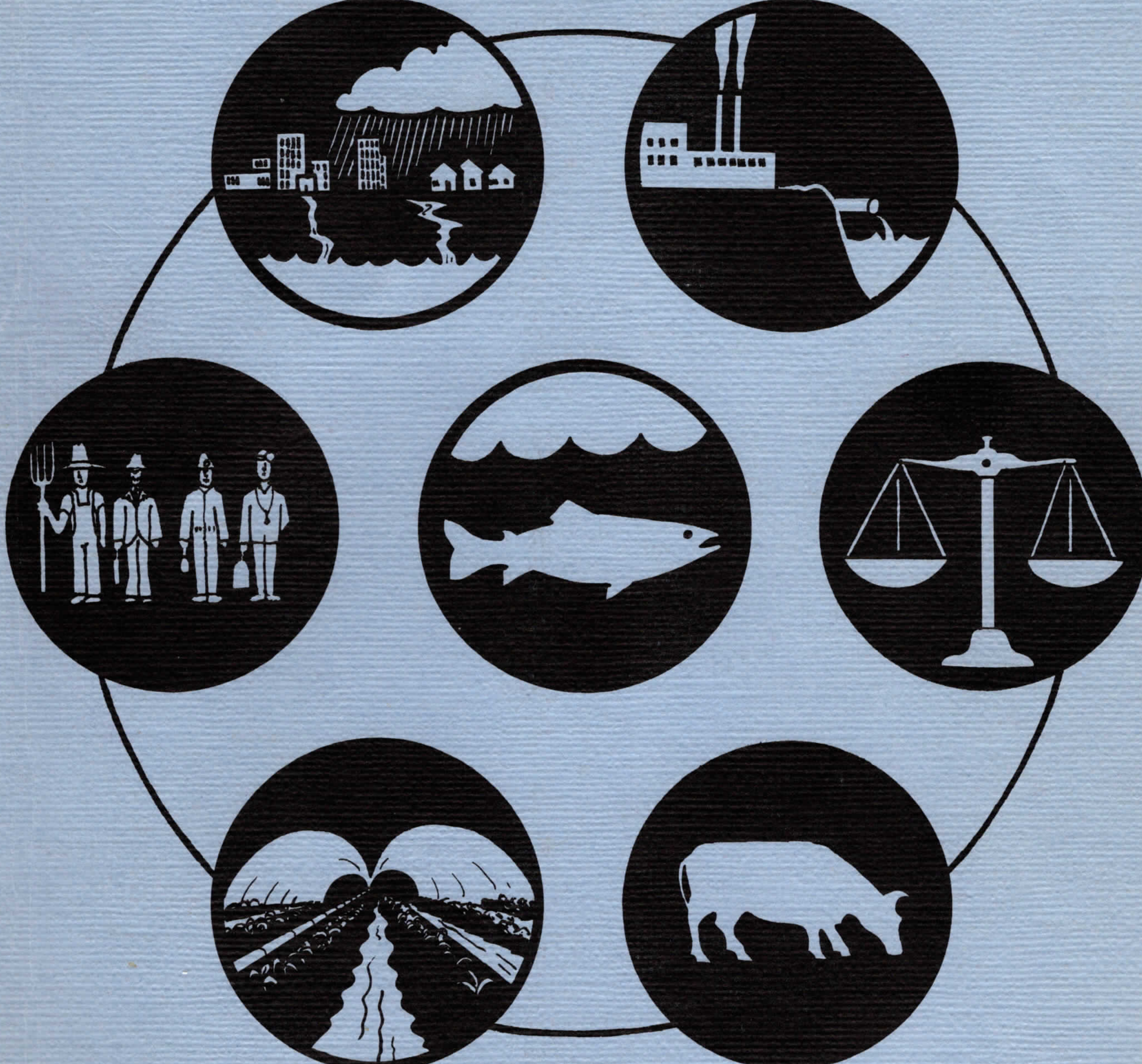
INTERIM REPORT — ENGINEERING

# WATER QUALITY IMPACTS OF IRRIGATED AGRICULTURE

### 3. EXECUTIVE SUMMARY



## Water Quality Management Plan

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS
LOVELAND, COLORADO

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PREPARED BY TOUPS CORPORATION
LOVELAND, COLORADO APRIL, 1977

# EXECUTIVE SUMMARY

# WATER QUALITY IMPACTS OF IRRIGATED AGRICULTURE IN THE LARIMER-WELD REGION

Prepared for

Larimer-Weld Regional
Council of Governments

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TOUPS CORPORATION
Loveland, Colorado

April 1977

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ABSTRACT

The objective of this project was to identify the water quality impacts of irrigation return flows on streams in the Larimer-Weld region of northern Colorado. The 6,700 square mile region contains 500,000 acres of irrigated land. Existing data was collected on agricultural practices in the region including irrigation and drainage systems, fertilizer and pesticide use, and soils. A sampling program, including flow measurement provided data on the quality and quantity of both surface and subsurface returns. A hydrologic analysis identified diversions made from the rivers of the region as well as the return flows entering the rivers. Sampling data, hydrologic analysis, and analysis of agricultural practices resulted in definition of the impacts of irrigated agriculture upon water quality.

The streams of the region are dried up repeatedly at various points of diversion. Below these points many stream segments and downstream diversions are sustained entirely by irrigation return flow. Salinity is the most significant problem resulting from irrigated return flows in the region. The discharge of salts with return flows is associated with seepage from lakes, canals, and irrigated lands. In certain areas underground seepage waters flowing over saline shale formations dissolve salts which are subsequently discharged to streams. High nitrate levels were denoted in tile drainages from farms using heavy manure applications plus commercial fertilizers. Sediment discharges were restricted to a few areas with fine soils. There appears to be a potential for reducing the discharge of salinity by reducing seepage losses in canals and reduction of losses of applied irrigation water. Nitrate levels in streams might be reduced by better fertilizer management.

There is no information presently available to define the effectiveness of potential management practices in reducing the discharge of pollutants, the cost, or the financial feasibility of those practices. Development of this information is the objective of the Best Management Practices Project. This project is being implemented during the 1977 irrigation season. It involves detailed analysis of factors controlling pollutant loading at four individual sites in the region.



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Larimer-Weld Regional Council
of Governments
208 Water Quality Management
Study

and flow measurements were also taken throughout the region to identify impacts of return flows on water quality and quantity. More than 150 locations were sampled and measured throughout the region.

The sampling and measuring program was augmented with data collected from the State Engineer's Office concerning the amount of water diverted at approximately 100 diversion structures throughout the region. In addition, pertinent information on soil types that can affect water quality was collected. Collection and analysis of this data has resulted in the definition of the impacts of irrigated agriculture on the water quality and quantity in the Larimer-Weld region.


## SUMMARY

Irrigated agriculture has been the cornerstone of the economy in the Larimer-Weld region since the 1870's. There are approximately 500,000 acres of irrigated land in the region which are distributed among four drainage basins--the South Platte River, Big Thompson River, Cache la Poudre River and the St. Vrain River. The latter three drainages are tributary to the South Platte. Irrigation has made the Larimer-Weld region one of the most productive agricultural regions in the United States. Value of all crops produced in the region was approximately $173 million in 1975.

Water for irrigation is supplied by natural runoff from snowmelt and is supplemented with trans-mountain diversions. Approximately 100 diversion structures have been built on the streams in the region to provide water to a complex storage and distribution system. During the irrigation season, these diversions dry up the river at several points. All rivers in the plains area of the region are totally managed to optimize the use of water throughout the year.

The supply system includes approximately 2500 miles of canals, with capacities ranging from 5 cubic feet per second (cfs) to 1000 cfs. In addition, there are 70 private reservoirs with a capacity of 400,000 acre-feet and major reservoirs associated with the Colorado-Big Thompson diversion project with a capacity of 270,000 acre-feet.

Common irrigation methods include furrow irrigation (56% of the irrigated land), flooding (34%), and sprinkler irrigation (10%). There are 2,700 farms in the region containing irrigated land.

It is estimated that about 10 percent of the irrigated land in the region is served by drainage. The SCS estimates that 410 miles of subsurface drainage and 97 miles of open surface drains are currently in use in the two-county region.

Nitrogen and phosphorous fertilizers are the major fertilizers used in the region. Potasium and zinc are used to a lesser extent. Manure is a highly significant fertilizer material in the region, especially in areas near concentrated animal feeding operations surrounding Greeley. Fully 75 percent of the irrigators applied insecticides at the recommended rate during 1976 to either corn or beets. Alfalfa, beans, and small grains were less likely to receive insecticide applications with only approximately 50 percent of the growers applying one or more insecticides at the recommended rates to these crops during 1976. Herbicides are used by approximately 80 percent of all irrigated crop growers in the region.

An extensive sampling program was conducted to identify the pollutional characteristics of irrigation return flows. Major constituents sampled included the common anions and cations, ammonia, biochemical oxygen demand, and nitrates. Salinity was found to be the most significant pollutant in the region. Salinity levels in tile drain discharges commonly ranged from 1000 to 3000 mg/l with the actual range being from 500 to 6000 mg/l. Over 50 percent of the tile drain samples exceeded 1500 mg/l. The occurrence of highly saline discharges in the region is closely related to irrigation over shallow shale deposits which are found in approximately 20 percent of the irrigated area. The principal loading mechanism is the flow of subsurface irrigation return flows and seepage from unlined canals horizontally across the shale layers. Horizontal flow over the shale provides an excellent opportunity for dissolution of salts and an increase in salinity in return flows. These conditions exist in each of the four major drainage basins. Salt

Nitrate concentrations in irrigation return flows were most often in the range of 4 to 12 mg/l as nitrogen. Higher concentrations were found in areas where manure from feedlots has been applied continuously over many years and in conjunction with commercial fertilizers. Manure applications of 15 to 20 tons per acre are common in some areas of the region. Continued application at these high rates results in the presence of excess nitrates in the soil.

Sediment does not appear to be a major problem associated with irrigation discharges in the region. This partly results from the fact that there are few direct discharges of irrigation tailwater to streams. The rivers of the region tend to have flood plains serving as buffer zones prohibiting direct tailwater discharges. Some isolated occurrences of excessive sediment were found in the Big Thompson River drainage.

Phosphorous levels were quite low in samples taken in tile drains due to the fact that phosphorous rapidly becomes attached to soil particles and remains in the soil profile. Phosphorous levels in tailwater samples commonly ranged from 0.1 to 0.4 mg/l. No samples were taken of pesticides due to the high cost of analysis.

Levels of biochemical oxygen demand, ammonia, and fecal coliform were consistently low in surface and subsurface drainage from irrigated lands. Biochemical oxygen demand averaged 2.5 mg/l; ammonia concentration averaged less than 0.1 mg/l as nitrogen; and fecal coliforms were found to be very low.

It is not possible to understand the water quality impacts of irrigation return flow in the region without understanding the regional hydrology. The hydrologic impact of irrigation diversions and return flows is significant. Diversions structures dry up all of the streams in the region at numerous points. Below these points irrigation return flow in the form of seepage, drainage, or tributary inflow constitutes practically all of the flow in the river. Many water rights on the downstream reaches of the streams are fulfilled entirely by losses from upstream areas, i.e., irrigation return flows. Data indicates that most rivers in the area gain from 1.5 to 3.0 cfs per mile.

On the Cache la Poudre River irrigation return flows are by far the largest discharge. Return flows are approximately 150 million gallons per day (mgd) over the length of the river compared to less than 25 mgd for point source discharges. Total dissolved solids concentrations on the Poudre River increased from approximately 50 mg/l at the point where the river leaves the mountains to over 1500 mg/l at the mouth of the river approximately 50 miles downstream. Nitrate levels increased from near 0 to 6 mg/l in the lower reaches. Sediment levels in the Poudre River increased from 20 mg/l in upstream reaches to approximately 80 mg/l in the lower reaches.

On the Big Thompson River, irrigation return flow discharges are approximately 44 mgd as compared to the point sources of approximately 15 mgd. Total dissolved solids increase from very low levels to approximately 1200 to 1500 mg/l in the lower reaches of the river. The Little Thompson River enters the Big Thompson near Milliken and discharges a large salt load to the river. Nitrate levels in the Big Thompson increase from near 0 to 2 mg/l as nitrogen near the mouth of the river.

Irrigation return flows contribute approximately 26 mgd in the Little Thompson River. Other discharges are less than 5 mgd. The Little Thompson has the highest salinity levels of any rivers in the region. The river has concentrations of nearly 1500 mg/l upstream of Berthoud. Concentrations continue to increase to over 2000 mg/l slightly east of Berthoud. Tributaries and drains entering the Little Thompson have consistently high dissolved solids levels resulting from irrigation over shallow underlying shale deposits. The Little Thompson also has the most significant sediment problems in the region. In the lower reaches of the Little Thompson, sediment levels reached 150 to 200 mg/l. This can be partially attributed to irrigation of fine soils in the Little Thompson basin.

Irrigation discharge to the St. Vrain River is approximately 62 mgd. Other discharges in the area are less than 5 mgd. Salinity levels are approximately 1200 mg/l near the mouth of the St. Vrain. Several tile drains sampled in the St. Vrain region had extremely high total dissolved solids levels. Nitrate levels in the St. Vrain River generally range between 2 and 3 mg/l as nitrogen.

Irrigation return flows contribute approximately 125 mgd to the South Platte River as it flows through the region. Municipal and industrial discharges contribute approximately 1 mgd. Total dissolved solids levels are 600 to 700 mg/l where the river enters the region in south Weld County. As the stream leaves the region, total dissolved solids levels are generally 1200 to 1500 mg/l. Nitrate levels appear to be fairly constant in the Larimer-Weld region, ranging from 3 to 4 mg/l as nitrogen.

Legally defined water quality standards developed by the State of Colorado specify that all waters of the state will achieve or maintain water quality standards to enable attainment of a fishery or recreational uses of the stream. These standards include assignment of acceptable levels of chemical constituents in water which will enable attainment of fishable or recreational waters. Data collected as part of the 208 program indicates that agricultural discharges would not specifically interfere with attainment of these goals. In some instances in the Larimer-Weld region, discharge of sediment may exceed limits established under water quality regulations. The major impediment to achieving fisheries in the plains area of the region is the diversion of water under legally decreed water rights which causes streams to dry up.

In addition to legally established standards, water pollutants may interfere with established beneficial uses of water. However, water quality does not appear to have impaired the use of water for irrigation or stock watering in the region. Regulations promulgated under the Federal Safe Drinking Water Act place limitations on inorganic chemicals, organic chemicals, turbidity, and microbiological contaminants in drinking water. Of the constituents limited, nitrate is the only constituent tested for in the analysis of irrigation return flow. Nitrate concentrations in drinking waters are limited to 10 mg/l as nitrogen. Nitrate levels in streams have not been found to exceed the 10 mg/l limit. Nitrate levels in excess of 10 mg/l have been found in public drinking water supplies in some communities along the South Platte River which are dependent on groundwater for supply. It is highly probable that nitrate discharges to groundwater basins from application of commercial fertilizer and manure to irrigated lands contribute to excess nitrogen in the groundwater basins.

Existing data is not adequate to determine if there is a long-term trend towards increasing salinity, nitrates, or other pollutants in the groundwater basins of the region.

## CONCLUSIONS

The analysis of water quality impacts of irrigation return flows has led to the development of conclusions in several categories as described below.

### Wasteloads From Irrigated Agriculture

1. Factors affecting on-farm generation of agricultural waste loads include irrigation methods, drainage practices, physical characteristics of the soil, chemical characteristics of the soil, quality of water applied for irrigation, topography, on-farm irrigation efficiency, and subsoil conditions.

Fertilizer

2. Factors affecting on-farm generation of agricultural waste loads are highly variable within the region, and will produce variable results in terms of quality and quantity of discharges.

3. The principal pollutants discharged by irrigated agriculture in the Larimer-Weld region are salinity, nitrates, and sediment.

4. Levels of biochemical oxygen demand, ammonia, and fecal coliforms were uniformly low in irrigation discharges.

5. Sediment problems were limited to a few streams in the area.

## Water Quality Impacts of Irrigation Return Flows

1. Water quality impacts of irrigation return flows are directly dependent on the hydrology of streams in the region.

2. Through the many reaches of streams, irrigation return flow is the sole source of water supply.

3. Irrigation return flows increase levels of salinity from approximately 50 mg/l as the major tributaries leave the mountains to 1200 to 1500 mg/l at the confluence of the South Platte.

4. Salinity levels of the South Platte River increase from approximately 700 mg/l to 1200 mg/l as it flows through the Larimer-Weld region.

5. Irrigation discharges to streams are by far the largest discharge and are on the order of 345 mgd as compared to approximately 46 mgd from municipal and industrial discharges.

6. Diversion of water in the streams for municipal, industrial, and agricultural water supply is the controlling factor limiting the legally specified water quality goals, i.e., fishery and recreational.

7. Irrigation return flows have contributed to excess salinity and nitrates experienced in groundwater basins.

Potential for Pollutant Reduction

1. Due to the highly variable factors controlling discharge of pollutants from the 2,700 irrigated farms in the region, the application of control measures must be site specific in order to be effective in preventing, controlling, or abating pollution from irrigated agriculture.

2. The potential for pollutant reduction exists through best management practices developed and applied in specific areas of the region.

3. Discharge of salts could be reduced by reducing excessive seepage and subsurface return flows across shallow lying shale areas of the region.

4. Nitrate levels could be reduced through better fertilizer management.

5. No information is presently available on the cost-effectiveness of such measures.

6. Application of best management practices for reduction of pollutant discharge could have both long-term and short-term effects.

Many of the questions raised regarding cost-effectiveness of pollution control measures for irrigated agriculture will be answered in the best management practices analysis. This analysis is presently underway and will be completed in November, 1977.

# WATER QUALITY IMPACTS OF IRRIGATED AGRICULTURE IN THE LARIMER-WELD REGION

## 1.0 IRRIGATION IN THE LARIMER-WELD REGION

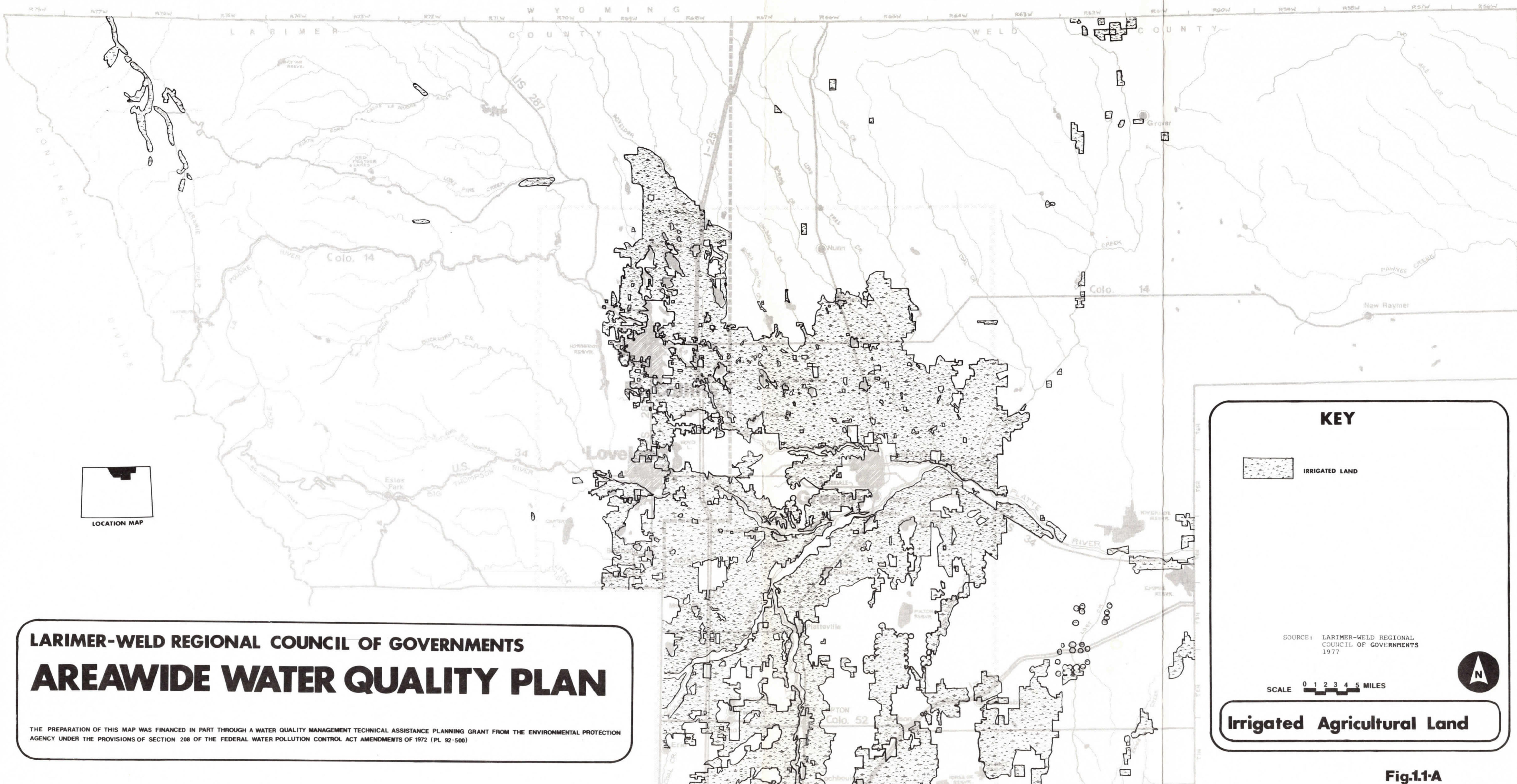
Irrigated agriculture has been the cornerstone of the economy in the Larimer-Weld region since the 1870's. There are approximately 500,000 acres of irrigated land in the Larimer-Weld region. Without irrigation, the semi-arid climate will support only winter wheat and rangeland.

### 1.1 DISTRIBUTION OF IRRIGATED LAND

The 500,000 acres of irrigated land in the two-county area is spread over several river basins: the St. Vrain, Little Thompson, Big Thompson, Cache la Poudre, and the South Platte (Figure 1.1-A). Much of the irrigated land in the region lies to the west and north of the South Platte. From the Weld County line east to the Colorado boundary, most of the irrigated land is in a narrow strip along the river. With the use of wells and center pivot sprinklers, additional irrigated land has been developed in the past decade in the portion of Weld County southeast of the South Platte River. Table 1.1-A provides a breakdown of the irrigated areas within the region by county and river basin.

TABLE 1.1-A. IRRIGATED ACRES BY SUBBASIN WITHIN LARIMER AND WELD COUNTIES

| SUBBASIN | LARIMER CO. | WELD CO. |
|---|---|---|
| Big Thompson (Includes Big Thompson & Little Thompson) | 32,400 | 45,500 |
| Cache la Poudre | 70,600 | 83,300 |
| South Platte | 0 | 133,900 |
| South Platte Tributaries (Includes Boxelder, Lost Creek & Crow Creek subbasins) | 0 | 109,600 |
| St. Vrain (Includes Boulder Creek subbasin) | 0 | 33,200 |
| Subtotal | 103,000 | 405,500 |
| TOTAL FOR TWO-COUNTY AREA ---------508,500 | | |




## LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

# AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972 (PL 92-500)

**Irrigated Agricultural Land**

Fig.1.1-A



? OVERLAY USED ON BASE MAP!

## 1.2 ECONOMICS

The irrigated portion of Larimer and Weld Counties is the most productive agricultural land in the state and one of the most productive in the nation. The value of all crops produced in the region was nearly $78 million in 1971 and $173 million in 1975. [1976 Colorado Agricultural Statistics, Colorado Department of Agriculture, July, 1976]. Major crops grown include: corn for silage (48% of the state total), sugar beets (38%), dry beans (28%), barley (24%), corn for grain (19%), oats (18%), hay (17%), potatoes (10%), and winter wheat (9%). A portion of the crops grown in the region support one of the most extensive livestock feeding operations in the nation.

## 2.0 IRRIGATION PRACTICES

### 2.1 WATER SUPPLY SYSTEM

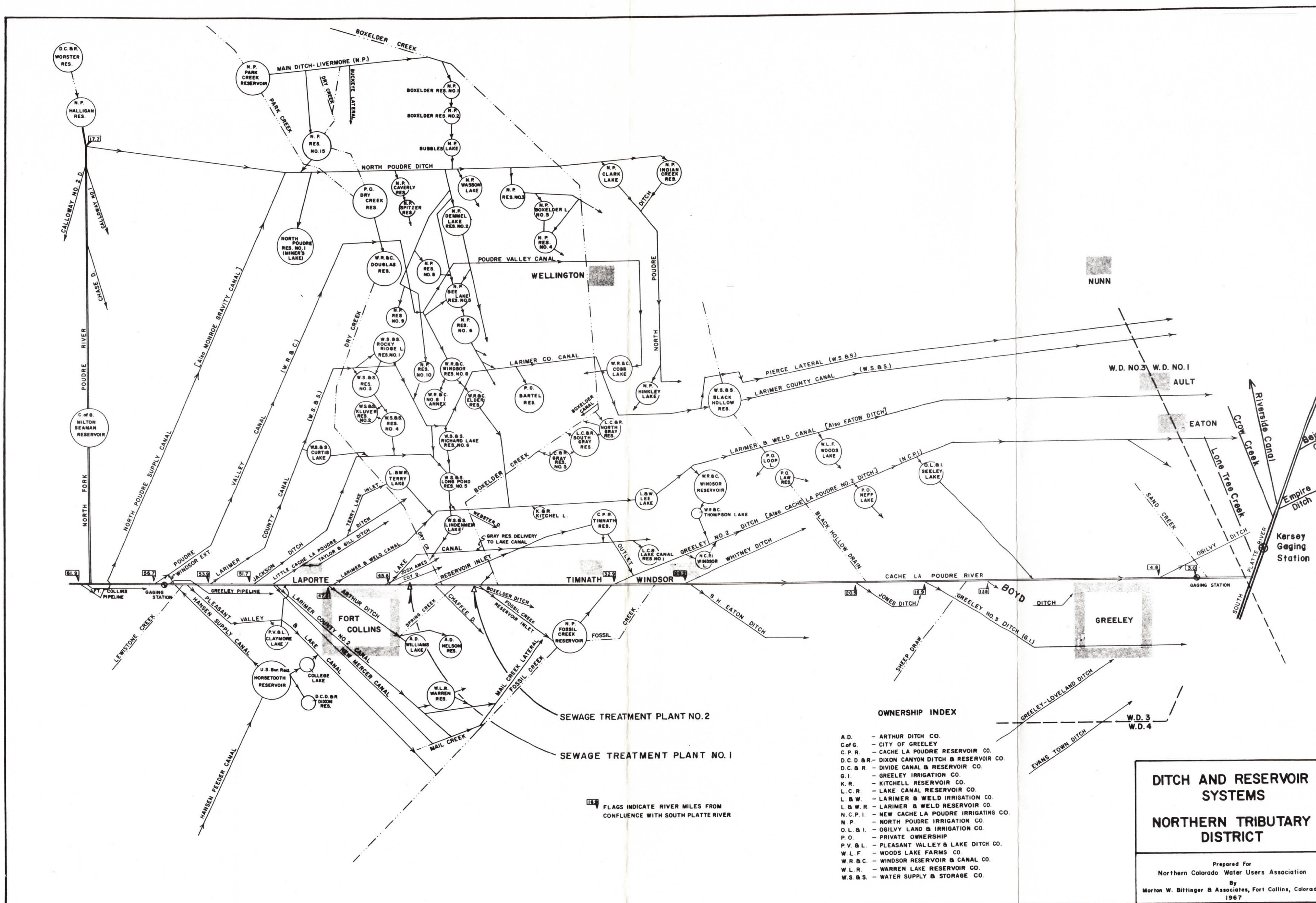
Water supply consists of natural east slope runoff as well as augmentation with water from the west side of the Continental Divide by the Colorado-Big Thompson Project and other trans-mountain diversion projects. Natural flows in the rivers of the region consist primarily of snowmelt occurring in May and June. For the remainder of the irrigation season, irrigators are dependent on winter storage, trans-mountain diversions, and irrigation return flows for water supply.

#### 2.1.1 Diversions

Diversion structures have been built on all streams in the region (see Figures 2.1.1-A, B, and C). The Cache la Poudre has the most complicated system. Additional diversions exist on tributaries. During the irrigation season, these diversions dry up the river at several points. The other rivers of the region have a smaller number of diversions, yet these rivers may be totally depleted by these diversions. The river is managed such that a system of storage and exchange of water among irrigators serves to optimize water availability. There are 500 to 600 exchange agreements in effect on the Cache la Poudre River.

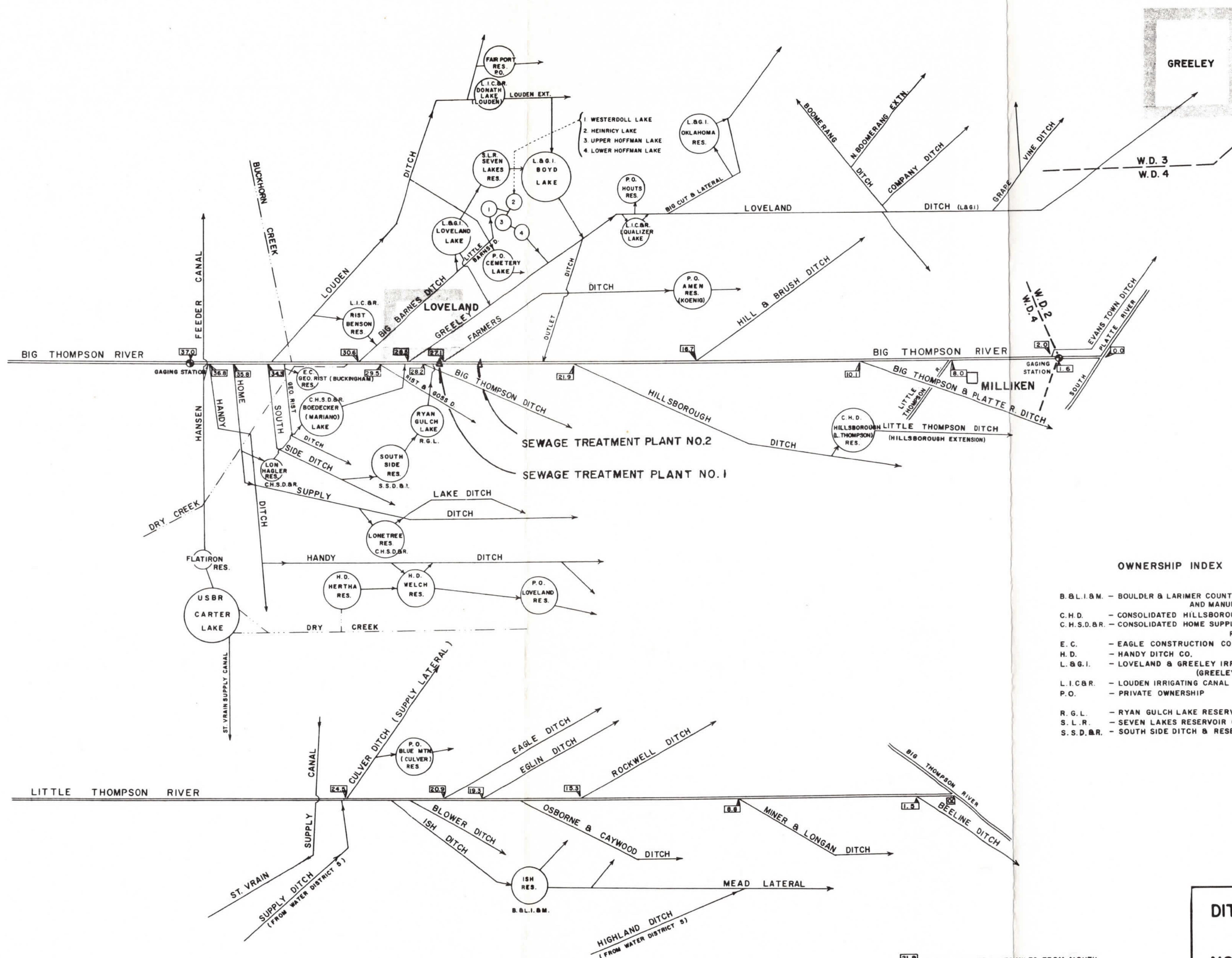
Storage reservoirs provide water for late season use and for exchange. Private reservoirs in the region have a storage capacity of approximately 414,500 acre-feet. Colorado-Big Thompson Project reservoirs on the eastern slope have a capacity of approximately 270,500 acre-feet. Many of the private reservoirs are concentrated along the western edge of the irrigated region. The terrain through this area provides excellent reservoir sites in natural depressions.

The canal system in the Larimer-Weld region remains largely unchanged from the original system built between 1870 and 1890 (see Figure 2.1.1-D). There are approximately 1,243 miles of major canals with capacities ranging from 30 to 1,000 cubic feet per second (cfs). Less than 40 miles (3.1 percent of the total length) has been concrete lined. Small ditches and laterals with capacities ranging from 5 to 30 cfs are estimated to have approximately the same number of total miles as the major canals. A greater percentage of laterals are lined as a result of Federal cost-sharing programs for on-farm improvements.



DITCH AND RESERVOIR SYSTEMS
NORTHERN TRIBUTARY DISTRICT
Prepared For
Northern Colorado Water Users Association
By
Morton W. Bittinger & Associates, Fort Collins, Colorado
1967
OWNERSHIP INDEX
A.D. - ARTHUR DITCH CO.
C of G. - CITY OF GREELEY
C.P.R. - CACHE LA POUDRE RESERVOIR CO.
D.C.D.&R. - DIXON CANYON DITCH & RESERVOIR CO.
D.C.& R - DIVIDE CANAL & RESERVOIR CO.
G.I. - GREELEY IRRIGATION CO.
K.R. - KITCHELL RESERVOIR CO.
L.C.R - LAKE CANAL RESERVOIR CO.
L.& W. - LARIMER & WELD IRRIGATION CO.
L.& W.R. - LARIMER & WELD RESERVOIR CO.
N.C.P.I. - NEW CACHE LA POUDRE IRRIGATING CO.
N.P. - NORTH POUDRE IRRIGATION CO.
O.L.& I. - OGILVY LAND & IRRIGATION CO.
P.O. - PRIVATE OWNERSHIP
P.V.& L. - PLEASANT VALLEY & LAKE DITCH CO.
W.L.F. - WOODS LAKE FARMS CO.
W.R.& C. - WINDSOR RESERVOIR & CANAL CO.
W.L.R. - WARREN LAKE RESERVOIR CO.
W.S.& S. - WATER SUPPLY & STORAGE CO.
FLAGS INDICATE RIVER MILES FROM CONFLUENCE WITH SOUTH PLATTE RIVER
SEWAGE TREATMENT PLANT NO. 2
SEWAGE TREATMENT PLANT NO. 1
NORTH FORK POUDRE RIVER
CACHE LA POUDRE RIVER
SOUTH PLATTE RIVER
NORTH POUDRE SUPPLY CANAL [Also MONROE GRAVITY CANAL]
NORTH POUDRE DITCH
LARIMER COUNTY CANAL (W.S.&S.)
PIERCE LATERAL (W.S.&S.)
LARIMER & WELD CANAL [Also EATON DITCH]
GREELEY NO. 2 DITCH [Also CACHE LA POUDRE NO. 2 DITCH] (N.C.P.I.)
GREELEY NO. 3 DITCH (G.I.)
LAPORTE
FORT COLLINS
TIMNATH
WINDSOR
WELLINGTON
BOYD
GREELEY
NUNN
AULT
EATON
Kersey Gaging Station
W.D. NO.3 W.D. NO.1
W.D.3
W.D.4


FIG. 2.11-A




21.9 FLAGS INDICATE RIVER MILES FROM MOUTH

## OWNERSHIP INDEX

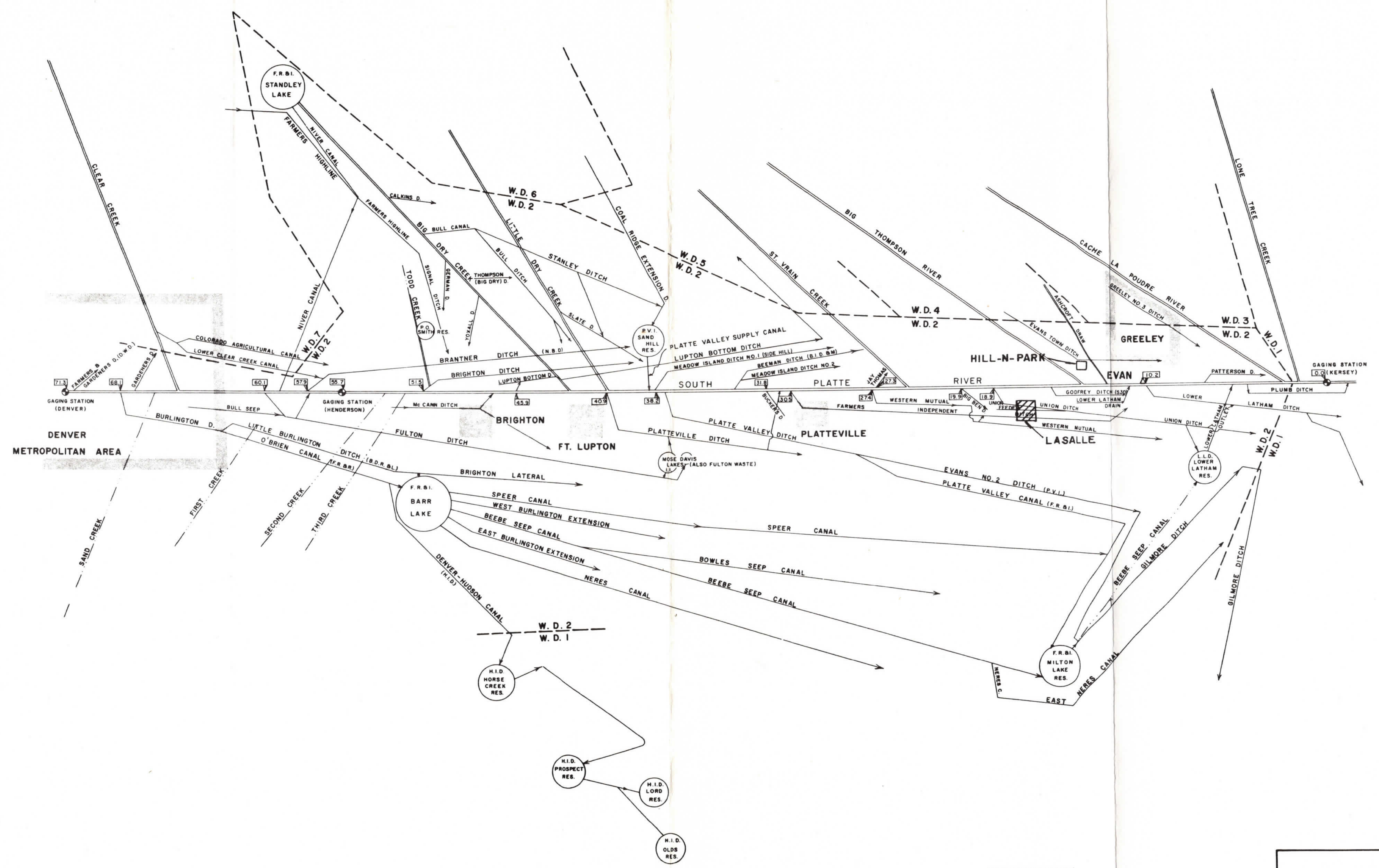
- B.&L.I.&M. – BOULDLR & LARIMER COUNTY IRRIGATING AND MANUFACTURING CO.
- C.H.D. – CONSOLIDATED HILLSBOROUGH DITCH CO.
- C.H.S.D.&R. – CONSOLIDATED HOME SUPPLY DITCH AND RESERVOIR CO.
- E.C. – EAGLE CONSTRUCTION CO.
- H.D. – HANDY DITCH CO.
- L.&G.I. – LOVELAND & GREELEY IRRIGATING CO. (GREELEY & LOVELAND)
- 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.

# DITCH AND RESERVOIR SYSTEMS

# NORTHERN TRIBUTARY DISTRICT

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

FIG. 2.1.1-B




55.7 FLAGS INDICATE RIVER MILES FROM DOWNSTREAM GAGING STATION

**OWNERSHIP INDEX**

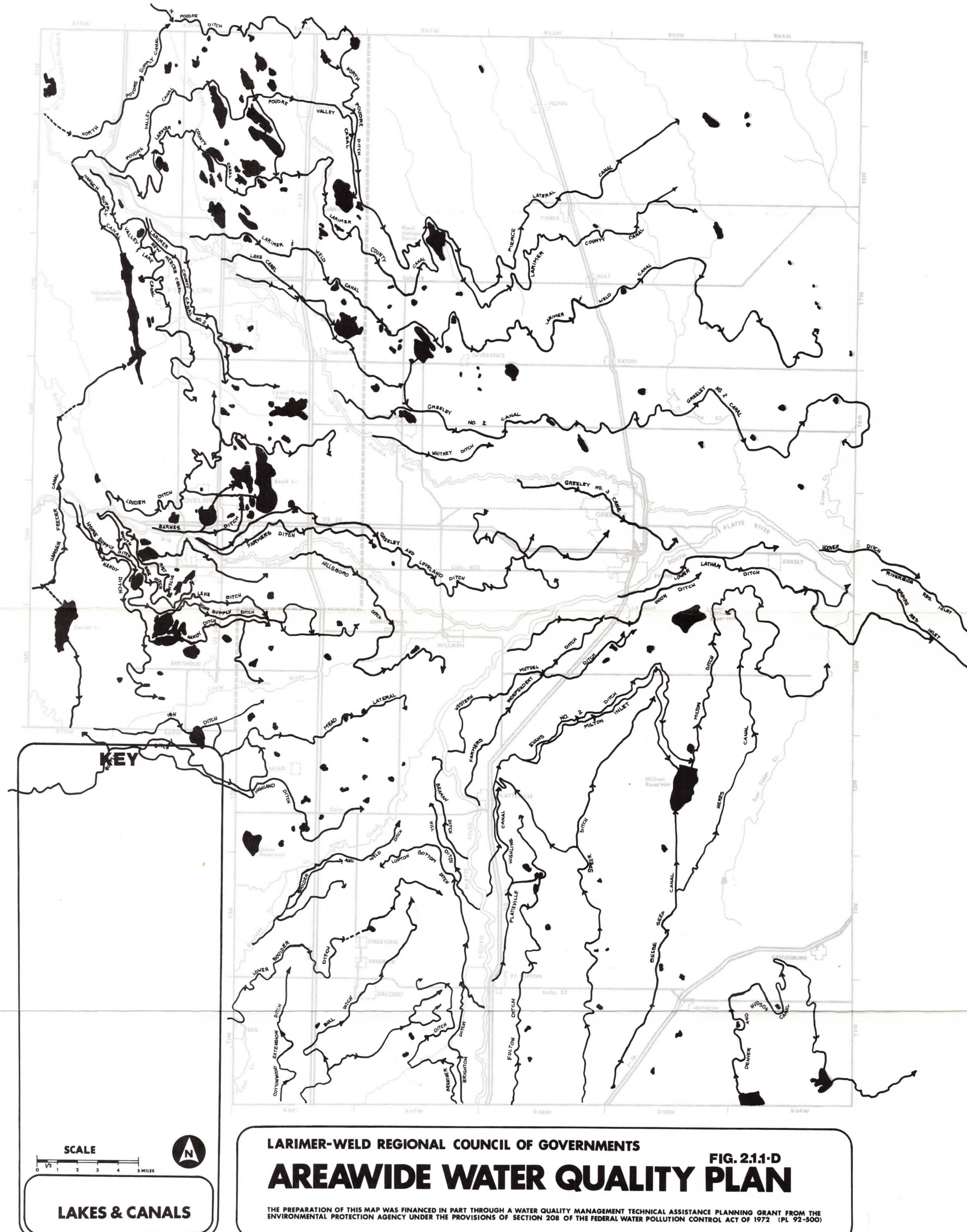
| | | |
|---|---|---|
| B.D.R.& L. | - | BURLINGTON DITCH, RESERVOIR & LAND CO. |
| B.I.D.& M. | - | BEEMAN IRRIGATING DITCH & MILLING CO. |
| D.W.D. | - | DENVER WATER DEPARTMENT |
| F.R.& I. | - | FARMERS RESERVOIR & IRRIGATION CO. |
| H.I.D. | - | HENRYLYN IRRIGATION DISTRICT |
| I.I. | - | IONE INVESTMENT 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.3 D. | - | SECTION 3 DITCH CO. |

**DITCH AND RESERVOIR SYSTEMS**

**UPPER PLAINS DISTRICT**

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

**FIG. 2.1.1-C**




LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS

FIG. 2.1.1-D

# AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

Seepage losses are significant in unlined canals of the region. On the average, one-third of the water diverted for irrigation seeps out of the canals but ultimately finds its way to lower canals or rivers.

## 2.2 APPLICATION SYSTEMS

The furrow, flooding, and sprinkler irrigation methods are all used in the Larimer-Weld region. The distribution of lands irrigated by these three methods is shown in Table 2.2-A.

TABLE 2.2-A. IRRIGATION METHODS IN LARIMER-WELD COUNTIES

| METHOD | ACRES | PERCENT |
|---|---|---|
| Furrow | 289,000 | 56.9 |
| Flooding | 170,500 | 33.6 |
| Sprinkler | 49,000 | 9.6 |

### 2.2.1 Furrow Irrigation

Furrow irrigation is used with row crops of corn, beets, beans, and others. Generally, water is siphoned out of the head ditch and run down a furrow which is generally 1/16 to 1/8 mile long for sandy loam soil, and 1/8 to 1/4 mile long for a heavier soil. A variation of the furrow method is called corrugation irrigation. This method is used to irrigate close-growing crops such as alfalfa, small grains, and pasture grasses.

### 2.2.2 Flood Irrigation

Two types of flood irrigation are used in the region: graded border and contour ditch. These methods are in reality quite different, yet are applied to similar crops. Contour ditch irrigation is generally used on fields that are too steep (over 3 to 4 percent) for other methods of surface irrigation. Ditches are constructed along the contours with from 0.1 to 0.2 percent grade, and are spaced at intervals throughout the field. Close growing crops can be irrigated with this method to hold erosion to a minimum. Pasture grasses and alfalfa hay are the major crops irrigated with this method. The contour ditch method is one of the less efficient methods of irrigation.

The border method of irrigation is used on approximately the same amount of land as the contour ditch method. This method involves a strip of land which has undergone land leveling to reduce slope, with a slope away from the head of the field. The border method is considered to be one of the most efficient methods of surface irrigation.

### 2.2.3 Sprinkler Irrigation

Sprinkler irrigation has shown increasing popularity in the region. A center-pivot sprinkler system is used on nearly all of the recent sprinkler systems. The sprinkler systems are generally quite efficient in water use and may be used with nearly any crop. Labor requirements are less with the center-pivot than with surface irrigation, but energy requirements are higher. In the Larimer-Weld region, sprinkler systems are generally used with underground water sources. It is unusual to see a sprinkler system installed where a pump was previously not required to deliver the water to the field.

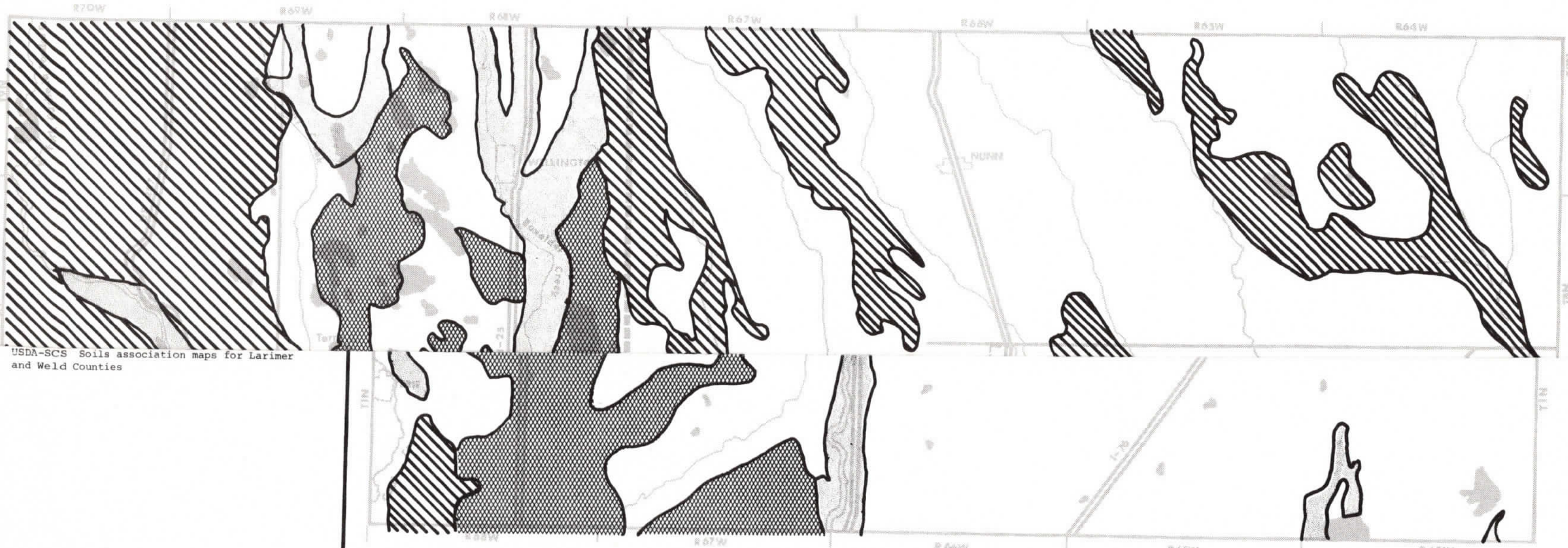
## 2.3 DRAINAGE

Irrigation requires removal of excess subsurface and surface water. It is accepted that in order to achieve efficient surface irrigation, some water must flow past the end of the field in order to provide sufficient time to fill the root zone in the lower part of the field. This tailwater may then go to any number of places, but generally flows into a "bar" ditch where it may be collected by a stream or seep into the ground.

Providing sufficient drainage is critical to the maintenance of the irrigated land. Drainage is required to remove high groundwater and salts.

Early drains were either open ditches or shallow wooden pipes. Manufactured clay tile replaced wooden structures years ago. Today, perforated flexible plastic tubing has gained tremendous acceptance.

In the Larimer-Weld region, many areas exist where a permeable soil overlies a nearly impermeable clay or shale layer (see Figure 2.3-A). Seepage from canals, together with over-application of irrigation water, has caused a perched water table on top of the impermeable material. This water table flows horizontally towards a stream and may outcrop causing a wet area. Areas exhibiting drainage problems have almost no crop potential unless artificial drainage is used to relieve the water table. The 1969 Agriculture Census shows that 50,029 acres of irrigated land in the region are being drained by subsurface and surface methods. This represents about 10 percent of the total irrigated land. Approximately 21 percent of all farms have some land benefiting from drainage. The SCS estimates that 410 miles of subsurface tile drain and 97 miles of subsurface open drainage ditches are currently in use in the two-county region.




USDA-SCS Soils association maps for Larimer and Weld Counties

SCALE

0 ½ 1 2 3 4 5 MILES

N

## SOILS
(Impervious Layers)

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS Fig. 2.3-A

# AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

It is not economically feasible to drain certain soil types. Flood plain areas are usually impractical to drain since there is no lower point to dispose of the water. Extremely tight soils present drainage problems since the drain cannot effect a large area.

## 2.4 CHEMICAL USE

### 2.4.1 Fertilizer

Nitrogen and phosphorous fertilizers are the major fertilizers used in the region. Potasium and zinc are used to a lesser extent. Manure is a highly significant fertilizer material in the region, especially in the areas near the concentrated animal feeding operations surrounding Greeley. In these areas, manure may supply the bulk of the fertilizer needs with chemicals being added only near the end of the growing season to give a late season boost. Average fertilizer use for various crops in the region are shown in Table 2.4.1-A.

TABLE 2.4.1-A. TYPICAL FERTILIZER USE IN LARIMER & WELD COUNTIES

| CROP | FERTILIZER (Pounds Per Acre) | | | | | SOIL TYPE | |
|---|---|---|---|---|---|---|---|
| | $NO_3$-N | $P_2O_5$ | $K_2O$ | Zn | Fe | Sandy Loam | Clay Loam |
| Corn | 200# | 40# | 20# | 3# | - | X | |
| | 160# | 40# | 20# | 3# | - | | X |
| Beets | 120# | 100# | - | 1# | - | X | |
| | 90# | 120# | - | 1# | - | | X |
| Barley | 80# | 20# | - | - | - | X | |
| | 50# | 20# | - | - | - | | X |
| Beans | - | 25# | - | 3# | - | X | |
| | - | 25# | - | 3# | - | | X |
| Alfalfa | - | 40# | - | - | - | X | |
| | - | 40# | - | - | - | | X |
| Onions | 120# | 100# | - | 3# | - | X | |
| | 90# | 120# | - | 3# | - | | X |
| Potatoes | 120# | 100# | - | 3# | - | X | |
| | 90# | 120# | - | 3# | | | X |

When making recommendations for fertilizer use in conjunction with manure applications, commercial laboratories use an average value of 4 lbs. available nitrogen (N), 2 lbs. of available phosphoric acid ($P_2O_5$), and 5 lbs. available potash ($K_2O$) for each ton of manure that will be applied to the field. An application of 15 tons of manure would have a value of 60 lbs. nitrogen, 30 lbs. phosphoric acid, and 75 lbs. potash. These values would then be subtacted from what the actual test would indicate as being required for top yields to determine commercial fertilizer requirements.

## 2.4.2 Pesticides

### 2.4.2.1 Insecticides

There are hundreds of insecticides available on the market today. Registration and review of the insecticides has eliminated the most persistent and dangerous forms from the market. Fully 75 percent of the growers applied one or more insecticides at the recommended rate during 1976 to either corn or beets. Alfalfa, beans, and small grains were less likely to receive insecticide applications, with only approximately 50 percent of growers applying one or more insecticides at the recommended rate to these crops during 1976. Table 2.4.2-A displays the commonly used insecticides in Larimer and Weld Counties.

TABLE 2.4.2 -A COMMONLY USED INSECTICIDES IN LARIMER AND WELD COUNTIES

| CROP | INSECTICIDE MOST COMMONLY USED | APPLICATION RATES POUNDS PER ACRE |
|---|---|---|
| Corn | Dimethoate (Cygon-400) | 1/3-1/2# |
| | Disyston | 1# |
| | Parathion | 1/2# |
| | Meta-Systox R | 1/3-1/2# |
| | Sevin 4-oil | 1# |
| | Dyfonate | 2.5 fl.oz/1000 LF of row |
| | Furadan (flowable) | 2.5 fl.oz/1000 LF of row |
| Beets (sugar) | Temic | 1-2# |
| | Thimet | 1# |
| | Dylox | 1/2-1# |
| | Parathion | 10 oz. |
| | Dyfonate | 1-1/2# |
| | Diazinon | 1-2# |
| Small Grain (Barley, wheat, oats) | Parathion | |
| | Disyston | 1/2-3/4# |
| Alfalfa | Furidan | 1/4# |
| | Cygon | 1/2# |
| | Sevin | 1-1-1/2# |
| | Malathion | 1-1/4# |
| | Encapsulated Methyl Parathion (PENNCAP-M) | 1 Quart |
| Beans | Sevin | 1# |
| | Serimol | 1# |
| | Parathion | 1/2# |

### 2.4.2.2 Herbicides

Herbicides are used to control growth of unwanted plants. Private interviews with growers producing irrigated crops in the Larimer-Weld region and discussions with fertilizer and chemical dealers located in the two-county region point out that herbicides are used by approximately 80 percent of all irrigated crop growers in the region. Table 2.4.2.-B shows major crops in the two-county region grown and the corresponding herbicides most commonly used along with the application rates.

TABLE 2.4.2 - B. HERBICIDES COMMONLY USED IN THE LARIMER-WELD REGION

| CROP | HERBICIDE MOST COMMONLY USED | APPLICATION RATES POUNDS PER ACRE |
|---|---|---|
| Corn | AAtrex | 1-1/2 to 2# |
| | 2,4-D | 1/2 to 3/4# |
| | Banvel | 1/8 to 1/4# |
| | Lasso | 3# |
| | Bladex | 1-1/2 to 2# |
| | Many combinations of the above | |
| Beet (Sugar) | Ro-Neet | 3-4# |
| | Betanal | 1-1-1/4# |
| | Dowpon Basfapon | 1-1/2-3# |
| | Betanex | 3/4-1-1/4# |
| Small Grain (Barley, wheat, oats) | 2,4-D | 1/2-1# |
| | Banvel | 1/8-1/4# |
| | Ca-byne | 1/4-3/8# |
| Beans | Treflan | 1/2-3/4# |
| | Eptam | 3# |
| | Lasso | 3# |
| Alfalfa | Princep | 1-1/2# |

## 3.0 WASTE DISCHARGES ASSOCIATED WITH IRRIGATED AGRICULTURE

### 3.1 SAMPLING PROGRAM

An extensive sampling program involving over one hundred and fifty sampling points was conducted to identify the relationship between irrigation and water quality in the Larimer-Weld region. Two general types of sampling sites were necessary in this analysis: (1) sampling sites which could be associated with specific fields and/or subbasin drainages were necessary in order to define the quality of irrigation return flows, and (2) sampling of rivers and returns to rivers was necessary in order to identify the impact of return flows upon water quality in major streams. A significant difference between the return flows leaving a small area and an actual impact upon the stream was expected, since the complicated irrigation network facilitates considerable reuse of any surface or subsurface return flow.

A flexible sampling program was desireable since the study was directed towards a large region with little or no previous data. Areas of specific interest had not yet been identified. In the flexible program, a committment was not made to sampling specific sites at regular intervals. Sites were sampled and identified; emphasis could change as necessary. Such a program allowed good coverage of a large area without committing resources to sites which might prove of little value.

In the program, samples were taken of rivers, tributaries, tile drains, tailwaters, as well as canal water.

#### 3.1.1 Pollutants Associated with Irrigated Agriculture

Pollutants associated with irrigated agriculture are salinity, nitrates, sediment, phosphorous, and pesticides. Samples were analyzed for these parameters with the exception of pesticides. Pesticide analyses were deleted from the initial assessment due to the high cost of analyses.

##### 3.1.1.1 Salinity

Salinity is a pollutant for both domestic and agricultural use. Saline water may contain concentrations of dissolved cations and anions to such an extent as to impair its quality. These cations (calcium, magnesium, or sodium) and anions (chloride, carbonate, bicarbonate, sulfate, or nitrate) become dissolved as water contacts saline rocks, soils, or shales.

Evaporation and transpiration from cropland, water bodies and wetlands, as well as transpiration by water-loving plants concentrates these dissolved solids. Increased salinity is displayed in drainage and subsurface returns. Tailwater from a field rarely exhibits significantly increased salinity.

3.1.1.2 Nitrates

Nitrates are a pollutant for domestic use. Concentrations greater than 10 mg/l of nitrates as nitrogen ($NO_3$-N) are considered unsuitable for domestic and dairy use due to the chance that they might cause methemoglobinemia in infants. Nitrates are nutrients necessary for plant and algae growth. Excessive nitrate loadings may contribute excessive algal growth in lakes if sufficient phosphorous is also available.

Nitrates are quite soluable and move through the soil with the wetting front as water is applied to the ground through irrigation. Because of this high soluability, excessive application of irrigation waters may cause a loss of nitrogen from the farm and a loading of nitrogen to receiving groundwaters or drainage streams.

3.1.1.3 Sediment

Sediment in water is a result of erosion. Erosion occurs in both irrigated and dryland areas, and in stream channels. Sediment consists of both the mineral and organic soil particles picked up as a result of this erosion. In irrigated areas, sediment may be picked up from erosion of canal banks and erosion of on-farm laterals and furrows.

On-farm sediment pickup is generally associated with furrow irrigation. With furrow irrigation, the water stream has a direct contact with bare soil. The potential for erosion is a function of the soil type, slope, and the velocity of the furrow stream.

Sediment loads from sprinkler irrigated areas and border irrigated areas are generally very small compared to furrow irrigation. Border irrigation is used with close growing crops which hold the soil and minimize erosion. Sprinkler irrigation is designed for zero runoff, wherever possible, although erosion problems can occur with sprinkler irrigation where a zero runoff situation cannot be attained due to very tight soil.

Sediment is a pollutant to many uses of water. It impairs the clarity of water, reducing recreational and fishery possibilities. It may settle out in unwanted places and it may carry phosphorous and pesticides into receiving waters.

### 3.1.1.4 Phosphorous

Phosphorous is a nutrient required for algal growth. In many cases, it is the limiting nutrient in natural waters. Phosphorous in the root zone not used by the plant generally becomes quickly attached to soil particles, especially clay particles. As a result, drainage waters from the root zone rarely contain significantly more phosphorous than the applied water. Surface runoff, on the other hand, may contain phosphorous either attached to soil particles or in soluable form which is readily available to plants. The relationship between the amount of phosphorous in the available or attached forms is generally a function of phosphorous fertilizer management. Phosphorous fertilizers incorporated into the soil upon application are generally well bound up in the soil. Where phosphorous is not well incorporated, a runoff event shortly following application may produce loading of soluable phosphorous in surface runoff.

### 3.1.1.5 Pesticides

Pesticides include herbicides and insecticides. The characteristics of each of these are highly variable as are loading mechanisms or the means by which pesticides reach receiving waters.

Individual pesticides may travel either with sediment, drainage water, or both sediment and drainage water. A survey of the characteristics of hundreds of pesticides was conducted by the SCS and the results are displayed in Table 3.1.1.5-A.

TABLE 3.1.1.5-A PESTICIDE CHARACTERISTICS*

| PREDOMINANT TRANSPORT MECHANISM | PERCENT OF SAMPLE |
|---|---|
| Associated with Sediment | 46 |
| Associated with Water | 30 |
| Associated with Sediment and Water | 16 |
| Unknown | 8 |
| | 100% |

* U.S. Department of Agriculture, Soil Conservation Service, Agricultural Research Service, Control of Water Pollution from Croplands, Volume 1. "A Manual for Guideline Development". April, 1975.

## 3.2 POLLUTANT LEVELS IN THE IRRIGATION RETURN FLOWS OF THE LARIMER-WELD REGION

### 3.2.1 Salinity

Salinity is the most significant pollutant in the Larimer-Weld region, as in much of the western United States. In the Larimer-Weld region, excess salinity results from water contact with underlying shale formations.

#### 3.2.1.1 Salinity Levels in the Rivers and Drains of the Region

Salinity levels in the rivers carrying return flows are typically from 1,000 to 1,500 mg/l. Approximately 32 percent of the total number of subsurface drain effluent samples were in this range, and approximately 50 percent of the tile drain samples exceeded 1500 mg/l. Figures 3.2.1-A, B, C, and D show the distribution of total dissolved solids encountered in all samples taken at drains, in rivers, and on tributaries.

#### 3.2.1.2 Shale Areas in the Larimer-Weld Region

Figure 3.2.1-E shows the location of the various shale groups in the Larimer-Weld region. There are several geologic types of shale impacting water quality, and each type has an individual effect on water quality; however, all of the effects have not been well identified yet.

As waters seep from canals, reservoirs and irrigated lands in certain areas of the nation, they encounter an impermeable shale layer and flow horizontally (Figure 2.3-A). This horizontal flow over the shale back towards the river is the major source of salinized return flows. Indications are that the break between overlying soils and the underlying shale is in some cases less than distinct. Under these conditions, water has excellent opportunities to dissolve ions from the shale and increase salinity.

Some shale deposits are slightly permeable, notably the Pierre shale transition layer and the lower Hygiene sandstone member of the Pierre shale. While these are only slightly permeable, the highly salinized water associated with these returns have a measureable impact on water quality in certain areas. Fossil Creek below the Fossil Creek damsite is an example of this. Primarily supplied by seepage and with only a 1 or 2 cubic feet per second (cfs) typical flow, the creek exhibits total dissolved solids levels of 3,000 mg/l.

# Salinity - All Basins

*Fig. 3.2.1-A* **ABI. All Samples**

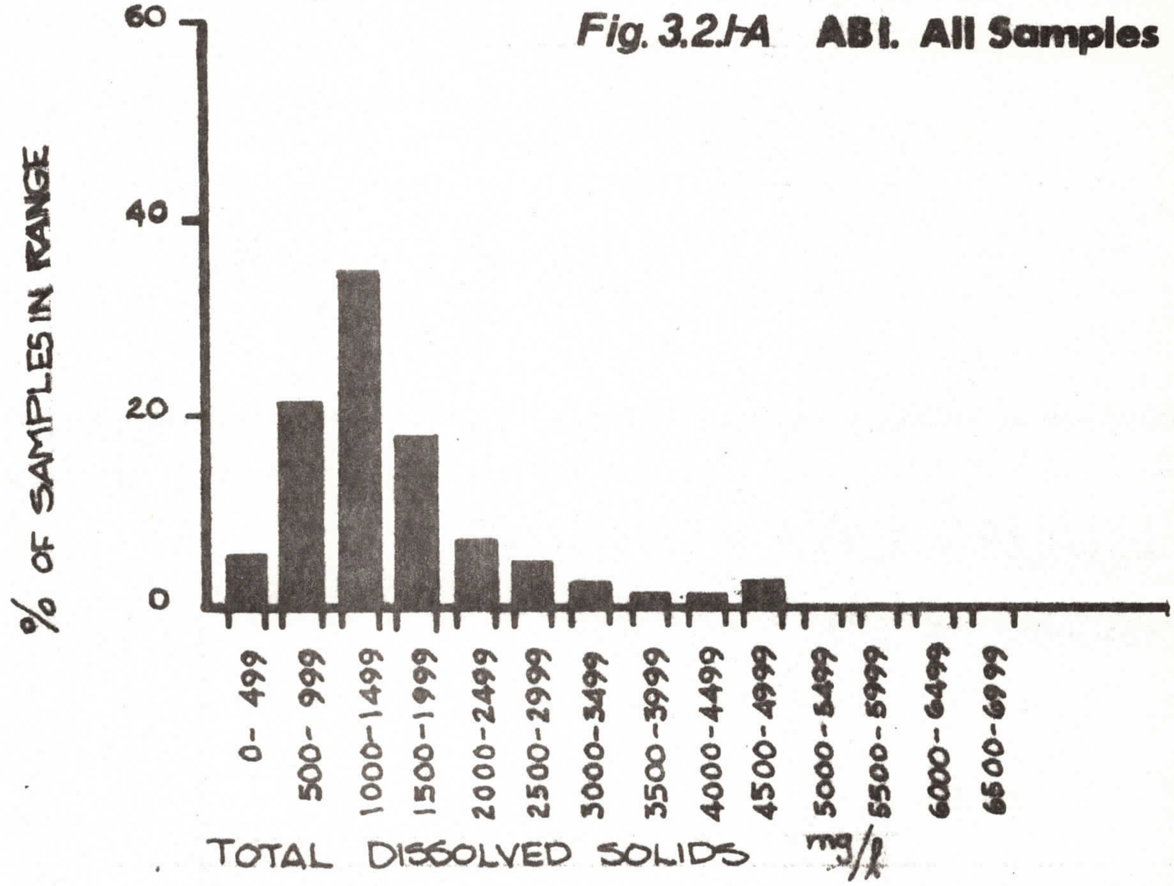



*Fig. 3.2.1-B* **ABII. River Samples**

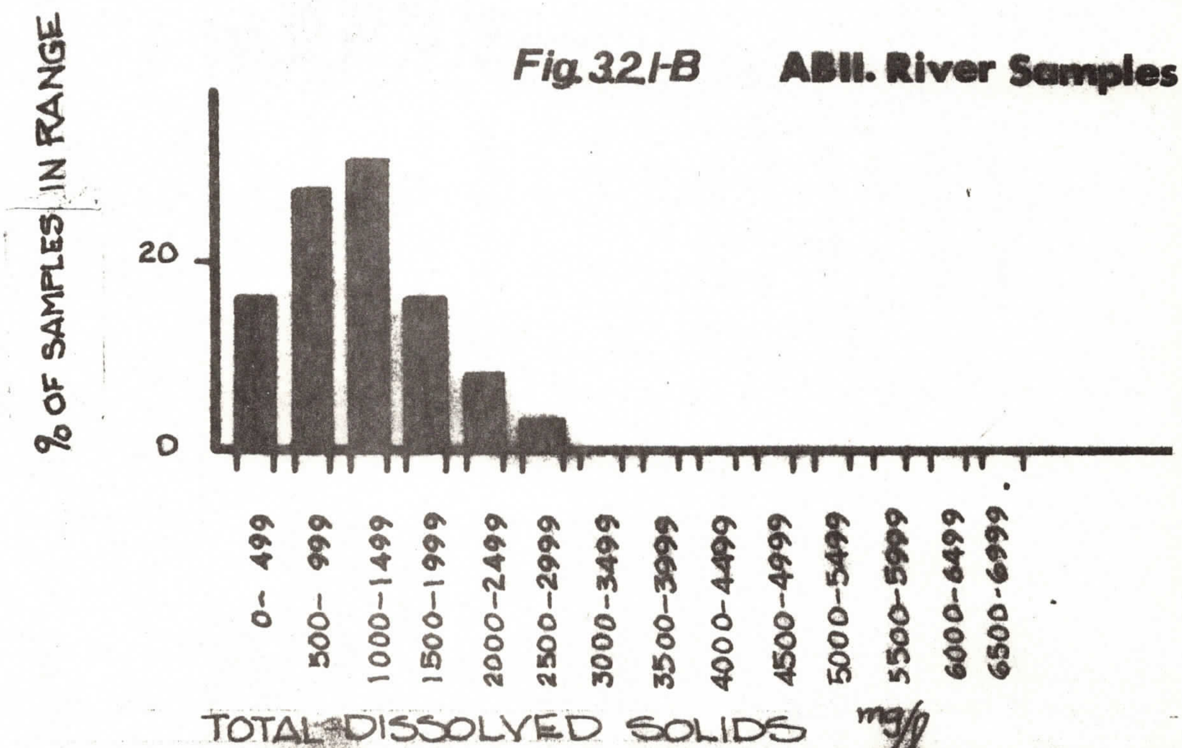


*Fig. 3.2.1-C* **ABIII. Drainage Samples**

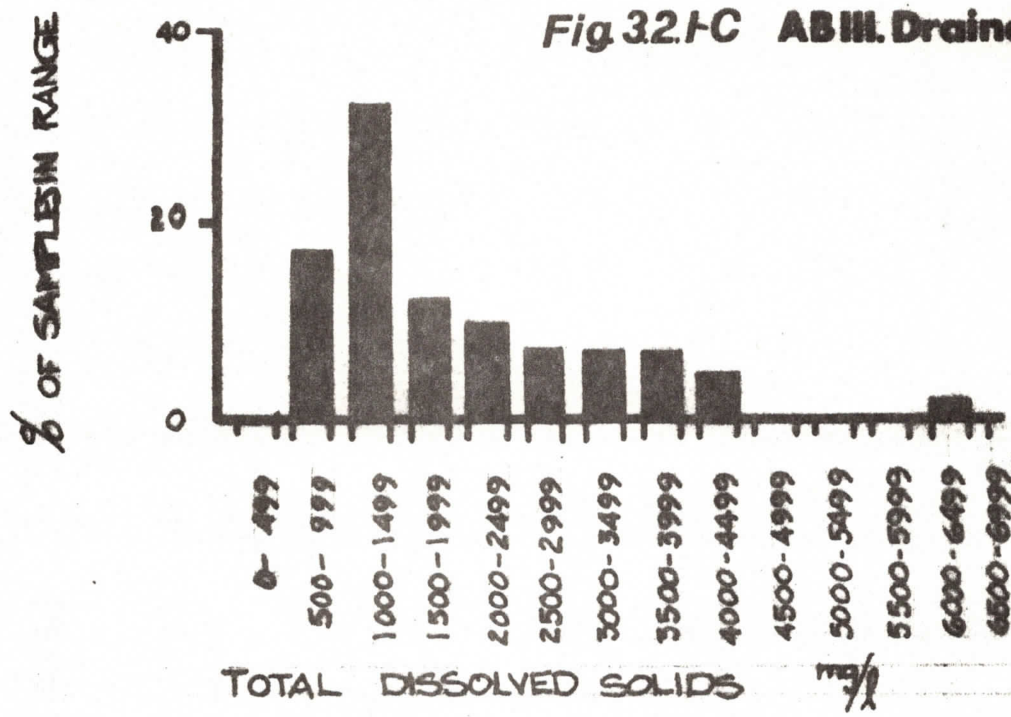
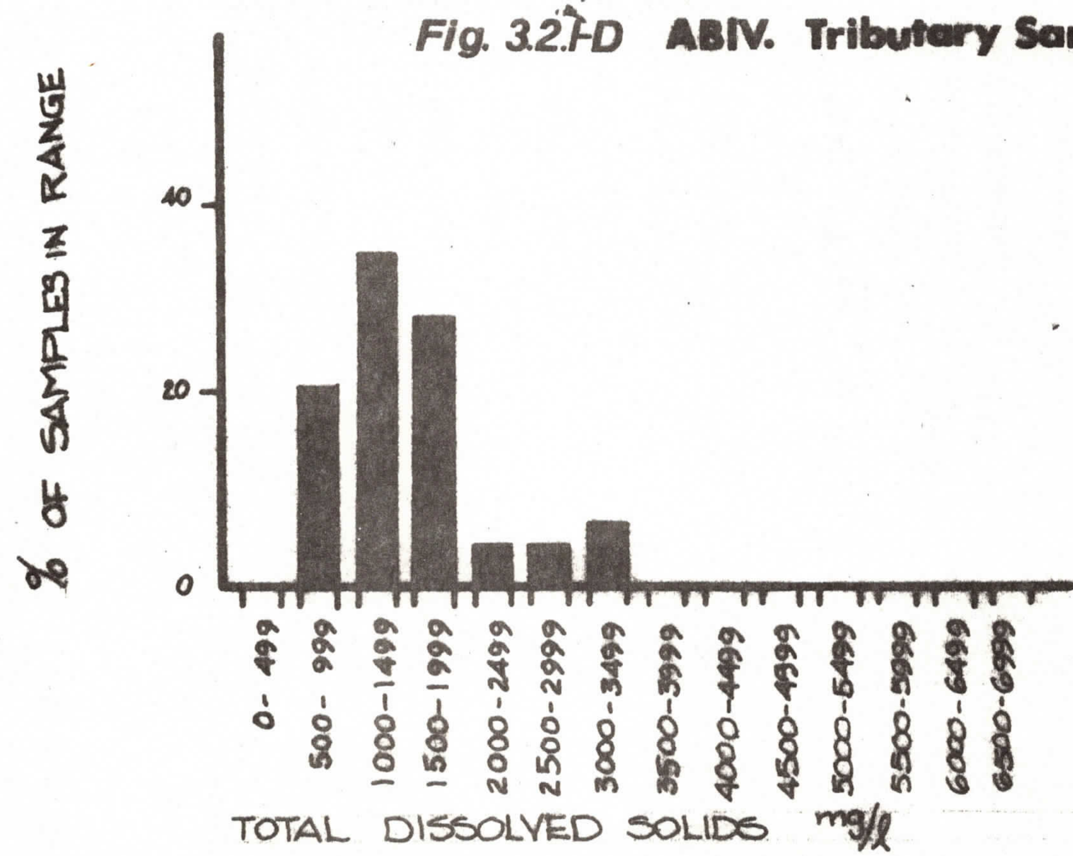
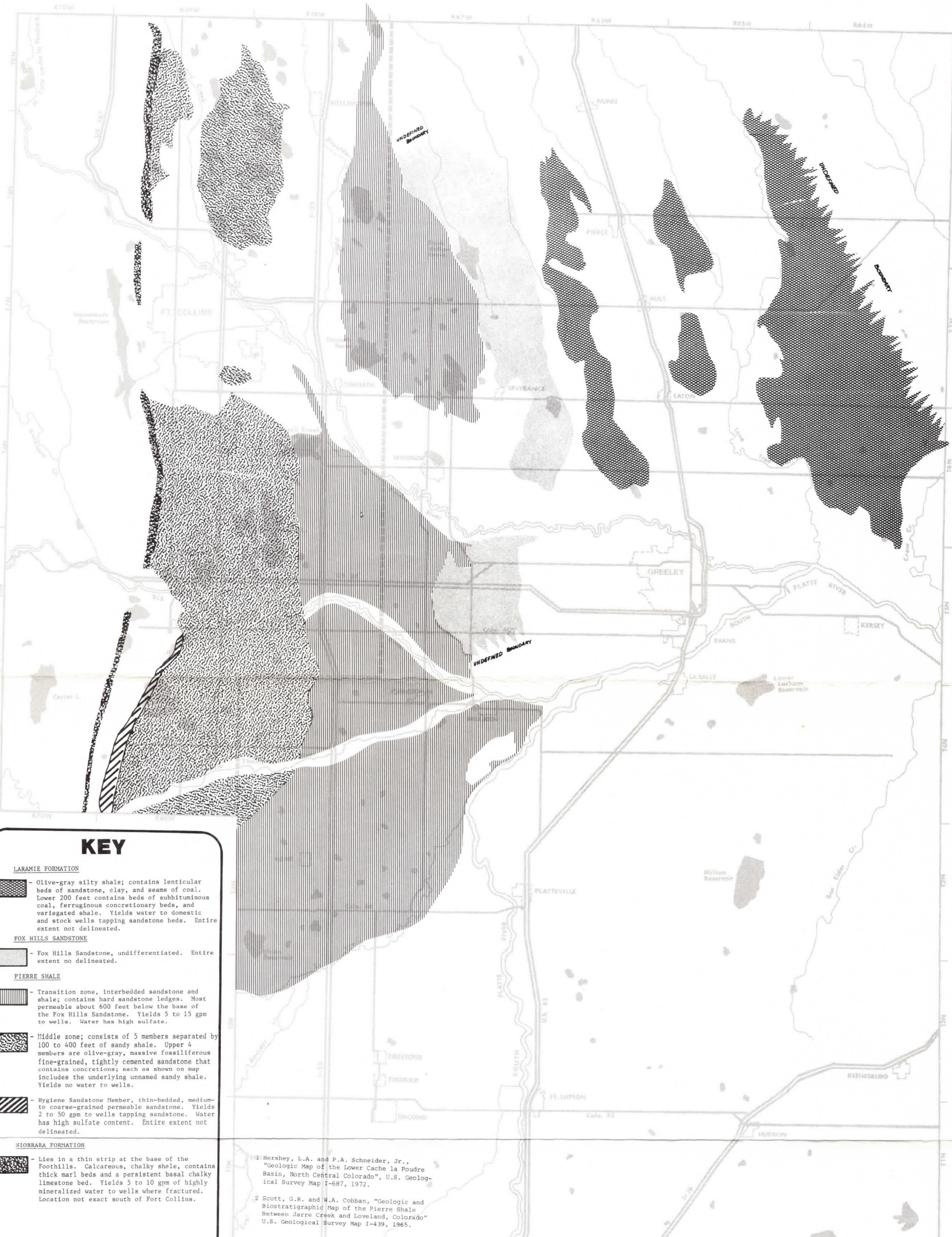



*Fig. 3.2.1-D* **ABIV. Tributary Samples**






# KEY

LARAMIE FORMATION

- Olive-gray silty shale; contains lenticular beds of sandstone, clay, and seams of coal. Lower 200 feet contains beds of subbituminous coal, ferruginous concretionary beds, and variegated shale. Yields water to domestic and stock wells tapping sandstone beds. Entire extent not delineated.

FOX HILLS SANDSTONE

- Fox Hills Sandstone, undifferentiated. Entire extent no delineated.

PIERRE SHALE

- Transition zone, interbedded sandstone and shale; contains hard sandstone ledges. Most permeable about 600 feet below the base of the Fox Hills Sandstone. Yields 5 to 15 gpm to wells. Water has high sulfate.
- Middle zone; consists of 5 members separated by 100 to 400 feet of sandy shale. Upper 4 members are olive-gray, massive fossiliferous fine-grained, tightly cemented sandstone that contains concretions; each as shown on map includes the underlying unnamed sandy shale. Yields no water to wells.
- Hygiene Sandstone Member, thin-bedded, medium- to coarse-grained permeable sandstone. Yields 2 to 50 gpm to wells tapping sandstone. Water has high sulfate content. Entire extent not delineated.

NIOBRARA FORMATION

- Lies in a thin strip at the base of the Foothills. Calcareous, chalky shale, contains thick marl beds and a persistent basal chalky limestone bed. Yields 5 to 10 gpm of highly mineralized water to wells where fractured. Location not exact south of Fort Collins.

SOURCE: LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS 1977

SCALE

0 1/2 1 2 3 4 5 MILES

N

## Geologic Formations

1 Hershey, L.A. and P.A. Schneider, Jr., "Geologic Map of the Lower Cache la Poudre Basin, North Central Colorado", U.S. Geological Survey Map I-687, 1972.

2 Scott, G.R. and W.A. Cobban, "Geologic and Biostratigraphic Map of the Pierre Shale Between Jarre Creek and Loveland, Colorado" U.S. Geological Survey Map I-439, 1965.

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS Fig 3.2.1-E

# AREAWIDE WATER QUALITY PLAN

THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT OF 1972 (PL 92-500)

Excess salinity in irrigation return flows occurs primarily in the areas along the front range where the Upper Cretaceous shales are observed (Figure 3.2.1-E). Evapotranspiration in the Larimer-Weld region and in downstream regions of the South Platte basin concentrates these salts. This evapotranspiration occurs both from croplands and from areas with high water table problems.

### 3.2.2 Nitrates

Nitrate concentrations in the groundwaters of the Larimer-Weld region are often above 10 mg/l as nitrogen which has been established as an upper limit for drinking water supplies by the U.S. Environmental Protection Agency.

#### 3.2.2.1 Nitrate Sources

Nitrogen occurs naturally in many forms. Nitrogen comprises 78 percent of the earth's atmosphere and it is from this atmospheric nitrogen that commercial fertilizers are manufactured. In the Larimer-Weld region, both commercial fertilizers and manure are used to a great extent for fertilizer. Manure applications of 15 to 20 tons per acre are common in some areas of the region.

#### 3.2.2.2 Nitrate Levels in the Waters of the Larimer-Weld Region

Nitrate levels are highly variable in the drains and streams of the region. A wide range was noted among the sampling points. For tile drains which had quite high levels of nitrates, it was noted that in each of these drains heavy manure applications were applied each year and commercial fertilizers were often used in addition to heavy manure applications. Figures 3.2.2-A, B, and C show nitrate levels found in the sampling study.

### 3.2.3 Sediment

Sediment has never received a great deal of attention in the irrigated area of the Larimer-Weld region. Nearly all soil loss work conducted has been associated with dryland areas. Rivers of the region tend to have flood plains serving as buffer zones prohibiting direct tailwater discharges to the river. Levels of suspended solids concentrations in river samples, tributary, and tailwater samples are shown in Figures 3.2.3-A, B, and C. A noticeable rise in suspended solids was observed in the lower reaches of some rivers, notably the Little Thompson. This is attributable to steep slopes and fine soils. This is further discussed in Section 4.4.2.2.

# Nitrates

*Fig. 3.2.2-A* **I. Tile Drains**

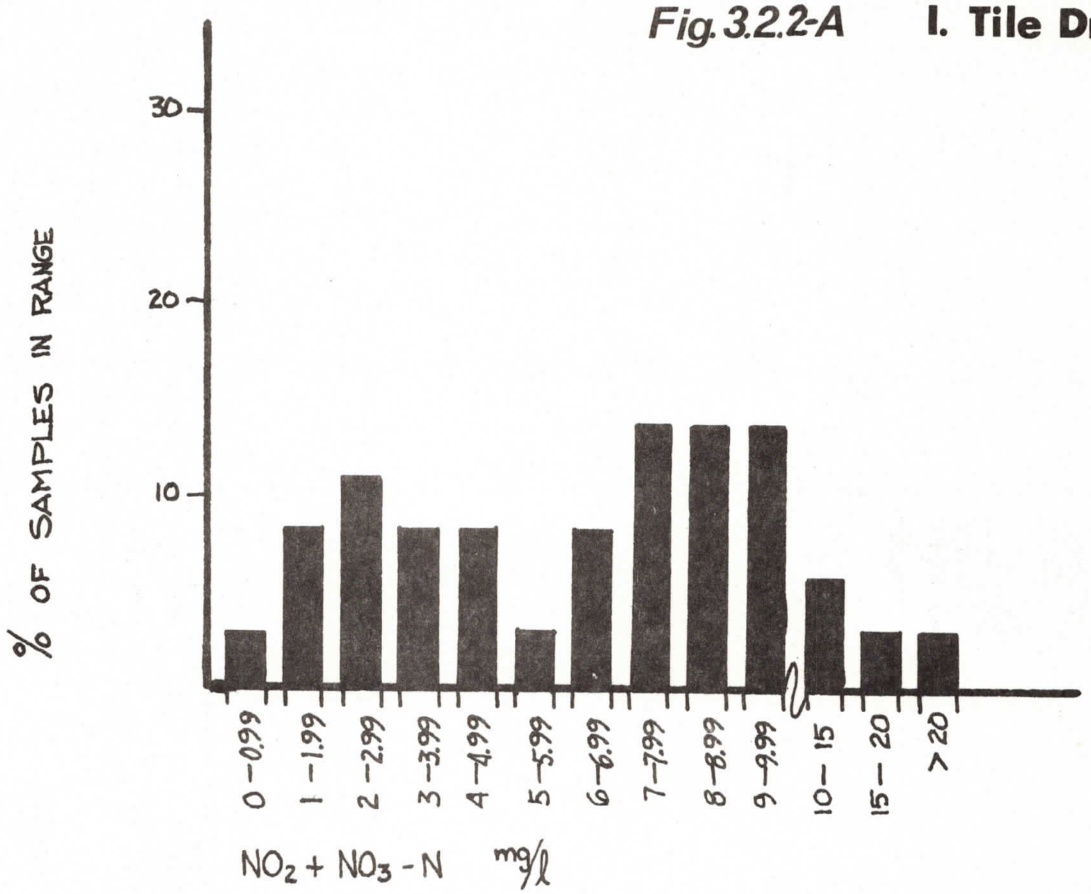



*Fig 3.2.2-B* **II. Tributaries**

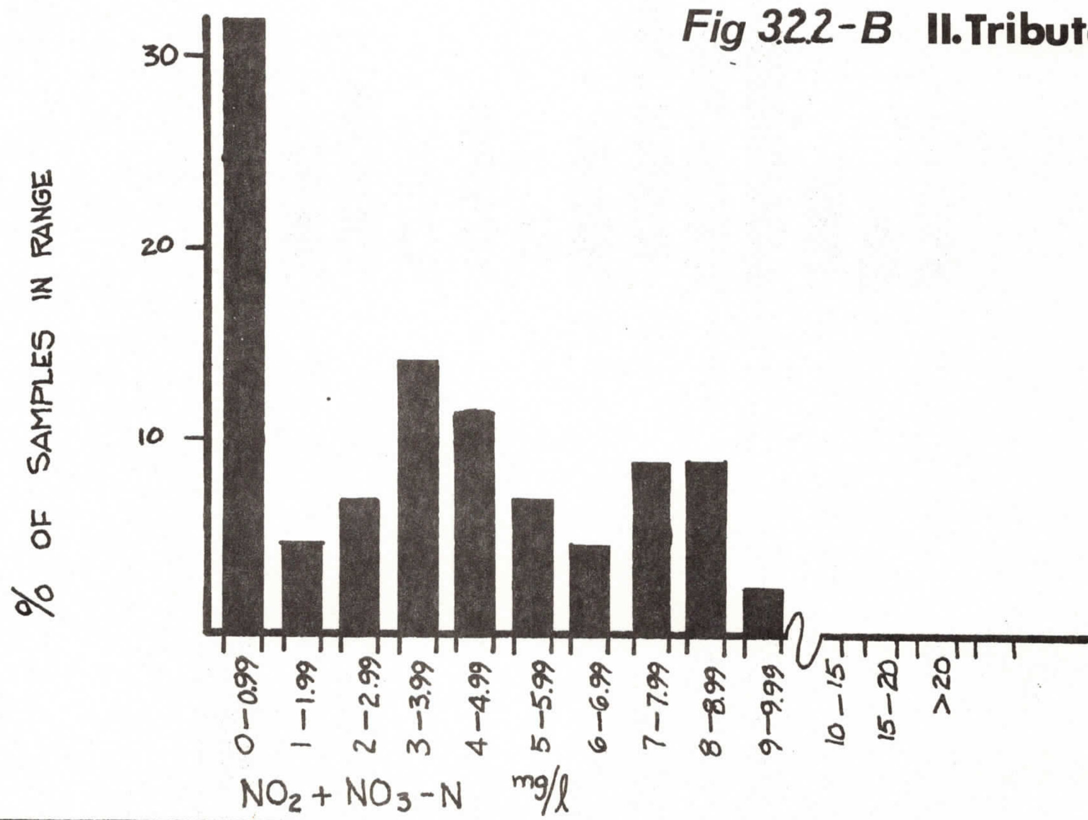
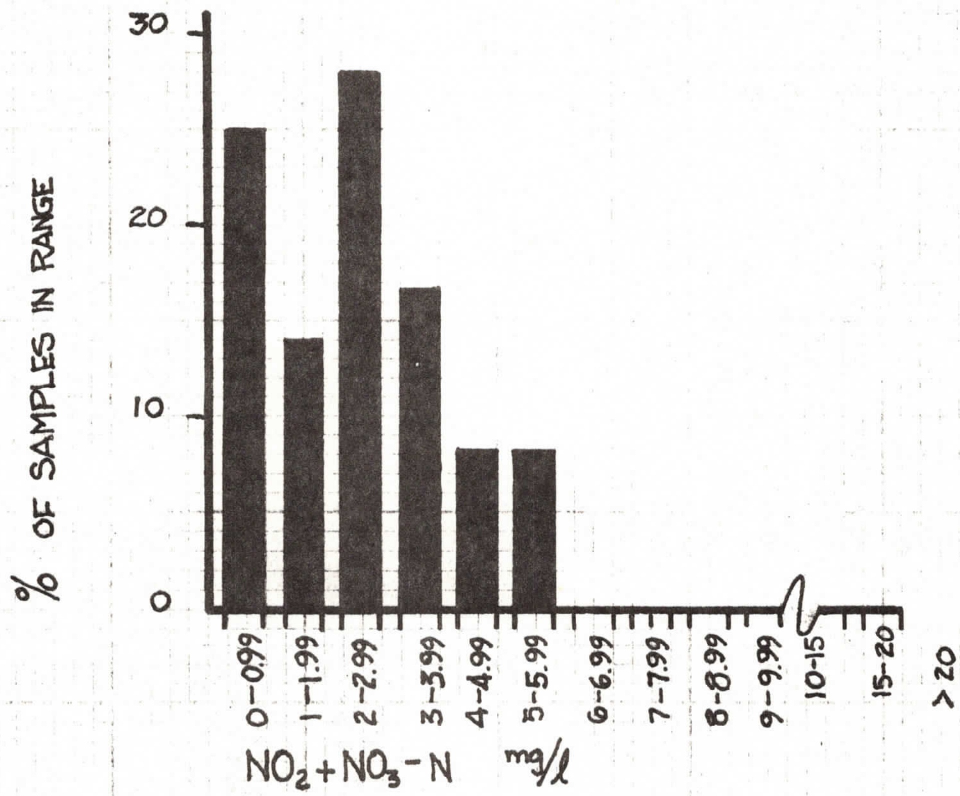


Fig 3.2.2 - C **III. River Samples**



# Sediment

Fig. 3.2.3-A **I. River Samples**

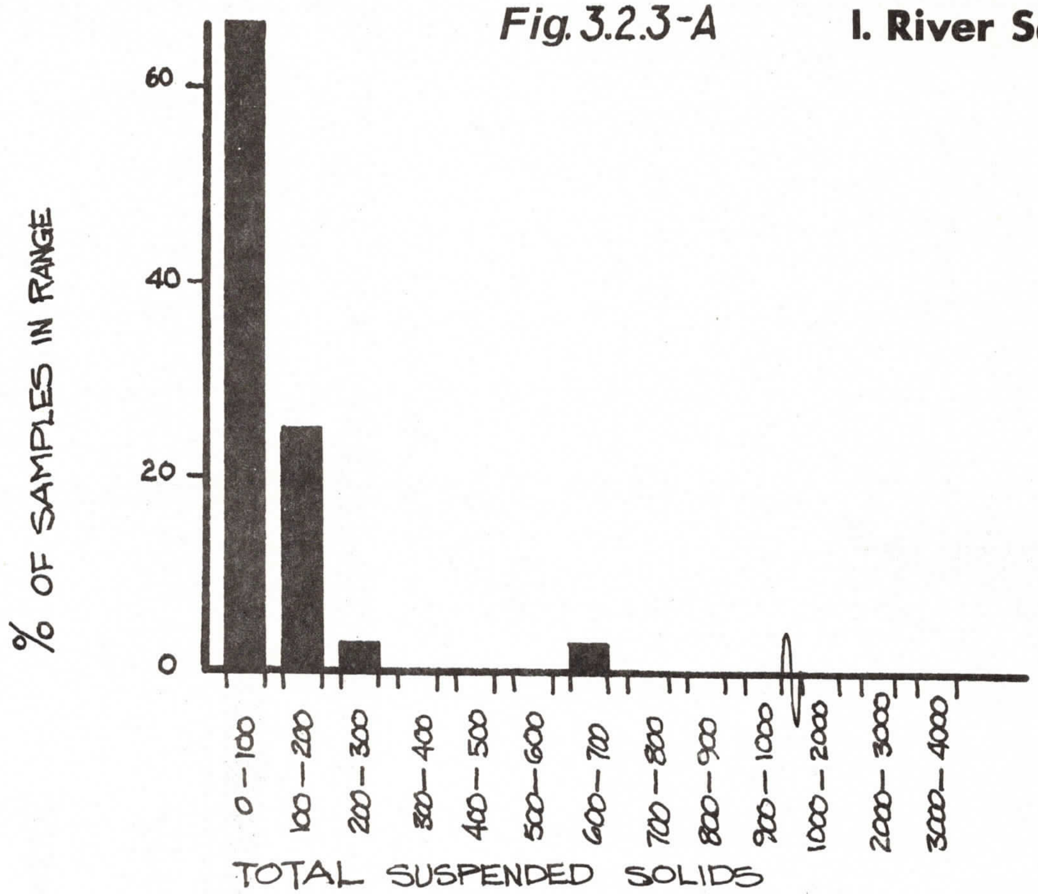
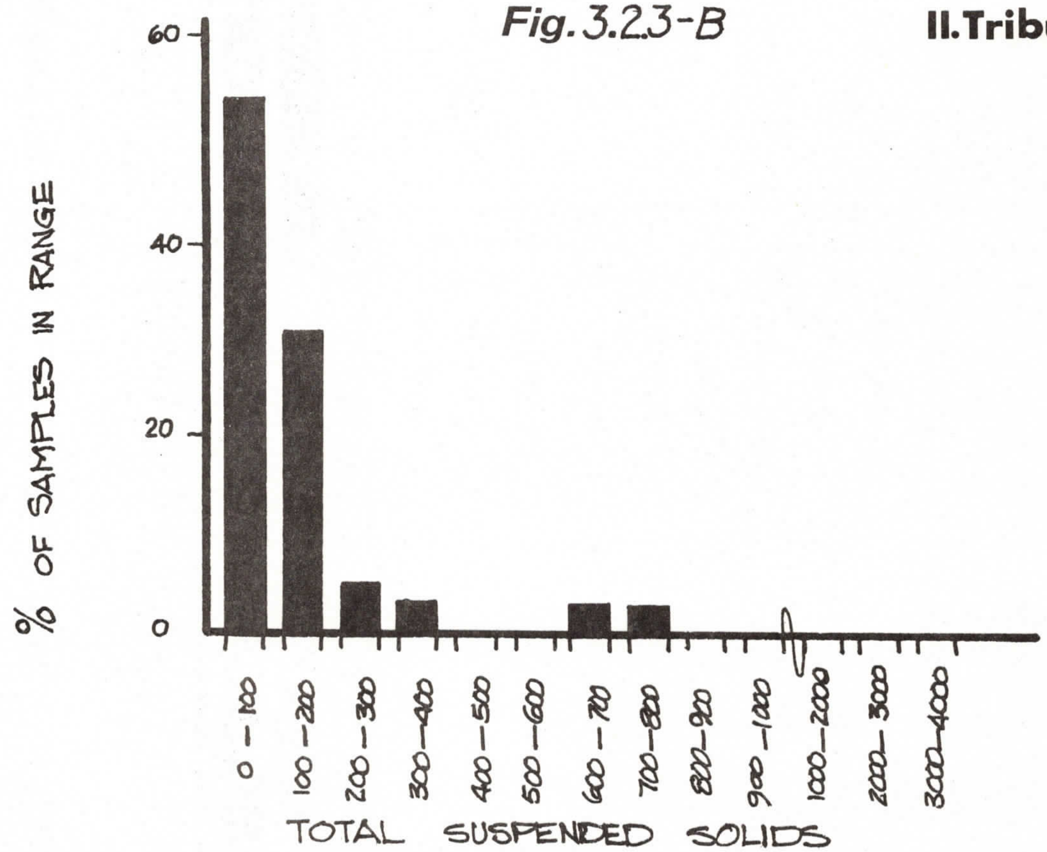



Fig. 3.2.3-B **II. Tributaries**



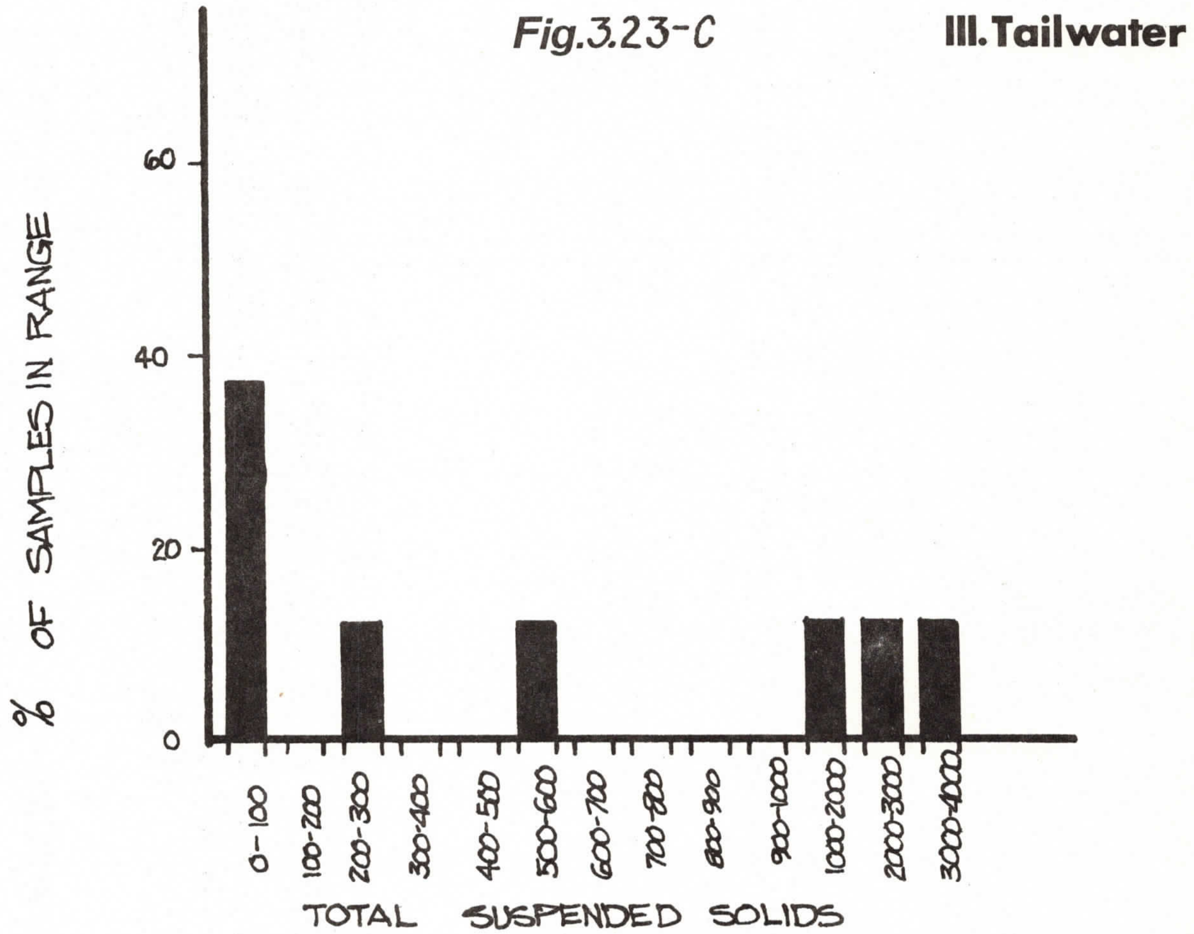


Fig.3.23-C
III. Tailwater
% OF SAMPLES IN RANGE
60
40
20
0
0-100
100-200
200-300
300-400
400-500
500-600
600-700
700-800
800-900
900-1000
1000-2000
2000-3000
3000-4000
TOTAL SUSPENDED SOLIDS

### 3.2.4 Phosphorous

Phosphorous levels were generally quite low in the samples taken of tile drains due to the nature of phosphorous, which rapidly becomes attached to soil particles. Total phosphorous levels in river, tributary, and tailwater samples are displayed on Figures 3.2.4-A, B, and C.

### 3.2.5 Pesticides

Due to the large number of pesticides used, high cost of analysis, and limited funding, no samples were analyzed for pesticide concentrations. Secondary data was relied upon for the pesticide analysis of this report. The U.S. Geological Survey (USGS) has maintained stations in the region and positive pesticide samples relative to the total number of samples for each sample during a time period are shown in Table 3.2.5-A.

TABLE 3.2.5-A. SUMMARY OF USGS PESTICIDE DATA

| ELEMENT | STATION: SOUTH PLATTE AT JULESBURG | | | SOUTH PLATTE AT KERSEY | POUDRE AT GREELEY |
|---|---|---|---|---|---|
| | 1972 | 1973 | 1974 | 1973 | 1974 |
| Aldrin | | | | | |
| Chlordane | | | | | |
| DDD | | | | | |
| DDE | 1/1* | | 1/4 | 3/4 | |
| DDT | | | 1/4 | 1/4 | |
| Diazinon | | 1/3 | 2/4 | 4/4 | 1/1 |
| Dieldrin | 1/1 | | 1/4 | 2/4 | 1/1 |
| Endrin | | | | | |
| Heptachlor | | | | | |
| Heptachlorepoxide | | | | | |
| Lindane | | | | | |
| Malathion | | | | 1/4 | |
| Methyl Parathion | | | | | |
| Parathion | | | | 1/4 | |
| PCB | | | | | |
| 2,4-D | 1/1 | | 2/4 | 3/4 | |
| 2,4,5-T | | | | 3/4 | |
| Silvex | | | 1/4 | 2/4 | |

* Positive Pesticide Samples/Total Samples Taken

# Phosphorous

## I. Tributaries Draining Irrigated Areas

*Fig. 3.2.4-A*

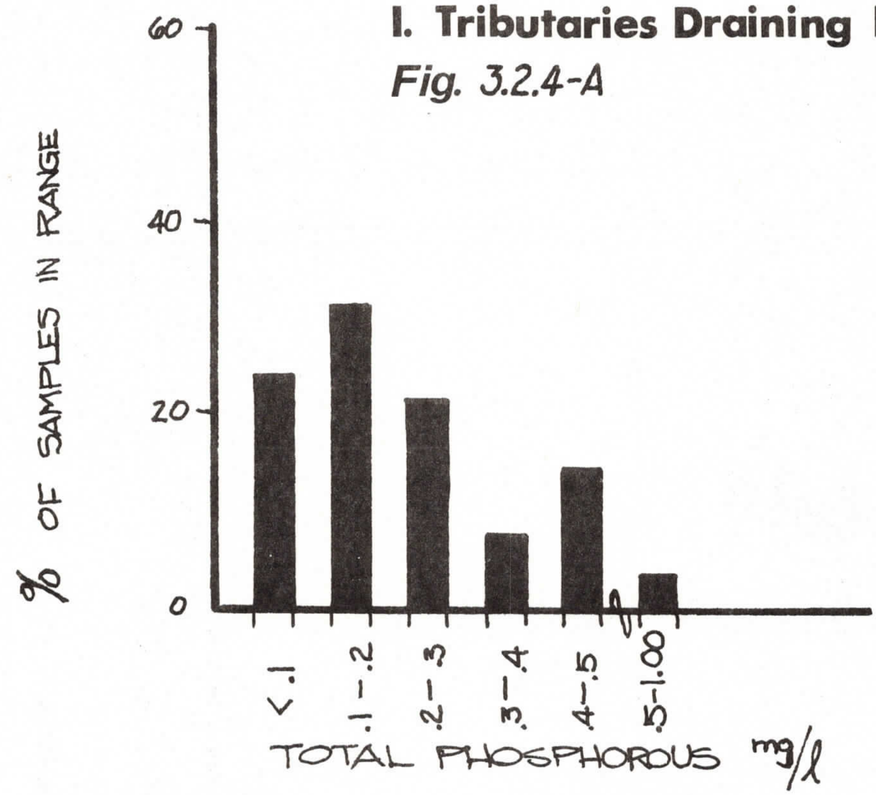


Fig. 3.2.4-B **III. Drains**

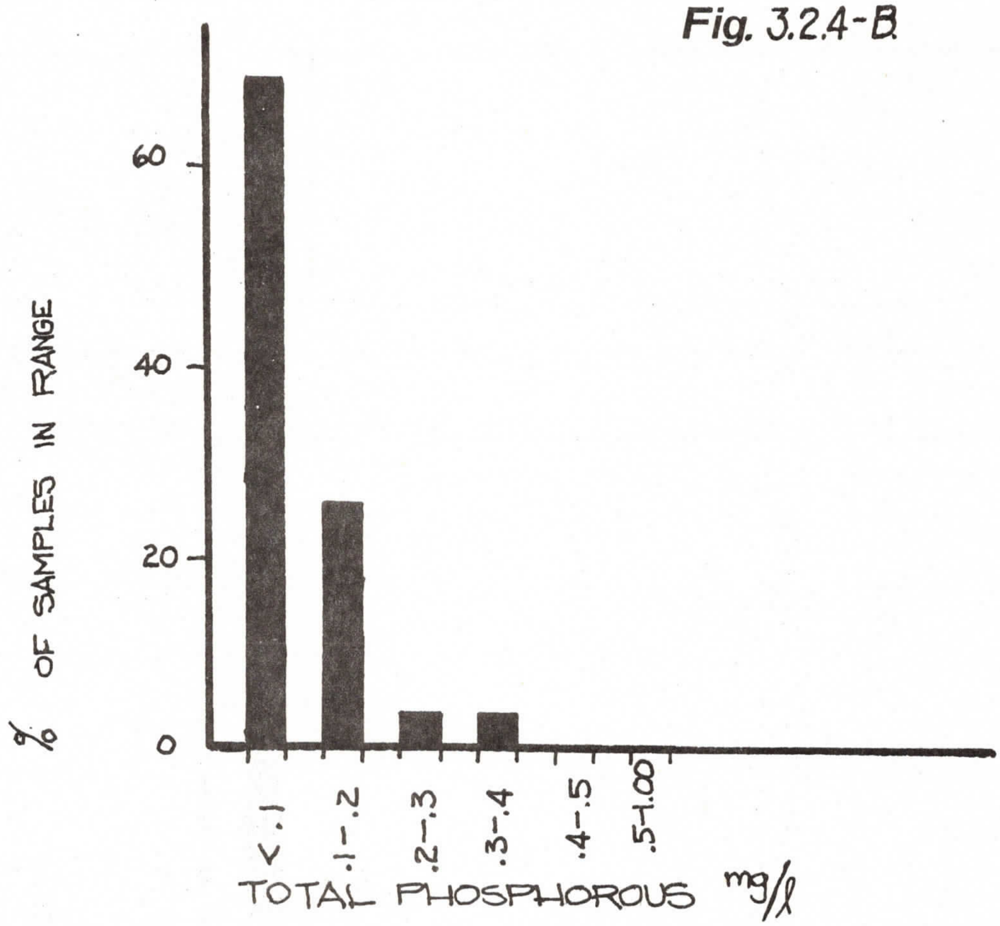
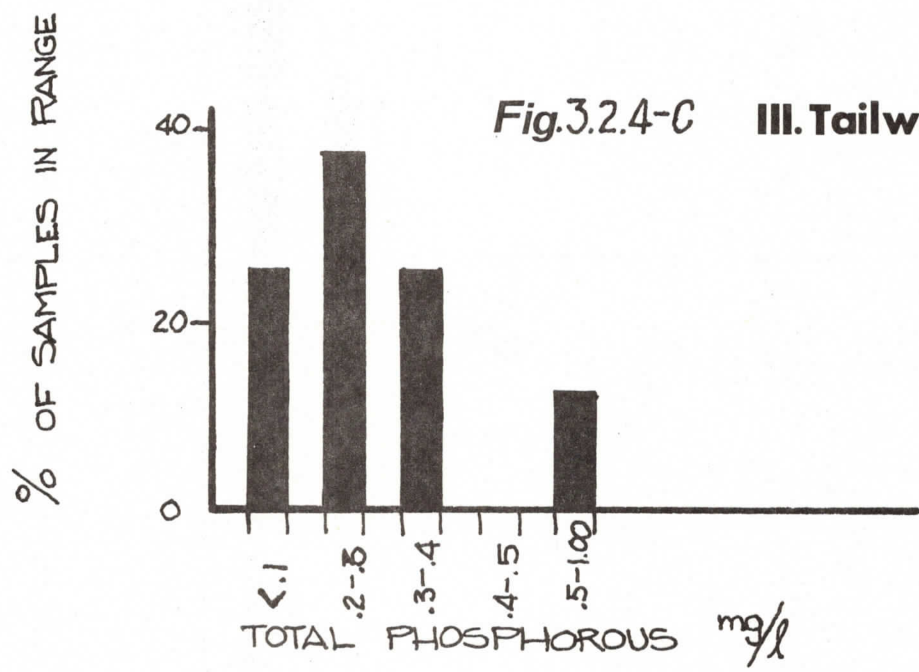



Fig. 3.2.4-C **III. Tailwater Samples**



### 3.2.6 Biochemical Oxygen Demand ($BOD_5$), Ammonia ($NH_3$), and Fecal Coliform Analysis

Levels of $BOD_5$, $NH_3$, and coliform bacteria sampled for in the program were consistently low in surface and subsurface drainage from irrigated lands. $BOD_5$ from all the agricultural samples averaged 2.5 mg/l. Ammonia ($NH_3$) concentrations averaged less than 0.1 mg/l as nitrogen (N). Fecal coliforms were similarly low.

## 4.0 ANALYSIS OF WATER QUALITY IMPACTS OF IRRIGATION RETURN FLOWS IN THE LARIMER-WELD REGION

### 4.1 INTRODUCTION

Irrigation return flows impact the water quality and quantity in the Larimer-Weld region. The hydrologic impact of irrigation diversions and return flows is significant. Streams are dried up at several points and seepage constitutes nearly all the flow below these points.

This seepage provides water to the rivers for subsequent diversions. Thus, downstream rights are fulfilled by the losses from upstream areas. The amount of this seepage back to the river varies throughout the region. Data collected as part of the 208 program indicates that most rivers in the area are thought to gain from 1.5 to 3.0 cfs per mile.

Salinity is the most significant pollutant associated with irrigation return flows in the region. Salt loads are primarily attributable to subsurface seepage returns. Salinity problems are noted in all of the rivers in the region. Some of the rivers such as the Little Thompson have noticeably higher salinity levels than other rivers. This may be attributed to the geology of each region and the types of lands irrigated.

Nitrates are a pollutant of lesser concern, although there is a definite potential for nitrate management improving return flows. High nitrate levels are especially noted in the area where heavy manure applications are made year after year and are often combined with significant chemical fertilizer applications.

Sediment has not been identified as being a serious pollutant in the Larimer-Weld region. However on a locational basis, some problem areas have been identified such as the lower reaches of the Little Thompson River where fine soils are combined with slopes which have erosive potential.

### 4.2 CACHE LA POUDRE RIVER

#### 4.2.1 Hydrologic Analysis

Hydrology of the Poudre River is the result of irrigation development since 1860. Over twenty separate diversions take water from the Poudre (Figure 2.1.1-A). Through the summer months, the Poudre River is generally dry below at least four of these diversion structurs.

During the irrigation season (May through September), zero flow conditions occur frequently below the Fossil Creek Reservoir Inlet, almost always below the B.H. Eaton Ditch and the Boyd & Freeman Ditch, and always at the Greeley No. 3 and Ogilvy Ditch. Diversion requirements below the points where these rivers are dried up are met primarily through return flows. Flow profiles for the Poudre River are shown in Figures 4.2.1-A and B.

During the storage season (October through April), the Cache la Poudre is generally dried up upstream of Fort Collins. This is done in order to introduce as much water to the storage system as possible. The Larimer County Canal, the Larimer and Weld Canal, Timnath Reservoir Inlet, and the Fossil Creek Reservoir Inlet are ditches which usually dry up the river. A continuously gaining stream, supplied largely by groundwater inflows, often exists from the Fossil Creek Reservoir Inlet to the mouth east of Greeley during the storage season. An exception to this condition exists when the Greeley No. 2 canal diverts water to its storage facilities.

### 4.2.2 Sources of Irrigation Return Flows

Irrigation return flows to the Poudre occur as groundwater seepage, tile drain flow, and tailwater flow. These may enter the river either directly or through a tributary. Tailwater is often allowed to flow into a roadside ditch. From there the tailwater is abandoned and tends to either seep into the ground or be collected by another ditch to be reintroduced into the distribution system or a tributary stream. The flood plain area of the Poudre River is generally used for non-irrigated grazing land and serves as a buffer to prevent direct tailwater discharges to the river.

Groundwater seepage to the Poudre represents the major loading of return flows to the river. Investigations of the amount of seepage to the river were conducted in three ways: (1) water balances using State Water Commissioner's data; (2) contact with individuals having years of experience with the system; and (3) flow measurements and inflow/outflow analysis conducted as part of the 208 program. The results of all these methods indicated that seepage returns to the Poudre River is approximately 3 cfs per mile through the irrigated area.

Tributary inflow to the Poudre is also a significant source of return flow. Several tributaries enter the river in the Fort Collins area, notably Dry Creek, Spring Creek, and Boxelder Creek. Fossil Creek and Consolidated

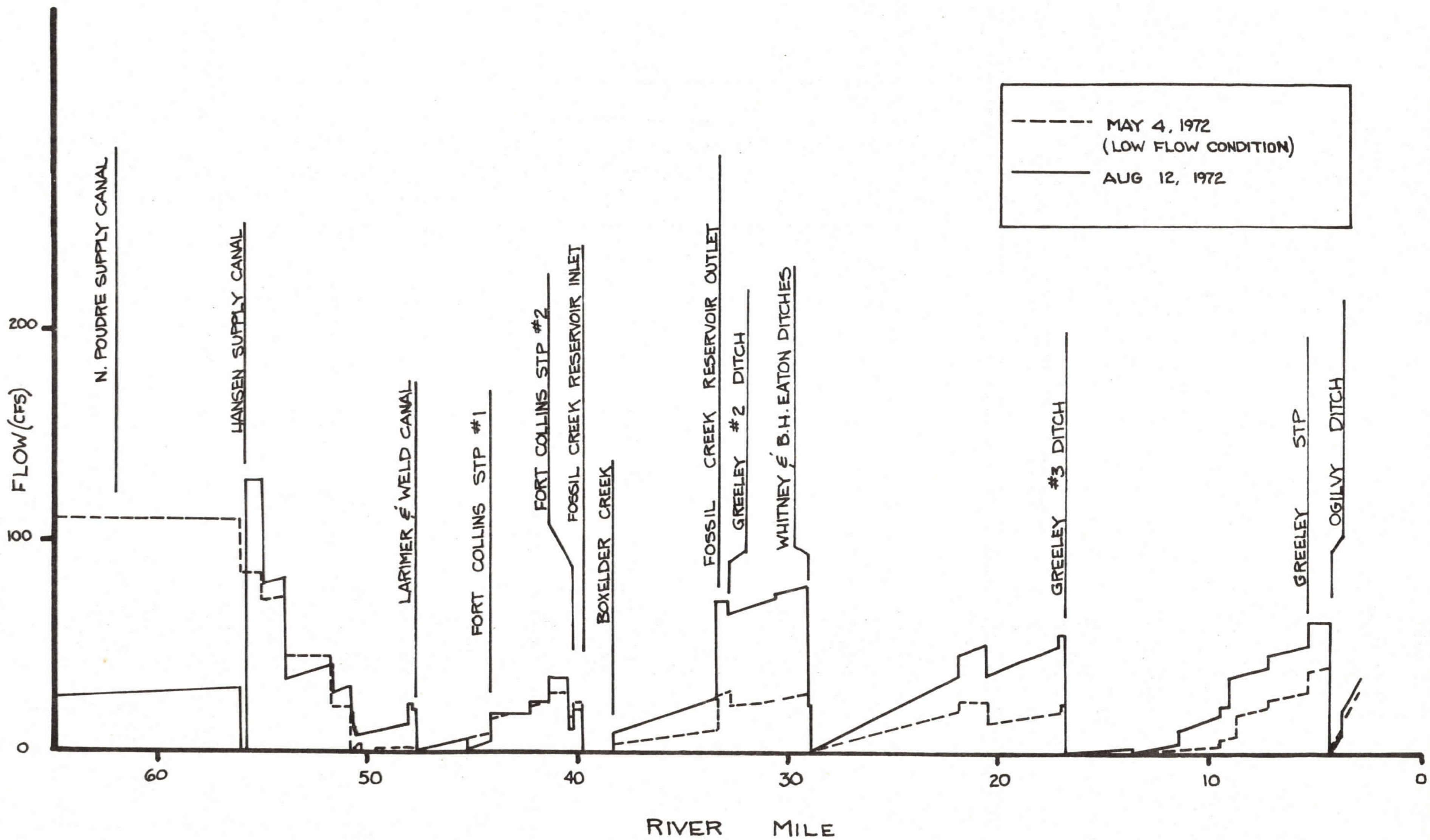



FIG. 4.2.1-A

**Stream Flow Cache La Poudre**

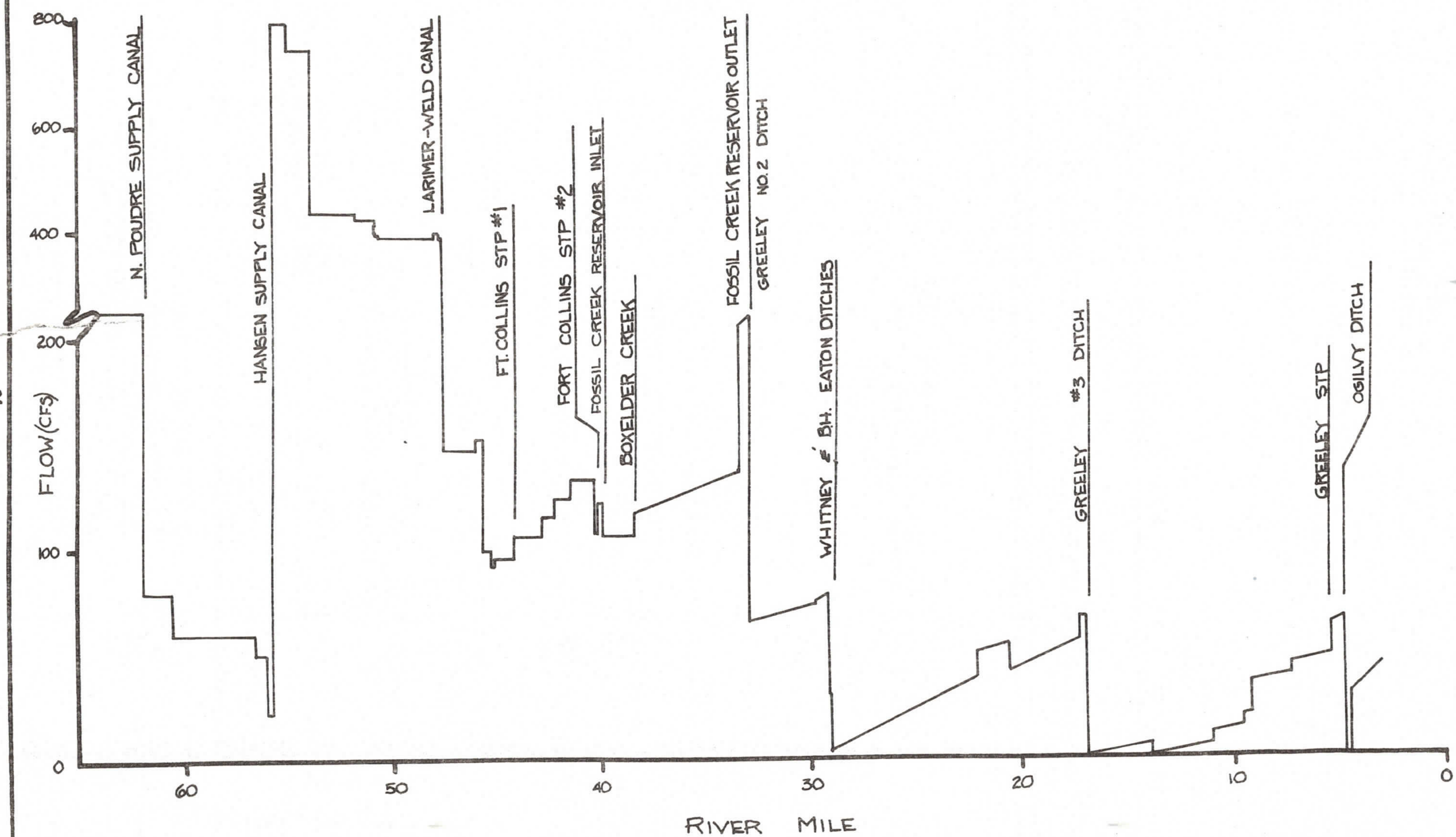



FIG. 4.2.1-B **Stream Flow Cache La Poudre** AUG. 31, 1976

Law Ditch enter the river in the middle reaches, while Sheep's Draw, Graham Seep, and Eaton Draw enter the Poudre River in the lower reaches. Flows were measured in nearly all of these tributaries and it was noted that flows were very consistant through the summer and early fall. This stable condition indicates that seepage contributes a high percentage of the total flow.

#### 4.2.2.1 Relationship to Other Dischargers

Irrigation return flows are by far the largest discharge to the river on a volume basis. These inflows represent approximately 235 cfs (150 million gallons per day [mgd]) over the length of the river. Other significant dischargers are the City of Greeley (6 mgd) and the City of Fort Collins (16 mgd), as well as the Windsor municipal plant (1.5 mgd). The Great Western Sugar Plant at Greeley may contribute up to 5 mgd during the processing season (October through February). The volumes of any one of these dischargers is much less than the irrigation return flow.

### 4.2.3 Water Quality Analysis

#### 4.2.3.1 Salinity

The total dissolved solids levels in the Poudre River increase from approximately 50 mg/l where it flows out of the mountains to over 1500 mg/l at the mouth approximately 50 river miles downstream (see Figure 4.2.3-A). Each time the river is dried up and seepage returns flow in to resupply the river, the levels of salinity increase. Significant increases in salinity levels occur in the upper areas around Fort Collins and to a lesser extent in the Windsor area where irrigation return flows from shale areas have a higher dissolved solids level. In the lower reaches of the Poudre where soils are not affected by saline lower formations, the seepage waters tend to be somewhat less saline.

#### 4.2.3.2 Nitrates

Nitrate levels increase in the Poudre River from very small levels upstream of Fort Collins to approximately 6 mg/l in the lower reaches (Figure 4.2.3-B). A significant amount of this loading is due to the irrigation return flows.

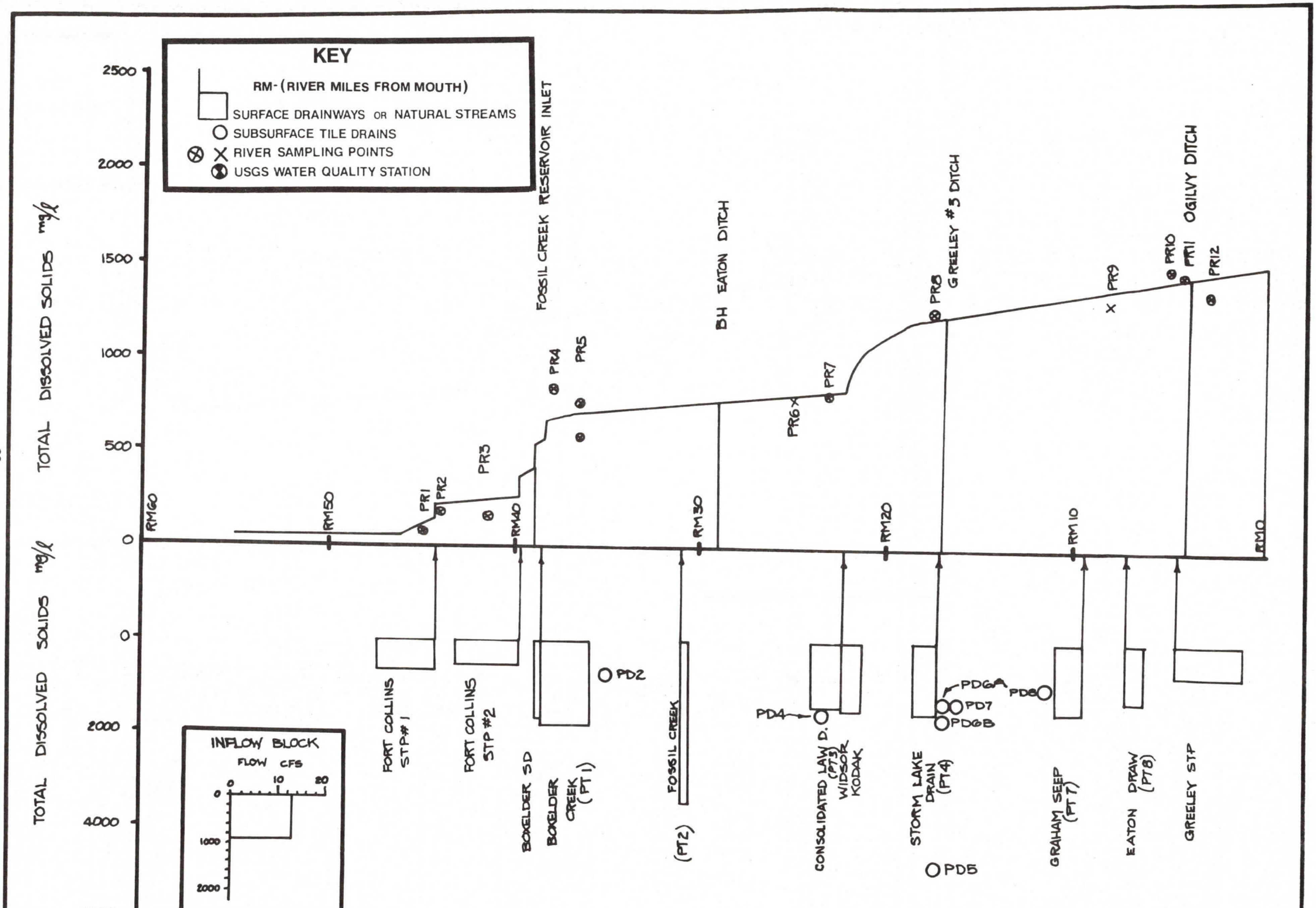


FIG. 4.2.3-A **TDS Cache La Poudre River**

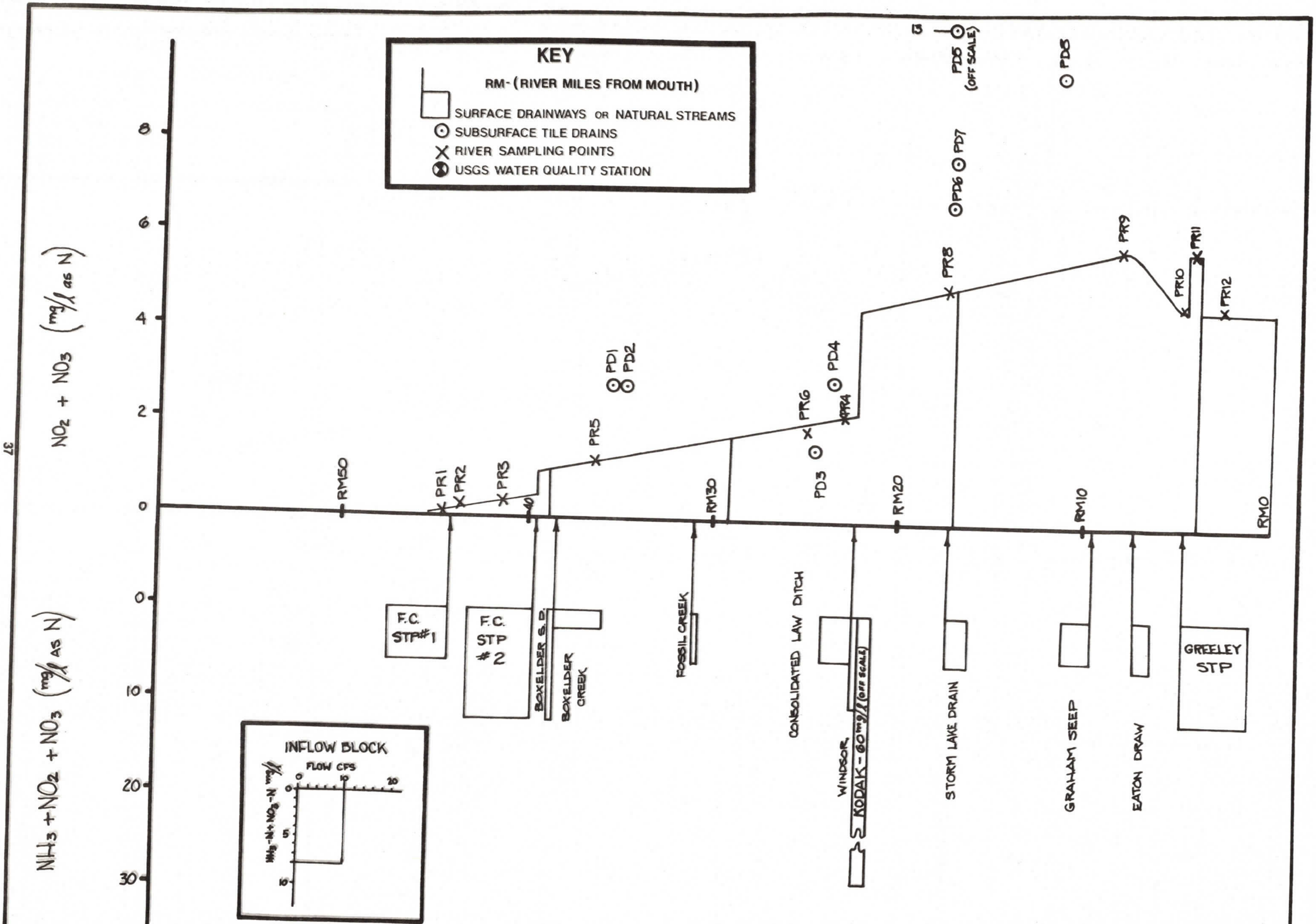



FIG. 4.2.3-B Nitrate Levels - Cache La Poudre

#### 4.2.3.3 Sediment

Sediment levels in the Poudre River increase from approximately 20 mg/l upstream from Fort Collins to approximately 80 mg/l in the lower reaches (see Figure 4.2.3-C). Sources of sediment may include irrigation water as it travels through canals, enters tributaries, and flows back into the river. Changing bed and bank conditions from the large stones in the upper reaches to the silty bed and banks in the lower reaches contribute to sediment loading. Sediment loading in the Poudre is an extremely complex phenomenon determined by a number of variable factors (soils, bed and bank conditions, flow velocity, tributary inflow, groundwater seepage, etc.). These factors make it impossible at this time to attribute sediment loading to a dominant source.

## 4.3 BIG THOMPSON RIVER

### 4.3.1 Hydrologic Analysis

During the storage season (October to April), the Big Thompson is generally dried up by either the Home Supply or the Barnes Ditch west of Loveland (Figures 4.3.1-A & B). Downstream flows are made up of groundwater inflows and waste discharges.

During the irrigation season (April to October), the river may first be dried up by the Barnes, Loveland and Greeley, or Farmers Ditch. Requirements for lower ditches are met by return flows, and any of the lower ditches may again dry up the river. A continuous river exists for only 8 to 10 days of the year when releases of Colorado-Big Thompson Project water are made in order to make up for well depletion.

#### 4.3.1.1 Sources of Irrigation Return Flow

Irrigation return flows contribute flow to the river through tributary flow and seepage inflows. It is estimated that approximately 46 cfs of seepage inflow occur over approximatley 35 river miles of the Big Thompson. This represents approximately 1.3 cfs per mile. Minor tributaries contribute between 20 and 25 cfs to the river.

Irrigation return flow is the largest discharge to the river, representing approximately 68 cfs (44 mgd). Other significant discharges are from the Loveland (6 mgd) and Estes Park (season) sewage treatment plants, and from the Great Western Sugar Plant (5 mgd) in Loveland during the processing season.

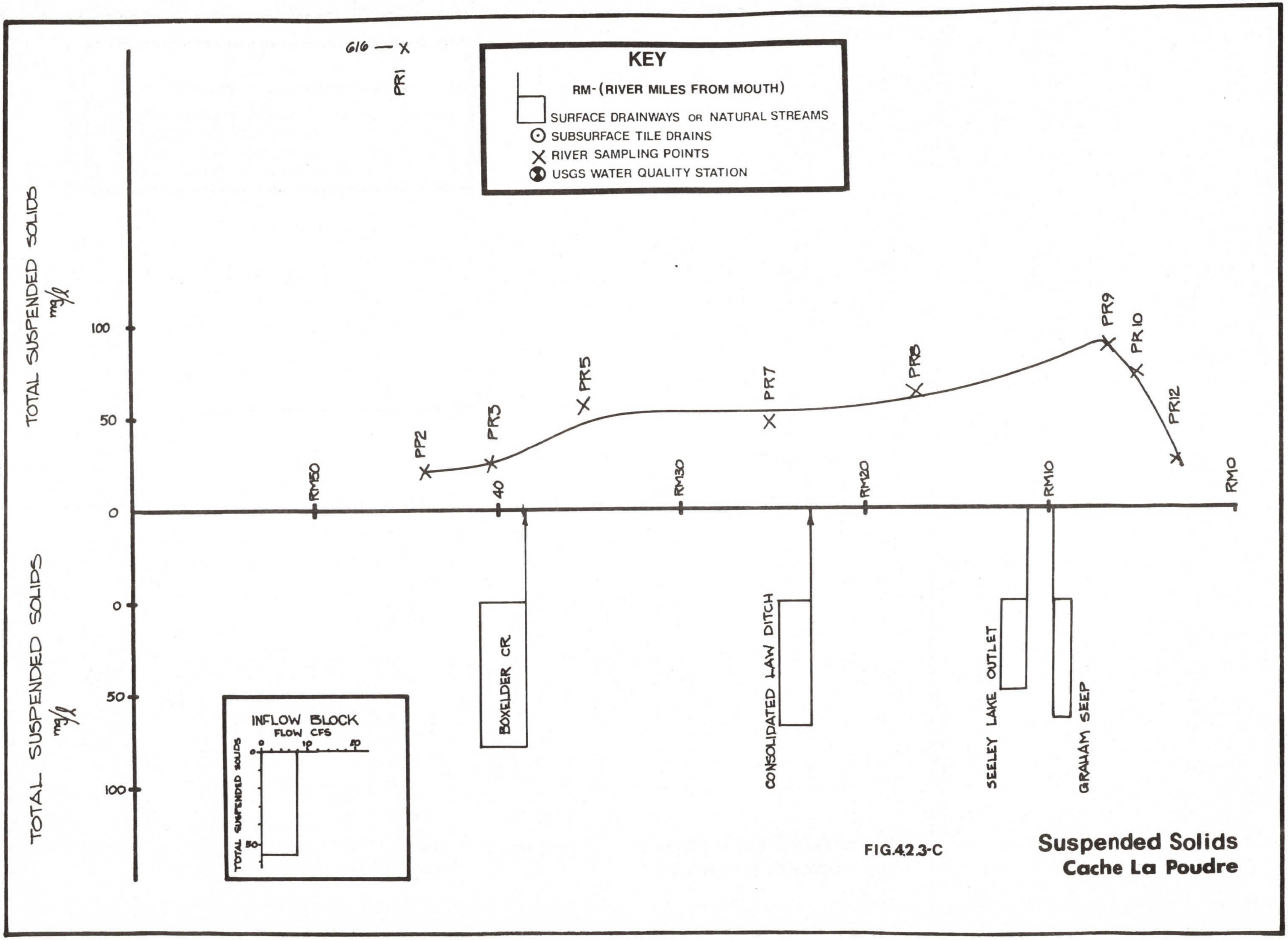



FIG.4.2.3-C

**Suspended Solids**
**Cache La Poudre**

### 4.3.2 Water Quality Analysis

#### 4.3.2.1 Salinity

Total dissolved solids increase from very low levels upstream of Loveland to 1200-1500 mg/l in the lower reaches (see Figure 4.3.2-A). Most of the saline soils west of Loveland do not receive irrigation. The majority of irrigation in the Big Thompson drainage is on the better soils to the east of Loveland. The Little Thompson River enters the Big Thompson at River Mile 8 near Milliken and discharges a large salt load to the Big Thompson River.

#### 4.3.2.2 Nitrates

Nitrate levels in the Big Thompson increase significantly from the lower reaches to the mouth (see Figure 4.3.2-B). Even so, levels at the mouth are generally fairly low--less than 2 mg/l as nitrogen. In fact, nitrate levels were found to be less than 1 mg/l to the confluence with the Little Thompson River.

## 4.4 LITTLE THOMPSON RIVER

### 4.4.1 Hydrologic Analysis

The Little Thompson River has very minimal native flows. Water for irrigation in the Little Thompson basin is for the most part supplied by other rivers. Canals supply water to the river from St. Vrain Creek as well as the Colorado-Big Thompson (C-BT) Project water (see Figures 4.4.1-A and B). In addition, the Handy and Home Supply Ditches which originate in the Big Thompson basin flow over the basin divide and are actually used to irrigate in both basins. The Boulder-Larimer (Ish) Ditch is the largest ditch diverting water from the Little Thompson and below the diversion of the Ish Ditch, flows are generally quite small. Return flow supplies much of the water for downstream use.

#### 4.4.1.1 Sources of Irrigation Return Flow

Measured flows and water budgets from the State Water Commissioner's data indicate that seepage into the Little Thompson is approximately 1.5 cfs per mile. This represents approximately 35 cfs of seepage through the irrigated length of the river. A few small tributaries flow into the Little Thompson. Most have flows of approximately 2 cfs during the summer months.

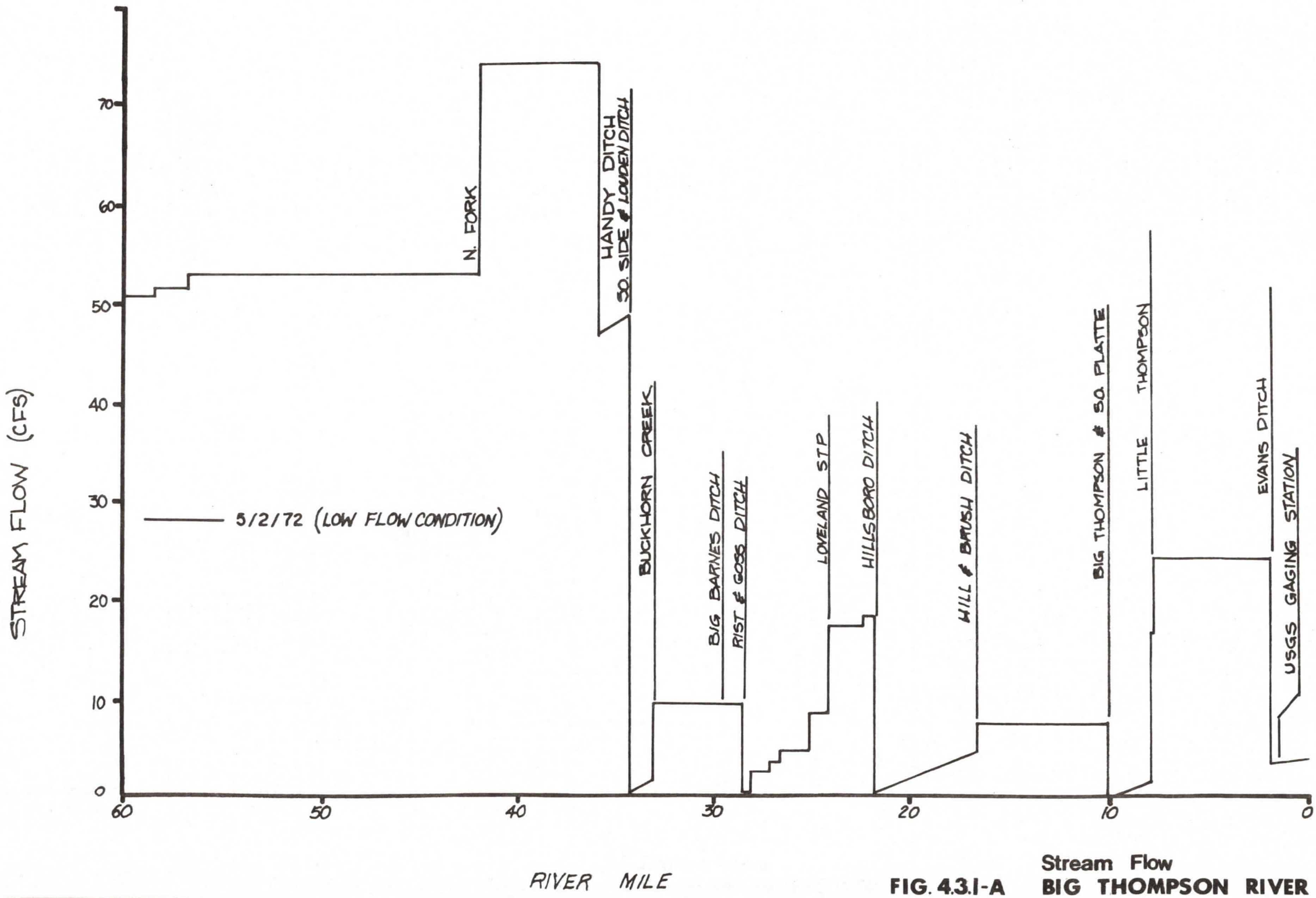



FIG. 4.3.1-A Stream Flow BIG THOMPSON RIVER

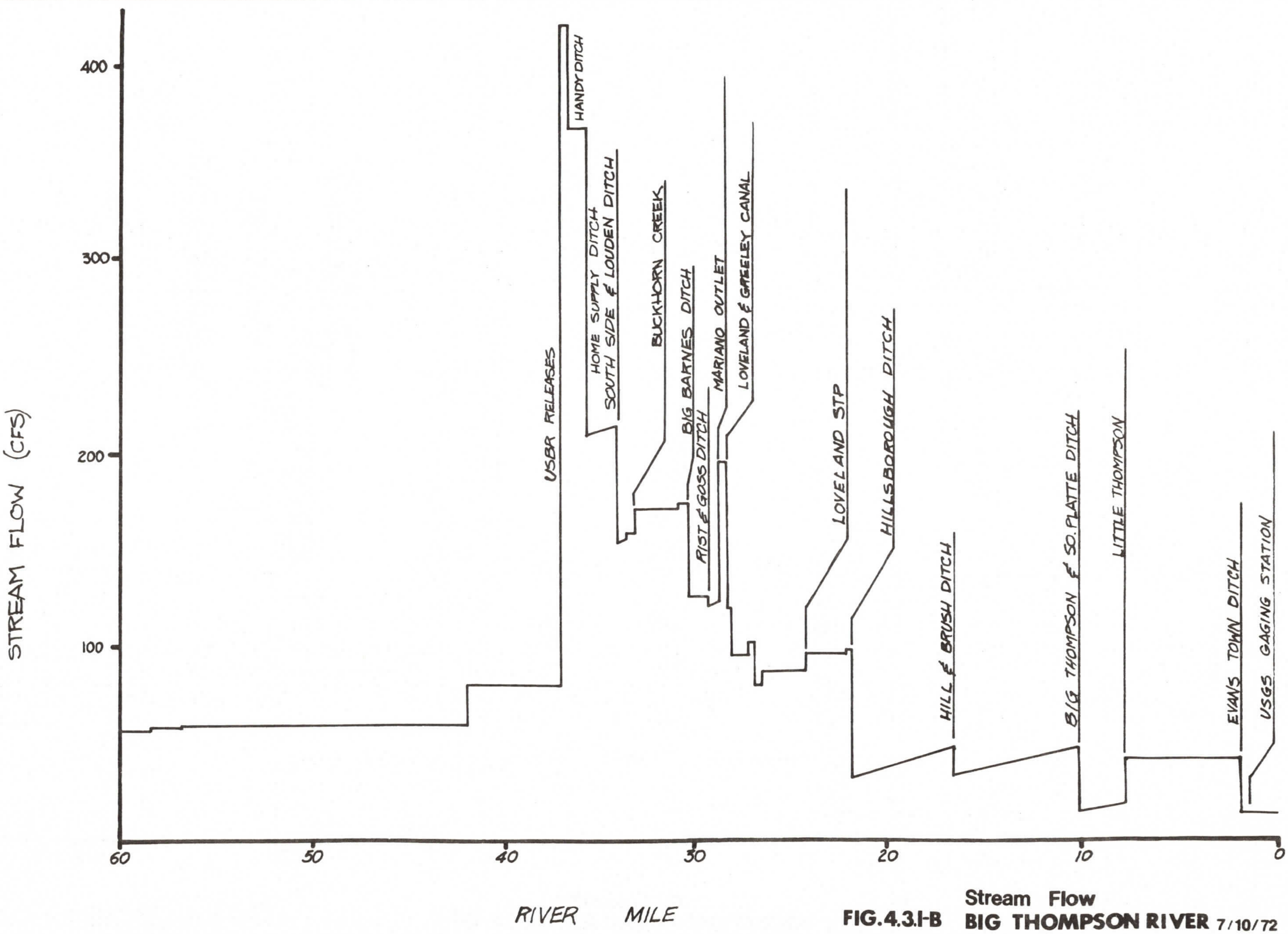
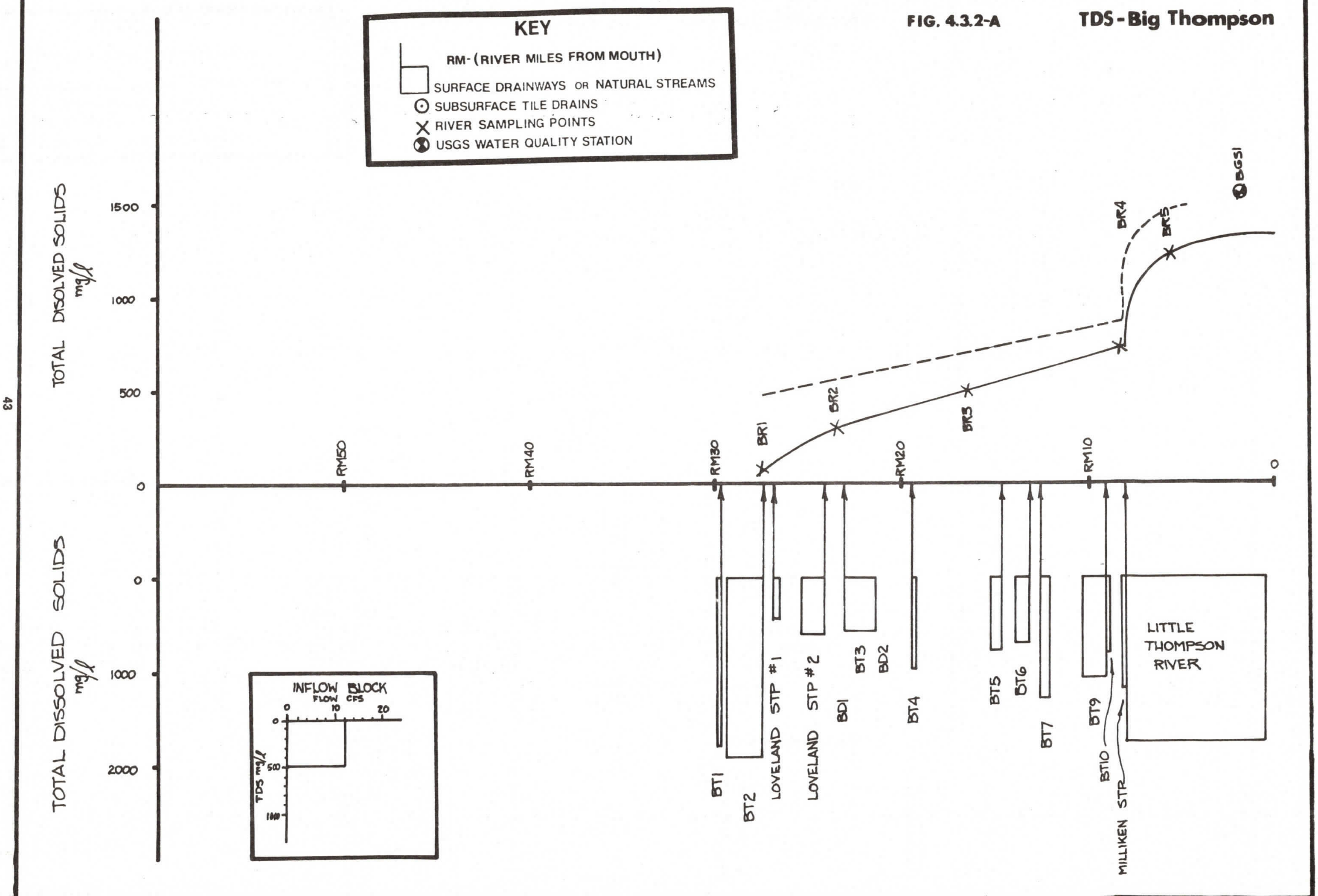
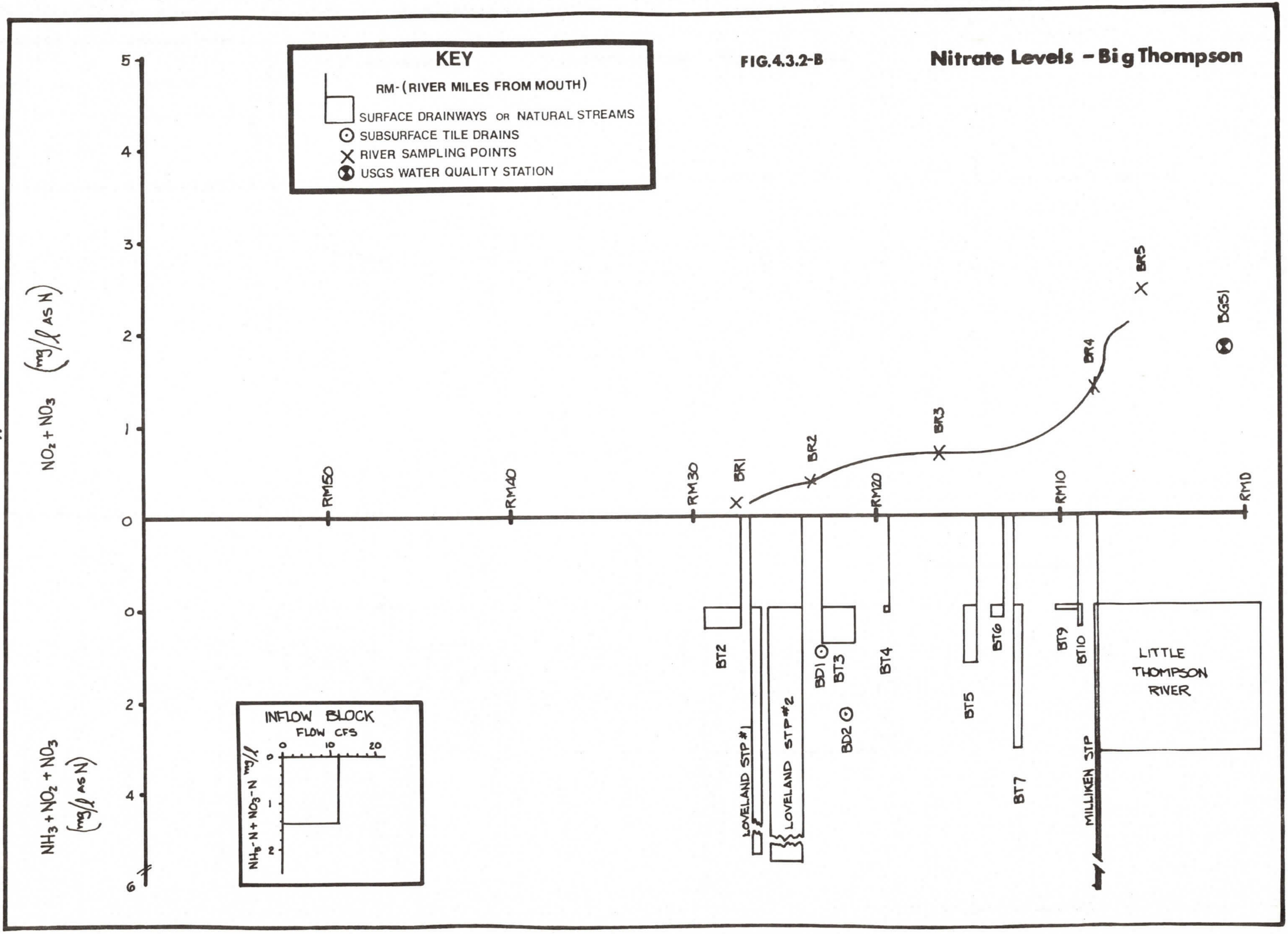
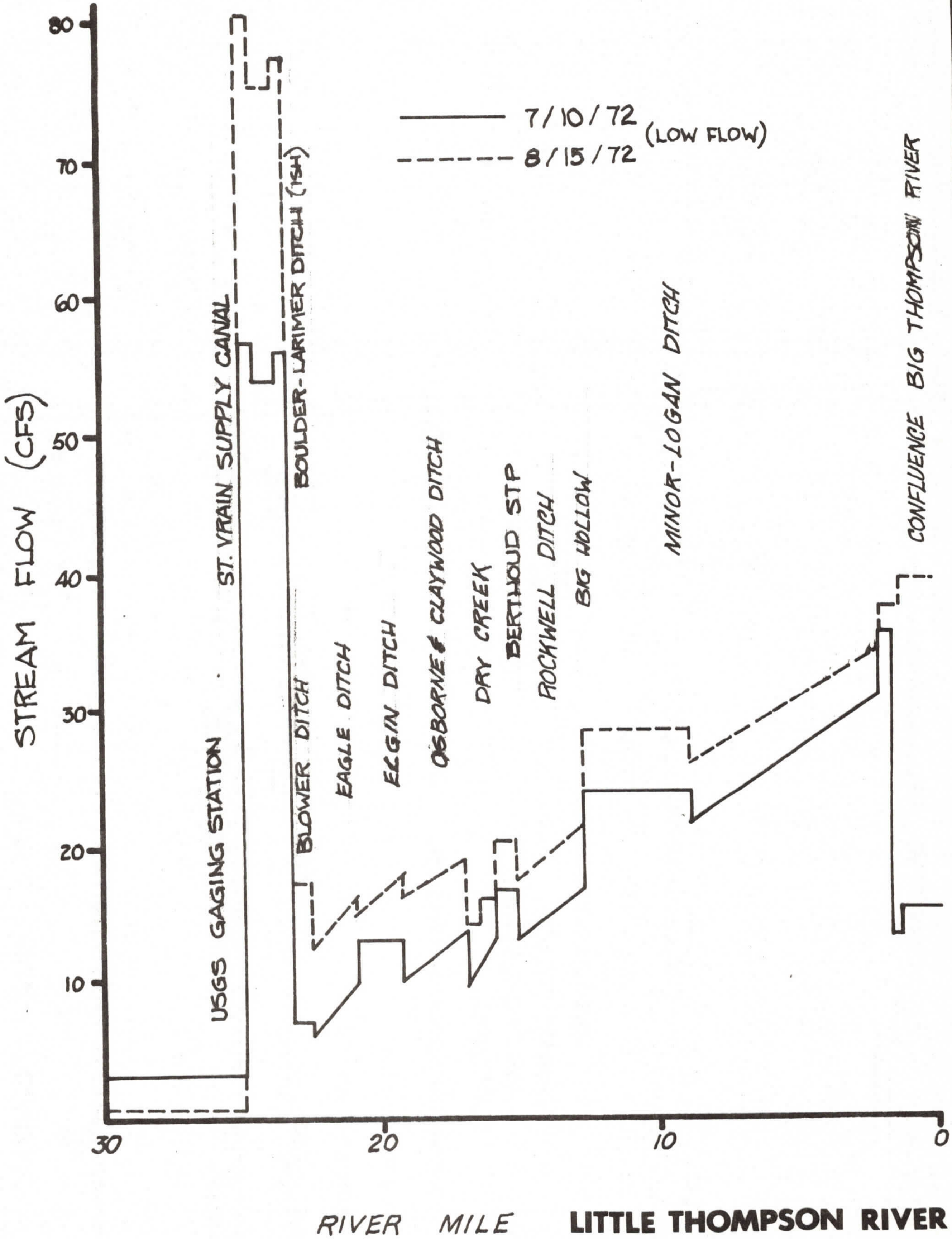



FIG. 4.3.I-B Stream Flow BIG THOMPSON RIVER 7/10/72

FIG. 4.3.2-A TDS - Big Thompson

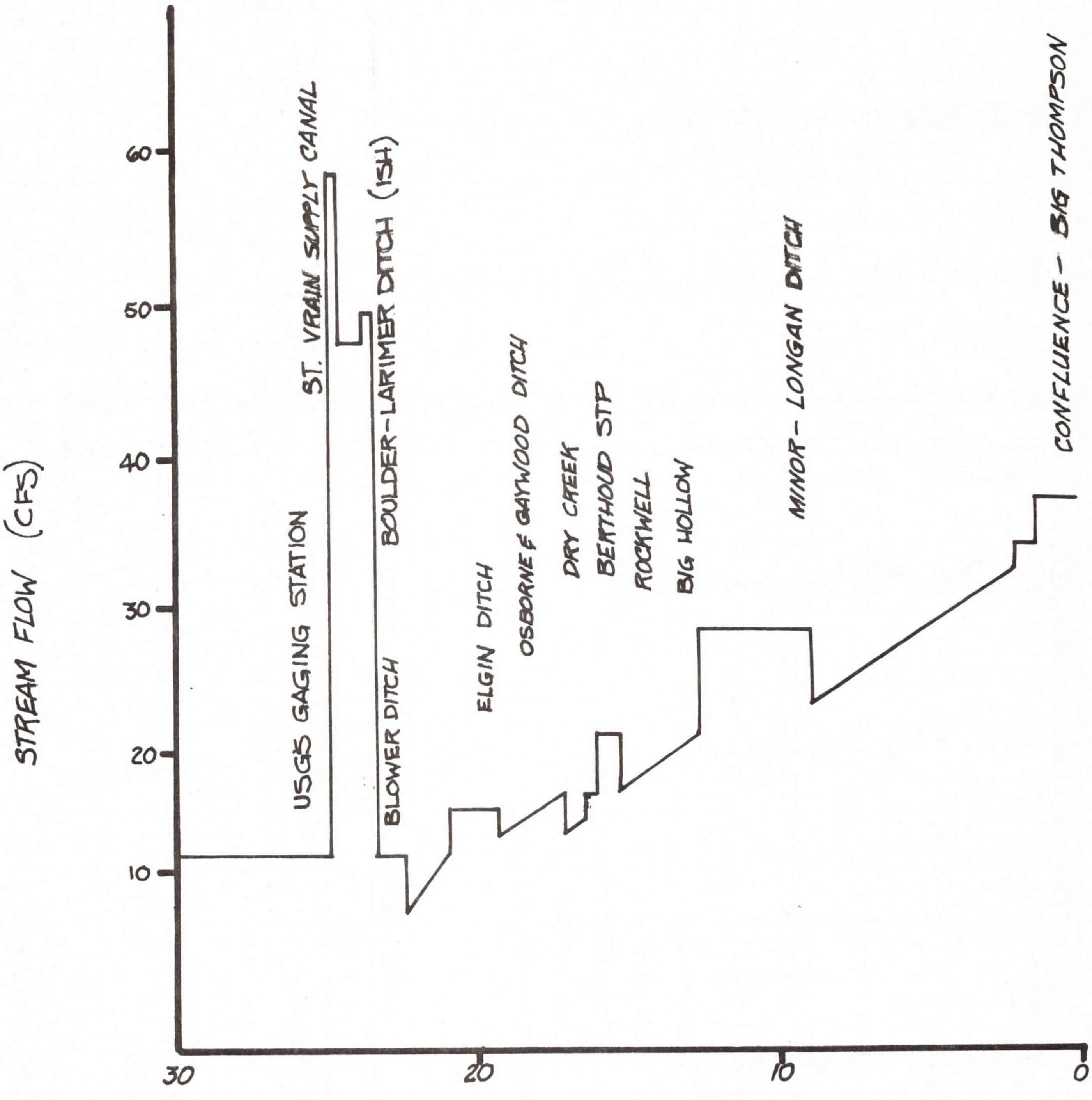



Nitrate Levels – Big Thompson
FIG.4.3.2-B
KEY
RM- (RIVER MILES FROM MOUTH)
SURFACE DRAINWAYS OR NATURAL STREAMS
SUBSURFACE TILE DRAINS
RIVER SAMPLING POINTS
USGS WATER QUALITY STATION
NO2 + NO3 (mg/ℓ AS N)
NH3 + NO2 + NO3 (mg/ℓ AS N)
5
4
3
2
1
0
0
2
4
6
RM50
RM40
RM30
RM20
RM10
RMO
BR1
BR2
BR3
BR4
BR5
BGS1
BT2
LOVELAND STP #1
LOVELAND STP #2
BD1
BT3
BD2
BT4
BT5
BT6
BT7
BT9
BT10
MILLIKEN STP
LITTLE THOMPSON RIVER
INFLOW BLOCK
FLOW CFS
0
10
20
NH3-N + NO3-N mg/ℓ
0
1
2




**LITTLE THOMPSON RIVER**

FIG. 4.4.1-A




**LITTLE THOMPSON RIVER**
**9-2-76**

**FIG. 4.4.1-B**

Irrigation return flow accounts for approximately 40 cfs (26 mgd) to the Little Thompson River. Other discharges to the Little Thompson River include the Berthoud sewage treatment plant (0.42 mgd), Johnstown sewage treatment plant (0.3 mgd), and Great Western Sugar Plant at Johnstown (4 mgd).

### 4.4.2 Water Quality Analysis

#### 4.4.2.1 Salinity

The Little Thompson River has the highest salinity levels of any of the rivers in the region. The river has concentrations of nearly 1500 mg/l upstream of Berthoud and concentrations continue to climb to over 2000 mg/l slightly east of Berthoud (see Figure 4.4.2-A). Tributaries and drains entering the Little Thompson River have consistently high dissolved solids levels. Reasons for this are easily seen when the soils of the area are observed. Nearly all of the soils in the western portion of the Little Thompson irrigated area are shallow soils overlying shale formations.

#### 4.4.2.2 Nitrates

Nitrate levels increase from very low levels as the river comes out of the mountains to approximately 2 mg/l in the Berthoud area. Downstream from Berthoud, nitrate levels remain at approximately 2 mg/l as nitrogen (see Figure 4.4.2-B).

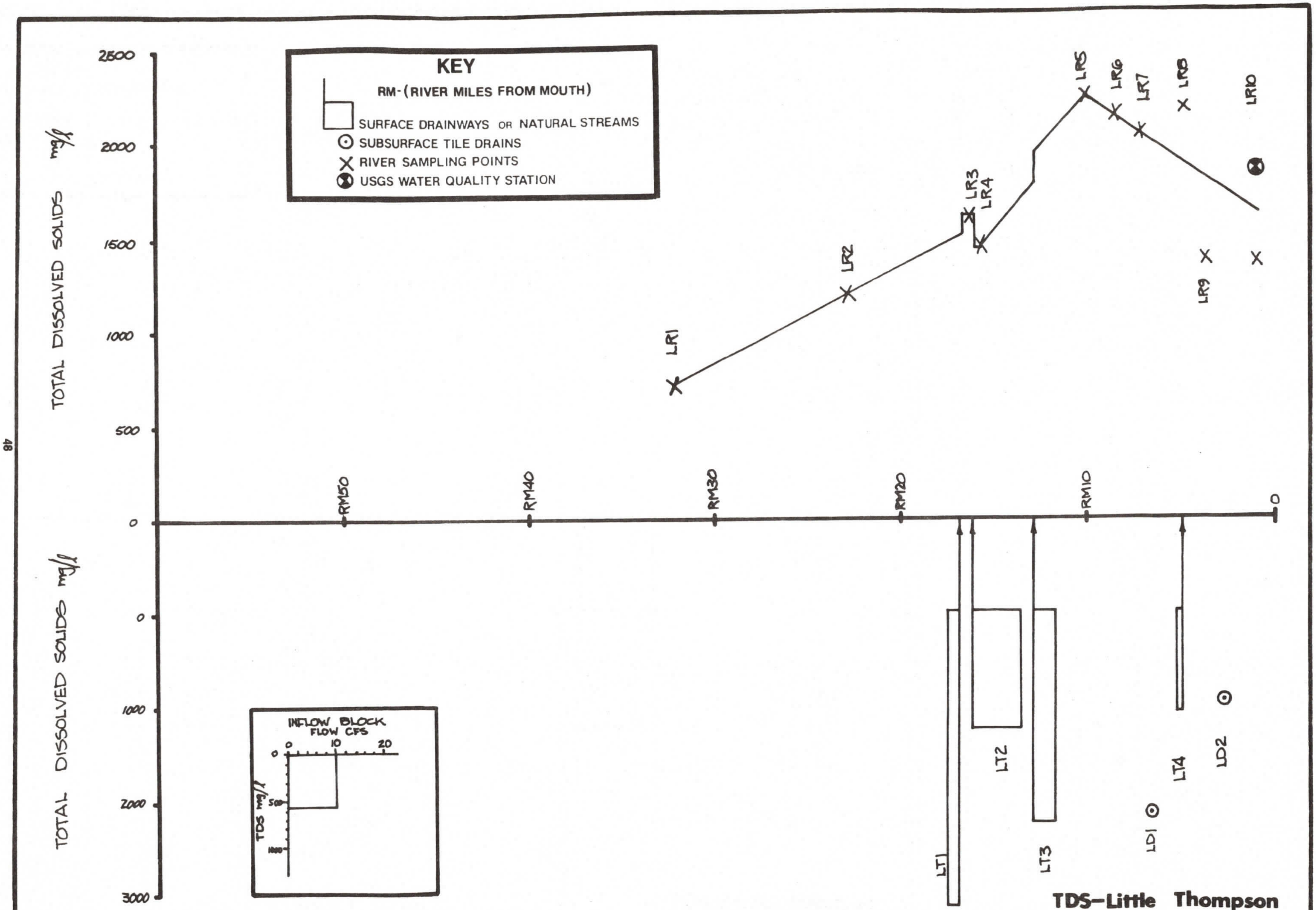
#### 4.4.2.3 Sediment

The Little Thompson River appears to have the most significant sediment problems in the region (see Figure 4.4.2-C). Suspended solids levels increase significantly in the lower reaches of the river, and the Little Thompson has the highest suspended solids levels of all rivers in the region with some samples at the mouth ranging from 150 to 200 mg/l. These levels can be attributed to irrigation of the fine soils noted in the lower Little Thompson basin.

## 4.5 ST. VRAIN CREEK

### 4.5.1 Hydrologic Analysis

St. Vrain Creek flows into Weld County from Boulder County. Nearly all of the major diversions occur in Boulder County. The river has a typical summer flow of 40 to 50 cfs at the Boulder-Weld county line. Seepage returns increase flows from the Boulder-Weld county line to the mouth and summer flows at the mouth are generally around 150 to 180 cfs (see Figure 4.5.1-A).




TDS–Little Thompson

FIG. 4.4.2-A

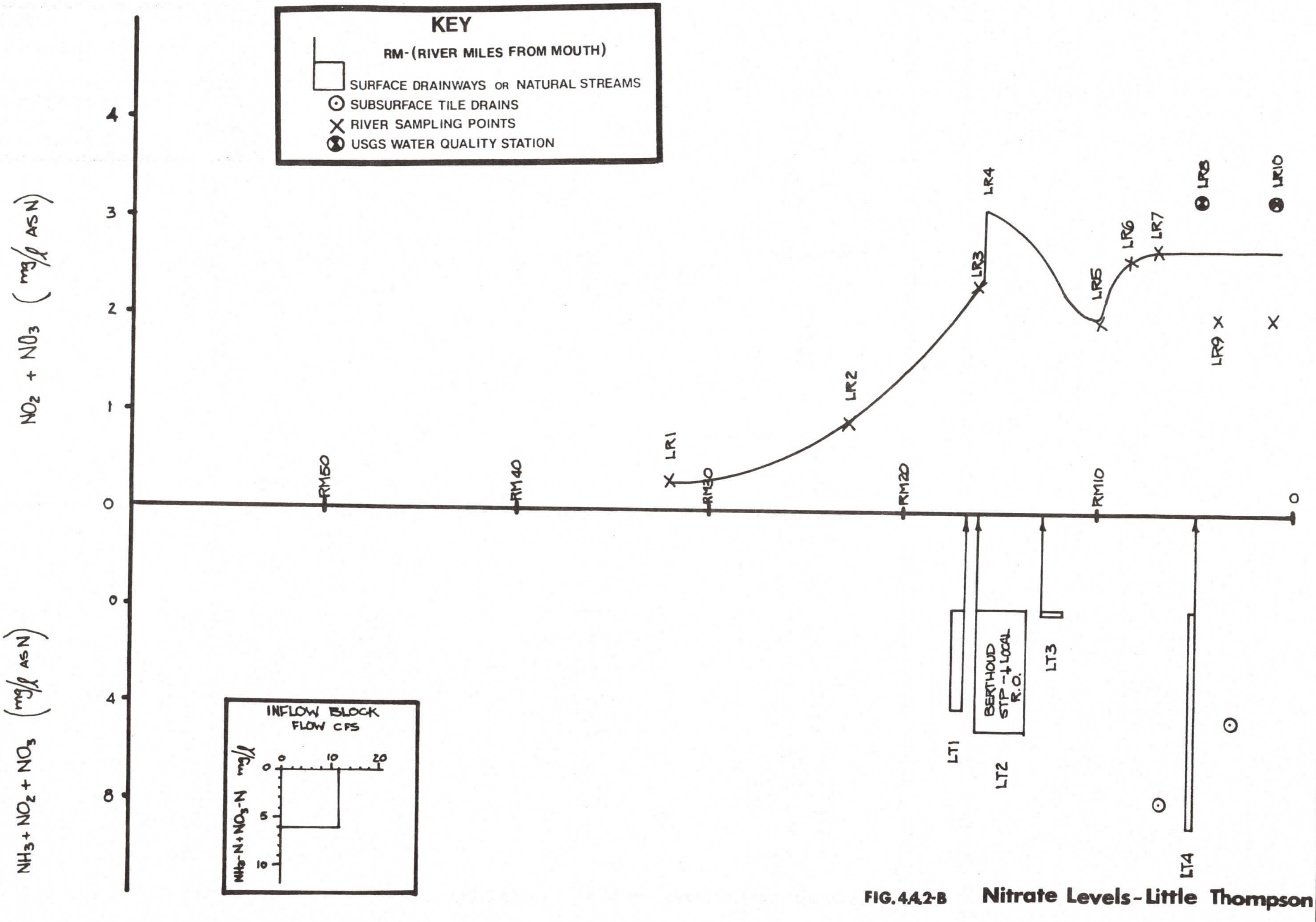



FIG. 4.4.2-B Nitrate Levels - Little Thompson

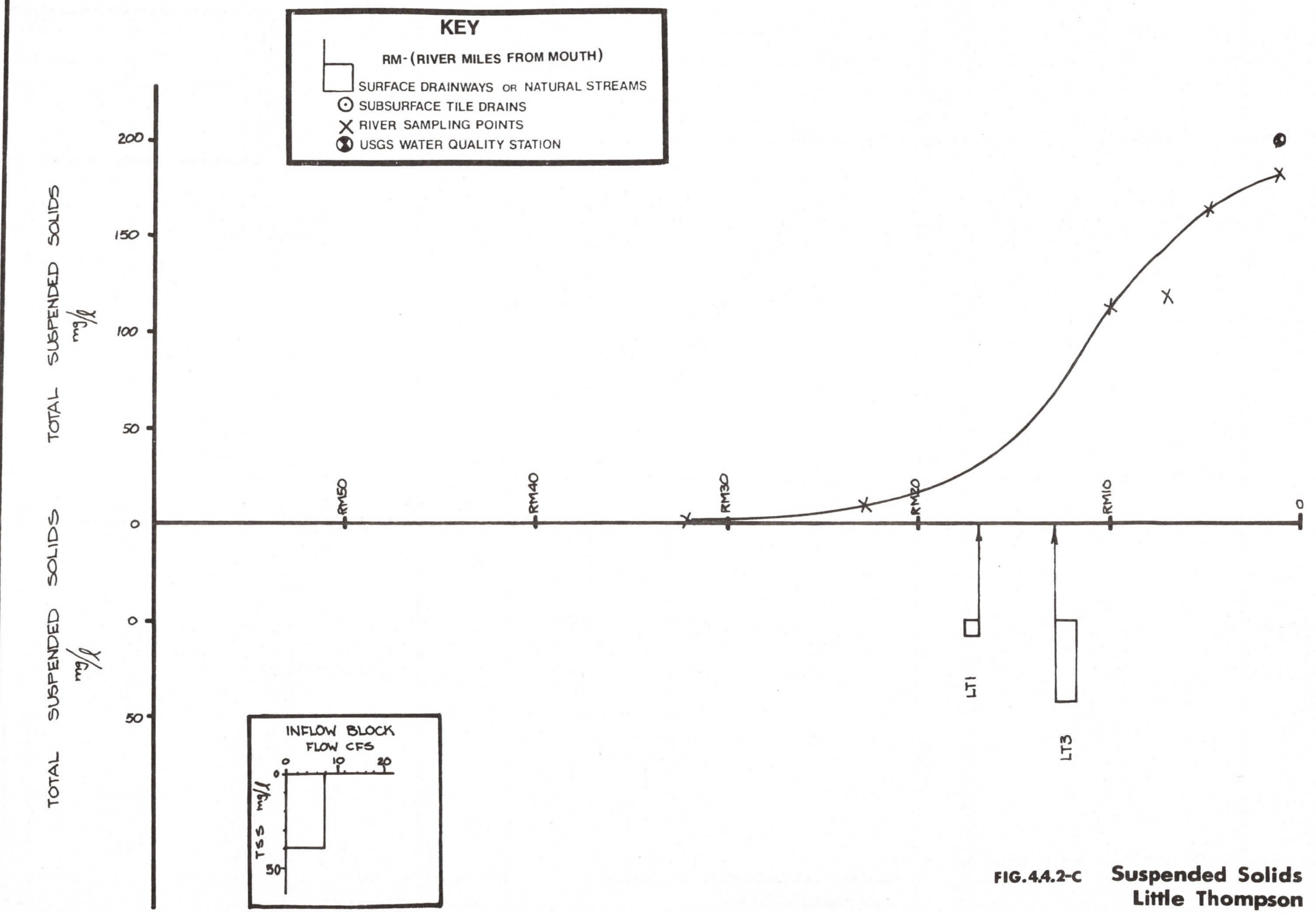



FIG.4.4.2-C **Suspended Solids Little Thompson**

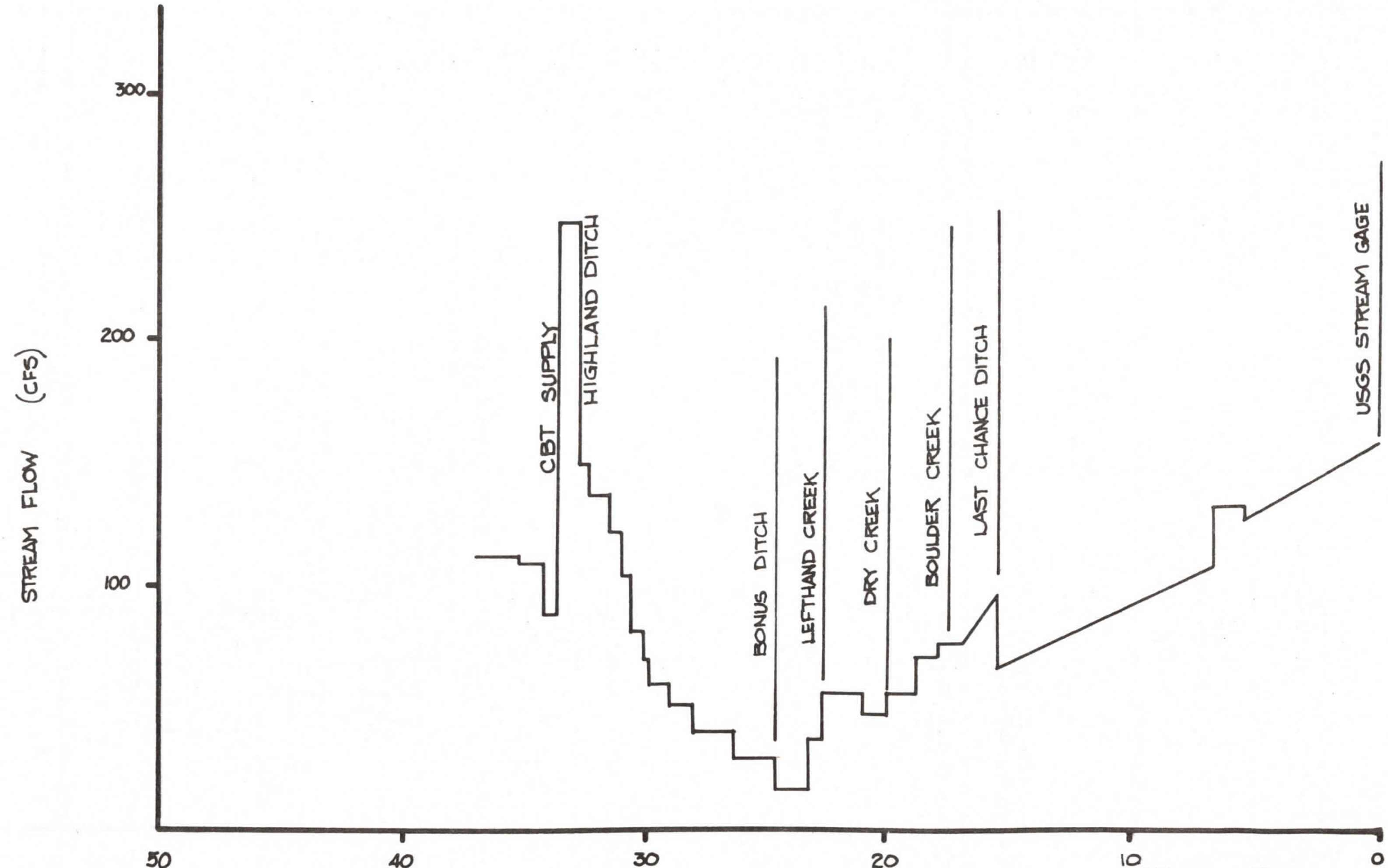



**FIG. 4.5.1-A** **Stream Flow**
**ST. VRAIN CREEK**
8-31-76

4.5.1.1 Sources of Irrigation Return Flow

The major tributaries to the St. Vrain Creek between the Boulder-Weld county line and the mouth contribute approximately 40 cfs. These major tributaries are Dry Creek, Spring Creek, Boulder and Left Hand Creeks. The other tributaries included in the 40 cfs estimate are much smaller than these and contribute less than 1 or 2 cfs each.

Seepage and minor tributary flow are the major sources of return flow to the St. Vrain Creek. A water budget conducted during the 1976 irrigation season indicated approximately 4 cfs per river mile was being gained by St. Vrain Creek in the reaches downstream from Longmont. This accounts for nearly 96 cfs between the Boulder-Weld county line and the mouth of St. Vrain Creek.

Other Weld County dischargers to the St. Vrain Creek are Erie Sanitation District (0.12 mgd), Tri-Area Sanitation District (0.31 mgd), and Public Service Company-Fort St. Vrain (3 mgd). Most of these discharges are fairly small compared to the 96 cfs (62 mgd) contributed by irrigation return flows.

4.5.2 <u>Water Quality Analysis</u>

4.5.2.1 Salinity

Total dissolved solids levels exhibit only a small increase through the Weld County region and generally total dissolved solids levels at the mouth are less than 1200 mg/l (see Figure 4.5.2-A). Despite these relatively low levels in the river, several of the tile drains sampled in the St. Vrain region had extremely high total dissolved solids levels.

4.5.2.2 Nitrates

Nitrate levels in the St. Vrain Creek generally range between 2 and 3 mg/l (see Figure 4.5.2-B).

4.6 SOUTH PLATTE RIVER

4.6.1 <u>Hydrologic Analysis</u>

The hydrology of the South Platte is like other rivers in the region--a result of diversions for irrigation and return flows. The other rivers in the region--St. Vrain Creek, the Big Thompson River, and the Cache la Poudre River, all flow into the South Platte. Water is continually removed for irrigation from the South Platte and return flows continually resupply it (see Figure 4.6.1-A).

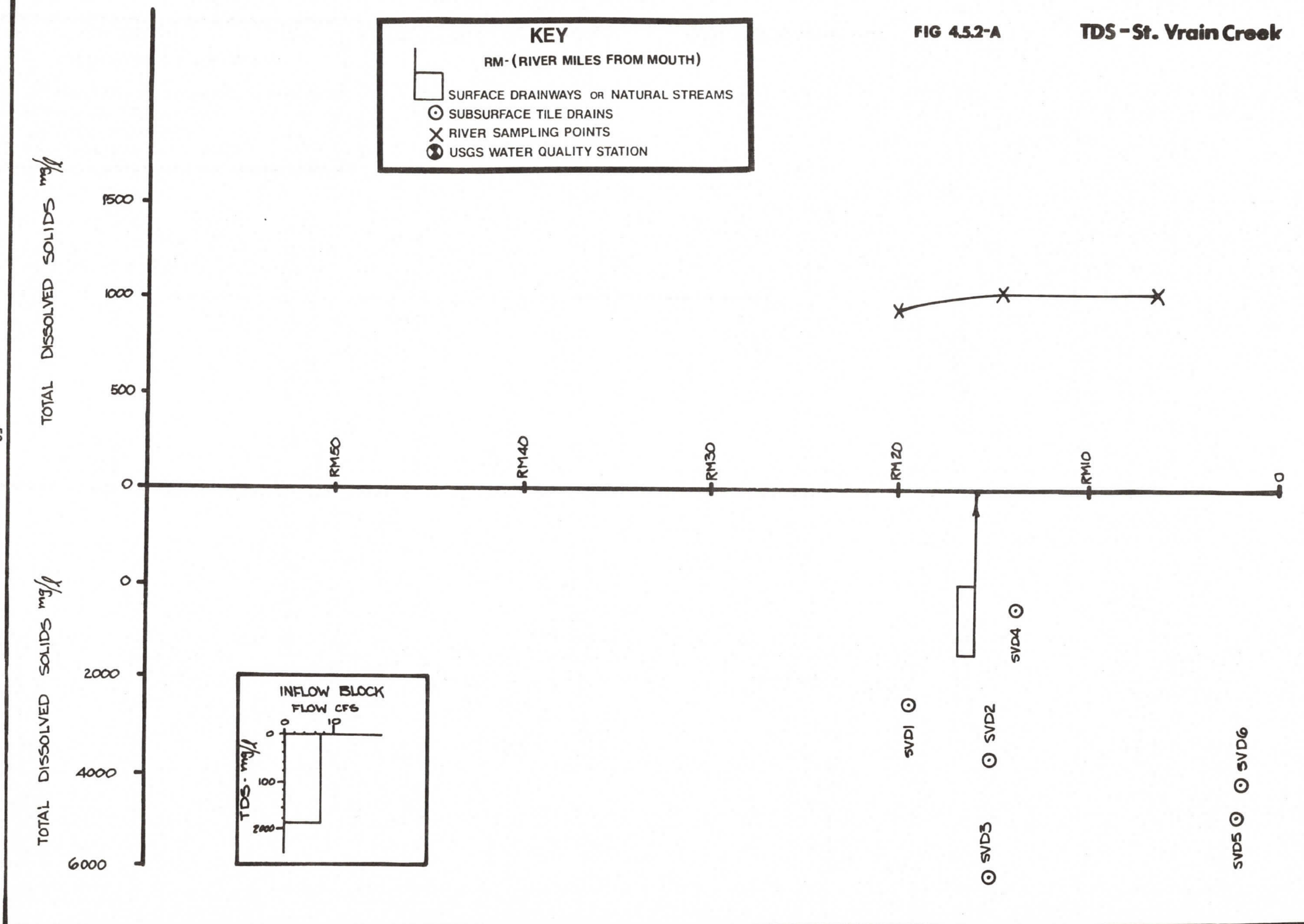
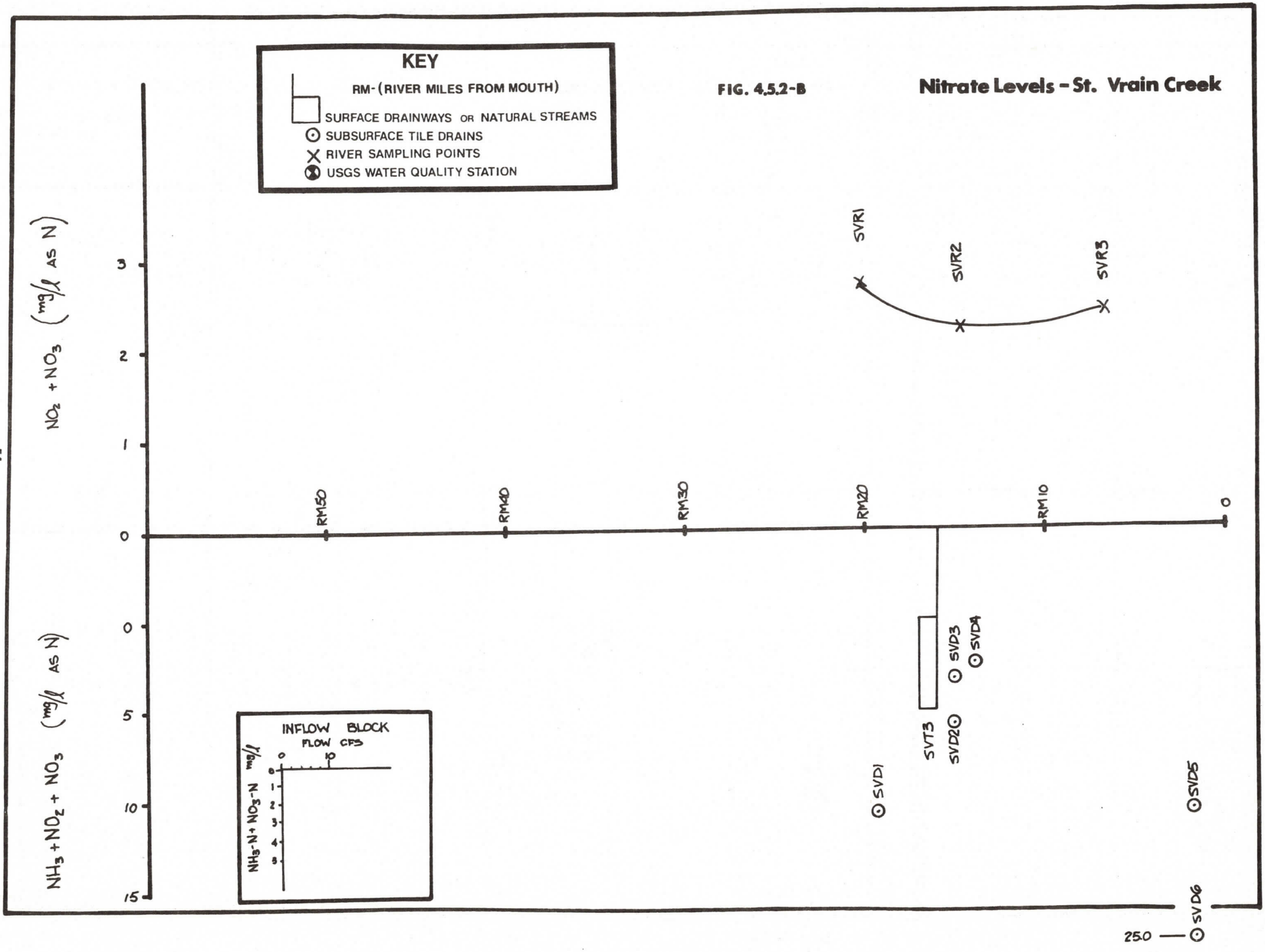



FIG 4.5.2-A TDS - St. Vrain Creek

## Nitrate Levels - St. Vrain Creek

FIG. 4.5.2-B



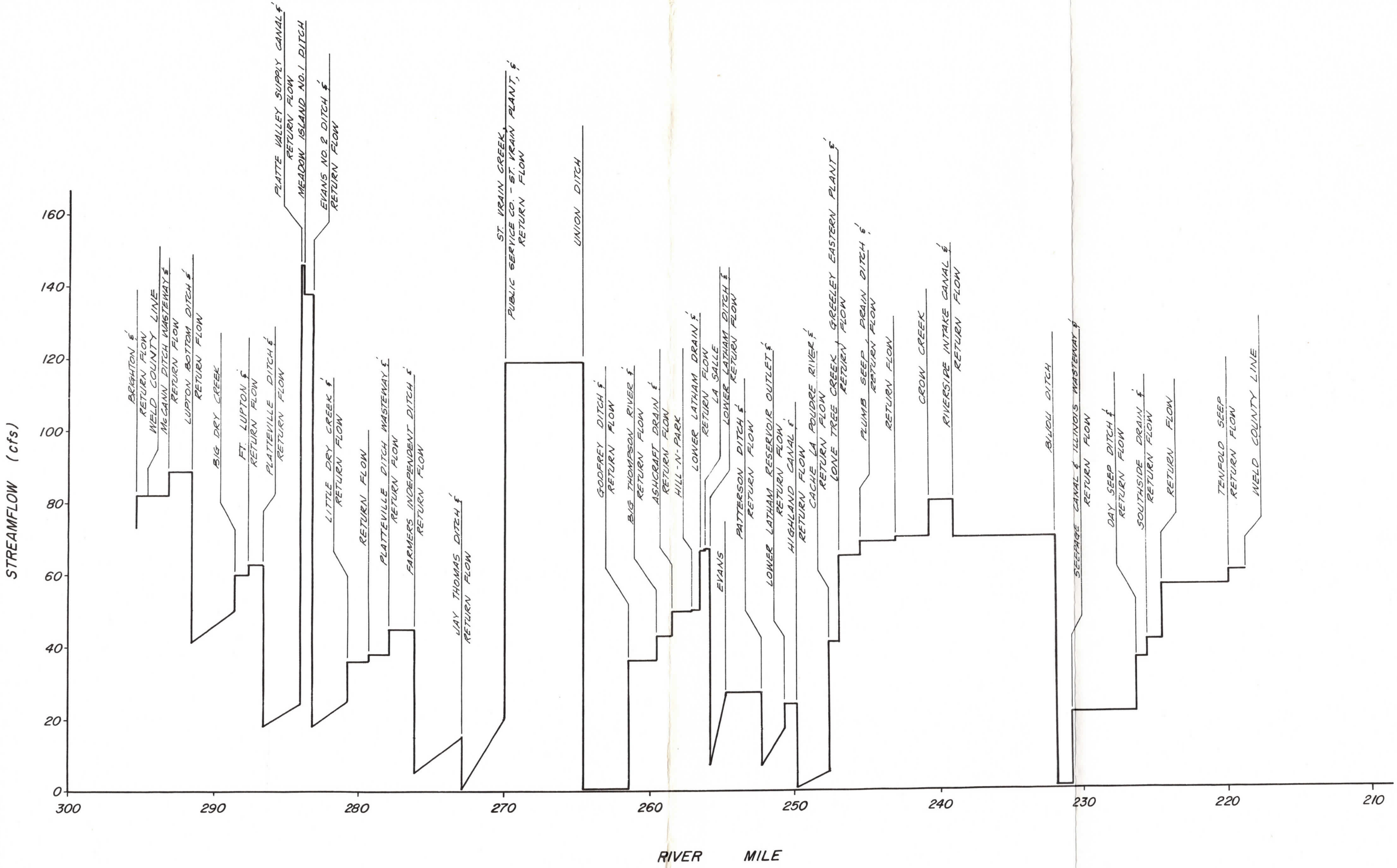



**FIG. 4.6.1-A LOW FLOW CONDITIONS - SOUTH PLATTE RIVER**

#### 4.6.1.1 Sources of Return Flow

All of the excess waters from the region are eventually drained by the South Platte. Each of the other major rivers is tributary to the South Platte. These, plus other significant tributaries contribute over 200 cfs total through the region. In addition, seepage returns are thought to be in excess of 2.5 cfs per mile.

There are only a few small municipalities and industries discharging to the South Platte. A few towns discharge to the river; however, most of these discharges are small compared to the total flow available to the river (Fort Lupton - 0.64 mgd).

### 4.6.2 Water Quality Analysis

#### 4.6.2.1 Salinity

Total dissolved solids levels are in the 600 and 700 mg/l range in southern Weld County. East of Greeley, total dissolved solids levels are typically in the 1200 to 1500 mg/l range. These levels change as a result of inflows from the streams in the Larimer-Weld region (see Figure 4.6.2-A).

#### 4.6.2.2 Nitrates

Nitrate levels appeared to be fairly constant in the range of 3 to 4 mg/l through the Weld County reach of the South Platte River. No significant increase was apparent through the region (see Figure 4.6.2-B).

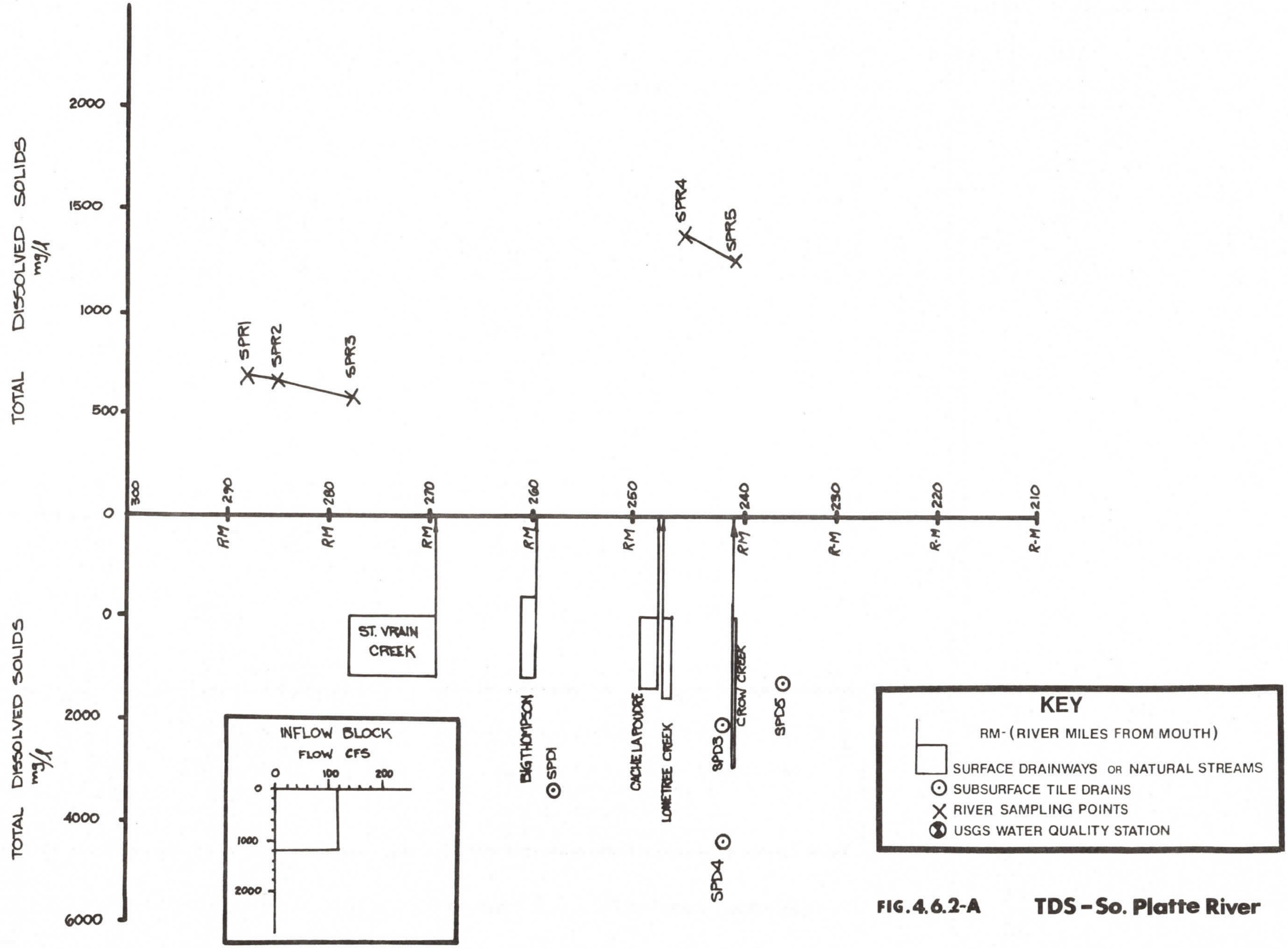



FIG. 4.6.2-A TDS – So. Platte River

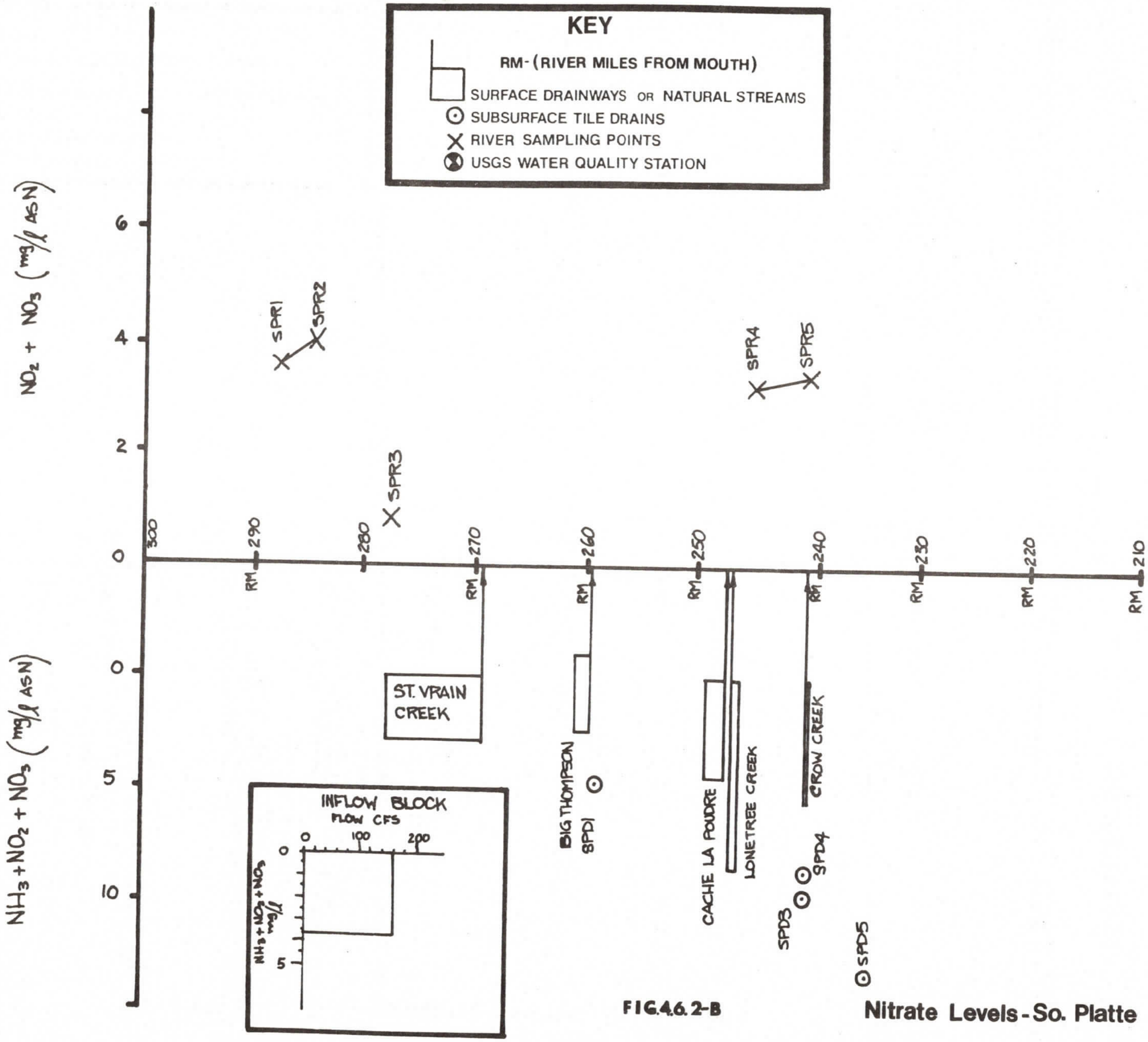



FIG. 4.6.2-B

**Nitrate Levels - So. Platte River**

## 5.0 IRRIGATION RETURN FLOW AND WATER QUALITY STANDARDS

Water quality standards define acceptable levels of chemical constituents in water. "Acceptable level" must be related to the use of water. In accordance with Colorado Water Quality Control Law, the Water Quality Control Commission has defined all waters of the State as either being waters which would be used for recreation or waters able to sustain a fishery. This definition has resulted in the application of legal water quality standards which will enable attainment of the legally defined beneficial uses, i.e., recreation or fishery. Other beneficial uses such as irrigation, stock watering, municipal water supply, industrial water supply, etc., have implied water quality standards. In other words, pollutant levels in water used for these purposes may interfere with the use of water for that purpose. With the exception of the National Primary Drinking Water Standards established by EPA, no legal water quality standards exist for other uses. The "standards" based on beneficial uses are not hard and fast rules which are universally applicable. Many of these standards were developed as the result of experience and vary with local conditions.

In addition to the legally defined and beneficial use standards, certain pollutants may have long term effects and interfere with beneficial uses in the future. An example of this is the possibility for continued buildup of salinity levels in ground water aquifers. The discussion of water quality standards in the context of irrigation return flows is therefore divided into three categories: (1) stream water quality standards defined by the State of Colorado; (2) water quality standards related to beneficial uses; and (3) long term effects of pollutant discharges.

### 5.1 STATE WATER QUALITY STANDARDS

The State of Colorado currently has in-stream standards for settleable solids, floating solids, taste, odor, color, toxic materials, oil and grease, radioactive material, fecal coliform bacteria, turbidity, dissolved oxygen, pH, temperature, fecal streptococcus. Each stream has been classified as a recreational or fishery stream. The parameters for which there are standards are not all directly applicable to irrigation return flows. In fact, "settleable solids" and "turbidity" are the only two constituents which are significant in agricultural return flow. Numerous factors control levels of these two constituents in streams, and information is not available to define the relative impact of irrigation return flows.

The State has not defined a numerical limit for total dissolved solids (salinity). Rather, it has defined the goal of maintaining total dissolved solids levels at existing levels. In essence, this means no substantial increase in total dissolved solids levels in the streams of the state. At this time, no adequate long-term data exists to determine if salinity levels are increasing.

## 5.2 WATER QUALITY IMPACTS AND BENEFICIAL USE

### 5.2.1 Irrigation

Irrigation return flows increase total dissolved solids in all streams of the region. In some cases, levels of dissolved solids in streams exceed recommended limits for various crops. However, the recommended limits are highly dependent on local drainage and soil conditions and irrigation practices. Crop damage due to excess salinity is not believed to be a problem in the Larimer-Weld region or the lower South Platte basin.

Excess sodium in irrigation waters may also cause crop damage. However, waters of the Larimer-Weld region and the South Platte basin do not exhibit a sodium hazard.

### 5.2.2 Stock Watering

While limits for water quality to be used for stock watering have not been precisely quantified, waters of the region are generally suitable. The State of Colorado recommends that stock waters be less than 2500 mg/l TDS. Waters of the South Platte basin are generally below this limit. Certain underground waters may be unsuitable for stock watering as a result of geologic conditions, however.

### 5.2.3 Domestic Use

Several physical (aesthetic), chemical, and bacteriological standards have been established for water intended for domestic use. Irrigation return flows and waters receiving them may possibly be of diminished physical and chemical quality. Physical parameters impairing water quality are turbidity and color. While tailwater contains some turbidity, this can generally be removed by standard water treatment techniques.

Regulations promulgated by EPA place limitations on inorganic chemicals, organic chemicals, turbidity, and microbiological contaminants in drinking water. Of the constituents limited under the Safe Drinking Water Act, nitrate is the only constituent tested for in the analysis of irrigation return flow. EPA limits nitrates to 10 mg/l as nitrogen. Streams in the region are impacted by nitrate discharges from irrigated agriculture. However, levels in the streams have not been found to exceed the 10 mg/l limit established in EPA regulations. Nitrate levels in excess of 10 mg/l have been found in public drinking water supplies in some communities along the South Platte River which are dependent on ground water for supply. Nitrate discharges to ground water basins from application of commercial fertilizer and manure to irrigated lands contribute to the excess nitrate experienced in the ground water basins.

## 5.3 LONG-TERM WATER QUALITY IMPACTS

In many western river basins, long-term increases in salinity levels have been observed. This situation is referred to as an "adverse salt balance" and may result from continued concentration of salts in the water as ground water is used and reused year after year. Another cause is that the inflow of salts into basins or subbasins exceeds the outflow of salts.

In the South Platte basin, inadequate historical data exists to determine if an adverse salt balance exists. Salinity levels are high in the lower South Platte basin and increase substantially between Denver and the Nebraska line in both surface and ground waters. Methods exist which would enable projection of future water quality at the basin level. However, this would require development of hydrologic and salinity budgets at the basin level. Without such an analysis, it is not possible to determine the long-term effects of salinity and nitrate loading in the Larimer-Weld region.

## 6.0 POTENTIAL FOR BEST MANAGEMENT PRACTICES

This document has presented an assessment of water quality impacts of irrigation return flows in the Larimer-Weld region. Several individual, defineable problems have been recognized. This chapter reviews these problems and the potential for solving them with best management practices.

### 6.1 MAJOR POLLUTANT DISCHARGES

Salinity is the major pollutant discharged as a result of irrigation throughout the region, and in nearly all cases excess salinity loading is the result of irrigation of soils overlying shallow shale layers. Return flow leaches salts as it flows horizontally across these shale deposits.

Nitrates discharges were found to be high where heavy manure applications were made year after year. In most cases, applications of commercial fertilizer were made in addition to manure to ensure an adequate supply of nitrogen for high crop yields. The problem appears to be associated with the timing of nitrogen applications vs. crop needs, the fact that some leaching of nitrates is unavoidable where irrigation is practiced, and buildup of nitrogen in the soil resulting from continuous yearly application of manure.

Sediment and phosphorous were found to be lesser problems in the region. While this is not a region-wide problem, the lower Little Thompson basin was found to have problems with sediment discharges. Problems may also exist in scattered areas throughout the region.

Levels of biochemical oxygen demand, ammonia, and fecal coliforms were uniformly low in irrigation return flows. Data on the occurrence of pesticides in streams is extremely limited, and due to the expense involved no pesticide data was collected as part of the 208 program. Some limited data will be collected during 1977.

### 6.2 REDUCTION IN POLLUTANT DISCHARGES

Experience gained as a result of developing the agricultural source analysis and other projects indicates that there is a potential for reducing the discharge of pollutants--salinity, nitrates and sediment--in the Larimer-Weld region.

The salinity problem associated with shallow shale deposits is the result of seepage of irrigation water below the root zone and the flow of that water across the shale deposits. It would appear that reduction of the amount of water flowing across the shale deposits will reduce the total amount of salts discharged in the region. This reduction in the amount of water flowing across the shale deposits could be accomplished by a number of methods, including canal lining, irrigation scheduling, and other measures which have long been practiced as soil and water conservation measures.

Excessive discharges of nitrates are the result of over-application of manure and commercial fertilizers in excess of crop requirements. Improved fertilizer management could reduce nitrate discharges to streams in the region.

Significant direct discharges of sediment as a result of irrigation occur only in limited areas within the region. However, it is probable that better management of irrigation tailwater would reduce the quantity of sediment discharged to streams.

## 6.3 BENEFITS AND COSTS OF BEST MANAGEMENT PRACTICES

The agricultural source analysis conducted as part of the Larimer-Weld 208 Program did not include a benefit/cost analysis for best management practices; however, some general statements can be made.

Best management practices have been defined as follows:

> "The term best management practices (BMP) means a practice or combination of practices that is determined by the state (designated areawide planning agency) after problem assessment, examination of alternative practices, and appropriate public participation, to be the most effective, practicable, (including technological, economic, and institutional considerations) means of preventing or reducing the amount of pollution generated by non-point sources to a level compatible with water quality goals."

The implications of this definition are significant. Best management practices which could be applied to reduce pollutant discharges include many practices which have long been applied with the objective of soil and water conservation, i.e., canal lining, irrigation scheduling, tailwater recovery systems, etc. Only in the last several years have these management practices been analyzed in the context of reducing the discharge of pollutants to the nation's waterways.

In the Larimer-Weld region, the application of best management practices could reduce the discharge of salinity, nitrates, and sediment to the rivers of the region. If adequate data were available, the benefits could be quantified in terms of lower concentrations of salts, nitrates and sediment.

At this time it does not appear that the discharge of pollutants from irrigated agriculture are the dominant cause inhibiting legally specified beneficial uses of the streams in the region, i.e., recreation and fisheries. Other factors such as the man-made hydrology of the streams in the region appear to be the controlling factors limiting these beneficial uses.

In the Larimer-Weld region, the dominant historical use of water has been for the purpose of irrigation. Irrigation discharges do not appear to have impaired this use. The impairment of groundwater supplies for municipal use due to excess salinity and nitrates is related to discharge of these pollutants as a result of irrigation. The problems associated with ground water quality in the region have developed over a long period of time. The benefits of implementing best management practices for the purpose of ground water improvements would not be realized for an equally long period of time or perhaps longer.

The greatest unknown associated with the discharge of pollutants from irrigated agriculture is the long-term effects of these discharges on surface and ground water supplies. If discharges of salinity as a result of irrigation are causing a continued buildup of salts in groundwater basins, water use for irrigation itself could be impaired at some point in the future. Historical data is inadequate to determine if this is occurring. While methods exist to develop projections of salinity in the future, these methods have not been applied in the South Platte basin. As a result, the long-term benefits of salinity control in the basin cannot be evaluated. This is unfortunate because this one factor alone could determine the economic feasibility of applying best management practices to irrigated agriculture.

Although some BMP's may result in offsetting benefits such as water conservation, reduced fertilizer costs, and possibly increased crop yields, it must be recognized that no best management practices are free. Implementation of even the simpliest best management practice--better on-farm water management--would require that additional labor costs be absorbed by individual irrigators.

Other best management practices--canal lining, sprinkler systems, tailwater recovery systems--will require capital investments, and may increase operating costs. Irrigation scheduling, i.e., scientific water management, will require technical assistance to be provided to individual irrigators. This assistance will require expenditures for technicians, the sampling of soils and waters, and computer systems.

In summary, the information developed as part of the 208 program indicates that reasonable water quality benefits can be achieved through implementation of best management practices. The benefits could accrue to existing and future water users. Inadequate information exists to project the magnitude of the benefits, or the cost of implementing best management practices.

## 6.4 THE BEST MANAGEMENT PRACTICES ANALYSIS

The Environmental Protection Agency has provided a research and development grant to the Larimer-Weld Regional Council of Governments for the purpose of defining institutional, financial, and technical feasibility of implementing best management practices in the Larimer-Weld region. From a technical standpoint, best management practices analysis will involve detailed data collection on individual farms in areas exhibiting excess discharge of salinity, nitrate, and sediment. The data collection effort and subsequent analysis of the data will specifically define the causes of pollutant discharges and the relationship of those discharges to the factors contributing to the discharges, i.e., applied water quality, topography, soils, irrigation practices, land management practices, irrigation methods, etc. Once these specific causes and relationships are defined, the effectiveness of best management practices in controlling or reducing the discharge of pollutants will be identified.

The best management practices analysis will provide information on the costs of pollution control measures for irrigated agriculture and the potential benefits of these measures in terms of reduction of pollutant discharge. The best management practices analysis is being conducted during the 1977 irrigation season.