CHERRY CREEK BASIN

WATER QUALITY MANAGEMENT

MASTER PLAN

TECHNICAL REPORT

DRCOG

Denver Regional Council of Governments

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In cooperation with
counties, municipalities, water
and sanitation districts in the
Cherry Creek Basin

and

Colorado Department of Health
Water Quality Control Division
4210 East 11th Avenue
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ABSTRACT

TITLE	Cherry Creek Basin Water Quality Management Master Plan Technical Report
AUTHOR	Denver Regional Council of Governments
SUBJECT	This technical report describes the data and calculations that formed the basis of the Cherry Creek Task Force's recommendations outlined in the Cherry Creek Basin Water Quality Management Master Plan.
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ABSTRACT	This technical document describes results of analysis performed by DRCOG which enabled the Cherry Creek Basin Task Force to recommend a phosphorus control program which would maintain the 0.035 milligram per liter total phosphorus reservoir standard (as established by the Water Quality Control Commission). Point and nonpoint phosphorus control options were analyzed. Based on the results of analyses, the Task Force recommended a phosphorus control program for point and nonpoint sources of phosphorus in the basin.

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EXECUTIVE SUMMARY

This technical report provides clarification of and support for the phosphorus control program described in the Cherry Creek Basin Water Quality Management Master Plan. The data and analysis performed by DRCOG which enabled the Task Force to make their recommendations for the phosphorus control program are described in this report.

Land use data provided to DRCOG by local governments were the basis for assumptions about how the basin would develop. From these assumptions, projections of population and employment in the basin were made. The land use information also provided estimates of runoff volumes and loads in the basin.

A range of acceptable effluent treatment options were identified. Using the population and employment projections, point source phosphorus loading using different treatment options was calculated. Alternatives for service area scenarios were identified. From the long list of possible point source phosphorus control alternatives, five were identified for further analysis. The five alternatives chosen were analyzed for their ability to meet water quality standards.

Nonpoint phosphorus control options were considered concurrently with point source options. A goal of 50 percent basinwide nonpoint phosphorus removal was established. A subbasin approach was identified as the most effective approach in attaining the 50 percent removal goal.

Richard P. Arber and Associates, Inc., were hired to do cost and water rights impact analysis on the nonpoint source and the five-point source phosphorus control alternatives. Their analysis identified the twelve-plant option as having the least impact on water rights and as one of the least expensive. Their analyses also identified rapid infiltration and detention followed by rapid infiltration as the most cost-effective means of controlling nonpoint phosphorus.

In addition to the analyses done by Arber and Associates, an analysis of the non-quantifiable aspects of the five point source alternatives was done. This non-quantifiable analysis helped to evaluate options and was used with other information on water quality, water rights impacts, and costs.

Based on the analysis described above, the Task Force made recommendations on a basinwide phosphorus control program. This technical report provides the link between all the analyses performed during the course of this study and the final policies continued in the Master Plan.

I. INTRODUCTION

The Cherry Creek Basin Water Quality Management Master Plan was designed to identify the most feasible and effective means for achieving the 0.035 milligram per liter (mg/L) total phosphorus established for Cherry Creek Reservoir. The plan made specific recommendations with respect to four major topics. These are:

1. Point Source Control
2. Nonpoint Source Control
3. Phosphorus Allocation Among Sources
4. Institution

With adoption of the plan as an amendment to DRCOG's Clean Water Plan, the Colorado Water Quality Control Commission (WQCC) is considering adopting specific control regulations for the Cherry Creek Basin. The control regulations relate to controlling phosphorus in the basin by establishing wasteload allocations by sources, defining effluent limitations, controlling nonpoint sources, monitoring the water quality in the basin and establishing a process by which the WQCC can regularly review the program. The WQCC will also adopt the plan as an update to DRCOG's existing Clean Water Plan.

The purpose of this document is to provide the technical information which supports the policy oriented plan. Details will be provided with respect to projections of population and employment, basinwide phosphorus limitation, nonpoint generation rates and control strategies, point source effluent limitations and scenarios, and general discussion will be provided regarding the institution and plan implementation.

The intense effort in preparing the Master Plan and this supporting technical document was a cooperative effort by DRCOG, state and federal agencies, and local governments in the Cherry Creek Basin. These entities formed a Task Force which was responsible for guiding the study and making final recommendations according to an approved scope of work. The entire effort was directed at maintaining the total phosphorus standard and beneficial uses of Cherry Creek Reservoir.

II. BASIN DEVELOPMENT

The type and rate of growth in the Cherry Creek Basin will have a direct impact on the water quality of Cherry Creek Reservoir. In an attempt to quantify future reservoir impacts, it was necessary to define projections of land use, population and employment of the basin. This information was used to determine the volume of water and phosphorus load from nonpoint sources and also determine the volume of wastewater. The timeframe used was 1985 through 2010, with some recognition of estimates of land use at buildout.

Land Use

Land use information in the plan was provided by local governments and reflected anticipated land use at buildout based on conditions (zoning, platting and planning) recognized as of June, 1984. Land use categories were separated into seven general groups which represent general growth patterns in the basin. The land use categories are:

1. Large lot residential (≤ 1 D.U./acre)
2. Residential (> 1 D.U./acre)
3. Residential (> 11 D.U./acre)
4. Commercial (retail and office)
5. Industrial (light industrial and office)
6. Airport Property
7. Open space (parks, flood plains and agriculture)

Figure 1 displays the land use patterns in the basin. It was necessary to disaggregate the basinwide land use into smaller sub-areas. The sub-areas chosen were the subbasins defined by natural drainage ways (Figure 2). This resulted in a total of 30 subbasins within which land use was measured. Table 2 presents the areas of each land use category within each of the 30 subbasins.

Projections of Population and Employment

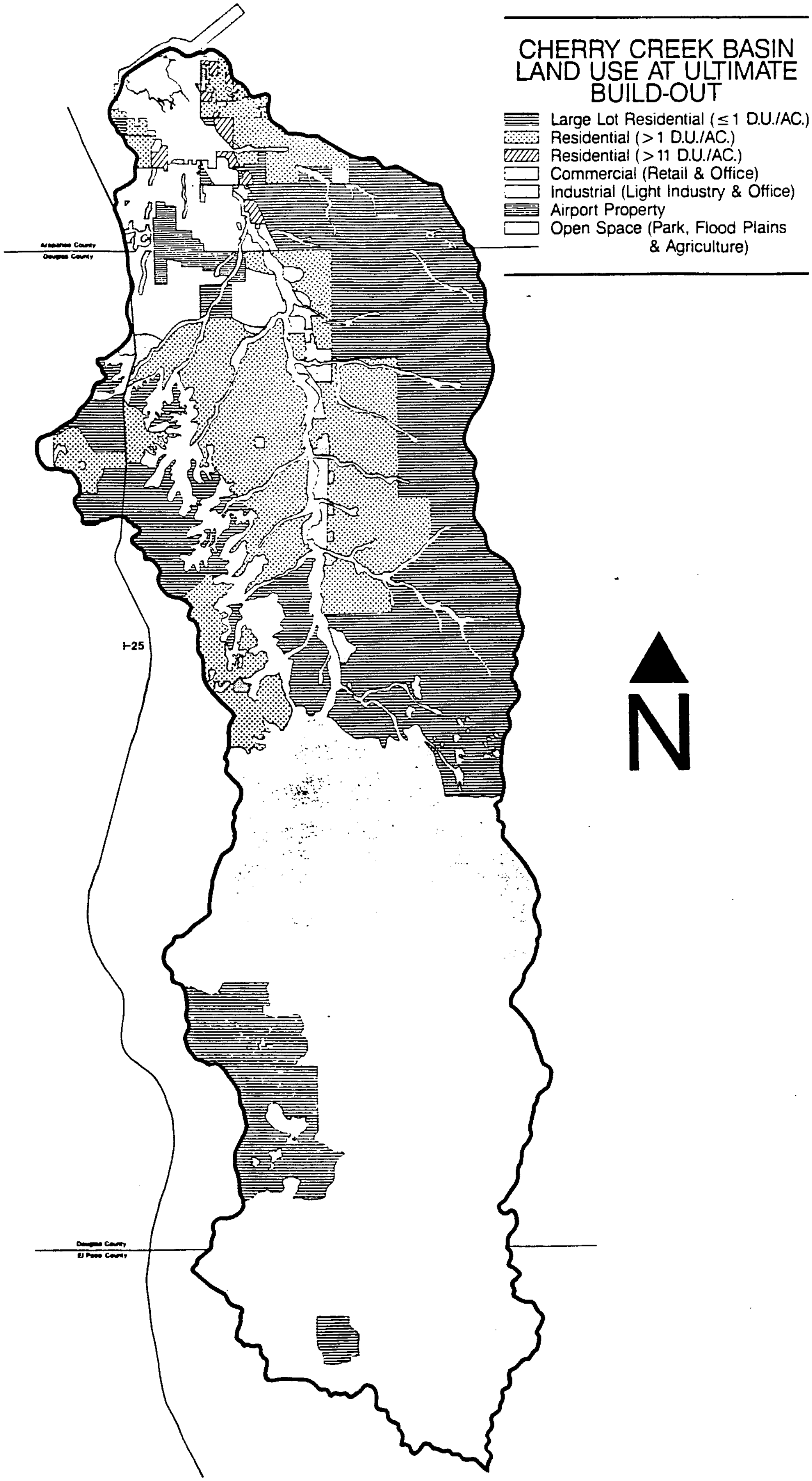
Land use information in Table 2 was translated into estimates of population and employment. The population estimates were derived from three residential categories of and specific assumptions regarding the number of density units (D.U.'s)/acre and the number of persons per household. Table 1 presents the assumptions used for density units/acre and persons per household.

Table 1
Density Units Per Acre And Persons Per Household By Residential Land Use

Land Use	Density Units/Acre	Persons/Household
Large Lot Residential	0.3	3.4
Residential	6.0	2.7
Residential (Multi-Family)	12.0	2.1

Employment estimates were determined from information from two sources. Land use information from the local governments defined the total acres of commercial and industrial land. The Lincoln Report was used for providing the methodology of calculating the number of employees based on Floor to Area Ratios (FAR)

Figure 1



CHERRY CREEK BASIN
LAND USE AT ULTIMATE
BUILD-OUT
Large Lot Residential (≤1 D.U./AC.)
Residential (>1 D.U./AC.)
Residential (>11 D.U./AC.)
Commercial (Retail & Office)
Industrial (Light Industry & Office)
Airport Property
Open Space (Park, Flood Plains
& Agriculture)
I-25
N

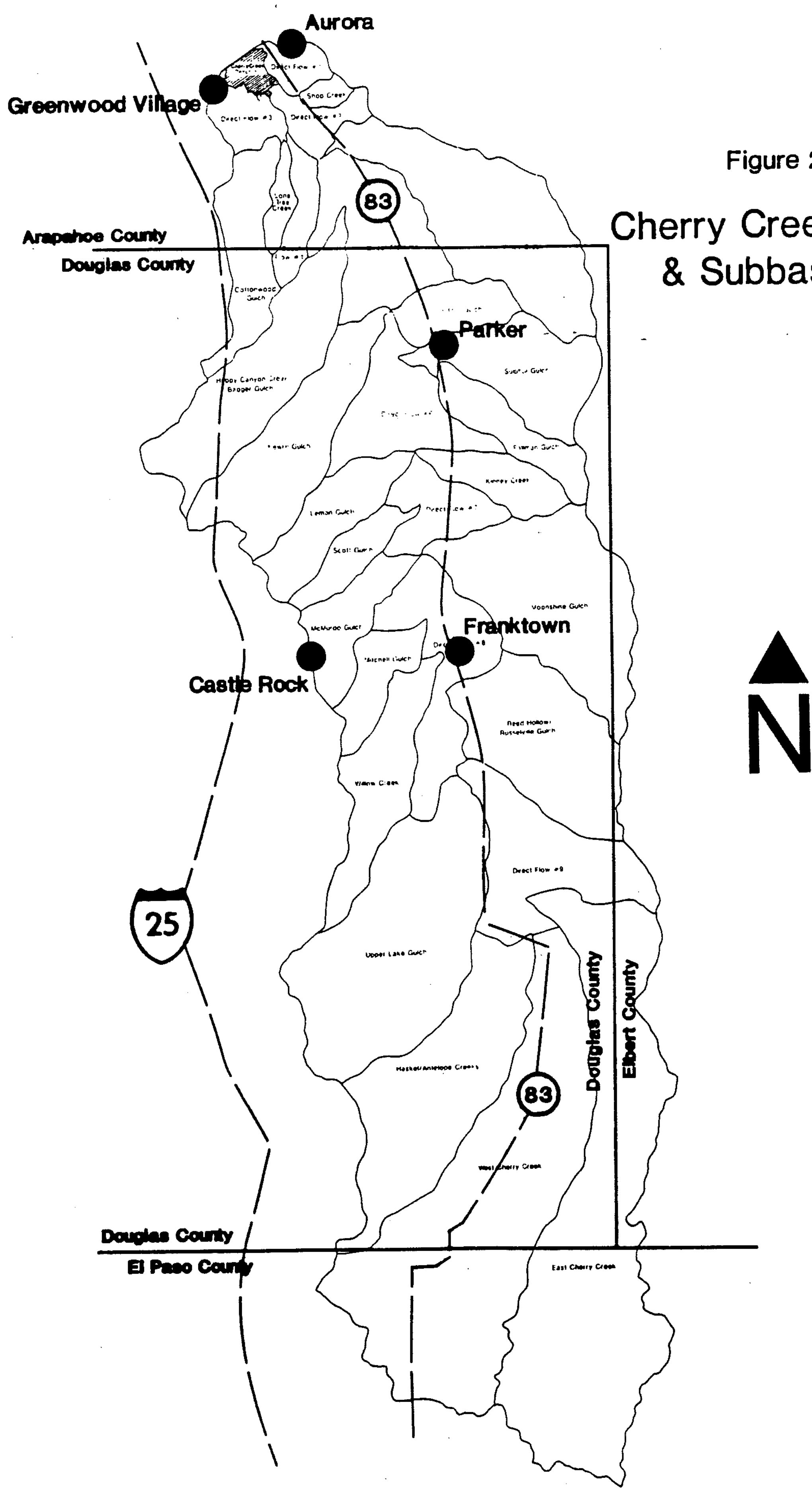


Figure 2

Cherry Creek Basin & Subbasins

Table 2

DISTRIBUTION OF LAND USE (ACRES) IN THE CHERRY CREEK BASIN AT ULTIMATE BUILDOUT

Drainage Area	Large Lot[2] Residential	Residential[3]	Residential[4]	Commercial	Industrial	Open Space	Airport Property	Total Acres[5]
Baldwin Gulch	2,049	634	0	258	188	156	0	3,285
Cottonwood Gulch	109	95	140	204	3,964	366	541	5,411
East Cherry Creek[1]	0	0	0	0	0	16,268	0	16,268
Happy Canyon	2,736	4,100	0	216	1,124	2,167	401	10,744
Haskel/Antelope Creek	6,096	0	0	0	0	9,714	0	15,810
Kinney Creek	1,188	1,873	0	69	55	253	0	3,438
Lemm Gulch	1,970	1,613	0	0	0	1,629	0	5,212
Lone Tree Creek	0	0	0	0	628	73	424	1,125
McMurdo Gulch	470	2,174	0	25	0	1,611	0	4,280
Mitchell Creek	579	1,551	0	71	0	1,037	0	3,238
Moonshine Gulch	10,863	2,999	0	52	39	1,140	0	15,093
Newlin Gulch	3,680	3,536	0	120	106	2,713	0	10,155
Piney Creek	11,669	2,069	33	94	0	774	0	14,639
Reed Hollow	6,946	0	0	0	0	4,652	0	11,598
Scott Gulch	283	1,427	0	0	0	860	0	2,570
Shop Creek	0	582	55	11	0	51	0	699
Sulphor Gulch	6,083	817	0	289	22	426	0	7,637
Tallman Gulch	2,043	1,771	0	0	0	278	0	4,092
Upper Lake Gulch	3,910	0	0	0	0	16,838	0	20,748
West Cherry Creek[1]	719	0	0	0	0	19,482	0	20,201
Willow Creek	798	571	0	0	0	5,523	0	6,892
Direct Flow:								
#1	0	344	201	96	0	99	0	740
#2	47	571	238	50	0	22	0	928
#3	129	608	44	58	0	22	0	861
#4	0	95	0	0	1,241	140	476	1,952
#5	2,613	1,429	363	338	1,504	1,211	79	7,537
#6	0	5,314	0	298	258	736	0	6,606
#7	0	2,619	0	82	565	630	0	3,896
#8	3,127	917	0	331	0	3,519	0	7,894
#9	0	0	0	0	0	9,576	0	9,576
TOTAL	68,107	37,709	1,074	2,662	9,694	101,966	1,921	223,125

[1] Area extends into El Paso County
[2] ≤ 1 D.U./acre
[3] > 1 D.U./acre
[4] > 11 D.U./acre (multi-family)
[5] A total of 245,537 acres exist in the basin. Of that 222,725 acres lie within Douglas and Arapahoe counties. The difference, or 22,812 acres lie within the unincorporated area of El Paso County.

and the number of square feet occupied by an employee.[1] Using a FAR of 0.3 and 234 square feet per employee resulted in approximately 55.8 employees per acre. An exception to this approach was taken with the airport property where the factor of 55.8 employees/acre was only applied to the terminal areas and not all of the land covered by runways.

Twenty Year Projections

A necessary element of the plan was to develop a twenty-year projection of population and employment based on land use. This was accomplished by using the estimate of population and employment as previously described which represented a buildout. That was then compared to estimates of existing population and employment for 1980 and 1983. These three points then allowed for the estimation of population and employment for the years 1990, 2000 and 2010.

The method used to project estimates for 1990, 2000 and 2010 was a typical population logistic curve (Gompertz equation).[2] The general shape of the curve is believed to describe realistically the actual growth of a population in a

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[1]The Lincoln Company, "the Arapahoe County Airport Influence Area Development Forecast," prepared for the Planning Departments of Arapahoe and Douglas counties, June, 1983.

[2]Walter Isard, "Methods of Regional Analysis: An Introduction to Regional Science," the M.I.T. Press, April, 1969, p. 13.

physically delineated area. With this methodology, the twenty-year projections of population and employment appear in Table 3.

Table 3

Basinwide Projections of Population and Employment

	1990	2000	2010
Population	90,000	186,600	298,700
Employment	58,900	155,000	276,700

These basinwide projections were then allocated among each of the 30 subbasins. This was accomplished by comparing the increase in subbasin land use between the years 1983 and buildout and applying that percent increase to the total population and employment for the individual years. Where necessary, adjustments were made to reflect conditions which did not fit into this pattern. Examples of this were where development is already near buildout such as Inverness, or where an individual development area overlapped several subbasins.

With the projections established over the planning period, it was then necessary to categorize the population into two different groups; large lot residential and sewered population. Sewered population was further defined into that population which would receive sewer service inside the Cherry Creek Basin and that sewered population within the basin which received sewer service through an agency outside of the basin. By making these distinctions between groups of population, it was possible to gain a better estimate as to that portion of the total basin population which would directly contribute to the total wastewater produced in the basin.

Tables 4 and 5 show the projections of population for the total basin and for the individual categories of population. Table 6 displays the projections of employment for the basin.

Table 4

Projections of Total Basin Population By Subbasin

	1990	2000	2010
Baldwin Gulch	3,000	4,400	6,100
Cottonwood Gulch	1,700	2,200	2,900
East Cherry Creek	0	0	0
Happy Canyon	5,600	15,500	27,000
Haskel/Antelope Cr	500	1,400	2,500
Kinney Creek	3,300	7,700	12,800
Lemon Gulch	2,800	8,700	15,800
Lone Tree Gulch	0	0	0
McMurdo Gulch	2,500	7,700	13,700
Mitchell Creek	1,200	3,600	6,400
Moonshine Gulch	5,900	14,200	24,000
Newlin Gulch	4,700	14,400	25,800
Piney Creek	8,800	14,600	21,400
Reed Hollow	1,100	2,000	3,100
Scott Gulch	1,600	5,000	9,000
Shop Creek	10,000	10,100	10,300
Sulphur Gulch	3,500	6,000	8,900
Tallman Gulch	2,400	6,800	11,900
Upper Lake Gulch	300	900	1,500
West Cherry Creek	100	200	300
Willow Creek	800	2,200	3,900
Direct Flow #1	5,600	6,400	7,300
Direct Flow #2	3,100	5,000	7,200
Direct Flow #3	4,200	5,200	6,500
Direct Flow #4	300	500	700
Direct Flow #5	5,100	9,800	15,200
Direct Flow #6	6,200	18,600	33,100
Direct Flow #7	4,500	10,300	17,300
Direct Flow #8	1,600	4,200	7,200
Direct Flow #9	0	0	0
Total	90,400	187,600	301,800

Table 5

Year 2000 Projections of Population by Subgroup

Basin	Sewered Population In Basin	Sewered Population Out of Basin	Large Lot Population	Total
Baldwin Gulch	2,800		1,600	4,400
Cottonwood Gulch	0	2,100	100	2,200
East Cherry Creek	0		0	0
Happy Canyon	9,600	3,200	2,700	15,500
Haskel/Antelope Cr	0		1,400	1,400
Kinney Creek	6,400		1,300	7,700
Lemon Gulch	7,700		1,000	8,700
Lone Tree Gulch	0		0	0
McMurdo Gulch	6,800		900	7,700
Mitchell Creek	2,900		800	3,700
Moonshine Gulch	9,900		4,300	14,200
Newlin Gulch	12,200		2,200	14,400
Piney Creek		9,100	5,500	14,600
Reed Hollow	0		2,000	2,000
Scott Gulch	4,400		600	5,000
Shop Creek		10,100	100	10,200
Sulphur Gulch	3,800		2,200	6,000
Tallman Gulch	5,500		1,300	6,800
Upper Lake Gulch	0		900	900
West Cherry Creek	0		200	200
Willow Creek	1,800		400	2,200
Direct Flow #1		6,300	100	6,400
Direct Flow #2		4,700	300	5,000
Direct Flow #3		5,000	200	5,200
Direct Flow #4	500		100	600
Direct Flow #5	7,600		2,200	9,800
Direct Flow #6	16,600		2,000	18,600
Direct Flow #7	9,300		1,000	10,300
Direct Flow #8	2,800		1,400	4,200
Direct Flow #9	0	0	0	0
Total	110,600	40,500	36,800	187,900

Table 6

Projections of Employment By Subbasin

	1990	2000	2010
Baldwin Gulch	2,350	5,610	9,940
Cottonwood Gulch	26,970	55,990	94,470
East Cherry Creek	0	0	0
Happy Canyon	3,880	14,150	27,770
Haskel/Antelope Cr	0	0	0
Kinney Creek	360	1,310	2,570
Lemon Gulch	100	370	740
Lone Tree Gulch	2,970	7,610	13,780
McMurdo Gulch	70	260	520
Mitchell Creek	210	750	1,470
Moonshine Gulch	480	1,140	2,030
Newlin Gulch	5,190	18,940	37,160
Piney Creek	270	990	1,950
Reed Hollow	0	0	0
Scott Gulch	0	0	0
Shop Creek	30	120	230
Sulphur Gulch	900	3,280	6,440
Tallman Gulch	0	0	0
Upper Lake Gulch	0	0	0
West Cherry Creek	0	0	0
Willow Creek	0	0	0
Direct Flow #1	280	1,010	1,990
Direct Flow #2	140	530	1,040
Direct Flow #3	170	610	1,200
Direct Flow #4	3,900	13,360	25,900
Direct Flow #5	6,630	20,560	39,030
Direct Flow #6	1,610	5,870	11,520
Direct Flow #7	1,870	6,830	13,410
Direct Flow #8	960	3,500	6,860
Direct Flow #9	0	0	0
Total	59,340	162,790	300,020

III. NONPOINT

The significance of nonpoint source loading to Cherry Creek Reservoir was well documented in the Clean Lakes Study.[3] With the updating of land use as identified in Table 2, it was necessary to re-calculate the nonpoint source loading. This re-calculation was anticipated to produce a different nonpoint load than was projected in the Clean Lakes Study.

The method used to predict the nonpoint loading was that developed in the Clean Lakes Study.[4] This method determined phosphorus loading and runoff volume according to land use. The coefficients used to predict nonpoint phosphorus loading and runoff volume according to land use appear in Table 7.

Table 7

Unit Area Phosphorus
Loading and Runoff Volume
by Land Use

Land Use	lbs-Phos./Ac/Yr	Increases Runoff/Ac/Yr
Commercial	1.99	11.95
Residential	0.834	3.17
Large Lot and Open Space	0.070	0.38

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[3]Denver Regional Council of Governments, "Cherry Creek Reservoir Clean Lakes Study, April, 1984, Denver, Colorado

[4]Denver Regional Council of Governments, "Chatfield and Cherry Creek Reservoir Clean Lakes Study, Technical Memoranda," TM No. 6, (unpublished).

The Cherry Creek Reservoir Clean Lakes Study also recognized the need to adjust the coefficients in Table 7 due to the difference in urban runoff data collected in Denver and the urban runoff data collected in the Cherry Creek Basin. To account for this difference, scaling factors were applied to the annual load by land use to adjust data when transferring it from the small site coefficients to larger subbasins. Table 8 shows the scaling factors applied to the coefficients in Table 7 for projecting nonpoint contributions in the Cherry Creek Basin.

Table 8

Scaling Factors Used in the Cherry Creek Basin*

Land Use	Phos. Load Scaling Factor	Runoff Scaling Factor
All types	0.116 PEI + 0.004	0.185 PEI - 0.057

*The Shop Creek subbasin phosphorus loading scaling factor was held constant at 10.7

The three land use categories presented in Table 7 are far fewer than those categories identified basinwide in Table 2. The seven categories in Table 2 were aggregated into the three categories because their land uses are similar and in some cases, only small quantities of a particular land use existed in the basin. Examples of this are the airport property and multi-family residential. The total area of these two land uses is small when compared to the other land uses and, therefore, they were considered to be part of the commercial and residential land use categories.

To compute the nonpoint load or runoff volume, information in Tables 7 and 8 are combined and multiplied by the number of acres of an individual land use. For example, to compute the phosphorus load and runoff volume from 10 acres of commercial land, the following equations are used:

Phosphorus load: 10 (1.99) x (0.116 PEI + 0.004) = pounds/year

Runoff Volume: 10 (11.95) x (0.185 PEI - 0.057) = inches/year

Both equations predict an annual quantity of nonpoint source pollution. Summing the load and runoff from all land uses produces the total annual basin nonpoint contribution. The only missing variable is the PEI or the Percent Effective Impervious area. The PEI is that developed portion of a basin which is impervious and hydraulically connected to a drainage system.

With the method defined, it was then possible to estimate nonpoint loading and runoff volumes for the years 1990, 2000 and 2010. These were computed for each subbasin based on land use, PEI runoff and loading coefficients and by assuming an average annual rainfall.

As an example, to compute the nonpoint phosphorus load and runoff volume for two basins (Shop Creek and Moonshine Gulch), the two examples are provided to illustrate the method.

These two examples not only illustrate the method to compute the land use runoff but also show the difference in nonpoint loading due to differences in land use. The Shop Creek example presents loading from a developed subbasin while the Moonshine Gulch shows loadings from a relatively undeveloped subbasin.

The nonpoint loadings which appear in the plan are based on the land use assumptions which were submitted to DRCOG. As those assumptions change, the nonpoint loading will also change. As such, it may be necessary to re-calculate the nonpoint loading whenever necessary to adjust for changing land use conditions.

Example 1: Load and Runoff Calculations for Shop Creek

Load Calculations:

[(Comm. Load Factor x Comm. Ac.)+(Res. Load factor x Res. Ac.) +
(LL & OS Load Factor x LL & OS Ac.)] x (0.116 PEI + 0.004) = Load in pounds/yr.

Runoff Calculations:

[(Comm. R.O. x Comm. Ac.) + (Res. R.O. Factor x Res. Acres) +
(LL & OS R.O. Factor x LL & OS Ac.)] x (0.185 PEI - 0.057) = R.O. in inches

Land Use	Load Factor	Runoff Factor	Acres	Acres	Acres
Commercial	1.99 ✓	11.95 ✓	8	20.5	36
Residential	0.834 ✓	3.17 ✓	224	607.8	1,080
Large Lot & Open Space	0.007 0.07	11.95 0.38	14,869	14,485	14,013
PEI			20.0	20.4	21.0

Typos, ?

1990 Load = [(1.99 x 0.6) + (0.834 x 617.3) + (0.07 x 81.7)] x 10.7[1]
= 5,583 pounds/year

1990 Runoff +[(11.95 x 0.6) + (3.17 x 617.3) + 0.38 x 81.7)] x (0.185(20) - 0.057)
= 7,268 inches ÷ 12 = 606 feet

[1]is a Scaling factor specifically determined for Shop Creek using measured data.

Example 2: Load and Runoff Calculations for Moonshine Gulch

Land Use	Load Factor	Runoff Factor	Acres	Acres	Acres
Commercial	1.99	11.95	8	20.5	36
Residential	0.834	3.17	224	607.8	1,080
Large Lot & Open Space	0.07	0.38	14,869	14,485	14,013
PEI			1.0	1.6	2.4

1990 Load = [(1.99 x (0.6) 8 + (0.834 x 224) + (0.07 x 14,869)] x
[0.116 (1.0) + 0.004] = 149 pounds/year ✓

1990 Runoff = [(11.95 x 8) + (3.17 x 224) + (0.38 x 14,869)] x
[0.185 (1.0) - 0.057] = 826 inches ÷ 12 = 68.83 feet

IV. POINT SOURCES

This chapter describes the different types of point source effluent treatments that were considered for the Master Plan. Initially, nine different treatment options had effluent phosphorus concentrations ranging from 0.2 mg/L to 0.025 mg/L. They are described in Table 9.

Table 9

Treatment Options Considered in the Cherry Creek Basin

A - Direct discharge, effluent phos. = 0.2 mg/L
B - Land application, percolate phos. = 0.2 mg/L
C - Land application of advanced treated wastewater of 0.2 mg/L, percolate phos. = 0.1 mg/L
D - Direct discharge, effluent phos. = 0.1 mg/L
E - Land application, percolate phos. = 0.1 mg/L
F - Land application of advanced wastewater of 0.1 mg/L, percolate phos. = 0.05 mg/L
G - Direct discharge, effluent phos. = 0.05 mg/L
H - Land application, percolate phos. = 0.05 mg/L
I - Land application of advanced treated wastewater of 0.05 mg/L, percolate phos. = 0.025 mg/L

The treatment options considered correspond to treatments expected to occur in the future (direct discharge) as well as treatments existing in the basin (land application). A direct discharge treatment option is one in which all the effluent is directly discharged into a stream, lake or other water body. All the effluent from direct discharging systems is assumed to reach Cherry Creek Reservoir. Land application treatment options involve applying effluent on land by either rapid infiltration or slow rate land application. Land application by rapid infiltration is assumed to have the same effect on the reservoir as direct discharging systems. Slow rate land application is assumed to reduce the volume of effluent and phosphorus concentration by 50 percent due to crop uptake and soil sorption. For example, a volume of 1.0 mgd of effluent with a phosphorus concentration of 0.1 mg/L slow rate land applied would result in a percolate volume of 0.5 mgd and a phosphorus effluent concentration of 0.05 mg/L. Only half of the original 1.0 mgd (or 0.5 mgd) is assumed to reach the reservoir.

The range of phosphorus concentrations for the treatment options was chosen to reflect available technology. In the Clean Lakes Study an effluent phosphorus concentration of 0.2 mg/L was determined to be achievable[5] Drawing from data submitted by Summit County dischargers, the Colorado Department of Health determined that effluent concentrations of 0.1 mg/L and 0.05 mg/L were also achievable. A consistent percolate quality of 0.025 mg/L was determined not to be achievable. Because of the urgent need to reduce phosphorus levels in the reservoir, 0.1 mg/L was determined to be the highest acceptable concentration of phosphorus. Based on these determinations, treatment options A, B and I were eliminated from further consideration.

Having reduced the number of treatment options to six (C through H), the volumes of effluent and phosphorus loads generated by the effluent were determined. Using the population and employment projections in Chapter II,

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[5]Denver Regional Council of Governments, "Cherry Creek Reservoir Clean Lakes Study," April 1, 1984.

wastewater flows were determined for the basin in 1990, 2000, and 2010 using the following equation:

$$\text{Wastewater Flow in gal. per day} = (\text{sewered pop} \times 85 \text{ gal/day}) + (\text{employees} \times 35 \text{ gal/day})$$

This equation includes ten gallons per person and employee for infiltration/inflow. Flows in gallons per day were then converted to Ac-ft per year to meet the data requirements of the modeling effort described in Chapter VI. The conversion was accomplished using the following equation:

$$\text{Ac-ft. per year} = \frac{\text{gal/day} \times 365 \times 0.1337}{43{,}560}$$

The loads of phosphorus (in pounds per year) were calculated for each of the treatment options. To calculate the annual pounds of phosphorus the following equation was used:

$$\text{load (in lbs/yr)} = \text{mgd} \times \text{conc. of effluent} \times 8.34 \times 365$$

It is important to note that the mgd for slow rate land application treatment options (C, E, F, and H) were reduced by 50 percent before use in the above equation. The loads and volumes of phosphorus generated in the basin by treatment option are displayed in Table 10.

Table 10

Phosphorus Loads and Volumes of Effluent by Treatment Option

Treatment Type	1990		2000		2910	
	L (1)	V(2)	L	V	L	V
C	807	2,969	2,162	7,954	3,836	14,116
D	1,613	5,938	4,323	15,908	7,671	28,232
E	807	2,969	2,162	7,954	3,836	14,116
F	404	2,969	1,081	7,954	1,918	14,116
G	807	5,938	2,162	15,908	3,836	28,232
H	404	2,969	1,081	7,954	1,918	14,116

The information in Table 10 described a situation in which all treatment plants in the basin use the same treatment option. It is unrealistic to assume that all plants in the basin would use the same treatment option. Therefore, other alternatives considered mixing the treatment options to create an alternative closely following the present treatment practices in the basin.

Determining wastewater flows and loads for those alternatives with a mixture of treatment options was more complicated than for alternatives that assumed a constant treatment option. The reason it was more complicated was because separate calculations were performed for each treatment plant in the basin. These individual loads and flows were then summed to produce the basin total.

Having determined wastewater flows and phosphorus loads for the treatment options, various wastewater service alternatives were created. The following chapter discusses all the point source and nonpoint source phosphorus control alternatives that were evaluated in this study.

V. ALTERNATIVE ANALYSIS

Chapters III and IV discussed the nonpoint and point loadings in the basin. This chapter discusses the alternatives evaluated to control those loads. The goal of evaluating alternatives was to select a preferred alternative which could be used in the plan.

Literally thousands of different alternatives were possible by combining the various point and nonpoint phosphorus control options. To reduce the alternatives to a more manageable number, several preliminary analyses and assumptions were made. Only nonpoint options with proven success records documented in literature were chosen. In addition, a subbasin approach to nonpoint phosphorus control was selected. Point source options were chosen to closely reflect plants and treatment options existing in the basin and/or those that could reasonably occur. A cost analysis and water rights impact assessment was done to assess the quantifiable impacts of the chosen alternatives. An analysis of non-quantifiable impacts was done to further assess the suitability of alternatives chosen. Using the results of these analyses, the Task Force was able to choose one option upon which to base the plan.

Nonpoint Source Alternatives

Chapter III demonstrated what a significant contribution nonpoint phosphorus was of the total load to the reservoir. The reservoir phosphorus standard would be maintained if the nonpoint load is controlled. Therefore, it was recognized that before phosphorus could be allocated to point sources, it was necessary to account for loadings from nonpoint sources. The goal of the nonpoint phosphorus control program is 50 percent removal of the basinwide annual nonpoint phosphorus load. Since no data exists on the success of a basinwide nonpoint phosphorus removal program, the 50 percent removal represents an expectable goal requiring advanced technology and basinwide coordination of the facility operations.

Originally, eleven nonpoint control structures were considered. These appear in Table 11.

Table 11
Nonpoint Control Options

Rapid Infiltration*
Detention Followed by Rapid Infiltration*
Erosion Control on New Construction
Subbasin Detention
Mechanical Treatment*
Grassed Waterways
Channel Stabilization
Septic Tank Policy
Wetlands*
In-lake Management
Detention with Sand Filtration*

*See text below

Of the options listed in Table 11, only those with proven phosphorus removal efficiencies were evaluated further. Those options are identified by an asterisk. Review of literature and results from the Nationwide Urban Runoff Program indicated that these options were capable of removing at least 50 percent of the total phosphorus.[6,7,8] The other options in Table 11 were regarded as Best Management Practices (BMP's).

The issue of locating the control structures was discussed in detail by the Task Force. The decision was made to locate the structures at the end of each subbasin drainage rather than site specifically by development area. The subbasin approach was chosen because it was the best way to coordinate the program and achieve the 50 percent removal goal. A subbasin approach captures more runoff from all areas more effectively. It also avoids a multiplicity of structures and reduces operating and maintenance costs.

Preferred Alternative, Nonpoint Sources

Four nonpoint alternatives were analyzed in this chapter. Detention followed by sand filtration was shown to be the most effective, while the use of wetlands as a phosphorus control structure was shown to be the least. The analysis performed on the nonpoint control alternatives indicated that the highest phosphorus removal rates were achieved when stormwater was filtered through a media such as sand or gravel. Therefore, rapid infiltration or sand filtration were recommended. Detention was also recommended as it removed phosphorus; but

[6]Denver Regional Council of Governments, "Urban Runoff Quality in the Denver Region, September, 1983.
[7]U.S. EPA "Results of the Nationwide Urban Runoff Program," Vol. 1, Final Report, December 1983.
[8]Urban Drainage and Flood Control District, "Douglas and Arapahoe Counties Drainage Criteria Manual," Draft 1984.

it was also needed to stablize flow prior to applying the stormwater flow to the filtration basins.

Point Source Alternatives

Selecting point source alternatives was more complicated than selecting nonpoint alternatives because decisions had to be made regarding the number of plants and the type of treatment for each plant. The point source alternatives involved identifying service areas and selecting treatment facilities for the service areas. The six alternatives that were selected are listed below:

1. **One-plant Option:** One plant, located approximately where Arapahoe Water and Sanitation District's proposed treatment facility exists, would treat all wastewater generated in the basin (Fig. 3).
2. **Two-plant Option:** Two plants, one located approximately where Arapahoe Water and Sanitation District's proposed treatment facility exists and the other located in Parker, would treat all wastewater in the basin. The Parker plant would treat all wastewater generated upstream from their plant. The Arapahoe plant would treat all wastewater generated between it and the Parker plant (Fig. 4).
3. **Three-plant Option:** One plant located in Denver Southeast Suburban Water and Sanitation District was added to the two-plant option. It would serve all wastewater generated upstream from it and reduce the amount of wastewater the Parker plant would need to treat (Fig 5.).

Figure 3

One Plant Service Area Option

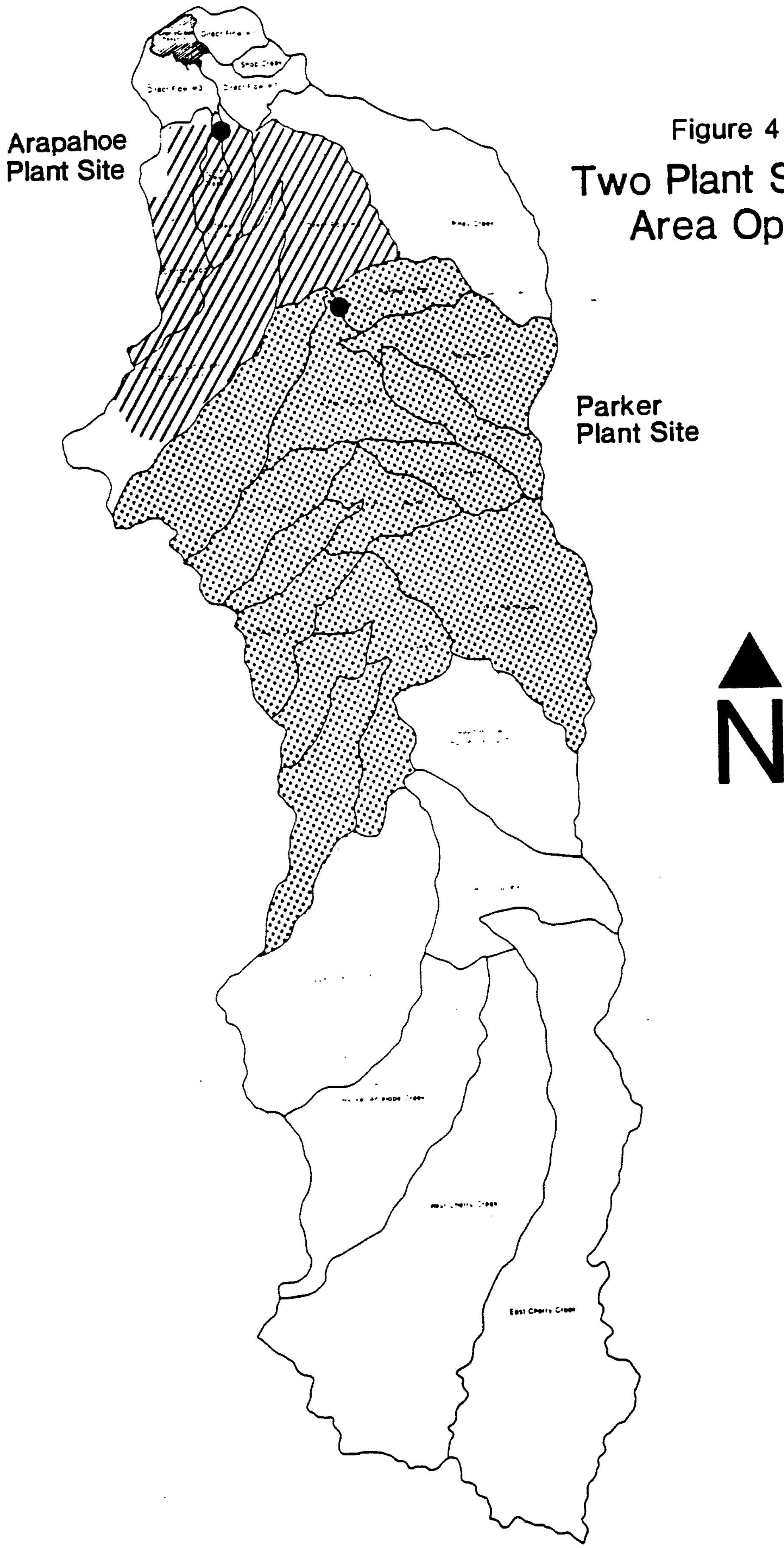


Figure 4
Two Plant Service Area Option

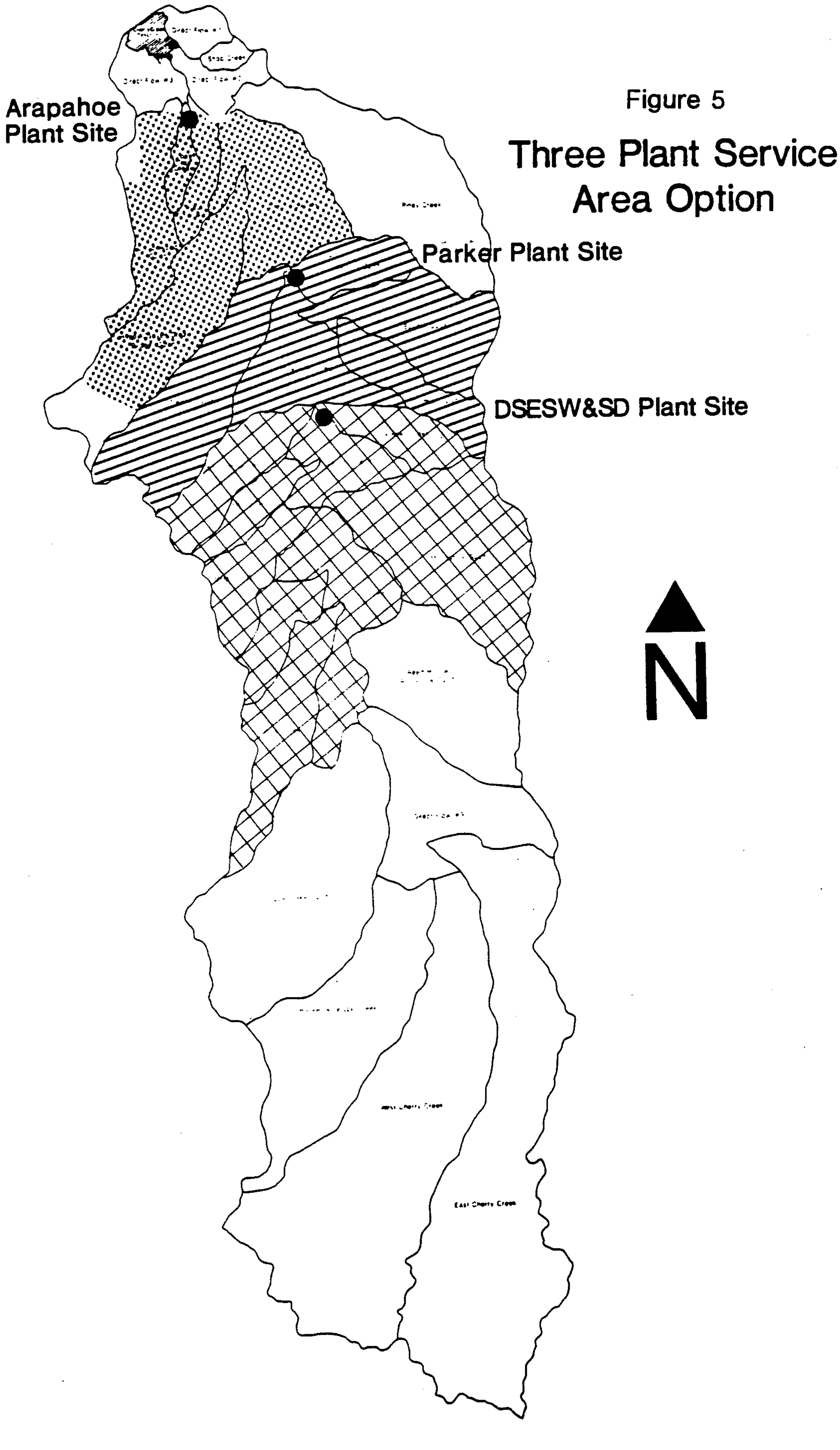


Figure 5
Three Plant Service Area Option

4. **Four-plant Option:** One plant located where Castle Rock's Cherry Creek facility exists, was added to the three-plant option. It would treat all wastewater generated upstream from it and would reduce Denver Southeast wastewater by that amount (Fig 6.).

5. **Ten-plant Option:** The ten existing plants in the basin with four of them acting as joint-use facilities for the basin was assumed. The ten existing plants are: Arapahoe; Cottonwood; Inverness; Meridian; Stonegate; Parker; Denver Southeast; Castle Rock; (Cherry Creek; McMurdo; Mitchell) with Arapahoe, Parker, Denver Southeast and Castle Rock, (Cherry Creek) as the joint-use facilities (Fig. 7).

6. **Twelve-plant Option:** The ten existing plants plus two additional plants in Rampart Range and Castle Rock (Newlin Gulch) (Fig 8.).

The report concluded that the subbasin approach to nonpoint phosphorus control is an effective one. It also concluded that testing needs to be done to document the amount of phosphorus actually removed by these structures. This must be done to ensure that the goal of 50 percent basinwide removal is met.

<u>Non-quantifiable Analysis</u>

The analyses described above addresses the quantifiable aspects of point and nonpoint source phosphorus control. These are: water quality, costs, and water rights impacts.

Figure 6

Four Plant Service Area Option

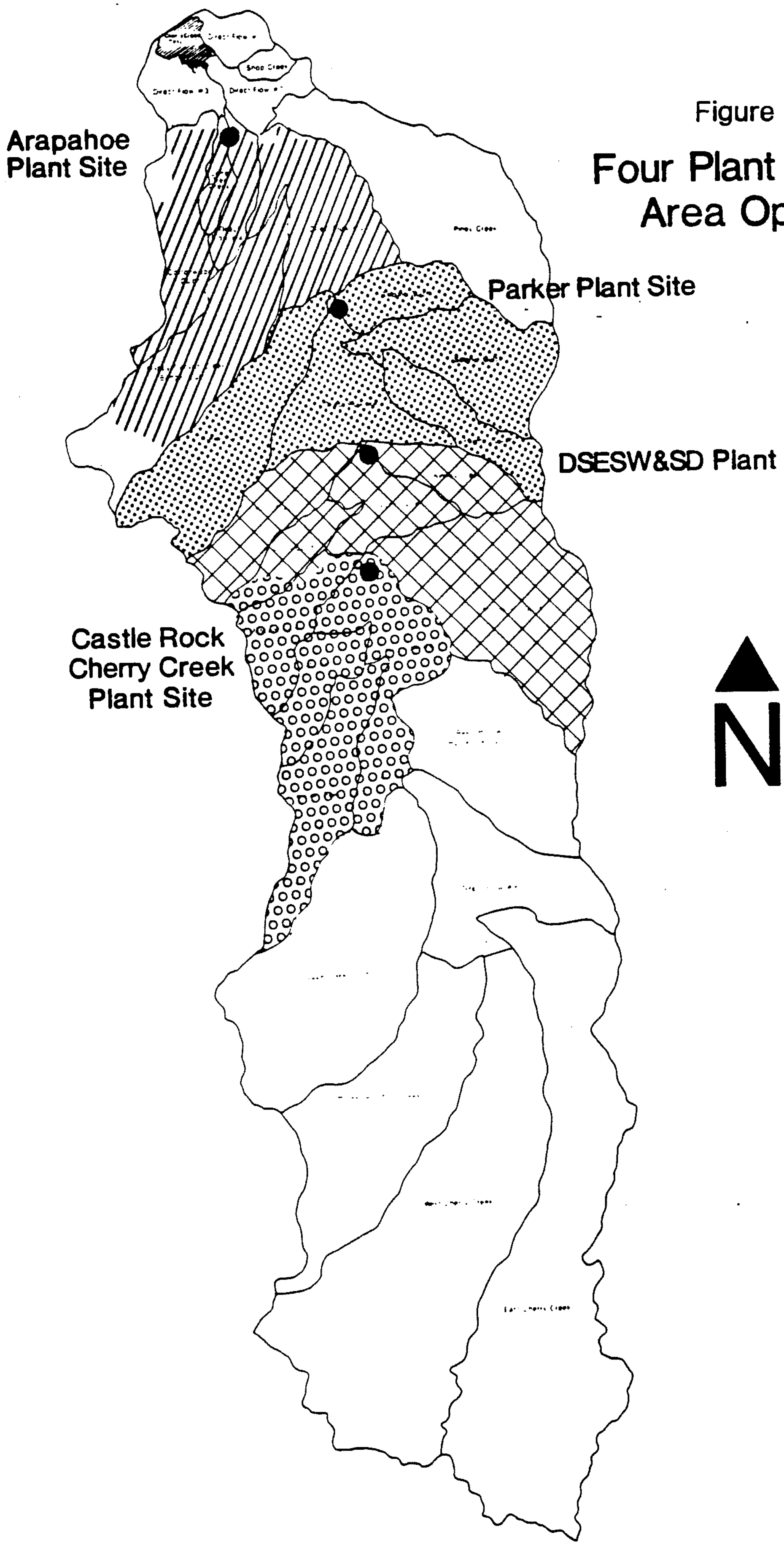


Figure 7

Ten Plant Service Area Option

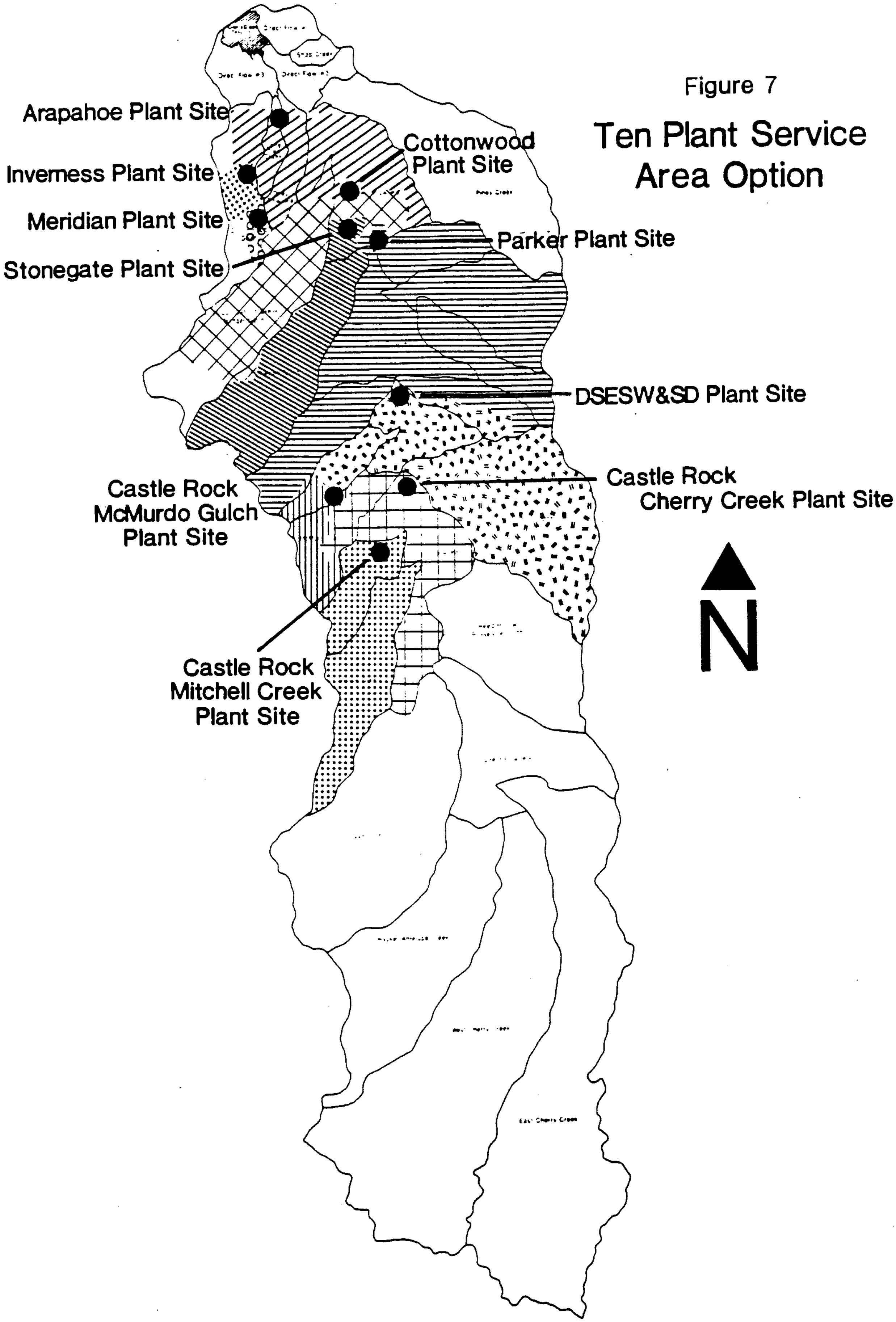
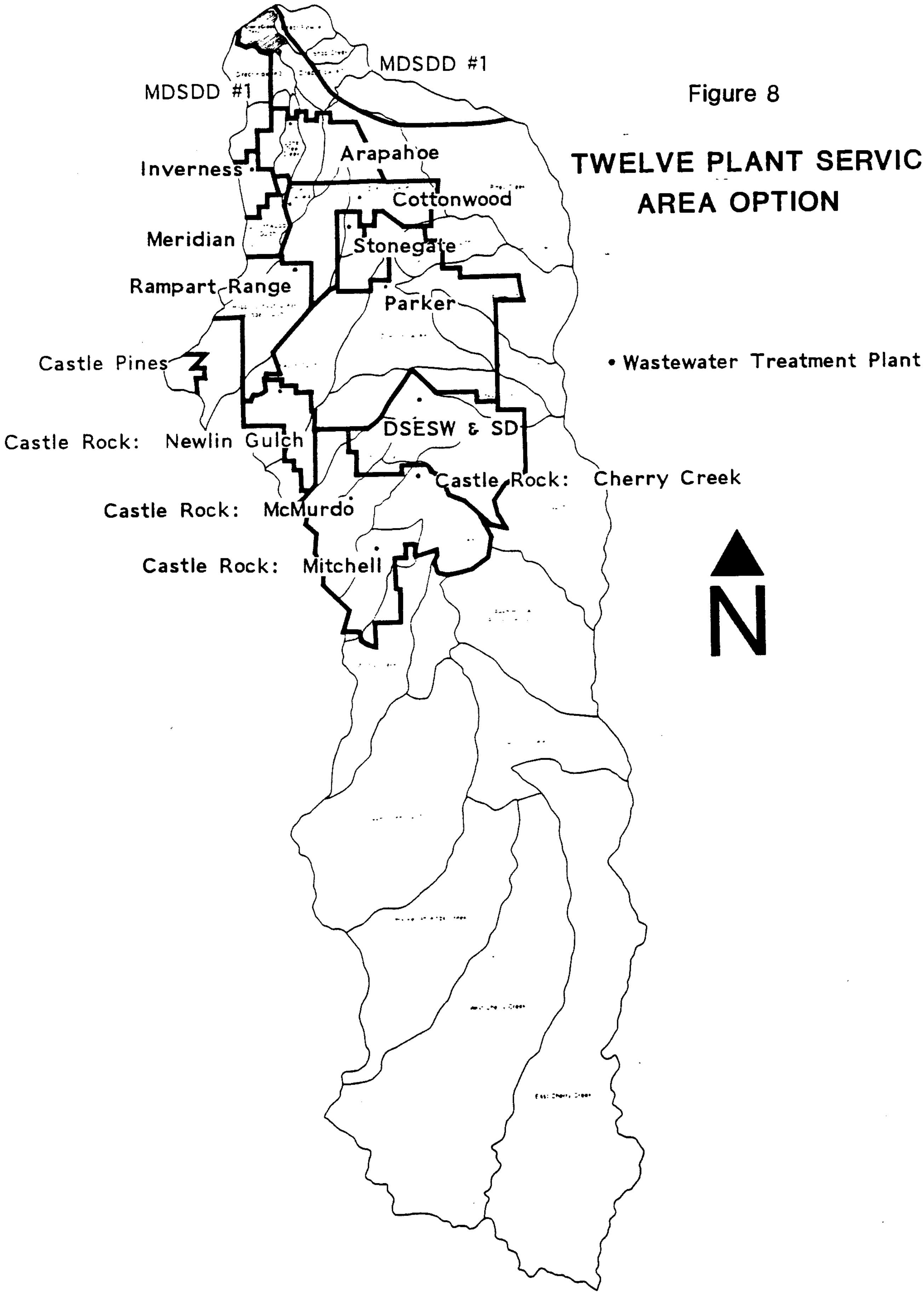


Figure 8

TWELVE PLANT SERVICE AREA OPTION



The cost analysis performed allowed the Task Force to verify the economic feasibility of their selected alternatives for point and nonpoint phosphorus control. Another analysis was also performed to study the non-quantifiable aspects of the selected alternatives. The non-quantifiable characteristics of this analysis included: environmental impacts; potential for implementation; flexibility potential for phasing; reliability of meeting standard; energy usage; ease of operation; potential for expansion; aesthetics; reuse potential; innovation; impact on existing facilities; and management. Alternative 5 (the twelve-plant option) was ranked the highest of all five alternatives based on non-quantifiable characteristics. Table 12 is a summary of the non-quantifiable analysis.

Preferred Alternative, Point Sources

All of the point alternatives selected above assumed that existing facilities would be used for their expected lifetimes. The joint-use facilities would be built as the need arose.

With the service areas of the selected alternatives defined, the next step was to determine which treatment options the facilities would use. The seven types of treatments selected for consideration are described in Chapter IV. With six possible service area scenarios and seven different treatment options identified (with any combination of treatment options possible), the number of alternatives was still much too great. Before the cost and water rights impacts analysis could be performed, the Task Force reduced the number of possible alternatives to five.

Table 12

Summary of Non-quantifiable Analysis of Five Alternatives

Criteria / Alternatives[1]	1	2	3	4	5	Comments
Environmental Impacts	3	5	2	4	1	AWT will not provide enough water for a fishery with direct discharge.
Land-Use Impacts	4	1	3	5	2	Land application removes land from devel-opment AWT uses the least amount of land.
Implementation	3	4	2	5	1	
Flexibility	4	3	2	5	1	
Phasing						
Energy Consumption without Water Rights Pumping	3	1	4	2	5	
Ease of Operation	2	3	4	1	5	
Potential for Expansion						
Aesthetics						Odor or foam problem from direct discharge and perhaps land application.
Reliability	1	5	4	3	2	
Reuse Potential	2	4	3	5	1	Larger number of plants and land appli-cation provide greater reuse potential.
Innovation						
Impact on Existing Facilities	4	5	2	3	1	
Management						Institutional aspects need to be known.
Total	26	31	26	33	19	

[1]facility alternatives

Scale: Ranking according to facility with greatest and least effect, impact, or value.

1. Four joint use facilities plus ten existing: secondary treatment with land application.
2. Four joint use facilities plus ten existing: advanced WWT with direct discharge.
3. Four joint use facilities plus ten existing: mixed secondary with land application and AWT with direct discharge.
4. Two joint use facilities plus ten existing: secondary treatment with land application.
5. Twelve existing facilities: mixed secondary with land application and AWT with direct discharge.

Cost Analysis, Point and Nonpoint Alternatives

To perform cost analysis on the nonpoint and point options selected by the Task Force, Richard P. Arber Associates, Inc. was hired. The cost analysis is contained in three volumes that evaluate: Costs of Wastewater Treatment Options, Costs and Water Rights Impacts of Selected Point Source Treatment Options, and Costs of Nonpoint Control Options.[9,10,11]

The first volume of the Arber reports deals with costs of the wastewater treatment options selected by the Task Force. The results of this report were used to verify the economic achievability of the treatment options. They were also used to estimate the cost of phosphorus removal associated with each treatment option.[12]

The second volume of the Arber reports was a cost and water rights impact analysis on five alternatives selected by the Task Force.[13] The alternatives

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[9] Richard P. Arber Associates, Inc., Cherry Creek Basin Master Plan, "Volume 1: Costs of Wastewater Treatment Options," prepared for DRCOG May 1985.

[10] Richard P. Arber Associates, Inc. and Gronning Engineering Co., Cherry Creek Basin Master Plan, "Volume 2: Costs and Water Rights Impacts of Selected Point Source Treatment Alternatives," prepared for DRCOG, May 1985.

[11] Richard P. Arber Associates, Inc., Cherry Creek Basin Master Plan, "Volume 3: Costs of Nonpoint Control Options," prepared for DRCOG, May 1985.

[12] Cherry Creek Basin Master Plan, "Volume 1: Costs and Wastewater Treatment Options," Richard P. Arber Associates, May 1985.

[13] Cherry Creek Basin Master Plan, "Volume 2: Costs and Water Rights Impacts of Selected Point Source Treatment Alternatives," Richard P. Arber Associates, Inc. and Gronning Engineering Co., May 1985.

selected by the Task Force are listed below in Table 13. They were chosen because they represent a good cross-section of possible service area scenarios and treatment options. They also represent five alternatives considered very likely to occur.

Table 13
Alternatives Selected by the Task Force for Cost and Water Rights Impacts Analysis

Alternative 1: Four Joint Use Facilities Plus Ten Existing
Type of Treatment: Secondary treatment followed by land application resulting in a percolate quality of 0.05 mg/L

Alternative 2: Four Joint Use Facilities Plus Ten Existing
Type of Treatment: Advanced treatment with direct discharge, effluent phosphorus of 0.1 mg/L

Alternative 3: Four Joint Use Facilities Plus Ten Existing
Type of Treatment: Mixture of land application resulting in 0.05 mg/L phosphorus and advanced treatment with direct discharge resulting in 0.1 mg/L phosphorus.

Alternative 4: Two Joint Use Facilities Plus Ten Existing
Type of Treatment: Secondary treatment followed by land applicating resulting in percolate quality of 0.05 mg/L phosphorus.

Alternative 5: Twelve Existing Facilities
Type of Treatment: Mixture of land application resulting in 0.05 mg/L phosphorus and advanced treatment resulting in 0.1 mg/L phosphorus.

The details of the assumptions and methodology used in developing costs and water rights impacts are described in the report. The water rights report concluded that use and reuse of water in the Cherry Creek Basin should be given the highest priority.[14] Only Alternative 5 (the twelve-plant option) required

[14] Richard P. Arber Associates Inc., Volume 2.

that no water be imported into the basin. In addition, Alternative 5 was one of the least expensive alternatives.

The third volume of the Arber report analyzed the costs for nonpoint control options selected for analysis by the Task Force. The four nonpoint control options studied in order of cost-effectiveness are:[15]

1. Detention followed by sand filtration.
2. Rapid infiltration alone.
3. Detention followed by rapid infiltration.
4. Wetlands.

Based on the analysis described in this chapter the twelve-plant option (or Alternative 5), which would ensure compliance with the standard, was selected by the Task Force. It had the least impacts on water rights, was one of the least expensive and also ranked highest in the non-quantifiable analysis. It utilized all existing treatment plants fully. The twelve-plant option and its use in the allocation process will be discussed in the following chapter.

[15]Cherry Creek Basin Master Plan, "Volume 3: Costs of Nonpoint Control Options," Richard P. Arber Associates, Inc., May 1985.

VI. BASIN PHOSPHORUS LIMITATION AND ALLOCATION

This chapter discusses the maximum phosphorus load that can be allowed in the basin and still maintain the 0.035 milligrams per liter (mg/L) total phosphorus standard adopted for the reservoir by the Colorado Water Quality Control Commission (WQCC). The standard will be maintained by controlling the annual quantity of phosphorus discharged into the reservoir from all sources. This annual quantity is termed the "allowable annual reservoir phosphorus loading." Water quality modeling, discussed later in this chapter, predicted that, for the preferred alternative, a total of 14,270 pounds of phosphorus could enter the reservoir annually without exceeding the allowable annual reservoir phosphorus loading. The portion of the allowable annual reservoir phosphorus loading which is due to point source only is termed the "critical point source load." The method used to determine the allowable annual reservoir phosphorus load and the critical point source load is discussed in this chapter.

In determining the allowable annual phosphorus loading, it was necessary to define the quantity of phosphorus contributed by each source. Data generated in Chapter III and Chapter IV on nonpoint and point source phosphorus show that point and nonpoint loads increase as land use changes and growth occur. In 1982, a total of 5,180 pounds of phosphorus were contributed to the reservoir. Most of this loading (77 percent) came from nonpoint sources with the remainder due to background sources. Less than 1.0 percent of the 1982 load was attributable to point sources due to the relatively small quantity of wastewater produced. The expected quantity of point source phosphorus is shown in

Table 14 and the anticipated nonpoint quantity in the basin appears in Table 15. Background sources are listed in Table 16 and represent those conditions measured in 1982 as part of the Cherry Creek Reservoir Clean Lakes Study. Total basin phosphorus loads are listed in Table 17 and represent the sum of point, nonpoint and background loads.

Table 14

Projected Annual Point Source Loading for the Twelve plant Option

	1990	2000	2010
Phosphorus Load (pounds)	657	2,310	4,210
Volume (acre-feet)	5,153	16,132	29,352

Table 15

Projected Annual Nonpoint Source Loading

	1990	2000	2010
Phosphorus Load (pounds)	10,835	21,531	43,909
Volume (acre-feet)	3,675	10,997	26,557

Table 16

Projected Annual Background Loading

	Baseflow	Groundwater	Precipitation	Total
Phosphorus Load (pounds)	350	130	690	1,170
Volume (acre feet)	400	-220	1,360	1,560

Table 17

Projected Annual Total Phosphorus Loading

	1990	2000	2010
Phosphorus Load (pounds)	12,662	25,011	49,289
Volume (acre-feet)	10,388	28,689	57,469

It is important to note that Tables 14, 15, 16 and 17 do not represent flows and loads at the critical point. They represent flows in three discreet years (1990, 2000 and 2010).

The total phosphorus loads shown in Table 17 were modeled to determine the resulting in-lake phosphorus concentration. The Canfield/Bachmann in-lake phosphorus model was used for these calculations and is described below:[15]

$$TP = Z \left[\frac{L}{K\ 0.114(L/Z)0.589 + p}\right]$$

Where: TP = inlake total phosphorus concentration (mg/L)
L = total phos. loading mg/M(2)/yr per loading of lake surface area: surface area = 3.45x10(6)M(2)
Z = mean depth 5.2 M
P = flushing rate inflow/lake volume: volume = 13,960 ac-ft
K = sedimentation coefficient, constant for Cherry Creek Reservoir (2.3)

[15]Denver Regional Council of Governments, "Cherry Creek Reservoir Clean Lakes Study," April 1, 1984, Denver, Colorado

This methodology results in the ability to predict an in-lake phosphorus concentration based on any of the wastewater treatment types described in Chapter II. The task of determining the exact poundage limit depends on the phosphorus concentration in the wastewater and the volume of water associated with each option. This task is made more difficult with the 12-plant option because it assumes a mixture of treatments. Additionally, the Canfield/Bachmann model was not intended to be used as a method to predict the loading and as such, it is difficult to solve the equation for the variable "L." Therefore, it was necessary to determine allowable annual phosphorus load that would maintain the 0.035 mg/L standard.

All information in this task with respect to phosphorus loading and critical point source loading is dependent upon two main factors: 1) the 0.035 mg/L total phosphorus standard for the reservoir and 2) that the reservoir responds to the basinwide phosphorus loading according the the Canfield/Bachmann model. This planning effort did not intend to challenge or change the reservoir standard and, therefore, it is accepted as a given control factor which will not be altered in this study. It is appropriate to investigate the Canfield/Bachmann model, because it is one of the important factors in determining the phosphorus limitations.

The Canfield/Bachmann model is a modification of the original Vollenweider model which is used to predict in-lake phosphorus from the annual basinwide phosphorus loading. Both models are relatively simple; they utilize a few reservoir characteristics and the annual basinwide phosphorus loading to predict an in-lake phosphorus concentration. The advantage of the Canfield/Bachmann model is that it incorporates a sedimentation coefficient. The sedimentation coefficient is a factor which takes into account that portion of the annual phosphorus load which settles out and does not become part of the reservoir water column. Including this coefficient appears to make the model more reliable as settling of phosphorus into the lake sediment appears to be a common phenomena.

The components of the Canfield/Bachmann model are: reservoir surface area, mean depth, lake volume, phosphorus loading, flushing rate, and sedimentation coefficient. The surface area, mean depth, and lake volume all remain constant while the flushing rate and sedimentation coefficient vary with the loading.

Monitoring of the reservoir and basin as part of the 1982 Clean Lakes Study provided inputs for the Canfield/Bachmann model. When the model was run with these inputs, the result was a predicted in-lake phosphorus concentration which was higher than the measured in-lake phosphorus concentration. To account for this discrepancy, the Colorado Department of Health adjusted the sedimentation coefficient by multiplying it by a dimensionless constant (2.3). All predictions of in-lake phosphorus concentration are now measured using the adjusted sedimentation coefficient. The basin has been monitored since 1982, but no calculations have been done to determine if the sedimentation coefficient needs to be adjusted.

Analysis and readjustment of the sedimentation coefficient is particularly important because of its dramatic effect on the model. To illustrate how sensitive the model is to changes in the sedimentation coefficient, an analysis varying the coefficient was performed. Table 18 shows the results of this analysis.

Table 18

Canfield/Bachmann Model Results for Various Sedimentation Coefficient Constants

	Sedimentation Coefficient Constant						
	0.5	1.0	2.0	3.0	5.0	10.0	15.0
In-Lake Pconc.[1]	112	70	40	28	17	9.0	6.0
In-Lake Pconc.[2]	103	68	40	29	18	10.0	7.0
In-Lake Pconc.[3]	96	66	40	29	19	10.0	7.0

[1]annual phosphorus load 12000 pounds; annual volume 14800 ac-ft.
[2]annual phosphorus load 14700 pounds; annual volume 24600 ac-ft.
[3]annual phosphorus load 16200 pounds; annual volume 32100 ac-ft.

The data show two important facts: 1) varying the sedimentation coefficient has a much greater effect on the in-lake phosphorus concentration than varying the annual phosphorus load and annual volume, and 2) there is an inverse relationship between in-lake phosphorus concentrations and sedimentation coefficient. This analysis emphasizes the need for continued monitoring of the basin and reservoir to more precisely calibrate the model.

Acknowledging the limitations of the Canfield/Bachmann model, analysis was done to determine in-lake phosphorus concentrations under the conditions represented in the twelve-plant option. The model determined that a maximum phosphorus load of 14,270 pounds could enter the reservoir on an annual basis and meet the 0.035 mg/L total phosphorus standard. The 14,270 pounds represents a combination of point, nonpoint, and background sources of phosphorus. The annual load is dependent upon the type of wastewater treatment used throughout the basin. By changing the type of treatment, the allowable annual load can fluctuate between 12,000 and 16,000 pounds. The fluctuation is due to the flushing effect from a direct discharging treatment facility, as compared to a land application facility.

In the twelve-plant option, a mixture of treatment options are assumed to exist in the basin and are described in Table 19. Their population, employment and wastewater flows are shown in Table 20. With this information, it was possible to determine the pounds generated by each of the treatment facilities. These pounds are also listed in Table 20. Using the point source loads as described in Table 20 and the nonpoint and background loads described in Tables 15 and 16, a methodology was developed to ascertain what part of the 14,270 pound maximum was attributable to point source loading.

The methodology used to determine point source loading at the critical point is most easily described as a series of steps:

1. Using the wastewater flows in 1990, 2000 and 2010, and the pounds of phosphorus generated by these flows, plot three points reflecting this relationship. Draw a line through these three points.
2. On the same graph, plot a curve reflecting the amount of available phosphorus. Available phosphorus is calculated by subtracting nonpoint and background phosphorus from the critical pounds of phosphorus; 44,270

Table 19

Wastewater Treatment Facilities
and Method of Treatment in The Twelve-Plant Option

Discharger	Type of Treatment and Effluent Concentration[1]
Arapahoe	AWT, discharge, 0.1 mg/L phos. for 1/2 year, sec. treatment, land application, 0.05 mg/L for 1/2 year
Inverness	Sec treatment, land application, 0.05 mg/L
Meridian	Sec treatment, land application, 0.05 mg/L
Cottonwood	Sec treatment, rapid infiltration, 0.05 mg/L
Stonegate	Sec treatment, land application, 0.05 mg/L
Parker	AWT, discharge, 0.1 mg/L for 1/2 year, Sec treatment, land application, 0.05 mg/L for 1/2 year
Denver Southeast	AWT, Rapid infiltration, 0.05 mg/L
Castle Rock (Cherry Creek, McMurdo, Mitchell Creek, and Newlin Gulch)	AWT, land application, 0.05 mg/L
Rampart Range	AWT, discharge, 0.1 mg/L for 1/2 year, Sec treatment, land application, 0.05 mg/L for 1/2 year

[1]Effluent concentrations are those recognized for the specific type of treatment by the Colorado Department of Health, Water Quality Control Division.

Table 20

Projections of Population, Employment, Wastewater Flow and Pounds Generated for Twelve-Plant Option

Facility	Population			Employment			Wastewater Flow (mgd)			Pounds of Phosphorus Generated		
	1990	2000	2010	1990	2000	2010	1990	2000	2010	1990	2000	2010
Arapahoe	700	2,100	3,900	14,400	39,400	72,500	0.60	1.6	2.9	114	305	553
Inverness	0	0	0	14,300	22,200	32,800	0.50	0.78	1.1	37.9	59.4	86.8
Meridian	0	0	0	7,600	16,600	28,500	0.26	0.58	1.0	20.1	44.1	75.9
Cottonwood	5,200	10,100	16,000	3,400	10,300	19,600	0.56	1.2	2.0	85.2	182.6	310.5
Stonegate	1,500	3,300	5,400	4,400	9,400	16,100	0.28	0.60	1.0	21.3	46.4	77.6
Parker	15,000	43,600	78,800	6,500	19,600	37,100	1.5	4.4	8.0	284.6	832.9	1,516.0
Denver Southeast	11,100	26,500	45,400	2,500	8,600	16,800	1.0	2.6	4.4	155.2	388.1	676.0
Castle Rock:												
Cherry Creek	1,300	4,200	7,700	1,000	3,600	7,100	0.15	0.48	0.9	11.4	365	68.4
McMurdo	2,100	6,700	12,300	100	200	300	0.18	0.58	1.1	13.7	43.4	80.7
Mitchell	1,500	4,700	8,500	200	800	1,500	0.13	0.42	0.78	9.0	31.9	59.1
Newlin Gulch	0	2,900	6,400	0	13,000	30,100	0	0.70	1.6	0.0	53.3	121.8
Rampart Range	0	4,600	10,300	0	6,400	15,800	0	0.62	1.4	0.0	116.0	263.7
Total	38,400	108,700	194,700	54,400	150,100	278,200	5.16	14.6	26.2	656.7	2,321.6	4,210.1

pounds of phosphorus are the critical basinwide pounds for the twelve-plant option. Nonpoint and background pounds in 1990, 2000 and 2010 are shown in Tables 12 and 13. The pounds of nonpoint source phosphorus were first reduced by 50 percent because it was assumed that the 50 percent nonpoint source reduction goal outlined in the plan could be achieved in 1990, 2000 and 2010.

3. Where the line plotted in Step 1 and the curve plotted in Step 2 cross is the point at which phosphorus from all sources will equal 14,270, or the critical point. From the graph, the point source pounds and population can be estimated.

Following this methodology, the critical point for the twelve-plant option was estimated to occur in the year 2000. The critical point source pounds were calculated to be 2,310. The background and nonpoint were calculated to be 1,170 and 10,790, respectively. Figure 9 represents this relationship.

The methodology described above determines that only 2,310 pounds of the annual 14,270 pounds could be generated by point sources and still maintain the standard. These 2,310 pounds were allocated to each of the treatment facilities in the basin by an allocation process described in the plan. Each facility's point source allocation will be reviewed annually, if requested, and incorporated into an annual basinwide water quality assessment report. The allocations will also be incorporated into discharge permits to maintain regulatory control over the process. Incorporating the allocation into discharge permits is the only means by which the State Department of Health can enforce the phosphorus control program and have the guarantee that a discharger is in compliance with the basinwide allocation program. The phosphorus allocations are shown in Table 21. The 2,159 allocated pounds shown in Table 21 allow for a current reserve of 151 pounds per year, increasing to a reserve of 303 pounds after Denver Southeast constructs their new treatment facility. This reserve could be used in the event a discharger needs to bypass or experiences an emergency situation where a breakdown might cause temporary exceedance of the facilities' allocation.

With the point source pounds of phosphorus calculated at 2,310 pounds, 10,790 pound were allocated to nonpoint sources. As discussed in the plan, two other contributors of phosphorus, septic systems and industrial discharger, needed to be recognized.

No data specifically addressing the impact of septic systems on Cherry creek Reservoir was available but, information from Lake Dillon and the Clean Lakes Study can provide an indication of the potential impact.

The work from Dillon stated that resulting effluent phosphorus concentration from septic systems "was equal to or lower than 0.12 mg/L."[16] Assuming a phosphorus concentration of 0.12 mg/L and 75 gallons per day per capita flow for septic users, the forecasted phosphorus loads from septic systems would be 530 pounds in 1990; 1,010 pounds in 2000; and 1,440 pounds in 2010.

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[16] Upper Blue River Wastewater Management Plan, Appendix C, Soils Evaluation Program, p. C-18.

Table 21

Twelve-Plant Phosphorus Allocation

Discharger	Future Allowed Phosphorus Discharge (lbs/yr)
Arapahoe	354
Inverness	68
Meridian	114
Cottonwood	213
Stonegate	53
Parker	533
Denver Southeast	365*
Castle Rock	
Cherry Creek	21
McMurdo	64
Mitchell	128
Newlin Gulch	86
Rampart Range	160
TOTAL	2,159

*The present facility at Denver Southeast Suburban Water and Water and Sanitation District requires 365 pounds of phosphorus annually. The 365 pound phosphorus allocation to Denver Southeast is temporary and should be reduced to 213 pounds of phosphorus in 1990 or when Denver Southeast completes construction of its 1.4 mgd facility, whichever occurs first.

**The Castle Rock, Cherry Creek plant will probably serve a portion of the Newlin Gulch facility up to 51 pounds annually. In this case, 51 pounds would be subtracted from the 86 pounds listed in this table and added to the Castle Rock, Cherry Creek facility.

However, the 1983 data indicates that the 0.12 mg/L value was too high for the Cherry Creek Basin. If we assume that all phosphorus in the groundwater was from septic systems, the septic system effluent would have had an average concentration of 0.058 mg/L in 1983. That concentration would result in future loads of 260 pounds in 1990; 490 pounds in 2000; and 700 pounds in 2010. Therefore, an initial allocation of 450 pounds which closely follows the year 2010 estimate, seemed a reasonable allocation until more information is known about septic systems' effects on the reservoir.

Although there may not be any industrial dischargers presently permitted in the basin, phosphorus was allocated to this source since industrial dischargers may operate within the basin independent of domestic wastewater facilities. Because both industrial dischargers and septic systems are considered nonpoint contributors at this point, their phosphorus allocation was subtracted from the original nonpoint allocation. The resultant allocated phosphorus loads are shown in Table 22.

Table 22

Critical Loading From All Sources
(Pounds Per Year)

Point Sources	2,310
Nonpoint Sources	10,290
Septic Systems	450
Industrial Sources	50
Background	1,170
Critical Load	14,270

The critical loads shown in Table 22 are based on the following assumptions.

1. The point source load is based on the number of treatment systems and the mix of wastewater treatment methods identified in Chapter V. Any changes in the number of facilities, type of treatment, or quantity of wastewater generated will change the critical point source loading limit in addition to changing the allowable annual reservoir phosphorus load.

2. The nonpoint source load is dependent upon the land use forecast and associated runoff coefficients. The land uses recognized in this planning effort include large lot residential, urban residential at two different densities, commercial industrial, airport property, and open space. The actual rate and distribution of growth may be different resulting in different nonpoint loading rates. Any significant changes in the nonpoint contribution, as measured through an annual monitoring program, will change the annual critical nonpoint loading and the allowable annual phosphorus limit.

3. The critical nonpoint source loading is actually 10,790 pounds which contains 450 pounds of phosphorus from septic systems. Lacking an intensive study to more precisely define the contribution from septic systems, the plan recognizes an annual loading of 450 pounds from this source regardless of the population served by septic systems. It also contains 50 pounds for industrial dischargers.

4. The 1,170 background source loading is considered to represent an average condition. If this amount changes, its affect on the allowable annual phosphorus limit will need to be determined. In any event an increase in the uncontrollable background loading in any one year which is the result of an act of nature should not jeopardize or reduce the point source allocation.

In this chapter the methodology and calculations necessary to determine the point source contribution to the critical loading were identified. The process by which the 2,310 point source pounds of phosphorus were allocated to the facilities in the basin is not based on technical methodology; but, rather, on decisions made by the Task Force. Therefore, this chapter is the end of the technical report.

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