Chlorophyll a as ug/l	Ratio of Chl:TP
Adopted Std	35	15.0	0.42
1982	30	10.7	0.36
1984	74	15.3	0.21
1985	63	4.2	0.07
1986	62	4.0	0.06
1987	95	8.3	0.09
1988	50	32.0	0.64
1989	45	5.6	0.12
1990	59	8.6	0.15
1991	109	9.8	0.09

Data indicates that the relation between algal chlorophyll and total phosphorous in Cherry Creek Reservoir has not been constant over time. Conditions were typical of a temperate waterbody in 1982 (Chl:TP ratio of 0.36) and support the assumptions underlying the phosphorus standard set for this waterbody. Since 1982, however, the phosphorus standard has been exceeded each year and the target chlorophyll value of 15 ug/L has been matched once (in 1984) and exceeded once (in 1988). During the years 1984-1987 and 1989-1991 the Chl:TP ratio was low relative to the norm for temperate lakes; ranging between $\leq$ 0.1 and 0.15.

Collectively, limnological data from Cherry Creek Reservoir show that the relation between phosphorus and algal chlorophyll is not constant from year to year and that algal chlorophyll does not necessarily increase or decrease in response to changes in the phosphorus content of the lake.

CHERRY CREEK BASIN WATER QUALITY AUTHORITY
1991 ANNUAL REPORT

Background

The Clean Lakes study of Cherry Creek Reservoir conducted in 1982 identified that eutrophication of the Reservoir could negatively impact the beneficial uses of the Reservoir (DRCOG, 1984). The Clean Lakes Study identified phosphorus as the major nutrient causing algal productivity and subsequent eutrophication. Based on the Clean Lakes Study, the Colorado Water Quality Control Commission (CWQCC) established an in-reservoir total phosphorous standard of 0.035 mg/l to maintain the chlorophyll *a* levels in Cherry Creek Reservoir at concentrations no higher than 15 ug/l (0.015 mg/l) as an average for the "growing season" (July through September).

During 1985, the local governments (cities and counties and special districts), private interests, and representatives of the State and Federal Government developed a strategy to meet the Reservoir growing-season phosphorus standard and chlorophyll *a* goal. The control strategy was outlined in the Cherry Creek Basin Water Quality Management Master Plan (DRCOG, 1985).

The Cherry Creek Basin Mater Plan was approved by the Colorado Water Quality Control Commission in 1985. Portions of the plan were adopted as the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.0, 5 C.C.R. 3.8.11), and effective December 30, 1985. The Master Plan was approved by the USEPA Region VIII office as the 208 Management Plan for the Cherry Creek Basin.

In 1985, an intergovernmental agreement was executed by the local governments within the Cherry Creek Basin, forming the Cherry Creek Basin Water Quality Authority (Authority). The Authority was created to develop and implement the means to protect the water quality of Cherry Creek, while allowing economic development to occur.

In 1987, the Colorado Legislature's Water and Water Quality Subcommittee conducted hearings on legislation to create a water quality management agency for the Cherry Creek Basin. Legislation was introduced at the 1988 General Assembly which statutorily created and empowered the Cherry Creek Basin Water Quality Authority.

Purpose of the Annual Report

The primary purpose of the 1991 Annual Report Summary is to inform the Colorado Water Quality Control Commission (CWQCC) of the Authority's progress in implementing the Master Plan during 1991. Also, the "Regulations for Control of Water Quality in Cherry Creek Reservoir" (Section 4.2.8, 5 C.C.R. 1002-19) require that an annual report phosphorus control strategies, be submitted. The purpose of this 1991 Annual Report Summary is to fulfill those requirements.

I. 1991 LOADINGS, WATER QUALITY AND FLOW INFORMATION.

A. Point Sources.

1. 1991 Annual Loadings.

The "Regulations for Control of Water Quality in Cherry Creek Reservoir" established annual phosphorous allocations for each wastewater treatment plant in the Cherry Creek Basin. The phosphorus allocated to each plant was expected to be adequate for the wastewater treatment plant's 1985 capacity plus the next incremental expansion for the plant. The original Control Regulation established maximum phosphorous concentrations for dischargers at 0.1 mg/l for October through March and 0.05 mg/l for April through September. Effective May 30, 1991 the Control Regulation was modified to require dischargers to produce an effluent phosphorous concentration level not to exceed 0.2 mg/l on an annual basis. Further, the annual pounds allocated could not be exceeded. The hydraulic capacity of each treatment plant would be determined utilizing the concentrations and total annual poundage criteria. This modification allowed the Authority to better focus on the nonpoint source control of phosphorous.

The Master Plan designates the type of wastewater treatment for each facility. In 1991, three dischargers were using secondary treatment followed by rapid infiltration and four dischargers were using secondary treatment with slow rate land application. Denver Southeast Suburban Water & Sanitation District, one of the three dischargers using rapid infiltration, completed construction of an advanced waste treatment facility, which become operational in May 1991.

The NPDES permits for all dischargers require monitoring of the phosphorus discharged. Dischargers utilizing rapid infiltration basins have established groundwater monitoring wells downgradient of the basin to monitor phosphorus concentrations.

To monitor phosphorus concentrations from slow rate land application sites, dischargers have installed vacuum lysimeters below the land application areas to withdraw leachate samples for phosphorus analysis. However, dischargers land applying effluent at agronomic rates frequently do not report any leachate in the lysimeters because the effluent is fully utilized by plants uptake and evapotranspiration.

The discharge of new phosphorus occurring from point source dischargers would be determined by subtracting the phosphorus levels detected in the samples obtained from background levels. Soils in the basin commonly contain significant levels of phosphorus, therefore phosphorus may be leached from the soil during land application. Currently, however the present loading calculations include background phosphorous. The Authority and the Division have discussed the possibility of excluding phosphorous within the soil and groundwater from the sample results reported pursuant to an NPDES permit, but at this time the Authority and the Division have been unable to develop an appropriate procedure.

Phosphorus loadings from the operating treatment facilities are calculated by the Water Quality Control Division from the dischargers' monthly reports. Table 1 presents the phosphorus loadings for each wastewater treatment plant, discharging during 1991. The phosphorus allocations for each wastewater treatment plant are also listed.

2. Site Applications/Permits

The Authority is responsible for reviewing all site applications, compliance schedules, and permits for wastewater treatment plants within the basin to ensure compliance with the Master Plan. The Authority's technical review committee reviews each application and recommends point source and nonpoint source controls, as appropriate, to the Authority. The following actions were taken by the Authority in 1991 regarding point source discharges:

a) The Authority recommended to the Division that the Denver Southeast Suburban Water and Sanitation District be relieved of the requirement to test effluent for industrial volatile organic solids because the influent is 100 percent domestic wastewater.

b) The Authority proposed to the Division and Commission that the criteria for discharge phosphorous concentrations be modified from 0.1 mg/l (October - March) and 0.05 mg/l (April - September) to a 30 day average not to exceed 0.2 mg/l throughout the year. The recommendation was adopted by the Commission with the added stipulation that individual plant

hydraulic capacity may be redetermined using the 0.2 mg/l criteria in order that total annual phosphorous allotment would not be exceeded.

c) The Authority recommended approval by the Division of an application by Parker Water and Sanitation District to include the following land application areas in its discharge permit:

- 25 acre polo field
- 3.75 acre medical center landscape
- Highway Greenbelt at Parker Road and E-470

d) The Authority recommended approval of an application by Cottonwood Water and Sanitation District to exchange an approved land application area at the Cottonwood Park for the same acreage at the E-470 Tollgate Plaza.

e) The Authority recommended to the Division that Cottonwood Water and Sanitation District be granted an emergency phosphorous allocation of 172 pounds for 1991.

f) The Authority approved an application by the Parker Water and Sanitation District to increase its land application area by 120 acres.

TABLE 1

POINT SOURCE PHOSPHORUS LOADINGS IN THE CHERRY CREEK BASIN
1991

Wastewater Facility	1991 Annual Average Wastewater Phosphorus Concentration mg/l	1991 Phosphorus Loading (lbs/yr)	Allocated Phosphorus Loading (lbs/yr)
Discharging Plants:			
Arapahoe	0.417	246	354
Cottonwood	1.663	454	213
Denver Southeast (2)	1.264	1614	365
Inverness (4)	0.00	0	68
Meridian (4)	0.00	0	114
Parker	0.087	91	533
Stonegate (4)	0.00	0	53
Plants Not Discharging:			
Castle Rock (Cherry)		0	21
Castle Rock (McMurdo)		0	64
Castle Rock (Newlin)		0	86
Rampart Range		0	160
Castle Rock (Mitchell)		0	128
Totals	3.431 (1)	2405	2,159 (3)

1) Flows and phosphorous loading for 1991 were calculated by the Water Quality Control Division from each discharger's monthly report and revised or verified by each discharger.

2) The facility at Denver Southeast Suburban Water and Sanitation District was allocated 365 pounds of phosphorus annually. The 365 lb phosphorus allocation was temporary and was reduced to 213 lbs of phosphorus when Denver Southeast completed construction of their 1.4 MGD AWT facility. Size of the Denver Southeast Suburban Water and Sanitation District Plant was reduced to 1.0 MGD facility which became operational on March 19, 1991. For the months of April through December phosphorous loading was 28.46 pounds for an average concentration level of 0.0265 mg/l.

3) Section 4.2.4(1), 5 C.C.R. 1002-19.

4) The facilities at Inverness, Meridian and Stonegate use slow rate land application and did not report leachate in their lysimeters.

B. Nutrient Inflow Characteristics from Reservoir Tributaries.

1. 1991 Loadings

The locations for water quality monitoring in the Cherry Creek Basin are shown on Figure 1. The storm event and ambient water quality analyses for 1991 at the Reservoir inflow and outflow sites were modeled and regression summaries relating concentrations of nutrients with streamflow were updated. These updated regression analyses were applied using the appropriate daily streamflow record to generate daily and annualized loadings total phosphorus and total nitrogen. The annualized tributary inflows to Cherry Creek Reservoir from the three inflow monitoring sites totalled 3,280 acre feet as compared to an annualized flow of 6,700 acre feet for 1990.

For 1991, the annualized nutrient loadings to Cherry Creek Reservoir totalled 1,620 pounds of phosphorus and 24,590 pounds of nitrogen, respectively.

2. Comparison to Previous Loadings.

Table 2 outlines annualized flows and loadings for the 1982 base year, that upon which the Control Regulation was established, and the years 1987 through 1991.

TABLE 2

INFLOW NUTRIENT LOADINGS

Source	Year	Annualized Inflows(acft)	Annualized Total Phosphorus (lbs)	Annualized Total Nitrogen (lbs)
DRCOG	1982[1)]	1,090	4,360	n.a.
In-Situ	1987[2)]	10,960	7,950	65,680
In-Situ	1988[3)]	8,960	9,520	72,270
ASI	1989[4)]	7,080	7,110	66,750
ASI	1990[4)]	6,700	3,720	39,310
ASI	1991[4)]	3,280	1,620	24,590

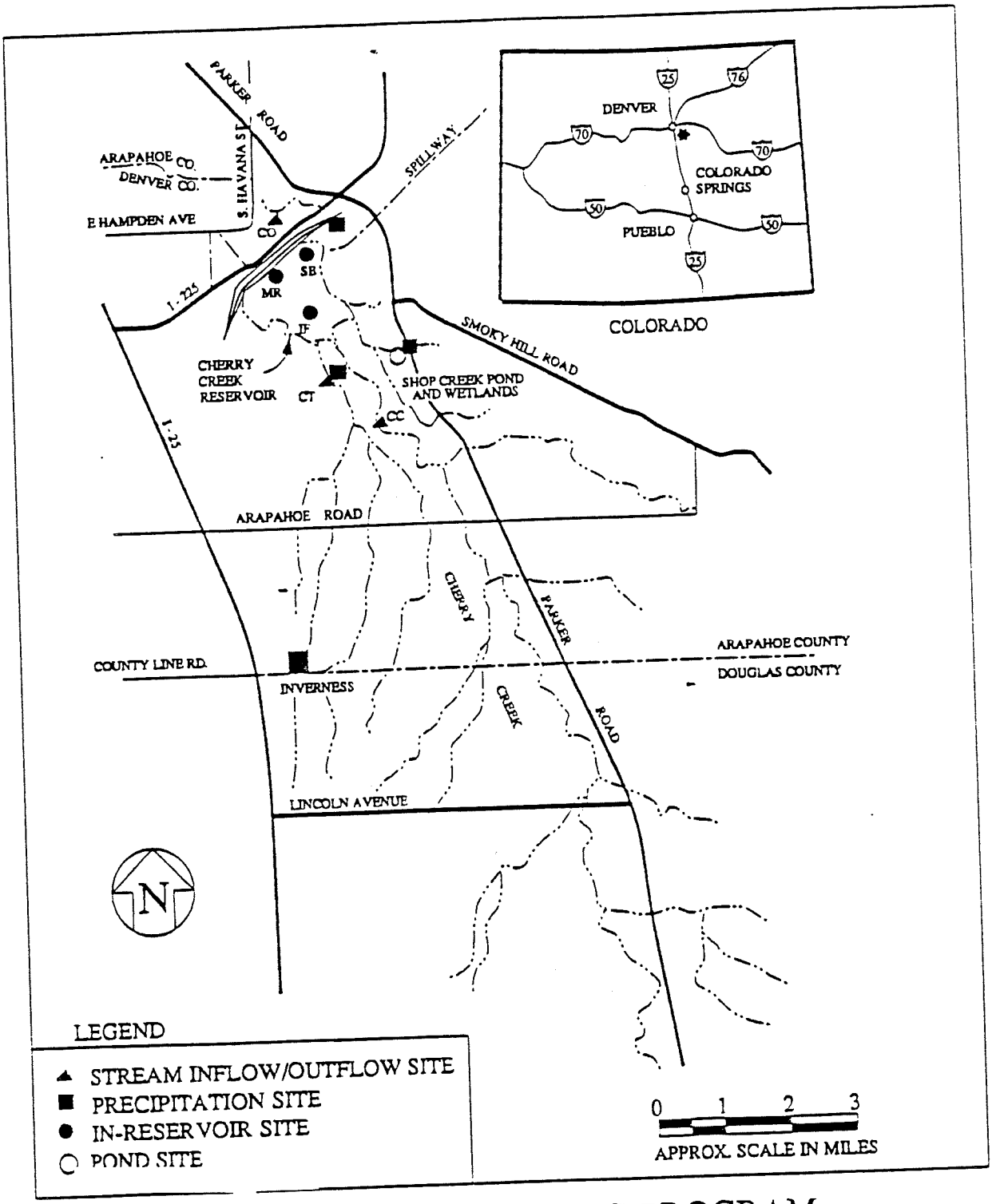
1) Calendar Year (January through December).

2) Water Year (October through September), with October through April extrapolated.

3) Water Year (October through September), with no missing months.

4) Water Year (October through September), with October through March extrapolated.

FIGURE 1



GENERAL MONITORING-PROGRAM
SAMPLING LOCATIONS

3. Bulk Precipitation

Bulk precipitation, wet fall and dry fall, falling on Cherry Creek Reservoir has been identified as a contributor of phosphorous. Phosphorous entering the Reservoir in this manner is attached to airborne dust which settles on the reservoir, may be stripped by rainfall from the atmosphere, or may be naturally occurring in the rainfall. The magnitude of bulk precipitation is dependent upon such factors as wind speed and direction, quantity of airborne dust and intervals between rainfall events.

During 1991 an estimated 16.5 inches of precipitation fell directly on the Reservoir, with an average total phosphorous concentration of 0.61 mg/l yielding a total phosphorous loading of 2,030 pounds.

The monitoring and sampling techniques to determine bulk precipitation contributions are imprecise; a catchment of 0.2 square feet compared to a reservoir surface area 850 acres.

Table 3 lists the historical contributions of phosphorous and nitrogen due to bulk precipitation.

TABLE 3
BULK PRECIPITATION

Source	Year	Precipitation[1] (in)	Total P (mg/L)	Total Annual P (lbs)[4]
DRCOG	1982[2)]	18.54	n.a.	690
In-Situ	1987[3)]	18.08	0.47	1,640
In-Situ	1988[3)]	23.30	0.42	1,880
ASI	1989[3)]	13.04	0.30	750
ASI	1990[3)]	15.24	0.65	1,910
ASI	1991[3)]	16.50	0.61	2,030

1) As measured at Cherry Creek Dam for the period shown.
2) Calendar Year (January through December).
3) Water Year (October through September).
4) Calculated as the loading over the 850 acres of Cherry Creek Reservoir surface area.

C. In-Reservoir Water Quality.

1. 1991 In-Reservoir Concentrations.

Three sites in Cherry Creek Reservoir have been sampled to assess temporal as well as spatial changes in water quality and biological conditions - one site each in the main body, swim beach, and Cherry Creek inflow. (See Figure 1.) All in-reservoir sampling surveys for 1991 were conducted by boat during open-water conditions. At each Reservoir sampling site, two sets of water quality samples are collected each time; samples are taken; one set is obtained from the middle of the euphotic zone (the depth is estimated using a secchi disk) and a second set is obtained near the Reservoir bottom (1 to 1-1/2 feet above the Reservoir bottom).

Average phosphorous concentrations for the 1991 growing season for all in-reservoir sampling was 0.109 mg/l, or 3.1 times the 0.035 mg/l standard. Chlorophyll a concentrations for the same period averaged 9.7 mg/l, or 67% of the 15 mg/L standard. In general no algal blooms were observed during the 1991 water year.

1991 nitrogen concentrations averaged 0.88 mg/l.

2. Phosphorous/Chlorophyll a Relationships.

The Clean Lakes Study, DRCOG 1984, utilized the Jones/Bauchman model (1976) to predict the anticipated relationship between phosphorous and chlorophyll a which would exist in the reservoir.

Figure 2 shows the Jones/Bachmann relationship for the years 1982 (adopted standard) through 1991. Except for 1983, no monitoring performed, the plotting of individual years results indicates that for all years except 1988 chlorophyll a levels were substantially less than anticipated given the concentrations of total phosphorous.

II. Nonpoint Source Control and Management

A. Shop Creek Pond/Wetlands System

1. Authority Monitoring

The Shop Creek Pond/Wetlands system is located immediately west of Parker Road and south of Quincy Avenue in the City of Aurora. The dual purpose Drainage/Water Quality Project was jointly funded by the Authority and the City of Aurora, with the Authority reimbursing Aurora for the costs of water quality features. The Authority considers the system to be a

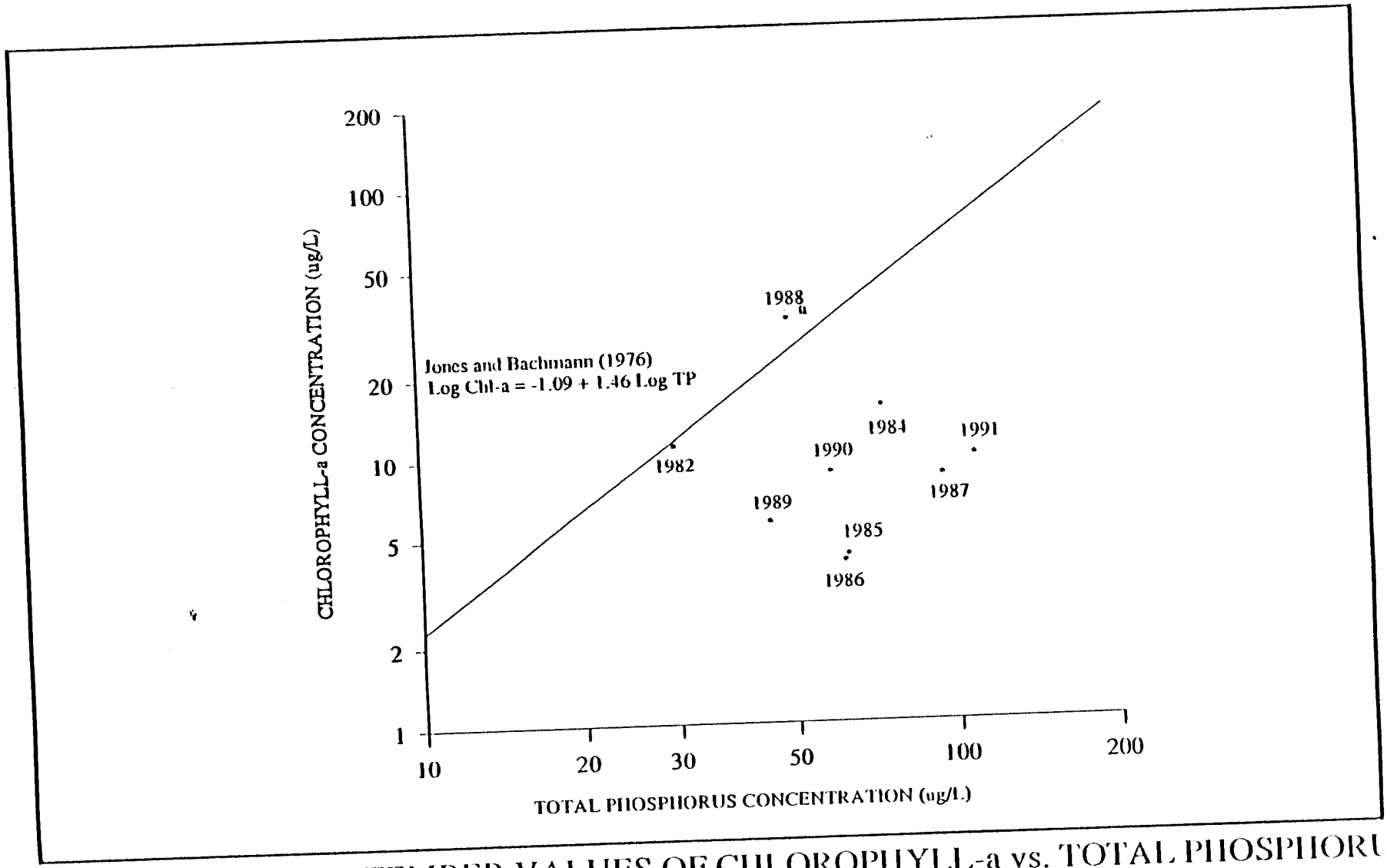


FIGURE 2

JULY THROUGH SEPTEMBER VALUES OF CHLOROPHYLL-a vs. TOTAL PHOSPHORUS
CHERRY CREEK RESERVOIR 1984 - 1991

demonstration project and as such has undertaken extensive monitoring of water quality parameters and removal efficiencies.

Shop Creek is directly tributary to the Reservoir. The Pond was constructed to optimize the capture of phosphorous during storm events by trapping fine sediments which are associated with suspended phosphorous. The Pond has a contributing drainage area of 640 acres, a storage capacity of 9.2 ac ft of which 4.8 ac ft is permanent storage, a surface area of 1.8 acres and a mean depth of 5.1 feet.

Three monitoring sites have been established; S-1, upstream of the pond, S-2 downstream of the pond, and S-3 downstream of the wetlands. The wetlands consists of native willows, cattails, and other plantings which provide sediment entrapment and uptake of phosphorous. Figure 3 identifies locations of the Shop Creek Project sampling sites.

Table 4 reports the pond/wetland system monitoring data for 1990 and 1991.

During 1990 and 1991 approximately 57% of the mass of the total phosphorous entering the pond was transmitted through the pond to become inlet loading to the wetlands for a removal efficiency of 43%. Approximately 70% of the phosphorous entering the wetlands is discharged to the reservoir, for a 30% efficiency. The overall system removal efficiency is 60%. However, it must be realized that the reported efficiencies are dependent upon the concentration levels, rate of water flow-through and the magnitude of storm events. Smaller water flows have a greater removal rate. Since monitoring results and associated efficiencies are based on factors which can vary widely, the results are considered preliminary and will become more reliable as the on-going monitoring program is continued and a long-term history developed.

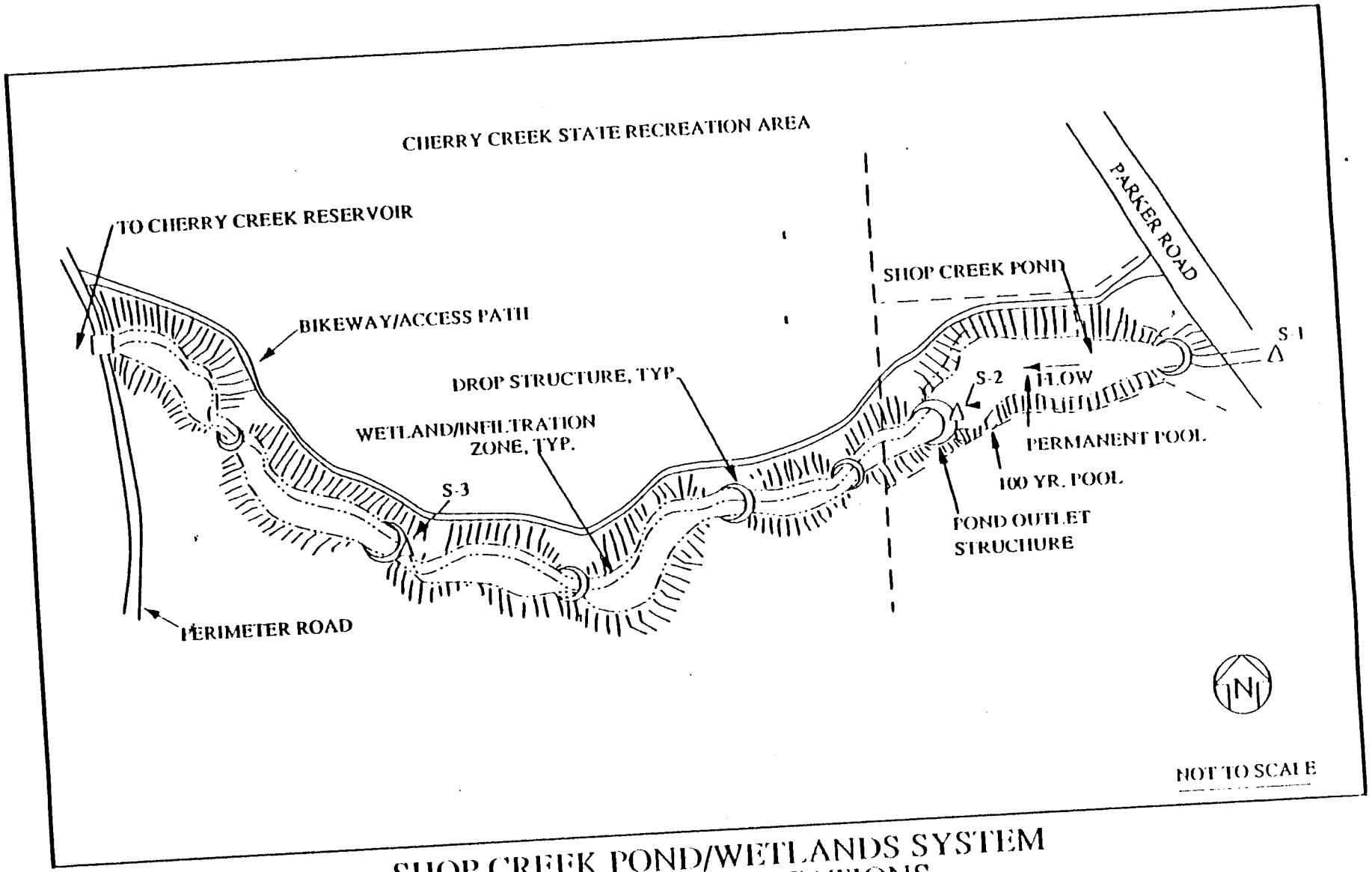


FIGURE 3

SHOP CREEK POND/WETLANDS SYSTEM MONITORING LOCATIONS

TABLE 4
SHOP CREEK MONITORING DATA
Phosphorous - Nitrogen - Suspended Solids
mg/l

Site	Year	Total P	Dissolved P	Total Ortho P	Dissolved Ortho P	Suspended Solids
S-1	1990	.46	.23	.24	.17	160
	1991	.32	.19	.13	.11	74
S-2	1990	.28	.17	.18	.14	37
	1991	.21	.14	.13	.10	21
S-3	1990	.19	.13	.13	.10	21
	1991	.30	.09	.07	.06	22

Site	Year	Nitrite	Nitrate	Kjeldahl N Phosphorous
S-1	1990	0.09	1.98	2.21
	1991	0.03	1.85	(1)
S-2	1990	0.09	2.34	2.13
	1991	0.06	2.30	(1)
S-3	1990	0.09	2.38	1.32
	1991	0.10	2.04	1.79

2. Urban Drainage and Flood Control District Shop Creek

In addition to monitoring of the Shop Creek Project funded by the Authority, the Urban Drainage and Flood Control District (UD&FCD) in cooperation with Authority and its consultants, funded certain additional monitoring. Appendix A is an Executive summary provided by UD&FCD.

B. Best Management Practices.

The methods established for the control of nonpoint source pollution are outlined by Best Management Practices (BMP), designed to prevent erosion and pollution from new and specific ongoing activities. Land use entities in the Cherry Creek Basin including the Towns of Castle Rock and Parker, the City of Aurora, Greenwood Village, and Arapahoe County have enacted BMP ordinances that require hay bales, rip rap drains, and other facilities to minimize sediment laden runoff from discharging into Cherry Creek tributaries. All development within the land use entities have included these control measures in their development procedures and criteria. Douglas County, the other major land use jurisdiction within the basin, has adopted Chapter 70 of the Uniform Building Code which addresses erosion control measures. These BMPs are believed to provide substantial controls and reductions of phosphorus loadings into the Cherry Creek Reservoir.

Major 1991 projects for which BMP's were required included widening of State Highway 83 and construction of a new road between Centennial Airport and Jordan Road. The Authority has specifically required that the entities responsible for construction of these highways implement and enforce their Best Management Practices.

C. On-Site Disposal System

In 1987 the Authority contracted with the Tri-County Health Department to provide an evaluation of present and future on-site septic tank phosphorous loadings to Cherry Creek Reservoir. The evaluation was based on a literature search and data relative to basin soils, geology and hydrology. The study concluded that the existing 3200 septic systems are a source of phosphorous; however, given the soils, geology, hydrology and construction regulations, existing systems are believed to achieve a high level of phosphorous removal; well below the 450 pounds allocated. The study also identified several potential Management Practices which may improve phosphorous removal and retention. Recommendations included the following:

1. Dosing to provide an equal distribution in the leach fields.

2. Increasing the separation between the bottom of the leach field and the top of the water table.

3. Use selected soils for leach field construction.

4. Locate systems away from drainageways.

In order to verify recommendations, and in conjunction with the construction of two septic systems, a follow-on study in conjunction with the construction of two new systems was authorized

in August of 1988. One system would incorporate the four recommendations, and a second utilized none of the recommendations. Monitoring systems were installed at each site to determine variations of phosphorous removal effectiveness associated with each system.

Results of the designed experiment from the two sites were inconclusive, but did result in several general observations:

1. No clear change in phosphorous retention was observed when effluent application was changed from gravity feed to dosing.

2. The effect of depth of unsaturated flow appears to have a much smaller impact on phosphorous retention than does the soil type / percolation rate.

3. The amount of phosphorous retained in the soil column appears to be directly related to the percolation rate. The faster the percolation rate, the smaller the amount of phosphorus removed in the soil column.

4. The use of low phosphate detergents reduced the phosphorus concentrations by 50 percent, however this may or may not effect phosphorus removal efficiency.

Although there may be an increase in phosphorous removal efficiency when utilizing the techniques studied; implementation costs exceed anticipated benefits. Therefore, the agencies permitting on-site disposal systems have not altered construction requirements.

III. 1991 Technical Studies and Reports

A. In Reservoir Studies

In 1990 the Authority contracted with Advanced Aquatics Technology Associates Inc. to conduct three in-reservoir studies: (1) Sediment Survey, (2) Limnocoral Study, and (3) Limiting Nutrient Study. following is a discussion of those studies which were completed in 1991.

Sediment Survey

Cherry Creek Reservoir being a shallow, well-mixed reservoir with minimal discharge has experienced a great deal of sedimentation since it began receiving water in 1957. Since flushing is minimal, sediments have washed into the reservoir and accumulated in depths of up to 77 inches. These sediments, originating from areas along Cherry Creek and Cottonwood Creek, are rich in nutrients. The shallow nature of the Reservoir causes the sediment to be easily resuspended by wind or boat action.

Nutrients released from resuspended sediments may promote algal blooms during warm periods.

The 1990 report of in-lake control options recommended that additional studies be conducted to determine the potential for phosphorous removal which has been captured in the sediment to be resuspended in the water column and become an available nutrient. Sediment resuspension is caused by wave action and power boating. The survey was designed to more fully understand these relationships and most importantly the overall relationship between sediments and water quality.

Study objectives were:

1. Estimate the depth and pattern of accumulated sediments.

2. Determine the physical and chemical composition of the sediments and evaluate potential impacts upon the reservoir water quality.

Major conclusions/observations:

1. Maximum reservoir depth is 25.8 feet, with an average depth of 12.4 feet. 1991 volume of Cherry Creek Reservoir as calculated was 10,440 acre-feet.

2. The depth of accumulated sediments is widely variable across the reservoir. The average sediment depth was calculated to be 1.6 feet, but depths ranged from insignificant at Cherry Creek inflow to an excess of 77 inches at the dam.

3. The sediment samples with the finest texture were collected adjacent to the dam. Samples with the coarsest texture were collected in the vicinity of the inflow of Cherry Creek and Cottonwood Creek.

4. Stratifications in the sediment cores indicate alternating periods of high mineral/low organic loading with periods of low mineral/high organic loading. The high mineral/low organic bands may represent periods of upstream basin development.

5. Cores exhibited a distinct oxidized surface zone that has been shown to have an effect on the control of chemical equilibria between the sediments and the overlying water. Any disturbance of this layer may result in accelerated transfer of nutrients to the water.

6. Chemical analysis of the sediment cores measured concentrations of the major nutrients affecting algal growth. The effect of lowering these concentrations on

algal growth may be assessed in the future by a micronutrient study.

As noted elsewhere in this report, further effort on the sediment removal alternative was postponed due to high cost and sludge disposal problems. Should this alternative become feasible in the future, a micro-nutrient study and the matter of nutrient availability from resuspended sediment will be underaken.

Limnocoral Study

The purpose of the Limnocoral Study was to determine the effects that the addition of alum to the water column would have on existing phosphorous concentrations. Test results indicated that alum addition had little impact on the reduction of phosphorous by means of either complexation of phosphorous ions or precipitation.

Limiting Nutrient Study

The Limiting Nutrient Study evaluated nitrogen and phosphorous as the limiting nutrients. For study purposes other potential limiting factors such as light and zooplankton grazing were considered fixed and not exerting any influence on test results. The study was based on the premise that "growth is limited by the substance that is present in minimal quantities with respect to the needs of the organism".

Study results concluded that addition of phosphorous significantly increased the production of chlorophyll a, whereas treatments with nitrogen did not increase the algal standing crop.

The differing results between the Limnocoral Study and the Limiting Nutrient Study regarding phosphorous as the limiting nutrient may be in part due to the basic nature of the techniques used. The limnocorals extended into the lake sediment and there may be a greater interaction between the sediment and the water column than previously thought. Absent the sediment as a phosphorous absorbing medium, the limiting nutrient appears to be nitrogen.

In order to further investigate the limiting nutrient issue, as noted in the Executive Summary, the Authority has contracted with the University of Missouri to undertake additional limiting nutrient and sediment studies in the summer of 1992.

IV. Annual Phosphorus Contributions

Following is an accounting of known and assumed phosphorous contributions as compared to the Cherry Creek Control Regulation.

Annual Phosphorous Contributions by Source

Source	Regulation (Pounds)	1990 (Pounds)	1991 (Pounds)
Nonpoint	10,290	3,720	1,620
Point	2,310	8,012 (1)	2,405
Septic Tank (2)	450	450	450
Industrial (3)	50	0	0
Background (4)	1,170	1,910	2,030
	14,270	14,092	6,505

(1) 6,739 pounds or 84% of total allowable was attributed to Denver Southeast Suburban Water and Sanitation District wastewater plant. A new AWT plant was activated March 19, 1992.

(2) The 1991 Septic Tank Study, Tri-County Health Department, concluded that "the current load to the reservoir from on-site systems is less than the allocated 450 pounds per year." Since actual contribution is unknown the 450 allocation is used in its entirety.

(3) Since there are at this time no industrial establishments in the basin, the 50 pound allocation is considered as not being used.

(4) The Master Plan (DRCOG) assumes the background loading of 1,170 pounds to consist of contributions by baseflow into the reservoir, alluvial groundwater and bulk precipitation. Since baseflow is accounted for in the annualized non-point source loading, and alluvial groundwater is not intercepted by the reservoir (Leonard Rice Consulting Engineers, Inc. - 1989); background is considered to consist of only bulk precipitation.

V. Publications

ADVANCED AQUATIC TECHNOLOGY ASSOCIATES, INC. Limiting Nutrient Study Cherry Creek Reservoir, September 1991

ADVANCED AQUATIC TECHNOLOGY ASSOCIATES, INC. Limnocoral Study of Cherry Creek Reservoir, September 1991

ADVANCED AQUATIC TECHNOLOGY ASSOCIATES, INC. Sediment Survey of Cherry Creek Reservoir, April 1991

sent email 2-2-12 requested copy

VI. Revenues and 1991 Audit

In 1991 the Authority collected revenues from the following sources:

1. Property taxes. A 0.5 mill levy assessed on all real property within that portion of the Cherry Creek drainage basin within Douglas and Arapahoe County.

2. Wastewater Surcharge. A fee of 5 cents per 1,000 gallons of treated wastewater effluent discharged by wastewater treatment plants, either land or RIB applied.

3. Building Permit Fees. All new building construction within the basin is subject to the following:

   (a) Single Family Residential including Town Homes and Patio Homes: $50.00

   (b) Non-residential and multi-family buildings: 3 cents per square foot for all impervious areas including building footprint, parking lots, access roads, etc.

4. Grading Fees: All non-building construction regardless of use such roadways, both private and public, but not streets or roadways in platted subdivisions: $280.00 per acre.

5. Recreation Fee. A fee of $1.00 per visit per vehicle, or a $3.00 annual permit per vehicle for unrestricted visitation to Cherry Creek State Park.

1991 Audit

Attached is a copy of the adopted 1991 Audited financial Statements.

APPENDIX A

SHOP CREEK

URBAN DRAINAGE AND FLOOD CONTROL DISTRICT

The Shop Creek watershed is located on the southeast rim of the Cherry Creek Reservoir, and the runoff from the watershed flows through a detention pond and then through a wetlands area before flowing into the reservoir. The detention pond and the wetlands are intended to remove some of the constituents from surface runoff before it enters the reservoir. The Cherry Creek Basin Authority has been sponsoring the ongoing monitoring of the quality and quantity of the surface runoff from the Shop Creek basin in Aurora, Colorado since the mid 1980s. The Urban Drainage and Flood Control District (UD&FCD) supplemented this data collection in 1990 and 1991 by funding an effort to obtain suspended solids and metals data.

This report presents the results of the analysis by UD&FCD of water quality data collected at three sites along Shop Creek. The collection of data at the three sites permitted the evaluation of the performance of a water quality pond and of the following wetlands. The data were used to calculate numeric and flow weighted average Event Mean Concentrations (EMCs), which were then used to estimate the monitoring season loads resulting from the storm runoff. For the non-storm periods of the monitoring season the average base flowrate and the measured concentrations were used to calculate the constituent base flow loads. Storm and base flow loads were then combined to find the total monitoring season load for a number of the monitored constituents.

Using the calculated loads, removal efficiencies for the various constituents were then estimated. The following table summarizes the removal rates calculated for those constituents that had a sufficient number of data points to permit this analysis:

1990-91 Estimated Average Monitoring Season Load Based Removals for Combined Storm and Base Flow Loads
(based on the flow weighted average EMC)

Constituent	Percent Removed By Pond	Wetlands	System
Total Phosphorous	32	7	35
Dissolved Phosphorus	46	-26	41
Total Ortho Phosphorus	39	2	42
Dissolved Ortho Phosphorus	50	-12	52
Total Nitrates	42	19	50
Total Nitrites	-199	34	-46
Kjeldahl	-195	54	-34
Total Nitrogen	-7	41	37
Total Copper	5	-16	-8
Dissolved Copper	23	16	36
Total Iron	65	1	64
Dissolved Iron	37	-25	31
Total Manganese	-29	23	0
Dissolved Zinc	-3	15	11
Total Zinc	14	33	44
Alkalinity	16	-11	0
Chemical Oxygen Demand	12	23	31
Total Suspended Solids	8	38	51

It is important to recognize that the removal efficiencies presented in the preceding table are based on data collected during 25 storms, while for base flows the analysis is based only 4 samples collected over two years. As a result, it is recommended that future water quality investigations obtain more base flow water quality data which should improve the accuracy and reliability of these estimates.

Wagner & White

Stephen M. Wagner, CPA
John D. White, CPA
John R. Haeck, CPA
William W. Humphrey, CPA
Elizabeth J. Feucht

Independent Auditors' Report

Board of Directors
Cherry Creek Basin Water Quality Authority
Englewood, Colorado

We have audited the accompanying general purpose financial statements of the Cherry Creek Basin Water Quality Authority, as of and for the year ended December 31, 1991, as listed in the table of contents. These financial statements are the responsibility of the Authority's management. Our responsibility is to express an opinion on these financial statements based on our audit.

We conducted our audit in accordance with generally accepted auditing standards. Those standards require that we plan and perform the audit to obtain reasonable assurance about whether the financial statements are free of material misstatement. An audit includes examining, on a test basis, evidence supporting the amounts and disclosures in the financial statements. An audit also includes assessing the accounting principles used and significant estimates made by management, as well as evaluating the overall financial statement presentation. We believe that our audit provides a reasonable basis for our opinion.

In our opinion, the general purpose financial statements referred to above present fairly, in all material respects, the financial position of the Cherry Creek Basin Water Quality Authority, as of December 31, 1991, and the results of its operations for the year then ended in conformity with generally accepted accounting principles.

March 5, 1992

Wagner & White, P.C.

Wagner & White, P.C. Suite 360, 165 South Union Boulevard, Lakewood, CO 80228 (303) 986-4600/Fax (303) 986-2860

Cherry Creek Basin Water Quality Authority

BALANCE SHEET - ALL FUND TYPES AND ACCOUNT GROUPS

December 31, 1991

	Governmental Fund Type	Account Group	Totals (Memorandum Only)
	General	Fixed Assets	
ASSETS			
Cash and cash equivalents	$ 521,834	$ -	$ 521,834
Accounts receivable	4,765	-	4,765
Accrued interest receivable	12,474	-	12,474
Taxes receivable - current year	2,244	-	2,244
Taxes receivable - ensuing year	324,008	-	324,008
Fixed assets	-	54,318	54,318
Total assets	$ 865,325	$ 54,318	$ 919,643
LIABILITIES			
Accounts payable	$ 41,164	$ -	$ 41,164
Deferred tax revenue	324,008	-	324,008
Total liabilities	365,172	-	365,172
FUND EQUITY			
Investment in fixed assets	-	54,318	54,318
Fund balance:			
Unreserved	500,153	-	500,153
Total fund equity	500,153	54,318	554,471
Total liabilities and fund equity	$ 865,325	$ 54,318	$ 919,643

The Notes to Financial Statements
are an integral part of this statement.

Cherry Creek Basin Water Quality Authority

STATEMENT OF REVENUES, EXPENDITURES, AND CHANGES IN FUND BALANCES - GENERAL FUND

Year Ended December 31, 1991

REVENUES	
Wastewater surcharge	$ 29,651
Building permit fees	46,611
Property taxes	311,034
Specific ownership taxes	24,173
Recreation fee surcharge	109,443
Miscellaneous income	20
Interest earnings	34,477
Grading fees	24,200
Total revenues	579,609
EXPENDITURES	
Accounting and audit	10,004
Printing and publications	3,225
Consulting fees	29,351
Decals	4,951
District management	41,976
Insurance	6,552
Legal - regulatory	8,677
Legal - internal authority	41,053
Legal - special projects	39,085
Miscellaneous	824
Septic tank study	2,230
Monitoring expense	104,849
Public information program	4,951
Shop Creek Cost-Sharing Agreement - City of Aurora	147,116
NALMS symposium	4,808
Baldwin treatment plant	9,053
Treasurers' fees	6,676
Water quality projects	6,660
Contingency	12,005
Total expenditures	484,046
EXCESS OF REVENUES OVER EXPENDITURES	95,563
FUND BALANCE - January 1, 1991	404,590
FUND BALANCE - December 31, 1991	$ 500,153

The Notes to Financial Statements are an integral part of this statement.

Cherry Creek Basin Water Quality Authority

STATEMENT OF REVENUES, EXPENDITURES, AND CHANGES IN FUND BALANCES - BUDGET AND ACTUAL - GENERAL FUND

Year Ended December 31, 1991

	Budget	Actual	Variance Favorable (Unfavorable)
REVENUES			
Wastewater surcharge	$ 22,000	$ 29,651	$ 7,651
Building permit fee	42,000	46,611	4,611
Property taxes	325,719	311,034	(14,685)
Specific ownership taxes	19,543	24,173	4,630
Recreation fee surcharge	130,000	109,443	(20,557)
Reimbursement - legal	21,500	-	(21,500)
Interest earnings	30,000	34,477	4,477
Miscellaneous income	4,000	20	(3,980)
Grading fees	17,500	24,200	6,700
Total revenues	612,262	579,609	(32,653)
EXPENDITURES			
Accounting and auditing	10,000	10,004	(4)
Printing and publications	6,000	3,225	2,775
Consulting fees	42,000	29,351	12,649
Decals	6,000	4,951	1,049
District management	35,000	41,976	(6,976)
Managment - special projects	8,000	-	8,000
Directors fees	500	-	500
Insurance	7,000	6,552	448
Legal - regulatory	23,000	8,677	14,323
Legal - internal authority	12,000	41,053	(29,053)
Legal - special projects	20,000	39,085	(19,085)
Legislative relations	500	-	500
Miscellaneous expense	1,000	824	176
Office expense	200	-	200
Septic tank study	5,000	2,230	2,770
Monitoring expense	77,000	104,849	(27,849)
Meetings and seminars	2,000	-	2,000
Public information program	6,000	4,951	1,049
Shop Creek Cost-Sharing Agreement - City of Aurora	125,000	147,116	(22,116)
NALMS symposium	-	4,808	(4,808)
Baldwin treatment plant	-	9,053	(9,053)
Treasurer's fees	6,595	6,676	(81)
Contingency	25,000	12,005	12,995
Water quality projects	650,012	6,660	643,352
Total expenditures	1,067,807	484,046	583,761
EXCESS (DEFICIENCY) OF REVENUES OVER EXPENDITURES	(455,545)	95,563	551,108
FUND BALANCE - January 1, 1991	455,545	404,590	(50,955)
FUND BALANCE - December 31, 1991	$ -	$ 500,153	$ 500,153

The Notes to Financial Statements are an integral part of this statement.