INTERIM REPORT ENGINEERING

WASTE LOAD ALLOCATIONS & WATER QUALITY MODELING

MAJOR RIVERS IN THE LARIMER-WELD REGION

Water Quality Management Plan

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS
LOVELAND, COLORADO

PREPARED BY
TOUPS CORPORATION
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Larimer-Weld Regional Council of Governments
208 Areawide Water Quality Management Plan

WASTE LOAD ALLOCATIONS AND WATER QUALITY MODELING

MAJOR RIVERS IN THE LARIMER-WELD REGION

Prepared For

Larimer-Weld Regional
Council of Governments

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DISCLAIMER

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1.0 EXECUTIVE SUMMARY AND ANALYSIS

1.1 INTRODUCTION

The establishment of maximum allowable wasteloads which can be discharged to rivers by municipal and industrial point source dischargers traditionally has been considered a fundamental element in water quality mangement planning. The wasteload allocation process had previously been applied in the Larimer-Weld Region in the development of the "Comprehensive Water Quality Management Plan - South Platte River Basin" by the State of Colorado. Establishment of maximum allowable wasteloads which can be discharged to rivers and still result in the attainment of water quality standards essentially determines wastewater treatment plant discharge requirements, treatment levels, and wastewater treatment costs for municipal and industrial dischargers. The underlying assumption in this procedure is that if treatment level requirements defined in the wasteload allocation process are achieved, then the water quality goals associated with in-stream standards will also be achieved. The validity of this assumption is analyzed in Section 1.4 of this Chapter. Regardless of validity, establishment of maximum allowable wasteloads through the wasteload allocation process is a fundamental requirement of 208 Planning, and it is with this objective that this effort was carried out.

The wasteload allocation process was facilitated by application of a computerized water quality model of streams in the region. The model, Pioneer I, was originally developed under contract to the Environmental Protection Agency in the early 1970's. The model is described in Chapter 2 entitled, "Water Quality Modeling." However, to insure reasonable levels of accuracy in the application to the 208 Program, additional water quality and hydrologic data were collected and incorporated into the modeling process. This effort is described in Chapter 3, "Hydrology," and Chapter 4, "Model Recalibration." Following the recalibration effort, the wasteload allocation procedure was implemented. The results of the wasteload allocations are described in Chapter 5 and summarized in section 1.3.4.

1.2 APPROACH TO THE PROJECT

There are a number of subtleties and intricacies involved in the wasteload allocation procedure. This section describes the approach that was taken in developing wasteload allocations for municipal and industrial dischargers.

1.2.1 Municipal and Industrial Discharges

All municipal and industrial point source discharges having NPDES permits were incorporated into the water quality model.

Existing wasteloads, both in terms of volume and quality have previously been defined in the report entitled, "Interim Report No. 6, Municipal and Industrial Point Source Analysis," Toups Corporation, May 1977. Data on the quality of municipal and industrial point source discharges was taken from existing NPDES permits or the sampling program conducted as part of 208 Plan development. Appendix B provides a synopsis of pertinent information concerning municipal and industrial dischargers in the region, including location maps for all point source discharges, characteristics of existing discharges in terms of quality, and projected discharge levels for municipalities. Industrial discharge volumes were assumed to remain constant through the planning period. Chapter 5 of this report entitled, "Wasteload Allocations for Existing and Future Conditions," provides the results of the allocation process for major municipal and industrial discharges impacting water quality standards for those constituents allocated. Many industrial discharge permits, such as those issued to gravel pit operations, had no effect on the wasteload allocation process and are not presented in Chapter 5. However, all municipal and industrial discharges were incorporated into the water quality model.

1.2.2 Water Quality Standards

Water quality standards and classifications presently in effect in the Larimer-Weld Region were used as the basis for the wasteload allocation process. Essentially, mountain streams in the region are classified as B_1, i.e., cold water fishery streams, and all streams in the plains area, including the South Platte, St. Vrain, Big Thompson, Cache la Poudre, are classified as B_2, or warm water fisheries. A number of chemical and biological chemical constituents are included in the classifications and standards for these beneficial uses; however, the model recalibration process indicated that the Pioneer I Model was limited in the number of constituents which could actually be incorporated into the allocation process. This results from two factors: 1) computational limitations of the model and 2) inadequate data base to support allocation of some constituents. As a result, the wasteload allocation process was limited to defining levels for dissolved oxygen and ammonia. These constituents are critical for maintenance of aquatic life in Class B_1 and B_2 waters. The minimum allowable dissolved oxygen levels in Class B_1 and B_2 waters is 6 mg/l and 5 mg/l respectively. The maximum allowable ammonia level in both Class B_1 and B_2 waters is 1/5 mg/l. This value has traditionally been accepted by the State of Colorado and the Environmental Protection Agency as the maximum allowable limit for this constituent (Engineering Consultants-Toups 1975). Values in excess of this are considered to be toxic to aquatic life (Willingham 1976). Any discharger causing a dissolved oxygen concentration in a stream of less than the limits mentioned above or greater than 1.5 mg/l was required to go to a higher level of waste treatment in order to meet stream standards. This criteria was strictly applied in accordance with present rules and regulations promulgated by the Colorado Water Quality Control Commission.

1.2.3 Treatment Level Definitions

Treatment level requirements for municipal and industrial dischargers were defined at three levels of treatment - secondary treatment, tertiary treatment, and advanced waste treatment. Associated discharge qualities of these three levels of treatment are shown in Table 1.2.3-A

TABLE 1.2.3-A LEVELS OF TREATMENT APPLIED TO MEET WATER QUALITY STANDARDS

Treatment Level	BOD_5 mg/l	Ammonia mg/l	DO mg/l
Secondary	30.0	15.	2.0
Tertiary	20.0	3.0	2.0
Advanced	10.0	1.5	2.0

Violation of either the dissolved oxygen or ammonia standards would cause municipal and industrial dischargers to go to the next higher level of treatment. In a number of cases, the ammonia standard was violated and dissolved oxygen standard was not violated; however, reduction of BOD levels is considered necessary from a practical standpoint in order to reduce ammonia concentrations in effluent discharges.

1.2.4 Waste Load Projections

The waste load projections used to develop year 2000 waste load allocations are based on the "208 Recommended Land Use Plan." Other alternative land use plans were developed in the 208 Planning process which featured both higher and lower levels of urban growth in the region. Sensitivity analyses were conducted using the extreme variations in urban growth projections. The sensitivity analyses indicated that extreme low flow conditions existing on the Cache la Poudre River and Big Thompson River virtually nullify the differences in water quality impacts of any reasonable range of land use alternatives for the year 2000. Regardless of which level of urban growth is achieved, major dischargers would be required to provide the same level of treatment to meet existing water quality standards. The only exceptions to this would be the Windsor and Kodak dischargers. Under the low urban growth projection, Windsor and Kodak would be required to provide tertiary rather than advanced waste treatment in the year 2000.

1.2.5 Permit Requirements

Permit requirements for all municipal and industrial discharges have not been specified in this report. Specification of permit requirements is dependent upon stream classifications that will be recommended and adopted as part of the 208 Planning process. Permit requirements will be recommended in the report entitled, "Areawide Technical Strategies for Achieving National Water Quality Goals in Larimer and Weld Counties, Colorado"(Interim WQMP report No. 21). That report includes tentative recommended stream classifications for the region.

1.3 SUMMARY

The wasteload allocation effort involved four elements: water quality modeling, hydrology, model recalibration, and wasteload allocations. These constitute Chapters 2 through 5 of this report. Brief summaries of each Chapter are provided below.

1.3.1 Water Quality Modeling

In order to facilitate water quality management planning in the South Platte River Basin, the U.S. Environmental Protection Agency (EPA) funded the development of a computerized water quality model of the South Platte River and its major tributaries from its head waters in Colorado to its confluence with the North Platte River in Nebraska. In general, the reliability of Pioneer I was weakened by a paucity of field data gathered for the initial calibration. Therefore, a program was implemented as part of the 208 Planning process to increase the accuracy of the model both in terms of hydrologic and water quality characteristics. Specific tasks included in the model upgrading were:

1. Review and application of Water Commissioner's information on the location and quantities of stream diversions and return flows;

2. The updating and application of water quality information on municipal and industrial dischargers in the study area;

3. Water quality sampling of municipal and industrial and agricultural dischargers;

4. Water quality sampling along critical stream segments above and below major municipal and industrial point source dischargers and major nonpoint source dischargers.

To allow for more accurate presentation of the stream system in the study area, the model was restructured to eliminate any stream not directly contributing to the two-county region. This included all streams south of the City of Brighton near the Weld-Adams County line and easterly of the Weld-Morgan County line. Major emphasis was placed on four significant streams in the study area: South Platte River, Big Thompson River, Little Thompson River, and Cache la Poudre River. A number of computational reaches on these streams was more than doubled over the number in the original Pioneer I Model, thereby greatly increasing the model's accuracy in simulating hydrologic and water quality conditions in those streams. Smaller tributary streams in the model were not further modified since wasteloads to those streams are of lesser significance to water quality management in the study area; however, coefficients effecting water quality calculations were modified to reflect knowledge gained in the analysis of the significant streams listed above.

1.3.2 Hydrology

The natural character of streams in the Larimer-Weld Region has been subject to extensive physical modification by man. For over a century, water resource development activities have resulted in the evolution of complex systems of transmountain diversions, reservoirs, canals, pipelines, in-stream diversion structures, and ditches. Table 1.3.2-A summarizes the number of diversion structures which divert water from major rivers within the two-county area.

TABLE 1.3.2-A DIVERSIONS - LARIMER-WELD REGION

STREAM	NUMBER OF DIVERSIONS (a)	RIVER MILES (b)
Cache la Poudre	27	62
Big Thompson	15	36
Little Thompson	9	24
St. Vrain	2	15
South Platte	20	73

(a) Within Larimer and Weld Counties.
(b) Point of first up-stream diversion to river mouth or Weld County Line.

In the mountainous areas of the region, stream flows are maintained throughout the year in most areas. In the plains area of the Larimer-Weld region, as in much of the arid west, low-flows are characteristically no flows. Intense modification and management of the hydrologic regime to conserve, extend, and optimize available water supplies renders the "seven-day, ten year low-flow" criteria meaningless in the plains area. However, low-flow hydrology was investigated extensively to determine the volume of the receiving water available to accommodate point source discharges under low-flow conditions. Hydrologic balances characteristic of temperate or warm months were computed to identify seasonal impacts on water quantity. The period of May through September was selected for analysis because of the governing influence in-stream temperature has on ammonia toxicity, a major water quality parament effecting fish and other aquatic life.

During the irrigation season, flows in the Cache la Poudre River may be exhausted down-stream from at least 11 diversion points. Diversions and return flows have a significant impact on water quality in the Cache la Poudre River. Below the Fort Collins No. 2 Wastewater Treatment Plant, river flows generally consist entirely of irrigation return flows and municipal and industrial dischargers during the irrigation season. The hydrologic analysis indicated that the Cache la Poudre River is dried up at least six points between Fort Collins No. 2 Plant discharge and the mouth of the Cache la Poudre River. Diversions significantly impact water quality in the Poudre. Waste discharges from a number of municipal and industrial plants are diverted out of the stream at some point.

Diversion structures from the Big Thompson River may dry up the river at at least five points between the mouth of the Canyon and the mouth of the river. Irrigation return flows contribute significantly to the total flow in the Big Thompson below the mouth of the Canyon. St. Vrain Creek is sustained heavily by irrigation return flows. Accretions to the river between Interstate 25 and the mouth are approximately 100 cfs or 4 cfs per mile. Point source dischargers are responsible for less than 5 cfs of the total flow in the St. Vrain River.

The South Platte River is characterized by extreme variations in flows during the irrigation season. Flows in the Platte vary from 150 cfs to zero as the river flows through Weld County. The Platte is dried up at three locations within Weld County.

1.3.3 Model Recalibration

The Pioneer I Model was recalibrated for critical segments of the two-county area to increase the model's accuracy. Tasks performed as part of the recalibration included: review and application of information on the location and quantification of stream diversions and return flows, application of water quality information on municipal and industrial discharges, application of water quality data collected in sampling programs along critical stream segments, and sensitivity analyses to revise model computations to match as closely as possible real world phenomena. Recalibration efforts were limited to three critical rivers in the study area, i.e., the Cache la Poudre, Big Thompson, and Little Thompson. Based on information gained from the recalibration effort on these streams, coefficients were adjusted on other streams in the region to better reflect the nature of these streams. Streams selected for recalibration were those most affected by municipal and industrial point source discharges. The recalibration of Pioneer I for the Cache la Poudre, Big Thompson, and Little Thompson Rivers was performed following a basic procedure algorhythm : 1) hydrologic data on stream flows, stream diversions, in-flows, return flows, and discharges previously characterized for the sampling/modeling period were utilized as fixed input to the model. 2) Water quality of each return flow, discharge, and head water flow of each river was characterized either from data collected during the sampling program, or from other analysis and utilized as fixed input to the model. 3) Model output obtained by utilizing a given set of water quality coefficients was then compared with field data of actual stream conditions obtained during the sampling program. 4) Water quality coefficients were then adjusted within the predetermined allowable range of values defined in Chapter 2 and result of model output rechecked with the field data. 5) The coefficients were continually adjusted until the model output which most closely matched the field data was obtained.

On the Cache la Poudre River, the model recalibration resulted in reasonably accurate computations of levels of dissolved oxygen, BOD, ammonia, nitrates, and total dissolved solids; however, fecal coliforms were not accurately modeled by the Pioneer I. On the Big Thompson River, a reasonably accurate correlation of model output and field data was achieved with the exception of fecal coliforms and total dissolved solids. On the Little Thompson River, reasonable results were achieved in the recalibration effort, with the exception of fecal coliforms.

Some discrepancies occurred in model recalibration. No ammonia was found in-stream below Loveland Plant No. 1 and 2 dischargers,even though these plants were discharging ammonia at levels of approximately 8 mg/l and 12 mg/l. Dissolved oxygen levels were found to increase on the Little Thompson River below Great Western in Johnstown. Discharges and no detectable oxygen sag occurred as a result of BOD loading at these locations as was to be expected. Results of the fecal coliform recalibration indicated that Pioneer I could not adequately reflect actual levels of fecal coliform in the streams.

1.3.4 Allocation of Existing and Future Wasteloads

The wasteload allocation procedure was carried out under a variety of conditions which are described in Chapter 5. Water quality impacts of municipal and industrial dischargers are extremely sensitive to volume of flow in-stream at the point of discharge. As indicated in the hydrology section, stream flows are extremely low to zero in the Cache la Poudre River and the Big Thompson River which receives most of the effluent discharged by municipalities and industries in the region. Table 1.3.4-A indicates level of treatment necessary to meet present water quality standards on streams in the region by major municipal and industrial dischargers impacting water quality, based on existing discharge rates and strict application of water quality standards.

All major discharges in the Cache la Poudre River would be required to provide tertiary or advanced waste treatment to meet water quality standards with existing flows. Loveland No. 2 and Great Western-Loveland would be required to provide tertiary treatment, and the Erie Water and Sanitation District would be required to provide advanced treatment with existing flows.

Application of projected waste flows based on the 208 Recommended Land Use plans impacts treatment level requirements on the Cache la Poudre River, Big Thompson River, and South Platte River, as shown in Table 1.3.4-B. All major dischargers on the Cache la Poudre, Loveland No. 2, and the Greeley-Delta Plant would be required to provide advanced waste treatment.

As an alternative to high levels of treatment, flow augmentation at various levels was considered for the Cache la Poudre and Big Thompson Rivers. Flow augmentation would also be necessary in both of these rivers to eliminate extreme hydrologic variations occurring during the irrigation season and to enable establishment of a self-propagating fishery characterized by a wide variety of species. The analysis indicated that an excess of 200 cfs of augmented flow would be necessary to avoid tertiary and advanced treatment by dischargers on the Cache la Poudre River. Augmentation at a level of 15 cfs would enable dischargers to the Poudre to provide tertiary rather than advanced treatment in the year 2000.

TABLE 1.3.4-A TREATMENT LEVELS NECESSARY TO MEET PRESENT WATER QUALITY STANDARDS BY EXISTING MAJOR, MUNICIPAL, AND INDUSTRIAL DISCHARGERS

BASIN DISCHARGER	TREATMENT LEVEL REQUIREMENT	LIMITING CONSTITUENT
CACHE LA POUDRE		
Fort Collins No. 1	Tertiary	Ammonia
Fort Collins No. 2	Advanced	
Boxelder S.D.	Advanced	
Windsor	Tertiary	
Kodak	Tertiary	
Greeley-1st Ave.	Tertiary	
BIG THOMPSON		
Estes Park	Secondary	
Upper Thompson	Secondary	
Loveland No. 2	Tertiary	
Great Western-Loveland	Tertiary	
Milliken	Secondary	
LITTLE THOMPSON		
Berthoud	Secondary	
Great Western-Johnstown	(Cooling water discharge)	
Johnstown	Secondary	
ST. VRAIN		
Tri-River S.D.	Secondary	
Erie Water and Sanitation District	Advanced	
SOUTH PLATTE		
Fort Lupton	Secondary	
Public Service - Ft. St.Vrain	(Cooling water)	
Hill-N-Park	Secondary	
La Salle	Secondary	
Evans	Secondary	

TABLE 1.3.4-B YEAR 2000 TREATMENT LEVEL REQUIREMENTS NECESSARY TO MEET PRESENT WATER QUALITY STANDARDS BY EXISTING MAJOR, MUNICIPAL, AND INDUSTRIAL DISCHARGERS

BASIN DISCHARGER	TREATMENT LEVEL REQUIREMENT	LIMITING CONSTITUENT
CACHE LA POUDRE		
Fort Collins No. 1	Advanced	Ammonia
Fort Collins No. 2	Advanced	
Boxelder S.D.	Advanced	
Windsor	Advanced	
Kodak	Advanced	
Greeley-1st Ave.	Closed	
BIG THOMPSON		
Estes Park	Combined with/ UTSD	
Upper Thompson	Secondary	
Loveland No. 2	Advanced	
Great Western-Loveland	Tertiary	
Milliken	Secondary	
LITTLE THOMPSON		
Berthoud	Secondary	
Great Western-Johnstown	(Cooling water discharge)	
Johnstown	Secondary	
ST. VRAIN		
Tri-River S.D.	Secondary	
Erie Water and Sanitation District	Advanced	
SOUTH PLATTE		
Fort Lupton	Secondary	
Public Service - Ft. St.Vrain	(Cooling water)	
Hill-N-Park	Secondary	
La Salle	Secondary	
Evans	Secondary	
Greeley-Delta	Advanced	Ammonia

On the Big Thompson River, approximately 100 cfs of augmented flow would allow Loveland No. 2 Plant to provide secondary treatment level and still meet instream water quality standards for ammonia. Augmentation with 15 cfs requires tertiary at Loveland No. 2 to avoid violation of the ammonia standard in the year 2000. Augmentation at the 15 cfs level in the Poudre and Thompson would be extremely extensive.

1.4 ANALYSIS AND CONCLUSIONS

Federal regulations defining procedures for allocation of wasteloads for point sources (Part 131-Preparation of Water Quality Management Plans, Federal Register Volume 30, No. 230, November 28, 1975) states in part:

> Paragraph 131.11 Plan Content. Recognizing that the level of detail may vary according to the water quality problems, the following elements shall be included in each water quality management plan...
>
> f. total maximum daily loads.
>   1. For each water quality segment or appropriate portion thereof the total allowable maximum daily load of relevant pollutants during critical flow conditions for each specific water quality criterion being violated or expected to be violated,
>   i. Such maximum daily loads shall be established at levels necessary to achieve compliance with applicable water quality standards.
>   ii. Such loads shall take into account:
>   ...
>   b. Provision of a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality...
>   2. i. Such flows shall be established at a level necessary to insure protection and propagation of a balanced and indigenous population of fish, shellfish, and wildlife."

The implied assumptions in these regulations are:

1. Attainment of numeric water quality standards will result in achievement of water quality goals, i.e., "protection and propagation of balanced, indigenous population of fish, shellfish, and wildlife."
2. Water quality is the sole factor limiting attainment of goals.
3. Reduction of maximum daily wasteloads discharged by point and nonpoint source dischargers will result in attainment of water quality goals.

These assumptions may be valid in some parts of the nation just as they are valid in some areas within the Larimer-Weld region, notably in the unpopulated mountainous areas provide more-or-less continuous free-flowing streams throughout the year, and an excellent physical habitat for aquatic life. However, in the populated areas of the region, such as the lower Cache la Poudre River and lower Big Thompson River basins, where stream hydrology and physiography has been altered by man these assumptions are invalid.

Bioassays conducted on the Cache la Poudre River have revealed the presence of 28 species of fish existing in the lower portions of the river. However, 99 percent of the "indigenous" species consisted of "rough, trash, or forage" fish, i.e., carp, suckers, etc. Thus a balanced indigenous population of fish, shellfish, and wildlife does not exist in the lower reaches of the Cache la Poudre, and it is not thought to exist in other streams in the plains area of the Larimer-Weld region. (Appendix A). The predominant factors limiting the indigenous population are:

1. Lack of physical habitat to support less hardy game species;
2. Extreme variations in hydrology place tremendous stress on aquatic biota, resulting in survival of only the hardiest species;

Information developed as part of the 208 Plan indicates that attainment of in-stream numeric standards alone would not result in a "balanced, indigenous population of fish, shellfish, and wildlife". The indigenous species do not represent a balanced population, thus a fundamental conflict in terms results. Consultation with experts in fishery and wildlife management indicated that stream engineering for the purpose of creating physical habitat as well as flow augmentation during critical low-flow months would be required to support a balanced population of fish life in the streams within the region.

Upgrading of municipal and industrial waste treatment plants to the levels indicated by rigid application of the wasteload allocation process would be very costly and essentially ineffective in achieving water quality goals. Water quality is not the sole determining factor or even the major factor in attainment of those goals. The benefits of upgrading waste treatment plants to meet the numeric criteria defined in the wasteload allocation process appear to be null in cases where treatment levels above secondary wastewater treatment are required, unless the physical habitat is upgraded and additional stream flow is provided during critical low-flow months.

Federal regulations require "provision of a margin of safety which takes into account any lack of knowledge concerning the relationship between effluent limitations and water quality". The water quality modeling and recalibration effort conducted as part of the 208 Program represents the state of the art as far as understanding relationships between waste discharges and water quality in the Larimer-Weld region. This program has advanced the understanding of these relationships, in particular the relationships among water discharges, water quality, and hydrology. The conditions modeled are representative of typical low-flow periods which occur routinely in the region. It is recognized, however, that there can be considerable variation in daily and hourly flows which would affect water quality impacts of any significant point source discharge. It is recommended that the margin of safety be applied to assure implementation of cost-effective wastewater treatment technology based on knowledge of existing conditions as opposed to implementation of more costly technology to achieve assumed and possibly non-existent benefits.

CONCLUSIONS

As a result of applying the wasteload allocations process within the Larimer-Weld region and other information developed as part of the 208 Program, the following conclusions are set forth:

1. Strict application of Federal and State regulations concerning the wasteload allocation process would substantially increase the cost of wastewater treatment within the region.

2. Attainment of the maximum allowable wasteloads defined in the wasteload allocation process would not result in attainment of water quality goals, i.e., "protection and propagation of a balanced, indigenous population of fish, shellfish, and wildlife".

3. Attainment of the maximum allowable wasteloads defined in the wasteload allocation process would not significantly alter indigenous aquatic communities found in the plains area of the region.

4. The predominate factor limiting the variety of aquatic biota in the plains area streams include: a) lack of an adequate in-stream physical habitat to support any but the hardiest of species; b) extreme variations in hydrology which place tremendous stress on aquatic communities.

5. Upgrading of municipal and industrial waste treatment plants beyond secondary treatment levels will result in no benefit in terms of water quality goals, unless physical in-stream habitat is upgraded and additional flow is provided during critical low-flow conditions.

6. Definition of treatment level requirements based solely on numeric water quality standards is not a cost-effective method of attaining water quality goals; other significant factors must be considered.

7. Additional data collection is required: 1) to better understand relationships among water quality, hydrology, stream physiography and indigenous species, and 2) to determine the conditions under which water quality becomes a significant factor affecting indigenous aquatic communities. Data collected should

include water quality, flow, bioassay, and physiographic data under a variety of hydrologic and climatic conditions.

8. The Environmental Protection Agency and State of Colorado should completely re-evaluate application and validity of existing regulations concerning determination of municipal and industrial waste treatment requirements throughout the wasteload allocation process. A thorough analysis of the process validity is needed in arid and semi-arid areas and in any case where application of the process results in specification of higher than secondary treatment level to meet numeric standards.

2.0 WATER QUALITY MODELING

In order to facilitate water quality management planning in the South Platte River basin, the U.S. Environmental Protection Agency (EPA) funded the development of a computerized water quality model of the South Platte River and its major tributaries from its headwaters in Colorado to its confluence with the North Platte River in Nebraska. The model, named Pioneer I, is capable of mathematically simulating the water quality in streams under varying hydrologic and waste loading conditions. The development of Pioneer I included a water quality sampling program of both streams and point source waste loads entering the streams, analysis of stream flow data, observation of physical stream characteristics, and definition of mathematical relationships among the observed data which enables computation of water quality in terms of concentrations of chemical and biological constituents.

Pioneer I is an expanded version of DOSAG-I code originally developed by the Federal Water Pollution Control Administration and later revised by the Texas Water Development Board. DOSAG-I was revised and adapted for EPA for the South Platte River basin. Pioneer I was utilized as part of the 303(e) Comprehensive Water Quality Management Plan for the South Platte River basin in Colorado to determine water quality limited and effluent limited stream segments plus wasteload allocations for major streams in that portion of the basin. During that study, an analysis of input, output, and computational capabilities of the model was performed and a number of improvements were made in the model's performance. As a result, the model's capabilities to accurately predict water quality in the Larimer-Weld region were improved. However, the Pioneer I model, while an excellent computational tool, had deficiencies which needed to be corrected prior to its application as part of the 208 areawide wastewater management plan for the Larimer-Weld region.

In general, the reliability of Pioneer I was weakened by the paucity of field data gathered for the initial calibration. Therefore, a program was implemented to increase the accuracy of the model both in terms of hydrologic and water quality characteristics as part of the Larimer-Weld 208 planning effort. Specific tasks included in the model upgrading were:

1. Review and application of Water Commissioners' information on the location and quantities of stream diversions and return flows;
2. The updating and application of water quality information on municipal and industrial discharges in the study area;
3. Water quality sampling of municipal, industrial, and agricultural discharges;
4. Water quality sampling along critical stream segments above and below major municipal and industrial point source and non-point source discharges;
5. Recalibration of Pioneer I based on the updated information gathered in the other tasks.

2.1 MODIFIED MODEL

To be an effective assessment tool, a water quality model must accurately represent the stream system it is simulating. Various tasks were directed towards developing a basic and valid understanding of the major stream systems in the Larimer-Weld region both in terms of hydrology and water quality. This information must then be applied to the model in such a manner that the model output represents to the extent possible the real world phenomena to a reasonable degree of accuracy. To accomplish this task on Pioneer I for the Larimer-Weld 208 program, a number of procedures have been followed which included:

1. A reduction of Pioneer I to include only the Larimer-Weld portion of the South Platte River basin;
2. The definition of water quality parameters critical to the model;
3. A literature review to determine an allowable range of values within which modeled parameters and coefficients can be realistically adjusted during calibration;
4. A sensitivity analysis of the model output;
5. A model calibration resulting in a reasonably accurate simulation of the modeled stream system.

2.1.1 Application of Pioneer I to Larimer-Weld Region

As previously discussed, Pioneer I was originally developed for the entire South Platte River basin. Each stream in the model is input as a number of connected sub-units or reaches. A reach is generally defined as a segment of river between points of inflow, outflow, and/or significant changes in hydraulic, biological, or physical characteristics in the river. The number of reaches which can be input to Pioneer I is limited to 300. Because of the large area initially modeled, i.e., the entire basin modeled, it was necessary to reduce the number of reaches by combining several diversions or discharges for model input which were actually separated by several miles. The accuracy of Pioneer I in the Larimer-Weld region was therefore severely restricted.

To allow for a more accurate presentation of the stream system in the study area, the model was restructured to eliminate any streams not directly contributing flow to the two-county region. This included all streams south of the city of Brighton near the Adams-Weld county line and easterly of the Weld-Morgan county line. Major emphasis was placed on the four significant streams in the study area: South Platte River, Big Thompson River, Little Thompson River, and Cache la Poudre River. The number of reaches on these streams was more than doubled over the number in the original Pioneer I, thereby greatly increasing the model's accuracy in simulating hydrologic and water quality conditions in those streams. Smaller tributary streams in the model were not further modified since wasteloads to those particular streams are of lesser significance to water quality management in the study area.

The increase in the number of reaches on the four major rivers in the study area necessitated a complete re-appraisal of the hydrologic and water quality data input to the model. Necessary revisions have been made of the quantity, quality, and location of stream diversions, return flows, point source waste discharges, and in-stream conditions. The following sections describe in detail those tasks which developed the necessary data for model input and output appraisal.

2.1.2 Definition of Critical Constituents

Pioneer I has the capability of mathematically simulating the following water quality constituents:

- Total nitrogen (conservative)
- Ammonia nitrogen (1st or 2nd order reaction)
- Nitrite nitrogen (1st or 2nd order reaction)
- Nitrate nitrogen (1st or 2nd order reaction)
- Carbonaceous biochemical oxygen demand (1st order reaction)
- Phosphorous (1st or 2nd order reaction)
- Fecal coliform bacteria (1st order reaction)
- Total dissolved solids (conservative)
- Metal ions (conservative)
- Chlorophyll _a_ (coupled with the nutrients in the phosphorous and nitrogen cycles)
- Dissolved oxygen (including benthic demand, carbonaceous BOD, ammonia and nitrite nitrogen oxidations, and algal photosynthesis and respiration as a function of chlorophyll _a_ concentration)
- General decay model (nth order decay reaction)

The river water quality parameters are solved in Lagrangian coordinates for a given set of input data on stream flow conditions, wasteloads, stream temperatures, and quality model reaction constants.

The river system within the model is subdivided into stretches which are in turn subdivided into reaches. The method used in selecting river reaches is such that waste inputs, diversions, return flows, or inflows occur at the junctions between each reach. Physical conditions are held constant for the length of a reach. Travel time within a reach is calculated utilizing Ward's equations which directly relate stream velocity and depth to streamflow empirically-determined regression coefficients. Travel time is then input into the respective water quality models to calculate changes in water quality concentrations within the reach. Model output presents constituent concentrations at both upstream and downstream points of each reach.

The number of water quality constituents which can be modeled by Pioneer I is fairly extensive. However, modeling efforts for this study have been limited to those parameters which have been historically simulated with a reasonable degree of accuracy in the South Platte as well as other river basins, and for which a fairly extensive base of field data exists to provide a good comparative basis for model results.

The parameters which have been included are:

- Dissolved oxygen
- BOD
- Ammonia nitrogen
- Nitrate nitrogen
- Fecal coliform
- Total dissolved solids

(Temperature is input as a constant for each stream segment in the model). Other parameters such as pH and suspended solids have not been studied primarily because they cannot be accurately modeled by Pioneer I's computational techniques. Residual chlorine has not been included because

1) It cannot be adequately modeled by Pioneer I;
2) A paucity of field data; and
3) Sampling programs conducted as part of this study found no detectible concentrations of residual chlorine in either discharges or stream samples.

Those parameters which have been selected for inclusion in Pioneer I are the most significant in terms of critical water quality problems within the Larimer-Weld region [ECI-Toups, 1975].

The mathematical techniques utilized within Pioneer I to model specific water quality parameters have been documented in previous reports [Waddel, et. al., 1974]. A summary of those techniques is provided in the following paragraphs for those constituents selected for modeling in this study.

2.1.2.1 Total Dissolved Solids

TDS in a steady-state stream system is a conservative substance, and therefore relatively easy to model. The TDS concentration can be determined by a simple mass balance for each reach in the system:

$$[TDS]_1 = \frac{[TDS]_2 Q_2 + n\ [TDS]_n Q_n}{Q_2 + n Q_n}$$

where

$[TDS]_1$ = TDS concentration in downstream reach, mg/l
$[TDS]_2$ = TDS concentration in upstream reach, mg/l
$[TDS]_n$ = TDS concentration of the nth inflow to the reach, mg/l
Q_1 = Flowrate in upstream reach, cfs
Q_n = Rate of nth inflow to the reach, cfs.

2.1.2.2 Fecal Coliform

Fecal coliform bacteria are modeled by a first-order decay equation:

$$\frac{d\,[FC]}{dt} = -\,K_{FC}\,[FC]$$

where

$[FC]$ = Fecal coliform concentration, mpn/100 ml

K_{FC} = Emperically determined rate constant, day^{-1}

The temperature dependence of the rate constant is given by:

$$K_{FC_{(T)}} = K_{FC_{(20)}}\,Y_{FC}^{\,T-20}$$

where

$K_{FC_{(T)}}$ = rate constant at temperature T, day^{-1}

$K_{FC_{(20)}}$ = rate constant at 20° C, day^{-1}

Y_{FC} = emperically determined constant

T = temperature, °C.

2.1.2.3 Ammonia and Nitrate Nitrogen

Two different models of nitrogen kinetics are available in Pioneer I. The choice of which model to use is largely dependent on the availability of algae data. Because this information is not readily available for the South Platte River basin, the more simplified model has been used to monitor ammonia nitrogen.

In the selected scheme, the nitrification of the ammonium ion to nitrate in two steps is modeled. This process is summarized by the following reactions:

$$NH_4^+ + \frac{3}{2}O_2 \rightarrow NO_2^- + 2H^+ + H_2O$$

$$NO_2^- + \frac{1}{2}O_2 \rightarrow NO_3^-$$

The overall energy reaction is given by:

$$NH_4^+ + 2O_2 \rightarrow NO_3^- + 2H^+ + H_2O$$

The kinetics of the overall energy reaction are described by first-order reaction equations:

$$\frac{d[NH_4^+]}{dt} = -K_N \; [NH_4^+]$$

$$\frac{D[NO_3^-]}{dt} = K_N [NH_4^+]$$

where

$[NH_4^+]$ = ammonium ion concentration, mg/l

$[NO_3^-]$ = nitrate concentration, mg/l

K_N = emperically determined rate constant, day^{-1}

In using these equations in the model, it is assumed that the oxidation rate of ammonia and formation of nitrate is limited only by the amount of ammonia present and not by the concentration of oxygen or the number of organisms present. Also, it is assumed that the nitrite conversion to nitrate is instantaneous and not limiting to the overall reaction. The dissolved oxygen consumed by the oxidation of ammonia and nitrite is then transferred to the dissolved oxygen model.

The effect of temperature on the nitrogeneous oxidation process is accounted for by the expression:

$$K_{N_{I(T)}} = K_{Ni_{(20)}} \theta_N^{T-20}$$

where

$K_{N_{I(T)}}$ = ith rate constant of temperature T, day^{-1}

$K_{N_{i(20)}}$ = ith rate constant at 20° C, day^{-1}

θ_N = emperically derived constant

T = temperature, °C.

2.1.2.4 Carbonaceous Biochemical Oxygen Demand

The modeling of carbonaceous BOD in Pioneer I includes both the suspended and soluble fractions. The kinetics of the BOD reaction are formulated in accordance with first-order reaction kinetics. Factors which must be taken into account include rate of oxygen uptake, rate of sedimentation of suspended BOD, and scour of BOD from the river bottom. The following equation is employed in Pioneer I to describe this process:

$$\frac{d[BOD_c]}{dt} = -(K_1 + K_3)[BOD_c] + P$$

where

$[BOD_c]$ = total carbonaceous BOD concentration, mg/l

K_1 = rate of oxygen uptake, day^{-1}

K_3 = rate of sedimentation of suspended BOD, day^{-1}

P = scour of BOD from the river bottom, mg/l/day.

The temperature dependence of K_1 is given by:

$$K_{1(T)} = K_{1(20)} \theta_B^{(T-20)}$$

where

$K_{1(T)}$ = K_1 at temperature T, day^{-1}

$K_{1(20)}$ = K_1 at 20°C, day^{-1}

θ_B = emperically determined constant

T = temperature, °C.

2.1.2.5 Dissolved Oxygen

The dissolved oxygen present in a river is a function of various interrelated parameters. These factors include the bacterial oxidation of organic and nonorganic matter, benthic demand, algal photosynthesis and respiration, reaeration, and temperature. The equation describing the effect of these parameters on dissolved oxygen can be written as a mass balance as follows:

$$\frac{d[DO]}{dt} = -(\text{BOD use}) - (\text{Benthic use}) \pm (\text{Algal production or use}) + (\text{Reaeration}).$$

The oxygen uptake by BOD includes nitrogeneous as well as carbonaceous BOD. The use of oxygen by carbonaceous BOD is given by:

$$\frac{d}{dt}\left[DO_{(BOD_c)}\right] = K_1 \left[BOD_c\right]$$

where K_1 has been previously defined.

For nitrogeneous oxidation of ammonia, the stoichiometric coefficients are used to convert to oxygen uptake:

$$\frac{d}{dt}\left[DO_{(BOD_n)}\right] = K_{N_1}\left[NH_4^+\right] N_1 + K_{N_2}\left[NO_2^-\right] N_2$$

where

$N_{1,2}$ = stoichiometric coefficients relating oxygen to ammonia nitrogen and nitrite nitrogen, respectively.

K_{N_1,N_2} = emperically determined rate constants relating to the decay of ammonia to nitrite and nitrite to nitrate, respectively, day^{-1}.

The ammonia and nitrite concentrations are computed as a function of river reach by the nitrogen model previously discussed.

Two options exist in Pioneer I to compute the benthic oxygen demand. As with the nitrogen model, the choice of calculation employed is dependent upon the availability of algae data. Since these data are not available, the net DO production is input as a constant for each reach of the system with the benthic data input in the form of an areal demand. The benthic oxygen demand is then given by:

$$\frac{d}{dt}\left[DO_{BEN}\right] = \frac{B_e}{H}$$

where

B_e = areal benthic demand, mg/cm^2/day

H = river depth, cm.

Because Pioneer I is a steady state model, diurnal variations of dissolved oxygen production by phytoplankton cannot be readily described. Instead, the average production over a 24-hour period is used. Again, two models are available for use. Because no algae calculations are performed, the net DO production is input as a constant for each reach:

$$\frac{d}{dt}\left[DO_{phy}\right] = P$$

where

P = dissolved oxygen production by phytoplankton, mg/l/day.

A total of four options are available in Pioneer I to predict the reaeration rates (K_2) in the river system. The four models provide either a specific K_2 value, a velocity and depth exponential model, a flow exponential model, or a Thackston-Krenkel slope dependent model.

For the original calibration of Pioneer I, the option of the velocity and depth exponential model was used to determine the K_2's. This option is based on observances that the K_2 is directly proportional to the mean stream velocity and inversely proportional to the mean depth. This relationship is based on the assumption that increasing velocity and turbulence increases surface reaeration of dissolved oxygen and promotes mixing and dispersion of oxygen throughout the stream depth. Also, an increasing depth will decrease the dispersion rate of dissolved oxygen in the river, resulting in lower quantities of surface reaeration.

The following equation can be used to represent the described phenomena:

$$K_2 = \frac{aV^b}{H^c}$$

where

V = stream velocity, ft/sec

H = stream depth, ft.

a,b,c = emperically determined regression coefficients.

The reaeration constant K_2 also will be a function of temperature. The correction factor taking temperature into account is given by:

$$K_{2_{(TP}} = K_{2_{(20}} \theta_K^{(T-20)}$$

where

$K_{2_{(T)}}$ = reaeration coefficient at temperature T, day^{-1}

$K_{2_{(20)}}$ = reaeration coefficient at 20°C, day^{-1}

θ_K = emperically determined constant

T = temperature, °C.

The combined effect of reaeration can now be presented by:

$$\frac{d}{dt} [DO_{rea.}] = K_2 \; (DO_{sat} - DO)$$

where

DO_{sat} = saturation concentration of dissolved oxygen at the given temperature and elevation, mg/l

DO = dissolved oxygen concentration, mg/l.

The combined effects of the various factors affecting dissolved oxygen can now be combined to yield one overall first order rate equation:

$$\frac{d[DO]}{dt} = -K_1 \ [BOD_c] = (K_{N_1} \ N_1[NH_4^+] + K_{N_2} \ N_2[NO_2^-])$$
$$-\frac{B_e}{H} + P + K_2 \ (DO_{sat} - DO)$$

Because no reaeration rate measurements were made for the South Platte River basin, data for the original model was obtained from analysis and application of data obtained from other rivers. However, a literature review revealed that the use of velocity-depth models for predicting K_2 values are unreliable [Brown, 1974; Tsivoglov and Neal, 1976; Velz, 1974]. Preliminary computer runs performed as part of this study revealed that, in the critical low flow regime being studied, reaeration rates were predicted as very high levels two to three times greater than those generally reported in literature [Brown, 1974; Velz, 1970; Tsivoglov and Neal, 1976; Metcalf & Eddy, 1972]. Based on these facts, it was decided to input values for K_2 as constants to the model and not utilize a velocity-depth calculation procedure. Using this procedure, unrealistically high dissolved oxygen levels in the streams downstream of significant wasteloads would be avoided.

2.1.2.6 Integrated Model

From the above descriptions of the various water quality parameters modeled, it is obvious that each parameter is interrelated to the others. The set of differential equations presented are solved by Pioneer I using a fourth order Runge-Kutta procedure. This technique is a widely used procedure that is both computationally fast and accurate for the functions being modeled.

2.2 WATER QUALITY COEFFICIENT ASSESSMENT

As indicated in previous sections, the modeling of non-conservative water quality parameters such as dissolved oxygen and ammonia nitrogen in a stream system is highly dependent upon a number of reaction coefficients. Previous use of Pioneer I for the 303(e) Basin Plan revealed, in some cases, a wide variation of values of those coefficients. Table 2.2-A presents the range of values utilized in the original Pioneer I for the four major rivers being analyzed for this study. The use of each listed coefficient is discussed in previous sections. As shown, variations exist for K_1, K_2, K_3, B_e, and K_{N1}. All others were held constant throughout the study area in the original model. The variations in the values for K_3 and B_e were especially widespread indicating that data input was probably adjusted to "force-fit" model output affected by those coefficients (i.e., dissolved oxygen) to field data. These coefficients can dramatically effect dissolved oxygen and related water quality parameters (BOD, ammonia).

TABLE 2.2.-A. RANGE OF WATER QUALITY COEFFICIENTS IN ORIGINAL PIONEER I FOR LARIMER-WELD REGION

COEFFICIENT	RANGE OF VALUES (base e)
Carbonaceous BOD decay, K_1 ($days^{-1}$)	0.3 - 0.5
Oxygen reaeration, K_2 (day^{-1})	4.0 -10.0
Carbonaceous BOD sedimentation, K_3 (day^{-1})	0.05- 7.5
Benthic oxygen demand, B_e ($mg/m^2/day$)	0 - 2,000
Ammonia nitrogen decay, K_{N_1} ($days^{-1}$)	0.1 - 0.4
Nitrite nitrogen decay, K_{N_2} ($days^{-1}$)	5.0
Fecal coliform decay, K_{FC} ($days^{-1}$)	1.38
BOD temperature coefficient, θ_B	1.047
Nitrogen temperature coefficient, θ_N	1.05
Fecal coliform temperature coefficient, θ_{FC}	1.0

Calibration of a model such as Pioneer I is usually performed by adjusting the water quality reaction coefficients so that model output reasonably represents the real world phenomena. To maintain model credibility during this process, it is necessary to determine a realistic range of values which may be utilized for those coefficients being tested. The previous sections described the need for recalibration for certain parameters not only because of the restructuring of the model hydrology, but also because some original coefficient values were questionable. Because these coefficients under question are difficult to measure either in the field or in the laboratory, literature values are commonly used to define reasonable ranges of values.

Prior to the literature search, field studies of the four major streams in the study area were conducted during August, 1976, to determine their physical characteristics during low-flow summer conditions. Observations were made of flow regime, stream bed conditions, aesthetic appearance of stream water, etc. It was noted that streamflow during low flow conditions is shallow and wide, with moderate flow velocity. Turbulent areas of reaeration, such as whitewater or rapids, were fairly limited indicating that high reaeration rates are probably not occurring. With the exception of the Big Thompson River, which was receiving runoff from the disastrous flood of that summer, the major rivers in the study area are similar in their flow characteristics. It can be expected that the Big Thompson River normally is similar to the other streams during the same period.

Preliminary sensitivity runs of the restructured model indicated that the dissolved oxygen model is highly sensitive to changes in the reaeration coefficients (K_2). The literature search for realistic values of K_2 revealed a very wide range of repeated values. Currently a velocity-depth model is the most widely used method of predicting K_2 [Nemerow, 1974]. However, these models predict unusually high values of K_2 in the low flow regime being studied. It was therefore decided to input a constant value of K_2 into the model and adjust other coefficients for calibration purposes.

Repeated values of K_2 for streams similar to those typical to the study area generally range from 1.0 to 5.0 (base e). [Metcalf & Eddy, 1972; Fair, et. al., 1968; Brown, 1974]. It was therefore decided to set K_2 to 3.0 (base e) for all reaches in the model. This value is fairly representative of the majority of stream segments included in the model.

Values for the BOD sedimentation (K_3), BOD scour (P), and benthic oxygen demand (B_e) are highly dependent upon local stream conditions. Because of this, values for these coefficients are not usually reported in the literature. The values for BOD scour in the original model were set at zero and were left at that value in the revised model. BOD sedimentation rates varied widely in the original model with extremely high values input in stream segments below major discharges on the Cache la Poudre River, again indicating an unrealistic "force-fit" of model output to field data. Stream segments upstream and downstream of those discharges have similar physical characteristics. Therefore, this discrepancy was eliminated by setting the K_3 values for all reaches equal to the more reasonable upstream values of 0.05/day. Sludge deposits in streams below major discharges do exert some benthic demand on oxygen along those segments. However, field study of the four major rivers above and below large discharges did not reveal large differences which would warrant the high variability of values for B_e used in the original model. Sensitivity runs of the restructured model indicate that the dissolved oxygen model is not sensitive to large variations in B_e and that a large range is acceptable for calibration efforts. It was therefore determined to limit the range of values for B_e to between 0 to 300 $mg/m^2/day$.

First-order decay equations are being utilized for BOD, fecal coliform, plus ammonia and nitrate nitrogen. Calibration efforts were therefore directed towards adjusting the first-order decay coefficients for each of those constituents (K_1, K_{F_C}, K_{N_1}, K_{N_2}). Carbonaceous

BOD decay has historically received the most attention of these constituents in water quality modeling. Values for K_1 which have been reported generally range from 0.05/day to 0.85/day [Butts and Kothandaraman, 1970; Thomas, 1948; Fair, et. al., 1968; Willis, et. al., 1975]. A range of 0.1 to 0.7/day was selected for calibration. The reaction of fecal coliform in receiving waters has also been the subject of a number of water quality modeling efforts. K_{F_C} values have been reported in a fairly small range of 0.35 to 0.70/day. [Willits, et. al., 1975; Canale, et. al., 1973; and Fair, et. al., 1968]. As shown in Table 2.2-B, a value of 1.38/day was utilized in the original Pioneer I. It was therefore decided to utilize a range of 0.4 to 1.4/day for K_{F_C} for calibration of fecal coliform.

Several studies have been conducted to estimate nitrification rates in streams based on the assumption of first-order kinetics [Willis, et. al., 1975; Bansal, 1976; Nesselson, 1953; Stratton, 1968; Stratton and McCarty, 1967]. Efforts to model nitrogen kinetics in streams have been less successful than those for carbonaceous BOD. One of the principal problems in nitrogen transformation has been the inability to account for all of the nitrogen under equilibrium conditions [Bansal, 1976]. Thus, a complete understanding of nitrogen kinetics is presently lacking. The published data on nitrification in natural streams are very limited, and the accuracy is often questionable due to the complex phenomena of nitrogen transfer and balance in flowing waters. Values which have been reported for K_{N_1} generally range from 0.05 to 1.50/day. The upper range of values usually includes ammonia losses by evaporation. Value for nitrification alone has been reported from 0.05 to 0.50/day. An acceptable range for calibration was set at 0.1-0.5/day. Because the conversion of nitrite to nitrate following the conversion of ammonia to nitrite is relatively instantaneous, a value for K_{N2} should be correspondingly high relative to K_{N1}. The value of 5.0/day in the original model was determined to be sufficiently large (a minimum of ten times greater than K_{N1}), in concurrence with reported values and was therefore retained at that value [Willis, et. al., 1975; Stratton & McCarty, 1967].

Values for the temperature coefficients in the original model for the respective constituents under consideration were found to be reasonably consistent with values found in the literature. It was also determined that significant changes in model output were obtained only after those coefficients were set to values well beyond the accepted range. These coefficients were therefore retained at their values in the original Pioneer I.

Presented in Table 2.2-B is a summary of range of values judged to be acceptable for calibration purposes on the revised Pioneer I model for the Larimer-Weld region. It should be noted that the presented values are in base e, as is required for input to Pioneer I.

TABLE 2.2-B. WATER QUALITY COEFFICIENTS UTILIZED FOR RECALIBRATION OF PIONEER I

COEFFICIENT	VALUES USED FOR CALIBRATION (base e)
Carbonaceous BOD decay, K_1 ($days^{-1}$)	0.1 - 0.7
Oxygen reaeration, K_2 ($days^{-1}$)	3.0
BOD sedimentation, K_3 ($days^{-1}$)	0.05
BOD scour, P (mg/l/day)	0.0
Benthic oxygen demand, B_e ($mg/m^2/day$)	0.0 - 300
Ammonia nitrogen decay, K_{N_1} ($days^{-1}$)	0.1 - 0.5
Nitrite nitrogen decay, K_{N_2} ($days^{-1}$)	5.0
Fecal coliform decay, K_{F_C} ($days^{-1}$)	0.4 - 1.4

3.0 HYDROLOGY

The natural character of river systems in the Larimer-Weld region has been subject to extensive physical modification by man. Throughout the past century, water resources development activity has resulted in the evolution of a complex system of transmountain diversions, reservoirs, canals, pipelines, and ditches. Manipulation of the surface water regime has progressed to the extent that municipalities and industries can rely on water supplies that are relatively dependable on a year-around basis. Availability of water for agricultural purposes has been extended throughout the irrigation season.

The region encompasses a major portion of the drainage of the Cache la Poudre, Big Thompson, and Little Thompson Rivers. Extensive reaches of the South Platte River and St. Vrain Creek are within the two-county area.

The surface water regime is the Larimer-Weld region typically exhibits distinct characteristics which correspond to two generalized physiographic provinces: the mountainous area and the plains area. Differentiation between the two systems occurs in an area approximated by the Canyon mouth-foothills region. In the mountainous province, stream flow is attributable to high country snowmelt and transmountain diversions. Reservoirs are operated on main-stems or tributaries to capture and regulate the release of native and imported supplies. Lakes associated with the Colorado-Big Thompson Project (C-BT) are integral components of the project operational structure. High mountain reservoirs function in the following capacities: recreation, power generation, and municipal/industrial/agricultural water supply. Flood control benefits are relatively minotr.

Plains reaches of rivers are subject to human impacts which far exceed those experienced in mountainous areas. Intense use is made of rivers for purposes of water supply and waste load assimiliation. For these reasons, the plains regime of regional streams will be the focus of this review.

3.1 ADMINISTRATION OF WATER RESOURCES

Authority at the state level over water resources within the Larimer-Weld region resides with the Division of Water Resources No. 1, headquatered in Greeley. Water districts within the Division generally correspond in area to various hydrologic drainages and have been established to facilitate the distribution and accounting of water contained in individual stream systems. The St. Vrain drainage lies within District No. 5. The Big and Little Thompson Rivers are within District No. 4. District No. 3 oversees the Cache la Poudre River. The South Platte River is administered by portions of District Nos. 1 and 2. Management of river flow to satisfy diversion requirements is the direct responsibility of district water commissioners. These individuals receive calls on the river, authorize setting of headgates, regulate storage releases, route flows to meet demands, and implement variable operational strategies dictated by demand, available resources, and weather conditions.

There are six major sources of water conveyed in the major stream channels of the Larimer-Weld region:

- Native river flow;
- Reservoir storage releases;
- Colorado-Big Thompson (C-BT Project water;
- Colorado-Laramie River Basin Transmountain importations (Cache la Poudre drainage only);
- Canal seepage, agricultural returns, tile drain effluent, and tributary inflow;
- Municipal and industrial discharges.

Colorado water law allocates available water in a stream to diverters on a priority basis according to historical usage. The foregoing water supplies are egulated and managed for the purpose of satisfying established water rights. It is this impetus which dictates the hydrologic character of the majority of stream reaches in the two-county area.

Daily flows purveyed through the system are itemized in terms of identity of diverter or storer and source of water. Origin may be attributed to:

- Direct flow in the river;
- Reservoir storage releases;
- C-BT Project water;
- Colorado-Laramie River Basin Transmountain importations (Cache la Poudre drainage only);
- Exchange water.

Exchange water does not represent an additional supply source; rather, it depicts water manipulated by a management agreement. Flows involved in an exchange are diverted for use from the system. An equivalent volume of replenishment or "make-up" water is introduced to the system at a concurrent or subsequent time from an alternate source. Satisfaction of diversion priorities is often accomplished by cooperative plans of management and exchange of water. Release of water from storage represents an important feature of such operations. The exchange arrangements provide great system flexibility. Their application is especially evident in the Cache la Poudre River drainage among members of the Cache la Poudre Water User's Association.

Delivery of water to various ditches may be accomplished through canals, reservoirs, and ditches that bypass the main-stem channel of major rivers in the region. In instances where the river channel is used to convey water to downstream users, these supplies often sustain flows in stream reaches at high levels that normally would not exist under unregulated conditions. A call for stored water by a downstream ditch may determine to a large degree the volume of river flow passing upstream locations. Fluctuating ditch headgate requirements cause concommittant fluctuations in streamflow.

Certain ditches possess a right to river flow in quantities which in effect result in diversion of all available flow from the main-stem channel. Downstream diverters rely on storage releases and accretions which regenerate river flow as a supply source. A significant component of supply to rivers in reaches downstream from canyon mouths during the irrigation season is provided by tributary discharges, canal waste, and agricultural returns. These accretions may be discharged to the river through natural drainage channels, through point source facilities such as municipal outfalls and tile drains, or through channel seepage. Diversion priorities of many downstream ditches are satisfied wholly or partially by such sources. Overland return flow to river systems is usually negligible due to the presence of the buffer zone flood plain.

In some locations, diversions which dry up streams remove total native river flow and all traces of municipal and industrial discharges. Major sections of the Cache la Poudre and Big Thompson Rivers are made up entirely of return flows. This is supported by records of the State Engineer and substantiated by water quality sampling data.

Stream management for irrigation purposes corresponds to two seasons:

- Storage season (October - April);
- Irrigation season (May - September).

Operation strategies implemented during these periods exhibit distinct characteristics.

Storage season activity is geared toward conserving and extending available water supplies. As much water as possible is introduced to storage. Efficient system regulation involves drying up rivers at points of reservoir diversion. System operation during the irrigation season makes use of natural flows, reservoir storage, and river accretions. During the early portion of the season, water needs are satisfied by direct runoff and return flows. High country snowmelt generally occurs from mid-May to mid-June. In July and August, calls for Project water and storage releases are significant. Many ditches are supplied exclusively by seepage and returns tributary to the main-stem river system.

The extensive system of municipal and irrigation water supply and diversion essentially controls all streamflow in the region. Table 3.1-A summarizes number of diversions which characterize the major rivers within the two-county area.

TABLE 3.1-A. DIVERSIONS - LARIMER-WELD REGION

STREAM	NUMBER OF DIVERSIONS [a]	RIVER MILES [b]
Cache la Poudre	27	62
Big Thompson	15	36
Little Thompson	9	24
St. Vrain	2	15
South Platte	20	73

[a] Within Larimer and Weld Counties.
[b] Point of first upstream diversion to river mouth or Weld County Line.

3.2 LOW FLOW HYDROLOGY

The use of the "7-day, 10-year" low flow condition to define waste assimilative capacity of surface waters has merit in regions where year-around flow exists. In the Larimer-Weld region, as in much of the arid West, <u>low flows</u> are characteristically <u>no flows</u>. Intense modification and management of the hydrologic regime to conserve and extend available water supplies further distorts the meaningful application of "7-day, 10-year" criteria to low flow conditions in the region.

Development of a water budget which reflects magnitude of water supply and diversion in the region under conditions of drought provides an appropriate means of evaluating low flow hydrology. Data necessary for such analysis include:

- Streamflow gaging data;
- Point-source discharge data;
- Assessment of non-point source contributions;
- Ditch diversion data;
- Generalized features of system management.

The Colorado Division of Water Resources, USBR, and USGS maintain on-going programs of gaging in the region at locations on major streams. Data for major mountain streams are available immediately downstream from canyons and at river mouths. Data for smaller tributaries and for major mountain streams in intervening reaches are typically fragmented or absent. Data for the South Platte is adequate to define flow at locations upstream, within, and downstream from Weld County.

In their daily operation of individual stream systems, district water commissioners gain an intuitive knowledge of seasonal volumes associated with point and non-point inflow and returns. Diversion priorities of many downstream ditches are satisfied wholly or partially by such sources. It is a common occurrence for flows in particular stream systems to be exhausted below upstream diversions. Downstream stream reaches are replenished by seepage, returns, discharges, and releases from storage. Records representative of effluent discharge from municipal and industrial sources are generally available.

Records compiled by the district water commissioners and maintained by the Division of Water Resources are comprehensive in nature. Origin and disposition of diverted flows within the various districts are tabulated. Because of the complex nature of water exchange, local operational practices must be investigated before any overview of in-stream hydrology can be developed. Such knowledge is best imparted by district water commissioners, the individuals responsible for day-to-day management of system flows. The dynamic and fluctuating nature of water supply and demand generally requires that major diversions be capable of being satisfied by water delivered through a variety of hydraulically contiguous facilities. Hence, a generalized methodology of system operation can be described, but exceptions will often be dictated by daily operating practice.

Low flow hydrology was investigated to determine volume of the receiving water available to accommodate point source discharges under stressed supply conditions. Hydrologic balances characteristic of temperate or warm months were computed to identify seasonal impact on water quantity. The period May through September was selected for analysis because of the governing influence in-stream temperature has on ammonia toxicity, a major water quality parameter affecting fish and other aquatic life.

Features associated with water resource management of rivers and reservoirs in Larimer-Weld region are described in the following sections.

Results of the water balance analyses are also shown. These inventories demonstrated that low flow conditions in the months selected for review tended to occur in the early portion of May and during August. The period of mid-May to mid-June was generally one of high flow because it coincided with the occurrence of high-country snowmelt. Stream flow augmentation with C-BT Project and Colorado-Laramie River Basin Transmountain waters is not usually practiced in the early portion of May. However, releases of these flows to drainages of the region normally occurs relatively soon thereafter. Imported water sustains flow in many reaches of the river systems at levels that normally would not be present under unregulated conditions.

3.2.1 Cache la Poudre River

Flows in the Cache la Poudre River system are managed by a sophisticated program of diversion and exchange. Water requirements of downstream senior diverters are often satisfied by reservoir storage releases. Upstream ditches may use exchanged river water. Flow in specific portions of the river may be exhausted in intervening reaches. The practice of exchange is implemented to a lesser extent in other drainage systems of the region.

In the Cache la Poudre River drainage, the main irrigation season usually begins during the latter part of April. Ditches on the downstream end of the system are the first to irrigate. Major ditches normally initiate calls for water in the first or second week of May. During the irrigation season, flow in the Cache la Poudre may be exhausted downstream from at least eleven diversion points. These include:

- Monroe Gravity Canal (North Poudre Supply Canal);
- Greeley Municipal Intake;
- Little Cache la Poudre Ditch;
- Larimer County No. 2 Canal;
- Larimer & Weld Canal;
- Fossil Creek Reservoir Inlet (often);
- Whitney Ditch;
- B. H. Eaton Ditch (almost always);
- Greeley No. 3 Ditch (always);
- Boyd & Freeman Ditch (almost always);
- Ogilvy Ditch (always).

Although the irrigation season normally ends on October 31, no irrigation of consequence occurs beyond the last Saturday in September. The North Poudre Supply Canal is generally the last ditch to shut down (Figure 3.2-A).

The practical storage season lasts from September 25 to April 25. During this period, available water is diverted into the system's many reservoirs. Water District No. 3 contains over 45 major reservoirs and nearly 40 active minor reservoirs and impoundments. Optimization of water resources during the non-irrigation season requires that a maximum quantity be diverted to storage. This task, efficiently implemented by the district water commissioner, involves drying up the Cache la Poudre at every possible point:

- Larimer County Canal;
- Larimer & Weld Canal;
- Timnath Reservoir Inlet;
- Fossil Creek Reservoir Inlet.

High-country snowmelt supplies the river system during the period from about mid-May to mid-June. Typical spring flow in the Poudre River decreases rapidly by late June. Decrees in the Poudre are then satisfied by reservoir releases rather than by direct surface flows. Aspects of system operation during a low flow year, 1972, are depicted in Table 3.2.1-A.

Characteristics of the Cache la Poudre water supply system are highlighted herein. Information was obtained from the District No. 3 Water Commissioner, Mr. Jack Neutze, and represents a generalized operational strategy. Exceptions may be routinely encountered in day-to-day system manipulation. Water supply facilities must be adjusted to keep pace with new conditions of weather or demands. For purposes of presentation, features of the Cache la Poudre system will be discussed in terms of four river reaches:

- Upstream from Gaging Station 06752000, Cache la Poudre River at mouth of canyon near Fort Collins;
- Downstream from Gaging Station 06752000 to Greeley No. 2 Ditch (New Cache la Poudre No. 2 Ditch);
- Downstream from Greeley No. 2 Ditch to Greeley No. 3 Ditch;
- Greeley No. 3 Ditch to Gaging Station 06752500, Cache la Poudre River near Greeley.

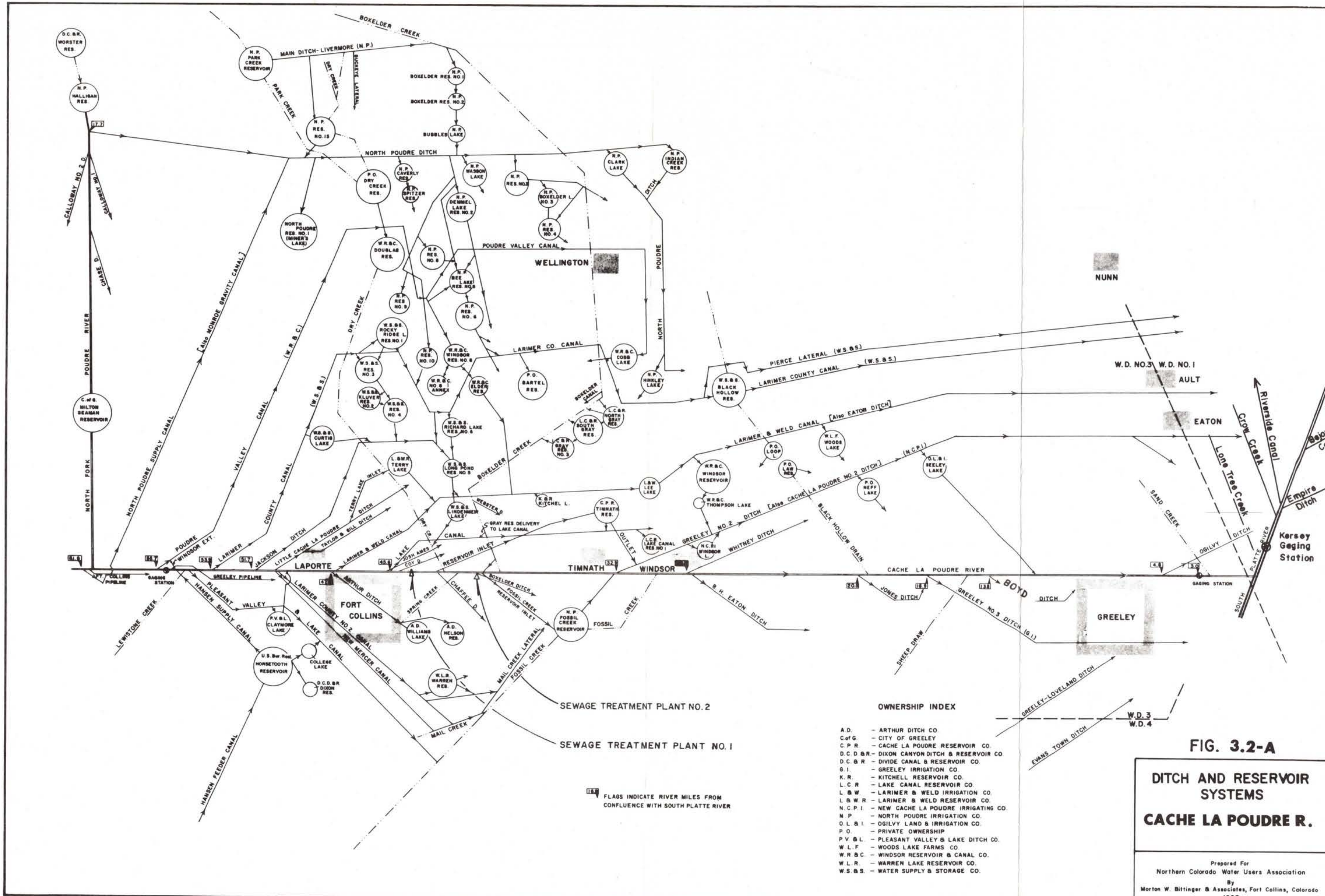


FIG. 3.2-A

DITCH AND RESERVOIR SYSTEMS

CACHE LA POUDRE R.

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1967

TABLE 3.2.1-A. LOW FLOW CONDITIONS IN CACHE LA POUDRE RIVER [a] - WATER DISTRICT NO. 3 - MID-APRIL TO MID-SEPTEMBER, 1972

DATE	FLOW (cfs) [b]	LOCATION [b]	REMARKS
4/20	35	Canal No. 3	Supply exceeds demand
4/27	0	Canal No. 3	Supply even with demand
5/4	0	Little Cache	Call on reservoirs
5/11	0	Larimer & Weld	Call on reservoirs
5/18	0	Canal No. 3	Call on reservoirs
5/25	0	Canal No. 3	Call on reservoirs
6/1	0	Canal No. 3	Call on reservoirs
6/8	300	Larimer & Weld	Supply exceeds demand (rain)
6/15	300	New Cache	Supply exceeds demand (rain)
6/22	0	Canal No. 3	Beginning to call on reservoirs
6/29	0	Canal No. 3	Call on reservoirs
7/6	0	Canal No. 3	Call on reservoirs
7/13	0	B. H. Eaton	Call on reservoirs
7/20	0	Canal No. 3	Call on reservoirs
7/27	0	Canal No. 3	Call on reservoirs
8/3	0	Canal No. 3	Call on reservoirs
8/10	0	Canal No. 3	Call on reservoirs
8/17	0	B. H. Eaton	Call on reservoirs
8/24	30	B. H. Eaton	Call on reservoirs
8/31	0	Fossil Creek Reservoir Inlet	Situation relieved by rain
9/7	0	Timnath Reservoir Inlet	Excess supply to storage
9/14	0	Little Cache	Excess supply to storage

[a] Per Water Commissioner's Field Notes, Water District No. 3.
[b] Point of minimum discharge occurring on the last day of the week. Visual, rather than gaged, flow estimate.

3.2.1.1 Reach Upstream from Gage at Mouth of Canyon

The main-stem Cache la Poudre River upstream from its confluence with the North Fork drains a watershed area that is essentially wilderness. Spot development exists along Poudre Canyon, but no point-source discharge to the river occurs. Native flows are augmented by transmountain water released to the main-stem through importation facilities tapping resources in the drainage of the Colorado and Laramie Rivers.

North Poudre Ditch generally intercepts all summer flow in the North Fork Cache la Poudre River. The river channel is normally dry immediately below this diversion. Inflow to the North Fork in the reach downstream from the ditch is collected by Seaman Reservoir, owned by the City of Greeley. Such inflow is attributed to groundwater seepage and localized runoff. Only a very minor amount of mountain meadow irrigation occurs in this region, so impact of agricultural returns is insignificant. Water impounded by Seaman Reservoir is generally very turbid. Discharge from the reservoir is intermittent. When the facility is required to spill, release of water occurs in a substantial volume. At such times the City of Greeley is informed to temporarily shut down the intake to their water treatment plant. This circumvents the need for city operators to combat a large slug of highly turbid water in the Greeley plant prior to municipal distribution. The City of Greeley is credited with a volume of direct river flow equal to the Seaman Reservoir release.

Greeley is entitled to a direct Poudre diversion of 12.5 cfs. The remaining supply is acquired through exchange or storage transfer. In the exchange agreement, Greeley intercepts flow intentionally left in the river for that purpose by the Larimer County Canal. Greeley repays the canal owner, Water Supply and Storage Company, at the end of the irrigation season with transferred C-BT Project water delivered from Horsetooth Reservoir. The city also utilizes an arrangement wherein it intercepts flows from the Poudre intended for downstream storage. Water is managed by an accounting procedure rather than by a true exchange. Because of the overdraw by the Greeley system, an appropriate charge is made to the junior reservoir involved in the transaction.

3.2.1.2 Reach Downstream from Gage at Mouth of Canyon to Greeley No. 2

Flow in the river is monitored by Gaging Station 06752000, Cache la Poudre at mouth of canyon near Fort Collins. Under normal summer conditions, it is fairly common for the Poudre to be dry from the Greeley municipal intake to the Hansen Supply Canal. The reach downstream from the City of Fort Collins municipal intake to the Hansen Supply Canal has been dry in the past, but the extremely rare occurrence is not attributable to typical system operating practices.

The Hansen Supply Canal delivers C-BT Project flows to the main-stem Poudre in response to orders for Horsetooth Reservoir water. An exception are orders requested by Poudre Valley Canal and the North Poudre Supply Canal. Project water intended for Poudre Valley Canal is discharged directly to the canal by facilities of the Hansen Supply Canal and Windsor Extension. Because of its upstream location from the Hansen Supply Canal, the North Poudre Supply Canal diverts river flow in exchange for its allocation of Horsetooth Reservoir water. Other main-stem ditches utilizing C-BT Project water include Larimer County (Water Supply and Storage), Jackson, Little Cache la Poudre, New Mercer, Larimer County No. 2, Arthur, Larimer and Weld, Lake, Chaffee, New Cache la Poudre (Greeley No. 2), and Whitney. Under normal operating conditions, the latter three diversions are satisfied by river flow, seepage, municipal discharges, and returns. It is an unusual occurrence when Horsetooth Reservoir water is delivered to their respective headgates. The Lake Canal is usually the lowest ditch on the system to receive Project water.

Claymore Lake almost exclusively serves the Pleasant Valley and Lake Canal. Because the reservoir outlet is located downstream from the canal headgate, the facility operates on an exchange basis. Flows discharged to the Poudre through the Claymore Lake outlet replace river flows diverted by Pleasant Valley and Lake Canal on a one-to-one basis. This operational procedure occurs about 99 percent of the time.

Diversions intended for Taylor and Gill Ditch are delivered through the facilities of the Little Cache la Poudre Ditch. The headgate of the Taylor and Gill Ditch is situated on the Little Cache off the main-stem Poudre River channel.

During summer conditions, the discharge of Lewstone Creek to the main-stem Poudre below the Hansen Supply Canal is normally less than 1 cfs. A live stream usually exists in the river from the Hansen Supply Canal to the Larimer and Weld Canal. Flow may get low on weekends since the Larimer and Weld Canal commonly isn't used at that time. In summer the Poudre is often dry immediately downstream from the Larimer and Weld Canal diversion. Seepage and returns tributary to the river below Lake Canal range to about 6 cfs and satisfy water requirements at the Coy Ditch.

Flow diverted by Chaffee and Boxelder Ditches consists of recharge contributed by returns, inflow, and the discharge of Fort Collins Wastewater Treatment Plant No. 1. Effluent also supplies the inlet to Fossil Creek Reservoir and that of Timnath Reservoir, when operating. The municipal discharge is normally diverted in its entirety from the river system in the reach to the Fossil Creek Reservoir inlet. Recharge contributed to this reach of the main-stem Poudre by Spring Creek is on the order of 5 to 10 cfs.

The intake to Fossil Creek Reservoir is normally operated during both summer and winter. That of Timnath Reservoir is typically operated in winter only. Effluent from the City of Fort Collins Treatment Plant No. 2 has the option of being discharged directly to the Poudre River or to the Fossil Creek Reservoir inlet channel. Direction of the discharge is controlled by the district water commissioner. Typical practice calls for discharge of effluent to whichever watercourse possesses flowing water at the time. The governing concept is to dilute the effluent as much as possible. An exception to the normal occurrence (in which the river is sustained by seepage, agricultural return flows, and municipal effluent downstream from Lake Canal) occurs occasionally when Horsetooth water is run all the way to Chaffee, Greeley No. 2, or Whitney Ditches. All flow in the Poudre is normally diverted into the Fossil Creek Reservoir inlet up until about September 10. During July and August, effluent in Fort Collins No. 2 discharges to the Fossil Creek Reservoir inlet.

Fossil Creek Reservoir serves a dual function of flow equalization and storage. Diversion requirements of ditches served by the main-stem Poudre decrease substantially on weekends because irrigation is often reduced or curtailed at such times. The district water commissioner has found it desirable to divert all summer flow through the reservoir. This practice enables flow in the river that otherwise would be lost downstream on weekends to be retained in storage for later use. Use of Fossil Creek Reservoir as an equalizing structure is also practiced through other portions of the year whenever possible.

Unless a portion of the inflow diverted to the reservoir is being introduced to storage, releases from Fossil Creek Reservoir usually exceed the volume of flows acquired at the intake on the Cache la Poudre River. This is because the reservoir is supplied by four other sources in addition to Poudre River diversions. The discharge of Fort Collins Wastewater Treatment Plant No. 2 may be directed into the reservoir inlet; seepage on the order of 10 to 15 cfs flows into the inlet channel along its length to the reservoir; Fossil Creek, impounded by the reservoir dam, contributes from 5 to 10 cfs to the reservoir; and effluent from South Fort Collins Sanitation District is discharged to Fossil Creek Reservoir. The Creek receives waste flows from New Mercer, Larimer County No. 2, Arthur, and Pleasant Valley and Lake Canals.

Routing Poudre flows through Fossil Creek Reservoir drys up the river immediately below the point of diversion. Downstream inflows to the main-stem above the reservoir outlet are contributed by seepage, tributary inflow, and returns. Boxelder Creek discharges 5 to 10 cfs to the Poudre in this reach. Effluent from the Boxelder Sanitation District wastewater treatment facility commingles with Boxelder Creek flows slightly upstream from the confluence with the Cache la Poudre.

Discharge from the Fossil Creek Reservoir outlet ranges up to 250 cfs when it is operated during the summer. Only a small amount of water discharges to the Poudre from the established drainage course of Fossil Creek below the Fossil Creek Reservoir Dam.

The quantity of flow indicated as a diversion at Greeley No. 2 may not be the actual volume of water diverted from the main-stem river channel. The district water commissioner's daily records are such that individual reservoir releases and the actual river diversion can be identified. Stored water is often delivered to Greeley No. 2 from Windsor and Timnath Reservoirs. This arrangement satisfies the Greeley No. 2 diversion priorities with river water diverted by the Larimer and Weld Canal or Timnath Reservoir inlet. Windsor Reservoir possesses two discharges: one goes directly to Greeley No. 2; the second is small, and goes directly to irrigation. Timnath Reservoir discharges directly to Lake Canal or to Greeley No. 2

3.2.1.3 Reach From Greeley No. 2 to Greeley No. 3

In addition to regulating river flow picked up by Greeley No. 2, Fossil Creek Reservoir supplies Whitney Ditch, B. H. Eaton Ditch, and Greeley No. 3. Of the total diversion requirement of B. H. Eaton Ditch and Whitney Ditch, only a portion is satisfied by return flows. The remainder is river water delivered to the Greeley No. 2 river point. In early summer during high country snowmelt runoff conditions, surface flows are often wheeled all the way to Greeley No. 3. In later summer, diversions from the Poudre by the B. H. Eaton Ditch normally exhaust the river immediately below that point. Enough inflow and agricultural returns contribute to the river below the B. H. Eaton Ditch to satisfy diversion requirements at Jones Ditch and Greeley No. 3. The latter diversion always dries up the river. Significant supply sources in this reach of the Poudre include the Windsor Municipal Wastewater Treatment Plant, Kodak industrial effluent, Black Hollow Drain (Consolidated Law Ditch), and Storm Lake Drain. The drains each typically convey from 5 to 10 cfs of recharge to the Poudre during summer.

3.2.1.4 Reach from Greeley No. 3 to Gage Near Greeley

Sheep Draw is a stream channel whose natural outlet to the Poudre is located downstream from Greeley No. 3. The drainage system has been modified so that flow in the draw is intercepted directly by Greeley No. 3. Inflow ranges from 10 to 15 cfs. It originates as localized seepage and returns as a waste flow from the Boomerang Ditch in the Thompson District.

Requirements of the Boyd and Freeman diversion are satisfied by main-stem returns. This ditch possesses the right to dry up the Poudre.

Discharge from Seely Lake is not continuous. Releases are made only when the Ogilvy Ditch is short of water. When the Seely Lake outlet is operated, flows approach 10 cfs. More often than not, diversion requirements at Ogilvy Ditch can be satisfied by tributary inflow, agricultural returns, and effluent from the Greeley Municipal Wastewater Treatment Plant. The lake itself is seldom emptied except for maintenance purposes. Typical operation normally draws the lake down to only about one-half capacity.

Graham Seep is another tributary which contributes about 5 to 10 cfs to the Poudre. Inflow from Eaton Draw is about 5 cfs. Sand Creek is picked up by the Ogilvy Ditch and doesn't actually flow directly to the Poudre River.

Greeley No. 3 possesses three wasteways which discharge directly to the Poudre. The outlet of the uppermost is situated about 2 miles below the ditch headgate, slightly downstream from the Boyd waste ditch. A second wasteway passes through the City of Greeley and drops into the Poudre above Ogilvy Ditch. A fairly constant flow is maintained in the channel to keep trash, grass clippings and other debris moving along. In late summer only about 10 cfs are discharged to the river through the wasteway. With the exception of seepage losses, flows diverted through Greeley No. 3 are applied for irrigation purposes. The 10 cfs returned to the Poudre represents flows tributary to Sheep Draw, intercepted by Greeley No. 3. The second wasteway of Greeley No. 3 conveys large flows only during spring runoff or for short durations after rainfall when urban runoff discharges to the wasteway. The third wasteway discharges to the Poudre east of Greeley in the reach between Ogilvy Ditch and Gaging Station 06752500, Cache la Poudre River near Greeley. Its discharge is responsible for a major portion of recorded flow passing the gage. Ogilvy Ditch always dries up the Poudre in summer. Flows gaged downstream are exclusively contributed by seepage, returns, and canal waste.

Seepage and agricultural returns represent a significant source of recharge to the Cache la Poudre River system. Magnitude of recharge varies seasonally, but in summer is approximately distributed among reaches of the Poudre according to the following estimated quantities:

- Upstream of Larimer and Weld Canal: 10 cfs;
- In the reach from Larimer and Weld Canal to Greeley No. 2: 50 cfs;
- In the reach from Greeley No. 2 to Greeley No. 3: 50 cfs;
- In the reach from Greeley No. 3 to Ogilvy: 40-50 cfs.

In the reach of the Poudre from the gage at the mouth of the canyon near Fort Collins to the City of Greeley, returns on the order of approximately 150 cfs contribute to the main-stem of the river. Some of this is in the form of seepage and some is discharged from various drains or channelized in natural tributaries.

Returns generally represent a seasonal steady state condition whereby seepage and waste from drains and canals north of the Poudre follow the gradient back to the main body of the Poudre River. The uppermost ditch of significance involved in the seepage exchange is the North Poudre. This ditch continously loses about 50 cfs, a volume that is subsequently picked up by the Larimer County Canal. This canal in turn loses about 50 cfs of seepage to the Larimer and Weld Canal. The latter canal loses about 50 cfs to Greeley No. 2. The entire system is one in which water follows a downgradient pattern. The three ditches other than the North Poudre lose about as much water as they gain. Because it is the uppermost ditch, the North Poudre incurs a net loss. The District Water Commissioner estimates the total volume of return flow tributary to ditches other than the main-stem Poudre River to be on the order of 150 cfs at any given time.

3.2.1.5 Low Flow Hydrologic Analysis

Results of the water budget computed for the Cache la Poudre River are depicted in Table 3.2.1-B.

TABLE 3.2.1-B. CACHE LA POUDRE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	87.5			131.1
40		Headwater Flow	.0	
	74.0			131.1
41		F & G - Rustic M 81	.0	
	61.9			131.1
42		North Poudre & Monroe Canals	.0	
	60.5			131.1
181		Fort Collins Diversion	-19.0	
	60.1			112.1
182		North Fork-Cache la Poudre	.0	
	56.7			112.1
183		Poudre Valley Canal	.0	
	56.2			112.1
184		Return Flow	.0	
	56.0			112.1
185		Greeley Diversion	-26.0	
	55.7			86.1
43		Hansen Supply Canal	.0	
	55.1			86.1
44		Lewstone Creek	1.0	
	55.0			87.1
45		Pleasant Valley & Lake Canal	-15.0	
	55.0			72.1
186		Return Flow	1.0	
	53.9			73.1
187		Larimer County Canal	-27.0	
	53.9			46.1
188		Return Flow	1.0	
	51.7			47.1
189		Jackson Ditch (Dry Creek)	-27.0	
	51.7			20.1

TABLE 3.2.1-B. CACHE LA POUDRE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
190		Return Flow	0.0	
	50.8			20.1
46		Little CLP, Taylor & Gill, New Mercer, Larimer No. 2 Canals	- 20.0	
	50.6			0.1
47		Return Flow	+ 1.0	
	48.0			1.1
48		Claymore Lake Outlet, Arthur Ditch, Larimer & Weld Canal	- 1.0	
	47.7			0.1
49		Return Flow	4.0	
	47.0			4.1
50		Fish & Game - Bellevue/Watson	.0	
	46.0			4.1
175		Josh Ames Ditch	.0	
	46.0			4.1
176		Return Flow	2.0	
	45.6			6.1
191		Lake Canal and Coy Ditch	.0	
	45.3			6.1
192		Return Flow	3.0	
	44.1			9.1
51		Fort Collins No. 1 Plant	8.7	
	44.1			17.8
193		Return Flow	1.4	
	42.9			19.2
194		Timnath Reservoir Inlet, Chaffee Ditch	.0	
	42.3			19.2
195		Dry Creek	5.0	
	41.3			24.2

TABLE 3.2.1-B. CACHE LA POUDRE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
52		Spring Creek	5.0	
	40.4			29.2
53		Boxelder Ditch	-11.0	
	40.2			18.2
54		Fossil Creek Reservoir Inlet	-18.1	
	39.8			.1*
55		Fort Collins No. 2 Plant	0	
	38.4			0.1
177		Boxelder S.D.	0.7	
	38.4			0.8
Junction		Boxelder Creek	4.3	
	38.3			5.1
126		Return Flow	5.0	
	33.4			10.1
197		Fossil Creek Reservoir Outlet	17.0	
	33.4			27.1
198		Return Flow	1.0	
	32.9			28.1
127		Greeley No. 2 Ditch	-6.0	
	32.9			22.1
128		Return Flow	2.0	
	30.7			24.1
129		Fossil Creek	1.0	
	30.7			25.1
130		Return Flow	2.0	
	29.2			27.1
131		Whitney Ditch, Eaton Ditch	-27.0	
	29.0			0.1
132		Return Flow	4.0	
	27.0			4.1

*When Fort Collins No. 2 Plant discharges to Fossil Creek Reservoir Inlet.

TABLE 3.2.1-B. CACHE LA POUDRE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
178		Great Western - Windsor	.0	
	22.1			4.1
133		Windsor	.9	
	22.0			5.0
179		Kodak	.6	
	22.0			5.6
134		Return Flow	8.5	
	21.8			14.1
135		Consolidated Law Ditch	5.0	
	21.8			19.1
199		Return Flow	5.0	
	20.5			24.1
200		Jones Ditch	-10.0	
	20.5			14.1
201		Return Flow	5.0	
	17.2			19.1
202		Storm Lake Drain	3.0	
	16.9			22.1
203		Greeley No. 3 Ditch	-22.0	
	16.9			0.1
204		Return Flow	2.0	
	14.7			2.1
205		Sheep Draw	.0	
	13.8			2.1
206		Boyd and Freeman Ditch	- 2.0	
	13.8			0.1
207		Return Flow	2.0	
	11.5			2.1
208		Seeley Lake Outlet	.0	
	11.5			2.1

TABLE 3.2.1-B. CACHE LA POUDRE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

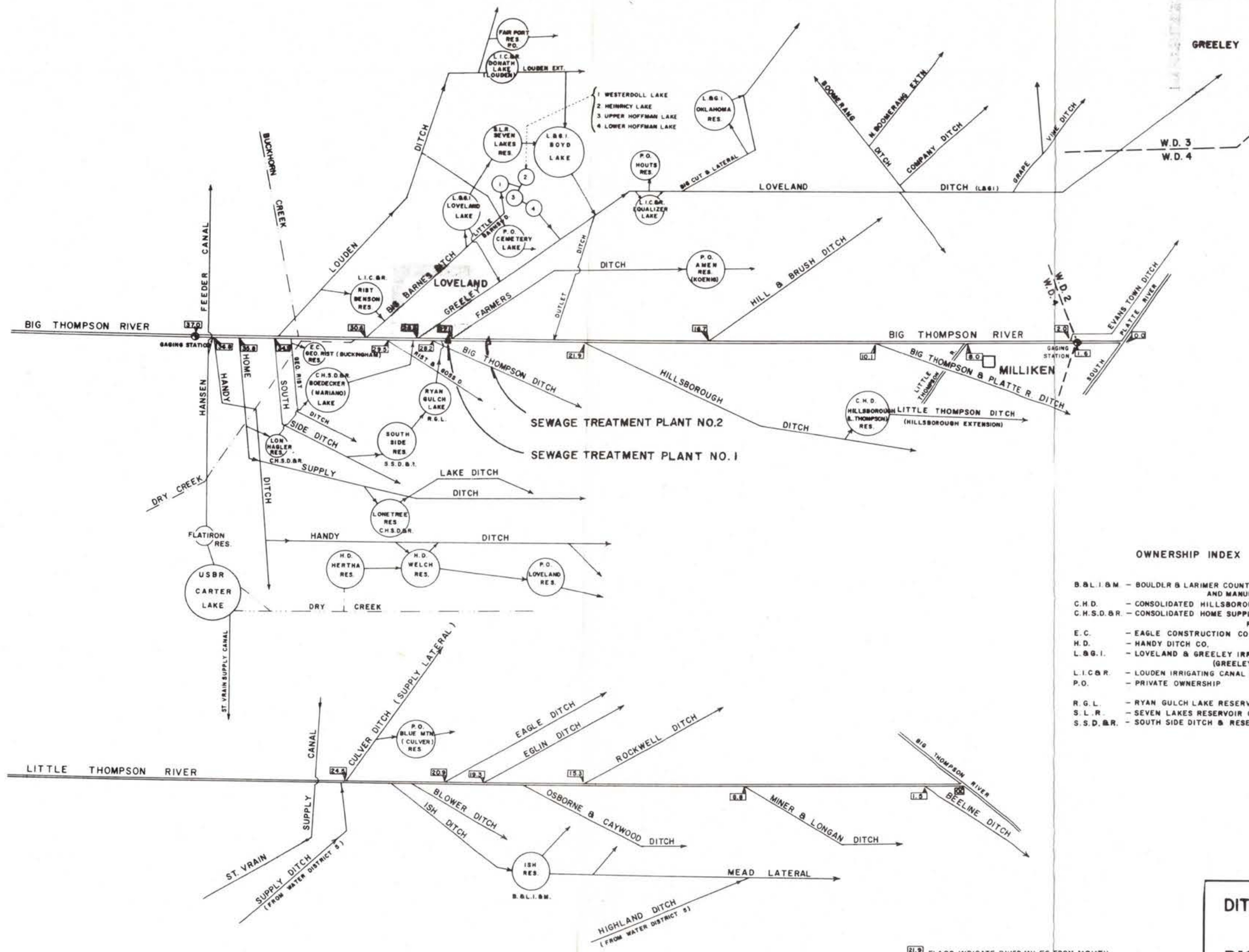
REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
209		Return Flow	2.0	
	10.0			4.1
136		Return Flow	1.3	
	9.6			5.4
210		Graham Seep	3.0	
	9.2			8.4
137		Greeley No. 3 Wasteway	7.8	
	9.2			16.2
138		Return Flow	3.0	
	7.3			19.2
139		Weld County By-Products	0.0	
	7.1			19.2
180		Monfort Packing	0.9	
	6.9			20.1
140		Eaton, Great Western - Eaton (to Eaton Draw)	0.3	
	6.9			20.4
141		Eaton Draw	4.7	
	6.9			25.1
142		Runoff	4.0	
	4.6			29.1
143		Greeley Plant	9.6	
	4.6			38.7
144		Return Flow	2.4	
	4.5			41.1
145		Great Western - Greeley	.0	
	4.3			41.1
146		Ogilvy Ditch	-41.0	
	4.3			0.1
147		Greeley No. 3 Wasteway	30.0	
	0.0			30.1

3.2.2 Big Thompson River/Little Thompson River

Flows in the Big Thompson River and its major natural tributary, the Little Thompson, are modified to a significant degree by U.S. Bureau of Reclamation and Northern Colorado Water Conservancy District operation of the C-BT Project. Flows that have been discharged to the Thompson drainage through components of C-BT, as well as native river flows, are managed for diversion purposes by the Water Commissioner, Lloyd Blewitt. Information presented herein was obtained from Ted Bell, hydrologist with the State Engineer's Office, and Gerald Whitsel, USBR, Western Division Water and Power System, System Control Center, Loveland, Colorado.

Western Slope waters collected by components of the C-BT Project are routed northeasterly from Grand Lake and Lake Granby to the hydrologic drainage of the Big Thompson River through the Alva B. Adams Tunnel. This facility ultimately discharges to East Portal Reservoir, a small impoundment situated approximately 4-1/3 miles southwest of Estes Park. Supplies are conveyed by Aspen Creek Siphon and Rams Horn Tunnel to the hydroelectric powerplant at Mary's Lake. Project water from the lake is subsequently piped by Prospect Mountain Tunnel to the Lake Estes hydroelectric generating station (Figure 3.2-B).

Lake Estes was formed by construction of Olympus Dam on the Big Thompson River. In addition to serving as the regulatory reservoir for all Project flows, Lake Estes is the receiving water for flows in the Big Thompson River, in Fish Creek, and for the Estes Park Sanitation District discharge. Ths bulk of the lake inflow is diverted eastward through the Bureau of Reclamation facilities. Flows are conveyed through Olympus Tunnel; Pole Hill Tunnel, Canal, Powerplant, and Afterbay; Rattlesnake Tunnel; Pinewood Lake; Bald Mountain Tunnel; and Flatiron Penstocks, Powerplant, and Reservoir. Flows in Flatiron are diverted to storage in Carter Lake or discharged directly to the Charles Hansen Feeder Canal. Carter Lake inflow and outflow is accomplished through pumphouse No. 3. This unit is a pumped storage facility which alternately serves to fill Carter Lake and to develop the head between Carter and Flatiron Lakes. Flows introduced to the Charles Hansen Feeder Canal from Flatiron Reservoir are returned to the main-stem Big Thompson River through the canal wasteway or Big Thompson Power Plant, or are conveyed northerly through the Big Thompson Canyon siphon to farm turnouts or Horsetooth Reservoir.



OWNERSHIP INDEX

B.&L.I.&M.	– BOULDLR & LARIMER COUNTY IRRIGATING AND MANUFACTURING CO.
C.H.D.	– CONSOLIDATED HILLSBOROUGH DITCH CO.
C.H.S.D.&R.	– CONSOLIDATED HOME SUPPLY DITCH AND RESERVOIR CO.
E.C.	– EAGLE CONSTRUCTION CO.
H.D.	– HANDY DITCH CO.
L.&G.I.	– LOVELAND & GREELEY IRRIGATING CO. (GREELEY & LOVELAND)
L.I.C.&R.	– LOUDEN IRRIGATING CANAL AND RESERVOIR CO.
P.O.	– PRIVATE OWNERSHIP
R.G.L.	– RYAN GULCH LAKE RESERVOIR CO.
S.L.R.	– SEVEN LAKES RESERVOIR CO.
S.S.D.&R.	– SOUTH SIDE DITCH & RESERVOIR CO.

21.9 FLAGS INDICATE RIVER MILES FROM MOUTH

FIG. 3.2-B

DITCH AND RESERVOIR SYSTEMS

BIG THOMPSON R.

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1967

Flows in Big Thompson Canyon are a result of native and Project water releases from Olympus Dam, from localized wastewater discharge, contributions from Dry Gulch and other minor tributaries, and from inflow of the North Fork. The magnitude of runoff generated within the North Fork drainage can be substantial.

The regulated discharge to the Big Thompson River from Olympus Dam is generally in accordance with criteria established by the State Fish and Game Commission. Releases are usually defined by the following schedule:

- 50 cfs - October
- 25 cfs - November through April 15
- 50 cfs - April 16 through April 30
- 100 cfs - May 1 through August 31
- 75 cfs - September 1 through September 15
- 50 cfs - September 16 through September 30

If inflow to Lake Estes is less than the Fish and Game criteria for release of water below Olympus Dam on any given day, the Bureau is required to discharge to the river a volume of water equal to inflow to Lake Estes.

Although a few exceptions exist, the Bureau is generally allowed to skim native inflow at Lake Estes in excess of that required to meet Fish and Game Commission stream flow maintenance criteria. Skimmed flows are diverted to Flatiron Lake and then conveyed to the Bureau's Big Thompson hydroelectric plant supply system through the Charles Hansen Feeder Canal. Skimmed flows represent water borrowed without charge by the Bureau to run the power station. Flows are returned to the Big Thompson River below the stream gaging station at the mouth of the Canyon. The Bureau generally tries to return to the main-stem Big Thompson a volume of water at least 1 percent greater than the volume of water skimmed at Lake Estes. This policy is to positively ensure system equity. Release occurs through either the Hansen Feeder Wasteway or through the powerplant tail race. The wasteway is used to supply the Big Thompson River if the sum of skimmed flows and project water requested for irrigation requirements exceed the 420 cfs capacity of the power plant.

Although design capacity of Olympus Tunnel is 550 cfs, the structure can readily accommodate 575 cfs under actual operating conditions. Capacity of the Charles Hansen Feeder Canal is 990 cfs. The canal extension in the reach north of the Big Thompson Siphon to Horsetooth Reservoir is designed to carry 550 cfs. The large capacity of the Hansen Feeder Canal, almost double that of adjacent facilities, enables the Bureau to take maximum advantage of the power-generating potential of Big Thompson River water skimmed into Olympus Tunnel at Lake Estes. Abundant flows are generally available for skimming during spring and early summer. System operation during these periods is oriented toward diverting available river supplies, rather than Project water from Alva Adams Tunnel, into Olympus Tunnel. Adams Tunnel is temporarily shut down and Project water is held in reserve for later release. During such time, calls for Project water must be satisfied in spite of the fact that Adams Tunnel is inactive. The 990 cfs capacity of the Charles Hansen Feeder Canal provides system flexability necessary for this to occur. Project water impounded in Carter Lake is allowed to flow through Flatiron Lake to the Hansen Feeder Canal.

Dille Tunnel, also referred to as Tunnel No. 1, can divert flows passing through the Narrows of the Big Thompson River Canyon and discharge them to the Hansen Feeder Canal upstream from the Big Thompson hydroelectric power plant turnout. Flows diverted through Dille Tunnel are returned to the river through the wasteway or powerplant, or are delivered to Horsetooth Reservoir. Diversions by Dille Tunnel are permissible because Fish and Game Commission stream flow maintenance requirements below the tunnel are less than those below Olympus Dam. The accounting procedure utilized by the Bureau considers that flows skimmed at midnight on a given day are returned to the main-stem Big Thompson at 7:00 a.m. the following day. A delay on return of an equivalent skimmed flow to the river system of 31 hours exists.

Dille Tunnel is located upstream from the gaging station at the mouth of the canyon. Hence, this station does not measure all native river flow in the system, but monitors only those contributions from the North Fork, localized inflow and discharges, and releases to the river channel for fish maintenance and aesthetic purposes that are not diverted by Dille Tunnel. Skimmed native river flows bypass the gage.

The Bureau of Reclamation maintains very detailed records of inflow, diversions, and releases at Lake Estes. Such information provides a comprehensive data base from which an efficient program of system management can be formulated. In addition, hydrologic data exists as an integral part of the accounting procedure used to identify Big Thompson River water skimmed by the Bureau to operate the Big Thompson hydroelectric powerplant generating station at the mouth of the canyon. Records of the Northern Colorado Water Conservancy District for releases from the Hansen Feeder Canal represent C-BT Project water and do not reflect "Operation Skim." The Bureau maintains detailed records on origin and volume of flow delivered or diverted through its various facilities.

An important Bureau practice which must be considered in computation of any hydrologic balance on the Big Thompson River system is that of using C-BT Project water to fill Carter and Horsetooth Reservoirs. When no calls exist on the river for irrigation water (all private reservoirs having been filled), the Bureau may exercise its water right and fill these two reservoirs. Volume of water involved in this operation may or may not be significant. C-BT Project water diverted out of Lake Estes and intended for storage will likely end up in Carter Lake. Diversions through Dille Tunnel intended for storage will be delivered to Horsetooth Reservoir. Storage operations by the Bureau since 1957 have occurred during April, May, June, July, November and December.

Carter Lake inflow and outflow is accomplished through Pumphouse No. 3. This unit is a pumped storage facility which alternately serves to fill Carter Lake and to develop the head between Carter and Flatiron Lakes. Horsetooth Reservoir is filled via the Charles Hansen Feeder Canal.

3.2.2.1 Big Thompson River

C-BT Project water distributed to the main-stem Big Thompson through the Hansen Feeder Canal usually goes to the Handy, Home Supply, Louden, South Side, George Rist, Big Barnes, Greeley-Loveland, Farmer's, and occasionally Hillsborough and Big Thompson and South Platte River Ditches. In early spring, diversion requirements are easily satisfied by direct river flows. In later summer, requirements are met with Project water. Records of transfers and exchanges are kept by the District Water Commissioner. Releases from Boedecker Reservoir and Ryan Gulch Lake are also tabulated in Commissioner reports (Figure 3.2-B).

Big Barnes Ditch and Greeley-Loveland Ditch occasionally alternate points of diversion. This practice, although not extensively used, involves delivery of flows intended for the Greeley-Loveland Ditch through the headgate of the Big Barnes Ditch. Flow may then be discharged from the Barnes Ditch through Lake Loveland, Seven Lakes, Boyd Lake, and eventually to Greeley-Loveland Ditch. A preferred method of operation is to run flows directly through Lake Loveland to the Greeley-Loveland Ditch. This relates to the fact that pumps may be used to deliver flows to the Greeley-Loveland Ditch when storage elevation in Boyd Lake drops. The Big Barnes and Greeley-Loveland Ditches are able to use the alternating point of diversion method of operation because they are both owned by the same entity, Loveland and Greeley Irrigation Company.

The Home Supply Dam, located on the Big Thompson River immediately upstream from the City of Loveland Water Filter Plant, provides no significant storage. The facility is a check structure only. It ensures that river water elevations will be sufficient to discharge into both the City of Loveland and Home Supply Ditch headgates. The city diverts from the north side of the lake.

Lon Hagler Reservoir and Boedecker Reservoir are both owned by Consolidated Home Supply Ditch and Reservoir Company. Lon Hagler Reservoir is generally filled only with Project water. Its decree is very recent, dating to the 1950's. This reservoir discharges to Boedecker Reservoir (Mariano Lake). Mariano Lake discharges to the main-stem of the Big Thompson for purposes of exchange when the Home Supply Ditch diverts more than its decreed right. This situation can occur only when the Big Barnes and South Side Ditch decrees have been satisfied.

Downstream ditches on the main-stem Big Thompson River very rarely receive C-BT Project water. One cfs or so may occasionally be delivered to the Hillsborough Ditch. Both the Hill and Brush Ditch and the Big Thompson and South Platte River Ditch normally receive flows contributed by agricultural returns.

In the upstream reach of the Big Thompson, the Farmer's Ditch and the Big Thompson Ditch both possess very good water rights. In later summer, the Big Thompson is often dry immediately below the Big Barnes Ditch diversion through the reach to an area upstream from the Mariano Lake outlet.

Discharge from this reservoir often satisfies requirements of the Greeley-Loveland Ditch, the Big Thompson Ditch, and Farmer's Ditch. Because its headgate is located in the reach of the Big Thompson River below Big Barnes Ditch that is often dry, the Rist and Goss Ditch is often without water. Diversions from the Big Thompson may dry up the river at the following locations:

- Louden Ditch;
- Loveland and Greeley Canal;
- Big Barnes Ditch;
- Hillsborough Ditch;
- Big Thompson and South Platte Ditch.

A stream gaging station, "Buckhorn Below Masonville," exists on Buckhorn Creek, a tributary to the Big Thompson downstream from the canyon. This station was destroyed in the Big Thompson Flood but has recently been rebuilt. The gage is sited on the Creek above the point of the Louden Ditch crossing. Typical flows at this station during summer are on the order of 10 cfs or less.

Irrigation which occurs in the mountains near Masonville occasionally relies on the "Buckhorn Exchange." This arrangement is an exchange of Buckhorn Creek flows for respective ditch allocations of C-BT Project water, delivered to the main-stem Big Thompson River through the Hansen Feeder Canal. Volume of the exchange normally runs between 5 and 6 cfs. When implemented, the Buckhorn Exchange is reflected in flow augmentation records of the Northern Colorado Water Conservancy District. Ditches involved include Victory, Perkins, Kerchner, Carter, and Buckhorn Highline.

3.2.2.2 Little Thompson River

A stream gaging station formerly existed on the Little Thompson River upstream from the point where Project water from the St. Vrain Supply Canal is discharged to the river. This station, "Little Thompson at mouth of canyon near Berthoud," hasn't worked since 1972 when it was washed out by a flood. Record ends with discontinuous streamflow data generated for one day each month for the period March through August 1972. Summer flows in this reach of the Little Thompson are relatively small. Before being augmented by C-BT Project water, flows in the Little Thompson used to dry up by about July 12. The Little Thompson may now exhibit flow throughout the summer (Figure 3.2-B).

Ditches on the Little Thompson River that receive C-BT Project water include Culver (Supply Lateral), Boulder-Larimer (Ish), Blower, Eagle, Osborne and Caywood, Rockwell, and Minor-Longan Ditches. Flows are discharged through facilities of the St. Vrain Supply Canal. A supply ditch from the St. Vrain River conveys water from this source into the Little Thompson drainage system. Flows in this ditch are generally used to irrigate areas to the south of the main-stem Little Thompson. Most of the time, summer flow in the Supply Ditch at the confluence with the main-stem Little Thompson is zero. The Supply Ditch occasionally discharges to the Little Thompson when Culver Ditch desires the flow. This practice is not common, however, because of the relatively high conveyance charge levied by the Supply Ditch. A comparable situation relates to the discharge of flows from the St. Vrain River to the Mead Lateral. Conveyance charges are relatively great; the practice is rare. In later summer the Little Thompson may dry up immediately below the Eglin Ditch diversion. Downstream ditches normally intercept water contributed by the City of Berthoud Wastewater Treatment Plant, canal waste, and agricultural return flow.

A gaging station formerly existed on the Little Thompson at the mouth near Milliken. Records are current through Water Year 1968 only. Typical flows at this location usually are on the order of 20 to 50 cfs. Smaller flows are often evident, especially in May.

3.2.2.3 Low Flow Hydrologic Analyses

Data representative of the surface water regimes of the Big and Little Thompson Rivers during low flow conditions are depicted in Tables 3.2.2-A and 3.2.2-B, respectively.

3.2.3 <u>St. Vrain Creek</u>

Characteristics of St. Vrain Creek during the irrigation season were obtained from Don Palmer, District Water Commissioner. Features of the drainage system are discussed herein.

St. Vrain Creek supports a large acreage of irrigated agriculture. Much of this acreage is in Boulder County. It should also be noted that most of the major diversions occur within Boulder County. Flows in the St. Vrain reach a minimum just before the Boulder-Weld county line. Summertime flows are typically 40 to 50 cfs at the Boulder-Weld county line. Lower reaches of the river in Weld County receive high volumes of return flow as seepage. Summer flows at Interstate Highway 25 are typically on the order of 20 cfs. At the mouth, summer flows are generally around 150 to 180 cfs.

TABLE 3.2.2-A. BIG THOMPSON RIVER - LOW-FLOW HYDROLOGIC ANALYSIS

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	63.0			50.2
35		Headwaters Flow	.0	
	58.4			50.2
166		Estes Park S.D.	0.8	
	56.8			51.0
167		Upper Thompson S.D.	1.6	
	42.0			52.6
36		Colorado Fish & Game-Drake	.0	
	41.9			52.6
37		North Fork Big Thompson	21.4	
	38.3			74.0
211		Tunnel No. 1	0.0	
	36.9			74.0
212		USBR Big T Releases	0.0	
	36.8			74.0
213		Handy Ditch	0.0	
	35.8			74.0
214		Loveland & Home Supply Ditch	-27.6	
	35.8			46.4
215		Return Flow	1.7	
	34.3			48.1
216		So. Side, Louden Ditches	-48.0	
	34.3			0.1
217		Return Flow	1.0	
	33.7			1.1
218		George Rist Ditch	.0	
	33.7			1.1
38		Return Flow	.0	
	33.2			1.1
Junction		Buckhorn Creek	7.6	

TABLE 3.2.2-A. BIG THOMPSON RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	33.2			8.7
99		Return Flow	.4	
	31.0			9.1
100		Dry Creek	.0	
	31.0			9.1
101		Return Flow	.0	
	30.6			9.1
102		Big Barnes Ditch	.0	
	30.6			9.1
103		Return Flow	.0	
	29.5			9.1
104		Rist & Goss Ditch	.0	
	29.5			9.1
105		Return Flow	.0	
	28.9			9.1
219		Mariano Outlet	.0	
	28.9			9.1
220		Return Flow	.0	
	28.5			9.1
221		Loveland & Greeley Canal	- 9.0	
	28.2			0.1
222		Big Thompson Ditch & Mfg.	.0	
	28.2			0.1
223		Return Flow	2.0	
	27.3			2.1
224		Ryan Gulch Lake Outlet	.0	
	27.1			2.1
225		Farmers Ditch	.0	
	27.1			2.1
226		Return Flow	1.0	

TABLE 3.2.2-A. BIG THOMPSON RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	26.7			3.1
168		Loveland No. 1 Plant	1.1	
	25.1			4.2
106		Loveland Packing	0.1	
	25.1			4.3
107		Return Flow	3.8	
	24.2			8.1
108		Loveland No. 2 Plant	5.4	
	24.2			13.5
109		Return Flow	3.6	
	22.5			17.1
110		Boyd Lake Outlet	.0	
	22.4			17.1
111		Return Flow	1.0	
	21.9			18.1
227		Hillsborough Ditch	-18.0	
	21.9			0.1
228 230		Return Flow Great Western - Loveland	4.0	
	20.0			4.1
169		Johnson's Corner	.0	
	16.7			4.1
112		Hill & Brush Ditch	.0	
	16.7			4.1
113		Return Flow	3.0	
	10.1			7.1
114		Big Thompson & So. Platte Ditch	- 7.0	
	10.1			0.1
115		Return Flow	1.0	
	8.0			1.1

TABLE 3.2.2-A. BIG THOMPSON RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
Junction		Little Thompson River	15.0	
	8.0			16.1
116		Milliken	0.2	
	7.8			16.3
117		Return Flow	7.7	
	2.0			24.0
229		Evans Ditch	-21.0	
	2.0			3.0
118		Return Flow	0.8	
	0.0			3.8

TABLE 3.2.2-B. LITTLE THOMPSON RIVER - LOW-FLOW HYDROLOGIC ANALYSIS

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	34.0			3.0
30		Headwater Flow	0.0	
	24.9			3.0
31		St. Vrain Supply Canal	53.5	
	24.5			56.5
32		Supply Lateral (Culver Ditch)	- 3.0	
	24.1			53.5
33		Supply Ditch from St. Vrain River	0.0	
	23.7			53.5
34		Culver Gulch	2.0	
	23.4			55.5
231		Boulder-Larimer Ditch (Ish)	-49.0	
	22.4			6.5
232		Blower Ditch	- 1.0	
	22.4			5.5
233		Return Flow	4.0	
	20.9			9.5
234		Eagle Ditch	0.0	
	20.9			9.5
235		Return Flow	3.0	
	19.3			12.5
236		Elgin Ditch	- 2.0	
	19.3			10.5
237		Return Flow	3.0	
	17.1			13.5
238		Osborne & Caywood Ditch	- 4.0	
	17.1			9.5
239		Return Flow	1.0	
	16.5			10.5
240		Dry Creek	2.0	

TABLE 3.2.2-B. LITTLE THOMPSON RIVER-
LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	16.0			12.5
170		Berthoud	0.7	
	16.0			13.2
241		Return Flow	3.3	
	15.3			16.5
242		Rockwell Ditch	- 4.0	
	15.3			12.5
243		Return Flow	4.0	
	12.7			16.5
244		Big Hollow	2.0	
	12.7			18.5
245		Return Flow	5.0	
	8.8			23.5
246		Minor-Longan Ditch	- 2.5	
	8.8			21.0
247		Return Flow	9.6	
	2.0			30.6
171		Great Western - Johnstown	6.4	
	1.5			37.0
248		Beeline Ditch	-25.0	
	1.3			12.0
172		Johnstown	0.5	
	1.3			12.5
173		Return Flow	2.5	
	0.0			15.0
		Big Thompson River		

Accretions to the river between Interstate 25 and the mouth are substantial, approximately 100 cfs. This corresponds to a seepage inflow rate of about 4 cfs per mile.

Several ditches divert water from St. Vrain Creek in Boulder County. The Bonus Ditch is the most downstream ditch in Boulder County. It nearly dries up the Creek. At the Boulder-Weld County Line, flows are typically 40 cfs during the irrigation season. Most of this is return flow and municipal wastewater from the city of Longmont. The latter component contributes approximately 20 cfs.

There are no diversions for a distance downstream of the county line. Dry Creek, Spring Gulch (Union Reservoir outlet) and Boulder Creek build up the flow in this area with irrigation returns. The Last Chance Ditch is the first ditch diverting water in Weld County. This is a fairly small ditch and does not significantly affect flow. The only other diversion is the Goose Quill Ditch which supplies Public Service Company. It is relatively small.

Most of the diversions from the St. Vrain are made in Boulder County. The creek collects return flow in Weld County, with only two small diversions.

The most significant tributaries to St. Vrain Creek and their typical flows are as follows:

Dry Creek	10 cfs
Spring Gulch	4 cfs
Boulder Creek	5 cfs
Lefthand Creek	20 cfs

Other tributary flows are much smaller than these, and these are thought to be the only tributaries discharging more than 1 or 2 cfs.

Seepage and inflow of the small tributaries accounts for over 100 cfs of inflow to the river over its length within the Larimer-Weld region. Non-point source accretions upstream from the City of Longmont in Boulder County are extremely minor when compared to those downstream.

Irrigation returns by far exceed other discharges in magnitude. Municipal and industrial returns are small in the Larimer-Weld region; however, significant waste discharges are made to the St. Vrain in Boulder County.

In Boulder County, the Longmont sewage treatment plant and Great Western, Longmont, both contribute large flows. In Weld County, dischargers include Erie Sanitation District, Tri-Area Sanitation District, and Public Service-Ft. St. Vrain. These sources represent slightly more than 5 cfs, with Public Service-Ft. St. Vrain contributing nearly 88 percent of this total. Irrigation return flow is by far the largest return of water to the creek.

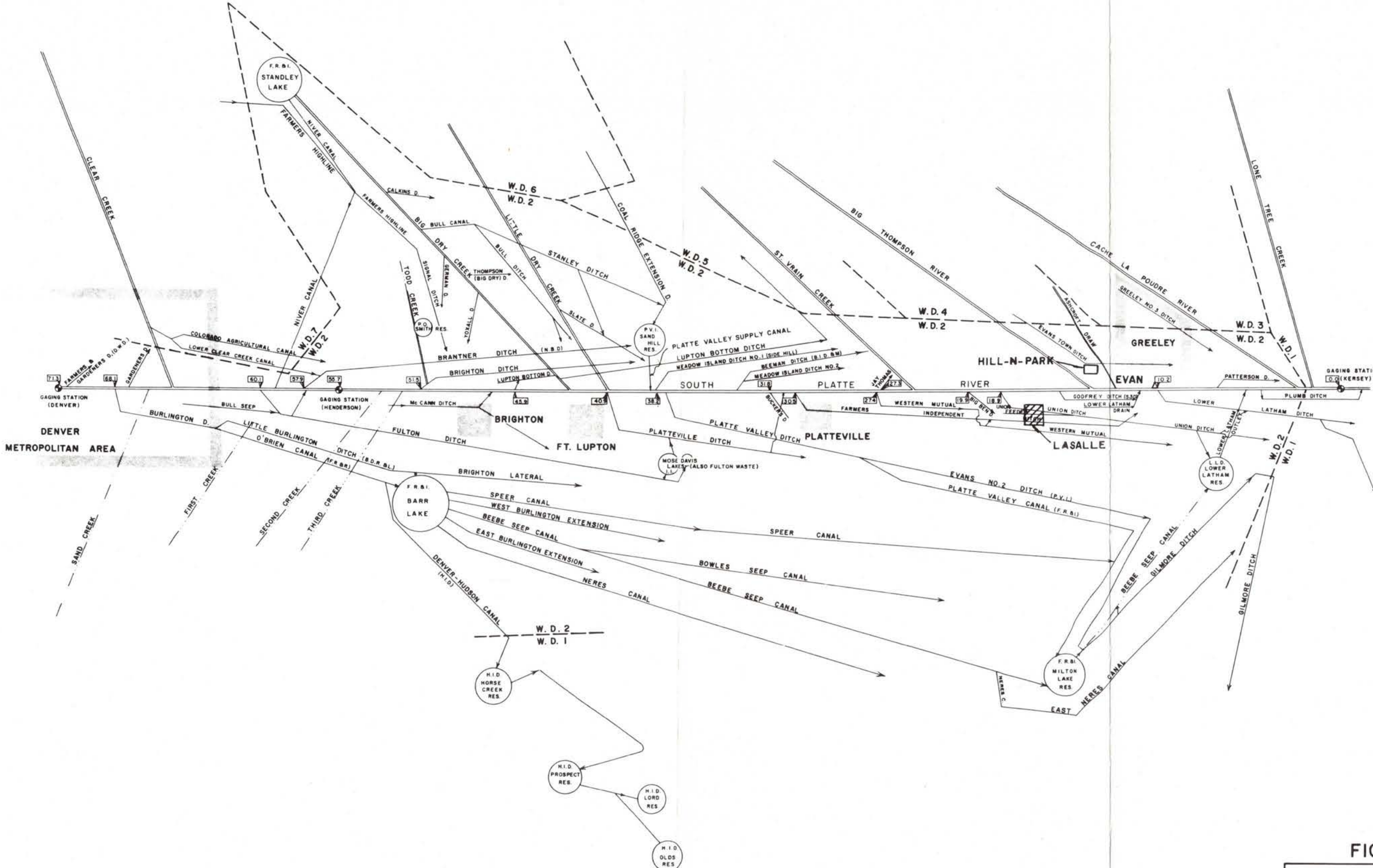
3.2.3.1 Low Flow Hydrologic Analyses

Flows in St. Vrain Creek were not specifically evaluated during conditions of low flow. This relates to the fact that hydrology of the river in the reach within Larimer-Weld would not be significantly altered over what generally occurs during a typical irrigation season. The bulk of river flow is the result of accretions from seepage in Larimer and Weld Counties, and municipal discharge from Longmont in Boulder County. Ditches are few in number in the two-county area, and volumes diverted are inconsequential with respect to total river flow. Only two dischargers contribute domestic wastes, and only in comparatively minor quantities.

3.2.4 South Platte River

Management of flows in the portion of the South Platte River system within the Larimer and Weld study area is within the jurisdiction of Water District Nos. 1 and 2 Commissioners. Upstream influences on the river determine to a large degree the character of flows tributary to the two-county area. Significant impacts include the municipal discharge of regional wastewater treatment plants and regulated releases by water resources development facilities.

Hydrologic characteristics of the South Platte River during the irrigation season will be briefly described herein. Streamflow conditions to a large degree are the result of management practices implemented by the water commissioners for Districts No. 1 and No. 2. These positions are held, respectively, by Mr. Bob Samples and Mr. Paul Meehl (Figure 3.2-C).



55.7 FLAGS INDICATE RIVER MILES FROM DOWNSTREAM GAGING STATION

OWNERSHIP INDEX

B.D.R.&L.	-	BURLINGTON DITCH, RESERVOIR & LAND CO.
B.I.D.&M.	-	BEEMAN IRRIGATING DITCH & MILLING CO.
D.W.D.	-	DENVER WATER DEPARTMENT
F.R.&I.	-	FARMERS RESERVOIR & IRRIGATION CO.
H.I.D.	-	HENRYLYN IRRIGATION DISTRICT
I.I.	-	IONE INVESTMENT CO.
L.L.D.	-	LOWER LATHAM DITCH CO.
N.B.D.	-	NEW BRANTNER DITCH CO.
P.I.&M.	-	PLATTEVILLE IRRIGATION & MILLING CO.
P.V.I.	-	PLATTE VALLEY IRRIGATION CO.
S.3D.	-	SECTION 3 DITCH CO.

FIG. **3.2-C**

DITCH AND RESERVOIR SYSTEMS

S. PLATTE RIVER

Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1968

Satisfaction of diversion requirements along the South Platte does not utilize the complex system of exchange to the degree that characterizes the Cache la Poudre, and to a lesser extent, the Thompson drainages. Exchange is employed chiefly in Water District No. 1 through use of releases from Prewitt Reservoir. Within Larimer and Weld Counties, the main-stem South Platte is replenished by seepage, returns, discharges, storage releases, and tributary inflow. The physical nature of the system has evolved a river management policy whereby ditch demands are usually met with direct main-stem flows delivered to a canal headgate. Hydraulic continuity among various ditches does not exist to the degree found in other stream systems of the region.

In its reach through Larimer and Weld Counties, the South Platte may be dry immediately downstream from at least five ditches:

- Jay Thomas Ditch;
- Union Ditch;
- Highland Canal (Plumb Ditch);
- Bijou Ditch;
- Weldon Valley Canal.

It is of interest to note that these diversions respectively are situated at points upstream from significant sources of river inflow:

- St. Vrain Creek;
- Big Thompson River;
- Cache la Poudre River;
- Seepage Canal/Illinois Wasteway;
- Jackson Lake Outlet.

Because of its impact on surface water hydrology within the Larimer-Weld region, the upstream character of the South Platte will be highlighted. The nature of water supply and disposal in reaches upstream and downstream from the region will be reviewed in order to provide data necessary to relate low flow stream hydrology to stream gaging stations in Adams and Morgan Counties.

The main-stem South Platte River downstream from the confluence with the North Fork has recently become subject to regulation by Chatfield Reservoir. This facility, with an intended pool of 20,000 acre-feet, equalizes inflow to Water District No. 2. Initial operation of the water resources development project occurred in 1976.

Cherry Creek is a major tributary to the South Platte River in its reach through Denver. Flows in the creek are regulated by Cherry Creek Reservoir. Significant uncontrolled natural runoff is contributed to the upstream portion of Water District No. 2 by Clear Creek.

The storage season in Water Districts No. 1 and No. 2 usually encompass the period from September 25 to the end of April. Major irrigation ditches in District No. 2 may begin operation anytime during April, but generally become active by about mid-month. Downstream from the Platteville Ditch, District No. 2 irrigators tend to start up a little later in the season. Irrigators in District No. 1 usually start up several weeks earlier than do those in District No. 2.

A gaging station on the South Platte River at Henderson provides a record of main-stem flow upstream from the Weld County Line. Second and Third Creeks are significant natural drainages in this reach of the South Platte. Flows in these watercourses are intercepted by O'Brian Canal, Little Burlington Ditch, and Fulton Ditch. In addition, Third Creek provides source water for McCann Ditch. Contributions to the South Platte by Second and Third Creeks consist of canal waste and returns collected in reaches downstream from the ditch crossings. Flows are generally on the order of 5 cfs.

Todd Creek does not convey flows directly to the South Platte River. Rather, creek flows discharge to Brighton Ditch about a half-mile downstream from the flumed Brantner Ditch overcrossing. During the irrigation season, Todd Creek collects seepage from upstream reservoirs. Flows to Brighton Ditch are generally small, less than about 1 cfs.

Brighton Ditch utilizes a diversion procedure typical of many ditches served by the South Platte. Volume of water acquired at the headgate is actually greater than that intended for use. Ditch operation involves returning a portion of the diverted flow to the main-stem South Platte through a wasteway located about a mile downstream. This practice ensures the irrigator of receiving flow at a desired rate. The wasteway discharge allows fine adjustment to be made on the volume of diverted flow. The water commissioner's records of the Brighton Ditch diversion represents the difference between the sum of headgate and Todd Creek flows and the wasteway return. A weir on Brighton Ditch is sited downstream from the Todd Creek confluence.

Fluctuations in the effluent volume released by the Denver Metropolitan Sanitation District's No. 1 treatment facility are evident through the reach of the South Platte downstream to the confluence with the St. Vrain Creek. Affected ditches often rely on a method of diversion comparable to that used by Brighton Ditch to guarantee acquisition of desired flow. An elapse of about one-half day occurs before fluctuations in the municipal discharge are apparent at Brighton Ditch.

McCann Ditch collects seepage, canal waste, and agricultural returns. Discharge to the South Platte from this ditch is on the order of 3 cfs.

Big Dry Creek supplies several ditches upstream from its confluence with the South Platte. Inflow tributary to the creek below the Yoxall Ditch diversion contributes from 8 to 10 cfs to the main-stem South Platte. Brantner and Brighton Ditches are flumed over the creek and thus do not intercept it. Lupton Bottom Ditch shares a common channel with Big Dry Creek for slightly over a mile. The two watercourses then separate once again. A diversion structure on the ditch at this junction ensures that native flow will be returned to Big Dry Creek. In a similar manner, Little Dry Creek commingles for a short distance in a common channel with flows conveyed by Meadow Island No. 1 Ditch. Headgates at the point of divergence reapportion flows to their respective channels. Little Dry Creek collects canal waste from Bull and Brantner Ditches. Although it can occasionally be dried up at Slate Ditch, the creek usually discharges from 8 to 10 cfs to the South Platte River during the irrigation season.

The Platte Valley Supply Canal is the outlet channel for Coal Ridge Reservoir (Sand Hill Reservoir). This facility is an impoundment for C-BT Project water delivered to the South Platte from Boulder Creek via Coal Ridge Extension Ditch. Project water discharged to the main-stem is subsequently picked up by Platte Valley Ditch and conveyed to Evans No. 2 (English) Ditch. Reservoir release and diversion by Evans No. 2 generally correlate 1 to 1.

Operation of Bucker's Ditch was discontinued several decades ago. No diversions occur at this location.

A wasteway exists on Platteville Ditch. Flows returned to the South Platte from this source are relatively small, on the order of a few cfs.

Western Ditch is a major diversion in the reach of the South Platte upstream from St. Vrain Creek. The ditch is equipped with a self-regulating headgate designed to maintain inflow at a constant predetermined volume despite fluctuating river conditions.

During the irrigation season, typical system operating practice dries up the South Platte River immediately below the Jay Thomas Ditch. Diversions at this location range from 2 to 9 cfs, but are generally about 4 to 8 cfs. Management policy requires that river water be maintained in the reach of the South Platte up to Western and Jay Thomas Ditches.

Big Bend is a relatively small ditch on the South Platte downstream from the confluence with St. Vrain Creek. The diversion structure is vulnerable to flood damage. The ditch hasn't been used for several years as a result of an especially severe washout occurrence. Almost all water rights to the ditch have now been transferred to groundwater wells. Rights of one owner were transferred to Union Ditch. Only a single individual currently possesses ditch rights in Big Bend. However, water cannot be transported because of the deteriorated ditch condition.

Union Ditch almost always dries up flow in the South Platte during late summer. Flows intended for Godfrey (Section No. 3) Ditch are generally diverted at the Union Ditch headgate and subsequently delivered to Godfrey through a turnout channel. Facilities also exist for delivering river water through Union Ditch to the Lower Latham Reservoir outlet from which it can be reintroduced to the river to satisfy Plumb Ditch.

Godfrey Ditch and Lower Latham Ditch contribute a significant flow of canal waste to the South Platte. Usual range of flow is 16 to 24 cfs. This channel originally discharged directly to Lower Latham Ditch. Under present operating practice, flows are introduced to the South Platte River upstream from the Lower Latham headgate and the ditch is credited with this volume of water.

Ashcroft Draw collects seep, runoff, and returns. Flow conveyed to the South Platte is approximately 2 cfs.

Diversions by Lower Latham Ditch are usually substantial. In the latter part of the irrigation season, the river is often dry immediately downstream from the Lower Latham headgate. Recharge to the river reach upstream from the ditch is significant. At times during the irrigation season, accretions may exceed diversion requirements. Flows thus remain in the river past the Lower Latham Ditch diversion.

Headgate requirements at Patterson Ditch and Plumb Ditch (Highland Canal) are satisfied by river inflow, seep, and agricultural returns. Use by these ditches may exhaust the river upstream from the confluence with the Cache la Poudre River.

Lone Tree and Crow Creeks are important drainage channels through which canal waste, seep, and agricultural returns are conveyed to the South Platte. Flows are variable, depending upon upstream irrigation practice. Reduced activity on weekends causes flow to drop sharply. During typical weekday summer conditions, flow in each of the two creeks ranges upward to 20 or 30 cfs.

Plumb Ditch (Highland Canal) possesses two wasteways to the main-stem South Platte. The return most utilized during the irrigation season is located about 1000 feet west of the Kersey bridge. Excess flow discharges to the South Platte through Sterling Seep and Draw. A supplemental wasteway, less frequently used, is situated an additional 1000 feet to the west. Volume wasted is on the order of 10 cfs.

Illinois Canal diverts water from the Riverside Intake Canal about one mile east of the latter's headgate on the South Platte. Seepage Canal parallels the Riverside Intake Canal for a portion of its length, and serves to collect waste and drainage from Seventy Ranch. In its downstream reach, Seepage Canal intercepts the Illinois Wasteway. Contributions by Seepage Canal average 10 cfs or less; those of the wasteway are usually on the order of 1 cfs. Flows commingle and discharge to the South Platte.

Bijou Canal is one of the few ditches in this reach of the South Platte that usually diverts a portion of its flow on an exchange basis. Excess river flows acquired by Bijou Canal are replenished to the South Platte system by regulated releases from Bijou No. 2 Reservoir, Jackson Lake, or Prewitt Reservoir. Bijou Canal diversions generally exhaust the river.

The outlet from Riverside Reservoir extends southerly about one-half mile to a point where it diverges into two separate channels. River Canal takes off in an easterly direction. Day Seep Ditch (Schultz Ditch) branches to the southwest and west. The ditch discharges about 12 cfs of seepage to the South Platte. Inflow from the South Side Drain occurs about one mile downstream from the intersection of Day Seep and the South Platte. This drain contributes approximately 2 cfs to the main-stem.

Penfold Seep and Putnam Seep collect drainage and waste generated in the area between Empire Reservoir/Bijou Canal and the South Platte. Accretions to the river from these two seeps are on the order of 2 cfs and 10 cfs, respectively.

Many small tributaries and seeps discharge to the South Platte in its reach between the Orchard Bridge and the Jackson Lake Outlet. Measurement of returns in this reach have identified inflow ranging to about 28 cfs. Milliron Draw is an important established drainage in this section of the river. Inflow from Kiowa Creek is negligible.

Weldon Valley Canal is a major point of diversion. When the ditch is operating, the South Platte is often spent immediately below the headgate.

In addition to releases from storage channelled through the Jackson Lake Outlet, seepage on the order of 2 to 3 cfs is tributary to the canal. Storage releases satisfy requirements at the Fort Morgan Canal and frequently supplement diversions of the Upper Platte & Beaver, Denver & Snyder, and Lower Platte & Beaver Ditches.

The Weldon Valley/Jackson Lake Seep contributes about 8 cfs to the main-stem South Platte approximately one-half mile upstream from the Fort Morgan Canal headgate. A number of other drains and seeps are found in the reach of the South Platte downstream to the Weldona gaging station at the Narrows near the Highway 144 bridge crossing. These include Tile Seep and Schaefer Seep, which generate about 2 cfs each, and a seep which discharges below the Weldona Bridge. The latter drain conveys about 8 cfs to the South Platte.

3.2.4.1 Low Flow Hydrologic Analysis

Low flow characteristics of the South Platte are presented in Table 3.2.4-A.

TABLE 3.2.4-A. SOUTH PLATTE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
	295.3			73.1
1		Brighton	4.0	
	295.3			77.1
2		Runoff	5.0	
	293.1			82.1
3		McCann Ditch Wasteway	3.0	
	293.1			85.1
4		Runoff	4.0	
	291.6			89.1
5		Lupton Bottom Ditch	-48.0	
	291.6			41.1
7		Runoff	9.0	
	288.6			50.1
Junction		Big Dry Creek	10.0	
	288.6			60.1
57		USGS Gage	0.0	
	287.6			60.1
7		Fort Lupton	2.0	
	287.6			62.1
58		Runoff	1.0	
	286.6			63.1
59		Platteville Ditch	-45.0	
	286.6			18.1
60		Runoff	6.0	
	284.1			24.1
61		Platte Valley Supply Canal	120.0	
	284.1			144.1
62		Runoff	2.0	
	283.9			146.1
63		Meadow Island No. 1 Ditch	- 8.0	
	283.3			138.1

TABLE 3.2.4-A. SOUTH PLATTE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
64		Evans No. 2 Ditch	-120.0	
	283.3			18.1
65		Runoff	7.0	
	280.8			25.1
66		Little Dry Creek	8.0	
	280.8			33.1
67		Runoff	3.0	
	279.4			36.1
68		Meadow Island No. 2 & Beeman Ditch	0.0	
	279.4			36.1
69		Runoff	2.0	
	278.0			38.1
70		Platteville Ditch Wasteway	2.0	
	278.0			40.1
71		Runoff	5.0	
	276.2			45.1
151		Farmers Independent Ditch	- 40.0	
	276.2			5.1
249		Runoff	10.0	
	275.0			15.1
250		Platteville (no discharge)	0.0	
	273.0			15.1
251		Western Mutual	0.0	
	273.0			15.1
252		Jay Thomas	- 15.0	
	273.0			0.1
72		Runoff	20.0	
	270.0			20.1

TABLE 3.2.4-A. SOUTH PLATTE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
Junction		St. Vrain Creek	66.0	
	270.0			86.1
93		Public Service Co. - St. Vrain Plant	4.7	
	270.0			92.8
94		Runoff	21.3	
	265.6			114.1
95		Big Bend Ditch	- 3.0	
	265.6			111.1
96		Runoff	8.0	
	264.6			119.1
97		Union Ditch	119.0	
	261.5			0.1
253		Godfrey Ditch	0.0	
	261.5			0.1
98		Runoff	36.2	
	259.6			36.3
Junction		Big Thompson River	3.8	
	259.6			40.1
119		Runoff	3.0	
	258.3			43.1
120		Ashcroft Draw	2.0	
	258.3			45.1
121		Runoff	4.9	
	257.0			50.0
122		Hill-N-Park	0.1	
	256.5			50.1
123		Lower Latham Drain	16.0	
	256.5			66.1

TABLE 3.2.4-A. SOUTH PLATTE RIVER -
LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
124		Runoff	0.7	
	256.2			66.8
152		LaSalle	0.3	
	255.9			67.1
153		Lower Latham Ditch	- 60.0	
	255.9			7.1
154		Runoff	19.3	
	254.7			26.4
254		Evans	0.7	
	252.2			27.1
255		Patterson Ditch	- 20.0	
	252.2			7.1
256		Runoff	10.0	
	250.6			17.1
257		Lower Latham Reservoir Outlet	2.0	
	250.6			19.1
258		Runoff	5.0	
	249.8			24.1
259		Highland Canal	- 24.0	
	249.8			0.1
125		Runoff	5.0	
	247.7			5.1
Junction		Cache la Poudre	30.1	
	247.7			35.1
148		Runoff	6.0	
	247.0			41.1
149		Lone Tree Creek	20.0	
	247.0			61.1
155		Greeley Eastern Plant	2.6	
	247.0			63.7

TABLE 3.2.4-A. SOUTH PLATTE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
156		Runoff	1.4	
	245.5			65.1
260		Plumb Seep & Drain Ditch	3.0	
	245.5			68.1
261		Runoff	1.0	
	243.3			69.1
262		Kersey	0.0	
	242.9			69.1
263		Hoover Ditch	0.0	
	242.9			69.1
264		Runoff	1.0	
	240.6			70.1
265		Crow Creek	10.0	
	240.6			80.1
266		Runoff	0.0	
	239.8			80.1
267		Empire Intake Canal	0.0	
	239.8			80.1
268		Runoff	0.0	
	238.9			80.1
269		Riverside Intake Canal/ Illinois	- 12.0	
	238.9			68.1
270		Runoff	2.0	
	231.8			70.1
271		Bijou Ditch	- 70.0	
	230.8			0.1
272		Seepage Canal & Illinois Wasteway	11.0	
	230.8			11.1
273		Runoff	10.0	
	226.4			21.1

TABLE 3.2.4-A. SOUTH PLATTE RIVER - LOW-FLOW HYDROLOGIC ANALYSIS (Cont.)

REACH	RIVER MILE	DESCRIPTION	AMOUNT (cfs)	STREAM FLOW (cfs)
274		Day Seep Ditch	12.0	
	226.4			33.1
275		Runoff	3.0	
	225.5			36.1
276		Southside Drain	2.0	
	225.5			38.1
277		Runoff	3.0	
	224.5			41.1
278		Jackson Lake Inlet	0.0	
	224.5			41.1
279		Runoff	15.0	
	219.9			56.1
280		Penfold Seep	2.0	
	219.9			58.1
281		Runoff	2.0	
	219.3			60.1
150		Weldon Valley Canal	0.0	
	218.7			60.1

4.0 MODEL RECALIBRATION

Pioneer I was originally calibrated when the model was first developed. However, considerable improvement in the model was necessary before it could be applied in 208 Water Quality Management Planning in Larimer and Weld Counties. As a result, Pioneer I was recalibrated for critical segments in the two-county area to increase the model's accuracy. As part of the recalibration, the tasks performed included: review and application of information; the location and quantification of stream diversions and return flows; the application of water quality information on municipal and industrial discharges; water quality sampling along critical stream segments and of major discharges; and development of criteria for model recalibration.

The water quality and quantity data for the sampled streams provide a basis for comparing model output to actual field conditions for model calibration. The sampling/calibration period (August 31-September 3, 1976) is representative of critical late summer conditions in the study area when stream flows are low and stream temperatures relatively high. These conditions result in the highest rate of oxidation of carbonaceous and nitrogeneous BOD, causing the most rapid lowering of dissolved oxygen levels in the streams.

4.1 SCOPE OF RECALIBRATION

The Cache la Poudre, Big Thompson, and Little Thompson Rivers are the most critical streams in terms of water quality problems due to point source discharges in the study area. Other streams such as the South Platte River, St. Vrain Creek and Coal Creek are less critical primarily since wasteloads from point source discharges such as municipal treatment facilities are relatively minor and do not greatly impact water quality of those streams. However, it should be noted that as a result of the disasterous flood in the Big Thompson River in late July, 1976, streamflows in that river were abnormally high during the period of sampling and modeling. As a result, recalibration efforts were limited to the three critical streams in the study area: the Cache la Poudre, Big Thompson, and Little Thompson Rivers. The original Pioneer I calibration on the remaining streams in the model was deemed sufficiently accurate in light of the limited water quality problems due to point source discharges to those streams.

Primary emphasis of the recalibration effort in terms of water quality parameters was placed on the accurate representation of dissolved oxygen, BOD, and ammonia and nitrate nitrogen. These parameters are most critical of those which can be accurately modeled by Pioneer I in terms of water quality in the study area. Less importance was placed on fecal coliform and total dissolved solids. As previously discussed, suspended solids and pH were not modeled since Pioneer I does not have the capability to accurately model those parameters. Residual chlorine has not been included since the sampling program revealed negligible concentrations in both discharges and stream samples (Table 4.1-A).

4.2 RECALIBRATION RESULTS

Recalibration of Pioneer I for the Cache la Poudre, Big Thompson, and Little Thompson Rivers was performed following a basic algorithm. Hydrologic data on stream flow, stream diversions, inflows, return flows, and discharges previously characterized for the sampling/modeling period were utilized as fixed input to the model. The water quality of each return flow and discharge, along with the headwaters of each river, was characterized either from data collected during the sampling program or from other analyses, and utilized as fixed input to the model. Model output obtained by utilizing a given set of water quality coefficients was then compared with field data of actual stream conditions obtained during the sampling program. The water quality coefficients were then adjusted within the pre-determined allowable range of values indicated in Table 2.2-A and resultant model output re-checked with the field data. The coefficients were continually adjusted until the model output which most closely matched the field data was obtained. Presented in Table 4.2-A are the water quality coefficients determined to provide the best fit of model output to the collected field data and therefore utilized in the recalibrated model. The result of the recalibration for each of the three rivers is discussed in the following sections.

4.2.1 Cache la Poudre River

The Cache la Poudre River is modeled by Pioneer I from above river mile 87 to its confluence with the South Platte River. Major dischargers to the river include Fort Collins No. 1 and No. 2, Boxelder S.D., Windsor, Kodak, and Greeley. Boxelder Creek flows into the Cache la Poudre downstream of the city of Fort Collins. Analysis of water quality samples taken during the sampling program reveals the following trends in water quality. The dissolved oxygen levels generally decline from

TABLE 4.1.-A WATER QUALITY DATA OF LARIMER-WELD RIVERS

Sample Description	Site ID	River Mile	Sample Date (1976)	Flow (cfs)	BOD_5 (mg/l)	D.O. (mg/l)	Suspended Solids (mg/l)	Ammonia NH_3-N (mg/l)	Nitrate NO_3-N (mg/l)	Total Dissolved Solids (TDS) (mg/l)	Electro Conductivity (umhos/cont)	Temperature (OC)	PH	Residual Chlorine (mg/l)	Fecal Coliforms (mpn/100ml)
Cache la Poudre															
Linden St.Bridge	PR1	45.0	8/31	130	2	8.0	616	0.0	0.11	92	105	17.0	7.7	0.0	104
Hwy. 14 Bridge	PR2	44.0	8/31	97	4	8.2	21	1.35	0.22	188	240	16.5	7.3	0.0	390
Prospect Ave.Bridge	PR3	41.2	8/31	136	3	6.4	25	0.62	0.31	164	200	17.5	7.0	0.0	5500
Harmony Rd.Bridge	PR5	36.3	8/31	118	6	7.6	56	0.74	1.30	596	650	18.0	8.1	0.0	5200
Hwy. 257 Bridge	PR7	23.0	9/1	20	4	7.1	48	0.0	2.11	804	1125	15.5	7.5	0.0	480
Rd.S. of Bracewell	PR8	17.5	9/1	46	7	6.3	64	0.48	5.04	1272	1200	18.0	8.3	0.0	390
8th St. Bridge	PR10	4.7	9/1	68	4	7.2	89	0.0	4.77	1500	1450	20.0	7.2	0.0	160
Rd. 4½ near G.W. Greeley	PR11	4.4	9/1	55	16	6.8	72	1.12	5.96	1484	1300	21.0	7.4	0.1	220
Rd. 45 E.of Greeley	PR12	2.9	9/1	19	5	7.6	24	1.12	4.70	1356	1300	22.0	7.2	0.1	100
Big Thompson															
1st St. Loveland	BR1	27.5	9/2	110	2.0	8.1	8	0.0	0.12	88	185	14.0	6.5	0.0	34.0
Co.Rd. #9 E.of Loveland	BR2	23.5	9/2	92	5.0	6.8	62	0.0	0.35	300	325	17.0	7.4	0.1	70
Larimer-Weld Co.Line	BR3	16.5	9/2	56	3.0	7.2	72	0.0	0.69	492	375	17.0	7.3	0.0	--
Hwy. 257	BR4	8.2	9/2	35	3.0	6.6	84	0.0	1.39	728	850	22.0	7.3	0.0	520
Near Adna	BR5	5.5	9/2	84	2.0	7.8	106	0.0	2.45	1248	1250	21.0	7.6	0.0	380
Little Thompson															
Rd.17S. of Johnstown	LR8	4.0	9/2	36	2.0	7.4	164	0.0	3.2	2180	2000	16.5	6.9	0.1	520
Hwy. 257	LR10	1.0	9/2	39	3.0	8.8	200	0.0	3.2	1872	1750	17.0	8.1	0.0	1200
South Platte															
Hwy. 57 near Ft.Lupton	SPR1	288.2	9/3	303	10	6.2	6	3.24	3.50	660	825	17.5	7.4	0.0	410
Rd. 14 N.of Ft.Lupton	SPR2	285.0	9/3	207	12	7.0	63	2.56	4.05	636	850	19.0	7.0	0.0	390
Rd.28S.of Platteville	SPR3	278.5	9/3	175	4	7.3	10	2.48	0.78	584	750	20.0	7.4	0.0	100
Coal Creek															
Rd. 8 S.of Erie	S20	3.5	9/3	0.2	83	8.1	7	0.0	0.43	600	1150	20.0	8.0	0.0	150
Rd. Weld 6 Line Road	S21	1.8	9/3	1.8	22	6.8	22	0.66	0.45	884	1075	21.0	7.6	0.0	350

ABLE 4.1-B WATER QUALITY DATA OF LARIMER-WELD DISCHARGES

PARAMETER

Discharge	Flow (cfs)	(mg/1)	BOD (mg/1)	D.O. (mg/1)	Suspended Solids (mg/1)	NH_3-N (mg/1)	NO_3-N (mg/1)	TDS (mg/1)	EC (umhos/cm^2)	Temp. (OC)	PH	Res.Cl. (mg/1)	Fecal Coliforms (mpn/100 ml)
ort Collins No. 1	13.0	8.4	15	5.3	22	5.32	0.16	528	650	17.5	7.1	0.2	400
ort Collins No. 2	14.0	9.0	42	3.5	84	11.0	0.54	380	500	18.0	7.7	0.0	11,000
oxelder S.D.	0.7	0.45	24	5.5	36	11.3	0.34	1684	1650	19.0	7.6	0.0	1,550
indsor	-		19	4.5	124	47[a]	0.78	1152	1450	20.0	8.2	0.0	40
odak	2.2	1.4	14	6.5	24	48	17.8	1468	1625	21.5	7.1	0.0	120
reeley	14.0	9.0	37	3.8	44	7.4	3.64	508	675	21.0	7.1	0.2	900
oveland - Old	1.3	0.84	13.0	6.6	21	8.0	1.2	720	700	18.0	7.5	0.2	400
oveland - Now	5.0	3.23	22.0	7.2	26	12.8	0.8	800	1050	-	7.3	0.3	400
Johnstown	0.9	2.58	10.0	5.7	9	1.2	7.2	1036	1000	16.0	5.3	0.0	3,800
Great Western Johnstown	1.7	1.1	20.0	-	9	0.0	8.8	1644	1800	22.0	8.4	0.0	1,510
Milliken	0.3	0.2	8.0	4.0	7	8.3	0.23	1040	1150	20.0	7.0	0.2	20
Fort Lupton	2.0	1.3	23	6.2	92	1.23	0.01	1364	1840	19.0	8.6	0.0	6,100
Erie	0.1	0.06	58	7.4	80	6.05	0.14	740	550	21.5	8.4	0.0	3,800

a Weld County measured 9.3 mg/l.

TABLE 4.2.A SUMMARY OF CALIBRATED WATER QUALITY COEFFICIENTS

STREAM	STRETCH	WATER QUALITY COEFFICIENTS (Base e)											
		K_1 (day^{-1})	K_2 (day^{-1})	K_3 (day^{-1})	B_e (mg/m^2 day)	P (mg/1/ day)	K_{N_1} (day^{-1})	K_{N_2} (day^{-1})	K_{F_C} (day^{-1})	Θ COLI	Θ BEN	Θ BOD	Θ N
South Platte River	Weld County Line to Big Dry Creek	0.3	3.0	3.5	10	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
	Big Dry Creek to Cache la Poudre River	0.3	3.0	0.05	100	0	0.1	5.0	1.4	1.0	1.0	1.047	1.
	Cache la Poudre River to Weld County Line	0.3	3.0	0.05	0	0	0.1	5.0	1.4	1.0	1.0	1.047	1.
Big Thompson River	Headwaters to Loveland No. 2 Discharge	0.3	3.0	0.05	0	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
	Loveland #2 Discharge to Little Thompson River	0.3	3.0	0.05	200	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
	Little Thompson River to South Platte River	0.3	3.0	0.05	0	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
Little Thompson River	Headwaters to Big Thompson River	0.3	3.0	0.05	0	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
Buckhorn Creek	Headwaters to Big Thompson River	0.3	3.0	0.05	0	0	0.3	5.0	1.4	1.0	1.0	1.047	1.
Cache la Poudre River	Headwaters to South Platte River	0.5	3.0	0.05	0	0	0.4	5.0	1.4	1.0	1.0	1.047	1.
Boxelder Creek	Headwaters to Cache la Poudre River	0.5	3.0	0.05	0	0	0.4	5.0	1.4	1.0	1.0	1.047	1.

above 8.0 mg/l above Fort Collins No. 1 to around 7.0 mg/l near the river mouth. Distinct sags were noted below Fort Collins No. 2 (to 6.4 mg/l) and immediately below Greeley (to 6.8 mg/l). However, downstream recovery to above 7.0 mg/l for those two segments was achieved. BOD levels were noted to increase as a result of major discharges, including Fort Collins No. 1 (2.0 mg/l to 4.0 mg/l), Fort Collins No. 2 (3.0 mg/l to 6.0 mg/l), Windsor and Kodak (4.0 to 7.0 mg/l) and Greeley (4.0 to 16.0 mg/l). The quick reduction to 3.0 mg/l further downstream of Greeley is a result of dilutions from return flows in the Greeley No. 3 wasteway. These model recalibration results are shown in Figure 4.2.1-A. Ammonia nitrogen concentrations were noted to increase significantly downstream of Fort Collins No. 1 (0.0 mg/l to 1.35 mg/l), Windsor and Kodak (0.0 mg/l to 0.5 mg/l), and Greeley (0.0 mg/l to 1.1 mg/l). However, ammonia levels further downstream of the discharges were not detectible, indicating that the complete loss of ammonia was achieved by oxidation. Correspondingly, nitrate nitrogen levels consistently increase from above Fort Collins No. 1 (0.11 mg/l) to downstream of Greeley (nearly 6.0 mg/l). This consistent increase is a result of nitrate-rich irrigation return flows and the oxidation of ammonia from point sources to nitrate. The model recalibration results for both ammonia and nitrate are shown in Figure 4.2.1-B. TDS concentrations also consistently increase from 50 mg/l above Fort Collins No. 1 to 1,500 mg/l above Greeley. This increase is attributable to TDS loadings from irrigation return flows and point source discharges and is depicted in Figure 4.2.1-C. Fecal coliform concentrations were noted to increase dramatically downstream of the Fort Collins area and are shown in Figure 4.2.1-D. Increases were noted downstream of Fort Collins No. 1 (104 mpn/100 ml to 390 mpn/100 ml), Fort Collins No. 2 (to above 5,000 mpn/100 ml). Fecal coliform levels from above Windsor and Kodak to below Greeley remained fairly steady between 100 and 500 mpn/100 ml.

As indicated in Figures 4.2.1-A through D, a reasonably close fit was achieved for the various parameters. Several other combinations of coefficients were utilized; however, none achieved as close a fit overall. As indicated in Table 4.2-A, the best data fit was achieved with the following: K_1 = 0.5/day; B_e = 9.0 mg/m^2/day; K_{N_1} = 0.4/day; K_{FC} = 1.4/day; and the remaining coefficients indicated as constants in Table 2.2-A. A benthic oxygen demand was not utilized since a consistent sag in dissolved oxygen was not noted in the sampling program that could not be achieved just by oxidation of BOD and ammonia. Previous sections of this report note the apparent use of the benthic demand to "force-fit" model output for the Cache la Poudre to field data. This type of fit was not necessary for the recalibration because of the sufficient sag in dissolved oxygen otherwise achieved.

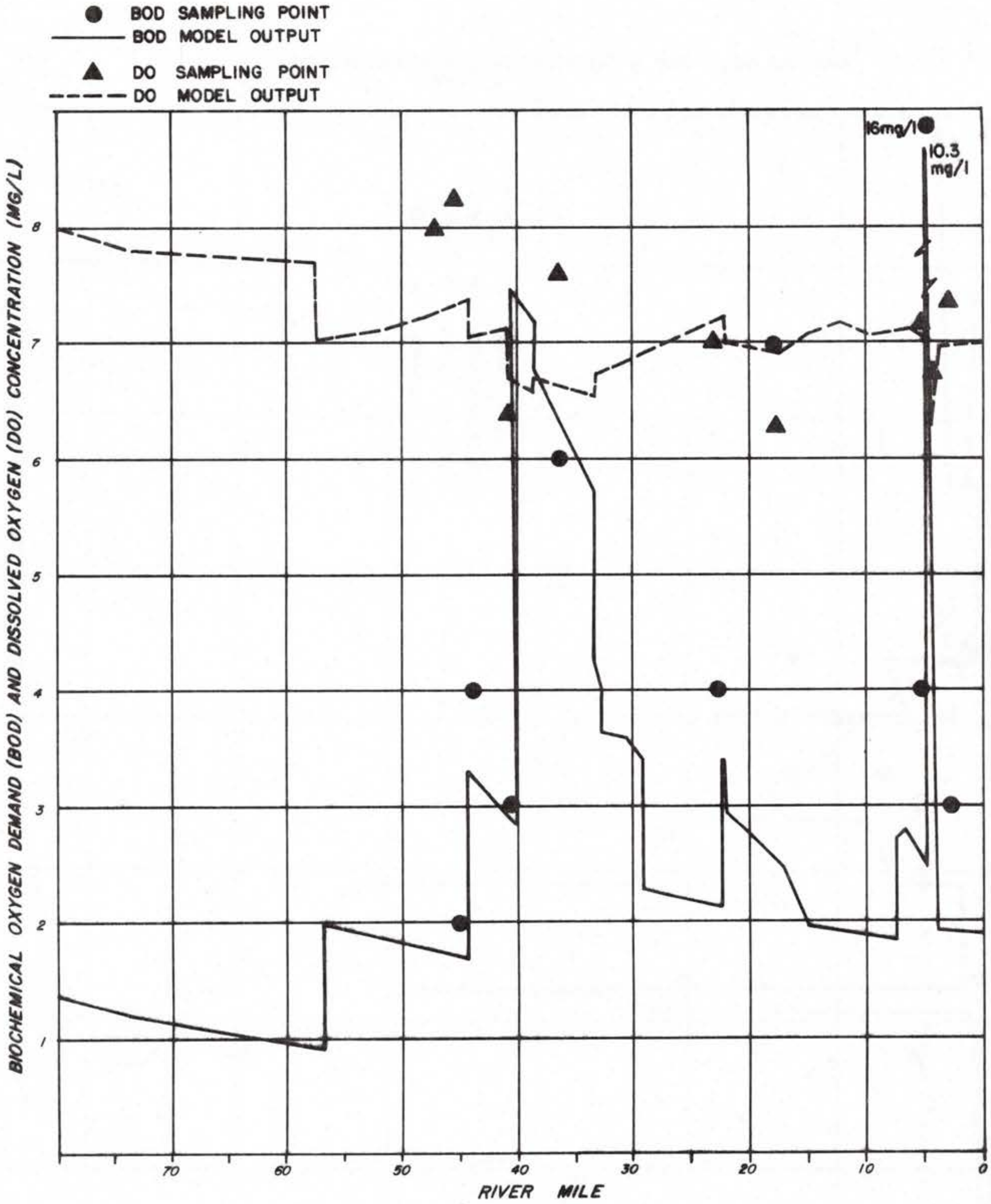


FIG. 4.2.1-A. MODEL RECALIBRATION RESULTS FOR CACHE LA POUDRE RIVER - DO AND BOD

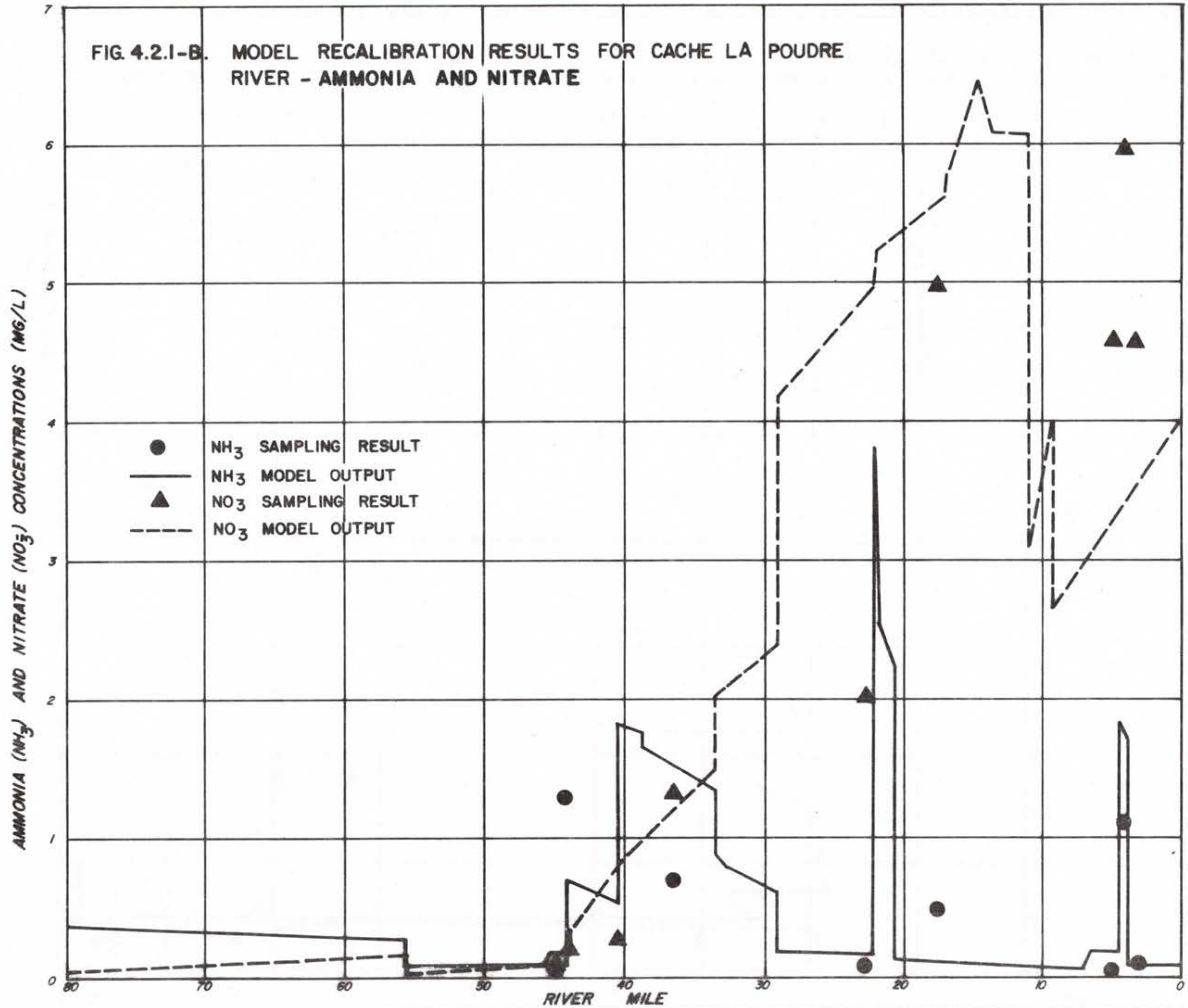


FIG. 4.2.1-B. MODEL RECALIBRATION RESULTS FOR CACHE LA POUDRE RIVER - AMMONIA AND NITRATE

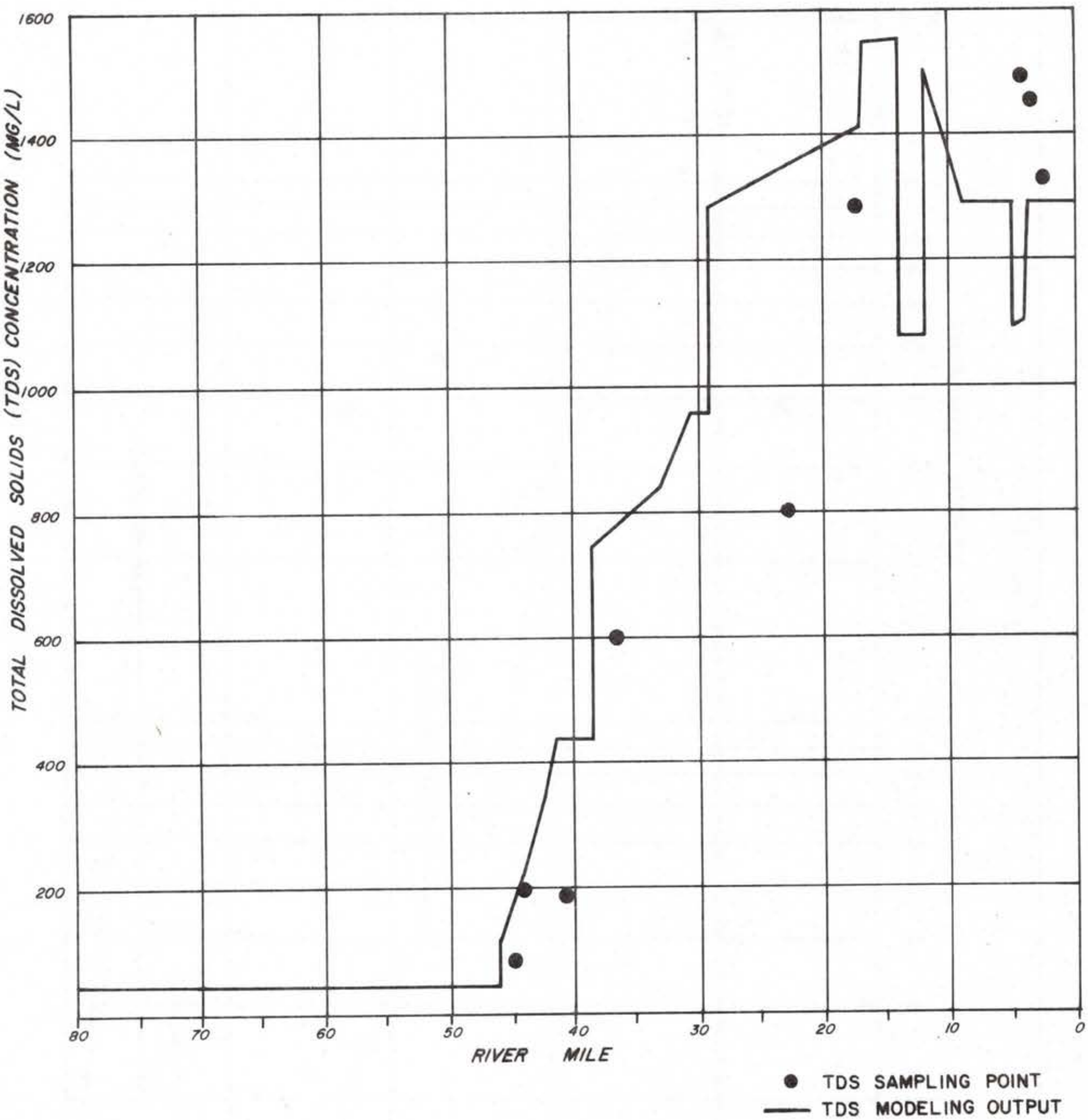


FIG. 4.2.1-C. MODEL RECALIBRATION RESULTS FOR CACHE LA POUDRE RIVER - TOTAL DISSOLVED SOLIDS

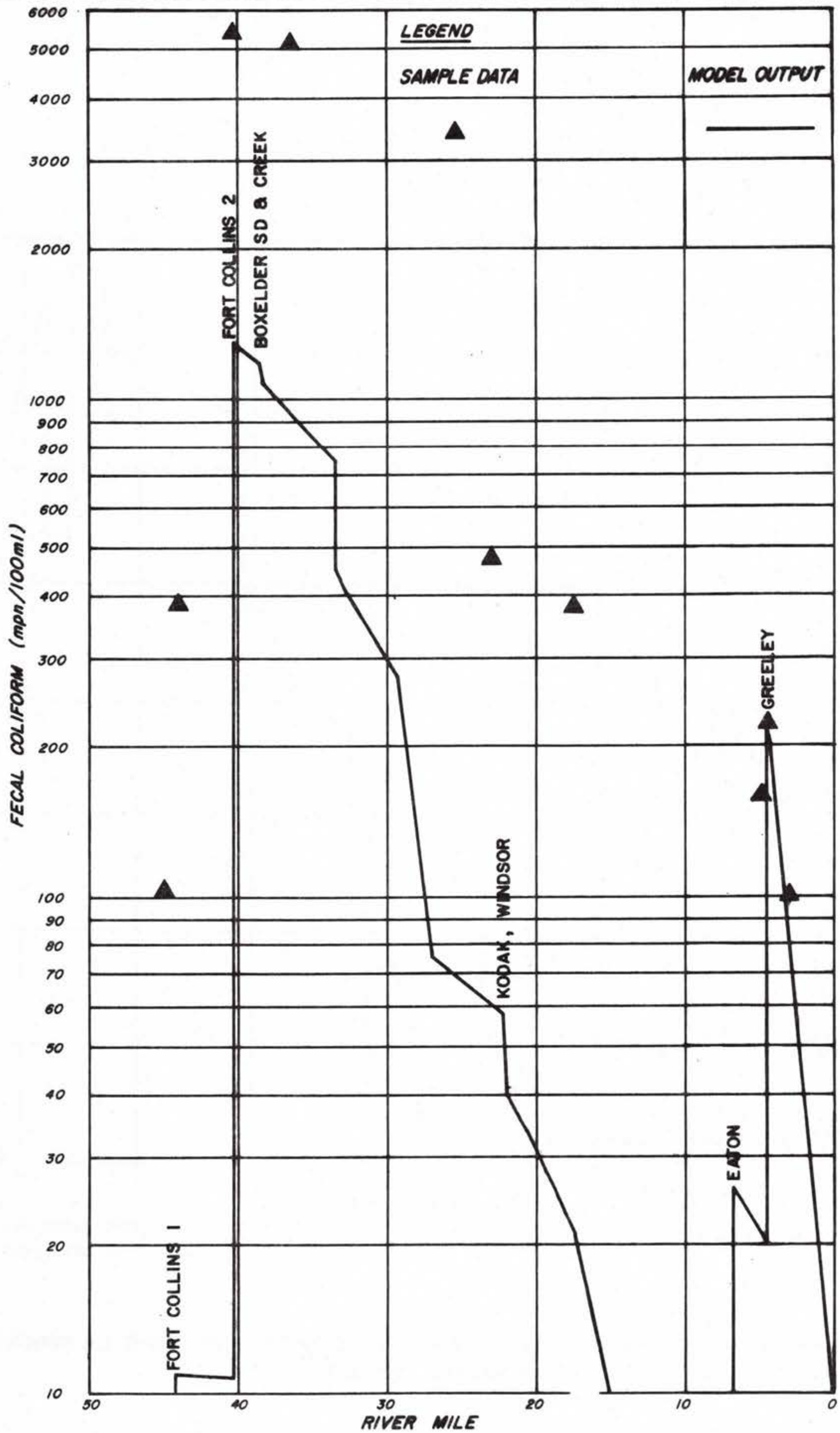


FIG. 4.2.1-D. MODEL RECALIBRATION RESULTS FOR FECAL COLIFORM - CACHE LA POUDRE RIVER

A close fit of model output for fecal coliform, however, was not achieved, except in the Greeley area of the river. Model output of the fecal coliform levels generally was significantly lower than the collected field data. This suggests that coliform loadings were underestimated upstream of and in the Fort Collins area. A larger data base would determine the extent of this error.

Although exact fits weren't indicated in the previous figures, model output generally conforms to the trends previously discussed. Given the limits on model accuracy due to limited scope of the recalibration, the recalibrated Pioneer I gives a reasonable picture of actual circumstances with the exception of fecal coliform, allowing for the use of the model for performing wasteload allocations on that stream (fecal coliforms excepted).

4.2.2 Big Thompson River

Pioneer I models the Big Thompson River from above Olympus Dam (river mile 63) to its confluence with the South Platte River. Major point source discharges in the Big Thompson at the time of the sampling program included Estes Park S.D., Upper Thompson S.D., Loveland No. 1 and No. 2, Great Western at Loveland, and Milliken. Also, Buckhorn Creek and the Little Thompson River flow into the Big Thompson. Field data collected during the sampling program on the Big Thompson revealed water quality characteristics somewhat similar to the Cache la Poudre River. Dissolved oxygen levels were noted above 8.0 mg/l upstream of the major discharges in Loveland with declines to less than 7.0 mg/l below those discharges, and a recovery to just below 8.0 mg/l downstream of the Little Thompson inflow. BOD levels increased from 2.0 mg/l to 5.0 mg/l downstream of the Loveland discharges and ultimately declined to 2.0 mg/l downstream of the Little Thompson. Dissolved oxygen and biochemical oxygen demand recalibration results are shown in Figure 4.2.2-A. Although no ammonia concentrations were detected during the sampling program, nitrate levels were noted to increase from near zero levels upstream of Loveland to almost 2.5 mg/l downstream of the Little Thompson. These recalibration results are shown in Figure 4.2.2-B. TDS concentrations were noted to increase rapidly along the same stretch, reaching over 1,200 mg/l downstream of the Little Thompson from a level of about 90 mg/l upstream of Loveland. Irrigation return flows are the major source of nitrate and TDS loadings on the river. Wastewater discharges also contribute to the increases of these constituents. Recalibration results for TDS are shown in Figure 4.2.2-C. Fecal coliform readings increased to 70 mpn/100 ml downstream of Loveland from an upstream level of 34 mpn/100 ml. Higher concentrations of 520 and 380 mpn/100 ml were noted immediately upstrean and downstream of the Little Thompson. These are shown in Figure 4.2.2-D.

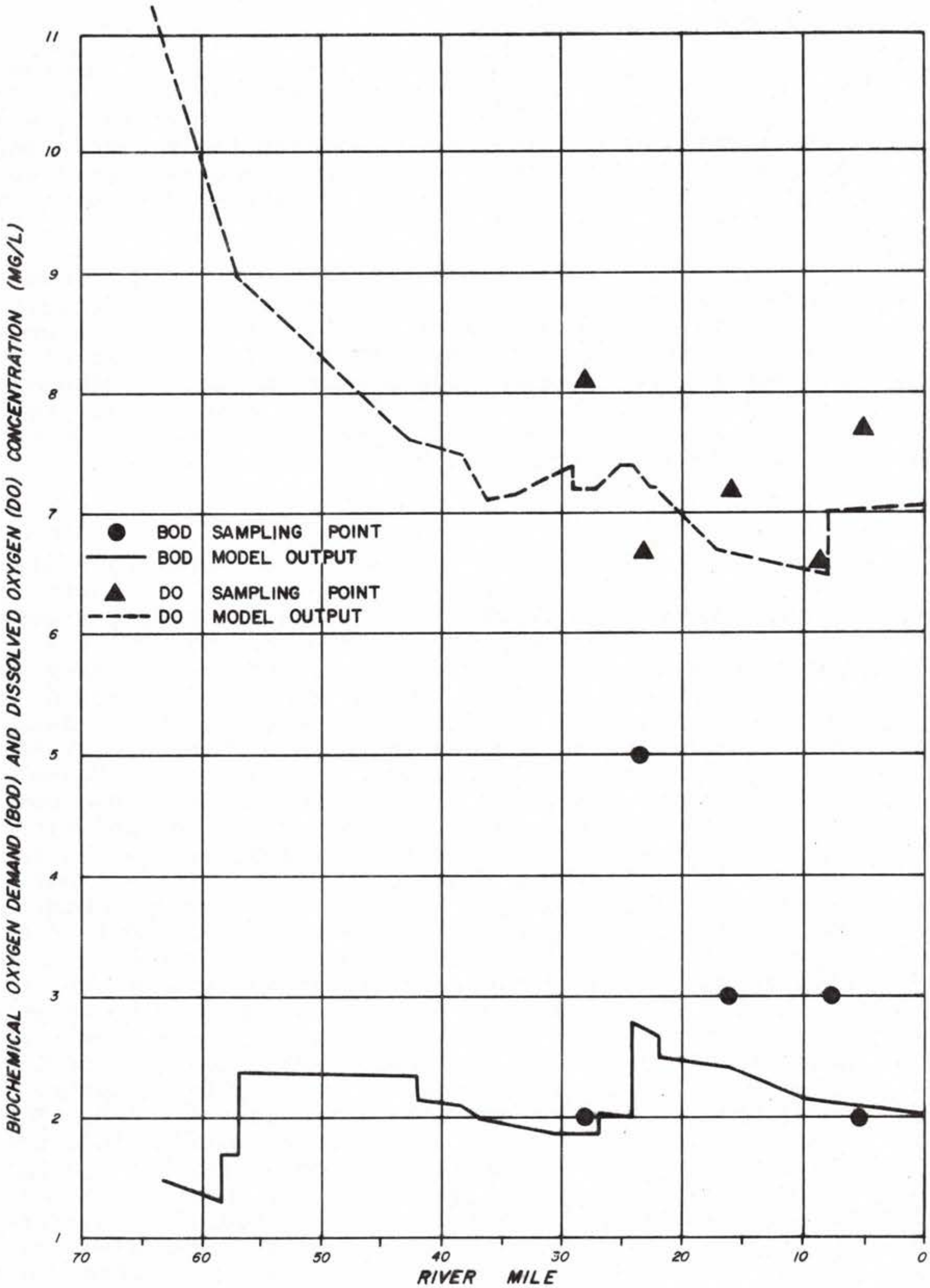


FIG. 4.2.2-A. MODEL RECALIBRATION RESULTS FOR BIG THOMPSON RIVER - DO AND BOD

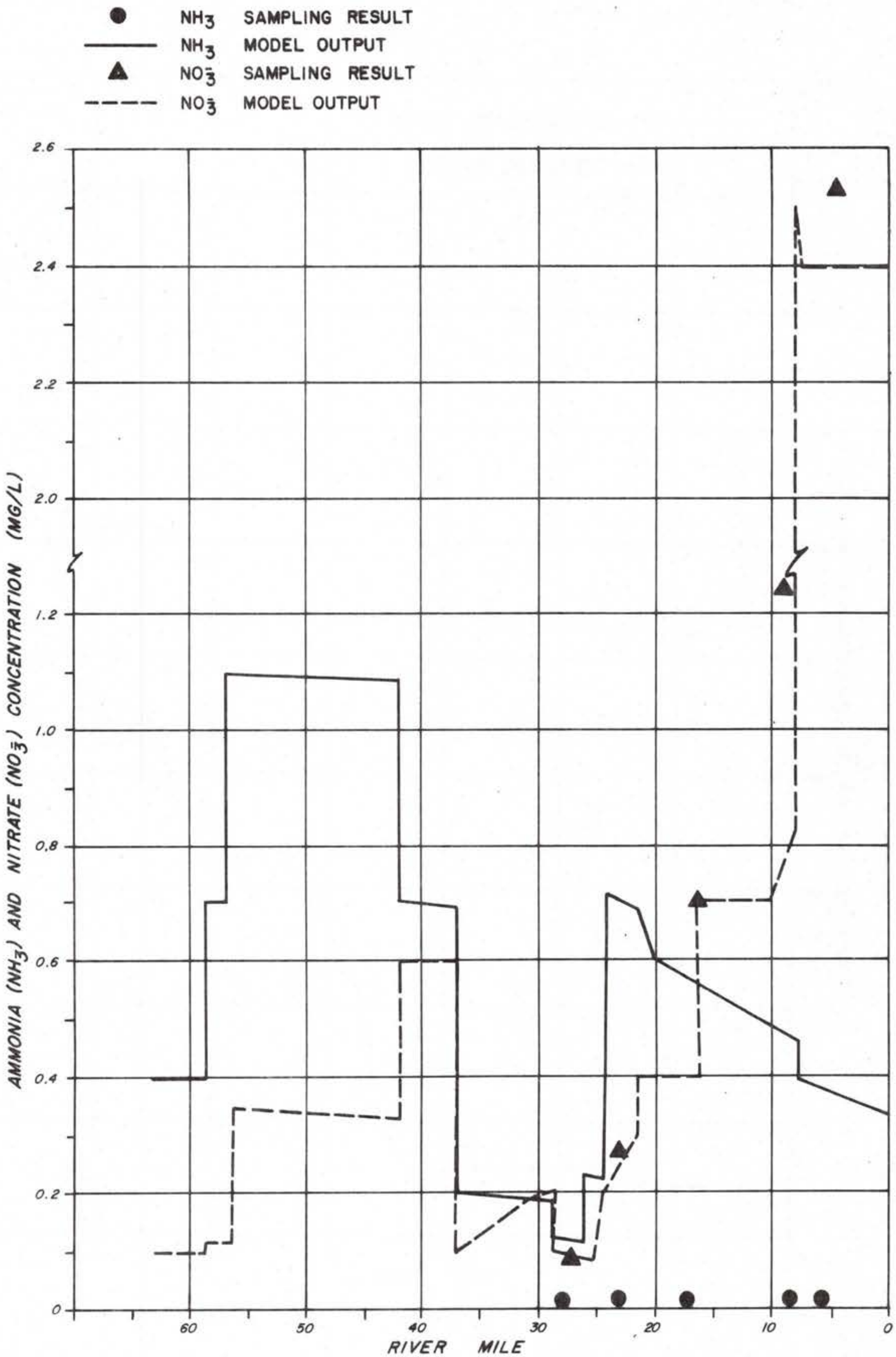


FIG. 4.2.2-B. MODEL RECALIBRATION RESULTS FOR BIG THOMPSON RIVER - AMMONIA AND NITRATE

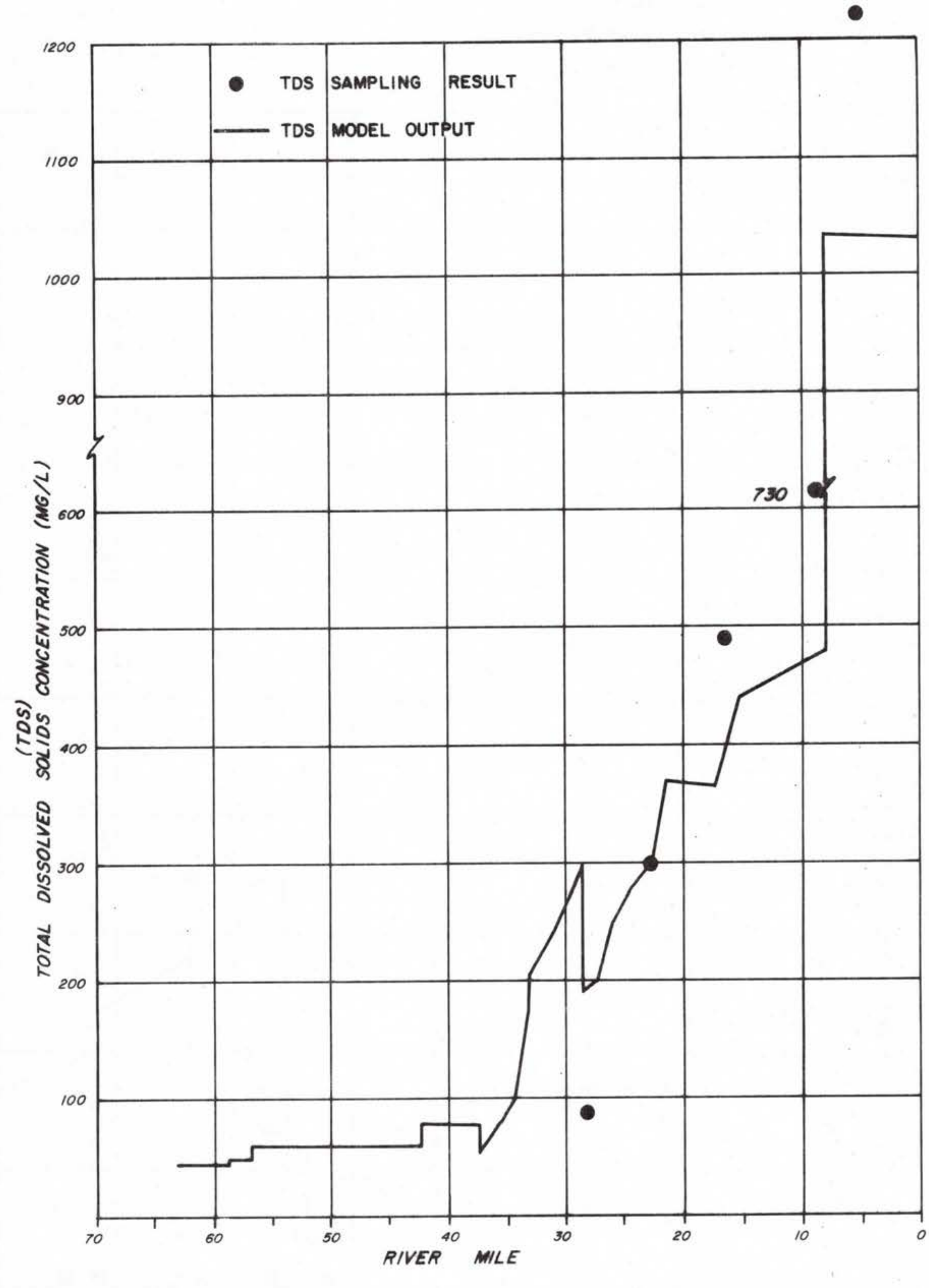


FIG. 4.2.2-C. MODEL RECALIBRATION RESULTS FOR BIG THOMPSON RIVER - TOTAL DISSOLVED SOLIDS

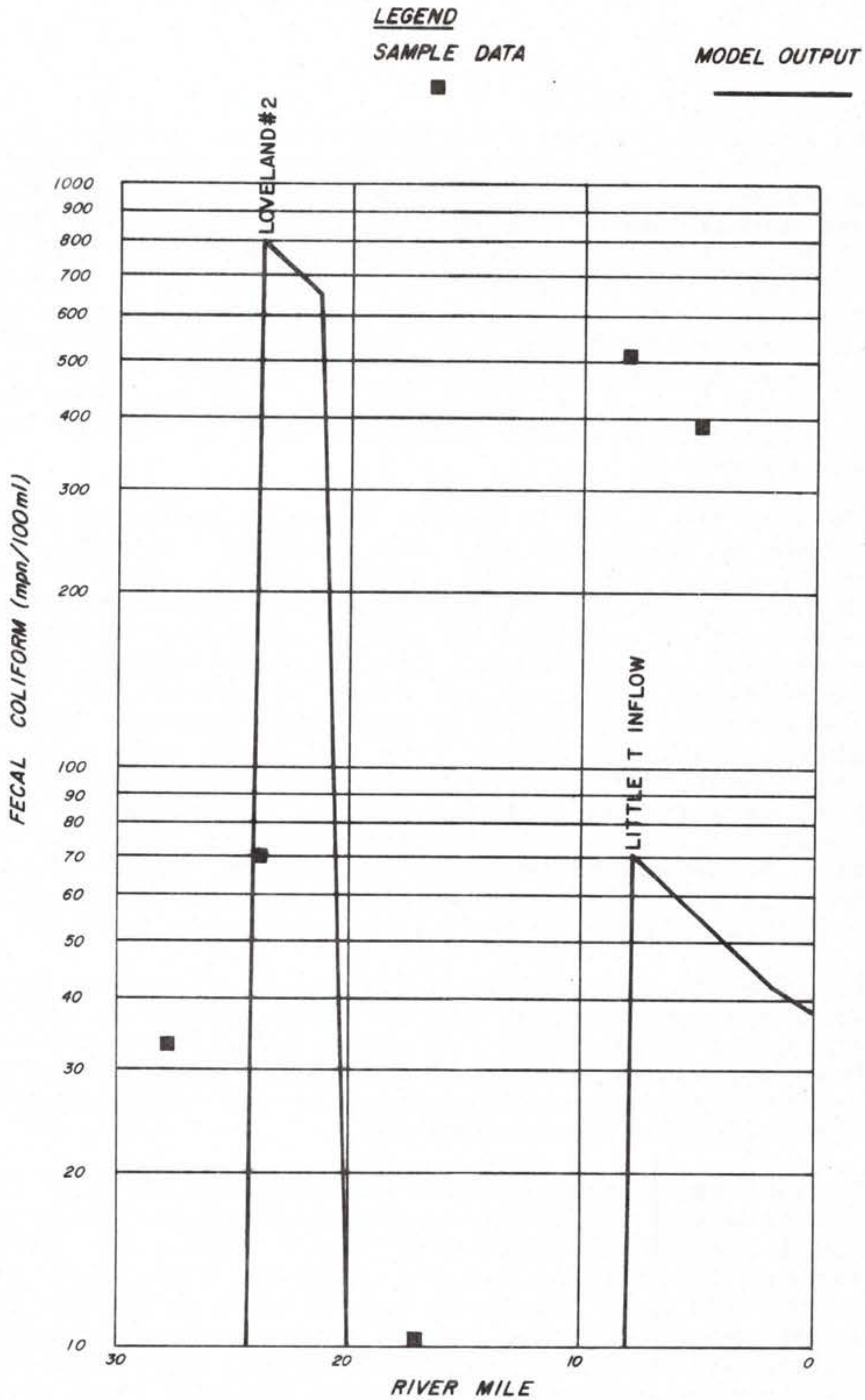


FIG. 4.2.2-D. **MODEL RECALIBRATION RESULTS FOR FECAL COLIFORM - BIG THOMPSON RIVER**

As shown in Table 4.2-A, the river was divided into three segments for the purpose of adjusting water quality coefficients. For the segments upstream of Loveland No. 2 and downstream of the confluence of the Little Thompson River, the final recalibration was achieved with the following coefficients: $K_1 = 0.3$/day; $B_e = 0$ mg/m^2/day; $K_{N1} = 0.3$/day; $K_{F_C} = 1.4$/day; and the remaining coefficients with constant values shown in Table 2.2-A. For the river segment between Loveland No. 2 discharge and the Little Thompson River, recalibration was achieved with the same coefficients with the exception that B_e was set equal to 200 mg/m^2/day.

As with the Cache la Poudre River, a reasonable fit of model output to the field data was achieved. A benthic demand was utilized for the middle segment of the river since a dissolved oxygen sag noted in that segment by the sampling program could not be achieved by simple oxidation of BOD and ammonia nitrogen. An assessment of the recalibration for ammonia is rendered problematical since no ammonia was detected in the river by the sampling program. However, because the nitrate nitrogen output fits the field data very closely, the ammonia nitrogen output is not considered unreasonable. Also as with the Cache la Poudre, the output of the model for fecal coliform predicted significantly lower coliform levels than revealed by the sampling program (Figure 4.2.2-D). Again, this is probably attributable to a lack of accurate data of coliform loading to the river, and not a modeling error.

Because the recalibration for the Big Thompson River resulted in a reasonably close fit of model output to the field data, the model can be used for wasteload allocations on the river. However, reasonable fecal coliform output should not be expected since a satisfactory fit for that parameter was not achieved by the recalibration.

Because water quality data was obtained at only five sampling points along the river, a detailed comparison of recalibrated model output and field data is not possible. However, Figures 4.2.2-A and 4.2.2-B indicate that, with the exception of the 8.8 mg/l dissolved oxygen reading at the downstream sampling point, model output corresponds to the field data reasonably well for dissolved oxygen, BOD, ammonia nitrogen, and nitrate nitrogen. Predicted TDS and fecal coliform levels, however, are both significantly lower than noted for the sampling program. As before, this is probably attributable to incomplete data on source loadings of these two parameters and not as a result of an error in modeling technique. As a result of the reasonable fit of recalibrated model output, wasteload allocations can be performed for the Big Thompson River, with the exception of TDS and fecal coliform.

4.2.3 Little Thompson River

The Little Thompson River is modeled by Pioneer I from river mile 34 to its confluence with the Big Thompson River. Only three significant point source dischargers are located on the river: Berthoud, Great Western at Johnstown, and Johnstown. Sampling of the Little Thompson River was performed upstream and downstream of the town of Johnstown (and Great Western at Johnstown). The dissolved oxygen concentration in the stream was actually noted to increase from 7.4 mg/l upstream to 8.8 mg/l downstream. It is believed that the latter reading is unreasonable and may have resulted from a sampling error or faulty equipment. BOD of the river was noted to increase from 2.0 mg/l at the upstream sampling point to 3.0 mg/l at the downstream sampling point. These results are depicted in Figure 4.2.3-A. Ammonia and nitrate recalibration results are shown in Figure 4.2.3-B. The concentration of TDS was noted to decrease from an upstream value of 2,180 mg/l to a downstream value of about 1,875 mg/l. This decrease may be the result of dilution by the two point source discharges between the sampling points since both contain significantly lower TDS concentrations in their effluent than in the river. Figure 4.2.3-C shows the TDS model recalibration results. These relatively high nitrate and TDS levels are not unreasonable since the Little Thompson receives a significant amount of agricultural return flow and runoff. The level of fecal coliforms was noted to increase from 520 mpn/100 ml upstream to 1,200 mpn/100 ml downstream, probably the result of the two discharges.

Final calibration was achieved utilizing the following water quality coefficients: K_1 = 0.3/day; B_e = 0.0 mg/m^2/day; K_{N_1} = 0.3/day; K_{FC} = 1.4/day; and the remaining constant coefficients indicated in Table 2.2-A.

4.2.4 Other Streams

As previously discussed, recalibration of Pioneer I was not performed on all streams in the model and study area. However, adjustments were made to some water quality coefficients on the non-recalibrated streams. Water quality coefficients for streams such as Boxelder Creek and Buckhorn Creek in the model which flow into one of the recalibrated rivers were given the same values as for the segment of recalibrated stream to which they flow. With the exception of the K_2 coefficients, the values for the water quality coefficients for the South Platte River were kept the same as in the original model. Previous sections discuss the setting of K_2 coefficients to 3.0/day for all modeled stream segments. Table 4.2-A summarizes the values of water quality coefficients utilized for these streams in the overall recalibrated model.

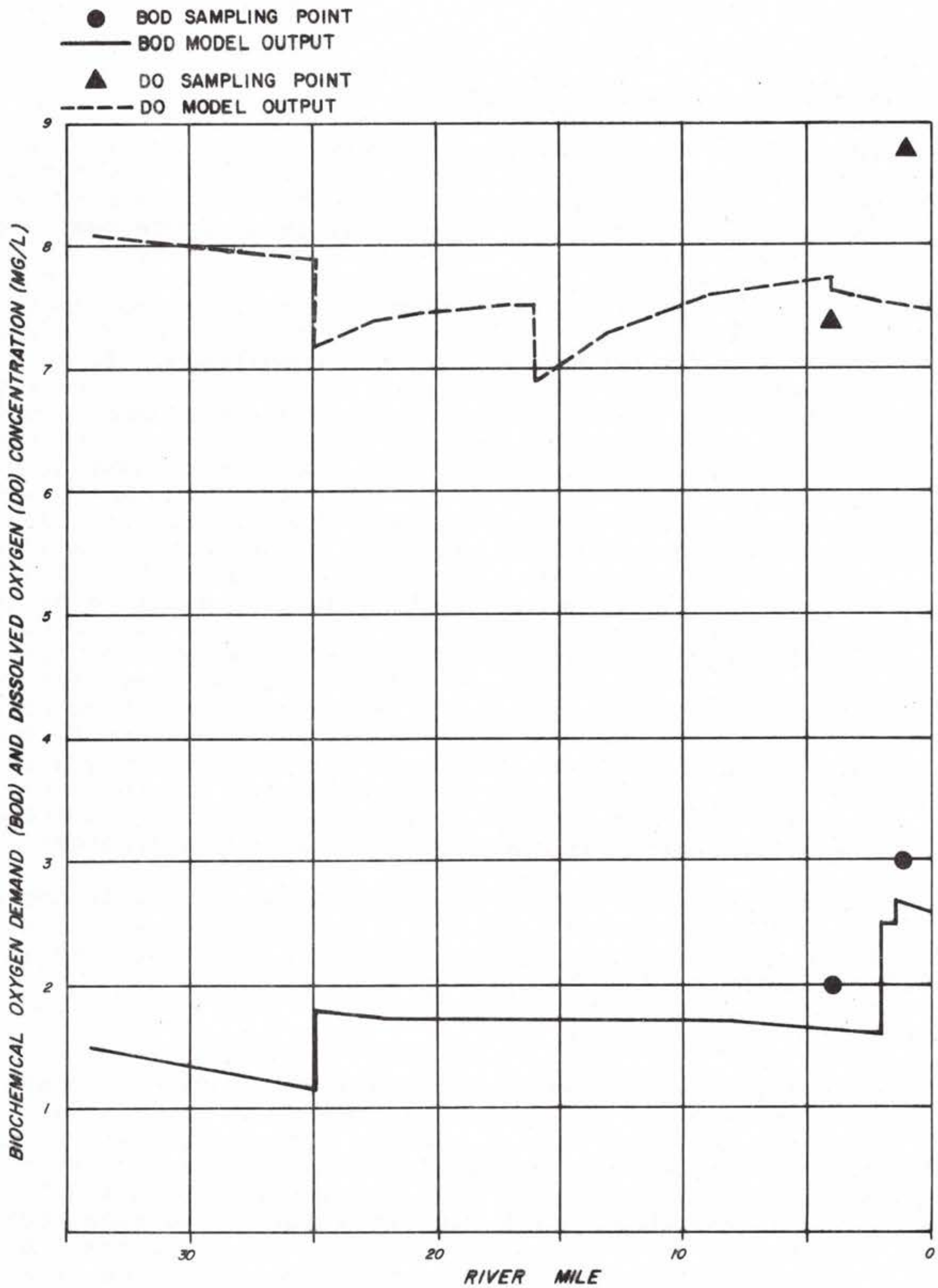


FIG. 4.2.3-A. MODEL RECALIBRATION RESULTS FOR LITTLE THOMPSON RIVER - DO AND BOD

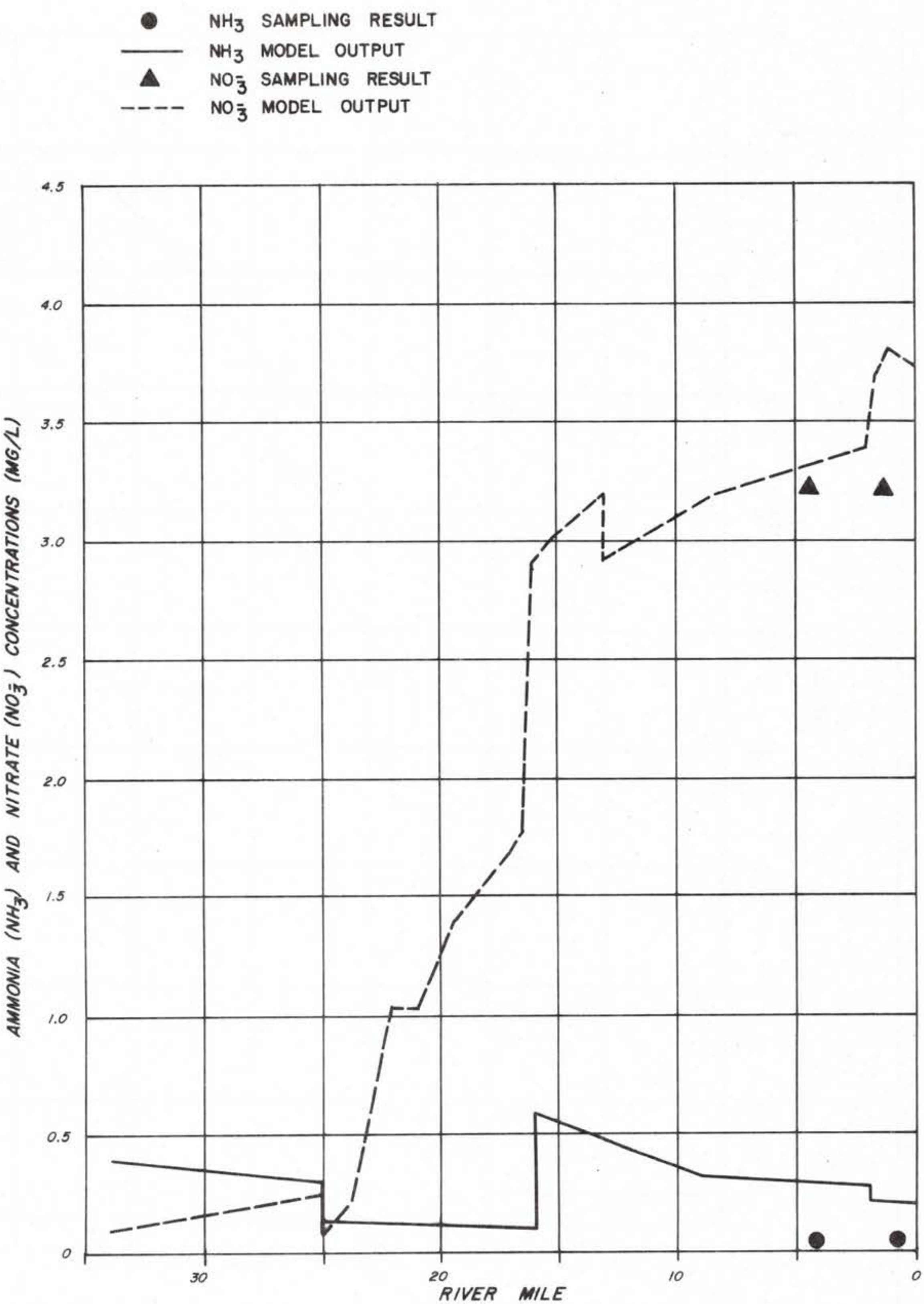


FIG. 4.2.3-B. MODEL RECALIBRATION RESULTS FOR LITTLE THOMPSON RIVER - **AMMONIA AND NITRATE**

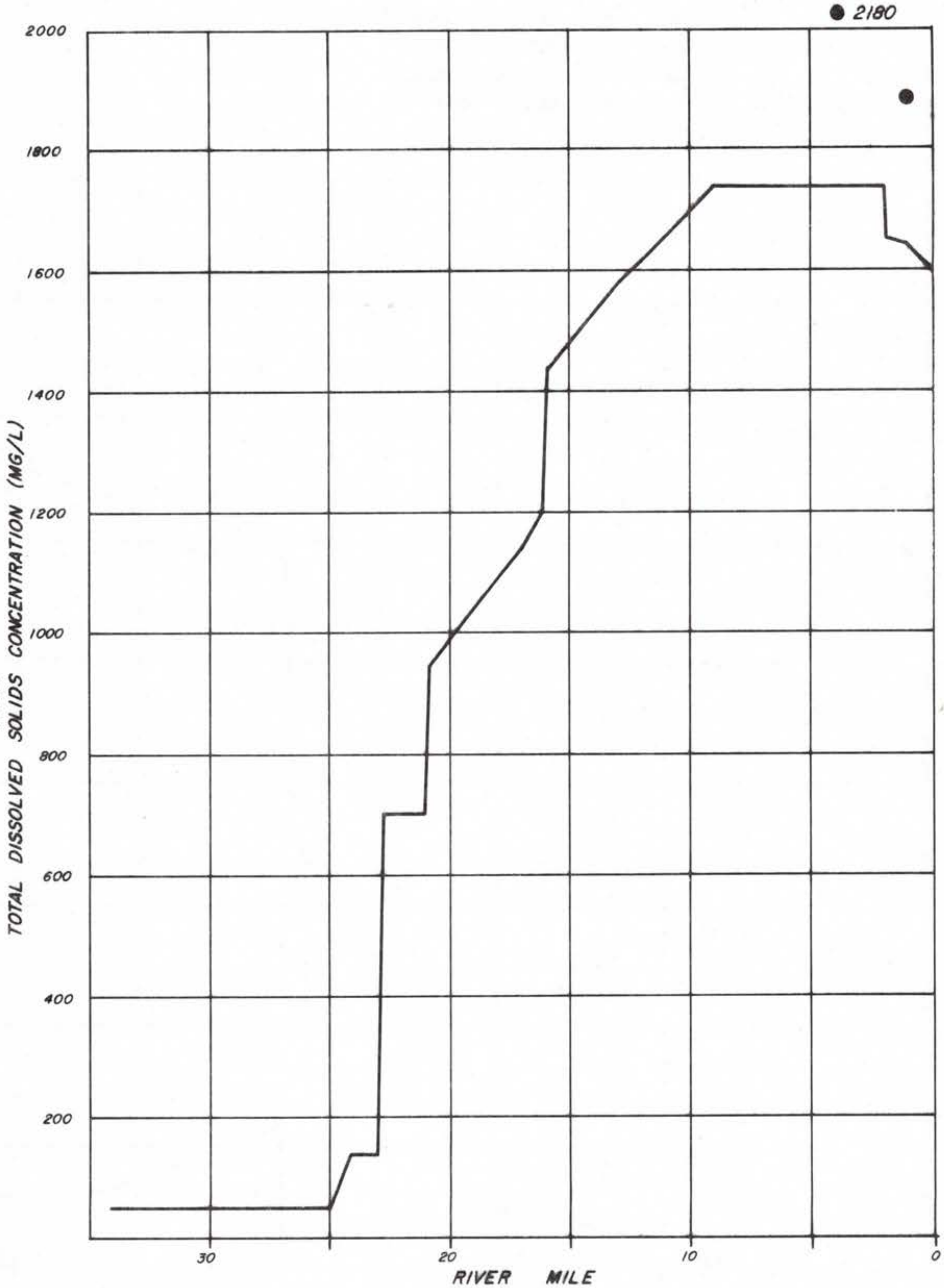


FIG. 4.2.3-C. MODEL RECALIBRATION RESULTS FOR LITTLE THOMPSON RIVER-TOTAL DISSOLVED SOLIDS

5.0 WASTELOAD ALLOCATIONS FOR EXISTING AND FUTURE CONDITIONS

This chapter summarizes the results of the wasteload allocations developed for present and future wastewater discharges. Point source wasteloads have been input into the Pioneer I Model and the resulting output depicts calculated instream water quality with respect to ammonia, nitrates, dissolved oxygen, biochemical oxygen demand and fecal coliforms. Two water quality parameters, ammonia and dissolved oxygen, are discussed in detail in the following sections. These two parameters have a relatively high level of resolution by the Pioneer I Model and both have established limits as set by the Water Quality Control Commission of the Colorado Department of Health. The Water Quality Control Commission has also established limits on instream fecal coliform bacteria concentrations, however, lack of data and lack of resolution by the model makes it inappropriate to use this parameter to establish wasteload allocations. Nitrate and biochemical oxygen demand, although important to stream ecology do not have instream limits as set by the Colorado Department of Health and are therefore not discussed in terms of establishing wasteload allocations.

The wasteload allocations presented herein assist in defining the level of treatment needed by the region's various wastewater treatment plants to attain and maintain instream water quality standards as presently established by the Water Quality Control Commission. The results of the wasteload allocation process should be regarded only as an estimate of instream water quality that can be attained through various point source control strategies. The allocation process alone is not a valid means of defining waste water treatment level requirements for municipal and industrial discharges for the following reasons:

- The water quality model on which true allocations are based while a valuable planning tool, is at best an approximation of actual instream water quality conditions.

- The long-term data base needed to develop a more complete understanding of instream water quality mechanics has not been developed.

- Flow and physical conditions in the rivers are the predominent factors determining attainability of the "fishable, swimmable" goal of the Clean Water Act. Unless those factors are considered, attainment of water quality standards alone will not be cost effective.

The results presented in the following sections should be considered in this context.

5.1 WATER QUALITY STANDARDS FOR THE STATE OF COLORADO

Water quality standards applicable to waters of the Larimer-Weld Region include limitations on the quality of effluent discharged by municipalities and industries, stream classifications applied by the Water Quality Control Commission to streams within the region, and the numerical water quality standards associated with stream classifications. This section defines effluent guidelines, stream classifications, and water quality standards as they are currently applied to the Larimer-Weld Region.

5.1.1 Effluent Guidelines for Municipalities and Industries

The specific standards applicable to all wastewaters discharged in Colorado are listed in Table 5.1.1-A.

TABLE 5.1.1-A SPECIFIC STANDARDS FOR DISCHARGE OF WASTE TO STATE OF COLORADO WATERS

Constituent	Allowable Level in Discharge
Suspended Solids	30 mg/l
BOD_5	30 mg/l
pH	Between 6.0 and 9.0
Fecal Coliform	Determined Individually
Chlorine	0.5 mg/l (max.)
Oil and Grease	10 mg/l

These standards represent the allowable constituent concentrations that can be discharged to waters of the State. In addition rules and regulations specify that no toxic substance may be discharged in a quantity resulting in a toxic concentration in the stream. This applies to a wide variety of biological and chemical constituents and provides the State with a mechanism for controlling those discharges. The toxic element most commonly found in municipal discharges is ammonia. The Environmental Protection Agency has determined that an ammonia concentration in excess of 1.5 mg/l in the stream is toxic to aquatic life. Although this value is extremely sensitive to changes in pH and temperature, it is generally accepted as the in-stream limit by the State of Colorado and EPA (ECI-Toups 1975).

Additional limitations have been established for specific categories of industries which exhibit common discharge characteristics. A number of major industries in the region, i.e., electronics, meat packing, etc., discharge waste to municipal treatment systems. In these cases, industries must meet pretreatment requirements to eliminate constituents not commonly removed by municipal wastewater treatment works. The municipalities are then subject to limitations described above, or more stringent limitations depending on instream water quality standards.

5.1.2 Stream Classifications and Standards

The State of Colorado has established water quality classifications for all waters of the State. These classifications include Classes A_1, A_2, B_1, B_2, and C. Class A waters are suitable for all beneficial uses including primary contact recreation, such as swimming and water skiing. Class B waters are suitable for all beneficial uses except primary contact recreation. The subscripts 1 and 2 denote cold water and warm water classifications respectively. Class C waters are those waters which have been excepted from A or B classifications on a case by case basis by the Water Quality Control Commission.

Associated with the classifications are numerical standards to insure that beneficial uses can be maintained within the class. These standards are shown in Table 5.1.2-A. In addition, toxic elements in toxic concentrations are prohibited in all Class A and B streams in the State. Table 5.1.2-B shows how these classifications have been applied in the Larimer-Weld Region. All streams are classified as B_1 and B_2 streams. Generally the B_1 streams (cold water fishery) are located in the mountainous areas and the B_2 streams (warm water fishery) are located in the plains areas.

State water quality standards specify that the design frequency and duration for water quality standards is a seven day/ten year low flow. That is a minimum seven day average flow which occurs on the average of once in ten years. This implies that low flows in streams may cause stream violations under drought conditions which occur very rarely, i.e., one week in ten years.

TABLE 5.1.2-A SUMMARY OF COLORADO WATER QUALITY STANDARDS (a)

	CLASS			
STANDARD	A_1	A_2	B_1	B_2
Settleable Solids	Free From	Free From	Free From	Free From
Floating Solids	Free From	Free From	Free From	Free From
Taste, Odor, Color	Free From	Free From	Free From	Free From
Toxic Materials	Free From	Free From	Free From	Free From
Oil and Grease	Cause a film or other discoloration	Cause a film or other discoloration	Cause a film or other discoloration	Cause a film or other discoloration
Radioactive Material	Drinking Water Standards	Drinking Water Standards	Drinking Water Standards	Drinking Water Standards
Fecal Coliform Bacteria	Geometric Mean of <200/100 ml from five samples in 30-day period	Geometric Mean of <200/100 ml from five samples in 30-day period	Geometric Mean of <1000/100 ml from five samples in 30-day period	Geometric Mean of <1000/100 ml from five samples in 30-day period
Turbidity	No increase of more than 10 JTU	No increase of more than 10 JTU	No increase of more than 10 JTU	No increase of more than 10 JTU
Dissolved Oxygen	6 mg/1 minimum	5 mg/1 minimum	6 mg/1 minimum	5 mg/1 minimum
pH	6.5 - 8.5	6.5 - 8.5	6.0 - 9.0	6.0 - 9.0
Ammonia	1.5 mg/1 maximum	1.5 mg/1 maximum	1.5 mg/1 maximum	1.5 mg/1 maximum
Temperature	Maximum 68°F. Maximum Change 2°F.	Maximum 90°F. Maximum Change: Streams - 5°F. Lakes - 3°F.	Maximum 68°F. Maximum Change 2°F.	Maximum 90°F. Maximum Change: Streams - 5°F.. Lakes - 3°F.
Fecal Streptococcus	Monthly average of <20/100 ml from five samples in 30-day period	Monthly average of <20/100 ml from five samples in 30-day period	-----	-----

(a) Water Quality Control Commission, Colorado Department of Health.

TABLE 5.1.2-B CLASSIFICATION OF WATERS IN THE LARIMER-WELD REGION

RIVER	CLASS
Headwaters of Cache la Poudre to River mile 56 (Greeley Water Treatment Plant Diversion)	B_1
Remainder of Cache la Poudre River	B_2
Headwaters of Big Thompson to River mile 35.8 (Loveland Water Treatment Plant)	B_1
Remainder of Big Thompson River	B_2
South Platte River	B_2
Boulder Creek	B_2
St. Vrain Creek	B_2
Little Thompson River to River mile 24.5 (Culver Ditch)	B_1
Remainder of Little Thompson River	B_2

5.1.3 Wasteload Allocation Process

The State of Colorado has defined both effluent quality standards which all discharges must meet and water quality standards for all streams in Colorado. In some cases however, even if municipalities and industries discharging to streams meet the basic effluent quality standards, stream quality standards will not be met. The objective of the wasteload allocation process is to identify:

1. Streams meeting water quality standards when effluent standards are met;

2. Streams not meeting water quality standards when effluent standards are met;

3. The allowable wasteload or revised effluent standard for discharges to streams not meeting water quality standards which would enable stream standards to be met.

Wasteload allocation procedure is carried out for existing and future conditions. The procedure includes the following elements:

1. The Water Quality Model is recalibrated to reflect actual flow conditions representative of low flow conditions and the impacts of discharges on flow and water quality in the stream. This was described in previous chapters.

2. Existing and future discharges are applied to the stream and any violations of stream standards established by the State are determined.

3. For those discharges causing violation of standards, pollutant concentrations are reduced by applying additional theoretical treatment levels. This process is continued until no further violations of stream standards occur.

By applying this methodology the treatment levels necessary to achieve instream water quality standards are determined.

The underlying assumption of this procedure is that stream classifications, i.e., cold water or warm water fisheries, are established by water quality considerations alone. As mentioned in the introduction of this chapter, this is not the case in the Larimer-Weld Region.

Wasteload allocations specified in this report have been developed under strict interpretation of the current rules and regulations promulgated by the Colorado Water Quality Control Division. These regulations state, in part:

> "DEGREE OF TREATMENT
>
> All wastes prior to discharge into state waters shall receive the degree of treatment necessary to comply with the Standards for the Discharge of Wastes, Water Quality Standards (Stream Standards) and the Antidegradation Statement."

Conditions exist within the region where water quality standards are violated by municipalities and industries at the point of discharge and for short distances downstream. These conditions might be considered as "mixing zone" conditions. The rules and regulations of the Colorado Water Quality Control Commission state, in part:

> "MIXING ZONE
>
> The area or volume of a stream designated by the division within which effluent shall become thoroughly mixed with the waters of the stream.
>
> The total area or volume of a stream designated as a mixing zone shall be limited to that area or volume which will not interfere with biological communities or populations of important species to a degree which is damaging to the ecosystem and which will not cause substantial damage to other beneficial uses."

Within the Larimer-Weld Region, no mixing zones have been defined "by the division," i.e., the Water Quality Control Division, Colorado Department of Health.

5.2 POPULATION PROJECTIONS

The 208 recommended population projections used to develop projected waste flows are shown in Table 5.2-A. The methodology applied in developing these projections is described in "Larimer-Weld Region Land Use Alternatives." These projections were adopted in December 1977 by the Larimer-Weld Regional Council of Governments Governing Board in conjunction with a Recommended 208 Land Use Plan. Waste flows associated with these projections are presented in subsequent sections.

5.3 TREATMENT LEVELS

To determine the potential cost of future wastewater treatment in the Larimer-Weld Region, the wasteload allocation process described in subsequent sections included assumptions regarding wastewater treatment levels. Essentially three potential levels of treatment were specified as necessary to meet water quality goals. These three treatment levels were applied to various discharges to determine the level of treatment needed to meet in stream water quality standards.

5.3.1 Secondary Treatment

For the purposes of developing wasteload allocations for the Larimer-Weld surface waters, a secondary treatment level was assumed to be capable of producing an effluent quality of 30 mg/l BOD, 15 mg/l Ammonia (NH_3), and 2.0 mg/l Dissolved Oxygen.

5.3.2 Tertiary Treatment

This more technically advanced and more costly level of treatment was assumed to discharge 20 mg/l BOD, 3 mg/l NH_3, and 2.0 mg/l Dissolved Oxygen.

5.3.3 Advanced Wastewater Treatment (AWT)

Advanced wastewater treatment was assumed to have discharge quality of 10 mg/l BOD, 1.5 mg/l NH_3 and 2.0 mg/l Dissolved Oxygen.

5.3.4 Flow Augmentation Options

In addition to these treatment level options presented, wasteload allocations for the region's major surface waters with various levels of flow augmentation were developed to determine the trade-off between levels of advanced waste treatment and flow augmentation.

TABLE 5.2-A REGIONAL AND COMMUNITY POPULATION PROJECTIONS

Municipality	River Basin	208 Recommended Land Use Projection (Population)
	Cache la Poudre	
Red Feather/ Crystal Lakes		2,000
Spring Canyon S.D.		2,000
Wellington		3,700
Fort Collins		149,400
South Fort Collins S.D.		10,000
Boxelder S.D.		6,000
Timnath		800
Windsor		10,000
Greeley		115,850
Nunn		350
Pierce		3,000
Ault		3,000
Eaton		4,600
Severance		800
	Big Thompson	
Estes Park S.D.		3,900
Upper Thompson S.D.		4,000
Loveland		60,900
Milliken		4,000
	Little Thompson	
Berthoud		7,000
Johnstown		2,200
	St. Vrain	
Erie		1,800
Mead		500
Firestone		1,600
Frederick		3,200
Dacona		4,600

TABLE 5.2-A (CONTINUED)

Municipality	River Basin	208 Recommended Land Use Projection (Population)
	South Platte	
Fort Lupton		9,000
Keenesburg		1,300
Hudson		1,500
Lochbuie		1,500
New Raymer		85
Platteville		3,600
La Salle		4,500
Evans		9,100
Rosedale		100
Garden City		250
Grover		175
Keota		20
Kersey		4,500

5.4 CACHE LA POUDRE RIVER

This section summarizes the results of the wasteload allocations for the Cache la Poudre River.

5.4.1 Existing and Projected Discharges

The flow rate and point of discharge for both existing and future municipal discharges and industrial discharges are presented in Table 5.4.1-A. Many of the industrial point sources along the Cache la Poudre River are not expected to increase discharge volume in the future. Year 2000 flows are assumed to be the same as existing flows for those sources. Municipal sources are presented with discharge rates based on the 208 Recommended Population Projection.

5.4.2 Hydrologic Conditions

The hydrologic conditions described in Chapter 3 of this report are representative of the low flow conditions which occur during the summer low flow period. Those hydrologic conditions are incorporated into the water quality model for wasteload allocation purposes. The representative hydrology indicates that the discharge from the Fort Collins No. 2 Treatment Plant is discharged to the Fossil Creek Reservoir Inlet (RM 40.2) rather than to the Cache la Poudre River, and wasteload allocations were performed under this condition. On occasion, the Water Commissioner will allow flow to pass the inlet. Under this condition, the Fort Collins No. 2 plant discharges to the river below the inlet. For the sake of completeness, wasteload allocations were developed for this case, and are presented in the following section. Significant points of diversion, return flow, and discharge are presented in Table 5.4.2-A.

TABLE 5.4.1-A EXISTING AND PROJECTED DISCHARGES TO THE CACHE LA POUDRE RIVER

Discharger	River Mile	Existing Discharge (mgd)	Projected (mgd)
Colorado Division of Wildlife-Poudre	83	4.0	-
Colorado Division of Wildlife-Bellevue, Watson	47	12.0	-
Fort Collins No. 1	44.1	5.0	6.0
Cowan Concrete Products, Lone Star Steel (via Spring Creek)	41.3	3.2	-
Fort Collins No. 2	39.8	5.8	9.0 (b)
Boxelder S.D.	38.4	0.45	1.0
Timnath	36	No discharge	
Flatiron Paving - Windsor	29.0	2.6 (a)	
Great Western - Windsor	27.0	Closed	
Windsor	22.1	1.7	1.7
Kodak	22.0	1.0	1.0
Flatiron Greeley W.	10.0	No discharge	
Weld Co. By-Products	7.3	No discharge	
Monford Packing	7.1	0.6	
Eaton and Great Western	6.9	0.2	0.4
Greeley	4.6	6.2	0 (c)
Great Western - Greeley	4.5	No discharge	

(a) Includes other flows from Spring Creek.
(b) Assumes substantial correction of existing I/I problem.
(c) Assumes all flow treated at Greeley Delta Plant will discharge to South Platte River.

TABLE 5.4.2-A SIGNIFICANT LOCATIONS ON THE CACHE LA POUDRE RIVER

LOCATION DESCRIPTION	RIVER MILE
Colorado F and G at Rustic	74.0
Greeley Water Treatment Plant Diversion	56.0
Larimer County Canal	53.9
Colorado F and G at Bellevue	47.0
Fort Collins #1	44.1
Fossil Creek Reservoir Inlet	40.2
Fort Collins #2 (When discharging to river)	39.8
Boxelder S.D.	38.4
Fossil Creek Reservoir Outlet	33.4
Fossil Creek	30.7
Windsor	22.1
Kodak	22.0
Monfort Packing	7.0
Greeley 1st Avenue	4.6
Ogilvy Ditch	4.3

5.4.3 Allocation of Existing Wasteloads

Fort Collins No. 2 Wastewater Treatment Plant can discharge to the Fossil Creek Reservoir or to the Cache la Poudre River. The actual point of discharge is determined by the Water Commissioner. As a general rule, the Commissioner directs wastewater flows to maximize dilution. If river water is allowed to by-pass the Fossil Creek diversion, Fort Collins No. 2 plant effluent is discharged to the river. If river water is being diverted to the Fossil Creek Reservoir Inlet, Fort Collins No. 2 plant effluent is discharged to the inlet.

Figure 5.4.3-A shows projected river water quality when Fort Collins No. 2 plant is discharging to the Cache la Poudre River with existing flow volume and effluent characteristics. Flow passing the Fossil Creek Inlet is 17 cfs.

In-stream ammonia standards are violated from the Fort Collins No. 1 Waste Treatment Plant (RM 44.1 to RM 29.0). DO violations occur following the Fort Collins No. 1 (RM 44.1) Fort Collins No. 2 (RM 39.8) and at Boxelder Sanitation District (RM 38.4). Ammonia concentrations are also in excess of the State standard of 1.5 mg/l below the Windsor and Kodak discharges (RM 22.0) and for 0.3 miles following the discharge by the Greeley Wastewater Treatment Plant (RM 4.6). The Greeley, Windsor, and Kodak effluents do not cause violations of dissolved oxygen (DO) standards.

Figure 5.4.3-B illustrates the in-stream water quality resulting from existing wasteflows and applying tertiary treatment levels to all discharges except Boxelder Sanitation District (RM 38.4) which is at secondary level, and having Fort Collins No. 2 plant discharging to the river. This allocation depicts an instantantous violation of dissolved oxygen (DO) at the Fort Collins No. 1 plant (RM 44.1). A minor violation (4.9 mg/l) of the dissolved oxygen standard occurs following Fort Collins No. 2 (RM 39.8) until mixing with Boxelder Creek (RM 38.3).

Violations of the ammonia standard occur at Fort Collins No. 2 (RM 39.8) and at Boxelder Sanitation District discharge (RM 38.4). These minor violations could be associated with a "mixing zone" condition, if a "mixing zone" had been defined previously by the Colorado Department of Health.

Under strict interpretation of the wasteload allocating process and not allowing for "mixing zone" conditions, the Fort Collins No. 2 plant would violate water quality standards

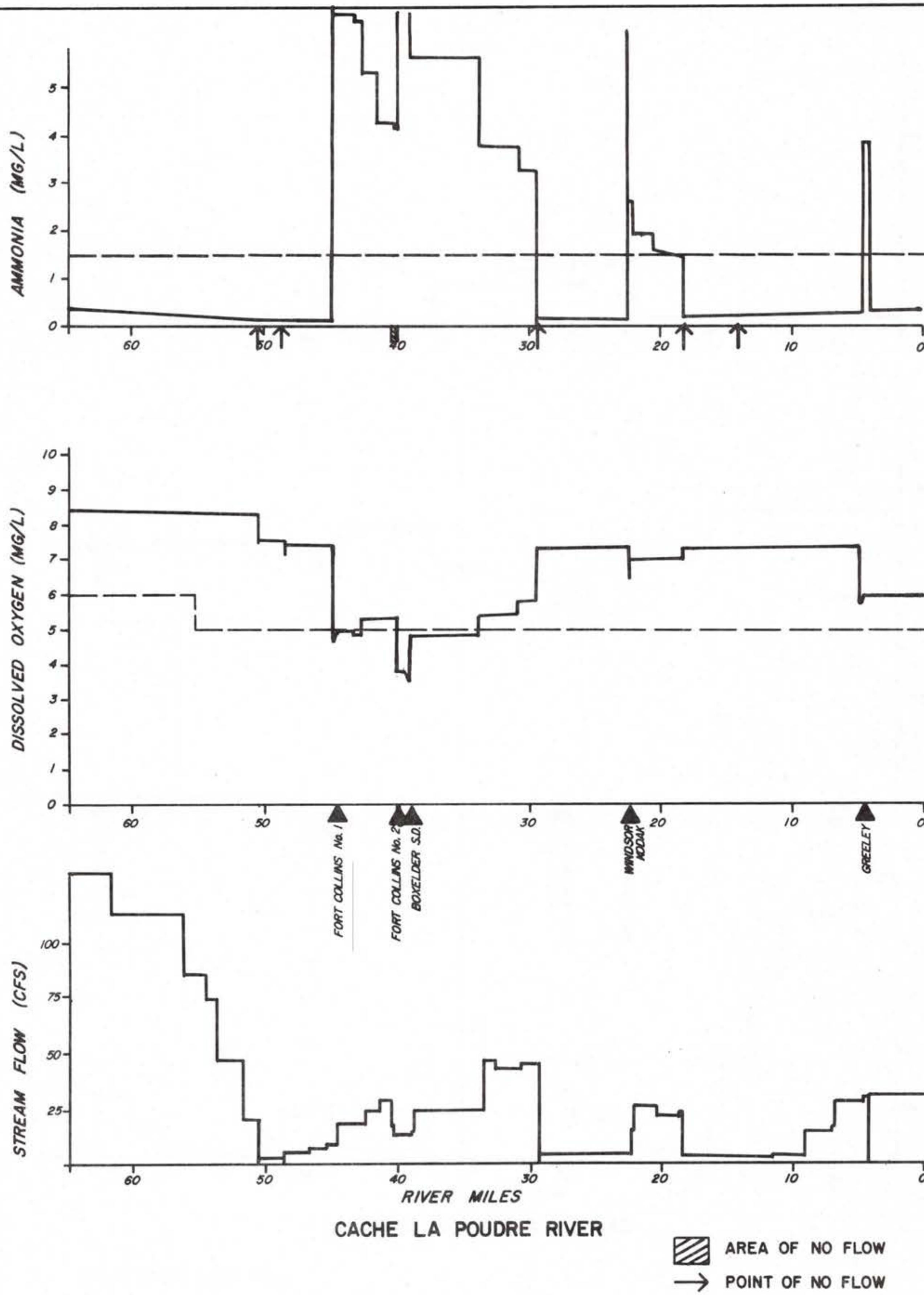


FIG. 5.43-A. EXISTING RIVER QUALITY WITH ALL DISCHARGES AT SECONDARY TREATMENT.

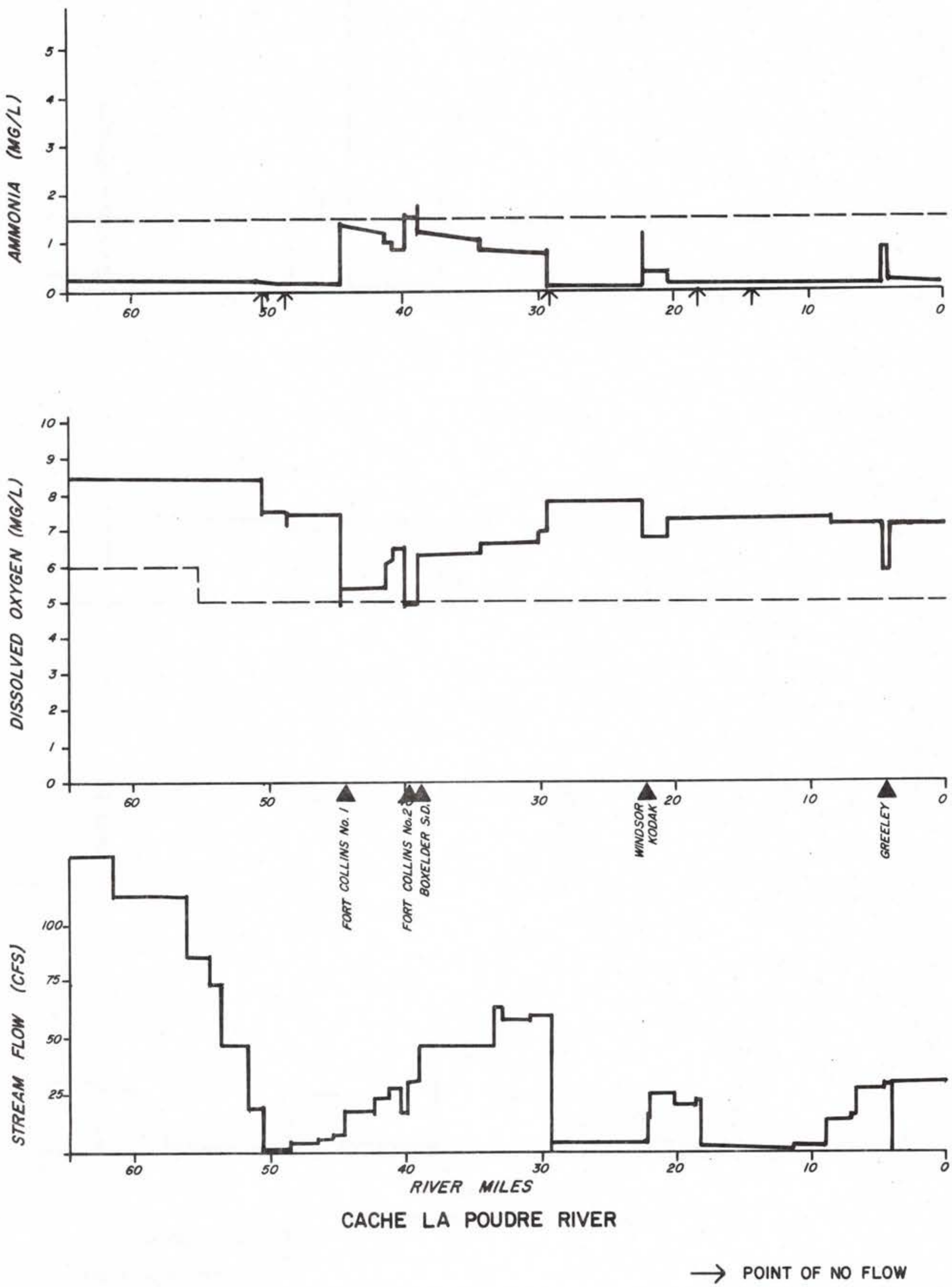
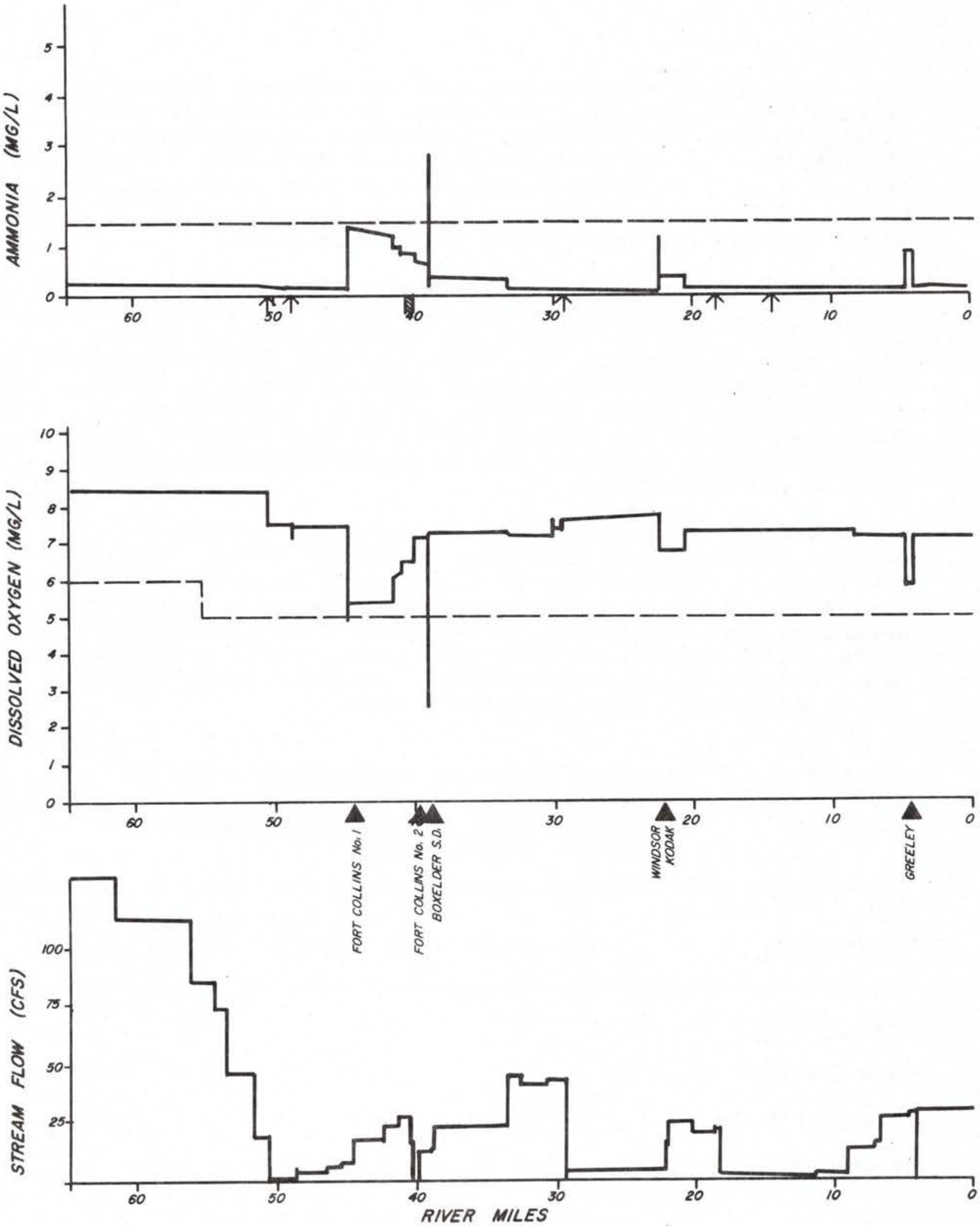


FIG. 5.4.3-B. EXISTING INSTREAM WATER QUALITY WITH ALL DISCHARGERS UTILIZING TERTIARY TREATMENT EXCEPT BOXELDER S.D.



CACHE LA POUDRE RIVER

AREA OF NO FLOW

→ POINT OF NO FLOW

FIG. 5.4.3-C. EXISTING INSTREAM WATER QUALITY WITH ALL DISCHARGERS UTILIZING TERTIARY TREATMENT AND FORT COLLINS NO. 2 NOT DISCHARGING.

when discharging to the river with an effluent quality of 20 mg/l BOD, 3 mg/l NH_3, and 2 mg/l DO, assuming 17 cfs in-stream flow for dilution. Additional allocation indicates that an effluent quality of 10 mg/l BOD, 1.5 mgs/l NH_3 and 3 mg/l DO would be required of Fort Collins No. 2 plant and Boxelder Sanitation District to maintain water quality standards under these conditions.

Wasteload allocations were also developed to reflect existing in-stream water quality on the Cache la Poudre River when Fort Collins No. 2 does not discharge to the river. Under these conditions, tertiary treatment level is required by all dischargers. River water quality with this level of treatment is shown in Figure 5.4.3-C. A violation of dissolved oxygen and ammonia occurs at the Boxelder Sanitation District discharge requiring advanced waste treatment to meet standards.

Table 5.4.3-A summarizes the wasteload allocations for present discharges to the Cache la Poudre River. Tertiary treatment is required by all dischargers except Boxelder Sanitation District, and advanced wastewater treatment is needed by Fort Collins No. 2 (RM 39.8) when discharging to the river during low flow conditions. This treatment plant would require only secondary treatment when discharging to the Fossil Creek Reservoir Inlet.

TABLE 5.4.3-A PRESENT ALLOWABLE WASTELOADS, FROM MUNICIPAL AND INDUSTRIAL DISCHARGES NEEDED TO MEET IN-STREAM STANDARDS - CACHE LA POUDRE RIVER

DISCHARGER	EFFLUENT QUALITY BOD (mg/l)	NH_3 (mg/l)	DO (mg/l)
Fort Collins No. 1	20	3.0	2.0
Fort Collins No. 2*	10	1.5	3.0
Boxelder S.D*	10	1.5	3.0
Windsor	20	3.0	2.0
Kodak	20	3.0	2.0
Greeley	20	3.0	2.0

* When Fort Collins Number 2 is discharging to river with 17 cfs dilution in-stream.

5.4.4 208 Recommended Land Use Projection

Wasteload allocations for future conditions were developed by applying projected wasteflows resulting from the 208 Recommended Land Use Plan to the rivers in the region. Use of secondary treatment by all dischargers results in many violations of water quality standards. Figure 5.4.4-A shows river water quality on the Poudre with projected flows at secondary treatment and Fort Collins No. 2 plant discharging to the river. Major violations of the State's water quality standards are noted from river mile 44.1 to river mile 29.2 where these flows are diverted to the Whitney ditch and return flows reestablish acceptable water quality. This entire reach exceeds the 1.5 mg/l in-stream NH_3 standard. Most of this reach also violates the in-stream DO standard of 5.0 mg/l.

Dischargers from Windsor and Kodak (RM 22.0) cause water quality violations for ammonia. At river mile 16.9 diversions by the Greeley No. 3 ditch and return flows reestablish the water quality to within State standards.

Figure 5.4.4-B shows the impact of projected wasteflows at secondary treatment with the Fort Collins No. 2 plant not discharging to the river. Water quality violations of both the ammonia and dissolved oxygen standards occur below the Fort Collins No. 1 plant, and the ammonia standard is violated below Boxelder Sanitation District, Windsor, and Kodak discharges. It is assumed that Greeley will discharge effluent to the South Platte via the Delta plant by year 2000.

With the Fort Collins No. 2 plant discharging to the river, upgrading of the treatment levels to effluent quality of 3 mg/l DO, 3 mg/l NH_3 and 20 mg/l BOD for both Fort Collins plants, Windsor and Kodak also results in water quality standard violations. Discharge by Fort Collins No. 1 (RM 44.1) causes an instantaneous increase of ammonia to 1.6 mg/l but does not cause a DO violation. Effluent from Fort Collins No. 2 (RM 39.8) causes in-stream ammonia to reach 1.8 mg/l and in-stream DO to go below 5.0 mg/l. Boxelder Sanitation District discharge at secondary treatment levels does not cause a DO violation, but the NH_3 concentration reaches 2.4 mg/l before mixing with Boxelder Creek. Ammonia concentrations remain above 1.5 mg/l for over 5 miles, requiring Boxelder Sanitation District to provide advanced treatment under these conditions. Windsor and Kodak do not cause the in-stream DO concentration to go below 5.0 mg/l but ammonia is increased to 1.6 mg/l. The in-stream water quality is graphically presented in Figure 5.4.4-C.

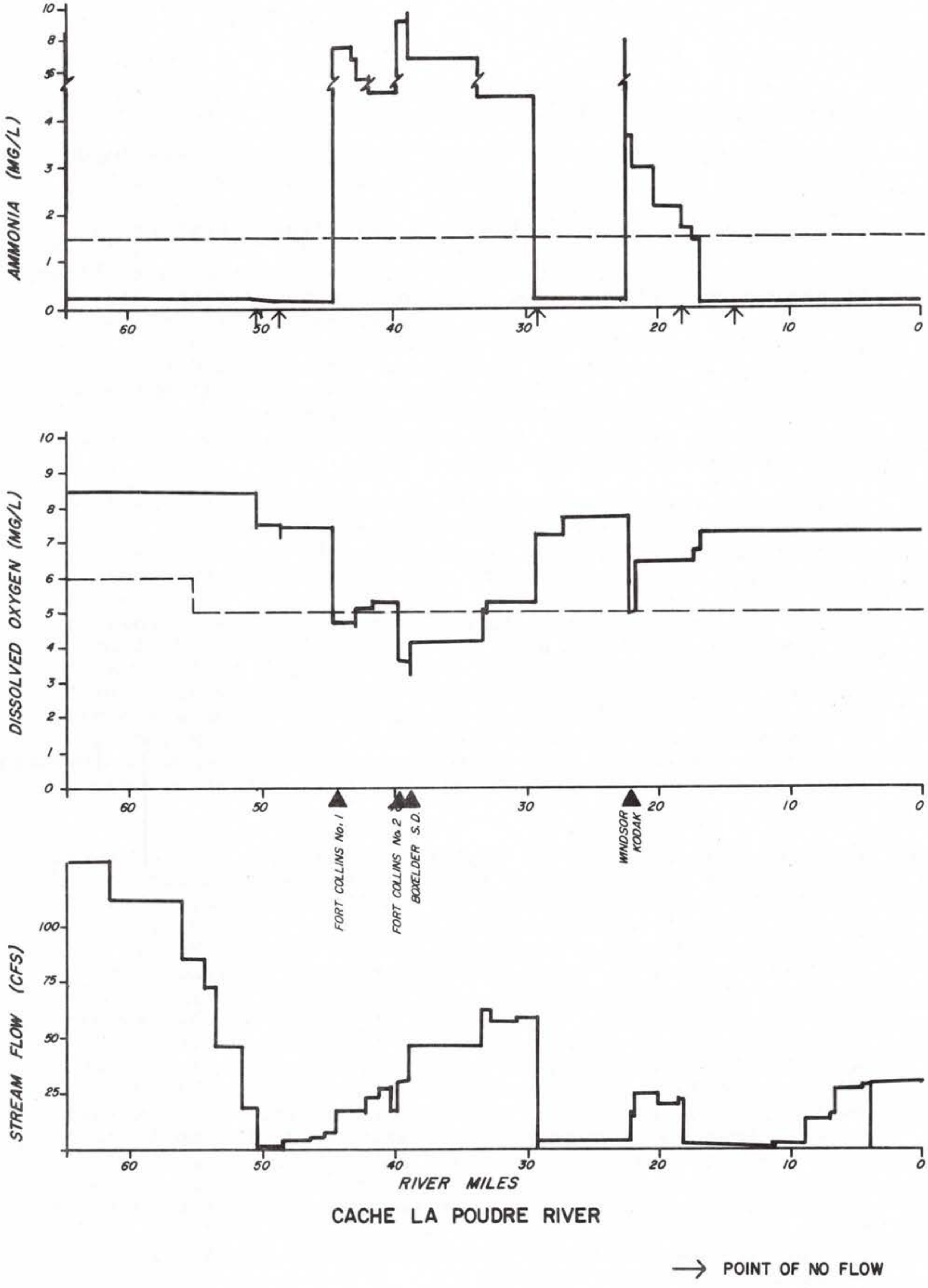


FIG. 5.4.4-A. FUTURE INSTREAM WATER QUALITY WITH ALL DISCHARGERS UTILIZING SECONDARY TREATMENT.

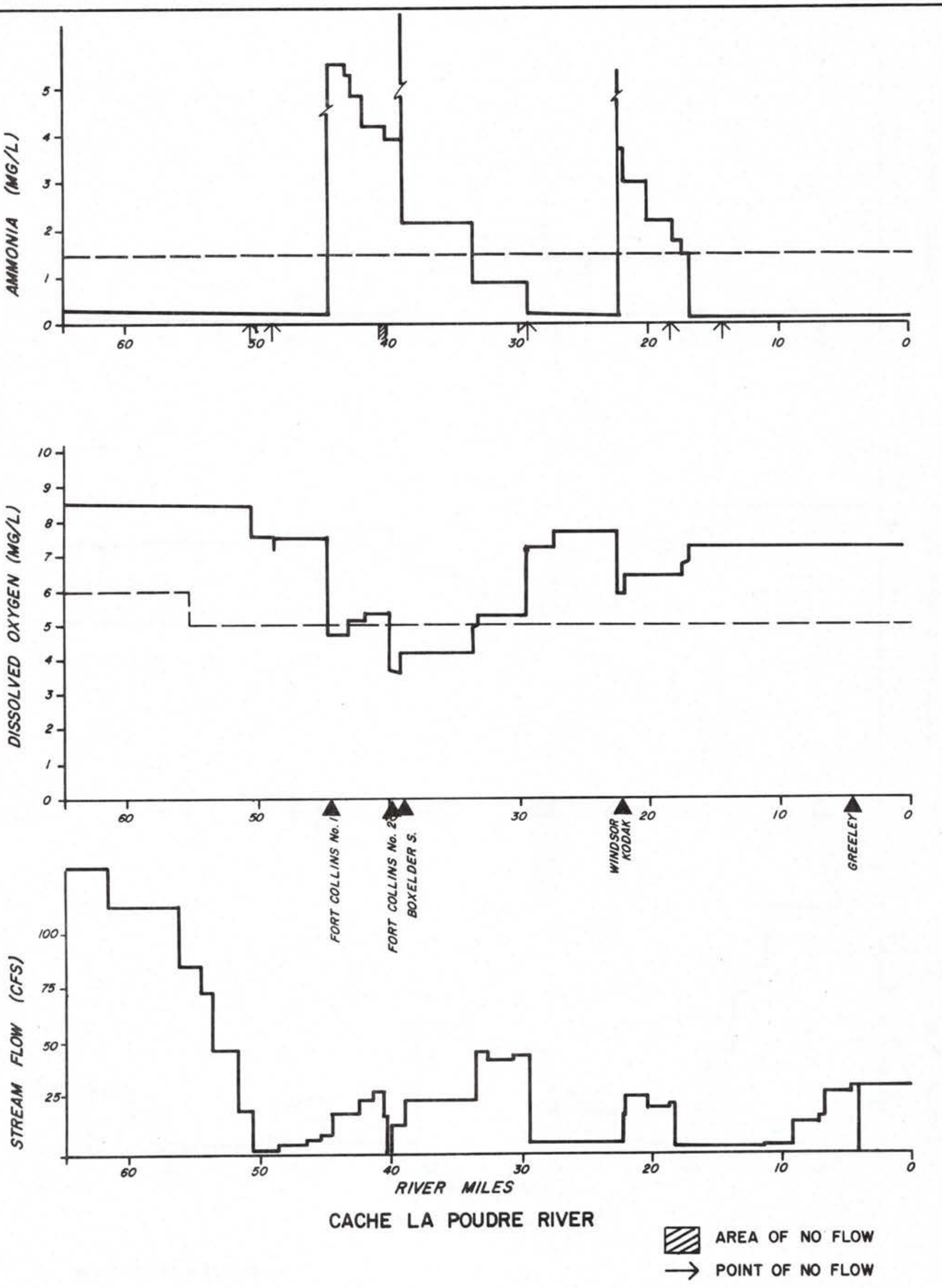
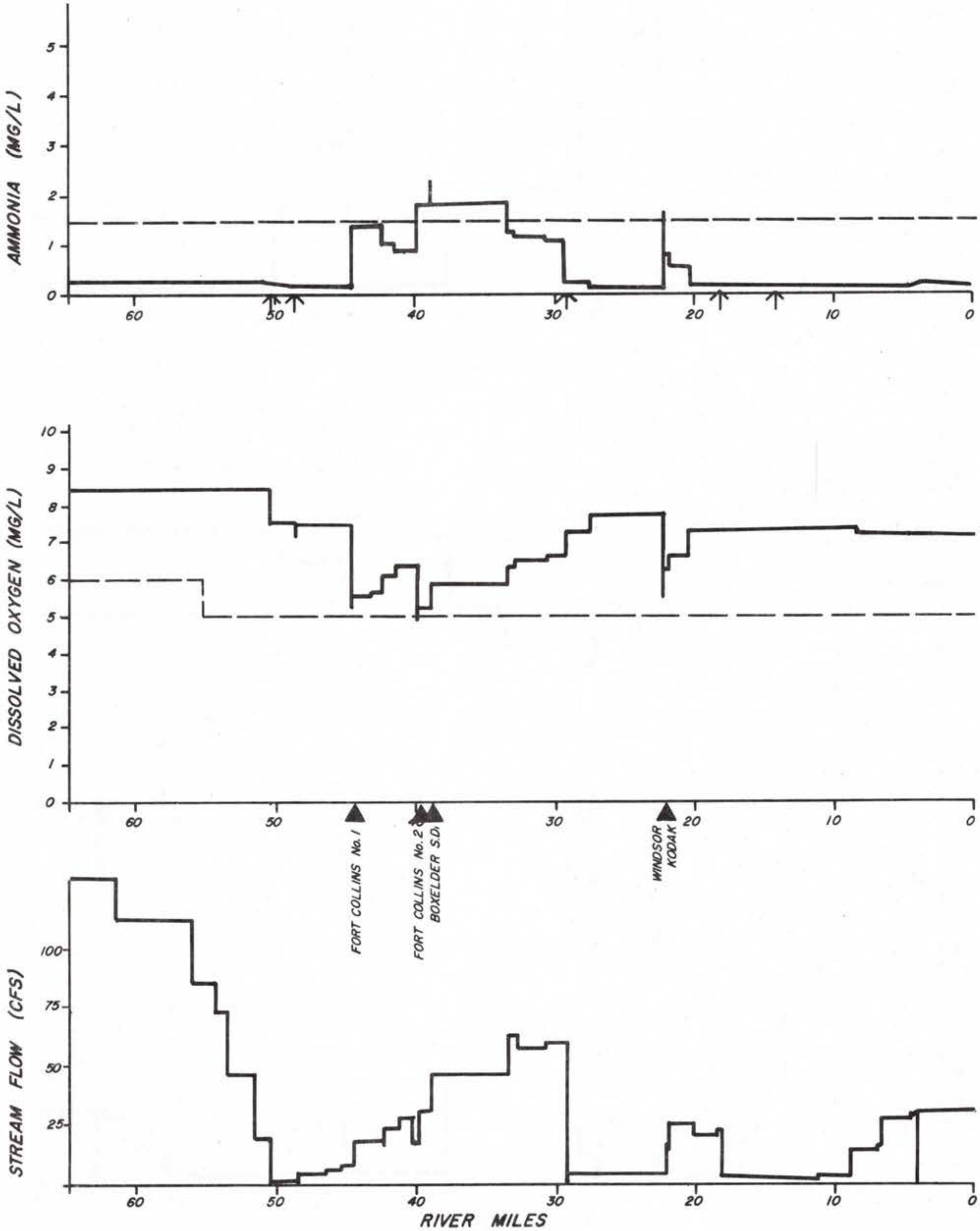


FIG. 5.4.4-B. YEAR 2000 INSTREAM WATER QUALITY ALL DISCHARGERS UTILIZING SECONDARY TREATMENT, FORT COLLINS NO. 2 NOT DISCHARGING



CACHE LA POUDRE RIVER

→ POINT OF NO FLOW

FIG. 5.4.4-C. FUTURE INSTREAM WATER QUALITY WITH ALL DISCHARGERS DISCHARGING AN EFFLUENT OF 3 MG/L DO, 3 MG/L NH_3, AND 20 MG/L BOD, BOXELDER S.D. AT SECONDARY TREATMENT

With the Fort Collins No. 2 plant not discharging to the river, Boxelder Sanitation District causes in-stream violations of the ammonia standard for a distance of five miles down stream of the discharge. The ammonia standard is violated with tertiary treatment requiring advanced waste treatment at Boxelder.

Table 5.4.4-A shows maximum allowable wasteloads for major municipal and industrial dischargers on the Cache la Poudre River based on projected year 2000 flows.

TABLE 5.4.4-A ALLOWABLE WASTELOADS TO THE CACHE LA POUDRE RIVER BASED ON 208 RECOMMENDED LAND USE PLAN PROJECTIONS FOR YEAR 2000

Discharger	BOD (mg/l)	NH_3 (mg/l	DO(mg/l)
Fort Collins No. 1	10.0	1.5	2.0
Fort Collins No. 2 (a)	10.0	1.5	2.0
Boxelder S.D.	10.0	1.5	2.0
Windsor	10.0	1.5	2.0
Kodak	10.0	1.5	2.0
Greeley (b)	-	-	-

(a) When discharging to river with 17 cfs in-stream flow.
(b) Greeley discharges to South Platte in year 2000 via Delta Plant.

5.4.5 Flow Augmentation and Wasteload Allocations for the Cache la Poudre River

From the above discussion it can be seen that a high degree of wastewater treatment is necessary to prevent in-stream water quality from being degraded to a level below State standards. The major reason for exceeding the water quality standards is the application of wasteloads to extreme low flows in the river. Optimization of water use by agricultural interests and municipalities both contribute to the low flow conditions. The implications of augmenting low flows are analyzed in this section.

Year 2000 municipal waste flows based on the 208 Recommended Plan were applied for this analysis.

Figure 5.4.5-A shows the results of a modeling run applying 15 cubic feet per second (cfs) flow augmentation with secondary treatment by all dischargers on the Poudre. The Fort Collins No. 2 Plant is discharging to the Poudre. This alternative strategy causes the in-stream dissolved oxygen level to go below 5.0 mg/l only after the Fort Collins No. 2 Plant discharge (RM 38.4).

The in-stream violations of the ammonia standard occur from the Fort Collins No. 1 Treatment Facility (RM 44.1) through Sheep Draw at river mile 14.7. This highest NH_3 concentration of 7.2 mg/l was in the stream after the Boxelder Sanitation District discharge (RM 38.4). Figure 5.4.5-B depicts the water quality of the Cache la Poudre River with 95 cfs flow augmentation during low flow conditions and the Fort Collins No. 2 Plant discharging to the river. All discharges are at secondary treatment level. This scheme does not show any in-stream violation levels of dissolved oxygen but illustrates that ammonia levels would be exceeded from the Fort Collins No. 2 Treatment Plant (RM 38.9) to river mile 9.2 for a distance of 31 miles.

Figure 5.4.5-C illustrates projected in-stream water quality with secondary treatment by all dischargers with 200 cfs of augmented flow on the Cache la Poudre River and with the Fort Collins No. 2 Plant discharging to the river. This alternative maintains DO levels of the stream at a high level but fails to keep NH_3 concentrations below 1.5 mg/l. The in-stream ammonia concentration is above 1.5 mg/l from Fort Collins No. 2 (RM 39.8) to river mile 33.4. The peak NH_3 concentration is 1.76 mg/l. The Kodak discharge (RM 22.1) causes the NH_3 level to exceed the standard by less than 0.1 mg/l.

Figure 5.4.5-D shows the in-stream concentration of ammonia and dissolved oxygen resulting from tertiary treatment level discharges by all wastewater treatment plants, except the Boxelder Sanitation District (RM 38.4) which utilizes secondary treatment, and with 15 cfs flow augmentation.

The limit of 1.5 mg/l NH_3 is exceeded by applying this alternative. The Boxelder Sanitation District (RM 38.4) effluent would cause the NH_3 level in the stream to reach 2.6 mg/l and remain above 1.5 mg/l for about 5 miles. The State water quality standard of 5.0 mg/l DO would not be violated.

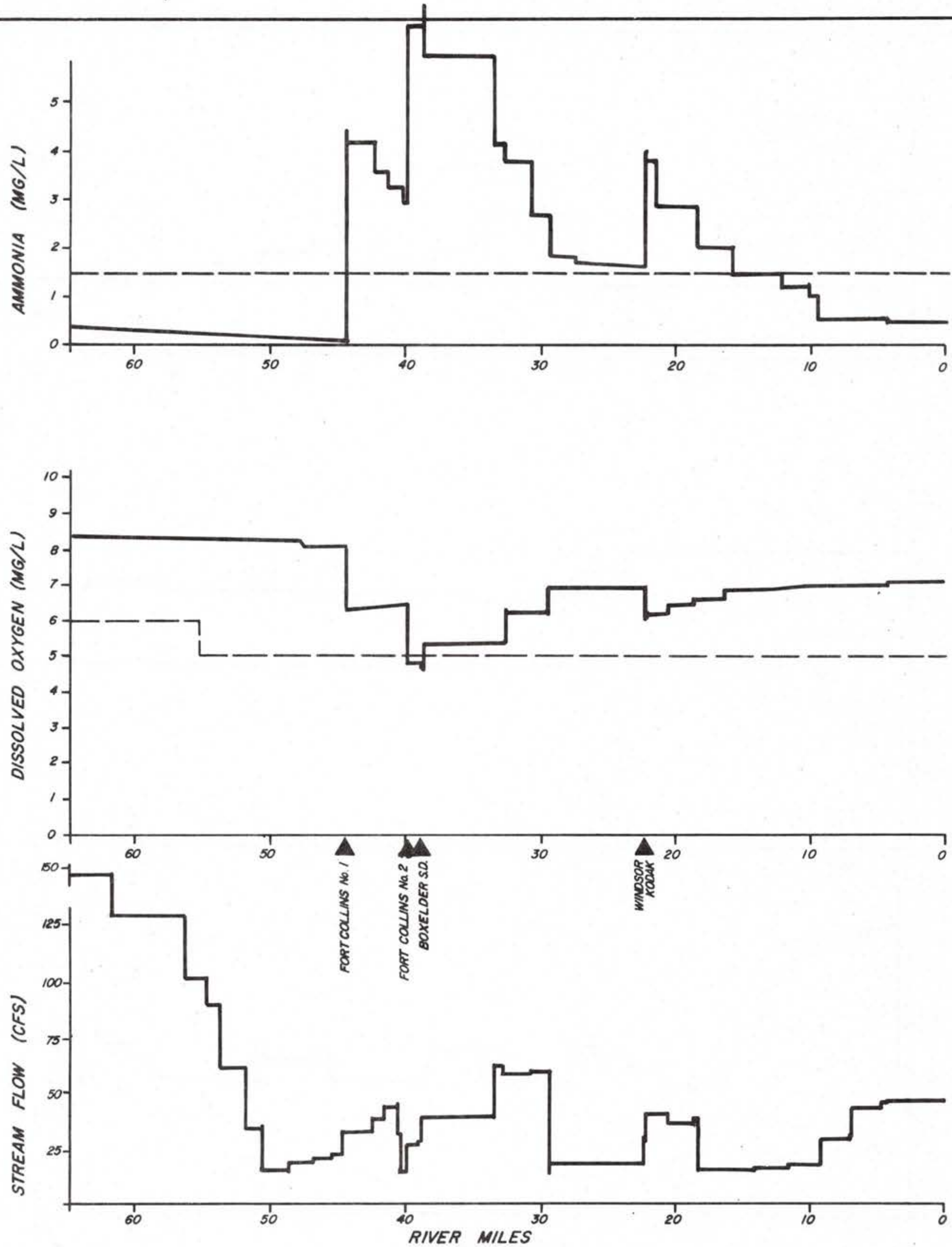
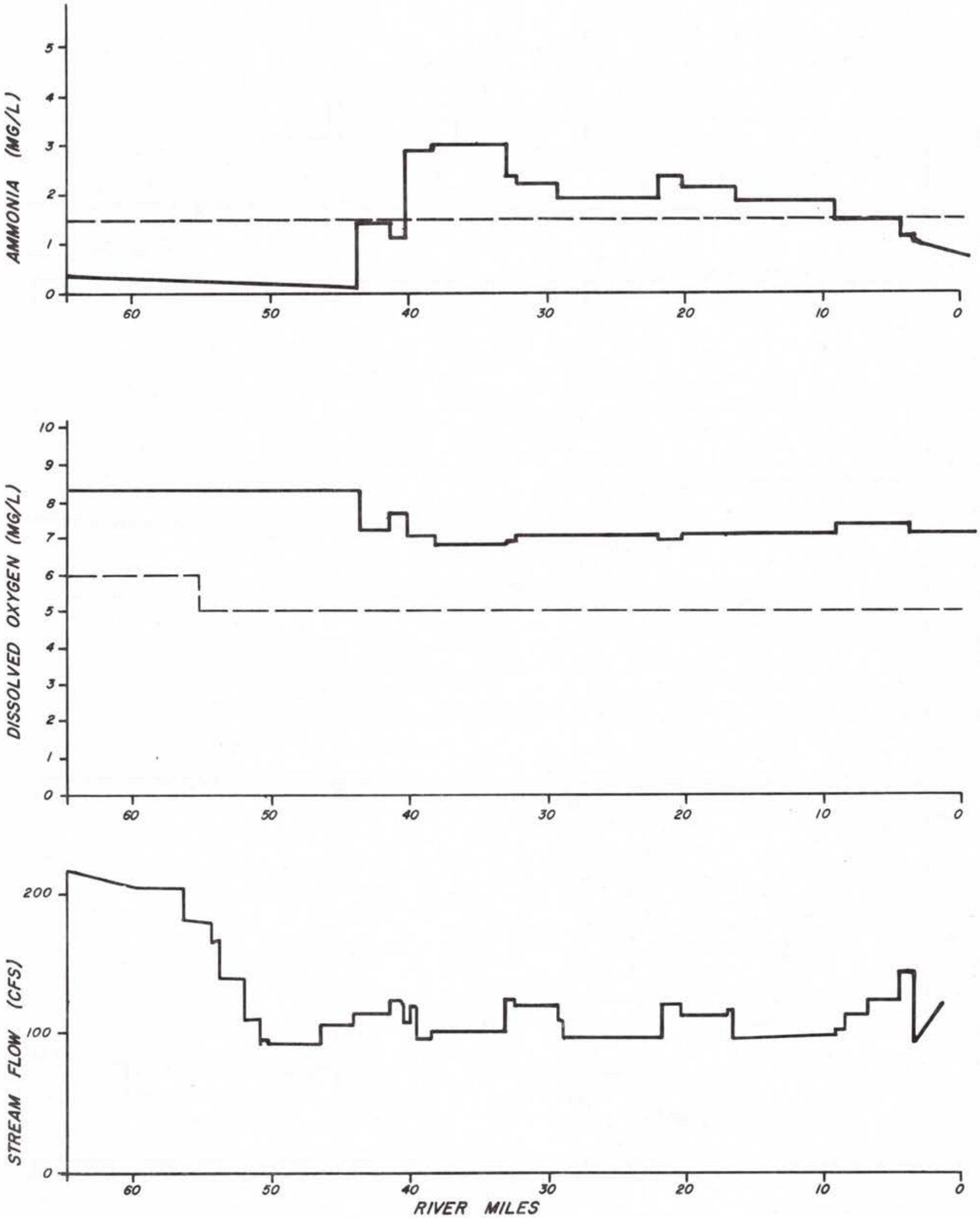


FIG. 5.4.5-A. 208 LAND USE PROJECTED INSTREAM WATER QUALITY WITH SECONDARY TREATMENT AND 15 CFS FLOW AUGMENTATION



CACHE LA POUDRE RIVER

FIG. 5.4.5-B. 208 LAND USE PROJECTED INSTREAM WATER QUALITY WITH SECONDARY TREATMENT AND 95 CFS FLOW AUGMENTATION

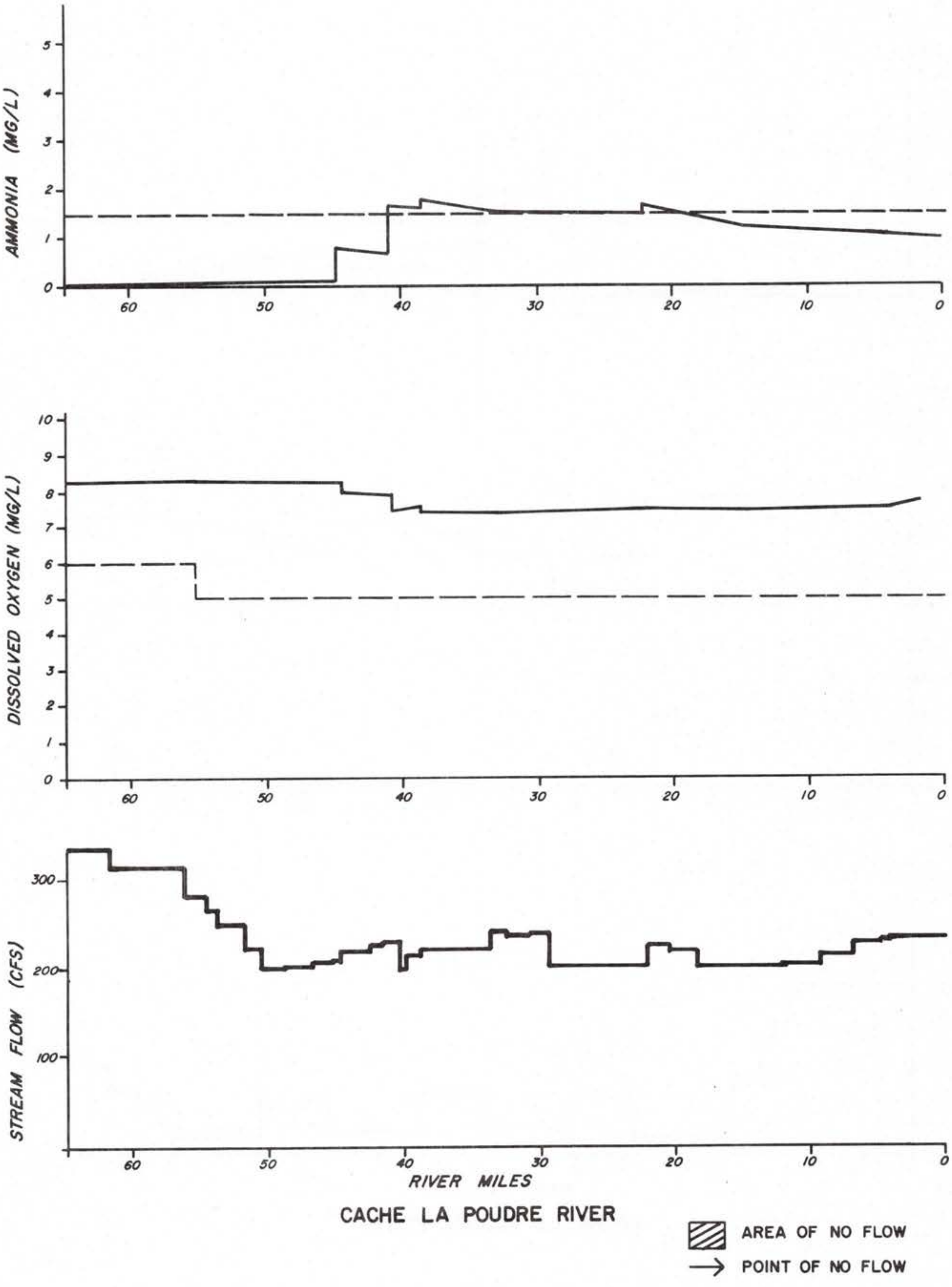


FIG. 5.4.5-C. 208 LAND USE PROJECTED INSTREAM WATER QUALITY WITH SECONDARY TREATMENT AND 200 CFS FLOW AUGMENTATION

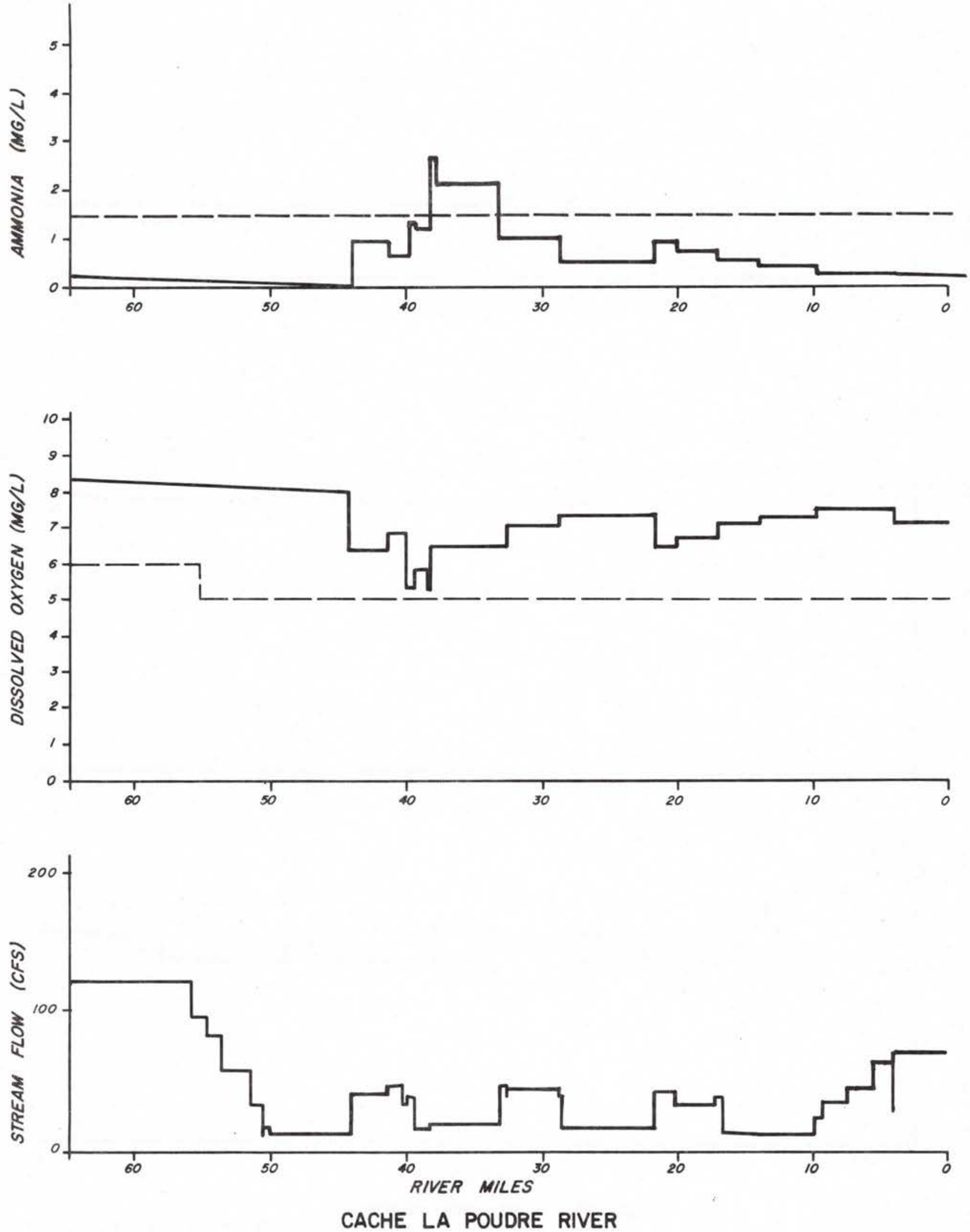


FIG. 5.4.5-D. 208 LAND USE PROJECTED INSTREAM WATER QUALITY WITH TERTIARY TREATMENT AND 15 CFS FLOW AUGMENTATION

The flow augmentation alternatives presented above include the Fort Collins No. 2 Plant discharging to the Poudre. Two additional augmentation alternatives were developed assuming the Fort Collins No. 2 Plant was not discharging to the river.

The initial analysis without Fort Collins No. 2 discharging to the river assumes the following treatment levels:

PLANT	TREATMENT LEVEL
Fort Collins No. 1	Tertiary
Boxelder S.D.	Secondary
Windsor	Secondary
Kodak	Secondary

and 15 cfs flow augmentation. With this configuration, no violations of the DO standard occur on the Cache la Poudre River. The ammonia standard is violated below the Boxelder Sanitation District. The ammonia level reaches 2.1 mg/l, but falls to 1.3 mg/l only 0.1 miles downstream. Ammonia standard violations occur below the Windsor and Kodak discharges for a distance of 4.8 miles, with ammonia levels reaching 2.2 mg/l at the Windsor discharge and 3.1 mg/l at the Kodak discharge.

A subsequent analysis with no discharge by the Fort Collins No. 2 Plant and 15 cfs flow augmentation assumed tertiary treatment at the Fort Collins No. 1 Plant, Windsor, and Kodak, and secondary treatment at Boxelder Sanitation District. No violations of the dissolved oxygen standard occur. A violation of the ammonia standard occurs below the Boxelder Plant, but no violation occurs below Windsor or Kodak.

5.4.5.1 Analysis of Flow Augmentation Alternatives

Flow augmentation of approximately 200 cfs would be required in order to maintain State water quality standards for ammonia with secondary treatment by dischargers to the Poudre, including Fort Collins No. 2 Plant. Augmentation with 15 cfs and 95 cfs and secondary treatment levels result in extended violations of the ammonia standard. Augmentation with 200 cfs for a period of three months to avoid tertiary treatment level requirements would require approximately 36,000 acre-feet of water. Purchase of that amount of water at the current price of $1,300/acre-foot would require an initial investment of $46,800,000.

Augmentation at low levels of 15 cfs would enable dischargers on the Poudre to provide tertiary rather than advanced waste treatment for year 2000 flows. In addition, flow augmentation will be required if the existing fishery in the Poudre is to be upgraded to a sport fishery; the Cache la Poudre River currently will not support a wide variety of aquatic life (Morrison 1978). This results from the extreme variations in hydrologic conditions and limited habitat rather than existing water quality conditions. Attainment of water quality standards without modification of hydrologic conditions and stream habitat will not improve the quality of aquatic life on the Poudre.

5.5 BIG THOMPSON RIVER

5.5.1 Existing and Projected Discharges

Table 5.5.1-A shows the point of discharge of major municipal and industrial point sources on the Big Thompson River. Existing flow rates and flow rates based on the 208 Recommended Plan for year 2000 are also shown on that table. Industrial dischargers are assumed to maintain the same discharge rates throughout the planning period.

TABLE 5.5.1-A EXISTING AND PROJECTED DISCHARGES TO THE BIG THOMPSON RIVER

Discharger	River Mile	Existing Flow (mgd)	208 Land Use
Estes Park S.D.(a)	58.4	0.5	0.7
Upper Thompson S.D. (a)	56.8	1.0	1.3
Colorado Division of Wildlife North Fork	42.0	3.0	-
Loveland No. 1	26.7	Closed	-
Loveland Packing	25.1	0.06	-
Loveland No. 2	24.2	4.2	6.1
Great Western Loveland (winter discharge only)	21.9	7.0	7.0
Johnson's Corner	20.0	0.06	0.06
Milliken	8.0	0.06	0.38

(a) Changes with seasonal and tourist load.

5.5.2 Hydrologic Conditions

Hydrology of the Big Thompson River is displayed in Table 3.2.2-A (Chapter 3). In the lower reaches of the river, it is dryed up at the following points:

Location	River Mile
Loveland and Greeley Canal	28.5
Hillsborough Ditch	21.9
Big Thompson and South Platte Ditch	10.1

The Hillsborough Ditch is 2.3 miles below the Loveland No. 2 plant discharge, and immediately above the Great Western plant discharge. The Great Western Plant discharges only during the October - February sugar beet campaign.

5.5.3 Allocation of Existing Wasteloads

The existing wastewater discharges do not violate the 1.5 mg/l State ammonia standards until the Loveland Wastewater Treatment Plant discharge (RM 24.2) causes the ammonia concentration in the river to increase to 7.1 mg/l (Figure 5.5.3-A). At river mile 21.9, diversion by the Hillsborough Ditch and return flow to the river reduces the ammonia concentration to 0.2 mg/l.

A violation of the dissolved oxygen standard (5.0 mg/l) occurs continuously from the Loveland No. 2 plant discharge (RM 24.2) to the confluence of the Big Thompson River and Little Thompson River (RM 8.0) immediately above the Milliken waste discharge. This violation results from benthic demand found to exist in the river at the time the recalibration sampling was conducted in August 1976. The cause of the benthic demand could not be isolated, but could have resulted from benthic deposits left by the Big Thompson flood of July 31, 1976, or from previous waste discharges occuring over the years. The sampling program indicated that the DO violation occuring in this reach does not result from the Loveland No. 2 plant discharge. Secondary effluent from Milliken does not cause stream standard violations.

Only the Loveland Wastewater Treatment Plant (RM 24.2) needs to be upgraded to maintain the Big Thompson River within the State standards for ammonia (NH_3) at existing discharges and low flow conditions. Effluent from the plant with an NH_3 concentration of 3.0 mg/l would cause the in-stream NH_3 concentration to reach 1.46 mg/l.

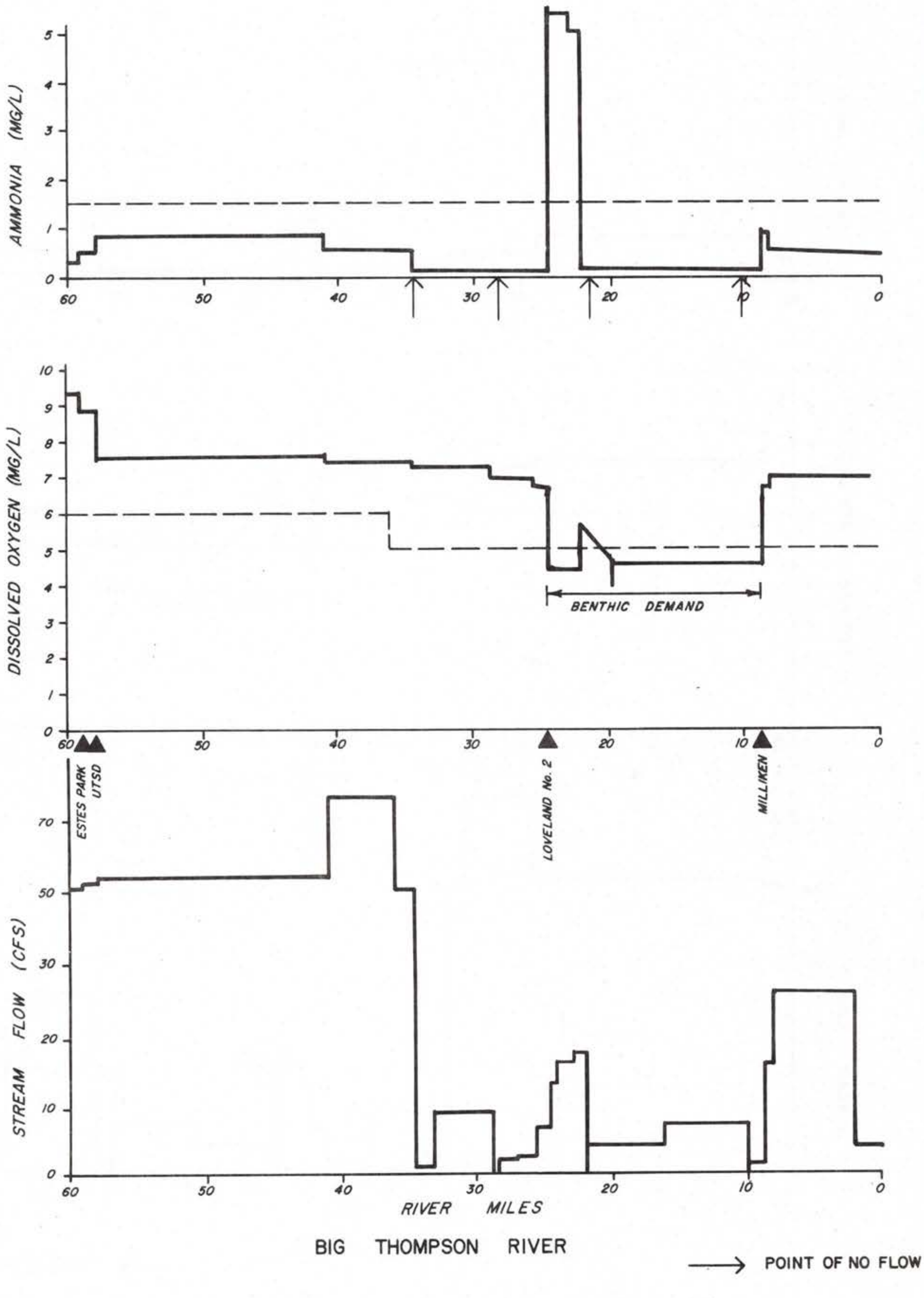


FIG. 5.5.3-A. EXISTING WATER QUALITY OF BIG THOMPSON RIVER AS DEVELOPED BY PIONEER I

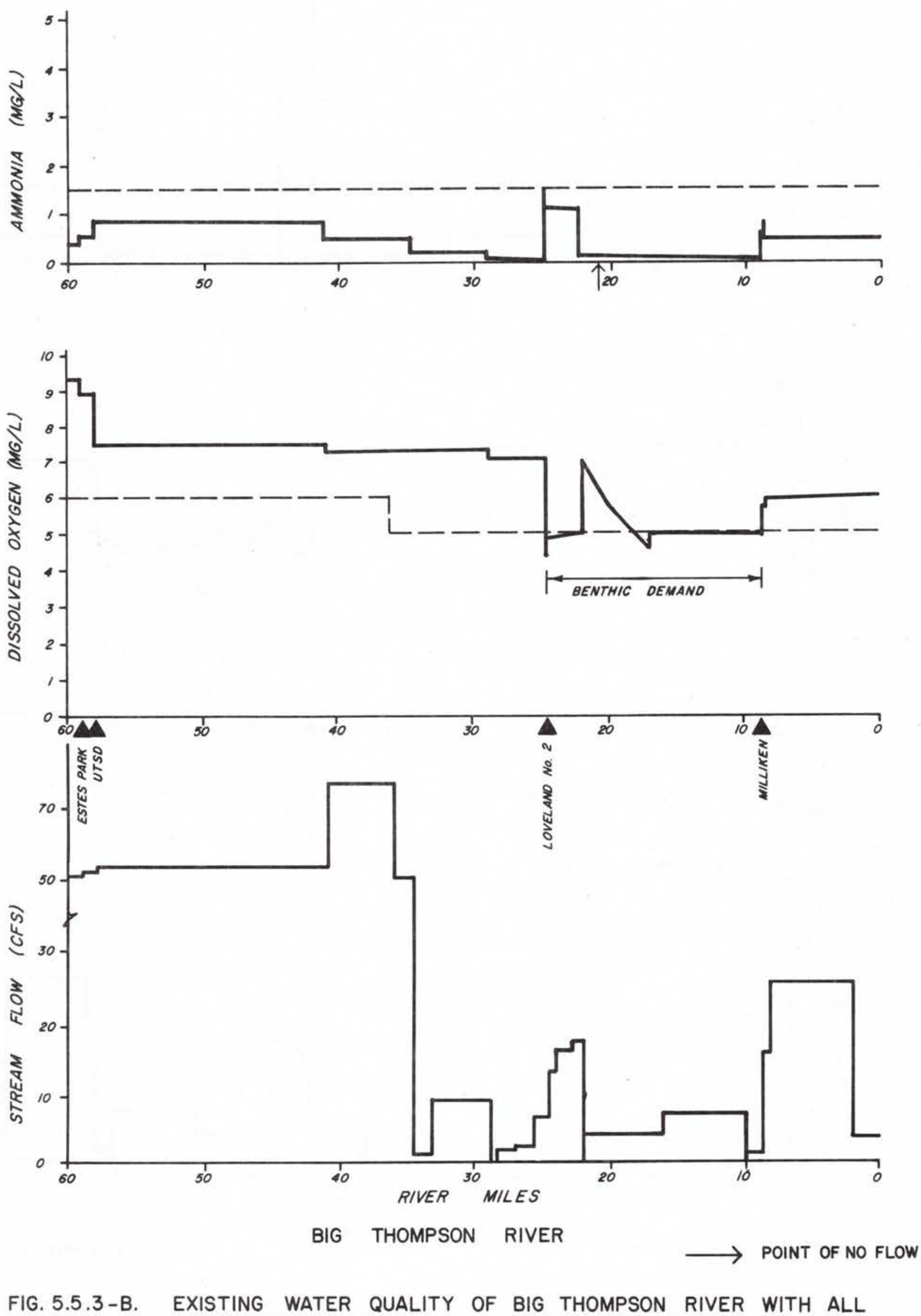


FIG. 5.5.3-B. EXISTING WATER QUALITY OF BIG THOMPSON RIVER WITH ALL TREATMENT AT SECONDARY LEVEL EXCEPT LOVELAND NO. 2 AT TERTIARY TREATMENT.

The in-stream DO level is below 5.0 mg/l due to benthic conditions. The model indicates that due to mixing conditions, benthic demand causes the DO sag to remain below 5.0 mg/l below river mile 20. This in-stream water quality is shown in Figure 5.5.3-B. Discharge by Loveland No. 2 (RM 24.2) at tertiary level would not cause violation of in-stream ammonia standards.

During the October to February period, the Great Western plant at Loveland discharges to the Big Thompson River below the Hillsborough ditch, which normally drys up the river. Stream flow immediately above the discharge point is estimated at 4.1 cfs, with the Great Western discharge being 7.0 mgd (11.0 cfs). Under existing operational conditions, the Great Western discharge causes violations of the ammonia and dissolved oxygen standards downstream of the Great Western discharge. Improvement of discharge quality to 3.0 mg/l ammonia results in in-stream ammonia concentrations of 2.1 to 2.2 mg/l for a distance of approximately five miles downstream of the discharge. Due to lower stream temperatures occuring in the fall (11.2^{o}C, 51^{o}F) the allowable level of in-stream ammonia is 3.2 mg/l, assuming a pH of 7.5. Reduction of BOD levels to 20 mg/l results in dissolved oxygen levels of 3.5 to 4.5 mg/l for a distance of approximately five miles downstream. Comparison of conditions with and without the Great Western discharge indicates that initial mixing causes the low value of 3.5 mg/l. Downstream values are lowered from 1.0 to 0.4 mg/l as a result of the discharge.

Reducing the BOD in the effluent to 10 mg/l has little impact on dissolved oxygen values in the five mile reach below the plant, due to the "benthic demand" factor identified in this reach of the Big Thompson.

Table 5.5.3-A shows the present effluent quality required by dischargers on the Big Thompson River. This allocation procedure indicates that Loveland Plant No. 2 and Great Western would have to upgrade treatment levels to meet the ammonia standard.

TABLE 5.5.3-A ALLOWABLE WASTELOADS FROM MUNICIPAL DISCHARGES NEEDED TO MEET IN-STREAM STANDARDS - BIG THOMPSON RIVER

Dischargers	EFFLUENT QUALITY BOD (mg/l)	NH_3 (mg/l	DO (mg/l)
Estes Park S.D.	30.0 (a)	15.0 (a)	2.0
Upper Thompson S.D.	30.0 (a)	15.0 (a)	2.0
Loveland No. 2	20.0	3.0	3.0
Great Western-Loveland	20.0	3.0	2.0
Milliken	30.0 (a)	15.0 (a)	2.0

(a) Present level of treatment meets or exceeds this quality.

5.5.4 208 Recommended Land Use Projection

A number of water quality violations are associated when secondary treatment is employed. The Loveland No. 2 Wastewater Treatment Plant (RM 24.2) causes the in-stream ammonia level to reach 8.7 mg/l and remain above 6.0 mg/l for five miles until the flow is diverted by the Hillsborough ditch; the DO level falls to 4.7 mg/l. At the point of discharge, due to the benthic demand, DO levels remain below 5.0 mg/l to the Hillsborough ditch (RM 21.9). There would be no stream standard violations caused by the Milliken Wastewater Treatment Plant (RM 8.0)

Figure 5.5.4-A illustrates the in-stream water quality when the Loveland No. 2 Wastewater Treatment Plant (RM 24.2) discharges tertiary treated wastes in the year 2000. This treatment level causes an instantaneous increase of ammonia to 1.8 mg/l requiring advanced waste to 1.5 mg/l NH_3 treatment at the Loveland No. 2 Plant. Dissolved oxygen decreases to 4.7 mg/l following the Loveland discharge and remains below 5.0 mg/l to the Hillsborough ditch due to benthic demand. At river mile 20.0 the oxygen again sags below 5.0 mg/l due to the benthic demand factor.

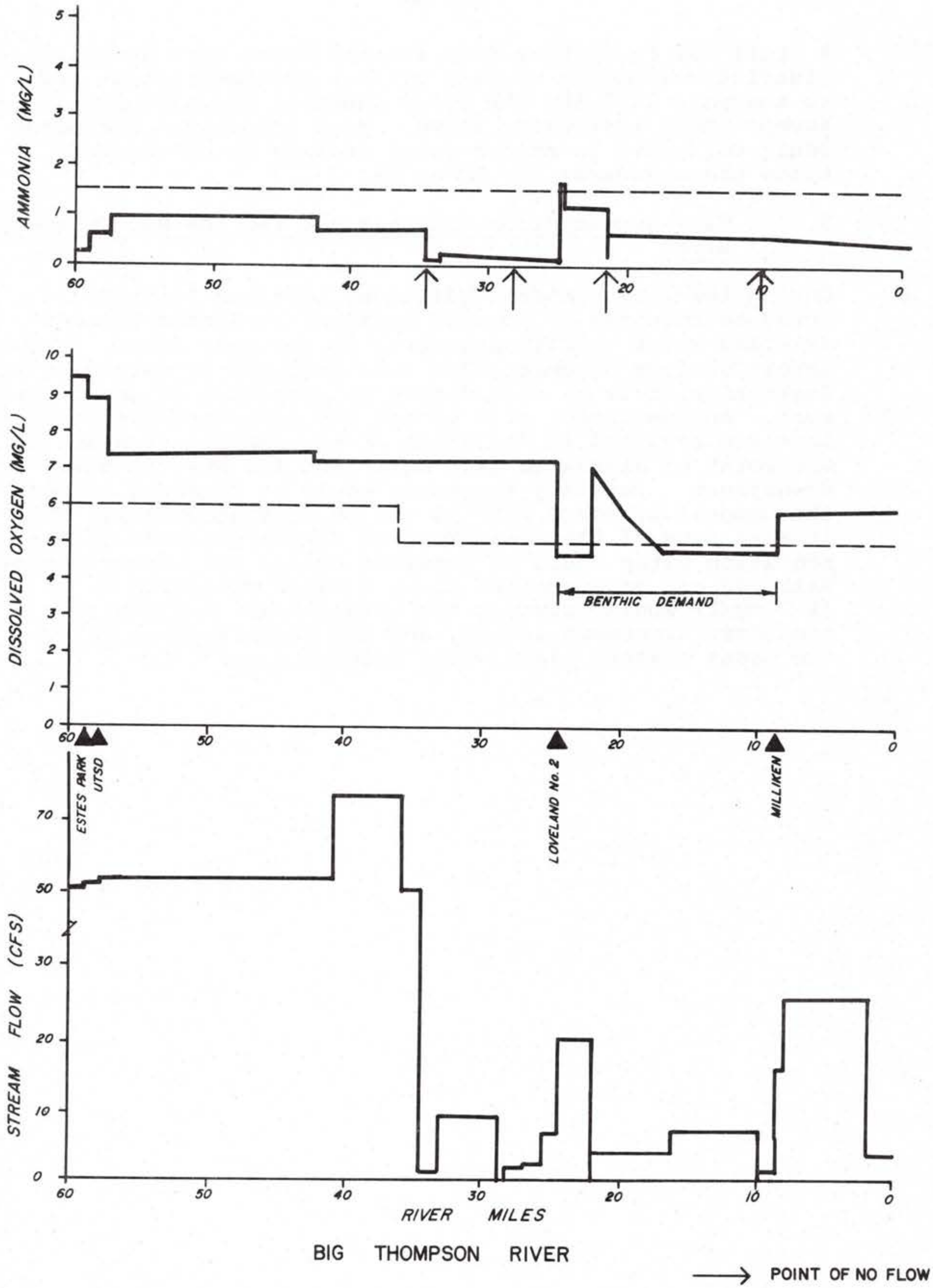


FIG. 5.5.4-A. 208 RECOMMENDED LAND USE PROJECTION INSTREAM WATER QUALITY FOR YEAR 2000 WITH TERTIARY TREATMENT AT LOVELAND

A draft 201 Facilities Plan for the Estes Park Sanitation District recommends closure of that treatment plant prior to the year 2000 and the Upper Thompson Sanitation District accept their wastewater flows. Such a combined discharge would not cause in-stream water quality to be degraded below the standards for DO or NH_3.

5.5.5 Flow Augmentation Alternatives for the Big Thompson River

During low flow summer conditions, Loveland Plant No. 2 would be required to provide advanced treatment to meet existing water quality standards in the year 2000. Various levels of flow augementation were analyzed to determine if augementation is an alternative to providing advanced treatment. Augementation with 15 cfs and secondary treatment at Loveland resulted in violation of the ammonia standard at the point of discharge (4.8 mg/l) and for several miles downstream. Tertiary treatment would be required to meet the ammonia standard with 15 cfs of augmented flow. This is also true of the Great Western discharge, even if augmentation water could be provided during the winter period. With 100 cfs of augmented flow, a minor violation (1.7 mg/l) would occur at the Loveland No. 2 Plant at secondary treatment levels, and the ammonia level below the Great Western Plant would reach 2.3 mg/l.

TABLE 5.6.1-A. EXISTING AND PROJECTED DISCHARGES TO THE LITTLE THOMPSON RIVER

Discharger	River Mile	Existing Flow (mgd)	208 Land Use
Berthoud	16	0.45	0.7
Great Western Johnstown (a)	2.0	Non-Contact Cooling Water	Non-Contact Cooling Water
Johnstown	1.3	0.22	0.32

(a) Not operating during low flow conditions.

5.6 LITTLE THOMPSON RIVER

The Pioneer I Water Quality Model was recalibrated for the Little Thompson River.

5.6.1 Existing and Projected Discharge

Table 5.6.1 lists the municipal and industrial point source dischargers in the Little Thompson River with their existing flow and future discharges. Under current permit conditions, the Great Western, Johnstown plant discharges only non-contact cooling water to the Little Thompson River, and no chemicals may be added to the cooling water.

5.6.2 Hydrologic Conditions

Unlike the Cache la Poudre and Big Thompson Rivers the Little Thompson River is not dried up during low flow conditions. Generally, the flow is greater than 10 cfs throughout the length of the river. Flows are less than 10 cfs from river mile 34.0 to mile 24.9, and from river mile 23.4 to 20.9. These areas of low flow do not affect the wasteload allocations on this river.

5.6.3 Results of Wasteload Allocation Process

Effluent from municipal and industrial dischargers does not presently cause a violation of the allowable in-stream water quality standards during low flow conditions. Future discharges will not cause in-stream water quality violations. For the year 2000 projection, lowest DO levels will not be below 6.0 mg/l and the Johnstown municipal discharge will cause the ammonia level to reach 1.1 mg/l, 0.4 mg/l below the State standard.

5.7 ST. VRAIN CREEK

Elements of the model associated with the St. Vrain Creek were not recalibrated as part of the 208 program. However, coefficients were altered to more accurately reflect the nature of the St. Vrain Creek based on recalibration efforts on other streams.

5.7.1 Existing and Projected Discharges

Only the Tri-Area Sanitation District presently discharges into the St. Vrain Creek at river mile 11.6 in the Larimer-Weld Region. Lyons and Longmont from Boulder County discharge into the St. Vrain before it enters Weld County. Tri-Area Sanitation District effluent enters the St. Vrain Creek at river mile 11.6 after traveling three miles in an irrigation ditch. The existing flow is 0.31 mgd, and the projected flow for the year 2000 is 0.94 mgd.

5.7.2 Hydrologic Conditions

Low flow conditions on the St. Vrain do not impose zero flow conditions in Weld County. Flow is above 30 cfs in all areas within the region.

5.7.3 Results of Wasteload Allocation Process

The Longmont Wastewater Treatment Plant contributes heavily to the low flow in the St. Vrain Creek at the Boulder-Weld County line. This large contribution by the Boulder County discharger causes ammonia concentrations to exceed the 1.5 mg/l limit established by the Colorado Department of Health for some distance downstream. The water quality impacts of the Tri-Area Plant are negligible due to high in-stream flow rates and small discharges by the plant. Contributions by the Tri-Area Sanitation District do not cause continued water quality violations presently or in the future.

5.8 COAL CREEK

Coal Creek is tributary to Boulder Creek, which subsequently flows into the St. Vrain.

5.8.1 Existing and Projected Discharges

The only discharger on Coal Creek within the Larimer-Weld Region is the Erie Water and Sanitation District plant at river mile 2.5. Existing flow is 0.13 mgd, and the projected flow is 0.18 mgd. Boulder County dischargers to Coal Creek up-stream of Erie include Lafayette and Louisville.

5.8.2 Hydrologic Conditions

A hydrologic analysis of Coal Creek was not developed as part of the 208 program. A recent 201 Facility Plan for Erie Water and Sanitation District states that near zero flow conditions occur intermittently during the summer at and below the point of discharge on Coal Creek.

5.8.3 Results of Wasteload Allocation Process

Based on previous calibrations of the Pioneer I model, dissolved oxygen and ammonia standards are violated by upstream discharges, and these violations continue into Weld County. Under these conditions the Erie Water and Sanitation District would be required to provide advanced waste treatment to meet existing water quality standards. The Erie discharge has little impact compared to other sources. For this reason and due to lack of adequate site-specific information, it is recommended that the Erie Water and Sanitation District be required to provide secondary treatment.

5.9 SOUTH PLATTE RIVER

The South Platte River portion of the model was not recalibrated as part of the 208 program. Coefficients were altered to reflect knowledge of regional conditions based on other recalibration efforts.

5.9.1 Existing and Future Discharges

Table 5.9.1-A shows existing and future discharges to the South Platte River.

5.9.2 Results of Wasteload Allocation Process

5.9.2.1 Existing Conditions

Water of the South Platte River enters Weld County with ammonia concentrations of above 3.2 mg/l according to summer 1976 sampling data. The limited nature of the sampling program did not allow determination of the duration of this violation or the up-stream source. When this concentration is input into the Pioneer I Model as the concentration of ammonia entering Weld County (river mile 295.3), it is not until river mile 284.1 at the entrance of Platte Valley Supply Canal that NH_3 levels are below 1.5 mg/l. Present discharges by Hill-n-Park, LaSalle, and Evans fail to cause further in-stream violations of NH_3 or DO with secondary treatment.

When the dissolved oxygen concentration of the South Platte River is above 6.0 mg/l when the river enters Weld County, no violations of DO occur. Existing dischargers on the South Platte River in Weld County do not need to upgrade present treatment levels to meet State water quality criteria with present discharge volumes, providing waters entering the County are already within the limits established by the Colorado Department of Health.

5.9.2.2 Future Alternatives

None of the three alternative land use projects cause violations of in-stream water quality standards providing South Platte River water quality is within the limits established by the State of Colorado when the river enters Weld County.

5.9.2.3 Greeley Delta

By the year 2000, Greeley is expected to have installed a second treatment facility that discharges 11.5 million gallons per day (17.8 cfs) into the South Platte River. Wasteload allocations on the South Platte River indicate that secondary treatment will not allow attainment of water quality standards. Discharge of a 30 mg/l BOD and 15 mg/l ammonia (RM 248.2) will cause the in-stream ammonia level to reach 11.6 mg/l and

TABLE 5.9.1-A. EXISTING AND PROJECTED DISCHARGES TO THE SOUTH PLATTE RIVER

Discharger	River Mile	Existing Flow (mgd)	208 Land Use
Fort Lupton	287.6	1.3	1.3
Public Service Fort St. Vrain	270.0	1.5	-
Hill-n-Park	257.0	0.04	0.06
LaSalle	256.2	0.1	0.45
Evans	254.7	0.45	0.9
Greeley Delta	248.2	0	11.5

remain above 1.5 mg/l until river mile 230.8 where return flows provide acceptable water. The DO standard is also exceeded until the confluence with the Cache la Poudre River at mile 247.7 provides sufficient oxygen to raise the in-stream DO above 5.0 mg/l.

Upgrading of Greeley Delta Plant (RM 248.2) to tertiary treatment continues to cause violations of the ammonia and dissolved oxygen standards until Cache la Poudre River water dilutes these wastes one-half mile below the point of discharge. The NH_3 concentration is 2.3 mg/l, and the DO concentration is 4.6 mg/l for the one-half mile stretch of the river.

5.9.3 Summary

Table 5.9.3-A summarizes the South Platte wasteload allocations. The Greeley Delta Wastewater Treatment Plant will be required to provide advanced waste treatment to avoid violation of the ammonia standard.

TABLE 5.9.3-A. WASTELOAD ALLOCATIONS FOR SOUTH PLATTE RIVER

Discharger	Effluent Concentration (mg/l) BOD	DO	NH_3
Fort Lupton	30	2	15
Public Service Fort St. Vrain[(1)]	10	2	1.0
Hill-n-Park	30	2	15
LaSalle	30	2	15
Evans	30	2	15
Greeley Delta	10	4	1.5

[(1)] Existing permit conditions.

APPENDIX A
REFERENCES

REFERENCES

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APPENDIX B

TECHNICAL DATA ON MUNICIPAL AND INDUSTRIAL POINT SOURCE DISCHARGERS

This appendix presents data on municipal and industrial dischargers originally presented in the 208 Water Quality Management Plan, Interim Report No. 6, entitled, "Municipal and Industrial Point Source Analysis, Wastewater Treatment Operation, and Maintenance Requirements," by Toups Corporation, April 1977.

LIST OF TABLES AND FIGURES
APPENDIX B

Table B-1

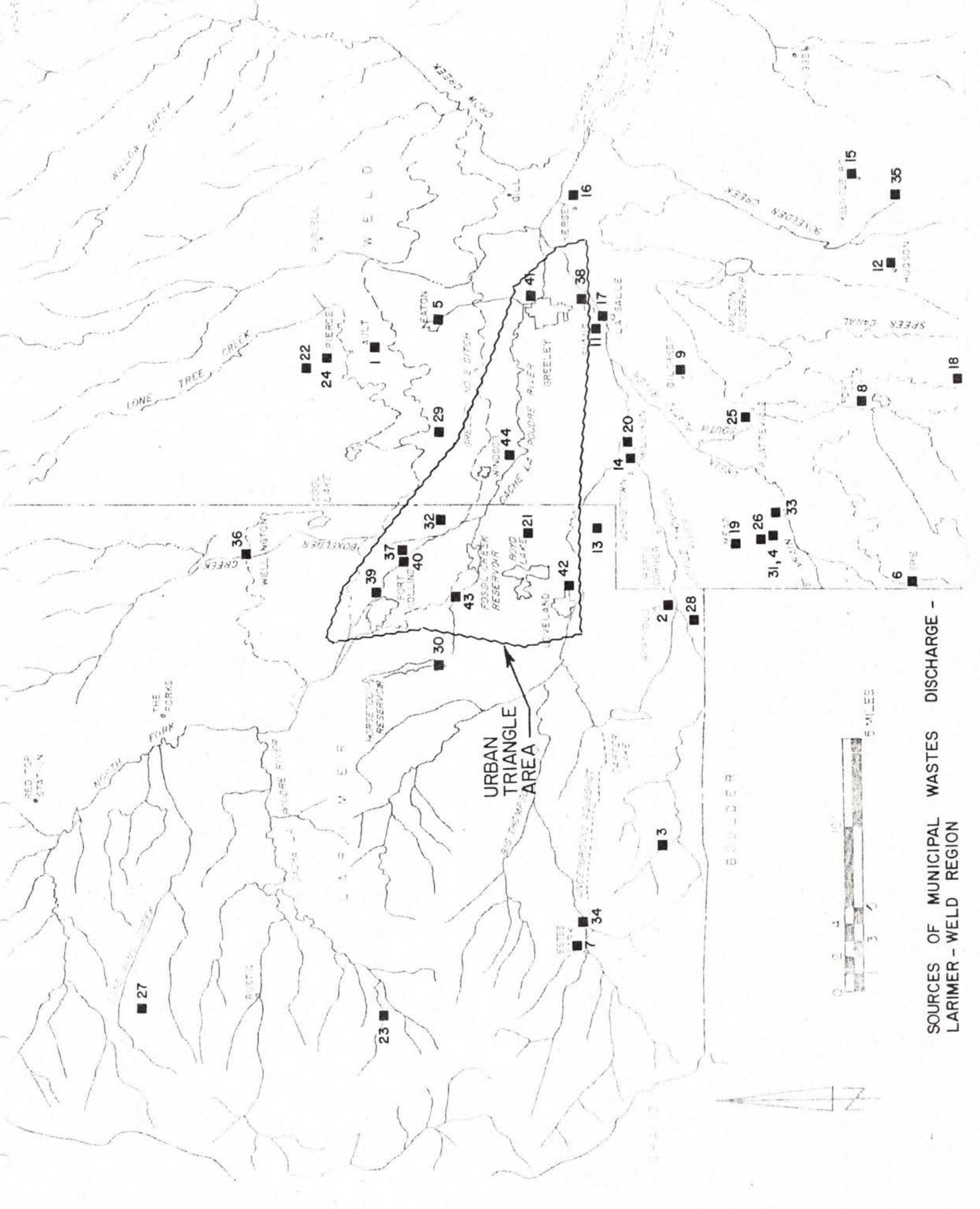
INDEX NO.		EXISTING AVERAGE FLOW (mgd)
	MUNICIPALITY - OUTLYING AREA	
M-1	Ault S.D.	0.09
M-2	Berthoud	0.48
M-3	Cottonwood Park	0.20
M-4	Del Camino	0.02
M-5	Eaton	0.21
M-6	Erie W.S.D.	0.13
M-7	Estes Park S.D.	0.40(a)
M-8	Fort Lupton	0.64
M-9	Gilcrest S.D.	0.04
M-10	Grover	0.025
M-11	Hill-n-Park S.D.	0.07
M-12	Hudson S.D.	0.06
M-13	Johnson's Corner	0.007
M-14	Johnstown	0.22
M-15	Keenesburg S.D.	0.05
M-16	Kersey S.D.	0.05
M-17	LaSalle	0.17
M-18	Lochbuie	-
M-19	Mead S.D.	0.035
M-20	Milliken S.D.	0.10
M-21	Mountain Range Shadows	0.01
M-22	Nunn	-
M-23	Pingree Park	0.01
M-24	Pierce	0.05
M-25	Platteville	0.14
M-26	Ramada Inn (I-25)	N/A
M-27	Red Feather/Crystal Lakes	N/A
M-28	Riverglenn	N/A
M-29	Severance	-
M-30	Spring Canyon S.D.	-

INDEX NO.		EXISTING AVERAGE FLOW (mgd)
M-31	Texaco (I-25)	0.023
M-32	Timnath	-
M-33	Tri-Area S.D.	0.31
M-34	Upper Thompson S.D.	0.20(a)
M-35	Weld Central H.S.	0.01
M-36	Wellington	0.06
	MUNICIPALITY - CORE AREA	
M-37	Boxelder S.D.	0.6
M-38	Evans S.D.	0.5
M-39	Ft. Collins #1	5.0
M-40	Ft. Collins #2	5.6
M-41	Greeley	6.2
M-42	Loveland	4.0
M-43	South Ft. Collins S.D.	0.5
M-44	Windsor	0.6

N/A = Data not presently available.

(a) = Does not include seasonal flows.

Figure B-1



SOURCES OF MUNICIPAL WASTES DISCHARGE -
LARIMER - WELD REGION

Table B-2

INDEX NO.		EXISTING AVERAGE FLOWS
	MAJOR DIRECT INDUSTRIAL DISCHARGERS	
I- 1	Eastman Kodak Co.-KCD	1.0
I- 2	Great Western Sugar Co. - Loveland	4.3
I- 3	Great Western Sugar Co. - Greeley	2.0
I- 4	Great Western Sugar Co. - Johnstown	5.4
I- 5	Loveland Packing Co.	0.05
I- 6	Public Service Co. - Ft. St. Vrain	1.5
	MINOR DIRECT INDUSTRIAL DISCHARGERS	
I- 7	Cowan Concrete Products	(a)
I- 8	Flatiron Paving Co.-Greeley	(a)
I- 9	Flatiron Paving Co.-Windsor	(a)
I-10	Flatiron Paving Co.-Loveland	(a)
I-11	Flatiron Paving Co. - Greeley (West)	(a)
I-12	Greeley Sand & Gravel	(a)
I-13	Eldred M. Johnson	(a)
I-14	Floyd Haag Sand & Gravel	(a)
I-15	Mountain Aggregate - Ft. Collins	(a)
I-16	Mountain Aggregate - (to St. Vrain)	(a)
I-17	Norden & Son Land Leveling	(a)
I-18	Poudre Pre-Mix	(a)
I-19	Colo. Division of Wildlife - Bellvue	1.0
I-20	Colo. Division of Wildlife - North Fork	3.0
I-21	Colo. Division of Wildlife - Poudre	4.0
I-22	Colo. Division of Wildlife - Watson Lake	12.0

INDEX NO.		EXISTING AVERAGE FLOWS
I-23	Colo. Division of Wildlife - Estes Park	3.0
I-24	Blacky Valencia	0
I-25	Western Fisheries Consultants	0
I-26	Ft. Collins - Poudre Canyon Water Treatment Plant (WTP)	-
I-27	Greeley-Bellvue WTP	-
I-28	Greeley-Boyd Lake WTP	-
I-29	Loveland WTP	-
I-30	Hydraulics Unlimited Mfg. Co.	0.02
I-31	Monfort Packing Co.	1.7
I-32	Lone Star Steel Co.	0.03
I-33	Terra Resources Inc.-Clarks Lake	0.009
	MAJOR INDUSTRIAL DISCHARGERS TO MUNICIPALITIES	DISCHARGE TO
I-34	Hewlett-Packard Co.	Loveland
I-35	Woodward Governor	Ft. Collins
I-36	Teledyne-Water Pic	Ft. Collins
I-37	Western Food Products Inc.	Ft. Collins
I-38	Eastman Kodak Co. (optional)	Windsor
I-39	Carnation Milk Co.	Johnstown
I-40	Ft. Lupton Canning Co.	Ft. Lupton
I-41	Meadow Gold Dairy	Greeley
I-42	Monfort of Colorado	Greeley

(a) Flows highly variable.

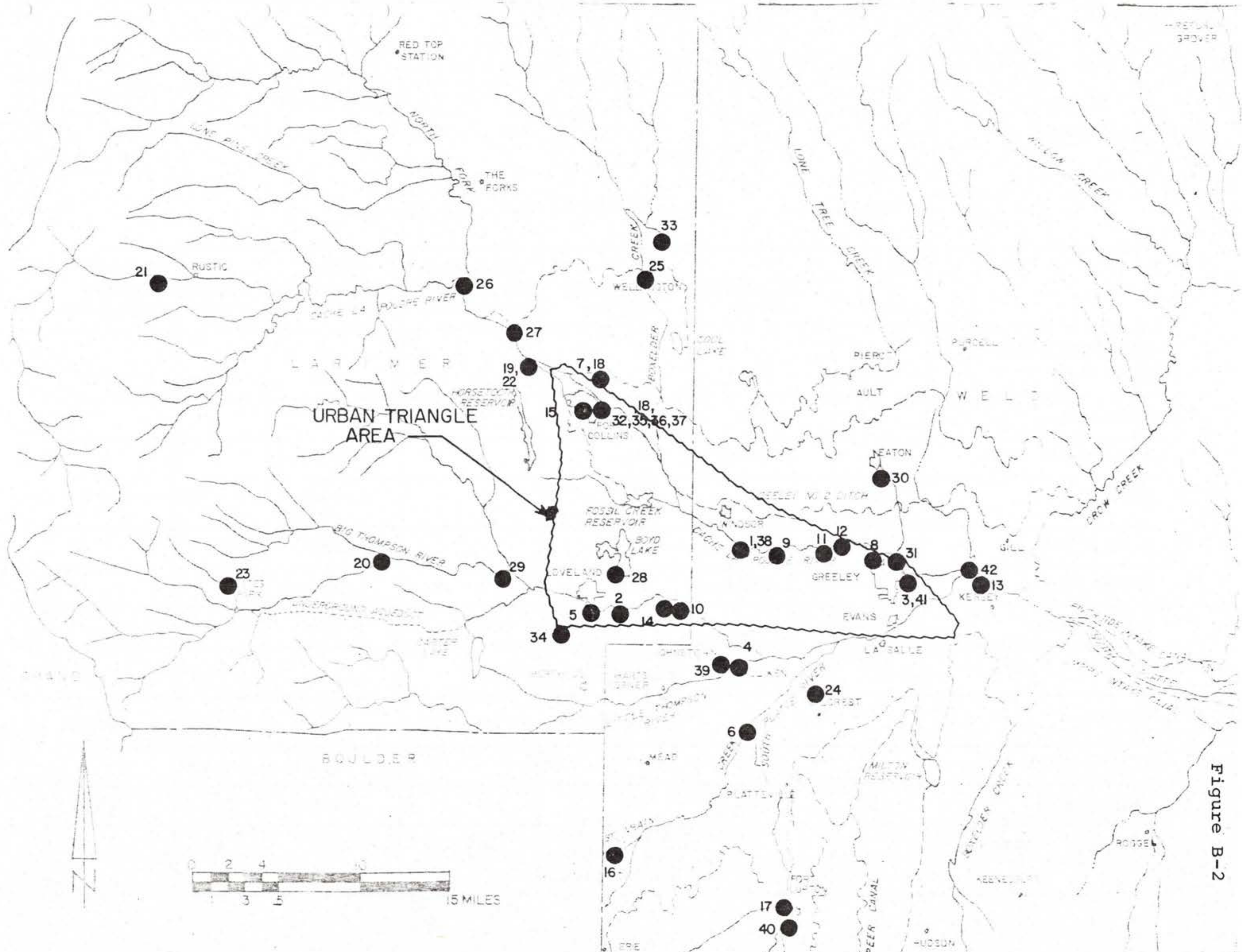


Figure B-2

SOURCES OF INDUSTRIAL WASTES DISCHARGE -
LARIMER - WELD REGION

Table B-3 Description of Sewerage Systems

	NUMBER OF TAPS	POPULATION SERVED	INDUSTRIES SERVED	INDUSTRIAL EQUIVALENT POPULATION	TOTAL EQUIVALENT POPULATION	SEWER SIZES	DATE SEWER INSTALLED
OUTLYING AREA							
Ault S.D.	400	950	-	-	950	8"	1952
Berthoud		2,500	-	-	2,500		
Cottonwood Park		2,000(a)	-	-	2,000(a)		
Eaton	800	2,100	Harsh Hoist	-	2,100	8"-36"	1930
Erie W.S.D.	404	1,300	-	-	1,399	8"-36"	
Estes Park S.D.		1,900(b)	-	-	1,900(b)		
Fort Lupton	900	3,300	Cannery	500	3,800	6"-12"	
Gilcrest S.D.	161	500	School (400 Students)	133	633	6"-10"	
Grover	73	120	School (150 Students)	50	170	8"	1975
Hill-n-Park S.D.	235	825	-	-	825	8"-10"	
Hudson S.D.	250	600	-	-	600	10"	1951
Johnson's Corner	2	-	Restaurant (200 Seat) + Gas Station	140	140	8"	

Table B-3 Description of Sewerage Systems (Cont.)

	NUMBER OF TAPS	POPULATION SERVED	INDUSTRIES SERVED	INDUSTRIAL EQUIVALENT POPULATION	TOTAL EQUIVALENT POPULATION	SEWER SIZES	DATE SEWER INSTALLED
OUTLYING AREA (Cont.)							
Johnstown	641	1,500	Carnation Milk	1,100	2,600	8"-10"	
Keenesburg S.D.	216	525	Hatchery; Turkey Processor	N/A		8"-10"	1953
Kersey S.D.	225	1,000	Rendering Plant (100/Day)	N/A		8"-10"	
LaSalle		1,500	Packing Plant	270	1,770		
Mead S.D.	80	225	School (1650 Students)	215	440	8"-10"	
Milliken S.D.	350	1,400	-	-	1,400	8"	1930's
Mountain Range Shadows		600	-	-	600		
Pingree Park		50	-	-	50		
Pierce	290	975	School (350 Students)	80	1,060	8"	1969
Platteville	443	1,500	-	-	1,500	6"-12"	1950's
Ramada Inn	-	-	Motel & Restaurant	-	-		

Table B-3 Description of Sewerage Systems (Cont.)

	NUMBER OF TAPS	POPULATION SERVED	INDUSTRIES SERVED	INDUSTRIAL EQUIVALENT POPULATION	TOTAL EQUIVALENT POPULATION	SEWER SIZES	DATE SEWER INSTALLED
OUTLYING AREA (Cont.)							
Red Feathers/ Crystal Lakes		200	-	-	200		
Riverglenn		50	-	-	50		
Spring Canyon S.D.		400	-	-	400		
Texaco	2	Varies	N/A	N/A		8"	
Tri-Area S.D.		3,100	-	-	3,100	12"	
Upper Thompson S.D.		5,000(b)	-	-	5,000(b)		
Weld Central H.S.	1	-	School (780 Students)	260	260	6"	
Wellington	400	1,250	-	-	1,250	12"	
URBAN TRIANGLE AREA							
Boxelder S.D.		4,350	-	-	4,350		
Evans S.D.		4,500			4,800		
Fort Collins No. 1		65,000(c)			114,000 (c,d)		

Table B-3 Description of Sewerage Systems (Cont.)

	NUMBER OF TAPS	POPULATION SERVED	INDUSTRIES SERVED	INDUSTRIAL EQUIVALENT POPULATION	TOTAL EQUIVALENT POPULATION	SEWER SIZES	DATE SEWER INSTALLED
URBAN TRIANGLE AREA (Cont.)							
Fort Collins No. 2 & 3		65,000(c)			114,000 (c,d)		
Greeley		55,000			62,000(d)		
Loveland Plant No. 2		21,000	Hewlett-Packard	1,500	35,000(d)		
South Fort Collins S.D.		2,000			2,000		
Windsor		2,700			5,900(d)		

N/A: Data not available.

(a) Estimated.

(b) Increases with summer tourist load.

(c) Total tributary to all plants.

(d) Includes I/I.

TABLE B-4

HISTORICAL DATA - EFFLUENT WASTEWATER

AGENCY	BOD_5 (mg/l) (a)	SS (mg/l) (a)	FECAL COLIFORMS (MPN/100 ml)	NH_3 (mg/l)
Ault S.D.*	37	62	48,000	4.6
Berthoud	2	10	12	
Del Camino (I-25)	19	31	150	0.8
Eaton	11	18	2,800	12
Erie W. & S.D.*	83	105	>20,000	18
Fort Lupton*	42	69	19,900	6.6
Hill & Park S.D.*	31	76	9,600	0.4
Hudson S.D.*	31	62	4,900	
Johnson's Corner*	46	94	800	
Johnstown*	34	50	1,000	4
Keenesburg S.D.*	35	58	6,000	6.3
LaSalle*	21	43	150	6.2
Mead S.D.*	47	130	1,830	2.6
Milliken S.D.	27	66	1,400	
Pierce*	28	44	270	2.8
Platteville*	35	62	< 100	5.7
Texaco (I-25)	100	180	20,000	19
Tri-Area S.D.*	40	70		2
Weld Central High School	57	50	4,500	1.7
Wellington*	18	11	300	
Estes Park S.D.	19	18		

(a) NPDES limitations: BOD_5 = 30 mg/l;
SS = 30 mg/l.

* Future NPDES limitations may be modified to reflect Best Waste Stabilization Pond Technology (BWSPT).

Table B-5

Sampling Program Results - Effluent Wastewater (a)

	Fort Collins No. 1	Fort Collins No. 2	Wind-sor	Greeley	Love-land No. 1	Love-land No. 2	Johns-town	Mill-iken S.D.	Fort Lupton	Platte-ville	Erie S.D.
BOD_5 (unfiltered)	15	42	19	37	13	22	10	8	23	26	58
BOD_5 (filtered)							9	6	19	16	31
COD								22	132	191	
Suspended Solids	22	84	124	44	21	26	86	7	92	46	80
Fecal Coliform	100	11,000	10	900	100	100	3800	20	6100	2500	3800
Oil & Grease								0.4			
Ammonia	5.3	11.0	47	7.4	8.0	12.8	4.7	8.3	1.2	1.7	6.1
Nitrate	0.16	0.54	0.78	3.6	1.2	0.84	0.02	0.23	0.01	0.01	0.14
Phosphate								2.5	2.6	2.4	
Sulfate									304	442	
Sodium								137	337	364	
Total Alkalinity								244	286	304	
TDS	528	380	1152	508	720	800	640	1040	1364	1724	740
pH							8.7	7.0	8.6	8.0	8.4
Temperature (°C)							19	20	19	21	21
D.O.							6.0	4.0	6.2	7.6	7.4
Electrical Conductivity								1150	1840	1800	550

(a) Samples collected by Toups Corporation, September, 1976.

Table B-6

Waste Load Projections

DESIGNATION	AGENCY	PRESENT ADWF (mgd)	1983				2000			
			ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)	ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)
1	Ault S.D.	0.09	0.20	.68	360	360	0.33	1.0	594	594
2	Berthoud	0.48	0.43	1.4	780	780	0.70	2.1	1260	1260
3	Cottonwood Park	0.20								
4	Del Camino	0.02								
5	Eaton	0.21	0.29	.95	525	525	0.40	1.3	720	720
6	Erie W.S.D.	0.13	0.15	.48	275	275	0.18	0.6	325	325
7	Estes Park S.D.	0.40	0.61 (a)	1.9	430	430	0.72 (a)	2.2	720	720
8	Fort Lupton	0.64	0.85	2.6	830	830	1.50	4.5	1200	1200
9	Gilcrest S.D.	0.04	0.07	.25	120	120	0.13		240	240
10	Grover	0.025	0.013	.05	25	25	0.015	.06	30	30
11	Hill-n-Park S.D.	0.07	NA	NA	NA	Na	0.65	2.0	1200	1200
12	Hudson S.D.	0.06	0.11	.39	200	200	0.15	.50	270	270
13	Johnson's Corner	0.007								

Table B-6 (Cont.)

Waste Load Projections

DESIGNATION	AGENCY	PRESENT ADWF (mgd)	1983				2000			
			ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)	ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)
14	Johnstown	0.22	0.28	0.9	300	300	0.38	1.2	400	400
15	Keenesburg S.D.	0.05	0.08	.28	150	150	0.13	0.45	230	230
16	Kersey S.D.	0.05	0.21	.71	390	390	0.30	1.00	540	540
17	LaSalle	0.17	0.32	1.0	580	580	0.45	1.4	800	800
18	Lochbuie	-	0.11	.37	200	200	0.15	0.5	270	270
19	Mead S.D.	0.035	0.04	.15	75	75	0.07	.24	125	125
20	Milliken S.D.	0.10	0.22	.73	400	400	0.40	1.3	720	720
21	Mountain Range Shadows	0.01								
22	Nunn	-								
23	Pingree Park	0.01								
24	Pierce	0.05	0.15	.51	270	270	0.30	1.00	540	540
25	Platteville	0.14	0.22	.73	400	400	0.40	1.3	720	720
26	Ramada Inn									
27	Red Feather/ Crystal Lakes	NA	0.25	.80	750	750	0.50		1490	1490

Table B-6 (Cont.)
Waste Load Projections

DESIGNATION	AGENCY	PRESENT ADWF (mgd)	1983				2000			
			ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)	ADWF (mgd) (b)	PWWF (mgd) (c)	BOD_5 (#/day)	SS (#/day)
28	Riverglenn									
29	Severance	-	0.03	.10	60	60	0.08	0.28	150	150
30	Spring Canyon S.D.	-	0.23	.78	425	425	0.35	1.1	630	630
31	Texaco I-25	0.023								
32	Timnath	-	0.05	.18	100	100	0.075	.28	150	150
33	Tri-Area S.D.	0.31	0.65	2.1	1200	1200	0.94	2.8	1700	1700
34	Upper Thompson S.D.	0.20 (a)	0.50 (a)	1.7	650	650	0.77 (a)	2.5	1400	1400
35	Weld Central H.S.	0.01	NA							
36	Wellington	0.06	0.17	.58	400	400	0.28	0.9	700	700

NA - Data not presently available.

(a) Does not include seasonal flows.

(b) Average dry weather flow.

(c) Peak wet weather flow.

TABLE B-7 DESCRIPTION OF MAJOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS	
						YES	NO
Eastman Kodak Company - Kodak Colorado Division	Photographic Products	1 mgd	Two aerated lagoons sand filtration, Cl2. Chemical feed facilities exist. Domestic waste treated at Windsor.	Cache la Poudre River	BOD_5, TSS, CN, Phends, NH_3, Cl_2, Metals (Ag, Al, Cr, Zn, B)		*-1
Great Western Sugar Co., Loveland Facility	Sugar & Molasses	4.3 mgd	Clarified ash flume water and condenser water flows are treated in 2 lagoons. There is some seepage from lime and acid water pond.	Big Thompson River	BOD_5, Fecal Coliform, Temperature	X	
Great Western Sugar Co., Greeley Facility	Sugar	*-2	Ash flume water is clarified and recycled. Condenser water is used for land application.	Cache la Poudre River *-2	BOD_5, Fecal Coliform, Temperature	X	
Great Western Sugar Co., Johnstown Facility	MSG *-3	5.4 mgd	Aerated lagoons	Little Thompson River	BOD_5, Fecal Coliform, Temperature	X	
Loveland Packing Co.	Pork Products	0.05 mgd	Grease trap, screening, extended aeration plant-projected pre-treatment facility	Big Thompson River	BOD_5, SS, Oil and Grease		*-4

*-1 NPDES Permit is based on proposed water quality standards.
*-2 Normally no discharge, but a permit has been obtained so emergency discharge is allowed.
*-3 The GWS-Johnstown facility has recently stopped producing molasses.
*-4 Projected discharge to Loveland municipal system.

TABLE B-7 DESCRIPTION OF MAJOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS Page 2

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS. YES	NO
Public Service Company, Fort St. Vrain	Nuclear electrical generating plant	1.5 mgd	Cooling towers and ponds. Reactor building wastewater (8-10,000 gal/yr) treated by ion exchange.	South Platte River	TDS, Temperature, SS, Cl_2	X	

TABLE B-8 DESCRIPTION OF MINOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS	
						YES	NO
Cowan Concrete Products	Sand & Gravel	*-1	Settling - no chemicals added	Cache la Poudre via Spring Creek	SS - Groundwater pumped from pits	X	
Flatiron Paving Co., Greeley Facility	Sand & Gravel	*-1	Settling	Cache la Poudre	SS - Groundwater pumped from pits	X	
Flatiron Paving Co., Windsor Facility	Sand & Gravel	*-1	Settling	Cache la Poudre	SS - Groundwater pumped from pits	X	
Flatiron Paving Co., Loveland Facility	Sand & Gravel	*-1	Settling - no chemicals added	Big Thompson River	SS - Groundwater pumped from pits	X	
Flatiron Paving Co., Greeley Facility (West)	Sand & Gravel	*-1	Settling - no chemicals added	Cache la Poudre	SS - Groundwater pumped from pits	X	
Greeley Sand & Gravel Co.	Sand & Gravel	*-1	Settling - no chemicals added	Cache la Poudre	SS - Groundwater pumped from pits	X	
Eldred M. Johnson	Sand & Gravel	*-1	Settling - no chemicals added	South Platte	SS - Groundwater pumped from pits	X	
Floyd Haag Sand & Gravel	Sand & Gravel	*-1	Settling - no chemicals added	Big Thompson River	SS - Groundwater pumped from pits	X	

TABLE B-8 DESCRIPTION OF MINOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS Page 2

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS. YES	NO
Mountain Aggregate, Ft. Collins	Sand & Gravel	*-1	Settling - no chemicals added	Cache la Poudre via Fossil Creek Ditch	SS - Groundwater pumped from pits	X	
Mountain Aggregate	Sand & Gravel	*-1	Settling - no chemicals added	St. Vrain River	SS - Groundwater pumped from pits	X	
Norden & Son Land Leveling	Sand & Gravel	*-1	Settling - no chemicals added	Ft. Lupton Bottom	SS - Groundwater pumped from pits	X	
Poudre Pre-Mix	Sand & Gravel, Ready-Mixed Concrete	*-1	Settling - no chemicals added	Cache la Poudre River	SS - Groundwater pumped from pits	X	
Colorado Div. of Wildlife, Bellvue Unit	Trout Rearing	1 mgd	Settling ponds	Cache la Poudre	SS - Water is frequently recycled through Watson Lake	X	
Colorado Div. of Wildlife, North Fork Unit	Trout Rearing	3 mgd	Settling ponds	North Fork Big Thompson	SS	X	
Colorado Div. of Wildlife, Poudre River Unit	Trout Rearing	4 mgd	Settling ponds	Cache la Poudre	SS	X	
Colorado Div. of Wildlife, Watson Lake	Trout Rearing	12 mgd	Wastes pumped to Watson Lake	Cache la Poudre	SS - Water is frequently recycled	X	

TABLE B-8 DESCRIPTION OF MINOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS Page 3

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS.	
						YES	NO
Colorado Div. of Wildlife Estes Park Unit	Brood fish for egg production	3 mgd	Settling	Fall River		*-2	
Blacky Valencia	Trout Rearing	0	No discharge	N/A	N/A		
Western Fisheries Consultants	Trout Rearing	0	No discharge	N/A	N/A		
Ft. Collins-Poudre Canyon Water Treatment Plant	Potable Water	-	Waste solids to holding ponds; water re-used	Cache la Poudre	SS, Al, pH	X	
Greeley-Bellvue Water Treatment Plant	Potable Water	-	Waste solids to holding ponds; water re-used	Cache la Poudre	SS, Al, pH	X	
Greeley-Boyd Lake Water Treatment Plant	Potable Water	-	Waste solids to holding ponds; water re-used	Big Thompson	SS, Al, pH	X	
Loveland Water Treatment Plant	Potable Water	-	Partial sedimentation	Big Thompson	SS, Al, pH		X

TABLE B-8 DESCRIPTION OF MINOR DIRECT INDUSTRIAL WASTEWATER DISCHARGERS

INDUSTRY NAME	PROCESS OR PRODUCT	FLOW RATE	TREATMENT AND PROCESS DESCRIPTION	RECEIVING WATERS	EXTRAORDINARY WASTEWATER CHARACTERISTICS	MEETS NPDES REQIMTS.	
						YES	NO
Hydraulics Unlimited Mfg. Co.	Chrome Plating	20,000 gpd	Non-contact cooling water only. No chemicals added	Eaton Town Ditch	Temperature	X	
Monfort Packing Co.	Red meat Products	1.7 mgd	Non-contact cooling water only. No chemicals added	Cache la Poudre	Temperature	X	
Lone Star Steel Co.	Steel Pipe	30,000 gpd	Non-contact cooling water only. No chemicals added	Spring Creek	Temperature	X	
Terra Resources Inc., Clark's Lake Muddy Sand Unit	Oil Well	9,000 gpd	Normally re-inject. Permit for emergency discharge	N. Poudre Irrigation Ditch	TDS, Oil & Grease, SS	X	

*-1 Flow from gravel operations is highly variable, dependent on amount of groundwater entering the gravel pit being worked.

*-2 The Estes Park Unit does not have an NPDES permit because it has less than 20,000 pounds of production per year.