Chatfield Basin

Water Quality Study

Denver Regional Council of Governments

CHATFIELD BASIN
WATER QUALITY STUDY

Denver Regional Council of Governments
2480 West 26th Avenue, Suite 200B
Denver, Colorado 80211

in cooperation with
Counties, Municipalities,
Water and Sanitation Districts
in the Chatfield Basin

and the
Colorado Department of Health
Water Quality Control Division
4210 East 11th Avenue
Denver, Colorado 80220

ABSTRACT

TITLE	Chatfield Basin Water Quality Study
AUTHOR	Denver Regional Council of Governments
SUBJECT	This water quality plan for the Chatfield Basin defines a point and nonpoint phosphorus control strategy and comprehensive wastewater plan through 2010.
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ABSTRACT	Guidelines for protection and management of water quality in Chatfield Basin through the year 2010 are presented, including two primary components: 1) methods for achieving the 0.027 milligrams per liter (mg/l) total phosphorus standard in Chatfield Reservoir, and 2) a comprehensive wastewater plan, including suggested effluent limitations, to protect surface water quality basinwide. A phosphorus allocation approach was developed requiring point source reductions in effluent phosphorus concentrations to 0.2 mg/l by January 1, 1991. When basinwide point source discharges total approximately 5.3 MGD, removal of nonpoint sources of phosphorus will become necessary. In the future, dischargers will need to reduce effluent ammonia concentrations to protect the unionized ammonia and nitrate stream standards for Plum Creek. A new service area scenario is outlined which calls for the implementation of two regional facilities. The policy for expansion and construction of new facilities in the future must be linked to the phosphorus allocation issue.

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EXECUTIVE SUMMARY

Chatfield Reservoir is a major flood control reservoir and recreational facility in the southwest Denver metropolitan area. Completed by the U.S. Army Corps of Engineers in 1976, this $85 million project provides a 1,479-acre lake which functions as a flood control structure for water supply, and as a recreational resource for approximately one million visitors each year. In conjunction with the reservoir construction, the Colorado State Division of Parks and Outdoor Recreation established a multi-million dollar state recreation area on 5,300 acres surrounding the reservoir.

By 1981, Chatfield Reservoir began to show signs of degraded water quality, or eutrophication. These water quality problems are due to both natural and human-induced causes, the latter due primarily to increased development in the basin. Development contributes increased wastewater flow from growing populations and greater storm runoff from more impervious surface.

Due to these increasing water quality problems, Chatfield Reservoir was selected for an Environmental Protection Agency-sponsored Clean Lake Study which was initiated in 1981 and concluded in 1984. During this study, it was determined that an increasing phosphorus level in the reservoir was most likely the cause of greater algal growth and resultant water quality degradation. Thus, a 0.027 milligrams per liter (mg/l) in-lake phosphorus standard was established for the reservoir by the Colorado Water Quality Control Commission (Commission) It was determined that maintaining phosphorus at this limited level by controlling inputs will prevent excessive algal growth. As a follow-up to the Clean Lake Study, the Chatfield Basin Water Quality Study (Basin Study) was initiated by the Denver Regional Council of Governments (DRCOG) to produce guidelines for protection and management of water quality throughout the Chatfield Basin into the 21st century. DRCOG also established the Chatfield Basin Study Task Force (Task Force) to oversee and finance the Basin Study. The Basin Study had two primary objectives: to identify the most feasible and effective means of achieving the 0.027 mg/l total phosphorus water quality standard in Chatfield Reservoir, and to determine the most feasible wastewater scenario, including suggested effluent limitations, to protect Plum Creek water quality.

As part of the Basin Study, DRCOG conducted reservoir modeling. Results indicated that a reduction in effluent phosphorus concentrations from point source discharges to 0.2 mg/l will improve water quality conditions in Chatfield Reservoir and, once achieved, will help protect water quality until somewhere around the year 2000, or until these discharges in the basin total approximately 5.3 million gallons per day (MGD). When flows exceed 5.3 MGD, which is expected to occur near 2000, removal of nonpoint sources of phosphorus will become necessary. Nonpoint sources of pollution are diffuse sources not associated with a single outlet. Runoff from urban surfaces such as streets, roofs and parking lots contributes a large percentage of nonpoint source pollution which drains into local water bodies. Runoff from agricultural and non-vegetated surfaces can also affect water quality. This pollution is difficult to quantify and is not normally treated or controlled.

Five service area alternatives were evaluated by the Task Force to determine the most feasible method for providing service while meeting water quality goals. During modeling efforts, it was assumed that all dischargers would be directly discharging into Plum Creek and none of the effluent would be land applied. Wastewater flow forecasts developed by DRCOG for the year 2010 were utilized. The service area alternative selected by the Task Force calls for construction of new facilities at Chatfield Green, Bell Mountain and Larkspur with the latter serving as a regional facility. The Castle Pines treatment facility will be expanded to include tertiary (technologically advanced) treatment capabilities and will serve a newly expanded service area including both Castle Rock and Castle Pines. All existing facilities will be required to implement tertiary treatment no later than January 1, 1991 to achieve the 0.2 mg/l phosphorus effluent standard. The policy for expansion and construction of new facilities in the future must be linked to the phosphorus issue.

A variety of basinwide management options was considered in determination of the best organizational scheme for the Chatfield Basin management agency. Since successful water quality management in the Chatfield Basin is dependent on the implementation of an effective nonpoint program, a single management agency offers the best solution. This management agency will be responsible for monitoring water quality in the reservoir, recommending phosphorus limits for point sources (if the 0.2 mg/l limit is changed), and implementing the nonpoint control program. Point source facilities will continue to be constructed and operated by municipalities and special districts. DRCOG and the management agency will coordinate ongoing planning activities in the basin, with the latter preparing plan amendment proposals for the Clean Water Plan. The Chatfield Basin management agency will be comprised of all affected local governments and private entities in the basin and will be responsible for the continued monitoring of water quality throughout the basin.

Based on the findings of the Basin Study, removal of 50 percent of the phosphorus from nonpoint sources will help protect reservoir water quality until total point source wastewater discharges in the basin reach 10 MGD. A key element of the program will be the development of a model nonpoint control ordinance by the management agency. This will include erosion control measures to reduce erosion potential, particularly during construction activities. A nonpoint control program must be implemented before basinwide wastewater discharges can exceed 5.3 MGD.

The first phase of the nonpoint control program will be the adoption and enforcement by the local governments of erosion control ordinances and best management practices (BMPs). BMPs include urban and agricultural runoff controls which means collecting, detaining and treating storm runoff water before it enters tributary streams and ultimately the reservoir.

In Plum Creek, which contributes flow to Chatfield Reservoir, both instream ammonia and nitrate concentrations will need to be controlled by reducing these concentrations in treated wastewater effluent. As wastewater flows to Plum Creek increase with further development, the Water Quality Control Division (WQCD) will need to apply stricter standards to dischargers. The Commission is adopting stricter standards for unionized ammonia concentrations throughout permitted state waters by applying limits on both acute and chronic (short and long-term) levels. The Task Force agreed to apply an equal-treatment approach to dischargers throughout the basin, which means that for these new standards and any other standards which have been or will be adopted, all dischargers will be required to treat effluent to equal levels. Recommendations regarding a total ammonia effluent limitation will be forthcoming after refinements are made on the model and the results of the State's revisions of the basic stream standards are incorporated. In the interim, dischargers have agreed to operate under existing permit limits. The Task Force recommends that the Chatfield Basin management agency, once officially formed, work diligently with DRCOG, the WQCD and the Division of Wildlife during the next year to determine the proper total ammonia effluent limit.

Modeling results predict no violations of the dissolved oxygen standard in Plum Creek through the year 2010. Therefore, current effluent limits for biochemical oxygen demand (BOD, or that value which represents most oxygen-consuming substances in the water) are adequate.

The results of this water quality study will be incorporated into DRCOG's Clean Water Plan. The implementation of the Study's recommendations will protect the water quality in Chatfield Reservoir and surface water throughout the basin. However, this implementation will require diligent efforts from DRCOG, the Colorado Department of Health, and the local governments within the basin.

I. INTRODUCTION

This study has been undertaken in an effort to protect and improve surface water quality within the Chatfield Basin. This 438 square mile watershed includes the drainages of Plum Creek, Deer Creek and portions of the South Platte River and its tributaries, all of which contribute flow to Chatfield Reservoir. This study focuses primarily on curtailing accelerated eutrophication in the reservoir now and in the future, in addition to providing for overall water quality protection within the watershed. A basinwide co-operative effort was undertaken by the public and private entities concerned with water quality in the basin in cooperation with the Denver Regional Council of Governments (DRCOG). The results of this Chatfield Basin Water Quality Study (Basin Study) will be incorporated in the DRCOG Clean Water Plan.

The Basin Study had two primary objectives: to identify the most feasible and effective means for achieving the 0.027 milligrams per liter (mg/l) total phosphorus water quality standard in Chatfield Reservoir and to determine the necessary wastewater quality which would protect the various water quality standards in the segments of Plum Creek. The Chatfield phosphorus standard was adopted by the Colorado Water Quality Control Commission (Commission) on August 14, 1984 to protect the reservoir from increasing eutrophication. The standard was established after a two-year, EPA-sponsored Clean Lakes Study jointly carried out by DRCOG and the WQCD.

The Plum Creek water quality standards are part of the stream standards for the South Platte Basin which have been adopted and revised on a regular basis by the Commission. This study focused on three major standards in addition to phosphorus: dissolved oxygen, ammonia and nitrate. The first two are primarily intended to protect the aquatic life of the stream while the nitrate standard is necessary to protect human health from polluted drinking water. The Commission is currently considering changes to the basic standards for Colorado which may require the standards of the Basin Study to be updated.

This Basin Study is the result of the cooperative efforts of DRCOG, state and federal agencies, local governments and industries in the Chatfield Basin. The DRCOG Executive Director named a Task Force representing these groups which was responsible for guiding the study and making final recommendations to the DRCOG Board of Directors and the Commission. The Task Force effort and these recommendations are based upon intensive technical analyses which have been documented in a series of memoranda for the Task Force. This Basin Study contains the policy recommendations for the basin developed in accordance with the approved scope of work.

The Basin Study does not replace the need for individual facility plans. It identifies locations of wastewater treatment facilities, nonpoint control strategies and necessary effluent limitations to protect the water quality. Implementation of the study relies upon the creation of an institutional mechanism responsible for ensuring that these recommendations are followed. The recommended institutional structure is a single "management agency" for point and nonpoint sources which would be composed of the principal agencies involved in land use and water quality. Through intergovernmental agreement, the management agency would be able to coordinate the implementation of the plan.

The Basin Study recommends a number of changes to the Clean Water Plan (CWP) and proposed contents for a Commission control regulation. The wastewater treatment portion of the study recommends a system of treatment facilities which should meet the needs of the basin through the year 2010. Methods of allocation for phosphorus, ammonia and nitrate are proposed for these facilities. The study also provides guidance for a nonpoint control effort, including a two phase program to achieve 50 percent removal of phosphorus from stormwater by 2010.

It is important to note that the Basin Study is not an attempt to control growth within the basin. While forecasts of growth were necessary to develop the study, these are not intended as limits. Instead, the study concentrated on outlining a program of wastewater facility improvements and nonpoint source controls that will protect water quality within the basin while growth takes place.

It is also important to recognize that watershed management is an evolving technology. The Task Force has utilized predictive water quality models which represent the best available technology in order to suggest a method to protect water quality in the Chatfield Basin. Although models were chosen and numbers generated for this Basin Study, it has been with the full awareness of the need for the continued development and maturation of the science of modeling. It is expected that as watershed management techniques improve, the conclusions and recommendations within this study will be updated to guarantee the most effective management of this watershed.

II. DEVELOPMENT AND POLLUTANT LOADING FORECASTS

This chapter of the Basin Study identifies the predicted urbanization in the basin by the year 2010. Areas expected to urbanize by 2010 were identified using DRCOG and local government plans. Future populations and the effects of future urbanization on water quality were predicted. This data is the basis for many of the conclusions and recommendations presented in this Basin Study. The methods used to obtain and analyze the data are discussed in this chapter.

Chatfield Basin land uses were defined for present (1985) and future (2010) conditions. Land use data was compiled by the local governments in the basin using their comprehensive plans and existing zoning as the basis for projecting urbanized portions of the basin. The future land use data reflects the land use plans in the basin as of June, 1986. Proposed new developments not included in those plans will need to go through the DRCOG plan amendment process. The information is also to be used solely for the purpose of the Basin Study and, as such, does not reflect official land use decisions of the county commissioners, town boards or councils or special district boards.

The urbanized land uses are aggregated to define the areas of future wastewater service, shown in Figure 1. This Basin Study assumes that all urban development occurs within these service areas through the year 2010. Although this information is an important element of the study, it is anticipated that urban growth may occur outside of these service area boundaries. The CWP will remain flexible enough to accommodate the inevitable changes in land uses through plan amendments pursuant to DRCOG's Integrated Plan Assessment process.

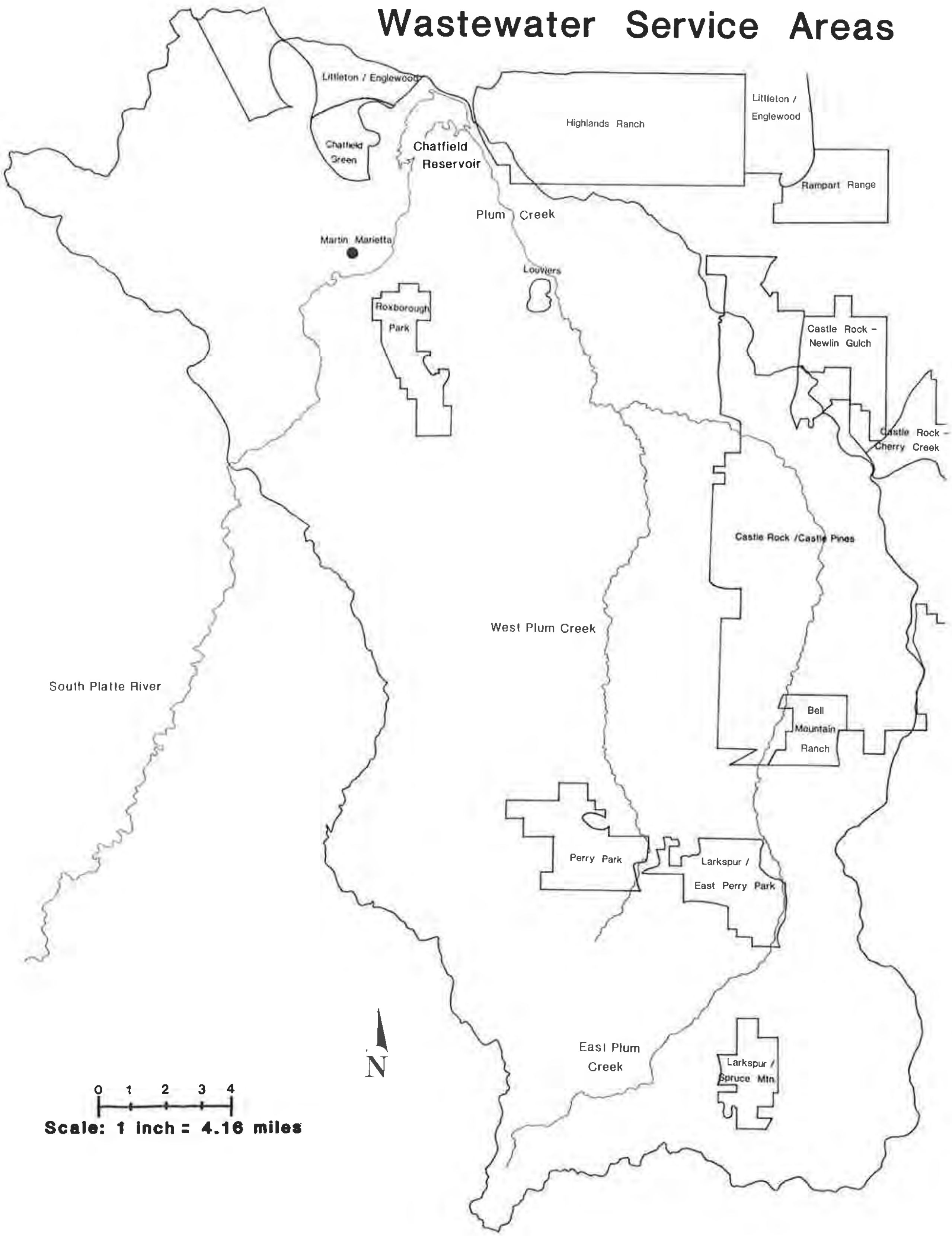
In preparing the data, each local government developed a set of land use assumptions or criteria for use within the Basin Study. The assumptions form the basis for all technical information developed throughout the Basin Study. All the land use projections are consistent with DRCOG's regional forecast found in the DRCOG Regional Development Framework. It is recognized that throughout the period required for implementation, new developments may be approved through DRCOG's Integrated Plan Assessment process.

All land use data was combined into five categories:

- Commercial/Industrial
- Open Space
- Residential, single family
- Residential, multifamily, and
- Residential, single family on large lots

Figure 1

Chatfield Basin Wastewater Service Areas



The total acres of each land use have been tabulated by subbasin for the year 2010 and are shown in Table 1 with the subbasins shown in Figure 2. A projected land use for the years 1985, 1990 and 2000 are included in Appendix B.

The local land use information was combined with estimates of densities and household sizes to produce estimates of population and employment. These local estimates ranged from 30 to 60 percent higher than the adopted DRCOG Regional Statistical Area (RSA) projections. The local numbers were used to distribute forecasts within the RSAs but the totals were reduced to conform to the RSA projections. For the purpose of this planning effort, all estimates and projections of growth are consistent with the adopted DRCOG forecasts. The projections of population and employment by subbasin are shown in Table 2.

The land use information serves other purposes in the formulation of the Basin Study. The extent of percent effective imperviousness which is the basis for estimating the quantity and quality of nonpoint source contributions will be defined by the land use data.

The categories selected coincide with stormwater pollutant export coefficients developed during the DRCOG urban runoff study (Urban Runoff Quality in the Denver Region, DRURP, 1983).

Estimates of nonpoint phosphorus loading to Chatfield Reservoir were made using the land use projections and models developed by DRCOG through the Denver Region National Urban Runoff Program. Based on the land use information, export coefficients were applied to the land uses to estimate the nonpoint runoff flow and phosphorus loading. This analysis was used to determine the extent of nonpoint pollution.

The quantity of runoff and phosphorus generated from nonpoint sources depends greatly upon land use. In general, the more intense the development and the greater the amount of impervious surfaces, the greater the runoff volume and the total phosphorus load. Rainfall no longer soaks into soils or is intercepted by vegetation as pervious surfaces are replaced by impervious surfaces. Phosphorus from fertilizer, auto exhaust, and loose soil in urban areas washes quickly into waterways.

Table 3 shows the predicted runoff and phosphorus for each subbasin. It should be noted that the coefficients used were based on developed areas, so that these numbers do not include any additional load caused by construction activity.

Subbasins showing the greatest runoff and loading volumes might be priority subbasins for nonpoint phosphorus controls when nonpoint source phosphorus control is required.

The land use projections presented in this chapter were used to predict population, employment, wastewater flows, and nonpoint source contributions.

TABLE 1

LAND USE ACRES BY SUBBASIN IN 2010

Subbasin	Single Family	Multi Family	Commercial/ Industrial	Large Lot	Open Space	Total
Bear Creek	991	0	10	0	9,499	10,500
Deer Creek	17	0	263	14,500	3,450	18,230
Garber Creek	0	0	0	424	8,441	8,865
Indian Creek	0	0	0	820	9,703	10,523
Jackson Creek	79	0	0	0	15,985	16,064
Jarre Canyon	0	0	0	100	3,416	3,516
Malin Draw	10	5	4	950	5,801	6,770
Massey Draw	1,394	133	343	1,050	3,378	6,298
Outside Basin (Castle Pines)	1,223	0	60	120	995	2,398
Sellers Gulch	597	196	80	0	8,885	9,728
South Platte Basin	254	0	0	3,810	22,674	26,738
Spring Creek	150	0	0	0	8,302	8,452
Willow Creek	502	17	20	0	8,174	8,713
Direct Flow 1	479	17	592	0	2,463	3,551
Direct Flow 2	219	15	3,694	1,460	15,756	21,144
Direct Flow 3	992	112	259	2,196	11,907	15,466
Direct Flow 4	463	277	247	870	6,403	8,260
Direct Flow 5	802	130	672	0	12,065	13,669
Direct Flow 6	852	0	509	665	34,039	36,065
Direct Flow 7	16	7	8	142	7,795	7,968
Direct Flow 8	0	0	0	1,330	6,244	7,574
Direct Flow 9	289	1	11	1,055	20,452	21,808
Direct Flow 10	0	9	680	0	7,311	8,000
Total	9,329	919	7,452	29,492	233,108	280,302

Figure 2

Chatfield Subbasins

TABLE 2

POPULATION AND EMPLOYMENT BY SUBBASIN: 1985-2010

SUBBASIN NAME	1985 TOTAL EMP	1985 TOTAL POP	1990 TOTAL EMP	1990 TOTAL POP	2000 TOTAL EMP	2000 TOTAL POP	2010 TOTAL EMP	2010 TOTAL POP
Bear Creek	25	730	40	800	50	1,310	100	2,680
Deer Creek	3,376	4,500	3,070	4,680	3,480	4,820	4,800	4,740
Garber Creek	0	220	0	260	0	360	0	390
Indian Creek	0	420	0	490	0	530	0	530
Jackson Creek	0	240	0	250	0	270	0	270
Jarre Canyon	0	20	0	30	0	60	0	60
Malin Draw	0	110	0	200	130	450	220	660
Massey Draw	6,307	15,600	7,700	18,840	8,810	22,710	11,180	25,140
Outside Basin (Castle Pines)	0	600	100	3,130	300	5,900	450	8,430
Sellers Gulch	350	5,030	1,170	6,390	2,820	8,830	4,460	14,910
South Platte Basin	0	990	1,690	410	3,030	950	4,100	2,760
Spring Creek	0	20	0	30	0	140	0	410
Willow Creek	0	20	0	2,000	130	3,870	250	6,590
Direct Flow 1	0	220	0	290	310	1,720	740	4,500
Direct Flow 2	750	690	900	970	2,200	1,720	4,350	3,560
Direct Flow 3	200	1,240	2,000	3,110	5,660	6,940	9,360	15,950
Direct Flow 4	2,000	2,370	4,360	3,950	7,070	7,040	13,780	14,940
Direct Flow 5	22	360	1,200	2,000	4,130	4,720	7,530	12,860
Direct Flow 6	63	350	540	2,200	1,630	4,700	2,630	6,080
Direct Flow 7	0	80	90	160	270	270	450	570
Direct Flow 8	0	430	0	490	0	640	0	850
Direct Flow 9	0	150	10	310	30	940	60	1,890
Direct Flow 10	11,400	0	6,110	460	10,220	585	19,780	710
BASIN TOTAL	24,493	34,390	28,980	51,450	50,270	79,900	84,240	129,480

TABLE 3

NONPOINT FLOWS AND PHOSPHORUS CONTRIBUTIONS BY SUBBASIN

Subbasin Name	Phosphorus Loading (Pounds Per Year)				Runoff (Acre-Feet Per Year)			
	1985	1990	2000	2010	1985	1990	2000	2010
Bear Creek	300	300	420	700	50	50	80	150
Deer Creek Canyon	680	720	760	780	220	240	260	270
Garber Creek	130	130	130	130	10	10	10	10
Indian Creek	160	160	160	160	10	10	10	10
Jackson Creek	280	280	280	280	20	20	20	20
Jarre Canyon	50	50	50	50	0	0	0	0
Malin Draw	100	150	250	390	10	30	70	130
Massey Draw	960	1,080	1,320	1,560	330	380	480	570
Outside Basin	100	310	570	790	20	80	160	230
Sellers Gulch	300	370	500	720	60	90	140	230
South Platte Basin	410	320	460	530	30	30	40	60
Spring Creek	130	130	150	210	10	10	10	30
Willow Creek	130	220	320	440	10	30	60	100
Direct Flow 1	90	100	220	400	10	20	60	120
Direct Flow 2	550	620	1,320	2,300	130	170	520	1,030
Direct Flow 3	370	520	800	1,310	70	130	250	440
Direct Flow 4	250	380	620	1,000	70	120	230	400
Direct Flow 5	270	680	970	1,710	40	220	360	700
Direct Flow 6	600	1,170	1,820	1,960	50	300	600	640
Direct Flow 7	120	120	130	150	10	10	10	20
Direct Flow 8	110	110	110	110	10	10	10	10
Direct Flow 9	330	350	420	500	20	20	40	70
Direct Flow 10	1,100	1,170	1,300	1,420	510	550	610	670
Basin Total	7,520	9,440	13,080	17,600	1,700	2,530	4,030	5,910

The year in which these projections actually occur is less important than their impact to water quality in Chatfield Reservoir. The impacts of these projections is the subject of the next chapter.

III. BASIN WATER QUALITY ASSESSMENT

The land use projections developed in the previous chapter were used to project future populations and the increase in nonpoint loading resulting from increased urbanization in the basin. As population in the basin increases, water quality in Chatfield Reservoir and its tributaries will be impacted and will require mitigation. An increase in population will result in more wastewater flow. An increase in the amount of urbanized area will result in more nonpoint loading and flow. This chapter describes the existing water quality in the basin and predicts the impacts to water quality as a result of urbanization in the basin.

Chatfield Reservoir and Plum Creek were evaluated to predict impacts of urbanization on water quality. In Chatfield Reservoir, the pollutant of concern is phosphorus because of its assumed role in the growth of algae. Water quality of the reservoir was evaluated to determine compliance with the 0.027 mg/l in-lake phosphorus standard by using the Canfield/Bachmann in-lake phosphorus model. The model was adapted to Chatfield Reservoir as part of the 1982 Clean Lakes Study.

In Plum Creek, the pollutants of concern are ammonia (in the unionized form), nitrate-nitrogen (nitrate), and dissolved oxygen. Nitrate is regulated as a toxic compound in drinking water supplies. In addition, the impact of in-stream nitrate concentrations on alluvial water supply wells located along East Plum Creek must be established as wastewater flows increase. Water quality in Plum Creek was evaluated for compliance with the 0.06 mg/l unionized ammonia standard, the 10 mg/l nitrate standard and the 5.0 mg/l dissolved oxygen standard. The Qual2e model was used to evaluate water quality in Plum Creek. The models and the assumptions made in using them are described later in this Basin Study. The results from these models form the basis of the recommended pollutant allocations made as part of this study. Results from the models also demonstrate that the recommended allocation will be adequate to protect the water quality standard established for these water bodies.

RESERVOIR PHOSPHORUS MODELING

The 0.027 mg/l total phosphorus standard on Chatfield Reservoir is the recommended maximum allowable concentration of phosphorus during the summer season. The standard can be maintained by controlling the amount of phosphorus entering the reservoir. Of the three primary sources of phosphorus--point, nonpoint, and background--only the point and nonpoint sources can be controlled since the background consists of less controllable sources, including groundwater, baseflow, precipitation and septic system input.

The primary sources of the annual reservoir phosphorus loading are the natural and human-made conditions in the Chatfield Basin, specifically stormwater runoff (nonpoint sources), wastewater treatment facilities (point sources) and baseflow in the South Platte River and Plum Creek (background). The present phosphorus loading into the reservoir is largely the result of the stormwater runoff, or nonpoint sources, and the baseflow in the South Platte River, Plum Creek and other tributaries. But, as more development occurs, treated wastewater and nonpoint sources will add more phosphorus. The combination of loads from point and nonpoint sources is expected to become the dominant source of annual reservoir phosphorus loading. Loads from point and nonpoint sources of phosphorus must be controlled to maintain the quality of the reservoir.

It is recognized that septic systems contribute phosphorus as a nonpoint source but the extent of this contribution is unknown. Septic system input was considered as a background source in this study. It is presently the responsibility of state and local health departments to monitor and inspect septic systems. Information on phosphorus input from this source is being gathered in a Cherry Creek Basin study. As more data becomes available, input estimates may be revised.

In determining the allowable annual reservoir phosphorus loading, it was necessary to define the quantity of phosphorus contributed from each source. Chatfield Reservoir is unusual in the fact that the South Platte River contributes the largest inflows and loadings. An assumption made in the reservoir modeling was that the proposed Two Forks dam would be constructed and in place by the year 2000. Flows and loads from the South Platte River therefore are both reduced between 1990 and 2000. (The net result of Two Forks was no measureable increase in in-lake phosphorus level.) Loads from point and nonpoint sources also change over time reflecting the increase in urbanization in the basin. Projected loads from the identified sources under two methods of control are shown in Table 4. Both methods of control assume that point source flows undergo tertiary treatment to achieve an effluent concentration of 0.2 mg/l phosphorus.

The contribution from point and nonpoint sources to the loading to Chatfield increases from 23 percent in 1985 to 55 percent in 2010 without nonpoint controls. The point source loads do not include loads from wastewater transmitted from Summit County through the Roberts Tunnel. The load from Summit County is expected to be 88.5 pounds per year and is not expected to occur until after the year 2020. These loads were not included in the analysis because the planning horizon for this study extends only to the year 2010. Summit County's total phosphorus contribution to Chatfield loadings is within the margin of error of the Canfield-Bachmann model.

TABLE 4
LOADING AND INFLOWS TO CHATFIELD RESERVOIR BY SOURCE

A. All Dischargers Direct Discharging at 0.2 mg/l of Phosphorus with No Nonpoint Controls

Flows (Ac-Ft/Yr)

Year	Point Source	Nonpoint	Background	Total
1985	1,500	1,500	117,100	120,100
1990	3,100	2,300	117,100	122,500
2000	5,800	3,700	89,300	98,800
2010	10,400	5,900	89,300	105,600

Loads (Lbs/Yr)

Year	Point Source	Nonpoint	Background	Total
1985	800	7,500	25,100	33,400
1990	1,700	9,600	25,100	36,400
2000	3,100	13,100	19,100	35,300
2010	5,700	17,600	19,100	42,400

B. All Dischargers Direct Discharging at 0.2 mg/l of Phosphorus with 50% Nonpoint Removal

Flows (Ac-Ft)

Year	Point Source	Nonpoint	Background	Total
1985	1,500	1,500	117,100	120,100
1990	3,100	2,300	117,100	122,500
2000	5,800	3,700	89,300	98,800
2010	10,400	5,900	89,300	105,600

Loads (Lbs/Yr)

Year	Point Source	Nonpoint	Background	Total
1985	800	3,700	25,100	29,700
1990	1,700	4,800	25,100	31,600
2000	3,100	6,500	19,100	28,800
2010	5,700	8,800	19,100	33,600

Transmittal of wastewater from Summit County to Chatfield Reservoir through the Roberts Tunnel is consistent with DRCOG's CWP and is a recommendation of this study, as long as the annual phosphorus loading from the wastewater does not exceed 88.5 pounds.

In order to determine what point source phosphorus allocation would protect the in-lake phosphorus standard, monitoring of the existing water quality in the basin was performed.

To develop a wasteload allocation that would be adequate to protect the reservoir's water quality, the amount of phosphorus the reservoir can accept without exceeding the in-lake phosphorus standard was determined. This amount is called the critical value. The critical value was determined for a variety of point and nonpoint phosphorus control conditions. Point source removal of effluent phosphorus was evaluated assuming effluent phosphorus concentrations ranging from 0.05 to 4.0 mg/l. Nonpoint phosphorus removal rates evaluated varied from 0 to 50 percent. A more detailed discussion of the specific conditions modeled is contained in Appendix C. The model (Canfield-Bachmann) used to determine in-lake phosphorus concentrations makes several assumptions. These include assumptions that inflowing phosphorus is instantaneously and completely mixed throughout the lake, that in-lake and outflow concentrations are equal, and that the in-lake phosphorus concentration is predicted as a seasonal average. This model approximates conditions in a lake or reservoir and, as with any model, cannot account for the dynamic nature of the actual ecosystem. It is difficult, if not impossible, to ascertain all the factors which influence algal production and therefore chlorophyll a levels in a given reservoir. However, it is recognized that a lack of phosphorus is often a limiting factor in algal growth, and thus, that increased phosphorus inputs can lead to greater algal production and higher chlorophyll a levels, though this has not been definitively established in Chatfield.

The in-lake phosphorus concentrations from the modeling results are shown in Table 5. The reservoir modeling showed that with effluent phosphorus concentrations greater than 0.2 mg/l, the in-lake phosphorus standard for the reservoir would likely be exceeded. If effluent phosphorus concentrations are reduced to 0.2 mg/l or below, nonpoint sources of phosphorus would become the dominant factor in exceeding the reservoir phosphorus standard. The model shows that phosphorus concentrations of 0.2 mg/l and removal of 50 percent of the nonpoint source phosphorus would maintain the in-lake standard through the year 2010. Without removing 50 percent of the nonpoint sources, effluent phosphorus concentrations of 0.2 mg/l will maintain the standard through the year 2000 under critical year conditions. The model predicts that when total phosphorus loading exceeds approximately 36,000 pounds per year, the standard will also be exceeded.

Based on the reservoir modeling the recommended phosphorus allocation is to have all dischargers treat to 0.2 mg/l of effluent phosphorus. The recommended allocation is that basinwide removal of 50 percent of the nonpoint sources of phosphorus begin by the year 2000. After wastewater flows

TABLE 5

IN-LAKE PHOSPHORUS LEVELS (UG/L) WITH IN-BASIN ASSUMPTION

Year	Scenario 1[1]	Scenario 2[2]	Scenario 3[3]	Scenario 4[4]	Scenario 5[5]	Scenario 6[6]
1985	25	23	25	25	26	30
1990	26	24	26	26	28	36
2000	27	24	26	26	31	44
2010	29	26	28	28	36	55

IN-LAKE PHOSPHORUS LEVELS (UG/L) WITH OUT-BASIN ASSUMPTION

Year	Scenario 1[1]	Scenario 2[2]	Scenario 3[3]	Scenario 4[4]	Scenario 5[5]	Scenario 6[6]
1985	25	23	25	25	25	27
1990	26	23	25	25	26	28
2000	26	23	26	26	26	28
2010	27	24	27	27	28	30

[1] All dischargers direct discharging at 0.2 mg/l, no nonpoint controls

[2] All dischargers direct discharging at 0.2 mg/l with 50 percent nonpoint removal

[3] All dischargers direct discharging at 0.1 mg/l, with no nonpoint controls

[4] All dischargers land applying to achieve 0.05 mg/l, with non nonpoint controls

[5] All dischargers direct discharging at 1.0 mg/l, no nonpoint controls

[6] All dischargers direct discharging at 4.0 mg/l, no nonpoint controls

discharged in the basin reach 5.3 MGD, nonpoint sources of phosphorus will need to be removed to maintain in-lake water quality. The recommended allocation is that removal of 50 percent of nonpoint sources of phosphorus begin no later than the year 2000. If effluent phosphorus is reduced to 0.2 mg/l and nonpoint sources of phosphorus are reduced by 50 percent, the in-lake phosphorus standard should be maintained until at least the year 2010 or until wastewater flows discharged in the basin reach 10 MGD. If nonpoint removal exceeds 50 percent, additional wastewater flows could be accommodated. It should be noted that the modeling was based upon direct discharge from all facilities and upon 1982 hydrology. Systems which treat to better than 0.2 mg/l would have a slight beneficial effect on in-lake phosphorus.

STREAM MODELING

Unlike the reservoir phosphorus modeling, the stream modeling addresses only a portion of the study area, the Plum Creek basin. The basin includes a number of classified stream segments, including East and West Plum Creek. The stream model - Qual2e - is not an annual model but instead, simulates stream water quality under a given set of conditions for a particular point in time. The model uses a series of mathematical equations, integrated functions and decay rates to simulate water quality conditions in a stream. The model was developed jointly by the National Council for Air and Stream Improvement Inc. and the Environmental Protection Agency (EPA). It has been in use for many years and is currently used by the WQCD to develop effluent limits. A sample of Qual2e model output is contained in Appendix D.

Qual2e takes measured data to calibrate equations which predict stream conditions. It can simulate up to 15 water quality parameters in any combination. The model first simulates the hydrology (flows and streambed characteristics) of the water body being modeled. It then models a slug or parcel of water as it travels from the beginning of a stream segment to the end of the segment. The following water quality parameters were modeled as part of this study: nitrite; nitrate; ammonia; dissolved oxygen; biochemical oxygen demand (BOD); and temperature.

Parameters evaluated by the stream modeling are those for which stream standards were established: dissolved oxygen, ammonia (in the unionized form), and nitrate. As the amount of wastewater discharged to Plum Creek increases, the amount of ammonia, nitrate and BOD in Plum Creek will increase. The greater the amount of BOD in a stream the smaller the amount of dissolved oxygen. The modeled stream parameters, however, do not represent alluvial groundwater quality conditions. This interrelationship must be evaluated before the 1990 CWP update.

This analysis is based on the stream standards and discharge permit methodologies in place in 1987. For example, the assumptions of base flows in the stream are currently determined using a statistical approach called the 7Q10, or lowest seven-day average expected to occur once in ten years. In Plum Creek, the only stream gauge with a long record is at Louviers. Its 7Q10 value of less than 1.0 cubic feet per second has been used in discharge permits. The Basin Study sampling shows that at very low flows, Plum Creek is a losing stream; that is, flows above Louviers are higher than below. The flows of September 19, 1986 are assumed to be comparable to the 7Q10.

If the regulations are changed to use a different definition of low flow, the analysis in this Basin Study should be modified. Similar changes may be necessary because of changes to the ammonia standard. The Commission is currently considering the addition of acute and chronic standards for unionized ammonia.

Past studies have shown that nonpoint sources of ammonia and nitrate are negligible except in areas where a large amount of agricultural activity is occurring. The land use estimates in Chapter II showed that there is relatively little agricultural activity in the Plum Creek basin. Analysis of instream ammonia and nitrate was, therefore, limited to point sources of ammonia and nitrate.

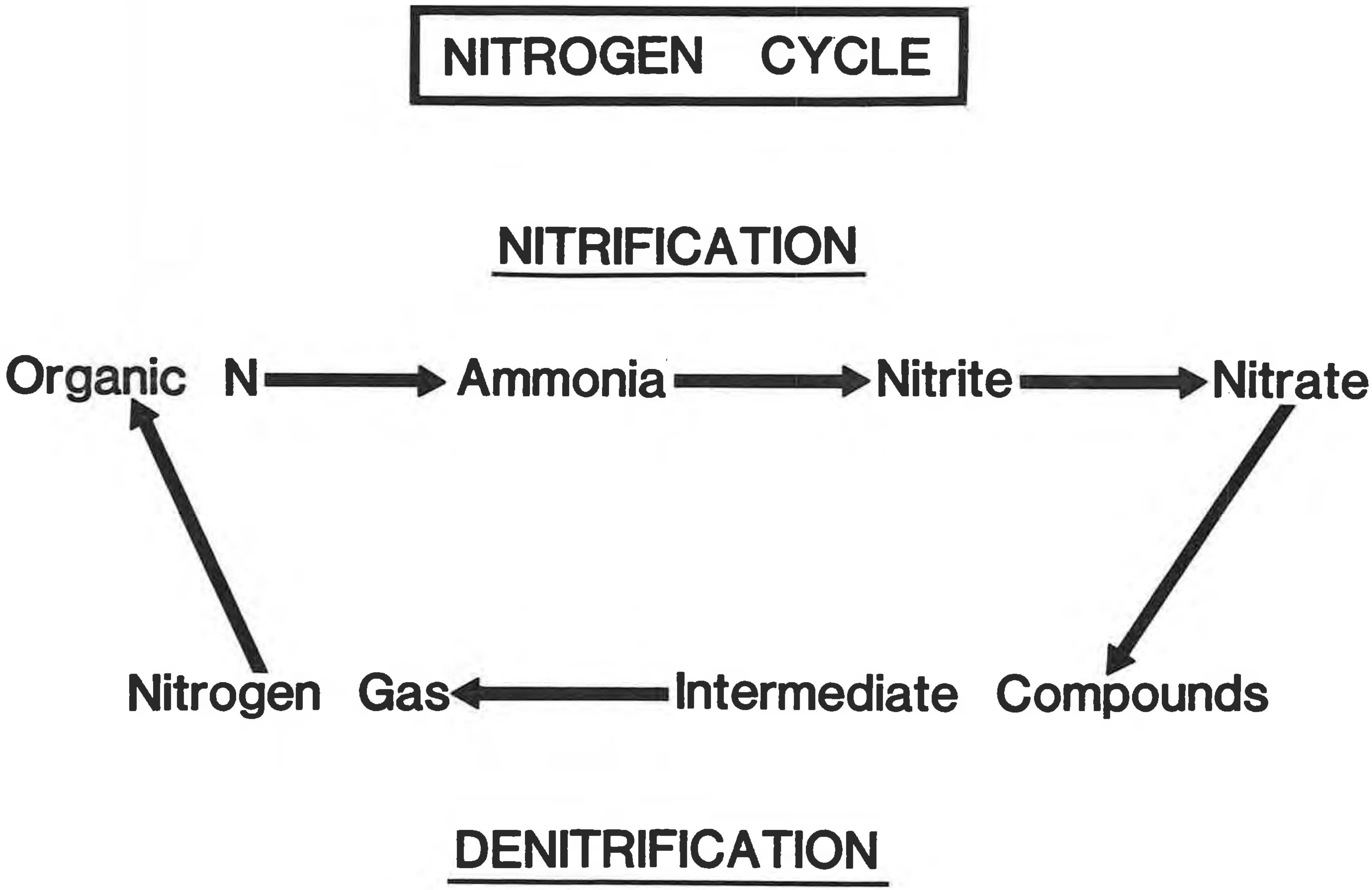
In most natural streams, there is a stepwise transformation of organic nitrogen to ammonia, to nitrite, and finally to nitrate. This transformation is called the Nitrogen cycle and is depicted in Figure 3. The Qual2e model simulates this cycle, incorporating characteristics that are unique to the particular water body being modeled (i.e. flow, temperature, streambed characteristics, time of day, day of year, amount of cloud cover, slope, etc.).

The greatest possibility for an ammonia stream standard exceedance is usually on warm, low flow days. Consequently, to analyze Plum Creek's water quality the model was calibrated for two days, September 19, 1986 and October 15, 1986. These days were selected because there was relatively little flow in Plum Creek on those days and because these days were relatively warm. Modeling for these days, therefore, represents a worst case condition and is comparable to the conditions assumed in writing discharge permits.

Results of the stream monitoring samples show that there are no current violations of the dissolved oxygen standard. The modeling expects no excursions to occur as wastewater discharges to Plum Creek increase between now and the year 2010. Therefore, standard effluent limits are adequate for BOD. The results also show that there are no current violations of the unionized ammonia and nitrate stream standards but violations of these standards are expected to occur as wastewater discharges to Plum Creek increase between now and 2010. Because of the predicted excursions of the ammonia and nitrate stream standards displayed with modeling, wasteload allocations for these pollutants are recommended in this plan.

Determining the proper limit for total ammonia in the stream is complicated. The unionized ammonia standard for all segments of Plum Creek below existing or planned treatment facilities is 0.06 mg/l. The percentage of total ammonia that is unionized is a function of temperature and pH. To determine the maximum allowable total ammonia concentration in Plum Creek, assumptions about the stream's temperature and pH are needed.

Figure 3


NITROGEN CYCLE
NITRIFICATION
Organic N
Ammonia
Nitrite
Nitrate
Intermediate Compounds
Nitrogen Gas
DENITRIFICATION

The data collected at four locations between 1986 and 1987 show a wide variation in allowable total ammonia (see Table 6). To ensure that no violations of the 0.06 mg/l standard occurred, total ammonia values would need to be kept below 1.0 mg/l throughout the basin through most of the year. The high pH values tend to occur in low temperature months, keeping the unionized percentage high. The current Castle Rock discharge permit used less stringent assumptions about temperature and pH, resulting in a total ammonia limit of 3.53 mg/l. Further discussions and additional data will be needed to determine the proper limit for total ammonia in Plum Creek. Until that time, an official wasteload allocation cannot be incorporated into the CWP. The Task Force recommends that the management agency work diligently with DRCOG, the WQCD and the Division of Wildlife during the next year to determine the proper limit.

During the one year period, the dischargers should operate under existing permit limits. Any permit for a new discharge issued during this one-year period should not contain a total ammonia limit more restrictive than 5 mg/l. Current permits do not require any dischargers to remove nitrates. This policy should continue during the one year period unless the discharge is above a potable water intake. For those situations, the permit should include a monitoring program for immediate downstream water supplies including both surface and alluvial groundwater sources.

Most standard secondary wastewater treatment facilities can reduce ammonia effluent concentrations to about 21 mg/l. To achieve total ammonia concentrations of less than 21 mg/l requires tertiary wastewater treatment processes. The wastewater treatment facility process to remove ammonia has a side effect of generating nitrate. Unlike ammonia, the amount of nitrate decays very slowly in most natural streams. In the analysis done for this study, nitrate is considered to be conservative (i.e. does not decay). Therefore, it accumulates in the stream. For this reason the highest concentration of nitrate in Plum Creek is predicted to occur in the last reach of the stream.

Analysis of available data on nitrate concentrations in Plum Creek shows that instream nitrate concentrations are not currently causing a water quality problem in Plum Creek. Instream nitrate concentrations were shown to decrease as flows increased and to increase as Plum Creek approaches Chatfield Reservoir.

Two different policies were considered in developing wasteload allocations for dischargers to Plum Creek for ammonia and nitrate: equal treatment and maximum assimilative capacity. The equal treatment approach requires all wastewater treatment facilities to meet the same effluent limits. The limits are the same as the most stringent limits established for any of the wastewater treatment facilities. The maximum assimilative capacity approach allows different effluent limits to be established for each wastewater treatment facility which allows greater amounts of pollutants to be discharged to Plum Creek

TABLE 6

AMMONIA LIMITS AT FOUR SAMPLE SITES NEEDED TO PROTECT UNIONIZED STANDARD OF 0.06 mg/l

	Total Ammonia Limit (mg/l)			
Sample Date	Bear Creek	East Plum Creek @ Larkspur	East Plum Creek @ Sedalia	West Plum Creek @ Sedalia
8/25/86			4.2	32.3
9/15/86	25.5	11.1	14.0	20.4
9/29/86			2.1	1.0
10/13/86	8.2	1.2	1.3	2.9
10/27/86			1.1	3.0
11/17/86	20.5	4.5	1.7	2.6
12/16/86	6.5	5.3	0.7	6.7
1/13/87	3.9	3.3	8.5	2.7
2/17/87	2.3	1.8	2.1	2.5
3/17/87	120.0	2.3	1.8	3.1
4/14/87	7.7	9.8	1.6	1.9
4/27/87			4.1	1.9
5/14/87	9.5	5.9	2.0	2.5
6/11/87	8.8	1.9	2.2	3.0
7/14/87	4.1	3.8	3.0	3.3
7/27/87			1.6	2.0
8/13/87	3.1	1.3	1.1	2.1

because it uses all of the creek's ability to assimilate pollutants. Effluent limits developed using the maximum assimilative capacity approach can, however, create a great deal of controversy in dividing wasteloads between dischargers.

The sample wasteload allocations developed using either approach indicated that wastewater treatment facilities would immediately need to achieve tertiary treatment levels. Because all the wastewater treatment facilities would need to use tertiary treatment techniques for nitrification/denitrification to maintain the estimated stream standards for ammonia and nitrate, regardless of the allocation approach chosen, the equal treatment approach is recommended for use in developing wasteload allocations for ammonia and nitrate. DRCOG has historically encouraged an equal treatment approach in developing wasteload allocations. In addition, equal effluent limits for ammonia and nitrate are consistent with the equal effluent limits established as part of the phosphorus allocation. The Basin Study recommends that, after an instream limit is established for ammonia, an equal treatment approach be used to allocate ammonia and nitrate wasteloads.

IV. MANAGEMENT OF POINT SOURCES

The preceding chapter described the effluent limits that are necessary to protect water quality in the Chatfield Basin. These effluent limits will be included in discharge permits for wastewater treatment facilities in the basin. There are, however, many possibilities for the number and location of facilities to provide wastewater treatment service in the basin. For example, all wastewater generated in the basin could be pumped outside the basin for treatment and discharge. Other possibilities are to consolidate all wastewater treatment in one regional facility in the basin or, conversely, maximize the number of treatment facilities to spread out pollutant loads to water bodies in the basin. Sizing and staging of facilities is an important element of this Basin Study and will direct the policies for expansions of existing and construction of new wastewater treatment facilities.

This chapter describes service area alternatives evaluated, the preferred alternative and recommended policies for expansion and construction of wastewater treatment facilities.

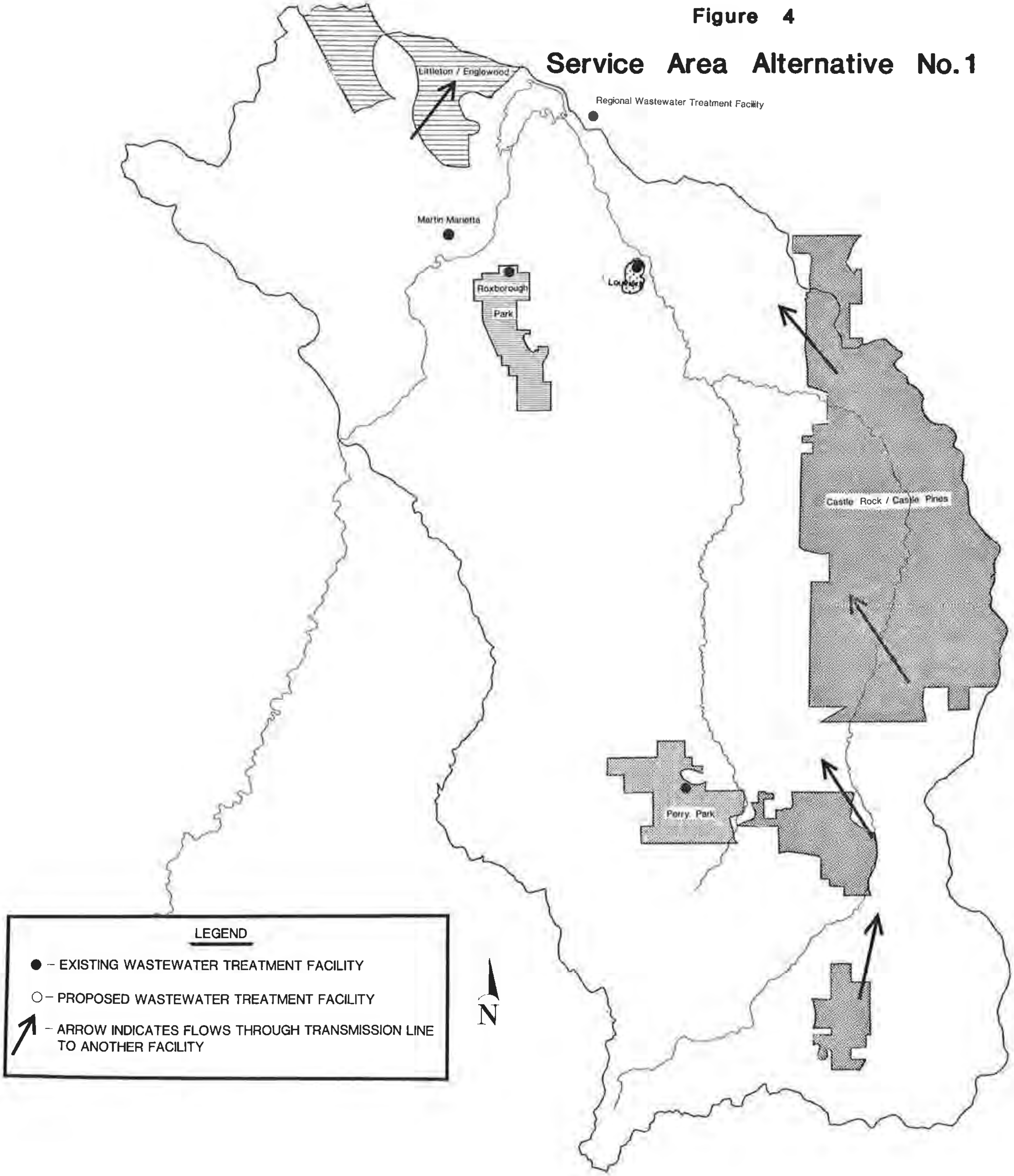
The Task Force evaluated five service area alternatives. These alternatives represent combinations of wastewater service areas and are called analysis areas. The analysis areas can be grouped into categories by the receiving waters to which they discharge: East Plum Creek, West Plum Creek, and west of the confluence of East and West Plum Creek. Larkspur, Perry Park, Bell Mountain Ranch, Sage Port (or Perry Park East) Castle Rock and Castle Pines are analysis areas that discharge to East Plum Creek. Perry Park's Waucondah Plant is the only discharger to West Plum Creek via its tributary, Bear Creek. Roxborough Park, Martin Marietta, Louviers, and Chatfield Green discharge to water bodies west of the confluence of East and West Plum Creeks. The five service area alternatives include consideration of all possible discharge points for the categories of analysis areas.

The analysis areas were defined based on either existing facility service areas or various proposals for new facilities. These were grouped into five alternatives by the Task Force as the most feasible approaches to providing wastewater service in the basin. The alternatives are shown in Figures 4 through 8. The service area alternatives, numbered 1 through 5, were evaluated for cost and other variables to determine the preferred approach to providing wastewater service over the long-term.

Alternative Number 1 (Figure 4) was developed to test the cost and water quality effects of taking almost all wastewater out of the basin for treatment. Existing treatment facilities at Martin Marietta, Perry Park, Roxborough Park and Louviers would still discharge within the basin. Only the Martin Marietta and Perry Park analysis areas are left with treatment facilities within the basin. Martin Marietta has special wastewater treatment needs while Perry Park is isolated along West Plum Creek. These two analysis areas have their own facilities in all five alternatives.

Figure 4

Service Area Alternative No. 1



In Alternative Numbers 2 through 5, the other analysis areas west of the confluence of East and West Plum Creeks are assumed to have their own facilities. The major differences between these alternatives are in the combination of facilities discharging to East Plum Creek.

In Alternative Number 2 (Figure 5) all dischargers send their wastewater to one in-basin regional facility for treatment and discharge. In Alternative Number 3 (Figure 6) wastewater treatment analysis areas are combined at two regional facilities. Wastewater flows from Castle Pines and Castle Rock are treated at the first regional facility. Flows from Bell Mountain Ranch, East Perry Park and Larkspur are treated at the second regional facility.

Alternative Number 4 (Figure 7) has the greatest number of facilities by assuming each analysis area on East Plum Creek would treat and discharge its own wastewater. Alternative Number 5 (Figure 8) again combines analysis areas to two regional facilities and Bell Mountain. The second regional facility treats flows from East Perry Park and Larkspur. The first regional facility treats flows from Castle Pines and Castle Rock. Bell Mountain Ranch treats and discharges its own wastewater. Wastewater flows were calculated for each alternative using the following formulae:

Population X 85 gallons per person per day = Residential Flows
Employment X 35 gallons per employee per day = Non-residential Flows

The sum of these two flow projections shows the total wastewater flow in the facility per day. The 85 gallons per person and the 35 gallons per employee include 10 gallons each for infiltration/inflow.

It should be noted that the service area analysis is not to the same level of detail as an individual facility plan. The Basin Study is intended to identify the facilities needed in the basin. It is then the responsibility of the management agency (or agencies) to prepare the facility level plans. Assumptions regarding phosphorus, ammonia and nitrate loadings have therefore been made to service areas rather than facilities.

Criteria used in evaluating the service area alternatives included water quality costs and non-quantifiable impacts. In alternatives where wastewater was pumped to a regional facility or out of the basin, costs for returning the amount of wastewater needed for reuse were evaluated.

Reservoir water quality impacts from Alternatives 2 through 5 were equal. The only alternative that has a different water quality impact on Chatfield Reservoir is Alternative Number 1, in which almost all wastewater is pumped out of the basin for treatment. This initially reduces the amount of phosphorus reaching Chatfield Reservoir; however, when all dischargers achieve 0.2 mg/l or better effluent phosphorus concentrations, the amount is so small that the impact to in-lake phosphorus levels is imperceptible. This alternative also eliminates any discharges of nitrogen to Plum Creek; however, the reduction of baseflow to Plum Creek resulting from this alternative offsets any benefit to aquatic life from the reduction in pollutant

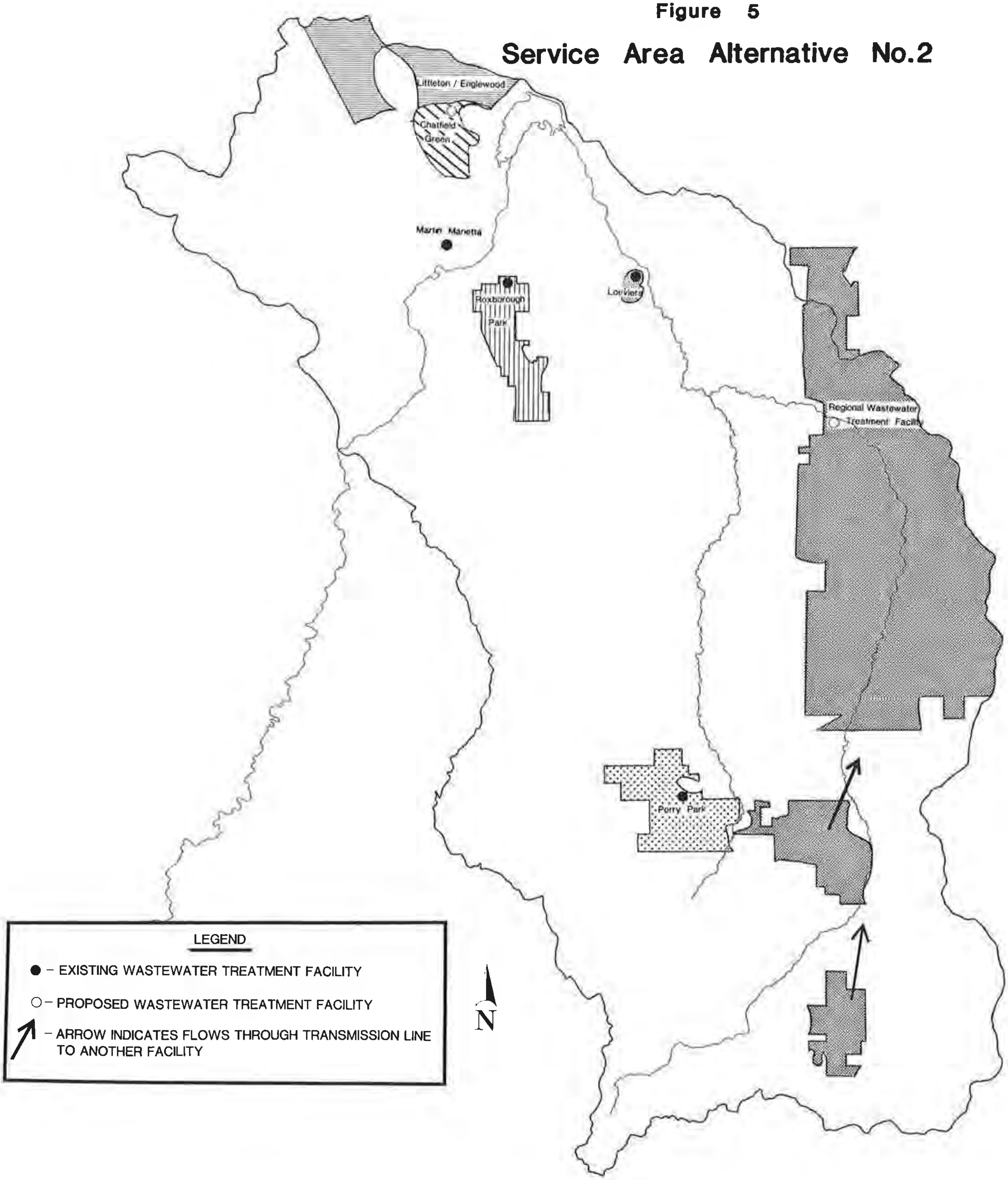


Figure 5

Service Area Alternative No.2

Figure 6

Service Area Alternative No.3

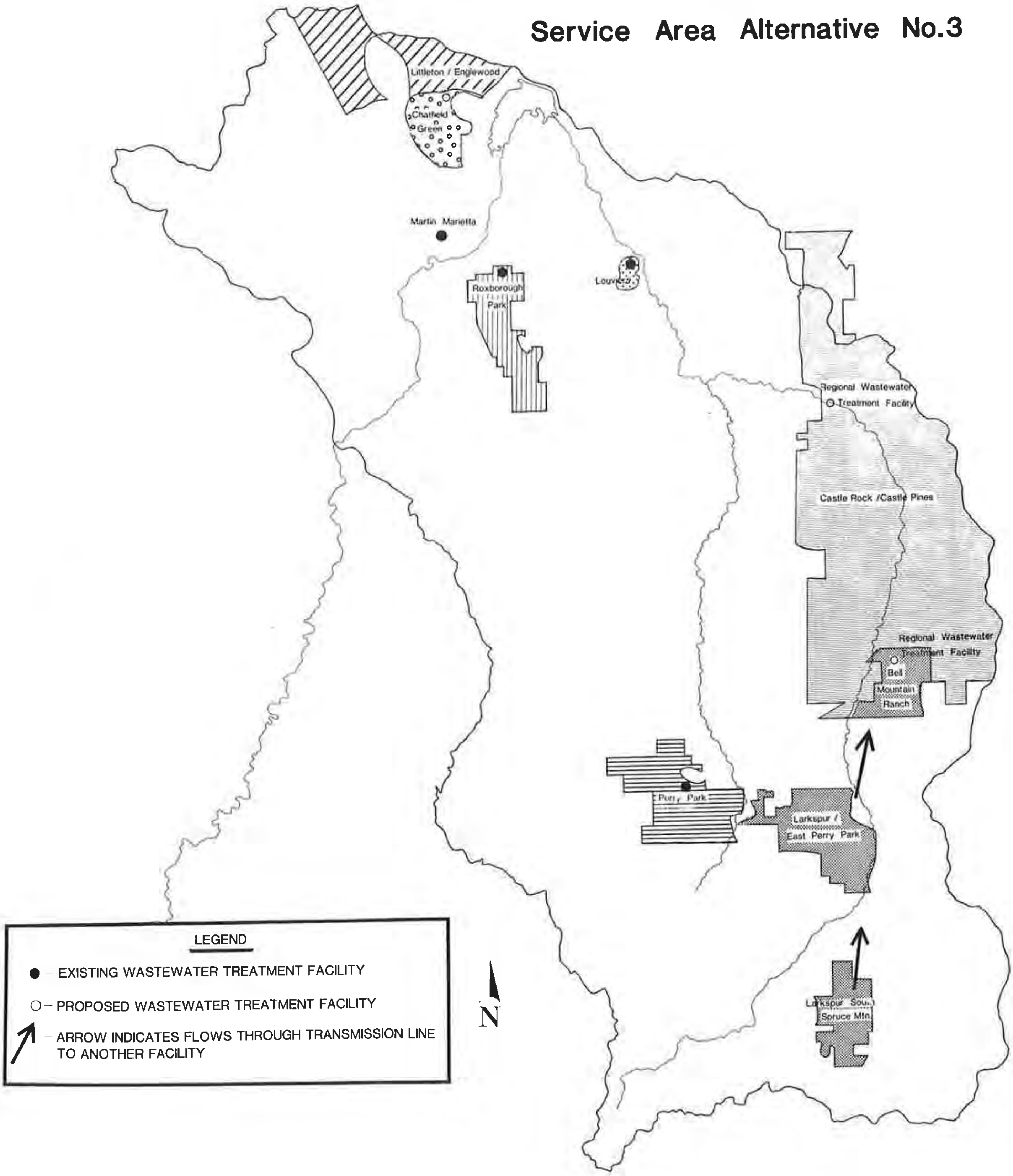


Figure 7

Service Area Alternative No.4

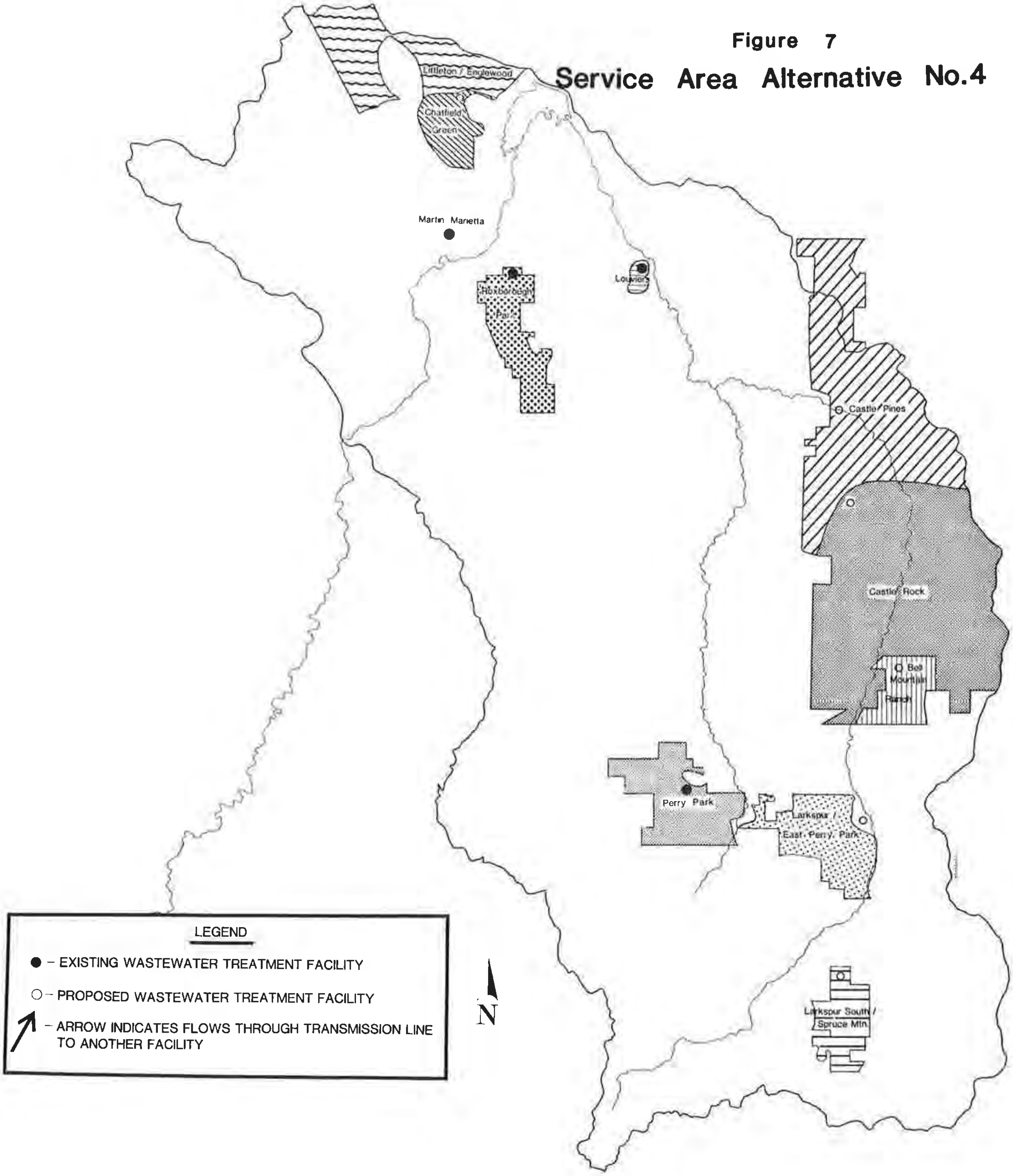
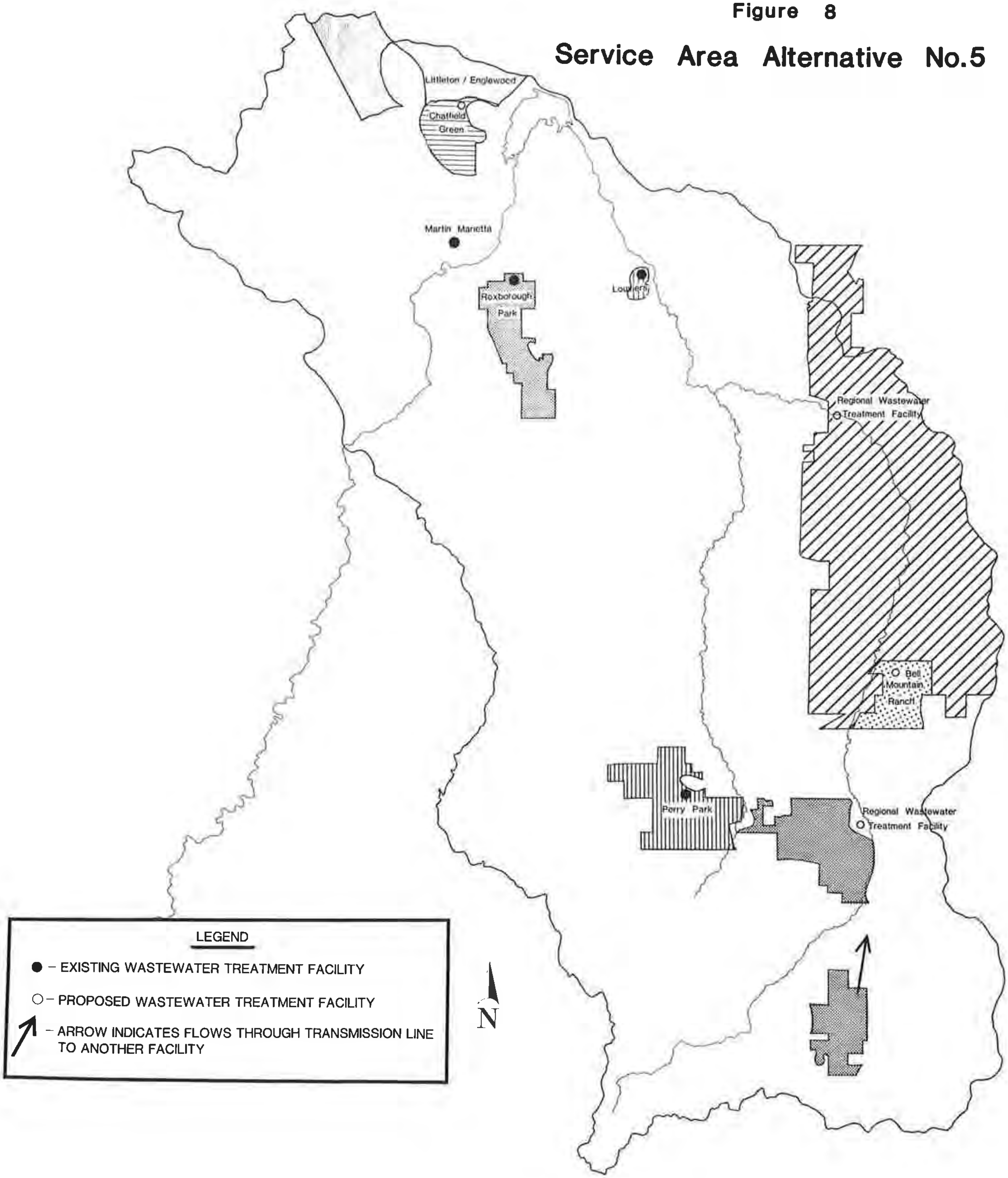


Figure 8

Service Area Alternative No.5



loading. Consequently, Alternative Number 1 is less desirable from the standpoint of total impacts on the lake and stream.

A planning-level cost analysis was performed for each of the five alternatives. Table 7 summarizes the capital and operation and maintenance costs expected over a twenty year period. (More information on the cost estimates is contained in Appendix E). The capital costs are expressed as present worth while the operations and maintenance costs are the average annual costs summed for the period. The interceptor costs include an estimate of costs to return portions of the treated effluent to some service areas for reuse or to meet water rights augmentation plans.

Alternative Number 4 is estimated to be substantially more expensive than the other alternatives, almost 50 percent higher than the least expensive.

Even though it does not require any regional interceptors or return lines, the costs of five different facilities and their operations and maintenance result in a high total.

Alternative Number 1 (a single regional facility below the reservoir) would have had the lowest cost if only the treatment facility were considered. The cost of the interceptor line and the return forcemains negates the consolidation advantages. Because of the minor benefit to the reservoir, the institutional difficulty in implementing this facility and the loss of flows in Plum Creek, this alternative was rejected.

Alternative Numbers 2, 3 and 5 are within 25 percent of each other for both capital costs and operations and maintenance. Because of the uncertainties involved in the cost estimation process, the Task Force treated these as equivalent.

An analysis of non-quantifiable parameters which characterize wastewater service areas was performed and is shown in Table 8. This analysis showed Alternatives Number 4 and 5 as having the least adverse effects on water quality and selection of service area. The non-quantifiable analysis considered impacts of the different service area alternatives on: aesthetics; lake water quality; implementation; flexibility; energy consumption without water rights pumping; ease of operation; land use aesthetics; reliability; reuse potential; and the impact on existing facilities. Comments on the rationale used in ranking the alternatives is included in the table. The alternative with the lowest total ranking is the most preferable.

Based on the criteria of water quality, costs and non-quantifiable impacts, Alternative Number 5 is the recommended system of treatment facilities in 2010. By providing these large facilities along East Plum Creek, the flows in the creek will be adequate to sustain aquatic life. The facilities are large enough to promote efficient advanced treatment to achieve the phosphorus and ammonia limits. By using three facilities, a number of opportunities to develop reuse are possible. The cost of the alternative is within 25 percent of the least expensive alternative and is substantially less expensive than Alternative 4.

TABLE 7

COST ESTIMATES OF ALTERNATIVES

Wastewater Facility	2010 Size (MGD)	Total Capital*	20-Year O&M ($ mil)
ALTERNATIVE 1			
Douglas County	8.94	36.70	31.30
		Total: 36.70	31.30
ALTERNATIVE 2			
Castle Pines			
RWWTP1	8.04	34.19	27.62
		Total: 34.19	27.62
ALTERNATIVE 3			
Castle Pines			
RWWTP1	6.50	24.14	20.82
Bell Mountain Ranch			
RWWTP2	1.54	12.68	10.28
		Total: 36.82	31.10
ALTERNATIVE 4			
Castle Pines	2.26	13.65	11.4
Bell Mountain Ranch	0.57	8.60	6.2
Castle Rock	3.77	17.25	15.2
Larkspur-North	0.87	9.45	7.4
Perry Park-Sage Port	0.10	1.38	3.0
		Total: 50.33	43.2
ALTERNATIVE 5			
Castle Pines			
RWWTP1	6.50	24.65	20.82
Bell Mountain Ranch	0.57	8.60	6.20
North Larkspur			
RWWTP2	0.97	9.67	7.96
		Total: 42.92	34.98

*Costs were not calculated for existing plants which were expected to occur in all 5 alternatives.

TABLE 8

SUMMARY OF NON-QUANTIFIABLE ANALYSIS OF FIVE SERVICE AREA ALTERNATIVES*

Criteria	Alt. 1	Alt. 2	Alt. 3	Alt. 4	Alt. 5	Comments
Aesthetics	5	4	3	1	2	The more WWTPs, the more consistent flows in Plum Creek. This maintains a better stream level.
Water Quality	1	5	4	2	3	Best water quality in lake is to pump pollutants out of basin as in Alt. 1. The more facilities treating effluent to tertiary levels, the better the stream quality.
Implementation	5	4	3	1	2	More intergovernmental agreements the more difficult an alternative's implementation.
Flexibility	5	4	3	1	2	More treatment plants, more flexibility.
Energy Consumption without Water rights Pumping	5	4	3	1	2	Alternatives with the greatest length and type of interceptors were rated highest.
Ease of Operation	1	2	3	5	4	One plant is the easiest to operate. This leads to reduced O&M costs.
Land Use Aesthetics	1	2	3	5	4	More WWTPs are less aesthetically pleasing.
Reliability	1	2	3	5	4	More potential for WWTP failures with more WWTP. Also more potential for permit violations.
Reuse Potential	5	4	3	1	2	Alternatives with the greatest amount of pumping would have the most difficulty maximizing reuse potential. Cost of pumping back for reuse decreases cost-effectiveness.
Impact on Existing Facilities	5	4	3	2	1	Considers existing agreements between WWTP's. Incorporating new facilities in with existing facility agreements (those already negotiated) is easiest to implement.
Total	34	35	31	24	26	

*Categories were ranked by alternative from one to five with one representing the best. The alternative with the lowest total is the most preferable from a non-quantifiable standpoint.

A modification of Alternative 5 has been considered which would have the Bell Mountain area served by the Castle Pines facility. This alternative would have greater non-quantifiable impacts on East Plum Creek but would be slightly less expensive. This modification of Alternative 5 would be equivalent to building their own facility if an agreement between Castle Rock and Bell Mountain is finalized.

Implementing this alternative will require some changes to the existing system. Construction of a land application facility on-site at Chatfield Green is expected to be less expensive than sending flows to the Littleton-Englewood Bi-City Treatment Plant at the sizes expected in this study. Although the cost of sending the flows to Bi-City is likely to be within 20 percent of an on-site facility, other factors favor the on-site facility. These include: necessity of providing existing interceptor lines, need to construct return lines for land application, ease of expansion of the service area to serve adjacent properties, and reluctance of connector districts to provide service. Within the proposed service area of the Larkspur/East Perry Park facility there are now two facilities (Larkspur and Sage Port) and a third planned (Spruce Mountain). The two operating entities (Larkspur and Perry Park Water and Sanitation District) should develop a facility plan which will describe how these facilities will be phased into the regional facility. Similarly, Castle Rock should develop a facility plan for the two existing facilities (Castle Rock and Castle Pines) in the service area of the Castle Rock regional facility. Facilities with currently approved permits are shown in Table 9 along with site application flows.

Projected population, employment and wastewater flows for Alternative Number 5 are shown in Table 10. These projections and service areas will be incorporated into the CWP as described in Chapter VI.

Based on the cost analysis in Appendix E, the alternatives available to serve the Chatfield Basin area are very close in cost. The alternative of service through the Englewood-Littleton facility is very sensitive to the number of taps. Increasing the number of taps increases the costs of this alternative substantially while the costs of an on-site facility are less sensitive. The recommendation of the Basin Study is to show a Chatfield Green facility in the CWP with a design capacity of 0.125 MGD. However, detailed development plans for this area may require further analysis of wastewater treatment options.

Dischargers from the service areas will be required to meet effluent limits established in previous chapters of this Basin Study. The management agency structure for implementation will be based, in part, on these service areas.

The amount of wastewater that can be discharged in the Plum Creek Basin is determined by the pollutant loadings to water bodies in the basin. The phosphorus allocation requires that all dischargers in the basin achieve 0.2 mg/l effluent phosphorus. This amount of point source control will be adequate to protect the in-lake phosphorus standard until the year 2000, or until actual wastewater flows in the basin reach 5.3 MGD.

TABLE 9

CURRENT AND PROPOSED CHATFIELD BASIN WASTEWATER TREATMENT FACILITIES AND FLOWS

Facility	Approved Flow By Site Application (MGD)	Design Capacity[1] (MGD)
Bell Mountain Ranch	0.3*	N/A
Castle Rock	0.9	0.9
Castle Pines	2.3	2.3
Larkspur North	0.075	0.075
Sage Port (East Perry Park)	0.10**	0.10
Spruce Mountain	0.15*	N/A
Louviers	0.04	0.04
Martin-Marietta	1.0	1.0
Perry Park (Wauconda)	0.32	0.32
Roxborough Park	0.60	0.60

[1]Design Capacity is often referred to as Discharge Permit Capacity or that capacity recognized by the WQCD.

* Bell Mountain Ranch and Spruce Mountain have been recognized by DRCOG to these capacities but have not been approved as facilities by the state WQCD.

**Sage Port is approved by the WQCD with this design capacity but has been placed in the inactive file due to lack of discharge. Sage Port currently (1988) has no approval to discharge into East Plum Creek.

TABLE 10

POPULATION AND EMPLOYMENT PROJECTIONS BY SERVICE AREA FOR ALTERNATIVE NUMBER 5

Service Area	Population				Employment			
	1986	1990	2000	2010	1986	1990	2000	2010
Littleton/Englewood	19,900	22,300	27,300	31,230	9,500	10,600	12,100	20,200
Chatfield Green	0	700	800	950	0	250	400	600
Martin Marietta	0	0	0	0	9,000	9,000	9,000	9,000
Roxborough Park	1,000	2,400	4,800	6,400	0	1,000	3,200	4,300
Castle Pine/Castle Rock *	7,800	16,300	31,400	71,900	2,600	4,400	17,800	37,800
Bell Mountain Ranch	0	1,600	3,800	5,400	0	300	3,300	6,000
Larkspur/East Perry Park**	300	2,600	5,700	7,100	100	500	1,600	3,700
West Perry Park	950	1,200	2,100	2,800	0	50	100	100
Unsewered	4,450	4,300	4,000	3,700	3,300	2,900	2,800	2,500
Total	34,400	51,400	79,900	129,480	24,500	29,000	50,300	84,200

*This service area will also treat flows from two subbasins (McMurdo and Mitchell) in the Cherry Creek Basin.

**This service area presently contains three approved treatment plants: Larkspur, Sage Port and Spruce Mountain. Projects are shown for the entire service area.

This assumes all flows are directly discharged. This threshold on actual flows can be adjusted to reflect wastewater that is land applied, if the impact of reduced flushing on the reservoir is included. When flows exceed 5.3 MGD, as expected in the year 2000, removal of nonpoint sources of phosphorus will become necessary.

By removing 50 percent of nonpoint sources of phosphorus, the in-lake standard should be protected until wastewater dischargers in the basin reach 10.0 MGD. A more detailed explanation of the nonpoint control is contained in the following chapter.

The policy for expansion and construction of wastewater treatment facilities must be linked to the phosphorus allocation. Based on current assumptions about the reservoir, it is critical that a nonpoint control program be in place by the time the total discharge in the basin reaches 5.3 MGD. DRCOG's policy will be to find site applications for facility expansions consistent with the plan as long as total approved capacity does not exceed the 2010 forecast of 10.0 MGD and actual flows do not exceed the 5.3 MGD predicted for 2000. Plan amendments for new facilities must also fit within these flows as well as meeting the other criteria for plan inclusion.

If the basin management agency has implemented a nonpoint control program, point source flows could exceed 5.3 MGD. If no nonpoint program is in place, wastewater discharge would be limited to the 5.3 MGD.

In terms of the ammonia and nitrate allocations, the effluent limits developed as part of this study reflect conditions DRCOG expects to occur between now and 2010. Should actual conditions vary greatly from these expectations, the ammonia and nitrate allocations will need to be reviewed for their adequacy in protecting stream standards. Any unexpected expansions or new facilities should include tertiary treatment. Their exact ammonia and effluent limits will, however, need to be calculated using the methods used in developing the allocations discussed previously.

V. NONPOINT CONTROL PROGRAM

Implementation of the point source pollutant control measures discussed above should be sufficient to protect water quality in the basin until the year 2000, when actual wastewater flows are expected to reach approximately 5.3 MGD. Plans for implementation of a nonpoint source control program (phase one) should be developed within three years after adoption of this plan by the Commission. Construction and development of actual nonpoint facilities (phase two) should begin around 1995.

Phase one of the nonpoint control program will promote implementation of nonstructural control measures and also collect and evaluate data for use in the second phase. The second phase will include construction of erosion control structures or other stormwater quality controls and continued monitoring of their effectiveness in removing phosphorus.

Specifically, the first phase of the program will require adoption and enforcement by the local governments of erosion control ordinances and Best Management Practices (BMPs). BMPs include urban runoff controls and agricultural controls. Urban controls include both structural and nonstructural measures such as detention devices, recharge devices and housekeeping practices. Wet detention basins and dual purpose basins were proven to be very effective in removing nonpoint pollutants from urban runoff during EPA's Nationwide Urban Runoff Program (NURP). Agriculture and open space controls are necessary to reduce influxes of sediment, nitrogen, and particularly, phosphorus. Less is known about effective methods to control agricultural runoff, but all available methods for both urban and agricultural nonpoint controls should be evaluated by the management agency and all involved entities to determine BMPs for the Chatfield Basin.

A key element of any nonpoint control program is to provide a model ordinance related to controlling nonpoint source pollution. An erosion control ordinance is probably the most effective BMP as erosion from construction can produce the largest quantity of sediments and pollutants. New developments will be required to implement on-site control measures to reduce erosion potential as much as possible during construction.

Douglas County and Jefferson County are in the process of formulating erosion control regulations. These regulations will require erosion control practices during construction as well as sets the criteria for nonpoint control and water quality enhancement. The Town of Larkspur has also adopted an erosion control ordinance. The Town of Castle Rock adopted an erosion control regulation for the Cherry Creek portion of its service area. It is anticipated that this regulation will be expanded to include the Chatfield Basin. As part of phase one of the nonpoint control program, Jefferson County would be required to adopt one. It is particularly important for Jefferson County to have an erosion control regulation in tact, if and when Two Forks Dam is built, to ensure that the regulations to control erosion from construction activities are in place and enforced during construction.

Phase one of the Chatfield Basin nonpoint control program will evaluate additional policies which could be implemented for control of erosion and implement those deemed appropriate. Additionally, phase one of the nonpoint control program will evaluate other ongoing nonpoint control programs to determine if these programs or portions thereof may be applicable to conditions in the Chatfield Basin. In particular, nonpoint source controls implemented in Summit County and the Cherry Creek Basin will be studied. Currently, a study on phosphorus input from septic systems is being conducted in the Cherry Creek Basin by Tri-County Health Department. Information on input from septics in two different soil types is being gathered over an 18-month period. Results of the data analysis will be compared against requirements in current regulations and in the formulation of BMPs. This information is transferable to conditions in the Chatfield Basin and will be incorporated by the management agency in phase one of the nonpoint control program. All information collected in this and other basin studies should prove useful in designing the most effective and efficient nonpoint control structures for the Chatfield Basin.

Another function of the first phase of the nonpoint erosion control program will be to determine if there are any sources of funding for construction of nonpoint control structures. Section 319 of the 1987 Clean Water Act specifies that federal funds should be allocated for nonpoint control management programs. Nonpoint control structures constructed as part of the nonpoint control program for the Chatfield Basin may be eligible for federal funding under section 319 of the Clean Water Act.

There may also be federal funding for nonpoint control structures through a Phase II Clean Lakes grant. Phase II Clean Lakes grants are intended to implement methods for controlling nonpoint source pollutants from entering a lake, to implement in-lake methods to improve lake quality, or to implement a combination of pollution and in-lake restoration measures. Grants for Phase II studies are only awarded after completion of Phase I Clean Lakes diagnostic studies. The 1982 Clean Lakes study completed for Chatfield Reservoir was a Phase I study, and the nonpoint control program recommended in this study contains elements of control programs recommended by the EPA in Phase II studies. Phase one of the nonpoint control program will attempt to obtain some of these funds for implementation of nonpoint control structures in the Chatfield Basin.

Additionally, phase one of the nonpoint control program will include continued water quality monitoring in the basin. Through this monitoring, the impact of increased urbanization on loadings to Chatfield Reservoir can continue to be assessed. The monitoring can also identify priority subbasins or those subbasins which would benefit most from implementation of nonpoint control structures.

Phase one of the nonpoint control program will also evaluate and refine existing models to more accurately reflect the relationship of phosphorus loading to in-lake phosphorus levels and the relationship of in-lake phosphorus levels to chlorophyll a concentrations. The Canfield/Bachman model was calibrated to Chatfield Reservoir as part of the 1982 Clean Lakes Study. It is then used to predict future in-lake phosphorus levels. The accuracy of this model's predictions can now be evaluated using monitored data collected since

1982. Other types of models are also available for predicting in-lake phosphorus levels. Phase one of the nonpoint control program will evaluate some of the other models available for prediction of in-lake phosphorus levels. The Jones/Bachmann chlorophyll a model was calibrated to Chatfield Reservoir as part of the 1982 Clean Lakes Study to define the relationship between in-lake phosphorus concentrations and chlorophyll a levels. Monitored reservoir data collected since 1982 may provide a better understanding of the exact relationship between phosphorus and chlorophyll a in Chatfield Reservoir. A better understanding of this relationship may result in modifications to the standards for phosphorus. Phase one will also include a review of the proportion of effluent that is land applied. This will increase the flow that can be directly discharged prior to implementation of a nonpoint source control program.

Completion of the criteria described in phase one of the nonpoint control program will define where the most effective nonpoint control structures can be implemented in the basin. Phase two of the nonpoint control program will focus on implementation of nonpoint control strategies. Construction of nonpoint control structures is one factor which may allow for the point source flows shown in Table 10 to go beyond 5.3 MGD.

The basin management agency will need to develop a system for balancing the expansion of point sources with the control of nonpoint sources. The overall goal should be to keep the total pounds of phosphorus entering Chatfield Reservoir below 36,000 pounds. This phosphorus loading rate, used in the reservoir modeling, does not include loading from construction activities. Therefore, the focus of the phase two program will need to be phosphorus removal which goes beyond the control expected from implementation of erosion control ordinances.

The second phase of the nonpoint control program should begin before wastewater flows in the basin reach 4.2 MGD (80 percent of the projected 5.3 MGD flow for 2000). Beginning phase two at this point, when loads to the reservoir are much less than those required to protect the standard, will allow time for implementation of the nonpoint control program. It will also allow the information collected in phase one to be incorporated in the plan.

By the year 2010 the nonpoint control program should be in place and fully functioning. Continued evaluation of the performance of nonpoint control structures in the basin will continue. No specific recommendations on types of control structures are being made as part of this study. Specific design criteria for those structures found to be the most effective in removing nonpoint sources of phosphorus will be developed as part of phase one of the nonpoint control program. Examples of nonpoint control that have been used in other basins include detention basins, dry basins, wet basins, dual purpose basins, grass swales and wetlands. These programs, or very similar ones, will most likely be recommended for construction in phase two of the program.

The second phase of the nonpoint control program will continue the water quality monitoring effort begun as part of phase one and expand it to include monitoring of the nonpoint control structures. By developing the nonpoint would allow greater focus on either nonpoint or point source issues within the relevant management agency but could lead to an uncoordinated effort. DRCOG and the WQCD would need to play a larger role in that coordination.

A third institutional alternative would be to have the four point source agencies described in Alternative Number 2 also serve as the implementers of the nonpoint control program. This alternative would probably be the most difficult to implement because nonpoint sources of pollution tend to be basinwide rather than limited to service area boundaries. The success or failure of a service area's management agency to implement a nonpoint control program could have a more drastic effect on its downstream neighbors than the same agency's success or failure in implementing point source control programs. Because of the basinwide nature of the nonpoint problem, this alternative was eliminated early in the development of the Basin Study.

Because the point source element of the plan is dependent on the success of the nonpoint control program, it appears that the single management agency approach will be the best institutional mechanism for the Chatfield Basin. The next section of this chapter describes some of the elements of such a mechanism.

RECOMMENDED INSTITUTIONAL SYSTEM

In view of the advantages of a basinwide management agency created through intergovernmental agreement, this institution is recommended as the preferred alternative. The management agency would be responsible for recommending the phosphorus limits for point sources and implementing a nonpoint control program. Point source facilities would continue to be constructed and operated by municipalities and districts. DRCOG and the management agency would coordinate ongoing planning activities in the basin, with the management agency preparing plan amendments for the CWP.

As mentioned earlier, there are a number of approaches to defining the membership of the management agency. The existing Chatfield Basin Association provides one model but it currently excludes Jefferson County. The Basin Task Force created by DRCOG probably contains too many agencies. The membership should be limited to the agencies with land use responsibilities (counties and towns), wastewater treatment facility operators, and districts with stormwater management powers.

The agency has seven basic responsibilities:

1. To review and submit to DRCOG proposed changes to the CWP which affect the Chatfield Basin. This would affect both point and nonpoint sources.

2. To review site applications for wastewater facilities in the basin for consistency with the plan. It may be appropriate to provide some form of weighted voting on this item to reflect the greater interest of the treatment facility operators. The management agency should develop a specific policy concerning facilities which choose to treat beyond 0.2 mg/l.

3. The pass through of federal construction funds to operating agencies. The mechanism for such funding should be spelled out in the intergovernmental agreement.

4. The development and implementation of the nonpoint control program. This will require the management agency to establish a method for funding the ongoing monitoring of the basin, the construction of demonstration nonpoint control facilities and the maintenance of the control program after it is in place.

5. The development of special criteria to monitor and control existing and future septic systems. The program should be enforced by general purpose governments and should involve the Tri-County Health Department and Jefferson County Health Department in developing and adopting best management practices techniques. In this study, phosphorus in septic systems was assumed to be part of background input and to not increase between 1986 and 2010. This input has been difficult to quantify. Data on septic systems is currently being gathered in the Cherry Creek Basin and should be incorporated in the Chatfield Basin portion of the CWP.

6. The monitoring of the total phosphorus load to the reservoir to ensure that the combination of point and nonpoint loads does not exceed 36,000 pounds. This limit is subject to change as more is known about the reservoir. Such a change would be processed as a CWP amendment and a change to the Commission control regulation.

7. To ensure against the exceedance of critical ammonia and nitrate levels in Plum Creek, particularly in light of potential increases in wastewater flows beyond 5.3 MGD if nonpoint controls are implemented on schedule.

It is not appropriate for DRCOG to specify the exact nature of the intergovernmental agreement creating the management agency. However, DRCOG will work with the entities in the basin to draft such an agreement. Once the management agency is established, DRCOG and the agency should develop a formal statement of the ongoing responsibilities of both parties in the basin. It is expected that the management agency will be in place within one year of the adoption of the 1988 update to the CWP. If no agreement is signed in that time, DRCOG will consider other options to recommend to the Governor for naming a management agency.

VII. CHANGES TO THE CLEAN WATER PLAN

This chapter contains the proposed changes to the CWP to recognize the recommendations of the study. These changes will be considered by DRCOG as part of the 1988 Integrated Plan Assessment. Once adopted by DRCOG, these changes will be the official water quality management plan for the basin. In addition, the chapter includes the outline for a proposed control regulation for the Commission. The Commission has the power to adopt control regulations for any portion of the CWP. The proposed regulation identifies the appropriate elements of the CWP for adoption.

CLEAN WATER PLAN CHANGES

Volume II of the CWP contains the details regarding the water quality control systems needed to protect the region's water bodies. Chapters II and III and the appendices will need changes to reflect the Basin Study. Chapter II describes the water quality of the basin, while Chapter III outlines the facilities needed between now and 2010. Five of the appendices will need to be changed to incorporate the Basin Study. The proposed changes to each part of the plan are described below.

Water Quality Analyses Chapter Changes

The following description of the water quality in the Chatfield Basin should replace the current information on pages 13-14 of the CWP, Volume II:

The Commission water quality standards for Chatfield Basin are found in Appendix H. The Chatfield Basin includes all of the Plum Creek subbasin and a portion of the South Platte River area whose runoff flows directly into Chatfield Reservoir. Segments of concern are segments 6, 10, and 13 of the South Platte River. Segment 6 was described in the Metro and South Metro Basins sections. Segment 10 is the mainstem of East and West Plum Creek and Plum Creek from the boundary of National Forest lands to Chatfield Reservoir. Segment 13 is the mainstem of Deer Creek, including the North and South Forks, from the source to Chatfield Reservoir. The other segments shown in Table 12 of Appendix H are not impacted by urban development.

Existing dischargers include Perry Park Water and Sanitation District (2 facilities), Larkspur (1 facility) and Castle Rock (2 facilities) for segment 10. Roxborough Park Metropolitan District discharges into segment 6 of the South Platte River and Martin-Marietta discharges into Brush Creek, its tributary. Future dischargers (identified in Chapter III) will include a Bell Mountain facility on segment 10 and a Chatfield Green facility which will probably discharge into Deer Creek (segment 13) very near the inlet to Chatfield Reservoir. Chatfield Reservoir, which is a part of segment 6, has an adopted standard for total in-lake phosphorus of 0.027 mg/l. Segments 6, 10 and

13 were classified for water supply and agriculture. Both segments 6 and 13 were classified for class 1 recreation and class 1 cold water aquatic life (with a 0.02 unionized ammonia limit). Segment 10 was classified for class 2 recreation and class 1 warm water aquatic life, which requires a 0.06 mg/l unionized ammonia limit.

In the last assessment of stream quality by the WQCD, the ammonia limit of segment 10 was identified as threatened, as was the phosphorus limit on Chatfield Reservoir. The Chatfield Basin Water Quality Study has confirmed that both standards would be exceeded in the future without additional water quality controls. However, the study also determined that Plum Creek is not now impaired. Values for all major water quality indicators were well within standards for the monthly samples during 1986-87.

Ammonia will become a more significant problem as growth occurs along Plum Creek. Temperature and pH data indicate that the stream can only assimilate a very small amount of total ammonia. Because this will require nitrification at the treatment facilities, the stream could also violate the nitrate standard as discharges increase. This suggests that denitrification will also be necessary.

The monitored data on Chatfield Reservoir indicates that the growing-season-average in-lake phosphorus standard of 0.027 mg/l was exceeded under certain hydrological conditions. The in-lake phosphorus value for Chatfield Reservoir was 0.049 mg/l in 1983, 0.034 mg/l in 1984 and 0.030 mg/l in 1985. The point and nonpoint loading did not vary substantially in those years. The differences were in the amount of flow in the basin which changed the background load and the flushing characteristics of the reservoir.

Of additional interest, while the phosphorus levels in the reservoir were higher in recent years, the chlorophyll a level did not exceed the goal of 0.017 mg/l. The relationship between phosphorus and chlorophyll a levels in the reservoir needs to be further researched to determine if the phosphorus standard is appropriate. While that research is underway, there is a need to achieve the 0.027 mg/l standard. The Basin Study determined that a basinwide limit of 36,000 pounds of phosphorus per year should protect the standard (assuming 1982 hydrology). The distribution of this limit among the various sources is described in the next chapter.

The direct discharges to the South Platte are not expected to affect the standards other than phosphorus. The flows from Roxborough Park, Martin-Marietta and Chatfield Green are very small in comparison to the upstream flow of the river. The CWP assumes that standard mass balance calculations will be adequate to determine permit limits for these facilities.

Wastewater Management Chapter Changes

The wastewater management chapter is intended to describe the unique features of the facilities planned for each basin. The 1987 update to the CWP only contains a brief reference to the Basin Study on page 21 for this section. This should be replaced with the following description:

In 1988, DRCOG completed a basin study for the Chatfield Basin which addressed the water quality management needs. The basin is expected to grow rapidly over the next 22 years, resulting in additional loads to the receiving waters: Plum Creek and Chatfield Reservoir. The results of the study outline a system of eight major wastewater treatment facilities and a nonpoint control program to deal with the phosphorus and ammonia problems in the basin.

The wasteload allocation program for phosphorus is based on the 0.027 mg/l standard for Chatfield Reservoir, adopted by the Commission. Using an in-lake model, it was possible to define the annual load of phosphorus from all sources which would protect the standard. The present phosphorus load into the reservoir is largely the result of the stormwater runoff and the baseflow in the South Platte River, Plum Creek and other tributaries. But, as conditions in the basin change and more development occurs, treated wastewater will add more phosphorus. The increase in developed land will also create an increase in the quantity of stormwater which reaches the reservoir. As a result, the combination of loads from point and nonpoint sources is expected to become the dominant source of annual reservoir phosphorus loading. The Study also assumed that Two Forks Reservoir will be built sometime between 1990 and 2000, with resulting changes in flows and loadings.

The results of the modeling indicate that the reservoir can assimilate approximately 36,000 pounds. This limit can be met until the year 2000 by restricting point source discharges to an effluent limit of 0.2 mg/l of phosphorus, resulting in the following allocation among sources:

Point Sources	3,100 pounds
Nonpoint Sources	13,100
Background (includes septics)	19,100
Total	35,300

As growth continues past 2000, controls will need to be placed on nonpoint sources to stay within the limit. The Basin Study has set a goal of reducing the nonpoint sources by 50 percent, resulting in a 2010 allocation of:

Point Sources	5,700 pounds
Nonpoint Sources	8,800
Background (includes septics)	19,100
Total	33,600

Rather than placing a specific poundage limit on each facility, the Basin Study recommends that the 0.2 mg/l phosphorus limit be included in each discharge permit. All dischargers will be required to meet the 0.2 mg/l phosphorus effluent limit by January 1, 1991.

A load of 88 pounds from Summit County is not expected to occur until after 2010 as permitted under the Summit County agreement. If needed before that time, this allocation should be reviewed and revised. Site applications for facility expansions will be found consistent with the plan as long as total approved capacity does not exceed the 2010 forecast of 10.0 MGD. Plan amendments for new facilities must also fit within these flows as well as meeting the other criteria for plan inclusion. The basin management agency must implement a nonpoint control program before point source flows exceed 5.3 MGD. If no nonpoint program is in place, wastewater discharge would be limited to the 5.3 MGD.

With the phosphorus limit determined, the Study defined the system of point source facilities needed to serve the expected population growth. A number of different wastewater treatment scenarios were evaluated, all of which were capable of producing acceptable effluent. Based on a set of criteria including cost and ease of implementation, a system of eight facilities is included in the plan. Four of the facilities exist in 1988: Martin-Marietta, Louviers, Roxborough Park and West Perry Park. One new facility is proposed west of the South Platte River to serve expected development south of Deer Creek. This facility is called Chatfield Green in the plan tables and maps. The Bell Mountain facility was added to the CWP in 1986 and is recommended for continued inclusion. An analysis of serving the Bell Mountain area through the Castle Rock/Castle Pines system determined that this would be an equivalent alternative, if an appropriate agreement can be arranged between the two entities.

During the 1987 Integrated Plan Assessment process, Douglas County submitted an amendment request concerning three potential developments called Sterling Ranch, Castle Rox and Douglas Commercial Properties. These areas are not yet recognized in the region's planned urbanization area and therefore cannot be shown in the CWP. If these areas are planned for development, they will be served by the Roxborough Park facility and its service area will be amended to reflect these changes.

The two remaining facilities are consolidations of existing and previously planned facilities in the Castle Rock and Larkspur areas. The plan shows a regional facility at the site of the existing Castle Pines facility to serve the Castle Pines and Castle Rock service areas. This facility is currently being purchased by the Town of Castle Rock. It is expected that Castle Rock will integrate their existing facility with the Castle Pines facility into one system. The cost analysis used in the Basin Study suggested that service to this area by one facility would be the least expensive for Castle Rock residents. The town is currently conducting a facility study to determine the best method for providing wastewater service. The findings of that effort will be incorporated into the CWP.

It should also be noted that flows from the McMurdo and Mitchell subbasins in the Cherry Creek Basin will be treated at the Castle Pines/Castle Rock facility and should be recognized in the CWP. The phosphorus allocation for these two subbasins is still shown as part of the Cherry Creek system, assuming that the effluent would be returned to that basin. Some of this effluent may be used for land application in the Chatfield Basin. If so used, that portion of the 192 pounds of phosphorus will need to be accounted for within the overall limit of 36,000 pounds and the point source limit, 3,135 pounds, for 2000.

In the Larkspur area, the plan shows a single facility serving both the Larkspur service area and the East Perry Park service area. Two existing facilities are in this service area: the Larkspur lagoon and the Sage Port facility. In addition, the Town of Larkspur is planning a second lagoon to serve the Spruce Mountain development. All three of these facilities are recognized as interim facilities by the CWP with the following capacities: 175,000 gal/day at North Larkspur; 250,000 gal/day at Spruce Mountain; and 100,000 gal/day at Sage Port. However, by the time any one of these facilities reaches 95 percent of capacity, it is expected that Larkspur and Perry Park will have a regional facility under construction. No expansions of the three interim facilities will be recognized unless a plan amendment is permitted and approved.

With a set of facilities defined, the effluent limits for pollutants other than phosphorus could be determined. The basin elected to apply an equal treatment criterion for all dischargers to Plum Creek. Two pollutants will require better than secondary treatment: ammonia and nitrate. Based upon the water quality data for the study, the total ammonia limit in the stream cannot be determined. Due to the relationship between the required effluent ammonia limit and subsequent nitrate concentrations from ammonia conversion, effluent nitrate levels must be determined after the total ammonia limit is established. It is recommended that the management agency work with DRCOG to develop a recommended wasteload allocation for ammonia and nitrate before the 1990 CWP update. In addition, the relationship of alluvial nitrate concentrations to in-stream levels in East Plum Creek should be determined for the next update.

To implement the Plan, the Basin Study recommends that the management agency structure in the basin be revised. The Governor is requested to name a single management agency for the basin to coordinate point and nonpoint activities. The management agency will be formed through intergovernmental agreement which is currently being defined. It is anticipated that this agreement will be in effect by the time of the 1989 update to the CWP.

Finally, the Basin Study outlines a nonpoint control program for the basin. The program is defined in two phases. The first phase includes ongoing monitoring, the implementation of Best Management Practices, the identification of priority subbasins for nonpoint control and the definition of a funding mechanism for major projects. Phase two, which must begin before 2000, will implement a program of nonpoint control structures and mechanisms with the goal of reducing the nonpoint load reaching Chatfield by 50 percent. The basin management agency will be required to monitor the effectiveness of the nonpoint program before point sources can exceed 5.3 MGD of flow.

Changes to Appendices

The Appendices to the CWP contain a number of tables which document the water quality management system described in the plan. The following changes will be needed to incorporate the Chatfield Basin Study into the plan.

Table 10 of the Study will need to be incorporated into Tables 1, 2 and 3 of Appendix A.

The information on Table 11 will be added to Tables 4 and 5 of Appendix B.

Table 9 (Appendix E) will be revised as shown by Table 12.

The phosphorus limit of 0.2 mg/l should be shown for Martin-Marietta in Table 10 of Appendix F.

The Wastewater Service Area Map will be revised as shown in Figure 8.

PROPOSED CONTENTS OF CONTROL REGULATION

The Commission has the statutory power to adopt any portion of an areawide water quality management plan as a control regulation.

This action changes that portion of the plan from a guidance document to a regulatory tool. As such, the WQCD can enforce the provisions of the regulation to ensure that the plan is implemented. While the actual language of the regulation will be prepared by the Commission staff, this section provides some suggestions for the content of that regulation.

The regulation can be modeled on the similar regulation which adopted the Cherry Creek Basin plan, which contains a set of definitions for items such as point source and nonpoint source. Such definitions should be included in the Chatfield regulation. There should also be a section outlining the wasteload allocation for total phosphorus discharge in the basin. The numbers in Table 4 should be used to write this section. It should be noted in the regulation that present industrial and septic contributions of phosphorus are contained in the background estimate of 19,100 pounds.

Another major section of the regulation should describe the point source effluent limitations. The 0.2 mg/l limit on total phosphorus should be identified and the requirement that nonpoint controls be in place before flows exceed 5.3 MGD. The regulation should outline monitoring and reporting requirements for the basin management agency to guarantee that the point and nonpoint controls are coordinated and implemented as needed.

The regulation should also document the use of an equal treatment approach to allocating ammonia and nitrate wasteloads as described in the plan. A nitrate monitoring plan should be devised to include both instream and alluvial water supply sampling requirements and a hydrological study documenting the movement of alluvial groundwater in relation to the stream flow conditions in East Plum Creek. The regulation may reference the proposed limits in the CWP and indicate how these values would be reviewed and updated. The regulation can also include a brief description of the nonpoint control program. This could note the two phase approach and provide a timeframe for implementing the various elements.

TABLE 11

REVISIONS TO TABLE 4 OF THE CLEAN WATER PLAN
CHATFIELD BASIN

Facility	1988 Expansion	1989 Expansion	1990 Expansion	1991 Expansion	1992 Expansion	1993-2000 1993-2000	2001-2010 2001-2010	1987 Capacity
Bell Mountain Ranch				Plan		Build		0.3
Castle Rock/ Castle Pines						Build		3.2
Chatfield Green	Plan		Build					---
Larkspur*				Plan		Build		.325
Louviers								0.04
Martin-Marietta								1.0
Perry Park (Waucondah)							Plan	0.32
Roxborough Park						Plan	Build	0.6

*Includes Sage Port and Spruce Mountain. Sage Port is approved to this design capacity by the WQCD but has been placed on the inactive file (1988) due to lack of discharge and has no current approval to discharge into East Plum Creek.

REVISIONS TO TABLE 5 OF THE CLEAN WATER PLAN

Chatfield Basin

Facility	Approved Capacity (mgd)	Capacity Needed by 2010
Bell Mountain	0.3	0.84
Castle Rock/Castle Pines	3.2	9.25
Chatfield Green	---	0.125
Larkspur*	0.425	0.91
Louviers	0.04	0.06
Perry Park (Waucondah)	0.32	0.30
Roxborough Park	0.6	0.88

*Includes Sage Port and Spruce Mountain

TABLE 12

REVISIONS TO TABLE 9 (APPENDIX E) OF THE CLEAN WATER PLAN

	Permit Number	BOD (mg/l) 30 Day Average)	TSS (mg/l 30 Day Average)	DO (mg/l Daily Mill.)	NH3-N (mg/l 30 Day Average)	TOT PHOS (mg/l)	RES. CL. Daily Max. (mg/l)	Fecal Coliform (/100 ml)	Total Coliforms
Bell Mountain Ranch	NI	30	30	----	**	0.2	----	----	23*
Castle Rock:									
Castle Rock	CO-0020265	30	30	----	**	0.2	0.003	2180	----
Castle Pines	CO-0038547	30	30	----	**	0.2	0.003	2000	----
North Larkspur:									
Larkspur North	CO-0035891	30	30	----	**	0.2	0.003	6000	----
Sage Port	NI								
Spruce Mountain	NI								
Louviers	CO-0027359	30	105	----	**	0.2	0.003	6000	----
Perry Park West	CO-0022551	30	30	----	**	0.2	0.5	1000	----
Roxborough	CO-0041645	30	30	----	**	0.2	----	200	23*

*Effluent land applied only.
**The standards for NH_3 and N are being revised. In the interim, existing permit standards should be maintained.
NI=No permit on file

The regulation should be drafted with the involvement of the basin Task Force members, DRCOG, WQCD, and the Commission. It should be scheduled for Commission action at the time the CWP is presented with the changes recommended by the study.

APPENDIX A

CHATFIELD BASIN TASK FORCE MEMBERS

This project has benefited greatly from the time donated by many individuals on this Task Force. Included is the list of Task Force members.

CHATFIELD BASIN TASK FORCE

AGENCY	REPRESENTATIVE
Bell Mountain Ranch	Larry Borger
Castle Pines Water and Sanitation District	Frank Walker
Castle Rock, Town of	Don Cooper
Castleton Center Water and Sanitation District	Lucy Strohmeier
Centennial Water & Sanitation District	John Hendrick
Chatfield Green	Holly Holder
Colorado Department of Highways	Sam Atencio
Cooley Gravel Company	Robert Laird
Corps of Engineers	Gregory N. Moore
Department of Natural Resources	Dave Weber
Denver Water Department	Jack Dice
Douglas County	Julio Iturreria
Explosives Technologies International	Bridget E. Balbierz
Jefferson County	Jean R. Jacobus, Ginny Chesney
Larkspur, Town of	Ernest Fazekas
Martin Marietta Corporation	Tim Mueller, Larry Fuscher
Perry Park Water and Sanitation District	Wayne Lorenz
Roxborough Park Metro District	Elizabeth Jones, Rich Wilson
Silver Heights Water and Sanitation	Charles H. Lewis
Spruce Mountain Ranch	Franklin Mullen
Summit County	R. Buckman Wenger

ADDITIONAL PARTICIPANTS

Division of Wildlife	John Woodling
In-Situ	Tim Steele
TST	Suzanne Bassinger
Tri-County Health Department	Rick Kinshella
U.S. Environment Protection Agency	Katie Richard-Haggard
Villages at Castle Rock Metro District 4	O. Karl Kasch
Water Quality Control Commission	David W. Hubly
Water Quality Control Division	Bill McKee

APPENDIX B

Land Use Tables for 1985, 1990, 2000 and 2010 by Land Use Type

TABLE 13

SINGLE FAMILY ACRES BY SUBBASIN

Subbasin	Jurisdiction	Total Basin Acres	1985 Single Fam Acres	1990 Single Fam Acres	2000 Single Fam Acres	2010 Single Fam Acres	Change in Acres Between 1985 and 2010
Bear Creek	Doug	10,500	271	296	486	991	720
Deer Creek	Jeff	18,230	17	17	17	17	0
Garber Creek	Doug	8,865	0	0	0	0	0
Indian Creek	Doug	10,523	0	0	0	0	0
Jackson Creek	Doug	16,064	77	78	79	79	2
Jarre Canyon	Doug	3,516	0	0	0	0	0
Malin Draw	Doug/Cr	6,770	1	1	4	10	9
Massey Draw	Jeff	6,298	880	982	1,188	1,394	514
Castle Pines	Doug	2,398	116	488	870	1,223	1,107
Sellers Gulch	Doug/Cr	9,728	199	256	354	597	399
South Platte Basin	Doug/Jeff	26,738	29	47	112	254	225
Spring Creek	Doug	8,452	8	11	50	150	142
Willow Creek	Doug	8,713	4	171	326	502	498
Direct Flow 1	Doug	3,551	72	94	231	479	407
Direct Flow 2	Doug	21,144	24	39	84	219	195
Direct Flow 3	Doug/Cr	15,466	99	218	426	992	893
Direct Flow 4	Doug/Cr	8,260	58	118	214	463	405
Direct Flow 5	Doug/Cr/L	13,669	67	273	414	802	735
Direct Flow 6	Doug/L	36,067	83	405	641	852	769
Direct Flow 7	Doug/Cr	7,968	1	2	5	16	15
Direct Flow 8	Doug	7,574	0	0	0	0	0
Direct Flow 9	Doug/Cr	21,808	10	45	168	289	279
Direct Flow 10	Jeff	8,000	0	0	0	0	0
Total		280,302	2,015	3,541	5,669	9,329	7,314

TABLE 14

MULTIFAMILY ACRES BY SUBBASIN

Subbasin	Jurisdiction	Total Basin Acres	1985 Multi Fam Acres	1990 Multi Fam Acres	2000 Multi Fam Acres	2010 Multi Fam Acres	Change in Acres Between 1985 and 2010
Bear Creek	Doug	10,500	0	0	0	0	0
Deer Creek	Jeff	18,230	0	0	0	0	0
Garber Creek	Doug	8,865	0	0	0	0	0
Indian Creek	Doug	10,523	0	0	0	0	0
Jackson Creek	Doug	16,064	0	0	0	0	0
Jarre Canyon	Doug	3,516	0	0	0	0	0
Malin Draw	Doug/Cr	6,770	1	1	2	5	4
Massey Draw	Jeff	6,298	65	79	106	133	68
Castle Pines	Doug	2,398	0	0	0	0	0
Sellers Gulch	Doug/Cr	9,728	67	84	116	196	129
South Platte Basin	Doug/Jeff	26,738	0	0	0	0	0
Spring Creek	Doug	8,452	0	0	0	0	0
Willow Creek	Doug	8,713	0	3	5	17	17
Direct Flow 1	Doug	3,551	0	0	5	17	17
Direct Flow 2	Doug	21,144	0	0	7	15	15
Direct Flow 3	Doug/Cr	15,466	0	13	41	112	112
Direct Flow 4	Doug/Cr	8,260	51	72	128	277	226
Direct Flow 5	Doug/Cr/L	13,669	1	10	31	130	129
Direct Flow 6	Doug/L	36,067	0	0	0	0	0
Direct Flow 7	Doug/Cr	7,968	0	1	2	7	7
Direct Flow 8	Doug	7,574	0	0	0	0	0
Direct Flow 9	Doug/Cr	21,808	0	1	1	1	1
Direct Flow 10	Jeff	8,000	0	3	7	9	9
Total		280,302	185	267	451	919	734

TABLE 15

LARGE LOT ACRES BY SUBBASIN

Subbasin	Jurisdiction	Total Basin Acres	1985 Large Lot Acres	1990 Large Lot Acres	2000 Large Lot Acres	2010 Large Lot Acres	Change in Acres Between 1985 and 2010
Bear Creek	Doug	10,500	0	0	0	0	0
Deer Creek	Jeff	18,230	14,500	14,500	14,500	14,500	0
Garber Creek	Doug	8,865	264	310	399	424	160
Indian Creek	Doug	10,523	660	760	820	820	160
Jackson Creek	Doug	16,064	0	0	0	0	0
Jarre Canyon	Doug	3,516	30	50	100	100	70
Malin Draw	Doug/Cr	6,770	335	475	860	950	615
Massey Draw	Jeff	6,298	640	722	886	1,050	410
Castle Pines	Doug	2,398	0	58	102	120	120
Sellers Gulch	Doug/Cr	9,728	0	0	0	0	0
South Platte Basin	Doug/Jeff	26,738	3,810	3,810	3,810	3,810	0
Spring Creek	Doug	8,452	0	0	0	0	0
Willow Creek	Doug	8,713	0	0	0	0	0
Direct Flow 1	Doug	3,551	0	0	0	0	0
Direct Flow 2	Doug	21,144	421	556	810	1,460	1,039
Direct Flow 3	Doug/Cr	15,466	494	730	1,360	2,196	1,702
Direct Flow 4	Doug/Cr	8,260	450	580	720	870	420
Direct Flow 5	Doug/Cr/L	13,669	0	0	0	0	0
Direct Flow 6	Doug/L	36,067	155	281	500	665	510
Direct Flow 7	Doug/Cr	7,968	58	120	142	142	84
Direct Flow 8	Doug	7,574	670	770	1,005	1,330	660
Direct Flow 9	Doug/Cr	21,808	200	285	597	1,055	855
Direct Flow 10	Jeff	8,000	0	0	0	0	0
Total		280,302	22,687	24,007	26,611	29,492	6,805

TABLE 16

COMMERCIAL AND INDUSTRIAL ACRES BY SUBBASIN

Subbasin	Jurisdiction	Total Basin Acres	1985 Comm/Ind Acres	1990 Comm/Ind Acres	2000 Comm/Ind Acres	2010 Comm/Ind Acres	Change in Acres Between 1985 and 2010
Bear Creek	Doug	10,500	2	2	2	10	8
Deer Creek	Jeff	18,230	212	233	250	263	51
Garber Creek	Doug	8,865	0	0	0	0	0
Indian Creek	Doug	10,523	0	0	0	0	0
Jackson Creek	Doug	16,064	0	0	0	0	0
Jarre Canyon	Doug	3,516	0	0	0	0	0
Malin Draw	Doug/Cr	6,770	0	1	3	4	4
Massey Draw	Jeff	6,298	193	223	283	343	150
Castle Pines	Doug	2,398	0	10	40	60	60
Sellers Gulch	Doug/Cr	9,728	6	21	51	80	74
South Platte Basin	Doug/Jeff	26,738	0	0	0	0	0
Spring Creek	Doug	8,452	0	0	0	0	0
Willow Creek	Doug	8,713	0	0	10	20	20
Direct Flow 1	Doug	3,551	0	0	22	592	592
Direct Flow 2	Doug	21,144	117	150	500	3,694	3,577
Direct Flow 3	Doug/Cr	15,466	45	87	167	259	214
Direct Flow 4	Doug/Cr	8,260	36	78	162	247	211
Direct Flow 5	Doug/Cr/L	13,669	15	197	351	672	657
Direct Flow 6	Doug/L	36,067	10	220	496	509	499
Direct Flow 7	Doug/Cr	7,968	0	2	5	8	8
Direct Flow 8	Doug	7,574	0	0	0	0	0
Direct Flow 9	Doug/Cr	21,808	0	1	1	11	11
Direct Flow 10	Jeff	8,000	519	551	616	680	161
Total		280,302	1155	1,776	2,959	7,452	6,297

TABLE 17

OPEN SPACE ACRES BY SUBBASIN

Subbasin	Jurisdiction	Total Basin Acres	1985 Open Space Acres	1990 Open Space Acres	2000 Open Space Acres	2010 Open Space Acres	Change in Acres Between 1985 and 2010
Bear Creek	Doug	10,500	10,227	10,202	10,012	9,499	- 728
Deer Creek	Jeff	18,230	3,500	3,480	3,463	3,450	- 50
Garber Creek	Doug	8,865	8,601	8,555	8,466	8,441	- 160
Indian Creek	Doug	10,523	9,863	9,763	9,703	9,703	- 160
Jackson Creek	Doug	16,064	15,987	15,986	15,985	15,985	- 2
Jarre Canyon	Doug	3,516	3,486	3,466	3,416	3,416	- 70
Malin Draw	Doug/Cr	6,770	6,433	6,292	5,901	5,801	- 632
Massey Draw	Jeff	6,298	4,520	4,292	3,835	3,378	- 1,142
Castle Pines	Doug	2,398	2,282	1,842	1,386	995	- 1,287
Sellers Gulch	Doug/Cr	9,728	9,456	9,367	9,207	8,855	- 601
South Platte Basin	Doug/Jeff	26,738	22,899	22,881	22,816	22,674	- 225
Spring Creek	Doug	8,452	8,444	8,441	8,402	8,302	- 142
Willow Creek	Doug	8,713	8,709	8,539	8,372	8,174	- 535
Direct Flow 1	Doug	3,551	3,479	3,457	3,293	2,463	- 1,016
Direct Flow 2	Doug	21,144	20,582	20,399	19,743	15,756	- 4,826
Direct Flow 3	Doug/Cr	15,466	14,828	14,418	13,472	11,907	- 2,921
Direct Flow 4	Doug/Cr	8,260	7,665	7,412	7,036	6,403	- 1,262
Direct Flow 5	Doug/Cr/L	13,669	13,586	13,189	12,873	12,065	- 1,521
Direct Flow 6	Doug/L	36,067	35,819	35,159	34,428	34,039	- 1,780
Direct Flow 7	Doug/Cr	7,968	7,909	7,843	7,814	7,795	- 114
Direct Flow 8	Doug	7,574	6,904	6,804	6,569	6,244	- 660
Direct Flow 9	Doug/Cr	21,808	21,598	21,476	21,041	20,452	- 1,146
Direct Flow 10	Jeff	8,000	7,481	7,447	7,379	7,311	- 170
Total		280,302	254,258	250,710	244,612	233,108	-21,150

APPENDIX C

RESERVOIR MODELING

RESERVOIR MODELING

As part of the Chatfield Clean Lakes Study, the Colorado Department of Health (CDH) selected a derivation of the Vollenweider model to characterize conditions in Chatfield Reservoir. This model was developed by Canfield and Bachmann (1980). It has a variable sedimentation co-efficient adjusted to Chatfield Reservoir and based on monitored data collected 1982. This model is shown below:

$$TP = \frac{L}{Z\ [k(0.114\ [(L/Z)^{0.589})]\ +\ p)]}$$

where:
- TP = in-lake total phosphorus concentration (ug/1),
- L = total phosphorus loading (mg/m^2/year),
- Z = mean lake depth (meters), = 5.4
- p = flushing rate (annual inflow/lake volume), and
- k = adjustment factor (3.6 for Chatfield).

Details of the derivation of this equation can be found in the Clean Lakes report by DRCOG and WQCD (DRCOG, 1984). The developed equation was considered to provide reasonable estimates of future in-lake total phosphorus concentrations. The model was used to evaluate scenarios.

Predicted in-lake total phosphorus concentrations were used to predict chlorophyll a concentrations using a modification of the equation developed by Jones and Bachmann (1976):

log chlorophyll a (ug/L) = -0.85 + 1.46 log total phosphorus (ug/L).

The value of the intercept in the original equation proposed by Jones and Bachmann (1976) was changed from -1.09 to -0.85. This made the equation more closely predict monitored chlorophyll a levels.

An objective of the Chatfield Basin Study was to develop ways to protect the 0.027 mg/l in-lake phosphorus standard established for Chatfield Reservoir (DRCOG, 1984). The phosphorus standard is based on 1982 conditions in Chatfield and a number of model assumptions. The Chatfield Basin Task Force has conducted and is continuing to conduct monitoring of the reservoir to improve the information on which this standard is based. The data since 1983 has shown summer average phosphorus levels above the .027 mg/l standards; however, the .017 mg/l chlorophyll a goal has not been exceeded. This may indicate a different relationship between chlorophyll a and phosphorus than was assumed in setting the standard. The modeling for the Basin Study assumed the .027 mg/l standard remains in place. Any change to the standard will require new changes to the CWP. As more data and improved modeling procedures are incorporated in analysis, changes to the phosphorus standard may be proposed.

The study was not focused on the accuracy of the Canfield/Bachmann and Jones/Bachmann equations or the impacts of in-lake phosphorus levels on chlorophyll a concentrations. Reservoir modeling was therefore performed using the Canfield/Bachmann model as calibrated in 1982 under a variety of conditions.

- all dischargers treating to 0.2 milligrams per liter (mg/l) with no nonpoint controls;
- all dischargers treating to 0.2 mg/l with 50 percent nonpoint phosphorus removal;
- all dischargers treating to 0.1 mg/l with no nonpoint controls;
- all dischargers land applying effluent to achieve a concentration of 0.05 mg/l with no nonpoint controls.

Acting on a request from the Task Force, two other conditions were modeled:

- all dischargers direct discharging at 1.0 mg/l, no nonpoint controls;
- all dischargers direct discharging at 4.0 mg/l, no nonpoint controls.

The resulting in-lake phosphorus concentrations for these alternatives are shown in Table 5 in the text.

Analyses of these scenarios resulted in a range of total critical loads of between 35,300 and 37,000 pounds per year (lbs/yr). This number is shown as the darkened reference line on Figure 9. The baseflow portion of the critical load is 19,110 lbs/yr which has been assumed to be uncontrollable. This leaves a controllable load of 17,300 lbs/yr (the darkened reference line on Figures 10 through 15). The controllable load is comprised exclusively of point and nonpoint (storm) loadings to the reservoir.

The 50 percent nonpoint source removal scenario with all dischargers treating to 0.2 mg/l results in the lowest in-lake phosphorus concentration. The highest in-lake phosphorus concentrations are predicted to occur when all dischargers are direct discharging at 4.0 mg/l and there is no control of the nonpoint sources. When effluent phosphorus concentrations are at 1.0 mg/l or higher, point sources are a major factor in determining in-lake concentrations. When all dischargers are discharging 0.2 mg/l of effluent phosphorus, nonpoint source loading is the major factor in determining in-lake phosphorus concentrations.

In all scenarios where effluent phosphorus concentrations are at 0.2 mg/l or below, the in-lake phosphorus standard is not exceeded until the year 2000 or later under 1982 conditions. If 50 percent of the nonpoint is removed, the standard will not be exceeded until the year 2010 or later. Therefore, the recommended allocation approach of all dischargers treating to 0.2 mg/l of phosphorus and removal of 50 percent of nonpoint phosphorus by the year 2000 should be adequate to protect the in-lake phosphorus standard.

The Canfield-Bachmann model for Chatfield is more sensitive to changes in phosphorus loading (lbs/yr input) than to changes in flow rates. Phosphorus modeling using 1982 hydrological and loading conditions--with constant phosphorus loads and varying flow rates--showed that a decrease of at least

25,000 acre-feet of inflow was required to increase the inlake phosphorus level by 1 ug/l. When flows were kept constant and phosphorus loading varied, an increase of 2500 lbs/yr of phosphorus was required to increase the level by 1 ug/l. This indicates that the model for Chatfield Reservoir is more sensitive to phosphorus loading since a 7 percent change in phosphorus loading will produce the same change in level as a 25 percent change in annual flow.

It is recognized that there are uncertainties associated with the prediction of phosphorus budgets in large reservoirs. The relationship between hydrologic characteristics and total phosphorus concentrations can be expressed quantitatively, though varying results can be produced when similar models are applied to different bodies of water. Variations in sampling methods and analytical techniques can also explain some discrepancies in preditive capabilities. It must continue to be recognized that the use of phosphorus budget models represents only an approximation of a number of potential situations. As more information is known about an individual lake, the modeling should be revised and refined.

REFERENCES FOR APPENDIX C

D.E. Canfield and R.W. Bachmann. 1980. Prediction of Total Phosphorus Concentrations, Chlorophyll a and Secchi Depths for Natural and Artificial Lakes, Can. J. Fish Aquatic Science, 38:414-423.

J.R. Jones and R.W. Bachmann. 1976. Prediction of Phosphorus and Chlorophyll Levels in Lakes, J. Water Poll. Control Fed. 48 (9): 2176-2182.

DRCOG 1984. Chatfield Reservoir Clean Lakes Study. Denver Regional Council of Governments and Colorado Department of Health. 155p.

Figure 9

Chatfield In-Lake Phosphorus Forecasts

Alternative Control Measures

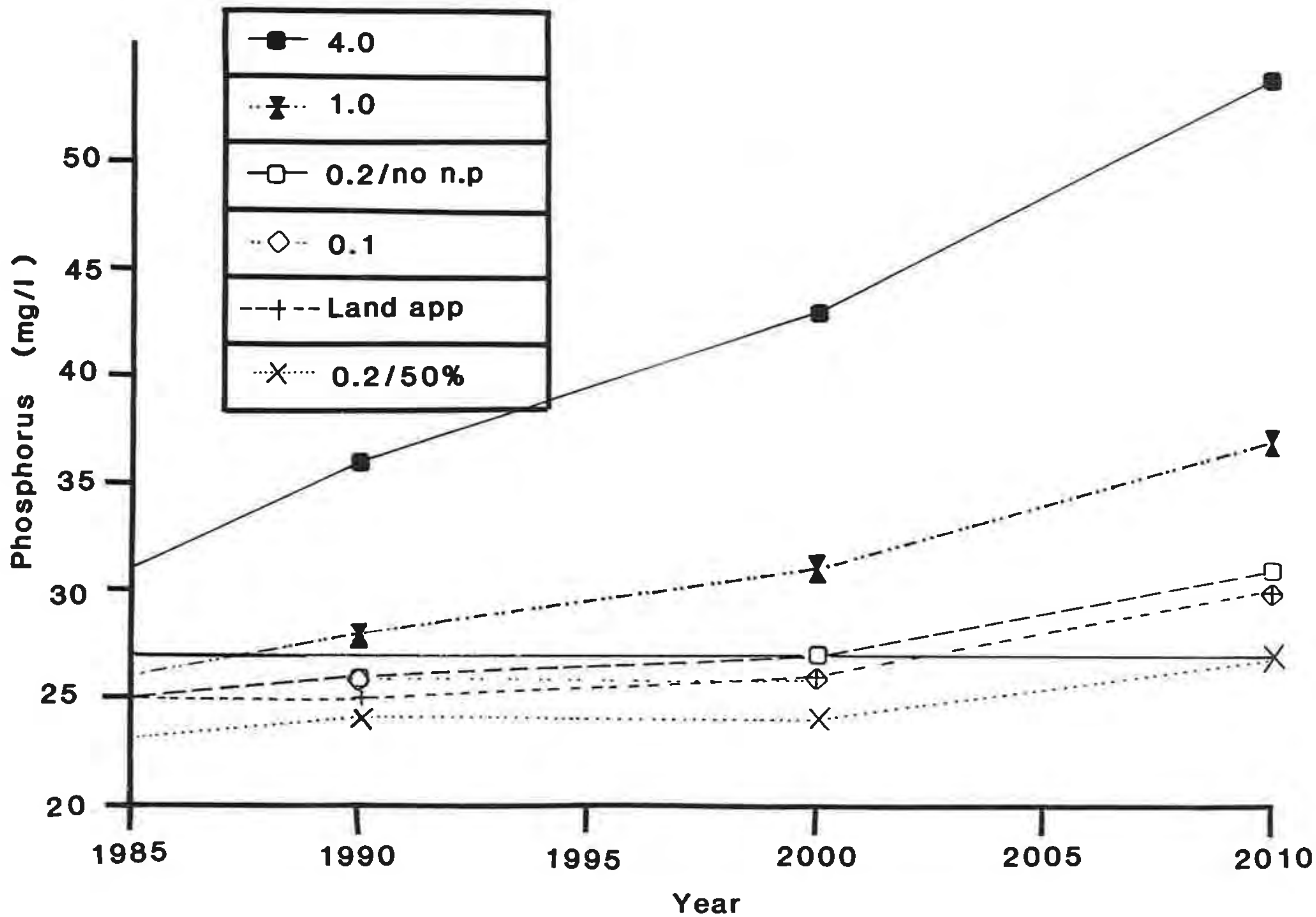


Figure 10

Consumption of Critical Load: 0.2 mg/l of Point Source Phosphorus With No Nonpoint Control

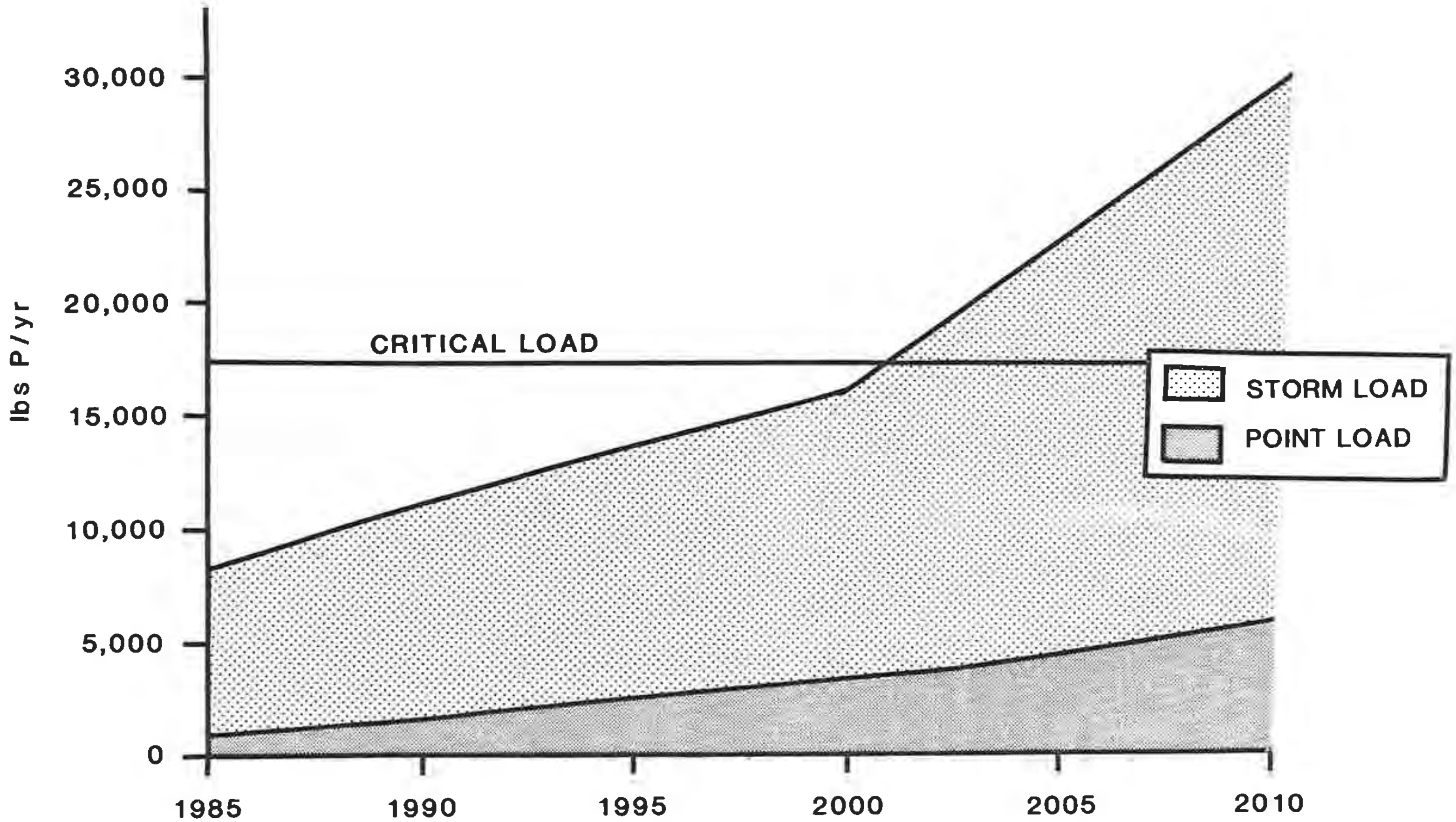


Figure 11

Consumption of Critical Load: 0.2 mg/l of Point Source Phosphorus With 50% Nonpoint Control

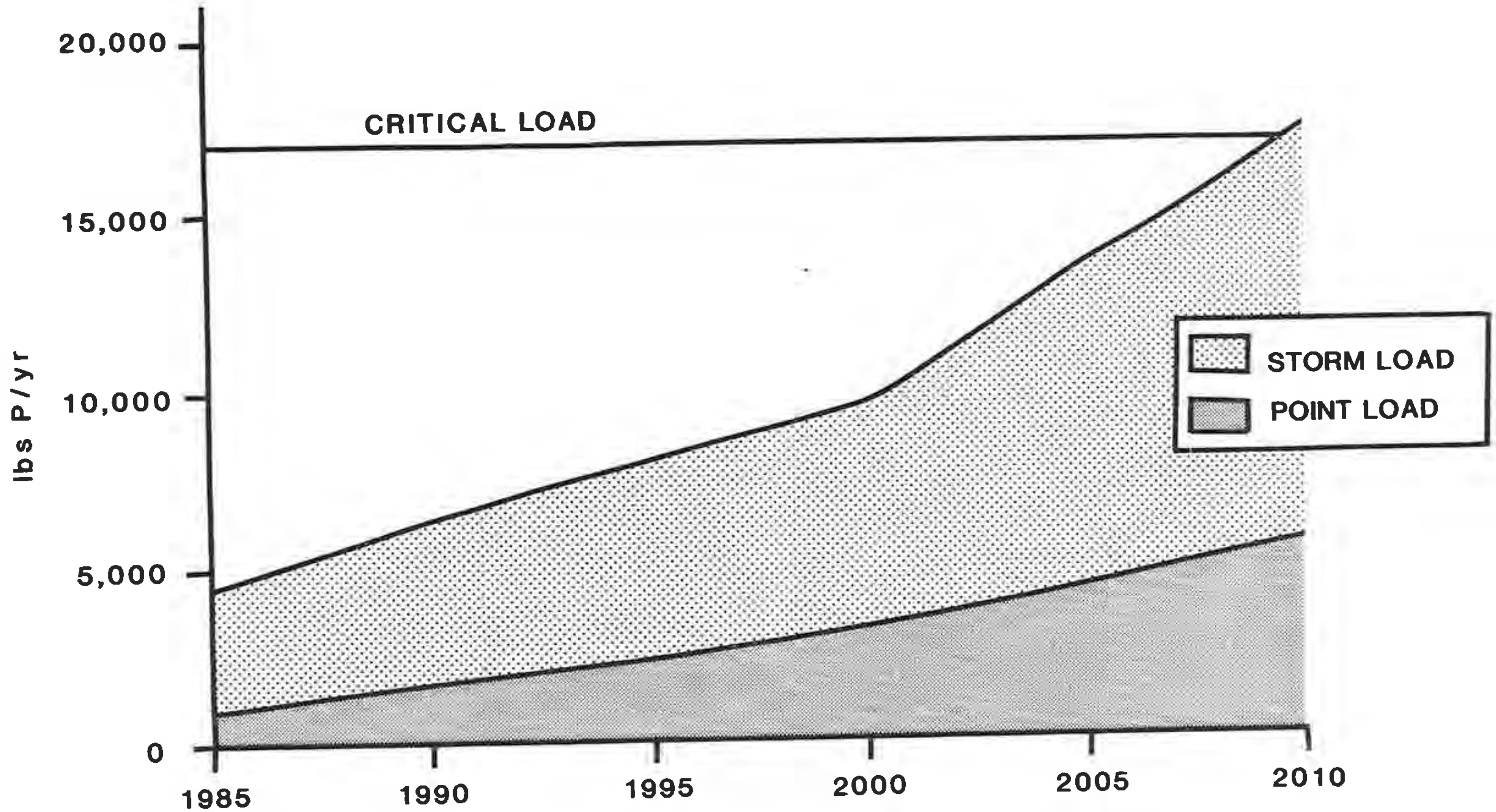


Figure 12

Consumption of Critical Load: 0.1 mg/l of Point Source Phosphorus With No Nonpoint Control

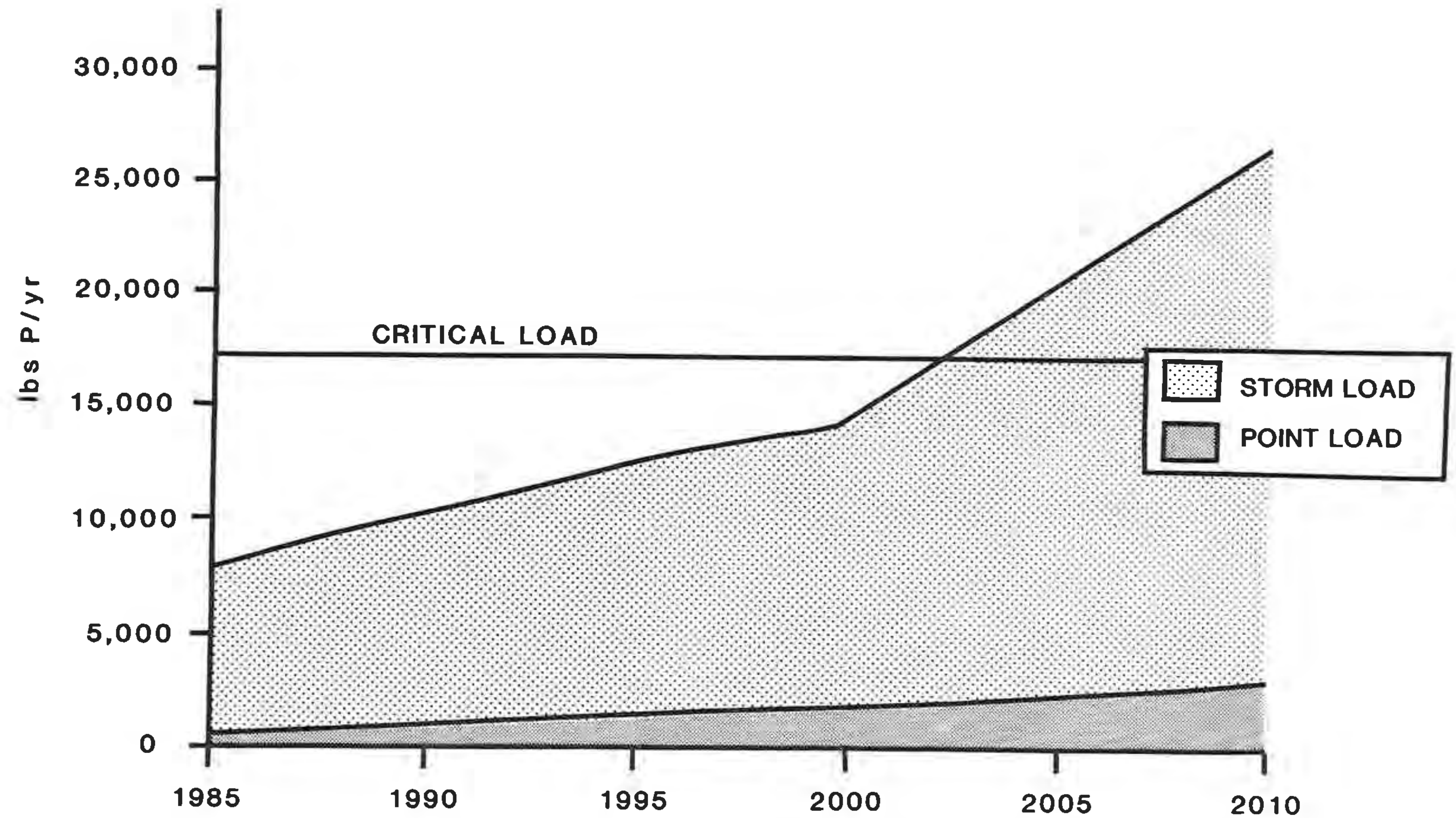


Figure 13

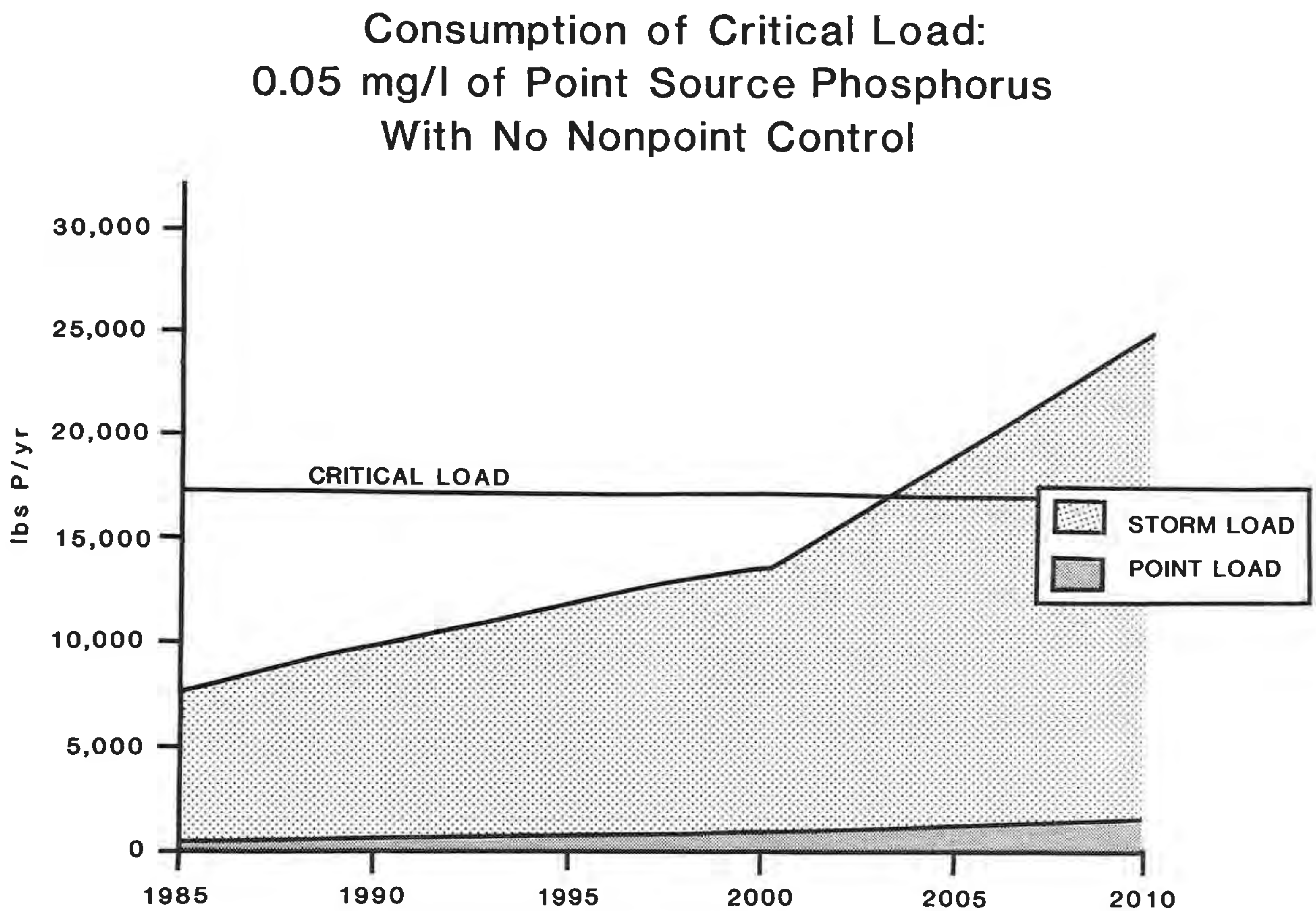

Consumption of Critical Load:
0.05 mg/l of Point Source Phosphorus
With No Nonpoint Control
30,000
25,000
20,000
15,000
10,000
5,000
0
lbs P/yr
CRITICAL LOAD
STORM LOAD
POINT LOAD
1985
1990
1995
2000
2005
2010

Figure 14

Consumption of Critical Load:
1.0 mg/l of Point Source Phosphorus
With No Nonpoint Control

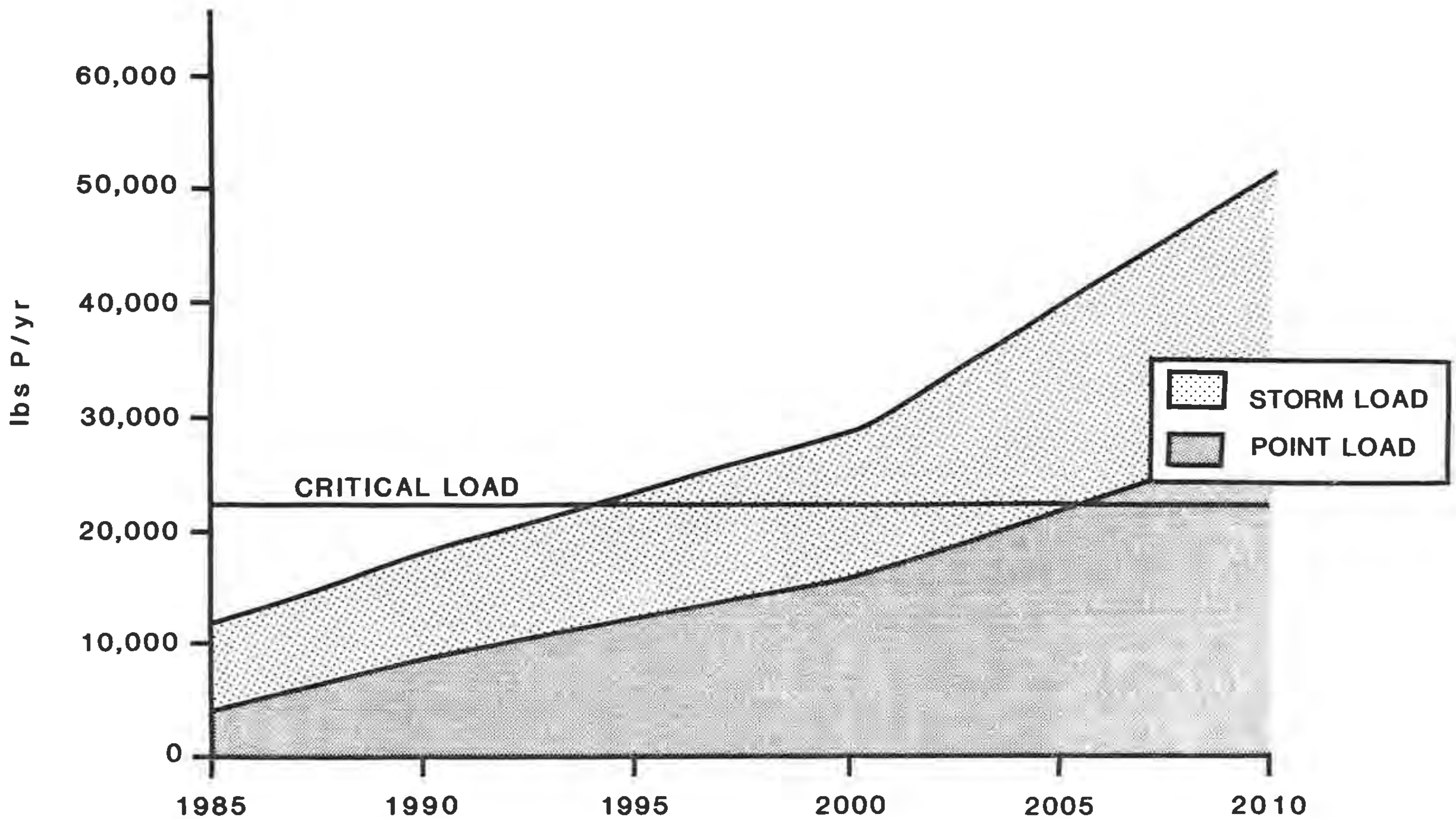
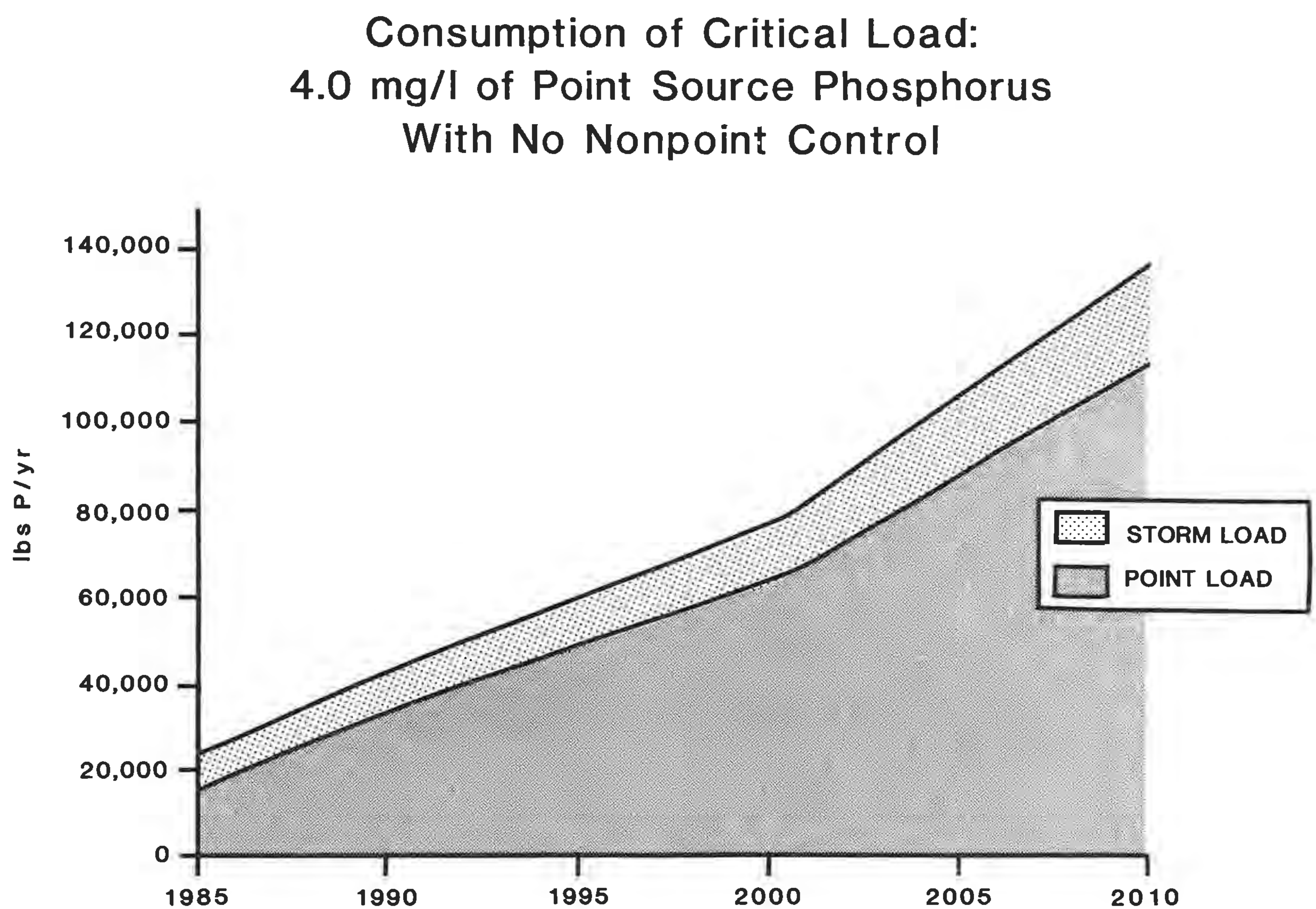


Figure 15



Consumption of Critical Load:
4.0 mg/l of Point Source Phosphorus
With No Nonpoint Control
140,000
120,000
100,000
80,000
60,000
40,000
20,000
0
lbs P/yr
1985
1990
1995
2000
2005
2010
STORM LOAD
POINT LOAD

APPENDIX D

Sample of Qual 2e Model Output

Alternative Number 5 (2010) with 9/15/86 Background Conditions

***** STEADY STATE SIMULATION *****

** HYDRAULICS SUMMARY **

ELE ORD	RCH NUM	ELE NUM	BEGIN LOC MILE	END LOC MILE	FLOW CFS	POINT SRCE CFS	INCR FLOW CFS	VEL FPS	TRVL TIME DAY	DEPTH FT	WIDTH FT	VOLUME FT-3	BOTTOM AREA FT-2	X-SECT AREA FT-2	DSPRSN COEF FT-2/S
1	1	1	50.00	48.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
2	1	2	48.00	46.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
3	1	3	46.00	44.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
4	1	4	44.00	42.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
5	1	5	42.00	40.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
6	1	6	40.00	38.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
7	1	7	38.00	36.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
8	1	8	36.00	34.00	1.00	0.00	0.00	0.234	0.523	1.229	3.480	45150.2	62697.8	4.28	55.68
9	2	1	34.00	32.00	2.02	1.13	-0.11	0.909	0.134	0.365	6.102	23489.1	72133.2	2.22	78.64
10	2	2	32.00	30.00	1.91	0.00	-0.11	0.883	0.138	0.358	6.052	22875.0	71467.7	2.17	75.27
11	2	3	30.00	28.00	1.80	0.00	-0.11	0.857	0.143	0.351	6.000	22242.6	70770.9	2.11	71.86
12	2	4	28.00	26.00	1.70	0.00	-0.11	0.830	0.147	0.344	5.945	21590.2	70039.2	2.04	68.41
13	2	5	26.00	24.00	2.63	1.04	-0.11	1.041	0.117	0.398	6.345	26649.5	75400.2	2.52	96.91
14	2	6	24.00	22.00	2.52	0.00	-0.11	1.019	0.120	0.392	6.305	26115.4	74865.4	2.47	93.72
15	2	7	22.00	20.00	2.41	0.00	-0.11	0.996	0.123	0.387	6.264	25569.1	74311.3	2.42	90.50
16	2	8	20.00	18.00	2.30	0.00	-0.11	0.973	0.126	0.381	6.221	25010.1	73736.8	2.37	87.25
17	2	9	18.00	16.00	2.19	0.00	-0.11	0.949	0.129	0.375	6.177	24437.2	73139.9	2.31	83.96
18	2	10	16.00	14.00	13.59	11.50	-0.11	2.443	0.050	0.686	8.101	58729.7	100049.1	5.56	358.14
19	2	11	14.00	12.00	13.48	0.00	-0.11	2.433	0.050	0.685	8.092	58504.0	99908.9	5.54	355.87
20	2	12	12.00	10.00	13.37	0.00	-0.11	2.423	0.050	0.683	8.082	58277.3	99767.5	5.52	353.59
21	3	1	20.00	18.00	0.06	0.00	0.00	0.087	1.413	0.379	1.829	7323.1	27319.3	0.69	7.74
22	3	2	18.00	16.00	0.06	0.00	0.00	0.087	1.413	0.379	1.829	7323.1	27319.3	0.69	7.74
23	3	3	16.00	14.00	0.06	0.00	0.00	0.087	1.413	0.379	1.829	7323.1	27319.3	0.69	7.74
24	3	4	14.00	12.00	0.06	0.00	0.00	0.087	1.413	0.379	1.829	7323.1	27319.3	0.69	7.74
25	4	1	4.00	2.00	0.10	0.00	0.00	0.227	0.539	0.197	2.242	4657.6	27827.3	0.44	11.74
26	4	2	2.00	0.00	0.47	0.37	0.00	0.467	0.262	0.300	3.359	10635.7	41802.1	1.01	34.32
27	5	1	12.00	10.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
28	5	2	10.00	8.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
29	5	3	8.00	6.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
30	5	4	6.00	4.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
31	5	5	4.00	2.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
32	5	6	2.00	0.00	0.53	0.00	0.00	0.386	0.317	0.293	4.688	14497.9	55689.0	1.37	27.83
33	6	1	10.00	8.00	13.80	0.00	-0.10	2.044	0.060	0.939	7.192	71291.2	95770.8	6.75	388.91
34	6	2	8.00	6.00	13.70	0.00	-0.10	2.038	0.060	0.937	7.178	70991.4	95582.4	6.72	386.97
35	6	3	6.00	4.00	13.60	0.00	-0.10	2.032	0.060	0.934	7.165	70690.6	95392.9	6.69	385.02
36	6	4	4.00	2.00	13.50	0.00	-0.10	2.025	0.060	0.932	7.151	70388.7	95202.4	6.67	383.07
37	6	5	2.00	0.00	13.40	0.00	-0.10	2.019	0.061	0.930	7.138	70086.1	95010.9	6.64	381.11

***** STEADY STATE SIMULATION *****

** REACTION COEFFICIENT SUMMARY **

RCH NUM	ELE NUM	DO SAT MG/L	K2 OPT	OXYGN REAIR 1/DAY	BOD DECAY 1/DAY	BOD SETT 1/DAY	SOD RATE G/F2D	ORGN DECAY 1/DAY	ORGN SETT 1/DAY	NH3 DECAY 1/DAY	NH3 SRCE MG/F2D	NO2 DECAY 1/DAY	ORGP DECAY 1/DAY	ORGP SETT 1/DAY	DISP SRCE MG/F2D	COLI DECAY 1/DAY	ANC DECAY 1/DAY	ANC SETT 1/DAY	ANC SRCE MG/F2D
1	1	7.78	4	5.35	0.46	0.20	0.09	0.23	0.10	0.47	0.09	2.72	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	2	7.74	4	5.38	0.47	0.20	0.09	0.23	0.10	0.48	0.09	2.75	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	3	7.72	4	5.40	0.47	0.20	0.09	0.23	0.10	0.48	0.09	2.76	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	4	7.71	4	5.40	0.47	0.20	0.09	0.23	0.10	0.48	0.09	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	5	7.71	4	5.41	0.47	0.20	0.09	0.23	0.10	0.49	0.09	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	6	7.70	4	5.41	0.47	0.20	0.09	0.24	0.10	0.49	0.09	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	7	7.70	4	5.41	0.47	0.20	0.09	0.24	0.10	0.49	0.09	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1	8	7.70	4	5.41	0.47	0.20	0.09	0.24	0.10	0.49	0.09	2.77	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	1	7.63	4	67.03	1.92	0.20	0.10	0.24	0.10	0.92	0.09	28.30	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	2	7.66	4	128.90	1.90	0.20	0.09	0.24	0.10	0.91	0.09	28.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	3	7.68	4	130.51	1.89	0.20	0.09	0.24	0.10	0.90	0.09	28.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	4	7.69	4	132.43	1.89	0.20	0.09	0.24	0.10	0.89	0.09	27.98	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	5	7.65	4	126.96	1.91	0.20	0.09	0.24	0.10	0.91	0.09	28.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	6	7.67	4	119.84	1.90	0.20	0.09	0.24	0.10	0.90	0.09	28.11	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	7	7.68	4	120.99	1.89	0.20	0.09	0.24	0.10	0.90	0.09	28.02	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	8	7.69	4	122.31	1.89	0.20	0.09	0.24	0.10	0.89	0.09	27.97	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	9	7.69	4	123.78	1.89	0.20	0.09	0.24	0.10	0.89	0.09	27.95	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	10	7.55	4	102.82	1.97	0.20	0.10	0.25	0.10	0.95	0.10	28.79	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	11	7.57	4	78.12	1.95	0.20	0.10	0.24	0.10	0.94	0.10	28.63	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2	12	7.59	4	78.06	1.94	0.20	0.10	0.24	0.10	0.93	0.10	28.52	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	1	7.80	4	24.09	0.46	0.20	0.09	0.23	0.10	0.46	0.09	2.70	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	2	7.71	4	24.42	0.47	0.20	0.09	0.23	0.10	0.49	0.09	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	3	7.70	4	24.45	0.47	0.20	0.09	0.24	0.10	0.49	0.09	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
3	4	7.70	4	24.46	0.47	0.20	0.09	0.24	0.10	0.49	0.09	2.78	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	1	7.84	4	153.89	0.45	0.20	0.09	0.23	0.09	0.46	0.09	2.69	0.00	0.00	0.00	0.00	0.00	0.00	0.00
4	2	7.65	4	137.95	0.48	0.20	0.09	0.24	0.10	0.50	0.09	2.83	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	1	7.68	4	89.27	0.47	0.20	0.09	0.24	0.10	0.67	0.09	28.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	2	7.70	4	107.54	0.47	0.20	0.09	0.24	0.10	0.67	0.09	27.93	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	3	7.70	4	107.49	0.47	0.20	0.09	0.24	0.10	0.67	0.09	27.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	4	7.70	4	107.47	0.47	0.20	0.09	0.24	0.10	0.67	0.09	27.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	5	7.70	4	107.47	0.47	0.20	0.09	0.24	0.10	0.67	0.09	27.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
5	6	7.70	4	107.47	0.47	0.20	0.09	0.24	0.10	0.67	0.09	27.91	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	1	7.61	4	66.05	0.48	0.20	0.10	0.24	0.10	0.93	0.09	28.57	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	2	7.62	4	38.58	0.48	0.20	0.10	0.24	0.10	0.92	0.09	28.47	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	3	7.63	4	38.61	0.48	0.20	0.10	0.24	0.10	0.92	0.09	28.38	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	4	7.63	4	38.64	0.48	0.20	0.09	0.24	0.10	0.91	0.09	28.31	0.00	0.00	0.00	0.00	0.00	0.00	0.00
6	5	7.65	4	38.69	0.48	0.20	0.09	0.24	0.10	0.91	0.09	28.26	0.00	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

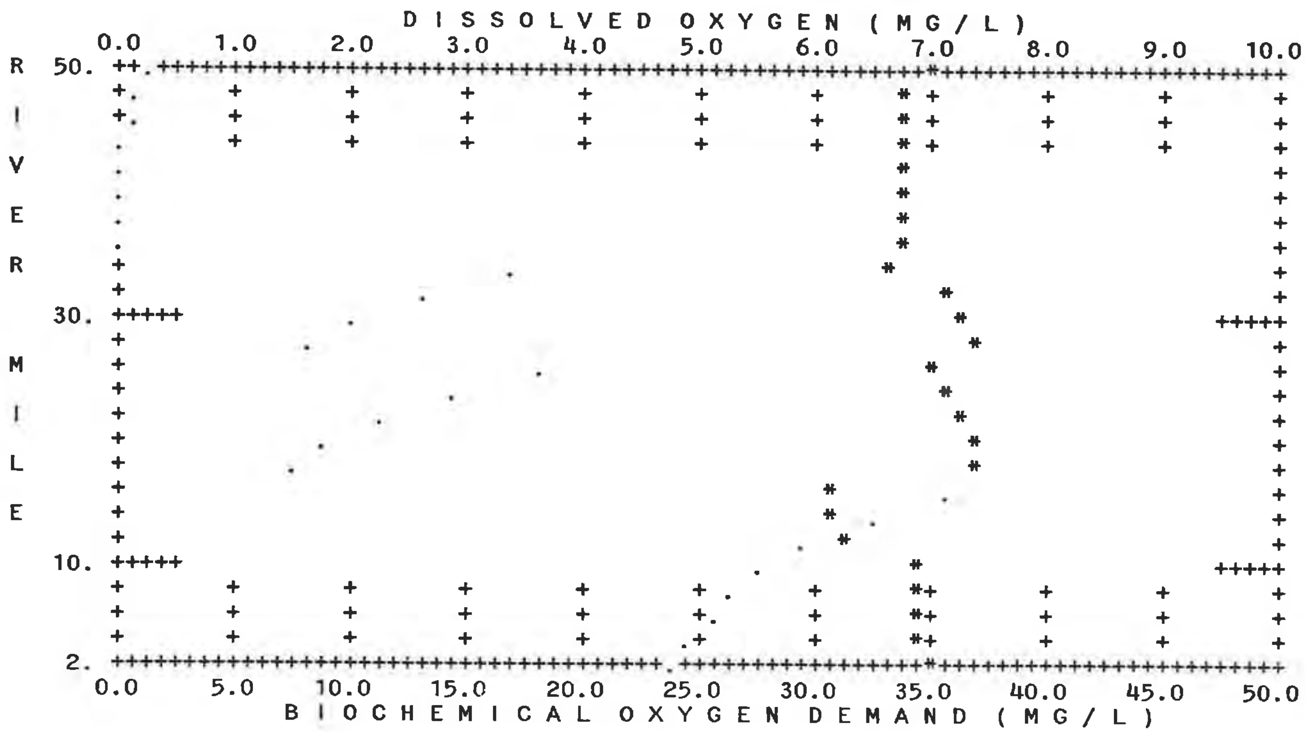
** WATER QUALITY VARIABLES **

RCH NUM	ELE NUM	TEMP DEG-F	CM-1	CM-2	CM-3	DO MG/L	BOD MG/L	ORGN MG/L	NH3N MG/L	NO2N MG/L	NO3N MG/L	SUM-N MG/L	ORGP MG/L	DIS-P MG/L	SUM-P MG/L	COLI #/100ML	ANC	CHLA UG/L
1	1	64.78	0.00	0.00	0.00	7.03	1.49	0.00	0.02	0.01	0.03	0.06	0.00	0.00	0.00	0.00	0.00	0.00
1	2	65.19	0.00	0.00	0.00	6.83	1.11	0.00	0.02	0.01	0.04	0.06	0.00	0.00	0.00	0.00	0.00	0.00
1	3	65.39	0.00	0.00	0.00	6.79	0.82	0.00	0.01	0.00	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1	4	65.50	0.00	0.00	0.00	6.79	0.61	0.00	0.01	0.00	0.05	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1	5	65.55	0.00	0.00	0.00	6.80	0.45	0.00	0.01	0.00	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1	6	65.58	0.00	0.00	0.00	6.81	0.34	0.00	0.01	0.00	0.06	0.07	0.00	0.00	0.00	0.00	0.00	0.00
1	7	65.59	0.00	0.00	0.00	6.82	0.25	0.00	0.01	0.00	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.00
1	8	65.61	0.00	0.00	0.00	6.80	0.46	0.00	0.02	0.00	0.17	0.20	0.00	0.00	0.00	0.00	0.00	0.00
2	1	66.43	0.00	0.00	0.00	6.71	17.14	0.00	0.50	0.01	4.95	5.46	0.00	0.00	0.00	0.00	0.00	0.00
2	2	66.05	0.00	0.00	0.00	7.25	13.40	0.00	0.45	0.01	5.00	5.46	0.00	0.00	0.00	0.00	0.00	0.00
2	3	65.84	0.00	0.00	0.00	7.36	10.43	0.00	0.40	0.01	5.05	5.47	0.00	0.00	0.00	0.00	0.00	0.00
2	4	65.73	0.00	0.00	0.00	7.42	8.14	0.00	0.36	0.01	5.11	5.48	0.00	0.00	0.00	0.00	0.00	0.00
2	5	66.21	0.00	0.00	0.00	7.10	18.15	0.00	0.59	0.02	6.66	7.27	0.00	0.00	0.00	0.00	0.00	0.00
2	6	65.97	0.00	0.00	0.00	7.22	14.60	0.00	0.53	0.02	6.72	7.27	0.00	0.00	0.00	0.00	0.00	0.00
2	7	65.82	0.00	0.00	0.00	7.31	11.70	0.00	0.48	0.02	6.77	7.27	0.00	0.00	0.00	0.00	0.00	0.00
2	8	65.73	0.00	0.00	0.00	7.38	9.34	0.00	0.44	0.01	6.82	7.27	0.00	0.00	0.00	0.00	0.00	0.00
2	9	65.69	0.00	0.00	0.00	7.43	7.61	0.00	0.40	0.01	6.88	7.29	0.00	0.00	0.00	0.00	0.00	0.00
2	10	67.36	0.00	0.00	0.00	6.20	36.15	0.00	0.95	0.02	8.76	9.73	0.00	0.00	0.00	0.00	0.00	0.00
2	11	67.11	0.00	0.00	0.00	6.24	32.65	0.00	0.91	0.02	8.79	9.73	0.00	0.00	0.00	0.00	0.00	0.00
2	12	66.89	0.00	0.00	0.00	6.36	29.48	0.00	0.87	0.03	8.83	9.73	0.00	0.00	0.00	0.00	0.00	0.00
3	1	64.45	0.00	0.00	0.00	7.23	0.52	0.00	0.02	0.01	0.13	0.16	0.00	0.00	0.00	0.00	0.00	0.00
3	2	65.49	0.00	0.00	0.00	7.21	0.27	0.00	0.02	0.00	0.15	0.17	0.00	0.00	0.00	0.00	0.00	0.00
3	3	65.60	0.00	0.00	0.00	7.20	0.14	0.00	0.02	0.00	0.16	0.19	0.00	0.00	0.00	0.00	0.00	0.00
3	4	65.61	0.00	0.00	0.00	7.20	0.16	0.00	0.03	0.00	0.24	0.27	0.00	0.00	0.00	0.00	0.00	0.00
4	1	64.08	0.00	0.00	0.00	7.68	0.85	0.00	0.03	0.01	0.15	0.19	0.00	0.00	0.00	0.00	0.00	0.00
4	2	66.17	0.00	0.00	0.00	7.28	31.50	0.00	1.01	0.06	7.21	8.29	0.00	0.00	0.00	0.00	0.00	0.00
5	1	65.79	0.00	0.00	0.00	7.28	24.11	0.00	0.78	0.02	6.58	7.38	0.00	0.00	0.00	0.00	0.00	0.00
5	2	65.66	0.00	0.00	0.00	7.43	19.89	0.00	0.65	0.02	6.72	7.39	0.00	0.00	0.00	0.00	0.00	0.00
5	3	65.62	0.00	0.00	0.00	7.46	16.41	0.00	0.54	0.01	6.84	7.39	0.00	0.00	0.00	0.00	0.00	0.00
5	4	65.61	0.00	0.00	0.00	7.48	13.54	0.00	0.45	0.01	6.94	7.39	0.00	0.00	0.00	0.00	0.00	0.00
5	5	65.61	0.00	0.00	0.00	7.50	11.17	0.00	0.37	0.01	7.02	7.40	0.00	0.00	0.00	0.00	0.00	0.00
5	6	65.61	0.00	0.00	0.00	7.52	9.33	0.00	0.31	0.01	7.09	7.42	0.00	0.00	0.00	0.00	0.00	0.00
6	1	66.70	0.00	0.00	0.00	6.95	27.95	0.00	0.82	0.03	8.79	9.64	0.00	0.00	0.00	0.00	0.00	0.00
6	2	66.56	0.00	0.00	0.00	6.93	26.86	0.00	0.78	0.03	8.84	9.64	0.00	0.00	0.00	0.00	0.00	0.00
6	3	66.44	0.00	0.00	0.00	6.95	25.81	0.00	0.74	0.02	8.88	9.64	0.00	0.00	0.00	0.00	0.00	0.00
6	4	66.33	0.00	0.00	0.00	6.98	24.80	0.00	0.70	0.02	8.92	9.64	0.00	0.00	0.00	0.00	0.00	0.00
6	5	66.24	0.00	0.00	0.00	7.01	23.86	0.00	0.66	0.02	8.95	9.64	0.00	0.00	0.00	0.00	0.00	0.00

***** STEADY STATE SIMULATION *****

** DISSOLVED OXYGEN DATA **

ELE ORD	RCH NUM	ELE NUM	TEMP DEG-F	DO SAT MG/L	DO MG/L	DO DEF MG/L	DAM INPUT MG/L	NIT INHIB FACT	COMPONENTS OF DISSOLVED OXYGEN MASS BALANCE (MG/L-DAY) F-FNCTN INPUT	OXYGN REAIR	C-BOD	SOD	NET P-R	NH3-N	NO2-N
1	1	1	64.78	7.78	7.03	0.75	0.00	0.99	14.93	3.99	-0.69	-0.07	0.00	-0.03	-0.03
2	1	2	65.19	7.74	6.83	0.91	0.00	0.98	0.00	4.89	-0.51	-0.07	0.00	-0.03	-0.02
3	1	3	65.39	7.72	6.79	0.93	0.00	0.98	0.00	5.03	-0.38	-0.07	0.00	-0.02	-0.01
4	1	4	65.50	7.71	6.79	0.92	0.00	0.98	0.00	4.98	-0.29	-0.08	0.00	-0.02	-0.01
5	1	5	65.55	7.71	6.80	0.91	0.00	0.98	0.00	4.90	-0.21	-0.08	0.00	-0.02	-0.01
6	1	6	65.58	7.70	6.81	0.89	0.00	0.98	0.00	4.82	-0.16	-0.08	0.00	-0.02	-0.01
7	1	7	65.59	7.70	6.82	0.88	0.00	0.98	0.00	4.76	-0.12	-0.08	0.00	-0.02	-0.01
8	1	8	65.61	7.70	6.80	0.90	0.00	0.98	0.00	4.86	-0.22	-0.08	0.00	-0.03	-0.01
9	2	1	66.43	7.63	6.71	0.92	0.00	0.98	18.11	61.89	-32.92	-0.26	0.00	-1.61	-0.45
10	2	2	66.05	7.66	7.25	0.42	0.00	0.99	-2.97	53.53	-25.50	-0.26	0.00	-1.43	-0.46
11	2	3	65.84	7.68	7.36	0.32	0.00	0.99	-3.10	41.74	-19.74	-0.27	0.00	-1.27	-0.42
12	2	4	65.73	7.69	7.42	0.26	0.00	0.99	-3.22	34.94	-15.36	-0.27	0.00	-1.13	-0.38
13	2	5	66.21	7.65	7.10	0.55	0.00	0.99	14.36	69.43	-34.69	-0.24	0.00	-1.87	-0.51
14	2	6	65.97	7.67	7.22	0.44	0.00	0.99	-2.59	53.23	-27.73	-0.24	0.00	-1.68	-0.54
15	2	7	65.82	7.68	7.31	0.37	0.00	0.99	-2.68	44.62	-22.14	-0.24	0.00	-1.51	-0.50
16	2	8	65.73	7.69	7.38	0.31	0.00	0.99	-2.76	37.76	-17.63	-0.24	0.00	-1.36	-0.46
17	2	9	65.69	7.69	7.43	0.27	0.00	0.99	-2.85	32.83	-14.35	-0.25	0.00	-1.24	-0.42
18	2	10	67.36	7.55	6.20	1.35	0.00	0.98	83.60	139.02	-71.13	-0.14	0.00	-3.17	-0.55
19	2	11	67.11	7.57	6.24	1.33	0.00	0.98	-1.00	103.85	-63.82	-0.14	0.00	-2.99	-0.80
20	2	12	66.89	7.59	6.36	1.23	0.00	0.98	-1.02	95.75	-57.32	-0.14	0.00	-2.84	-0.87
21	3	1	64.45	7.80	7.23	0.57	0.00	0.99	3.61	13.68	-0.24	-0.24	0.00	-0.04	-0.02
22	3	2	65.49	7.71	7.21	0.51	0.00	0.99	0.00	12.37	-0.13	-0.24	0.00	-0.04	-0.01
23	3	3	65.60	7.70	7.20	0.50	0.00	0.99	0.00	12.34	-0.06	-0.24	0.00	-0.04	-0.01
24	3	4	65.61	7.70	7.20	0.51	0.00	0.99	0.00	12.37	-0.07	-0.24	0.00	-0.05	-0.01
25	4	1	64.08	7.84	7.68	0.16	0.00	0.99	9.46	24.05	-0.39	-0.45	0.00	-0.04	-0.03
26	4	2	66.17	7.65	7.28	0.37	0.00	0.99	15.03	51.25	-15.03	-0.31	0.00	-1.78	-0.21
27	5	1	65.79	7.68	7.28	0.41	0.00	0.99	0.00	36.25	-11.40	-0.32	0.00	-1.84	-0.76
28	5	2	65.66	7.70	7.43	0.27	0.00	0.99	0.00	28.81	-9.37	-0.32	0.00	-1.52	-0.52
29	5	3	65.62	7.70	7.46	0.24	0.00	0.99	0.00	25.65	-7.72	-0.32	0.00	-1.26	-0.42
30	5	4	65.61	7.70	7.48	0.22	0.00	0.99	0.00	23.35	-6.37	-0.32	0.00	-1.05	-0.35
31	5	5	65.61	7.70	7.50	0.20	0.00	0.99	0.00	21.47	-5.26	-0.32	0.00	-0.87	-0.29
32	5	6	65.61	7.70	7.52	0.19	0.00	0.99	0.00	20.03	-4.39	-0.32	0.00	-0.73	-0.24
33	6	1	66.70	7.61	6.95	0.66	0.00	0.98	-0.84	43.73	-13.52	-0.10	0.00	-2.67	-0.86
34	6	2	66.56	7.62	6.93	0.69	0.00	0.98	-0.84	26.52	-12.95	-0.10	0.00	-2.51	-0.83
35	6	3	66.44	7.63	6.95	0.68	0.00	0.98	-0.85	26.19	-12.40	-0.10	0.00	-2.37	-0.79
36	6	4	66.33	7.63	6.98	0.66	0.00	0.98	-0.86	25.36	-11.88	-0.10	0.00	-2.24	-0.75
37	6	5	66.24	7.65	7.01	0.64	0.00	0.99	-0.86	24.58	-11.41	-0.10	0.00	-2.12	-0.71



DISSOLVED OXYGEN = * * * *

BIOCHEMICAL OXYGEN DEMAND = ...

COST ANALYSES

Cost analyses assessments were made for wastewater service area alternatives designated in the Basin Study. There were five service area alternative scenarios developed for this study. These scenarios ranged from continued wastewater treatment at existing facilities, to various combinations of subregional and individual facilities treating wastewater within the basin, to a single regional facility located outside the basin. The regional facility would be located in Douglas County and designated as Regional Wastewater Treatment Plant I (RWWTP 1). This facility would be located in the Highlands Ranch service area shown in the 1987 CWP, Volume II (DRCOG, 1980). This facility would either utilize the existing Marcy Gulch treatment facility or be constructed as a new facility. The existing and proposed facilities located within Chatfield Basin which were considered in the cost study included: Roxborough Park; Chatfield Green, (proposed); Perry Park-Sage Port; Perry Park-Waucondah; Louviers; Centennial or Marcy Gulch; Bell Mountain Ranch (proposed); Larkspur-North; Larkspur-South (proposed); Castle Pines; Castle Rock; and Martin Marietta. The subregional facilities would be combinations of these existing facilities. There were three subregional facility alternatives proposed by the Task Force: Castle Pines RWWTP 2; Bell Mountain Ranch RWWTP 3; and North Larkspur RWWTP 4.

There were six existing wastewater treatment facilities in the basin which did not affect alternative cost analyses or influence the selection process of the Task Force. These facilities were Martin Marietta, Centennial, Louviers, Perry Park-Waucondah, Chatfield Green and Roxborough Park. Cost data remains constant for these facilities between alternatives. Although these facilities were modeled and cost data was generated, this information was not used in subsequent cost analyses. The Larkspur-South facility was planned to be phased out by 2010 with wastewater flows sent either to Larkspur-North or RWWTP 4.

Facility cost factors which were considered in cost analyses included total project construction cost, present worth of facility over a 20 year design life, average annual operation and maintenance (O&M), treatment charge rate per thousand gallons of wastewater flow and total annual operation cost for entire facility. Cost data was evaluated in December 1987 dollars. Cost data was adjusted to reflect, generally, Denver region costs. Adjustments were made by applying the appropriate indices which included the Engineering News Record Index, Marshall and Swift Index or the EPA Large City Index. Transmission line cost factors which were considered in cost analyses included: total project cost of 2010 sized gravity and forcemain pipelines; right-of-way costs; pump stations and annual operation and maintenance charges for new pipelines and pump stations.

Facility cost factors were generated by a computer model designed to estimate capital and operation and maintenance cost of either existing facilities planning to up-grade or new facilities. Transmission line cost factors were determined by standard engineering practices and methods. The annual operation and maintenance for gravity and forcemain pipeline, irregardless of size, was found to average 2,000 dollars per mile for the Denver region in 1987. Unit costs for pump stations were individually calculated. Gravity pipeline unit costs per linear foot included manholes and miscellaneous construction costs. Forcemain pipeline unit costs per linear foot included check valves, air relief valves, fittings and miscellaneous apparatuses.

The planning period for cost analyses extends through the year 2010. Various cost estimates were made for service area alternatives based on 2010 flow projections. These flow projections were determined for alternatives in 1986, 1990, 2000 and 2010 (Table 18). These flows were based on population and employment estimates for designated areas and alternatives as provided by the Task Force and refined by DRCOG. Flow projections were made for all existing facilities. Total operation and maintenance costs for facilities and transmission lines were determined for the planning period between 1988 to 2010.

It was determined by the Task Force for cost analyses purposes that cost differences between alternatives which were less than 20 percent would not be considered significant. The intended use of cost estimates between alternatives, for planning purposes, is to eliminate those alternatives with extremely high costs. More refined cost analyses can be made as alternatives are eliminated.

Transmission line routes were determined for alternatives. Estimated lengths were electronically measured from a topographic map. Routes followed natural topographical features and did not necessarily indicate actual potential routes. New transmission line lengths and return flows are shown in Table 19. These lines were sized for 2010 flow projections. Wastewater would flow by gravity to the RWWTP 1 and subregional facilities. Since most of the service areas require some return flow to meet augmentation plans, forcemains would be required from the RWWTP 1 and subregional facilities.

Existing wastewater treatment facilities and a designed regional facility were modeled by the CAPDET computer program. The CAPDET model (Computer Assisted Procedure for the Design and Evaluation of Wastewater Treatment Systems) is a computer program for estimating capital and operational costs of wastewater treatment facilities. CAPDET was designed by EPA (1981) as a cost-estimating tool. The CAPDET model uses a unit cost approach to generate basic process design data, construction costs, and operation and maintenance costs.

Modeling can be done for existing facilities or proposed new facilities. Model input data requirements as specified in the user's guide (Hydromantis, Inc., 1985) are as follows:

1. unit processes specification which define unit process design parameters;
2. influent waste characteristics;
3. effluent waste characteristics;

TABLE 18

PROJECTED WASTEWATER FLOWS FOR TREATMENT FACILITIES IN CHATFIELD BASIN*

Wastewater Facility	1986 (mgd)	1990 (mgd)	2000 (mgd)	2010 (mgd)
NON-ALTERNATIVE FACILITIES**				
Martin Marietta	0.41	0.41	0.41	0.45
Centennial	0.38	0.86	2.71	4.19
Louviers	0.04	0.04	0.05	0.06
Perry Park-Waucondah	0.11	0.13	0.22	0.32
Chatfield Green	0.0	0.07	0.12	0.20
Roxborough Park	0.09	0.26	0.52	0.69
ALTERNATIVE 1				
Douglas County RWWTP 1	-	2.40	4.60	8.04
ALTERNATIVE 2				
Castle Pine RWWTP 2	-	2.10	4.08	8.04
ALTERNATIVE 3				
Castle Pine RWWTP 2	-	1.70	3.20	6.50
Bell Mt. Ranch RWWTP 3	-	0.37	0.93	1.54
ALTERNATIVE 4				
Castle Pines	0.30	0.63	1.34	2.60
Bell Mt. Ranch	0.0	0.15	0.44	0.57
Castle Rock	0.45	1.10	1.81	3.90
Larkspur-North	0.04	0.22	0.50	0.87
Spruce Mountain***	0.0	0.15	0.25	-
Perry Park-Sage Port	0.01	0.03	0.04	0.10
ALTERNATIVE 5				
Castle Pine RWWTP 2	-	1.70	3.20	6.50
Bell Mt. Ranch	0.0	0.15	0.44	0.57
North Larkspur RWWTP 4	-	0.24	0.54	0.97

* It is recognized that these numbers are not consistent with those in Table 10. They are based on flow projections used earlier in the study and agreed upon by the basin study task force. However, outcome was deemed not to differ significantly enough to warrant revision.

** These facilities do not influence cost analyses for alternatives.

*** Spruce Mountain facility will be phased out by 2010 with wastewater flow sent to a regional facility.

TABLE 19

NEW TRANSMISSION LINE LENGTHS, RETURN FLOWS AND CAPITAL COST REQUIRED FOR ALTERNATIVES

Wastewater Facility	2010 Size (mgd)	Interceptor Gravity (mile)	Interceptor Force (mile)	Return Flow (mgd)	Capital Costs Sewage ($Mil)	Capital Costs Return ($Mil)
ALTERNATIVE 1						
Douglas County RWWTP 1	8.94					
Castle Pine	2.60	13.4	13.4	1.00	4.89	4.31
Castle Rock	3.90	3.5	3.6	0.45	0.99	1.02
Roxborough	0.90	4.5	4.5	0.80	0.75	0.68
Bell Mt. Ranch	0.57	4.9	4.9	0.50	0.57	1.34
Larkspur-North	0.87	9.9	9.9	0.87	1.83	0.64
Perry Park-Sage Port*	0.10	0.2	-	0.0	-	-
Total Capital Cost					9.03	7.99
ALTERNATIVE 2						
Castle Pine RWWTP 2	8.04					
Castle Rock	3.90	3.5	3.6	0.45	0.99	1.02
Bell Mt. Ranch	0.57	4.9	4.9	0.50	0.57	1.34
Larkspur-North	0.87	9.9	9.9	0.87	1.83	0.62
Perry Park-Sage Port*	0.10	0.2	-	0.0	-	-
Total Capital Cost					3.39	2.98
ALTERNATIVE 3						
Castle Pines RWWTP 2	6.50					
Castle Rock	3.90	3.7	3.6	0.45	0.95	0.51
Bell Mt. Ranch RWWTP 3	1.54					
Larkspur-North	0.87	9.9	9.9	0.87	0.76	0.69
Perry Park-Sage Port	0.10	0.2	-	0.0	-	-
Total Capital Cost					1.71	1.20
ALTERNATIVE 5						
Castle Pines RWWTP 2	6.50					
Castle Rock	3.09	3.7	3.6	0.45	0.95	0.51
North Larkspur RWWTP 4	0.97					
Larkspur-North	0.87	0.74	0.74	0.87	0.07	0.13
Total Capital Cost					1.06	1.15

*Capital costs for facility are incorporated with Larkspur North costs.

4. scheme description;

5. unit cost data, cost indices input and optional direct construction cost data.

CAPDET contains a default data base, except for influent waste characteristics. This default data base can be upgraded to reflect local conditions. Electrical costs and labor rates were adjusted to reflect actual costs found at existing wastewater facilities. The remaining default cost data base was used as found in the CAPDET model. These default values are FOB equipment costs (first trimester 1977 dollars) and they are automatically updated by the model using EPA and Marshall and Swift indexes (Harris et. al., 1982). Total annual operation and maintenance costs include personnel, electrical use, material and chemical costs. The model has weighted personnel-hour estimates to account for 50 percent of operation and maintenance costs.

The CAPDET model divides the overall cost structure of a proposed project into four components:

1. construction costs of unit processes;

2. construction costs of associated support facilities;

3. indirect costs;

4. and operation and maintenance costs.

A unit cost technique is used in the model to generate construction cost estimates. Labor, equipment capacities, operation and maintenance costs and material quantities are calculated by applying unit price cost data to these categories. Cost data for associated support facilities is built into the CAPDET program and cannot be changed by the user. Estimation of operation and maintenance costs is done by applying unit cost to the following quantities: operational personnel hours, maintenance personnel hours, electrical use, chemical use and material supply (Pineau et al, 1985).

In a study of the CAPDET for Canadian wastewater facilities, CAPDET was shown to be an adaptable tool to use in preliminary process design and for predicting planning level cost information of wastewater facilities with acceptable accuracy (Pineau et al, 1985). Construction costs were predicted within $\pm$ 20 percent of actual costs. It was shown that personnel and electrical costs needed to be adjusted to reflect local conditions to obtain reasonable operation and maintenance cost estimates.

Existing unit process information was obtained for all facilities associated with the study. This information included treatment schemes, design capacities of processes and specific unit design characteristics. Influent wastewater characteristics were obtained from existing facility data, WQCD facility permits and average numbers derived from other treatment facilities in the Denver region. Unit prices and cost indices were adjusted for all facilities. This made it possible to compare facilities at 1987 dollars. Facilities were modeled with a 20 year design life at ten percent interest.

Model runs were made for existing facilities. Unit process default values were corrected and adjusted based on these runs and comparison made between model cost outputs and actual cost data. The smaller facilities proved to be the most difficult to model. Some of the cost differences between model precision and actual facility cost were greater than 30 percent. Since the CAPDET cost data for small facilities was not as reliable as for large facilities, an alternate method of making cost comparisons between service area alternatives was recommended by the Task Force.

Instead of using existing facility unit process schemes and cost estimates, an idealized wastewater treatment facility designed by CAPDET would be used for alternatives. This idealized facility would use projected 2010 flows.

The facility selected was an activated sludge treatment facility with tertiary removal of phosphorus and nitrogen. Since a tertiary facility would not be required for alternative 1 (Table 18) where wastewater flow would be sent out of basin to RWWTP 1, this facility was modeled as a secondary activated sludge facility.

Cost data for these modeled facilities are shown in Table 20. Flow sizes and number of facilities for each alternative have the major effect on alternative facility costs. The operation and maintenance costs for the 20 year planning period increase significantly with more facilities.

The important cost factors which cause differences between alternatives are capital costs of transmission lines (Table 19) and operation and maintenance costs associated with facilities and transmission lines (Table 21). The facility capital cost is the present worth of the facility based on a 20 year design life. The transmission line capital cost includes total construction, installation and right-of-way costs, but does not include interest charges. The 20 year operation and maintenance is the combined interceptor and facility charges, which includes administrative and laboratory costs.

Alternative 4, which uses only individual wastewater facilities, is the most costly at a total cost for the planning period of 93.5 million. Alternative 2 was the most cost-effective at 61.8 million. This alternative has a subregional facility RWWTP 2 at Castle Pines which provides treatment to Castle Rock, Bell Mountain Ranch, Larkspur North, Larkspur South and Perry Park-Sage Port. The difference between these alternatives is 44 percent. This difference would eliminate alternative 4 from further consideration. Alternatives 1 and 3 are close to alternative 2 in relation to costs with total costs of 68 and 76.9 million, respectively. The differences are nine and twenty percent, which fall within the no difference category. Alternative 5 has a total cost of 77.9 million which is 21 percent higher than alternative 2. Because of the uncertainties involved in cost estimation, alternative 5 could be considered to fall within the no difference category. The higher cost of this alternative is a result of a separate Bell Mountain Ranch facility. Combining the Bell Mountain Ranch facility with RWWTP 2 at Castle Pines would reduce the total cost of this alternative to 68.8 million. This amounts to about a ten million dollar savings over a 20 year period.

TABLE 20

COST DATA OF MODELED FACILITIES FOR ALTERNATIVES

Wastewater Facility	2010 Size (mgd)	Total Present Worth ($Mil)	Total Project Cost ($Mil)	Annual O&M ($Mil)	Charge Rate ($/T Gal)	Total Annual Cost* ($Mil)
ALTERNATIVE 1*						
Douglas Co. RWWTP 1	8.94	19.32	9.27	1.02	0.43	1.35
ALTERNATIVE 2						
Castle Pine RWWTP 2	8.04	27.64	16.29	1.26	0.60	1.86
ALTERNATIVE 3						
Castle Pine RWWTP 2	6.50	22.62	13.42	1.02	0.68	1.50
Bell Mt. Ranch RWWTP 3	1.54	11.18	7.07	0.46	1.36	0.71
ALTERNATIVE 4						
Castle Pines	2.60	13.65	8.5	0.57	1.07	0.88
Bell Mt. Ranch	0.57	8.60	5.7	0.31	2.81	0.51
Castle Rock	3.90	17.25	10.4	0.76	0.82	1.13
Larkspur-North	0.87	9.45	6.2	0.37	1.86	0.59
Perry Park	0.10	1.38	0.4	0.15	2.95	0.18
ALTERNATIVE 5						
Castle Pine RWWTP 2	6.50	22.62	13.4	1.02	0.68	1.50
Bell Mt. Ranch	0.57	8.60	5.7	0.31	2.81	0.51
North Larkspur RWWTP 4	0.97	9.45	6.2	0.39	1.70	0.62

*Total annual cost is the total annual operation cost for facility.

TABLE 21

TOTAL PROJECT COSTS (ESTIMATED)

Wastewater Facility	2010 Size (mgd)	Interceptor Capital ($ mil)	Interceptor O&M ($ mil)	Facility Capital ($ mil)	Facility O&M ($ mil)	Total Capital ($ mil)	20-Year O&M ($ mil)
ALTERNATIVE 1							
Douglas County RWWTP1	8.94	17.38	0.545	19.32	1.02	36.70	31.30
TOTAL COST						36.70	31.30
ALTERNATIVE 2							
Castle Pines (RWWTP 2)	8.04	6.55	0.121	27.64	1.26	34.19	27.62
TOTAL COST						34.19	27.62
ALTERNATIVE 3							
Castle Pines RWWTP 2	6.50	1.52	0.021	22.62	1.02	24.14	20.82
Bell Mt. Ranch RWWTP 3	1.54	1.50	0.054	11.18	0.46	12.68	10.28
TOTAL COST						36.82	31.10
ALTERNATIVE 4							
Castle Pines	2.26	-	-	13.65	0.57	13.65	11.4
Bell Mt. Ranch	0.57	-	-	8.60	0.31	8.60	6.2
Castle Rock	3.77	-	-	17.25	0.76	17.25	15.2
Larkspur-North	0.87	-	-	9.45	0.37	9.45	7.4
Perry Park-Sageport	0.10	-	-	1.38	0.15	1.38	3.0
TOTAL COST						50.33	43.2
ALTERNATIVE 5							
Castle Pines RWWTP 2	6.50	2.03	0.021	22.62	1.02	24.65	20.82
Bell Mt. Ranch	0.57	-	-	8.60	0.31	8.60	6.20
North Larkspur RWWTP 4	0.97	0.22	0.008	9.45	0.39	9.67	7.96
TOTAL COST						42.92	34.98

Cost analyses of wastewater service area alternatives was useful in eliminating the extremely high cost alternative. However, cost information was not capable of eliminating other alternatives, which fell within 21 percent of each other. The least cost-effective alternative is to have a large number of individual facilities. The use of subregional facilities can provide cost savings over a longer planning period. The larger regional (RWWTP 1) and subregional (RWWTP 2) facilities were the most cost-effective alternatives and can provide significant cost savings over a longer time period.

An evaluation was made to determine the cost-effectiveness of either building a Chatfield Green wastewater facility or sending flows to the Littleton-Englewood facility. Transmission cost information was provided by the Task Force and from sewer utility charges published by the Colorado Municipal League (1987). Cost information for various types of facility treatment schemes were generated by CAPDET.

The proposed Chatfield Green treatment facility was modeled as an oxidation ditch system. This type of system has been shown to be an economical facility in relation to construction cost and annual operation and maintenance, and capable of producing high quality effluent which meets stream standards. An aerated lagoon system was also modeled which was similar to a facility proposed for Larkspur-South. The aerated lagoon system has more land requirements than an oxidation system. This can substantially increase facility costs for aerated lagoons, dependent on configuration. Both facility types and variations of these types were modeled with a maximum size of 0.25 MGD. The proposed facility would need to treat a wastewater flow of 0.1 MGD in 2010. The oxidation ditch system and lagoon system were modeled with a facilitative lagoon storage reservoir and subsequent overland flow of effluent. Sludge was dried in sand beds and hauled-off for disposal.

A complete 0.1 MGD oxidation ditch system would cost about $848,000 to construct. The capital cost and 20-year operations and maintenance for this facility would be $15 million. The average annual operation and maintenance would be $125,000, which would amount to $2.5 million through the 2010 planning period. The present worth of a 0.1 MGD oxidation facility, which accounts for the time value of money, would be $2.18 million. The cost per-gallon of wastewater treated would be high for this facility because some components, such as yard piping, would still be sized to accommodate the projected capacity of 0.25 MGD. A larger lagoon system of 0.25 MGD would be more expensive to construct at 1.8 million. The annual operation and maintenance for this system would be $135,000. The total 20-year cost of a lagoon treatment system would be 4.77 million with interest.

Transmission and user charge costs for Chatfield Green wastewater flows sent to the Littleton-Englewood facility were determined for a 0.25 MGD flow projection. The Littleton-Englewood facility charges a flat rate for sewerage service for sources outside its service area. This rate was $73.82 per unit per year. There is also a sewer tap fee of $1,350 per unit. Chatfield Green would require a return flow of 0.1 MGD to meet augmentation plans in 2010. This reuse system would require a forcemain and pumpstation. The cost of transmission was evaluated for the planning period through 2010. The 2010 estimated population for Chatfield Green is 950 people with 600 employment. This produces a wastewater flow of 0.1 MGD. The actual transmission cost will be dependent on the number of taps. The estimated number of taps in 2010 would be 470. The tap fees and service charges were calculated based on 470 taps. Tap fees would be $987,000 and 20-year service charges would be $760,000. The cost of transmission lines and annual operation and maintenance is related to flow. The total operation and maintenance cost for gravity and reuse system through the year 2010 would be $1.15 million. There is an inclusion fee of $1,500 per acre, which would total $0.52 million. The present worth of the transmission system was estimated at $4.0 million, which is higher than the present worth of a new on-site treatment facility at $2.18 million.

The total cost, excluding interest on project costs of transmission lines would be $5.0 million. The total cost of an oxidation system would be $4.15 million, excluding interest. Although the total cost of a transmission system is higher than an on-site oxidation system, cost difference is less than 20 percent. Based on these cost analyses, the cost of building a wastewater treatment facility at Chatfield Green would be comparable to sending flows to the Littleton-Englewood facility for treatment. Since cost-effectiveness cannot provide a difference between constructing an on-site wastewater treatment facility compared with sending flows to the Littleton-Englewood facility for treatment, other factors must be considered in the selection of a preferred alternative.

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DRCOG STAFF
Robert D. Farley, Executive Director
David A. Pampu, Deputy Executive Director
Larry G. Mugler, Director of Development Services

PRINCIPAL CONTRIBUTORS:
Amy S. Conklin, Water Resources Planner
Kathryn L. Hoffman, Water Resources Planner
Russell N. Clayshulte, Principal Water Resources Planner