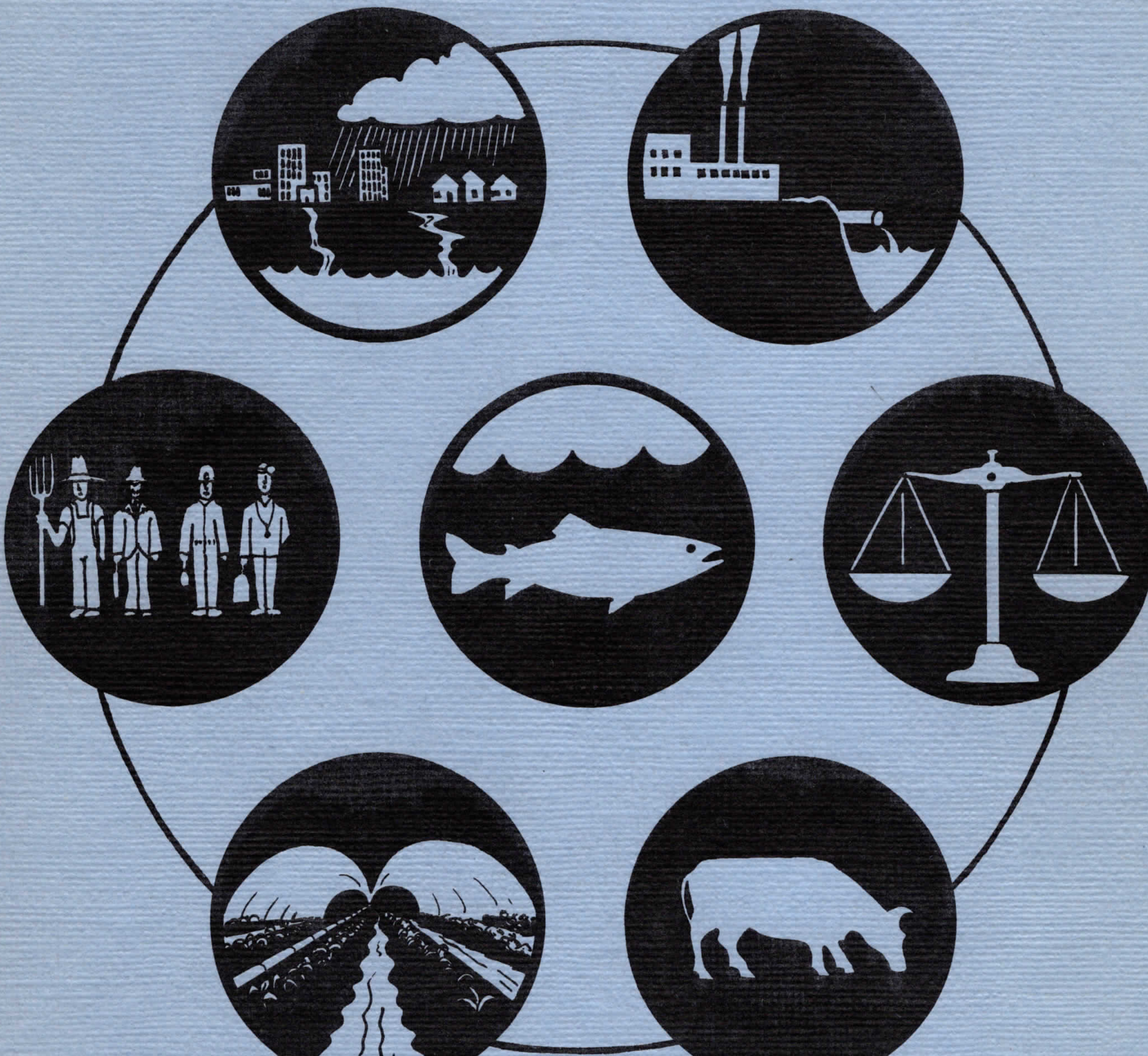
INTERIM REPORT ENGINEERING

CONCENTRATED ANIMAL FEEDING OPERATIONS

WASTE MANAGEMENT & RESOURCE RECOVERY



Water Quality Management Plan

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS
LOVELAND, COLORADO

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PREPARED BY TOUPS CORPORATION
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Larimer-Weld Regional Council of Governments

208 AREAWIDE WATER QUALITY MANAGEMENT PLAN

CONCENTRATED FEEDING OPERATIONS: WASTE MANAGEMENT AND RESOURCE RECOVERY

Prepared For

Larimer-Weld Regional
Council of Governments

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ABSTRACT

FEEDLOT EVALUATION FOR THE LARIMER-WELD REGION

Distribution and water quality impacts of confined livestock feeding activities in the Larimer-Weld region were investigated during the period December, 1976, to April, 1977. The primary objective of the study was to assess the nature and extent of water quality problems associated with operation and management of feedlots. The analysis included an evaluation of regional manure disposal practice and its relationship to water quality.

The feedlot investigation relied on basic data obtained from individuals and private concerns directly associated with the livestock feeding industry, and from local, state and Federal agencies.

The on-going program implemented by the State Department of Health has been extremely effective in curtailing wastewater/runoff discharges from confined feeding operations. Present impact of feedlots on surface water quality is considered to be insignificant in the two-county region. The state program evaluates pollution potential of feeders on an individual basis. Recommendations for best management practice control measures are site specific.

Groundwater degradation resulting from percolation of wastes from pen areas of continuously used feedlots is generally negligible. This relates to the presence of a relatively impermeable layer that forms at the manure-soil interface. Wastes leached to groundwater from abandoned or intermittently used feedlots pose a threat to water quality in localized areas.

Manure disposal rates presently employed in the region appear to be generally acceptable from the standpoint of maintaining integrity of underlying groundwater. However, long-term manure loading implemented on some fields is conducive to groundwater quality degradation. Localized problems are also created when the nutrient value of manure is excessively supplemented with commercial fertilizers. Annual analyses of agricultural soils are needed to determine optimum manure loading rates. Technical on-farm assistance on a one-to-one basis is needed to ensure that the resource value of manure is realized with no deleterious impact to water quality.

Depending on profitability of the livestock feeding industry, 835,000 to 950,000 fattened cattle are marketed annually in the Larimer-Weld region. Approximately 415,000 to 475,000 are on feed at any given time. More than 345,000 cattle, about 80 percent of the total supported, are known to reside on feedlots equipped with conventional wastewater/runoff control facilities approved by the State Department of Health.

Nearly 100 conventional control systems, representing a combined investment of over one million dollars, have been installed on confined livestock feeding operations in the two-county area since 1970. Beef feeders are responsible for 80 percent of the expenditure. The remaining 20 percent was spent by dairy, hog, and lamb operators. Per head costs for control facilities incurred by feeders are typically much lower than those reported by the National Commission on Water Quality for other areas of the country.

Over 30,000 head reside on feedlots determined by the Department of Health to pose no threat of waste runoff to receiving water because of hydrologic isolation. When the prevailing cattle market provides a good return on investment, an additional 100,000 cattle per year very likely are fattened on feedlots not known to be served by wastewater/runoff attenuation measures. A significant portion of these feedlots do not impact surface water quality by reason of topography, physical soil characteristics, or geographic remoteness from the regional hydrologic regime.

It is concluded that feedlot operation and manure disposal as practiced in Larimer and Weld Counties generally maintain regional water quality. Problems, when they exist, are localized in nature. Guidance should be provided area farmers to guarantee manures and commercial fertilizers are utilized at rates comensurate with water quality and crop requirements. Feeders should be assisted in implementing appropriate lot management principles.

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

1.0 EXECUTIVE SUMMARY

1.1 INTRODUCTION

The 208 Areawide Waste Management Plan sponsored by the Larimer-Weld Regional Council of Governments incorporates an evaluation of feedlot characteristics and impact on water quality as an integral component of the planning program. Reasons for this emphasis include:

1. The livestock industry in the two-county area is extremely large. Confined animal feeding operations represent a major sector of the agricultural economy, accounting for 80 percent of the agricultural wealth produced annually.
2. In Larimer and Weld Counties, the number of fattened cattle marketed each year exceeds the human population of the region by a factor of four.
3. The nature and magnitude of wastes associated with livestock on feed possess a tremendous potential for water quality degradation. Wastes generated per head per day are 6 times more potent in terms of biological oxygen demand than daily per capita contributions of domestic wastes. Potential for salinity and nutrient impairment of water is extreme.
4. Because cattle on feed are almost invariably supported on uncovered confinement facilities, wastes may be subject to transportation in overland runoff to surface waters of the region.
5. Manure generated by livestock represents a solid waste disposal problem of major significance.
6. Characteristics of livestock wastes are such that if not subject to proper control and management, they may degrade both the surface and groundwater regimes of the region.

The intent of the feedlot element of the 208 planning program was to determine characteristics of feeders in the region and evaluate water quality impacts attributable to feedlot operation and management. Manure disposal practice was also investigated.

Individuals and agencies associated with the livestock industry provided basic data used in the feedlot evaluation. Information on the identity and location of feeders was moderately complete. Data was generally deficient for smaller feeding operations. A major effort was expended in cataloging and inventorying available data compiled by the State Department of Health.

Agricultural researchers in the region directed Toups Corporation to pertinent literature and local studies oriented toward identifying water quality impacts of feedlot operation and manure application to land. These sources yielded much of the data from which conclusions of the feedlot evaluation were derived.

The format initially envisioned for the feedlot analysis segment of the agricultural portion of the 208 planning program anticipated that a major effort would be expended to locate, identify, and classify feedlots within Larimer and Weld Counties. In addition, feeders requiring permits and feeders impacting surface water quality would be identified. As the analysis of area feedlots progressed, a number of factors became apparent which altered the format of the investigation as originally anticipated. These specifically include:

- The on-going State Department of Health program to identify and characterize feedlots in the two-county area has been extremely thorough. The program has successfully identified feedlots responsible for the bulk of beef production in Larimer and Weld Counties.
- The number of active feeders fluctuates according to economics of the cattle and grain markets. The merit of obtaining a precise count of feedlots under present conditions is questionable, especially when relatively current data which define the magnitude of feeding operations have already been generated by local and state agencies.

- Feeding operations with a significant potential to impact water quality have been contacted by the State Department of Health. A major portion have already installed conventional wastewater/runoff systems; the remainder have been directed to do so.

1.2 SUMMARY AND CONCLUSIONS

1.2.1 Distribution and Size of Feedlots

Statistical data indicates that between 835,000 and 950,000 fattened cattle are marketed in the Larimer-Weld region in any given year. The exact number fluctuates according to profitability of the livestock feeding industry. Feeders normally produce an average of about two pens of cattle each year.

Data obtained from Colorado Department of Health files provided a basis for determining the average ratio of cattle feedlot inventory versus feedlot capacity for the two-county area. On an annual average basis, 70 percent of total capacity will be utilized for actual livestock production.

Density of cattle on feed in Larimer and Weld Counties ranges from less than 100 to over 300 animals per acre of feedlot. Typical concentrations are in the 100 to 200 head range, with an average density of about 150 head per acre considered representative of confined feeding operations in the region.

Numbers of active feedlots in the two-county area vary according to economic condition of the cattle feeding industry. It is estimated that approximately 1,250 feedlots exist with capacities greater than 20 head. Major operations supporting more than 300 head number about 200.

More than 345,000 cattle, nearly 80 percent of the total number of cattle on feed in the two-county area, are known to be supported on feedlots equipped with conventional wastewater/runoff control facilities. Total feedlot area served by these controls is on the order of 2,200 acres.

Over 30,000 head reside on feedlots determined by the State Department of Health to pose no threat of waste runoff to receiving water because of mitigating factors of soil type, terrain, or hydrologic isolation. These cattle are supported on about 200 feedlot acres. The total number of cattle fattened in the region on facilities provided with natural or conventional control measures represents approximately 85 percent of the total volume produced annually. Of the remaining cattle fattened on feedlots not presently known to be provided with control measures, more than 70,000 are fed on feedlots already identified by the State Department of Health. Feedlot acreage supporting these 70,000 head is on the order of 470 acres.

Feedlots which the State Department of Health has currently located and identified possess combined cattle inventories of approximately 450,000 head at any given time. Annual production from these facilities is about 900,000 head. When cattle prices are good, an additional 50,000 cattle per year very likely would be fattened on feedlots presently unidentified in Larimer and Weld Counties. This rate of production corresponds to an average feedlot inventory of 25,000, requiring about 170 feedlot acres. It is estimated that over 1,000 of these unidentified feedlots exist. Almost all operations are considered to be smaller than 300 head, a feature that would remove them from the permit program unless they were determined on a site-by-site basis to be impacting water quality.

1.2.2 Manure Handling and Disposal Methods

Manure generated by livestock supported on confined feeding operations represents an important aspect of agricultural solid waste management. Local disposal practice usually involves application of manure to cropland, a policy that recognizes the resource value of the waste. In addition to the fertilizer benefit to crops and soil provided by its nitrogen, potassium and phosphorous content, manure contributes other elements necessary for plant growth. Among these are included sulfur and micro-nutrients. The presence of organic matter contributed by manure is effective in improving physical and chemical properties of soil. A positive influence is exerted on water infiltration rates, water holding capacity, and ease of tillage. Manure also has a beneficial acidifying impact on soil.

Manure removal from feedlots in the two-county area is usually accomplished by any of three methods: it may be sold to area farmers, spread on fields owned by feedlot operators, or distributed to farmers according to barter arrangements. In the latter arrangement, feedlot operators purchase forage from local farmers with the agreement that the grower remove equivalent quantities of manure from the feedlot.

The micro-nutrient components of manure are considered to have monetary value equal to the cost of these amendments purchased in the form of commercial fertilizers. It was determined that a ton of fresh manure is worth approximately $7.50. This estimate considers an allowance of 50¢ for the micro-nutrient content and soil conditioning properties of manure. Based on current charges for commercial manure hauling and spreading services in the region, manure can economically be transported and applied up to a maximum of approximately 35 miles from its source. In the two-county area, however, most manure is stockpiled prior to use. Nutrient losses in storage may range to over 50 percent. Economic value and associated effective haul distance is decreased accordingly.

1.2.3 Water Quality Impacts/Impact of Regulatory Measures

1.2.3.1 Direct Feedlot Runoff

Direct discharges of wastes and runoff from feedlots have been mitigated to the extent that confined livestock feeding operations in Larimer and Weld Counties presently exert only a relatively minor impact on regional surface water quality. The majority of feeders with a significant potential of degrading quality of surface waters have implemented control measures; most of the remainder have been contacted by the State Department of Health and directed to do so. To date, conventional control facilities installed in accordance with the agency's design criteria total nearly 100. A total of 52 control systems were inventoried on cattle feedlots. Dairies served by control facilities number 27. A total of 17 other systems have been installed on lamb, hog, and goat feeding operations.

In terms of January 1977 prices, the livestock feeding industry in Larimer and Weld Counties has invested more than one million dollars toward wastewater/runoff control systems. Nearly 80 percent of the expenditure is attributable to beef feeding operations. Almost all of the control measure costs have been incurred since 1970, a period during which the livestock industry encountered a severe economic depression.

In the Larimer-Weld region, investment costs for wastewater/runoff control facilities installed on cattle feedlots are typically much lower than those reported by the National Commission on Water Quality for other areas of the country. This can largely be attributed to the relatively dry climate of northeastern Colorado. Initial costs borne by individual feeders vary according to sophistication of required facilities, feedlot slope, adjacent topography, local hydrologic influences, and amenability of the lot to accommodate control structures. However, economy of scale is generally realized. One time installation costs are almost always less than $5.00 per head of feedlot capacity. Most costs are in the $3.50 to $1.00/$2.00 range, with the lower costs being representative of many feedlots with capacities in excess of about 2,000 head.

Per head costs of installing control measures on dairies are usually much more expensive than those associated with beef feedlots. This typically relates to the sophistication of required facilities and the comparatively smaller capacity of dairy operations in the region. Cost per head of capacity in terms of waste equivalent to beef cattle ranges from $20.00 to over $40.00 for operations generally less than 200 cows. Larger sized dairies almost invariably incur costs less than $25.00 per head equivalent. Economy of scale is usually evident. Dairy farms larger than 200 head normally invest from $18.00 to $7.00 per head equivalent. (Waste generated by 700 dairy cows is approximately equal to that of 1,000 beef cattle on feed).

It has been determined that 0.4 to 0.5 inches of rainfall are generally necessary to initiate runoff from earthen base feedlots in the two-county area. On an average basis, 9 storms can be expected to exceed 0.4 inches in the region each year. Total feedlot runoff attributable to average annual occurrence of precipitation is on the order of 1.5 acre-inches per feedlot acre. A third of this runoff is initiated by one storm event of approximately 1.24 inches anticipated each year. State Department of Health criteria for the design of control facilities is oriented toward attenuation of intense 24-hour precipitation events of 10- and 25-year recurrence intervals. Runoff from feedlots in the Greeley area generated by these storms will be approximately 1.7 and 2.07 acre-inches per feedlot acre, respectively.

1.2.3.2 Percolation of Corral Wastes

Groundwater degradation resulting from continuously used feedlots in the region is not considered to be a significant problem. Maintenance and management of feedlot pens or corrals exerts an overriding influence on minimizing impairment of local groundwater. If left undisturbed, the anaerobic zone at the manure-soil interface that develops on a continuously used feedlot forms a relatively impermeable layer that inhibits nutrient infiltration to groundwater. It is important that the integrity of the manure seal be maintained.

Wastes leached to groundwater from improperly managed, abandoned, or intermittently used pens and corrals pose a threat to water quality in localized areas of the region. This relates to the fact that operating conditions are not conducive to formation of a manure seal. It is recommended that accumulated manures in abandoned or intermittently used corrals be scarified down to the existing soil surface, collected, and disposed to agricultural fields. Such corrective action should be appropriately implemented by individual feeders on a voluntary basis. The Soil Conservation Service and the CSU Agricultural Extension Service could diseminate pertinent information to owners of abandoned or intermittently used corrals through local news media. Technical direction should be provided as necessary by the above-mentioned agencies.

1.2.3.3 Manure Application to Land

Salt and nitrogen in manure are constituents which possess the greatest potential for degrading water quality. Deleterious impacts result when such substances are leached to underlying groundwaters. The biological oxygen demand associated with cropland manures is not considered to be a water quality problem in the Larimer-Weld area. Topography, climate, irrigation practice, and manure management techniques in the region are not conducive to runoff transport of oxygen demanding materials from fields to surface waters.

The rates at which manure should be applied to satisfy nutrient requirements of crops, maintain long-term agricultural productivity, and ensure quality of underlying groundwater is a subject of extreme complexity. The topic has been investigated by a number of researchers. Findings and conclusions are by nature site-specific. However, a number of generalized observations appear to be valid for manure disposal in the Larimer-Weld region. Highlights of pertinent investigations are summarized herein.

Optimum land applications of manure for crop utilization are largely dependent on individual on-farm characteristics. The amount applied and method of spreading is a function of the following factors:

- Physical and chemical characteristics of the applied manure;
- Physical and chemical characteristics of the soil;
- Type of crop.

It is highly recommended that individuals responsible for manure management sample agricultural soils and manures annually to determine the nature of their own particular situation. Manure application rates can be prescribed accordingly. This is especially important on farms where manure is routinely spread. Much of the nitrate benefit of manure is released as the waste decays in years succeeding initial application. It is desirable in any given year to evaluate total quantity of nitrates made available to cropland soils by the presence of newly applied and residual manures. Annual soil sampling also provides a means of assessing salt buildup in the soil profile. Salt content of applied manure and irrigation water may govern manure loading rates to agricultural soils in some instances.

Research conducted in the region has demonstrated that annual manure application rates of 25 to 50 tons per acre on a wet weight basis as removed from a feedlot allow for nearly optimum forage yields with a minimum of nitrate-nitrogen degradation of underlying soils. Because of residual manure nutrient value, this loading rate should be reduced on fields subject to a long history of manure application.

Annual rates in excess of 50 tons per acre may cause reduced plant populations due to increased soil salinity, increased nitrate accumulation in the subsoil, and reduced forage production with less efficient use of applied nitrogen. It should be emphasized that the foregoing criteria are generalized guidelines. Actual manure spreading practice should be formulated on a site-by-site basis.

Manure application rates needed to ensure specific poundage of available nitrogen per acre have been developed at Kansas State University. Data is generally applicable to conditions in the Larimer-Weld region. Annual recommended loading is always decreased in years subsequent to initial application in consideration of the cumulative benefits of residual manures.

Manure disposal practice presently implemented in the region generally appears to be acceptable from the standpoint of maintaining the integrity of underlying groundwater. Loading rates to fields owned by feedlot operators was determined to range from less than 5 to slightly over 30 tons per acre. Cumulative availability of nitrates in cropland subject to a long history of manure loading can lead to groundwater quality impairment if annual rates are excessive. Potential for degradation resulting exclusively from manure loading does not appear to be significant on many of the lands managed by feedlot operators. Some fields are overloaded, however, on a long-term basis. Application rates employed by area farmers were not evaluated due to lack of data. Localized problems could exist on any field where the nutrient value of manure is excessively supplemented with commercial fertilizers. Manure and fertilizer application practices in the region require additional investigation to determine water quality impacts. This is especially critical in areas of concentrated animal feeding. Inventory of manure and fertilizer loading rates should be conducted in association with a comprehensive water sampling program oriented toward identifying total dissolved solids and nitrate levels in groundwater.

2.0 INTRODUCTION TO FEEDLOT OPERATIONS IN THE REGION

Over the past several decades, animal production has undergone a transition from grazing on range or cropland to concentrated livestock confinement in buildings or feedlots. This evolution is attributable in great part to increased profitability resulting from concentrated operations. In addition, the increased appetite of Americans for meat, now estimated to be 120 pounds per capita annually for beef alone, has stimulated an industry geared toward satisfying the demand, both quantitatively and qualitatively. Supporting cattle and other livestock in confined feeding operations produces an environment conducive to maximum daily weight gain. Palatability of meat from finished animals can also be optimized by ration management.

Feeders in the Larimer-Weld region normally produce from two to two and one-half pens of cattle each year. Initial and final weight characteristics of livestock on feed depend upon market economics prevailing at any given time.

Several feedlot operators were contacted to determine the typical size of livestock put on feed. Farr Feeders indicated that initial weights of steers and heifers supported in their confined feeding facilities were on the order of 700-800 and 600-700 pounds, respectively. [Farr, 1977]. Steers are commonly slaughtered at 1,100 pounds. Weight of heifers when slaughtered is about 950 pounds. A fattening period of 125 to 130 days is typical. Monfort of Colorado indicated that steers on feed are brought in at from 750 to 850 pounds. After a feeding period of 120 to 140 days, finished weights on the order of 1,150 to 1,250 pounds are realized (Monfort, 1977).

2.1 CLIMATIC CONDITIONS

The climate of northern Colorado plays a major role in the production of beef cattle. A combination of environmental factors exist which greatly enhance the suitability of cattle to be fattened in confined feeding operations. The near ideal conditions include low humidity, cool summer nights, relatively mild winters, low rainfall, sunny days, clean air, and generally good quality water.

Precipitation amounts in the central Weld County area averages only about 12 inches per year. Feedlots seldom get bogged down with mud conditions. Sunny days with a mean average annual temperature approaching 50 degrees produces quick drying conditions during occasional wet periods of time which normally occur during spring months.

Dust conditions in confined feeding operations within the two-county region can be a problem. Most larger feedlot operations now control dust by sprinkler irrigation systems or by large water trucks. Both methods are effective. Most of the smaller feeding operations do not have dust problems of the magnitude of the larger lots and consequently seldom use water for dust control.

2.2 UTILIZATION OF LOCAL CROPS

Confined feeding operations in the area provide a dependable market for corn and sorghum for grain and silage. Alfalfa hay produced locally also has a ready market because of the vast feeding operations within the region.

Corn silage produced in the two-county area is well over 2 million tons per year and represents nearly 52 percent of the state total [Colorado Department of Agriculture, July, 1976. Barley, wheat, and sugar beet by-products are utilized by all classes of livestock. Wheat is normally not used as a livestock feed grain unless the price is in close relationship to the price of shelled corn. Recent low prices for wheat (March, 1977) indicates that wheat is being used in confined feeding operations.

In a generalized confined feeding situation, three basic rations are fed during the fattening period. These include a starter ration, a growing ration, and a finish ration. A starter ration can consist of as much as 80 percent roughage. Finish rations are composed of high concentrates. Shelled corn (ground or flaked), milo, cottonseed meal, and sorghum grains are the most commonly used concentrates. The roughage portion of the ration usually consists of either corn silage and/or alfalfa hay. Feeding rations are often high in roughage, often approaching 25 percent. Respective components of the roughage and concentrate fractions vary according to prevailing feed prices in an area.

Individual feedlot operators in the two-county region have devised ration formulas and feeding principles unique to their own enterprises. A number of diverse practices are employed, all of which are considered by a feeder to yield the most positive results and which stem from professional experience. At the Monfort facilities, corn is the primary ingredient in fattening. Both shell corn and corn ensilage are utilized. To enhance its palatability and digestibility, shelled corn is steamed at 212 degrees for 18 to 20 minutes and then sent through rollers. The flaked corn is then fed immediately to livestock. The flaking process reportedly increases livestock affinity for the grain, a factor which stimulates consumption. Most of the shell corn fed by Monfort is brought in from out of state. Nebraska and Kansas are principle suppliers. Monfort cattle consume approximately 25 million bushels of shelled corn each year. Corn ensilage is obtained from Weld County farmers. It is the primary roughage ingredient in the Monfort ration. From 15,000 to 20,000 acres of corn ensilage grown within a 10-mile radius of Monfort's Gilcrest and Kuner feedlots are utilized. During harvest, ensilage is hauled at a rate of 12,000 tons per day, 7 days a week. During summer months, the feedlots use green chopped alfalfa as a partial or total substitute for corn ensilage. Monfort's two lots use 1,000 tons of green chop per day, equivalent to the yearly production of over 150 acres.

Beet pulp pellets, a by-product of the sugar beet industry, are also used in the Monfort ration. Supplies are obtained from Colorado, Nebraska, Wyoming, and Montana.

Monfort's beef animals also receive a specifically prescribed protein supplement in their ration. It is fed at a rate of 1 pound per head per day.

Webster Feedlots normally raise all corn ensilage on their own farmlands. Shell corn is purchased. The ration served by Webster is comparable to Monfort's in that flaked corn is a basic ingredient. [Webster & Whitmore, 1977]. Corn flaking is considered by Webster to represent a very efficient way of using grain to improve meat quality. Fast rates of gain and good feed conversion are purportedly realized.

Farr Feeders utilize a feeding program based upon high moisture corn as the fundamental ingredient. Moisture content of corn is on the order of 30 percent. Use of the high moisture grain provides annual consistency in both quality and cost of feed. Rations consist of 80 percent moist corn and 20 percent dry corn. The blend is subsequently ground. It is extremely digestible and well suited to confined feeding operations. Corn consumed at the two Farr feedlots is grown locally. Approximately 30,000 acres are involved. [Farr, 1977].

Extensive investigation is being conducted by Stout-Wall Research, Inc., Loveland, Colorado, on the use of conditioned silage as the exclusive ration for confined livestock. Research findings have been applied successfully to dairy and beef fattening operations in the Larimer-Weld region. The recommended ration formulations are especially attractive because they eliminate dependence on expensive protein concentrates. This is extremely beneficial to farmer/feeders, who can thus supply the bulk of the required feed from their own lands. Another significant benefit is that forage is harvested green. This enhances protein content and entails less risk of crop damage by weather. [Stout, 1977].

2.3 LOCAL PACKING PLANTS

Livestock fattened in the confined feeding operations within the region are slaughtered in local packing plants or are hauled to plants in the Denver area. The huge Monfort Packing Plant in Greeley is by far the most significant butchering operation in the two-county area. The facility nearly always processes only beef produced in the two Monfort lots. About 2,000 persons are employed at the plant. The Monfort facility coordinates killing, dressing, fabrication, portion cutting, and packaging functions into one operation. Up to 13,000 head per week can be processed on a single-shift, five and one-half day basis. The plant can also accommodate 3,600 lambs daily.

Loveland Packing Company in Loveland is the second largest processing plant in the Larimer-Weld region. The facility processes hogs exclusively, on the order of 350 to 400 per day.

Approximately nine additional smaller meat packing operations reside in the two-county area. They are situated in Fort Collins, Greeley, Kersey, Pierce, and south of Windsor. The volume of livestock processed at these facilities is relatively minor when compared to that handled by Monfort and Loveland Packing. The smaller operations typically engage in custom slaughtering of beef, hogs, or lamb. Very small feedlot operators find it desirable to take advantage of the service provided by the custom packers.

With the exception of Monfort, the majority of the major feeders in the Larimer-Weld region prefer to process their cattle at commercial packing plants in the Denver area. Trucks rather than rail serve as the principal means of cattle transport.

2.4 ECONOMIC IMPACT ON LOCAL ECONOMY

Agriculture provides an extremely valuable contribution to the economies of Larimer and Weld Counties. In addition to serving as a primary stimulus to local and regional prosperity, the industry vitalizes sectors of the economy which provide related goods and services. Supporting industries are innumerable, and include the areas of fertilizer and chemical production; food preparation, packaging, and distribution; and heavy equipment and machinery manufacturing. Every dollar created by a basic industry such as agriculture is an impetus to economic growth and well-being at the county, state, and national levels.

Summarized in Table 2.4-A are statistics which demonstrate the importance of agriculture to Larimer and Weld Counties. Only primary dollars associated with crop and livestock production are depicted. Secondary and accelerated monetary benefits to the county economies are not determined. It is evident from the tabulation that the livestock industry is responsible for the bulk of agricultural wealth generated in the two-county region.

TABLE 2.4-A. VALUE OF AGRICULTURAL PRODUCTS - 1974 (a)

	LARIMER COUNTY		WELD COUNTY	
	$1000	%	$1000	%
Livestock, Poultry, and their products	39,467(b)	70.4	466,612(c)	81.2
Forest Products	5	-	-	-
Crops, including nursery products and hay	16,627	29.6	108,218	18.8
Total Value of Agricultural Products Sold	56,099	100.0	574,830	100.0

(a) U.S. Department of Commerce, July, 1976 and August, 1976.
(b) Value of dairy products sold ($1000) = $5,832.
(c) Value of dairy products sold ($1000) = $19,686.

The livestock industry is considered to be a "basic" business activity in that it sells mainly to customers outside the two-county region. It is one of several basic industries which form the demands that determine the market for local raw materials suppliers, labor, and processed goods.

The Larimer-Weld Regional Council of Governments has sponsored a study of future economic trends in the two-county area as part of the Water Quality Mangement Plan [Gray, et. al., 1977]. The direct and indirect impact of the livestock industry on regional economics was a major topic of review.

As a key sector of the economy, the livestock industry generates business activity in the region for each dollar of sales to final demand (retail consumers, government, and exports outside the two-county area). The amount of direct, indirect, and induced transactions created can be measured by a business multiplier. If sales by the lovestock industry increase, expenditure for locally produced goods will also increase. Producers of local goods are then indirectly required to purchase additional local goods and services themselves in order to meet the additional demand. Local employees hired directly will respend a given portion of their added income. This will serve to further stimulate expansion of the regional economy. The total effect of these impacts are reflected in the business multiplier.

Employment multipliers indicate the total added employment in Larimer and Weld Counties per dollar of additional sales to final demand by an industry. Increase in personal income per dollar of additional sales to final demand are depicted by an income multiplier. Data representative of the livestock industry are shown in Table 2.4-B.

Table 2.4-C forecasts sales growth of the livestock industry. This projection assumes that livestock production, food processing, electronics and precision instruments, and government are the four "basic" enterprises in the region. Anticipated future growth rate is depicted in Table 2.4-D.

TABLE 2.4-B. LIVESTOCK INDUSTRY ECONOMIC ANALYSIS [a]

1974 Value of Sales ($1,000)	477.64
1974 Employment (Number of Workers)	7,165
1974 Household Income ($1,000,000)	35.94
Business Multiplier [b] (Direct plus indirect plus induced)	1.673
Employment Multiplier [c] (Direct plus indirect plus induced)	0.0308
Income Multiplier [d] (Direct plus indirect plus induced)	0.136

[a] Gray et. al., 1977.
[b] In dollars of business activity per dollar of output delivered to final demand. The business multiplier measures the amount of direct, indirect, and induced transactions created by an increase in sales to final demand.
[c] In numbers of workers, part and full time, per $1,000 of output delivered to final demand. The employment multiplier indicates the total added employment in the two-county area per dollar of additional sales to final demand.
[d] In dollars of income generated per dollar of output delivered to final demand. The income multiplier depicts the increase in personal income per dollar of additional sales to final demand. This multiplier accounts for the repercussionary effects of second rounds of consumer spending in addition to the direct and indirect interindustry effects.

TABLE 2.4-C. LIVESTOCK INDUSTRY
PROJECTED SALES (a)

YEAR	$ (millions) LOW RANGE	HIGH RANGE
1975	477.64	477.64
1980	620.39	622.73
1985	776.55	781.30
1990	922.73	930.03
1995	1,006.95	1,017.45
2000	1,060.27	1,074.86

(a) Gray et.al., 1977.

The livestock sector of the economy is predicted to exhibit a cyclic growth of expansion and contraction in the future. This is evident in Table 2.4-D.

TABLE 2.4-D. LIVESTOCK INDUSTRY
ESTIMATED YEARLY PERCENTAGE GROWTH RATES
OF SALES TO FINAL DEMAND (a)

TIME PERIOD	PERCENT
1975-1980	+ 2%
1980-1985	+ 2%
1985-1990	- 2%
1990-1995	- 2%
1995-2000	+ 2%

(a) Gray, et. al., 1977.

Multiplier analysis is a valuable means of determining the impacts on total spending, total employment, or total income within Larimer and Weld Counties created by an increase in the final demand sales by a given industry. For example, consider a $100,000 increase in the export sales of the livestock producing sector. In order to expand fattened livestock sales by $100,000, a total of $167,300 in spending would be generated within the region. This is depicted by the business multiplier for the livestock industry of 1.673. Additional stimulation of employment is described by the employment multiplier: (100)(0.0308) = 3.08 added workers. The labor payroll will increase by ($100,000)(0.136) = $13,600, as shown by the income multiplier.

Multipliers are but one measure of the importance of any given industry to the economic welfare of the two-county area. Absolute size and expected volatility of growth are also important indicators of the role an industry will play in the future regional economy [Gray et. al., 1977]. The livestock industry is included along with food processing, electronics, and government as the four most important sectors of the economy. These activities are characterized by high multiplier effects, and/or high total value of sales and employment relative to other sectors, and/or are expected to have a relatively volatile growth in the 1975-2000 period. Cumulative economic expansion is brought about when the major sectors expand sales to final demand.

3.0 DISTRIBUTION AND SIZE OF FEEDLOTS

According to statistical data, cattle on feed in Larimer and Weld Counties on January 1, 1976, numbered 28,500 and 406,000, respectively. [Colorado Department of Agriculture, July, 1976]. Assuming the average pen turnover rate is about two per year, annual production would be on the order of 870,000 head. The two-county region is responsible for 47 percent of the total number of cattle on feed in Colorado.

During 1974, fattened cattle sold in Larimer County numbered 40,204. In Weld County, the total was 794,273. [U.S. Department of Commerce, July, 1976, and August, 1976]. These data, the most current available, are representative of the industry at a time when it was at the low point of an economic recession.

Cattle production during any given year is largely a function of the profitability of the livestock market. This is governed by many factors, among which are included grain prices and national beef importation policies. It is estimated that fattened cattle sold annually in the two-county area will generally be in the range of 835,000 to 950,000.

A number of sources exist from which data concerning identity or location of feedlot owners can be obtained. These sources, primarily governmental agencies, possess information that varies in degree of thoroughness and complexity. Characteristics of available data will be discussed herein.

- Colorado State Department of Agriculture, State Brand Inspector. Approximately 39,000 individual livestock brands exist within the State of Colorado. Owner identity is tabulated alphabetically on a state-wide basis. Evaluation and categorization of these data is beyond the resources of the 208 Wastewater Management Program.

- Colorado State Department of Health. Files of the State Department of Health contain extremely complete detail on individual feedlots and dairies. Typical available information includes: owner/operator identity and address, location of pen area, manure disposal area, climatic data, potential receiving waters, potential problems, capacity and operating inventory, and description of any waste or runoff control facilities. The agency also possesses results of a letter survey of feedlots conducted in 1972. This campaign was directed at feedlots possessing a capacity less than about 1,000 head. Number of confined livestock feeding operations presently known to exist by the State Department of Health are summarized in Tables 3.0-A and 3.0-B for Larimer and Weld Counties, respectively. Characteristics of confined livestock feeding operations identified by the State Department of Health are detailed in Appendices A and B for each county. The State is continuing to implement its program of feedlot/dairy identification as swiftly as constraints of manpower and budget will allow.

- The Colorado Cattle Feeders Association. The association maintains a record of current members. Ownership of a confined livestock feeding operation is not a prerequisite for membership, however. Total state-wide membership is 552. Almost exactly one-half of this membership reside within Larimer and Weld Counties. In 1976, the Colorado Department of Health conducted a letter survey of Association members. Approximately one-tenth of the total membership responded to the state inquiry.

- Colorado Department of Agriculture, Animal Industry Division, State Veterinarian. The office of the State Veterinarian formerly compiled and updated a list of Colorado registered quarantine feedlots. This practice has now been discontinued.

- U.S. Department of Agriculture, Colorado Department of Agriculture, Colorado Crop and Livestock Reporting Service. Data representative of feedlot numbers by size and fed cattle marketings in Colorado were identified in the newsletter "Colorado Cattle on Feed". [USDA, 1977]. According to this publication, there exist statewide 184 cattle feedlots with a capacity of 1,000 head or more. Lots with a capacity of less than 1,000 head numbered 318. Fed cattle marketed from these lots numbered 1,990,000 and 154,000 head, respectively.

TABLE 3.0-A. LARIMER COUNTY - NUMBERS OF CONFINED FEEDING OPERATIONS IDENTIFIED BY STATE DEPARTMENT OF HEALTH

IDENTIFIED FEEDLOTS WITH KNOWN CAPACITY			IDENTIFIED FEEDLOTS TOTAL NUMBER
TYPE	CAPACITY	NUMBER	
Beef			
	0- 299	12	
	300- 999	15	
	1000-9999	13	
	10,000+	0	
Sheep			
	0-2999	0	
	3000-9999	0	
	10,000+	1	
Subtotal Beef & Sheep		41	48
Hogs			
	0- 750	1	
	751-2498	0	
	2499+	2	
Subtotal		3	3
Dairies			
	0- 210	7	
	211- 700	2	
	701+	1	
Subtotal		10	19
TOTAL		54	70

TABLE 3.0-B. WELD COUNTY - NUMBERS OF CONFINED FEEDING OPERATIONS IDENTIFIED BY STATE DEPARTMENT OF HEALTH

IDENTIFIED FEEDLOTS WITH KNOWN CAPACITY			IDENTIFIED FEEDLOTS TOTAL NUMBER
TYPE	CAPACITY	NUMBER	
Beef			
	0- 299	37	
	300- 999	66	
	1000-9999	49	
	10,000+	17	
Sheep			
	0-2999	5 [a]	
	3000-9999	0	
	10,000+	7 [b]	
Subtotal Beef & Sheep		181	187
Hogs			
	0- 750	4	
	751-2498	1	
	2499+	0	
Subtotal		5	6
Dairies			
	0- 210	10	
	211- 700	4	
	701+	0	
Subtotal		14	23
TOTAL		200	216

[a] Four operations are combined with cattle feedlots possessing less than 300 head.

[b] Two operations are combined with cattle feedlots possessing from 1,000 to 2,000 head.

An agricultural statistician responsible for authoring the newsletter was contacted in order to obtain a breakdown of the statewide data on a county level [Fretwell, 1977]. Disaggregated data were made available for Larimer and Weld Counties. It should be noted that the Reporting Service relies on information communicated on a voluntary basis from livestock producers. Respondees are considered to be only a fraction of the total actual operators in business in the region.

- U.S. Department of Agriculture, Soil Conservation Service. In 1972, the Greeley office of the Soil Conservation Service developed maps which identified the location of 154 active feedlots in Weld County with a capacity of 500 or more cattle. SCS relied on information assembled by the Weld County Planning Office, the Weld County Assessor, and Weld County Public Health Department.

  The Weld County Planning Commission records indicated the presence of 1,294 total feedlots larger than 20 head, 154 of which possessed a capacity greater than 500 head. According to the Assessor's records, there existed a total of 1,243 feedlots in Weld County larger than 20 head. Of these, 146 were over 500 head capacity. Lots identified by the foregoing two sources are considered to be physically occupied by cattle [Sudduth, 1972].

  The sanitarian for the County Public Health Department conducted a windshield survey of feedlots. The roadside study inventoried all corrals and lots, regardless of size and irrespective of whether they were occupied or not. A total count of 3,173 was made [Sudduth, 1972].

- U.S. Department of Commerce, Bureau of the Census. A variety of statistical data concerning the livestock industry in Larimer and Weld Counties were generated as part of the 1974 Census of Agriculture [U.S. Department of Commerce, July and August, 1976]. Information is summarized for pertinent categories in Table 3.0-C.

TABLE 3.0-C. 1974 CENSUS OF AGRICULTURE
INVENTORY OF LIVESTOCK AND POULTRY (a)

		LARIMER COUNTY (b)	WELD COUNTY (c)
Cattle and Calves, Inventory	FARMS....	670	1,868
Fattened Cattle	NUMBER....	81,828	589,612
Sold..............	FARMS....	114	377
	NUMBER	40,204	794,273
Cows, Inventory.....	FARMS....	491	1,396
	NUMBER....	25,931	106,973
Beef Cows, Inventory	FARMS....	391	1,115
	NUMBER....	19,293	84,783
Milk Cows, Inventory	FARMS....	183	495
	NUMBER....	6,638	22,190
Hogs and Pigs, Inventory	FARMS....	119	326
	NUMBER....	18,319	30,957
Sold..............	FARMS....	113	309
	NUMBER....	33,475	54,362
Feeder Pigs Sold....	FARMS....	31	87
	NUMBER	5,221	19,278
Litters Farrowed Between December 1 of Previous Year and November 30....	FARMS....	70	200
	NUMBER....	2,838	6,189
December 1 of Previous Year and May 31..........	FARMS....	57	180
	NUMBER....	1,499	3,216
June 1 and November 30	FARMS....	64	157
	NUMBER	1,339	2,973
Sheep and Lambs, Inventory	FARMS....	118	211
	NUMBER....	85,230	263,989
Sold..............	FARMS....	118	210
	NUMBER....	98,553	648,761
Horses and Ponies, Inventory	FARMS....	308	577
	NUMBER....	2,010	3,131
Chickens 3 Months Old or Older, Inventory.....	FARMS....	186	407
	NUMBER....	35,160	1,122,744
Hens & Pullets of Laying Age, Inventory.....	FARMS....	180	400
	NUMBER....	34,439	993,592
Broilers Sold......	FARMS....	11	6
	NUMBER....	3,514	195

(a) All farms.
(b) U.S. Department of Commerce, August, 1976.
(c) U.S. Department of Commerce, July, 1976.

- Bio-Gas of Colorado, Inc. Bio-Gas of Colorado, Inc., recently completed a study financed by the Four Corners Regional Commission and sponsored by the Colorado Energy Research Institute [Burford & Varani, 1976]. The investigation identified all readily collectable agricultural wastes in the four state region of Arizona, Colorado, New Mexico, and Utah. Resource maps were prepared which show the location of livestock operations. Maps of the Larimer-Weld region have been made available through the courtesy of John L. Burford, Jr., of Bio-Gas of Colorado, Inc. Significant effort was expended by Bio-Gas to document the location of confined animal feeding operations. Records maintained by the Statistical Reporting Services and the Extension Services of the U.S. Department of Agriculture served as primary data for feedlot identification. Resources and scope of the Bio-Gas investigation did not allow detailed field survey. In addition, feedlot identity in many cases was limited to an owner's or operator's address. Hence, plotting of feedlots on the agricultural resource maps prepared by Bio-Gas may not correspond to the exact physical facility location. Information obtained from agency files can also reflect outdated data if not subject to an ongoing program of updating and confirmation.

  Table 3.0-D gives a breakdown of different animal feeding operations and size categories for the Larimer-Weld region as inventoried by Bio-Gas of Colorado, Inc.

3.1 SUMMARY OF DATA, FEEDLOT SIZE AND DISTRIBUTION

It is evident from data presented previously that estimates of size and number of confined livestock feeding operations vary greatly according to source of information and date of survey. Numbers of active feedlots in the two-county area fluctuate according to economic condition of the cattle feeding market. The depression recently experienced by the livestock industry has forced many feeders out of business. It is estimated that approximately 1,250 feedlots presently exist with capacities greater than 20 head. Major operations supporting more than 300 head number about 200.

3.2 DENSITY OF CATTLE ON FEEDLOTS

Density of cattle capable of being supported on feedlots in the two-county region is shown on Figure 3.2-A. This presentation is depicted in terms of confined livestock per township, and is based on an aggregation of available data. It is readily apparent from the figure that the greatest concentration of cattle on feed is found in the drainage of the Cache la Poudre River and in the regional vicinity of Greeley.

TABLE 3.0-D. NUMBERS OF CONFINED FEEDING OPERATION - BIO-GAS [a]

	LOT SIZE	NUMBER		TWO-COUNTY TOTAL
		WELD	LARIMER	
Cattle & Calves On Feed	100-499	86	23	109
	500-999	33	13	46
	1000+	58	11	69
Hogs on Feed	500-1499	8	4	12
	1500-2499	1	2	3
	2500+	0	1	1
Sheep on Feed	3000-5999	4	2	6
	6000-9999	7	1	8
	10,000+	6	1	7
Dairy Cattle	100-700	74	23	97

NOTE: Ninety-four dairy lots out of the total of 97 possessed less than 350 head and more than 100 head.

[a] Burford & Varani, 1976.

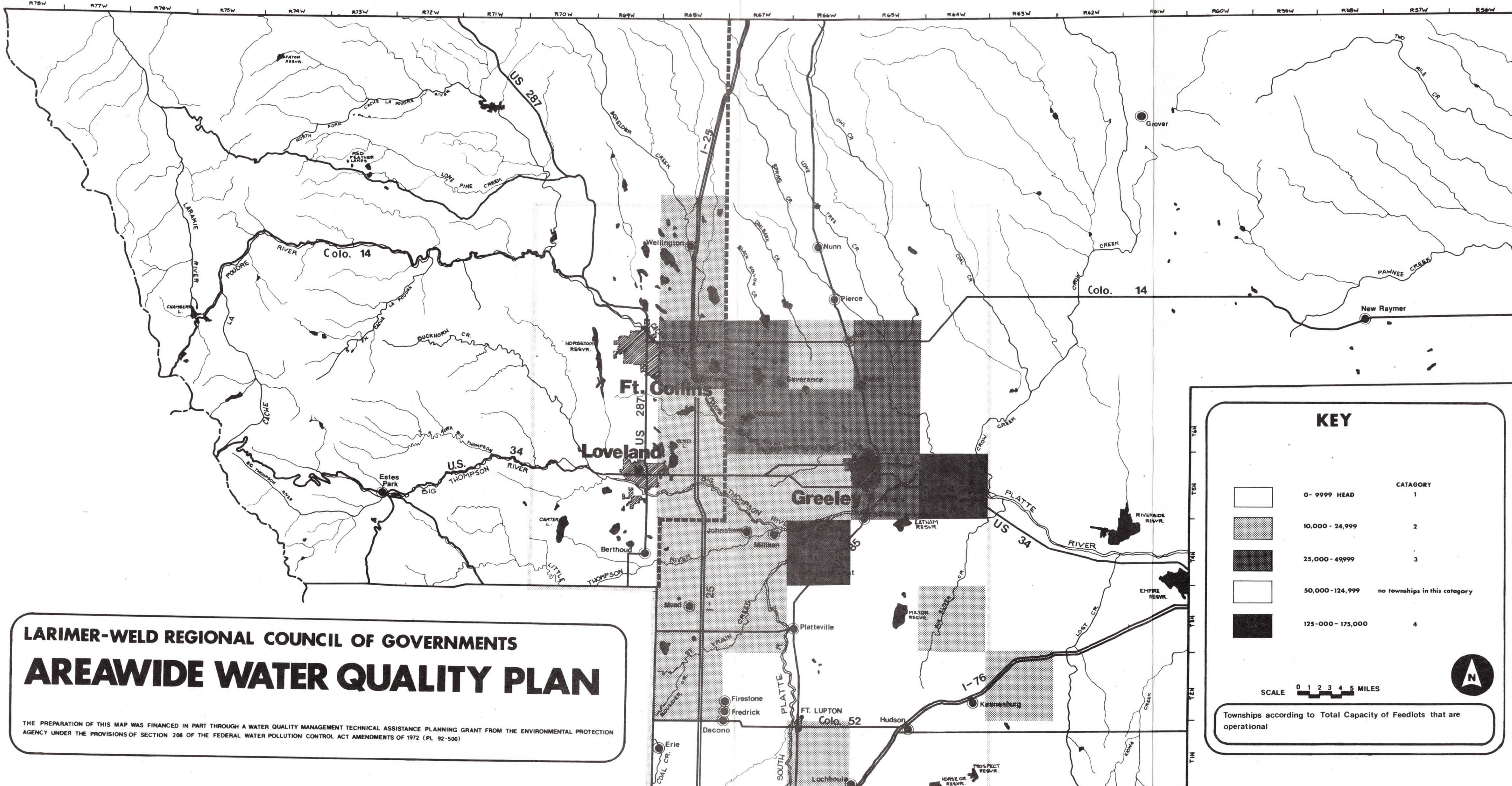

LARIMER-WELD REGIONAL COUNCIL OF GOVERNMENTS
AREAWIDE WATER QUALITY PLAN
THE PREPARATION OF THIS MAP WAS FINANCED IN PART THROUGH A WATER QUALITY MANAGEMENT TECHNICAL ASSISTANCE PLANNING GRANT FROM THE ENVIRONMENTAL PROTECTION AGENCY UNDER THE PROVISIONS OF SECTION 208 OF THE FEDERAL WATER POLLUTION CONTROL ACT AMENDMENTS OF 1972 (PL 92-500)
KEY
CATAGORY
0- 9999 HEAD 1
10,000 - 24,999 2
25,000 - 49,999 3
50,000 - 124,999 no townships in this catagory
125-000 - 175,000 4
SCALE 0 1 2 3 4 5 MILES
Townships according to Total Capacity of Feedlots that are operational
Ft. Collins
Loveland
Greeley
Estes Park
Berthoud
Wellington
Nunn
Pierce
Grover
New Raymer
Johnstown
Milliken
Platteville
Firestone
Fredrick
Dacono
Erie
Mead
FT. LUPTON
Hudson
Keenesburg
Lochbuie
US 287
I-25
I-76
US 34
Colo. 14
Colo. 52
SOUTH PLATTE
RIVER
CACHE LA POUDRE RIVER
BIG THOMPSON RIVER
LITTLE THOMPSON
LARAMIE RIVER
LONE PINE CREEK
CROW CREEK
PAWNEE CREEK
LOST CR.
COAL CR.

Figure 3.2-A

Data obtained from the Colorado Department of Health files provided the basis for determining the average ratio of cattle feedlot inventory versus feedlot capacity for the two-county area. On an annual average, 70 percent of total feedlot capacity will be utilized for actual livestock production. Supporting data are summarized in Table 3.2-A.

Density of cattle on feed in the Larimer-Weld region ranges from less than 100 to over 300 animals per acre of feedlot. Typical concentrations are in the 100 to 200 head range. Analysis of available data summarized in Appendices A and B indicates that an average density of about 150 head per acre is representative of confined feeding operations in the region.

TABLE 3.2-A. RATIO:INVENTORY/CAPACITY [a] CATTLE FEEDLOTS

COUNTY	FEEDLOT CAPACITY	AVAILABLE FEEDLOT DATA	RATIO AVERAGE OF AVAILABLE DATA
Larimer			
	0-299	5	0.76
	300-999	9	0.67
	1000+	7	0.68
	County Average		0.70
Weld			
	0-299	25	0.70
	300-999	47	0.71
	1000+	38	0.68
	County Average		0.70

[a] Data from Colorado Department of Health files.

4.0 MANURE HANDLING AND DISPOSAL METHODS

Cattle manure produced in feedlots represents the most significant source of livestock-related waste generated within Larimer and Weld Counties. Impacts of manures from poultry and livestock other than beef cattle maintained in confined feeding operations were also reviewed. Because of the relative insignificance of the quantities involved when compared to those from cattle feedlots, the investigation was cursory in nature. Orientation of the analysis developed herein will be directed exclusively toward confined beef feeding operations.

4.1 CHARACTERISTICS OF CATTLE MANURE

Manure generated in a confined cattle feeding facility consists of undigested and spilled feed, lignin and hemicellulose substances from roughage that are relatively stable and subject to slow degradation by micro-organisms, and ligno-protein materials produced in the digestive tract of livestock. The latter substances may represent up to one-quarter of the total dry manure weight and are very similar to humus in character [Burford & Varani, 1976].

Manure produced under present-day feeding conditions is enriched with dietary supplements including salt, mineral nutrients, and protein feed [Ruehr, 1976]. Manure is not generally mixed with bedding materials such as straw because use of this material in pens has largely been discontinued. Recent feedlot management often substitutes wood chips for better odor control and dehydration of the manure pack.

Quantity of manure generated by cattle in a confined feeding facility is directly related to the weight of the animals on feed and the character of the feed ration. Annual solid waste production in a beef feedlot is on the order of 1.25 cubic yards per head [EPA, 1972]. This generation rate reflects year-around head inventory on a continuously used feedlot rather than total annual number of animals fattened (two-pens). Assuming an average inventory of 450,000 head of cattle in the two-county region on feed, about 560,000 cubic yards of manure would then be generated yearly, equivalent to about one cubic yard for each irrigated acre. A 1,000 pound bovine can generate approximately 10.4 pounds of manure dry matter daily. Assuming a moisture content of 35 to 40 percent, total tonage equivalent of a yard of manure is nearly 2.5. On a wet weight basis, moisture content of manure generally is in the range of 10 to 60 percent, with samples typically averaging from about 35 to 50 percent. [Powers, et. al., May, 1974; Mathers and Stewart, 1970; Reddell, *et. al.*, 1972].

Average excretion associated with the 10.4 pounds of dry matter produced per head per day includes 0.38 pounds of nitrogen, 0.05 pounds of phosphorus, and 0.27 pounds of potassium [Viets, 1971]. High concentrate cattle rations generally contain 1 percent or more sodium chloride (salt) to stimulate feed consumption and possibly inhibit the formation of urinary calculi [Mathers and Stewart, 1974]. Manure salt content is a function of feeding practice. Nutrient character of manure varies greatly according to feedlot management, on-site handling or storage, and climate. A general range of elements present in manure is depicted in Table 4.1-A.

On a year-around operated feedlot with approximately 150 head per acre, slightly over 10 tons of nitrogen per acre will be excreted. A myriad of avenues exist by which nitrogen may be disposed. These include manure hauling, transport of overland runoff, deep percolation of nitrate and soluble organic nitrogen compounds, volatilization of ammonia, and site denitrification and loss as nitrogen gas. Physical conditions at a particular feedlot greatly determine the quantity of nitrogen that is ultimately disposed through available processes and strategies. Among these are feedlot management, slope, surficial character, and local climatic influences [Viets, 1972]. Character of livestock wastes at a feedlot are highly site specific and may vary greatly from time to time. Composition primarily depends on two factors: the character of ration fed at any given time, and the elapse of time since defecation. Fresh manure loses nearly one-half of its nitrogen content if several days are allowed to pass before it is applied to land. Ammonia volatilization and runoff are the major avenues of nitrogen escape.

4.2 REMOVAL FROM FEEDLOTS

Cattle pens are most commonly cleaned by means of scrapers and tractors. Some feeders manage manure collection according to strict operational principles. Windrow material is diligently removed from the pad surface. Care is exercised to avoid disturbing the feedlot surface, and subsequently destroying the integrity of the relatively impermeable manure pack. Holes caused by the pawing action of confined livestock are repaired. The foregoing strategies characterize more progressive feedlots in the Larimer-Weld region. On the opposite end of the spectrum, other feeders pay little attention to efficient manure handling principles.

TABLE 4.1-A. CHEMICAL CONSTITUENTS AS PERCENT OF THE DRY MANURE REPORTED BY VARIOUS RESEARCHERS (a)

N	P	K	Na	Ca	Mg	Reference
%	%	%	%	%	%	
1.98	0.27	1.12	2.84	2.80	1.53	(b)
0.64-1.59	0.309-0.541	0.85-1.40	0.15-0.32	0.62-1.03	0.299-0.500	(c)
0.88-3.5	0.40-1.00	0.98-2.33	0.20-1.13	0.60-1.98	0.40-0.78	(d)
1.6	-	0.67	0.16	-	-	(e)
3.6	0.60	2.24	0.76	-	-	(e)
2.5	0.65	1.75	0.92	-	-	(e)
3.5	0.66	2.25	-	-	-	(f)
2.3	0.74	1.00	-	-	-	(f)
2.3	0.83	2.42	1.3	-	-	(f)
1.04	0.417	1.09	0.228	0.776	0.393	(g)
3.12	0.710	0.39	0.168	0.558	0.445	(g)
0.89	0.570	0.97	0.249	0.980	0.42	(g)

(a) Compiled by Ruehr, 1976.
(b) Meek, et. al., 1974.
(c) Murphy, et. al., 1972.
(d) Powers, et. al., May, 1974.
(e) Mathers and Stewart, 1974.
(f) Reddell, et. al., 1972.
(g) Manges, et. al., 1972.

In the two-county area, soils dominating the surface areas of pens range in structure from tightly packed clays to loose sands. Feeders occasionally modify the natural character of pen surfaces to facilitate maintenance of a feedlot. Operations overlying sandy soils will occasionally spread wood chips in the pens after cleaning to help establish a firm manure pack which will maintain its integrity in wet weather. In other cases, feeders may backfill pens with sand after lot surfaces have been scraped. [Burford & Varani, 1976].

Cattle manure disposition and feedlot characteristics of 47 operations located in the regional area of Gilcrest, Colorado, (Weld County) were recently investigated. [Burford & Varani, 1976]. The feedlots surveyed consisted of 12 with capacities in excess of 1,000 head, including one of the largest facilities in the United States, and 35 smaller enterprises ranging in size from 100 to 1,000 head. A summary of the three most common manure disposal practices is described herein.

- Sale of manure. Of the total amount of manure available from these 47 feedlots in 1975, approximately 15 percent, or 57,000 tons, was sold to farmers in the Gilcrest area. The 1975 price was relatively uniform at about $1.00 per ton loaded into a custom haul or individual farmer's truck. The cost of scraping and loading the manure is borne by the feedlot.
- Barter system. About 215,600 tons of manure, or 57 percent of the total generated at the 47 feedlots in 1975, was distributed according to some form of barter arrangement. Terms of the agreements range from informal to contractual. In the barter system, the feedlot gives the silage farmer a ton of free manure for each ton of silage the farmer sells to the feedlot. Barter arrangements are employed primarily on large capacity feedlots. The feedlot incurs the cost of collecting and loading the manure. Information obtained from two feedlots indicates that loading out costs are on the order of $0.50 per ton of manure. The farmer bears the cost of hauling it away and applying it to his fields.

- Internal use of manure. Approximately 28 percent of the total manure available from the Gilcrest area feedlots under study was spread on fields owned by the feedlot operators. Operators and farmers with confined feeding facilities normally move the manure themselves at a cost estimated to range from $0.50 to $1.00 per ton. Some operators prefer to sell the manure if prices from $1.00 to $1.50 per ton can be obtained. Internal use of manure is a practice which typically characterizes smaller feedlots. However, two of the 12 large feeders surveyed in the Gilcrest area also use this management strategy.

Lots inventoried in the Gilcrest area normally try to clean out manure in feedlot pens at least twice a year. [Burford & Varani, 1976]. These periods correspond to early spring and to late fall months. This schedule generally characterizes feeders in the two-county region. Actual operating practice may vary considerably from the general rule during any given year, and pens may only be subject to one annual cleaning. Bi-annual manure collection is especially practiced in years when manure moisture content is low. This relates to the fact that cattle tend to play in such manure when it is piled up. As a result they may be subject to illness. [Amen, 1977]. Webster Feedlots prefer to have corrals cleaned about four times each year. [Webster & Whitmore, 1977]. Other feeders, including Farr, exercise a rigorous program of corral cleaning. It is not uncommon for their pens to be cleaned every 3 to 4 weeks. [Farr, 1977].

During the course of feedlot evaluation, the 208 engineering consultant interviewed a number of feedlot owners/operators and custom manure haulers in the two-county region. Ray Amen, a major feeder located in Weld County just east of the Larimer County line, indicated that manure from his feedlot is sold to silage farmers at a price of $1.50 per ton. Purchasing farmers load at their own expense. [Amen, 1977]. When not utilized on his own fields, the large Webster Feedlot near Greeley sells manure at prices in the $1.50 to $2.00 per ton range. [Webster & Whitmore, 1977].

It is not uncommon for individual farmers to haul manure. However, a significant portion of manure transport and spread is accomplished by custom haul. A portion of the available business in the two-county area is handled by Mountain Aggregates Company. In 1975, the charge for hauling and spreading the manure which is loaded out by the feedlots was $0.70 per ton plus $0.15 per ton-mile on the first five miles and $0.10 per ton-mile for distances in excess of five miles. [Burford & Varani, 1976].

Another major custom hauler serving the two-county region was contacted to obtain information on the current pricing structure. In cases where manure is loaded free-of-charge by a commercial feeder, the contracting farmer is charged $0.15 per ton-mile for hauling and $0.65 per ton spread on agricultural land. When contacted by an individual farmer/feeder for corral cleaning and manure spreading on adjacent land, this firm charges at a rate in the range of $12-$14 per load. Price varies according to location of the feedlot and manure weight.

4.3 DISTRIBUTION TO FARMLANDS

In the Larimer-Weld region, most manure produced in private and commercial cattle feedlots is returned to irrigated lands. Ideal waste management would return livestock manure to the soil at a rate comparable to its production [Norstadt & Porter, 1976]. Constraints imposed by the seasons, on-farm planting and harvesting practices, and feedlot management seldom allow the ideal to be implemented. The confined feeding operation is usually the site of manure storage. Hence, wastes are partially decomposed prior to application to agricultural lands. Manure solids are commonly collected into piles for temporary or long-term storage. Actual application to the soil is usually accomplished by means of a mechanical manure spreader. Land disposal of manure is a preferred method because it is relatively economical and possesses a proven history of acceptability.

Physical condition of animal waste determines to a large extent the ease of land application. Friable material that has been allowed to dry and decay is relatively easy to load and spread on a field. Bulky chunks of semi-solid materials obtained directly from the feedlot pen area are considerably more difficult to handle and to spread uniformly.

Commercially available manure spreaders are designed for maximum application rates of 10 to 20 wet tons per acre on a one-pass basis [EPA, January, 1974]. Spreader trucks generally possess an 18-foot bed. Manure loaded often weighs out at one-half to one ton per foot of truck length. Heavier manure densities reflect presence of foreign substances, such as sand or dirt scraped from a pen surface.

In the Larimer-Weld region, manure is generally incorporated into the soil of agricultural lands. It is often plowed under to depths varying from about 6 to 14 inches.

4.4 ECONOMIC VALUE OF MANURE

Handling and storage of manure prior to land application result in a major reduction in nutrient content. The soluble condition of approximately one-half of the nitrogen and three-fifths of the potash in fresh manure leads to great loss by leaching, even though manure may not be exposed to significant precipitation. Aerobic and anaerobic decomposition is responsible for decreases in the ammonium, nitrate, and elemental forms of nitrogen. When a standing manure pile is moistened or packed, a transition in decay from aerobic to anaerobic is initiated. Although subsequent losses of gaseous nitrogen are lessened somewhat, simplification of manurial constituents are stimulated. Leaching losses are restricted considerably if the manure pile is underlain by an impervious bottom.

It is reasonable to assume that probable losses of nitrogen, potash, and organic content of even carefully stored manure are on the order of one-half. Phosphoric acid may be decreased by at least one-third. Total fertilizer value of the manure is thus reduced to about one-half because elements lost are those that exist in forms most accessible for plant up-take. On farms and feedlots where manure is allowed to accumulate in piles for several months prior to use, losses may be even greater than those indicated herein.

The value of manure is generally calculated on the basis of its relative nitrogen (N), phosphorus (P), and potassium (K) fertilizer benefit. However, value computed in this fashion is always less than the positive effects actually realized in terms of increased crop production and physical soil conditioning [Biniek, 1972]. In addition to the fertilizer benefit to crop and soil provided by its nitrogen, phosphorus, and potassium content, manure contributes other elements necessary for plant growth. These include sulfur and micro-nutrients. Manure also has an acidifying effect on the soil. The presence of organic matter contributed by manure is effective in improving physical and chemical properties of soil. A positive influence is exerted on water infiltration rates, water holding capacity, reduced runoff, and ease of tillage.

Physical benefits to be derived from land disposal of animal wastes is a subject that requires comprehensive study. Direct and indirect economic impacts need to be defined. The economic value of manure should be determined on the basis of cost of nutrients supplied plus an allowance for improving the physical property of a soil. A number of fertilizer supply companies and distributors in the Larimer-Weld region were contacted to obtain current 1977 prices for various dry and liquid fertilizers. Data are summarized in Table 4.4-A. A pound value of phosphoric acid or nitrogen for each particular fertilizer is also determined.

Nitrogen and phosphorus components of manure are considered to have monetary value equal to the cost of these nutrients purchased in the form of commercial fertilizers. Manure also contains potassium, a nutrient vital to plant growth. However, soils in the Larimer-Weld region are not generally deficient in this element. Hence, its economic value as an amendment in manure was not considered.

Based upon the average of nitrogen and phosphorus contents of manure depicted in Table 4.1-A, an assumed moisture content of 35 percent, and the costs of commercial fertilizers summarized in Table 4.4-A, it is determined that nutrient value of a ton of manure is approximately $7.00. Assuming an allowance of $0.50 for the micro-nutrient content and soil conditioning qualities of manure, its total monetary worth is about $7.50. The fertilizer value of manure will probably become even more significant as prices for alternate inorganic fertilizers continue to rise. Commercial nitrogen fertilizers are manufactured from atmospheric nitrogen and hydrogen gas derived from the petroleum industry. A shortage of nitrogen fertilizer has been created by accelerated diversion of petroleum to satisfy energy needs [Ruehr, 1976]. This condition may become even more pronounced in the future.

Based on current charges for commercial manure hauling and spreading services in the region, fresh manure can economically be transported and applied up to a maximum of approximately 35 miles from its source. Economic haul distance decreases with age of manure and subsequent reduced nutrient value. Manures in the Larimer-Weld region are often stockpiled prior to land application. Losses of nutrients in storage, discussed previously, may represent about one-half the total nutrient content of fresh manure. Economic value is decreased accordingly. A 17-mile range is considered economical for stockpiled manures.

TABLE 4.4-A. 1977 COST OF COMMERCIAL FERTILIZERS - LARIMER-WELD REGION

	COST $/TON	FORMULA (a)	TOTAL NITROGEN N% (a)	AVAILABLE PHOSPHORIC ACID (a) (P_2O5)%	$/Lb.N	$/Lb.$P_2O_5$
Ammonium Nitrate	130-140	NH_4NO_3	32.5-33.5	-	19.7¢-22.2¢	-
Ammonium Sulfate	100-118	$(NH_4)_2SO_4$	20-21	-	24.4¢-28.8¢	-
Urea	190	$CO(NH_2)_2$	42-47	-	20.2¢-22.6¢	-
Aqua Ammonia		NH_4OH	24-30	-		
Anhydrated Ammonia	185-210	NH_3	81-82	-	11.4¢-12.9¢	-
Triple Super Phosphate	152-170	$CaH_4(PO_4)_3$	-	43-49	-	16.5¢-18.5¢

(a) California Fertilizer Association, 1953.

The demand for energy and its spiraling cost has prompted investigation of the economic feasibility of manure as a source of methane gas. A research project is presently being conducted at the Monfort of Colorado Kuner lot. Pilot plant facilities have been constructed and gas is being generated. The project is sponsored by the Energy Research and Development Agency (ERDA). Hamilton-Standard of Connecticut, a division of United Aircraft, was awarded the project contract. Monfort of Colorado is providing research assistance as well as a site for pilot plant facilities. Conceptual feasibility study of large-scale manure-fed methane gas generation units has recently been performed by Bio-Gas of Colorado, Inc. [Burford & Varani, 1976].

5.0 WATER QUALITY IMPACTS

Confined feeding operations may impact local and regional water quality in a variety of ways. The primary avenues of waste transport include:

- Discharge to receiving waters of feedlot wastes given mobility by tributary runoff;
- Percolation to groundwater of nitrates, salts, and other constituents from feedlot pen areas;
- Leaching of nutrients and salts from manures stockpiled on the premises of a feedlot;
- Transport of ammonia in air currents.

Potential secondary sources of degradation are represented by:

- Manures hauled off the feedlot and spread on agricultural or other lands;
- Waters collected in feedlot runoff retention ponds (lagoons) applied to cropland.

5.1 NATURE OF IMPACTS

Local agencies and individuals known to be among the forerunners in feedlot research and primary investigation were contacted during the course of the 208 wastewater planning program. Direction was sought concerning most current and applicable data pertinent to feedlots in the Larimer-Weld region [Norstadt, 1977; Sabey, 1977]. Published information considered to be of major significance to the area included:

- Distribution of Nitrates and Other Water Pollutants Under Fields and Corrals in the Middle South Platte Valley of Colorado [Stewart, et. al., 1967].
- Research Status on Effects of Land Application of Animal Wastes [Powers, et. al., May, 1975].
- Pollution Abatement from Cattle Feedlots in Northeastern Colorado and Nebraska [Porter, et. al., June, 1975].
- Guidelines for Land Disposal of Feedlot Lagoon Water [Powers, et. al., August, 1975].

- Guidelines for Applying Beef Feedlot Manure to Fields [Powers, et. al., May, 1974].
- Interactions of Beef Cattle Wastes with Soil [Norstadt & Porter, 1976].
- Infiltration Rates and Groundwater Quality Beneath Cattle Feedlots, Texas High Plains [Miller, 1971].
- Effect of Beef Cattle Manure on Soil Properties and Crop Growth [Ruehr, 1976].

Impacts of wastes associated with confined livestock feeding operations will be reviewed in terms of loading mechanism and hydrologic regime affected.

5.1.1 Feedlot Runoff

Confined livestock production results in the generation of large quantities of organic matter. The aquatic environment of a lake or stream may be severely impacted by input of organic wastes and compounds of nitrogen and phosphorus directly attributable to feedlot operations. The basic impact of nutrient enrichment on an aquatic environment is the enhancement of primary production by suspended algae (phytoplankton), attached algae (periphyton), and vascular aquatic plants [Summerfelt, 1972]. As a plant, algae grows at rates in accordance with the availability of nutrients such as phosphorus, nitrogen, and organic carbon. Although algae production is usually limited by a lack of dissolved organic nutrients, extremely rapid growth of algae can take place in surface water subject to excessive nutrient loading. Many of the man-made lakes and reservoirs in the plains area of the two-county region are situated in buffalo wallows and natural depressions. Hence they tend to be relatively shallow. Potential for algae growth from nutrient stimulation is high.

Surface water pollutants of significance associated with feedlot cattle wastes consist of oxygen-demanding materials (particularly organic matter), plant nutrients, and infectuous agents [Miner and Willrich, 1969]. Potential polluting constituents of secondary importance include color and odor. Organic matter is of importance because it serves as a substrate for aerobic bacteria. The metabolism of these organisms requires dissolved oxygen. Depletion of oxygen concentrations below levels necessary for fish survival may be caused by an over-abundance of organic material in an aquatic system.

Modification of an aquatic system attributable to excessive enrichment often interferes with municipal, industrial, and recreational uses of water. In addition, organic enrichment creates an environment detrimental to human health by encouraging survival and proliferation of disease organisms. Nitrate contamination of water supplies can lead to methemoglobulin anemia, or cyanosis in infants.

Local precipitation and tributary runoff are the most important hydrologic components affecting confined concentrated livestock feeding operations. Runoff and evaporation from the feedlot surface are essentially the only means by which water is removed. Very little rainfall percolates. Because vegetation does not exist in a continuously stocked feedlot, transpiration and interception do not influence water disposition.

5.1.2 Percolation of Corral Wastes

Widespread degradation of groundwater quality resulting from infiltration from corrals is not considered to be significant from continuously-operated feedlots in general [Swanson, 1972]. Groundwater pollution problems, should they occur, are localized in nature. This relates to the fact that movement of water into the underlying soil profile is insignificant or very low because of the formation of a relatively impermeable manure pack on continuously used feedlots.

5.1.3 Stockpiled Manures

It is common practice in the region to collect and store manures on a feedlot site for relatively long periods during the year prior to ultimate disposal on agricultural lands. This relates to the impracticality of incorporating manures into soils during crop planting, growing, or harvesting seasons. The months from November through March are generally available for manure disposal to fields.

As indicated previously, losses of nutrients during storage may range to over one-half of the fresh manure content. Leaching and airborne losses resulting from degradation are the primary avenues of escape. Groundwater quality can be degraded locally when constituents in stockpiled wastes are subject to percolation. Mitigating measures consist of locating manure storage areas over impermeable or relatively impermeable surfaces.

5.1.4 Airborne Ammonia

Airborne ammonia from cattle feedlots may contribute to nitrogen enrichment of rivers, lakes, and reservoirs. [Viets & Hutchinson, 1970]. As much as 90 percent of urinary nitrogen excreted on a feedyard can be released as ammonia directly to the air.

5.1.5 Manure Disposal

The soil to which manure is eventually applied, as well as the manure itself, contains bacteria which convert protein containing materials to forms of nitrogen readily accessible for plant uptake. The available forms consist primarily of free ammonia (NH_3) and ammonium (NH_4). Release of free ammonia is stimulated by warm temperatures and alkaline conditions. Fertilizer benefit to be realized from manure application to cropland relates significantly to availability of organic nitrogen. First year availability is defined as the percent of nitrogen in the form of protein which is decomposed by bacteria to free ammonia and ammonium forms of nitrogen. Most manures yield a first year nitrogen availability of about 50 percent.

Nitrogen content of manure influences the rate at which the waste will decay. Mineralization of nitrogen occurs only as the manure decays. Therefore, some of it is not released until the second, third, or fourth year after it is applied. Climatic influences are important because decomposition rates are affected by temperature and moisture. Leaching from a manure application site or from a stockpile is also related to moisture availability.

Opportunity for percolation of nitrate occurs when irrigation water or native precipitation are available to a soil in excess of the volume to satisfy needed evapotranspiration requirements and saturate the root zone to its water retention capacity. Nitrate can be leached away when the amount present in the root zone exceeds the ability of plants or soil microbes to utilize it.

Nitrates essentially move with the wetting front through a dry soil. If the leaching process is of sufficient intensity or frequency, nitrates that are not removed by denitrification may ultimately contact the water table. Little evidence exists which supports the conclusion that nitrates can move more than a few inches by diffusion even in saturated soils.

Concentration of salt in soils due to manure application is of concern because of the retarding effect salinity has on specific crops and its degrading impact on ground or surface water quality.

In addition to possibly contributing to the accumulation of salt in root zone areas, manure application to land poses additional problems if an improper balance of sodium and potassium in relation to calcium and magnesium exists. This situation can cause soil aggregates to disperse. Dispersed clay subsequently migrates into the soil profile. Soil pores become blocked, reducing infiltration of water. Dispersion might occur on a low salinity, medium textured soil if the ratios of the weight of sodium and potassium to the total weight of salt in manure and irrigation water exceeds 0.65 [Powers, et. al., May, 1975].

5.1.6 Lagoon Waters

In the two-county area, a management practice for feedlot runoff and drainage involves collection in structural basins or lagoons. It is common practice to dispose of lagoon water on agricultural lands. Irrigation systems range in complexity from simple gravity-flow arrangements to sophisticated pump-irrigation systems.

Lagoon water contains such plant nutrients as nitrogen, phosphorus, and potassium. The fertilizer benefit of lagoon water can be effectively utilized if application rates take into consideration negative crop and soil responses associated with excessive concentrations of specific constituents. Among these are included total salts, and salts of sodium, calcium, and magnesium. Unproductive soils can be created if salt buildup exceeds tolerance of cultivated crops. In addition, an improper balance of sodium plus potassium in relation to salts of calcium and magnesium may cause soil aggregates to disperse into individual particles. This phenomenon inhibits, if not almost stops, infiltration of water.

Nature of water collected in lagoons is extremely variable, even within a particular facility during different times of the year. Character of lagoon water is a function of storm intensity, slope of the feedlot, type of ration fed, and extent of lagoon evaporation [Powers, et. al., August, 1975]. Ration type seems to exert a dominant influence. High roughage rations utilizing forages such as alfalfa results in lagoon waters high in potassium, calcium, and magnesium salts. In contrast, grain rations yield waters comparably lower in these constituents.

Feedlot lagoons tend to be self-sealing. [Meyer, et. al, 1972]. Hence, water quality degradation directly attributable to percolating wastes is considered to be relatively insignificant.

5.2 EXTENT OF IMPACTS IN THE REGION

The significance of wastes generated by confined livestock feeding activities in the two-county area on water quality will be evaluated herein. Conclusions of research conducted in the region form the basis of the review.

5.2.1 Impact of Feedlot Runoff on Water Quality

Runoff of wastes from feedlots in Larimer and Weld Counties are considered to have a relatively insignificant impact on regional surface water quality. This is primarily attributable to the large number of wastewater/runoff control facilities presently installed on feedlots in the area, a subject which is described in depth in the subsequent section, "Effectiveness of Regulations and Practices."

5.2.2 Impact of Percolating Corral Wastes on Water Quality

Surface compaction associated with the tramping action of confined animals tends to seal the soil [Viets, 1971]. Current research supports the conclusion that unpaved feedlots pose no general threat to groundwater quality. Although pollutants in transit to underground water are concentrated in the vicinity of a feedlot, movement through the soil profile is relatively slow. Such water represents only a small portion of total aquifer recharge. Concentration of nitrate water under feedlots may be totally absent in some soil profiles or may decline noticeably with depth. It is believed that this phenomenon is caused by denitrification [Viets, 1971].

Percolation of undesirable mineral and organic compounds in the soil profile underlying confined cattle feeding operations was the subject of a detailed study conducted in northeastern Colorado [Stewart, et. al., 1967]. Nitrate and nitrogen compounds were given the primary emphasis. Soil cores were analyzed for nitrate, ammonium, nitrite, redox potential (oxidation-reduction potentials), water percentage, and hydraulic conductivity. In addition, organic carbon, pH and conductivity of saturated paste extracts, and bacterial counts were conducted on samples of selected cores.

A total of 19 feedlots were investigated, including 12 within the Larimer-Weld region. Corrals studied in the two-county area ranged in age from 65 years old to relatively new. Most of the pens contained from 75 to about 300 head. Operation of the feedlots varied from intermittent to continuous. Sampling activity provided a range of quality data that were occasionally quite diverse. Cores from some feedlots were devoid of nitrate; others were quite high. Dissimilarities are often caused by the differences in soil aeration status, as shown by redox potential values. The aeration differences are probably related to manure management and stocking rates of various corrals.

Average data characteristic of nitrate-nitrogen distribution beneath the feedlots studied in Larimer and Weld Counties are presented graphically in Figure 5.2-A. The nitrate distribution data demonstrates that corrals generally contained little nitrate in the top few inches, large amounts for the next several feet, and rapidly decreasing amounts at greater depths.

The absence of nitrate in significant quantities at shallow depths probably relates to the lack of oxygen, evidenced by the low redox values measured in many of the soil samples. No nitrate was found when a low redox potential existed. Because ammonium was generally present in corrals at high levels, substantial amounts of nitrate were found when the redox potential was high. The critical redox potential necessary for nitrate accumulation appears to be on the order of 320 to about 340 mv [Pearsall & Mortimer, 1939; Patrick, 1960]. This was substantiated by the findings of the northeastern Colorado study [Stewart, et. al., 1967].

The rapid decrease and sometimes complete absence of nitrate at deeper depths in the soil profile under corrals is attributable to denitrification. This occurs even at several feet below the ground surface. Consequently, much of the nitrate present under feedlots will probably never reach the water table [Stewart, et. al., 1967].

Soil profiles and groundwater may exhibit nitrate nitrogen from natural deposits and from the decomposition of organic material. Natural sources of nitrate should not be discounted in the appraisal of potential nitrate degradation attributable to agricultural practices.

Research was recently completed in the Fort Collins vicinity which sought to define how an earth-surfaced feedlot functions in temporary waste storage and decomposition [Norstadt & Porter, 1976]. The investigation identified processes and reactions occurring in the surface profile, and explored the related effects produced in underlying soil, water, and soil gases. The report concluded that feedlots stocked and managed in a manner comparable to the one reviewed do not appear to be a hazard to soil and groundwater.

5.2.3 Impact of Manure Disposal on Water Quality

Manure disposal represents a major aspect of agricultural solid waste management. In recent years, its significance has become even more pronounced with the development of large confined animal feeding operations, and the siting of many such facilities in relatively close proximity to one another. Present practice in the region does not generally involve hauling manure long distances from its source. Hence, manure application rates to soils in areas of dense feedlot concentrations may be excessive.

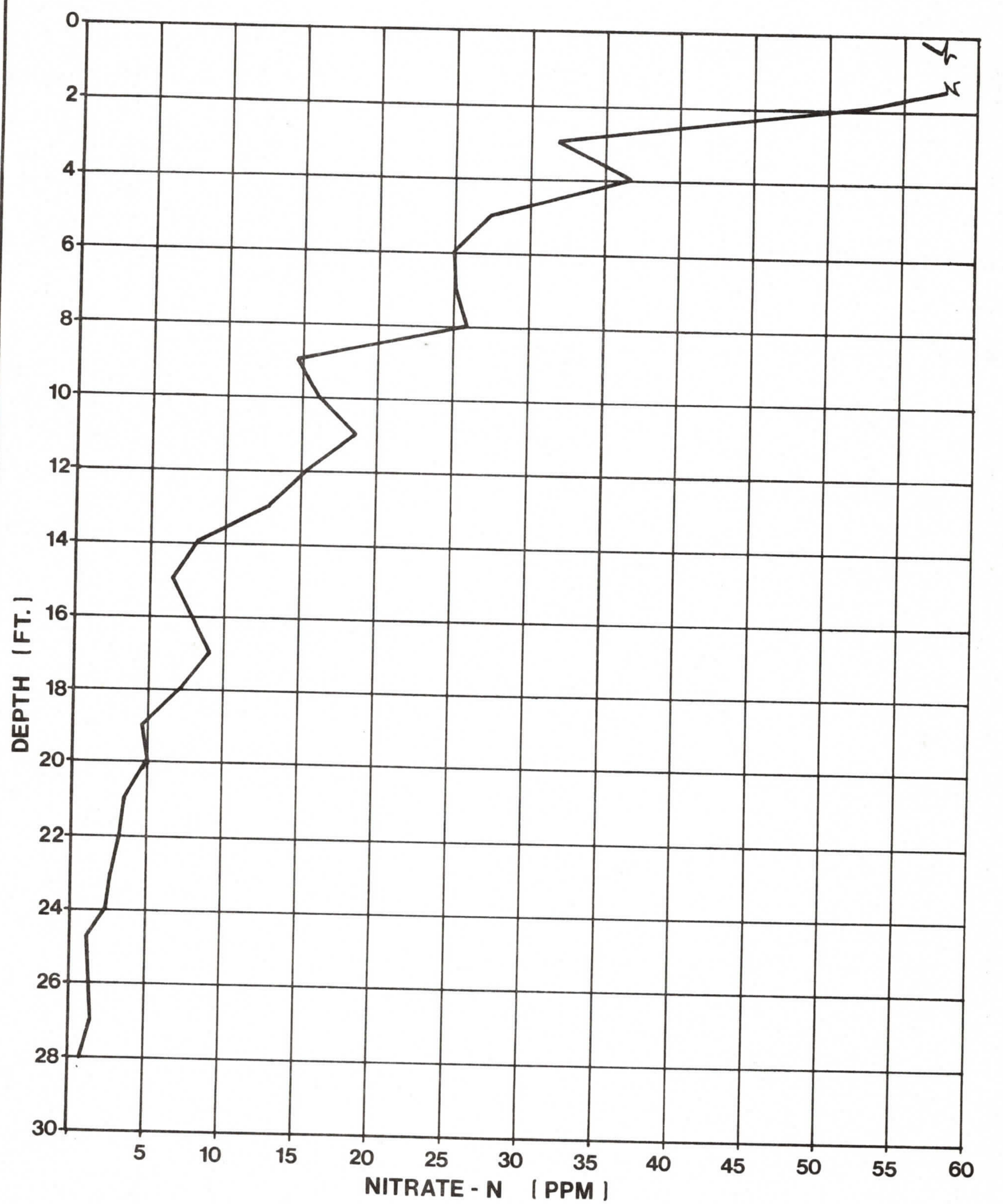


FIG. 5.2-A AVERAGE NITRATE - N DISTRIBUTION WITH SOIL PROFILE DEPTH UNDER CONTINUOUSLY AND INTERMITTENTLY USED CORRALS [a] LARIMER & WELD COUNTIES

[a] based on Stewart et al., 1967

An effort was made to determine manure application rates to irrigated lands where known heavy concentrations of cattle feedlots exist. Township 5N, Range 64 West (Kersey area), and Township 4N, Range 66 West (Gilcrest area) were found to be the two areas with the greatest number of cattle on feed. These two areas represent nearly 65 percent of the total cattle on feed within the two-county area. A seven mile radius was marked from the center of each township. Major feedlots were then located and plotted within each seven mile radius circle. Information is depicted on Figure 5.2-B. Each circle represents 98,520 acres. The Gilcrest area shows 54,400 acres of this total as irrigated lands where manure would be applied. The Kersey area has 63,000 acres of irrigated land, two out of every three acres. Acreage was calculated from SCS Weld County Land Use maps. The seven mile radius from the center of each township was chosen because personal interviews indicated that the actual spreading of cattle manure is generally conducted within seven miles of where it was generated.

Tables 5.2-A and 5.2-B list major feedlots located in the Gilcrest and Kersey areas, respectively. An average inventory for each feedlot for 1976 is also presented. The total cattle on feed (includes an estimated 20,000 head within each of these areas where cattle are being fed in lots from 0 to 300 head capacity) in the Gilcrest area was 138,000 and the Kersey area showed 152,800 head on feed. By using 10.4 pounds manure, dry weight basis, generated annually by a 1000 pound bovine [Viets, 1971], and by adding 35 percent moisture as average for a ton of manure, the Gilcrest area produces 400,000 tons of cattle manure yearly. Each irrigated acre within this area has available 7.4 tons of cattle manure. The Kersey area with 152,800 head on feed produces 446,000 tons of manure annually which converts to 7.1 tons of manure available for each irrigated acre within the area. These manure loading rates are based on average uniforn distribution to available irrigated lands, and are not purported to represent actual loading practice. Naturally all irrigated acres within each of the two areas studied would not have the same amount of manure applied annually. Some irrigated acres may have large amounts of manure applied and combined with heavy rates of commercial fertilizer would jeopardize the quality of ground waters.

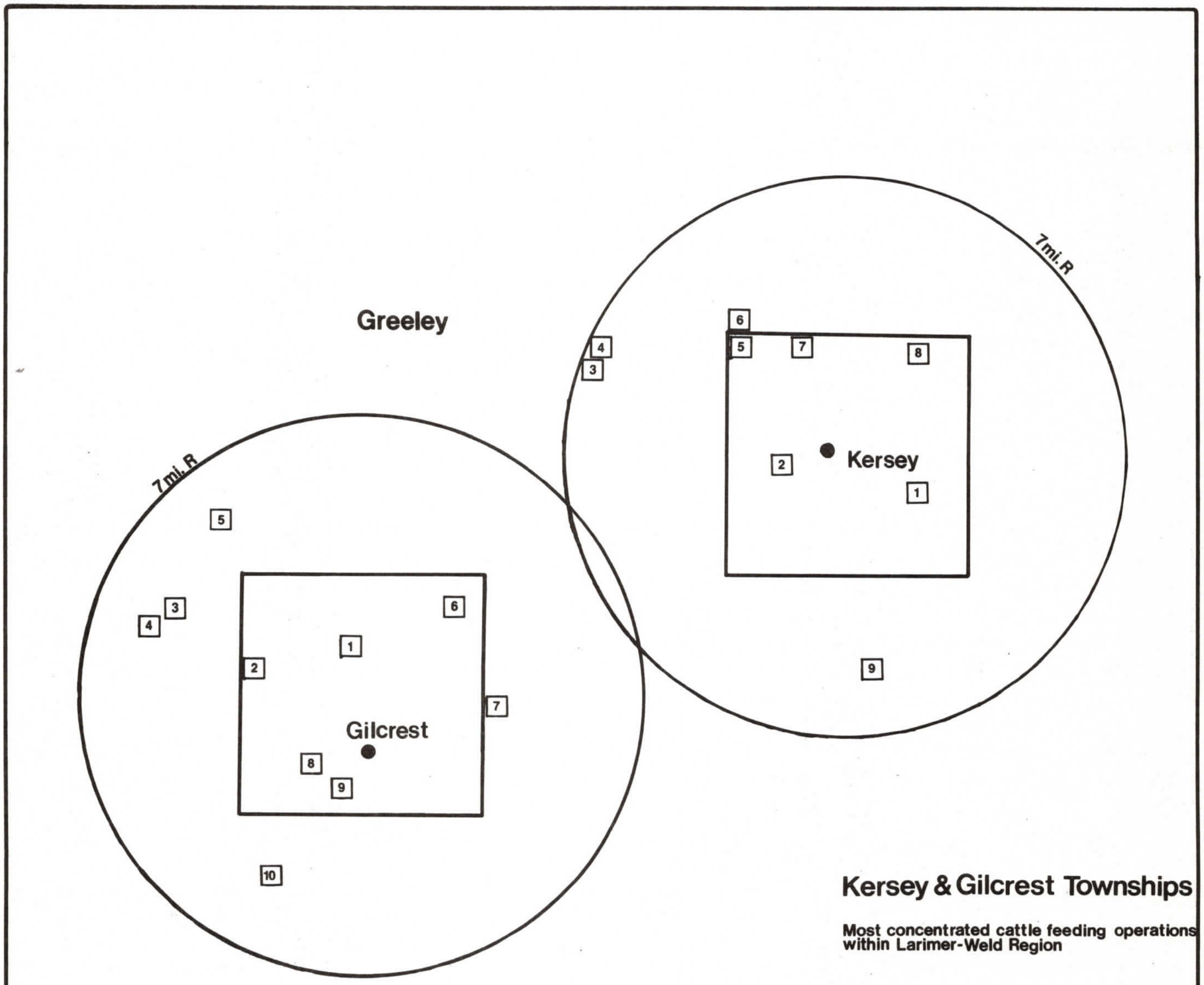

Greeley
7mi.R
7mi.R
Kersey
Gilcrest
1
2
3
4
5
6
7
8
9
10
Kersey & Gilcrest Townships
Most concentrated cattle feeding operations within Larimer-Weld Region

Figure 5.2 - B

TABLE 5.2-A. FEEDLOT INVENTORY
GILCREST TOWNSHIP AREA (a)

		AVG. INVENTORY (b,c)
1	Monfort's Gilcrest Lot	75,000
2	Ehrlich Feedlot	7,000
3	Colorado Alfalfa Products	2,500
4	Tom & Dean Binder	800
5	Blehm Feedlot	10,000
6	Miller Feedlot #1	15,500
7	Warren McMillen	2,000
8	Sidney & Leonard Strear	3,000
9	Strear #2 Lot	1,000
10	Tuttle Cattle Co.	20,000 (Sheep) 1,200 (Cattle)
	Total (Beef Only)	118,000
	Estimated Cattle in Small Lots	20,000
	TOTAL FOR GILCREST AREA	138,000

(a) Average inventory data may vary from that identified in Appendices A and B due to differing data and source of information.
(b) Burford & Varani, 1976.
(c) Colorado Department of Agriculture, 1976.

TABLE 5.2-B. FEEDLOT INVENTORY
KERSEY TOWNSHIP AREA (a)

		AVG. INVENTORY (b,c)
1	Monfort's Kuner Lot	74,000
2	Vic Klein	700
3	Farr Feedlot #1	15,000
4	P.L. Rutland	1,000
5	Webster Feedlot	15,000
6	Farr Feedlot #2	20,800
7	Ruben Sitzman Lot	500
8	Ed Meyer	4,000
9	Miller Feedlot	800
	Total	132,800
	Estimated Cattle in Small Lots	20,000
	TOTAL FOR KERSEY AREA	152,800

(a) Average inventory data may vary from that identified in Appendices A and B due to differing data and source of information.
(b) Burford & Varani, 1976.
(c) Colorado Department of Agriculture, 1976.

The investigation of nitrate occurrence under feedlots and corrals in Larimer and Weld Counties which was conducted in 1967 also sought to define presence of this nutrient in soils underlying irrigated fields. These agricultural lands have been subject to both manure loading and commercial fertilization. Results of the investigation are plotted in Figure 5.2-C. Cultivated crops included alfalfa, sugar beets, barley, potatoes, beans, and corn. It is evident from the graph that nitrate concentrations are greatest in the root zone area, and diminish rapidly with depth. It can be concluded that fertilization practice on the fields analyzed poses a negligible threat to groundwater quality.

It should be pointed out that the investigation summarized herein for nitrate distribution under irrigated fields in Larimer and Weld Counties took place in 1967 [Stewart, et. al., 1967]. The confined cattle feeding industry has experienced significant expansion since this time, as indicated in Table 5.2-C.

TABLE 5.2-C. GROWTH OF CONFINED CATTLE FEEDING

YEAR	CATTLE FATTENED ANNUALLY LARIMER COUNTY	WELD COUNTY	TOTAL
1964 [a]	36,907	367,116	404,023
1969 [a]	51,506	671,459	722,965
1974	40,204 [b]	794,273 [c]	834,477

[a] U.S. Department of Commerce, February, 1973.
[b] U.S. Department of Commerce, August, 1976.
[c] U.S. Department of Commerce, July, 1976.

Because of the increased magnitude of the regional manure management problem, livestock waste application to fields by individual farmers could be occurring at rates conducive to water quality impairment in the long-term.

It is recommended that additional investigation be conducted in known areas of concentrated animal feeding to determine on-farm manure and fertilizer application practices and associated water quality impacts. A groundwater sampling program would be an integral component of the proposed program (especially to measure levels of total dissolved solids and nitrates).

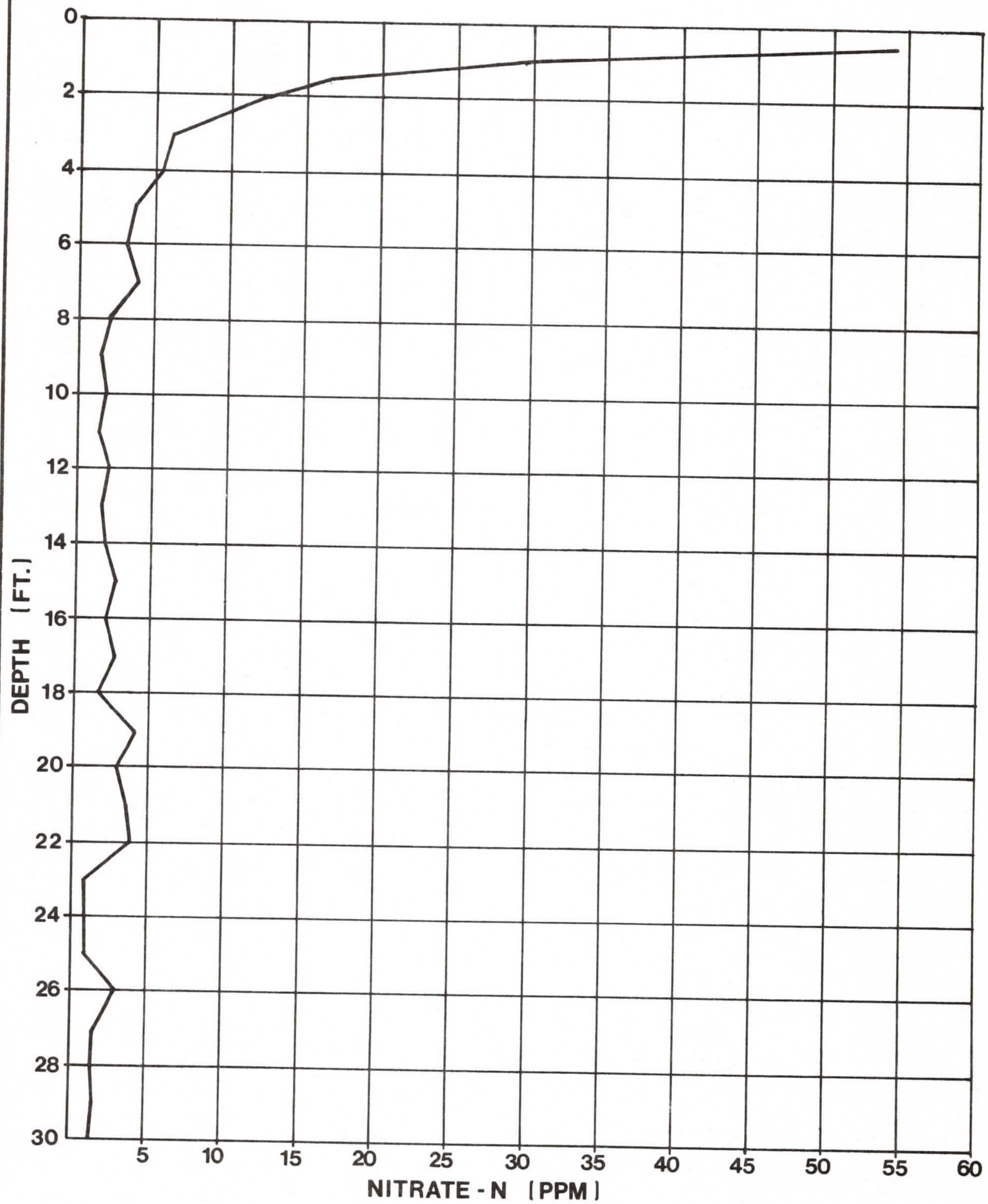


FIG. 5.2-C AVERAGE NITRATE-N DISTRIBUTION WITH SOIL PROFILE DEPTH UNDER IRRIGATED FIELDS [a]
LARIMER & WELD COUNTIES

[a] based on Stewart et al., 1967

Data are available in files maintained by the State Department of Health with which manure loading rates to agricultural lands managed by feedlot operators can be determined. Annual application rates range from less than 5 to slightly over 30 tons per acre. Cumulative availability of nitrates in cropland subject to a long history of manure loading can lead to groundwater quality impairment if annual rates are excessive. This does not appear to be occurring as a result of manure application rates practiced on many of the lands managed by feedlot operators. However, long-term manure loading implemented on some fields is conducive to groundwater quality degradation. The situation could be aggravated in any field where the nutrient value of manure is excessively supplemented with commercial fertilizers. A paucity of data on manure spreading rates practiced by individual farmers in the region did not allow potential water quality impacts to be evaluated.

A great many uncertainties exist concerning the direct relationship between existing manure and commercial fertilizer use and observed degradation in surface waters of the region. Irrigation return flows are known to be a source of river system nitrate enrichment. Such waters convey nitrates leached from fields subject to over-fertilization.

5.2.4 Existing Surface Water Quality

Nitrate characteristics of the major drainages in the region are presented in Figures 5.2.4-A through 5.2.4-E.

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 5.2.4-A). A significant amount of this loading is due to the irrigation return flows. In the Big Thompson, nitrate concentrations increase significantly from the lower reaches to the mouth (Figure 5.2.4-B). Even so, levels at the mouth are generally fairly low--less than 2 mg/l of nitrogen. In fact, nitrate levels were found to be less than 1 mg/l to the confluence with the Little Thompson River. Nitrate levels increase from very low levels as the Little Thompson 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). Levels of nitrate in the St. Vrain Creek generally range between 2 and 3 mg/l (Figure 5.2.4-D). Nitrate content 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 (Figure 5.2.4-E).

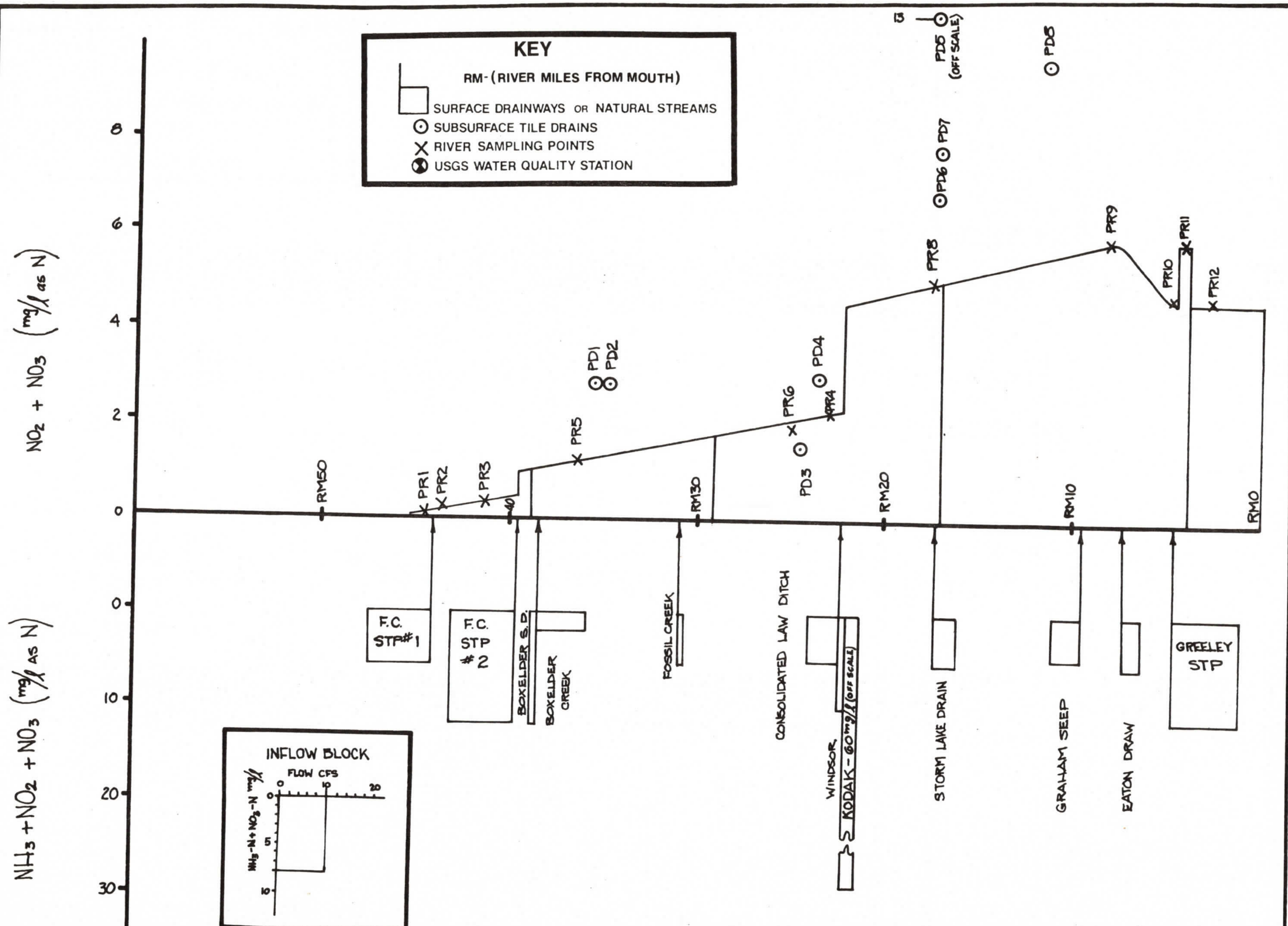
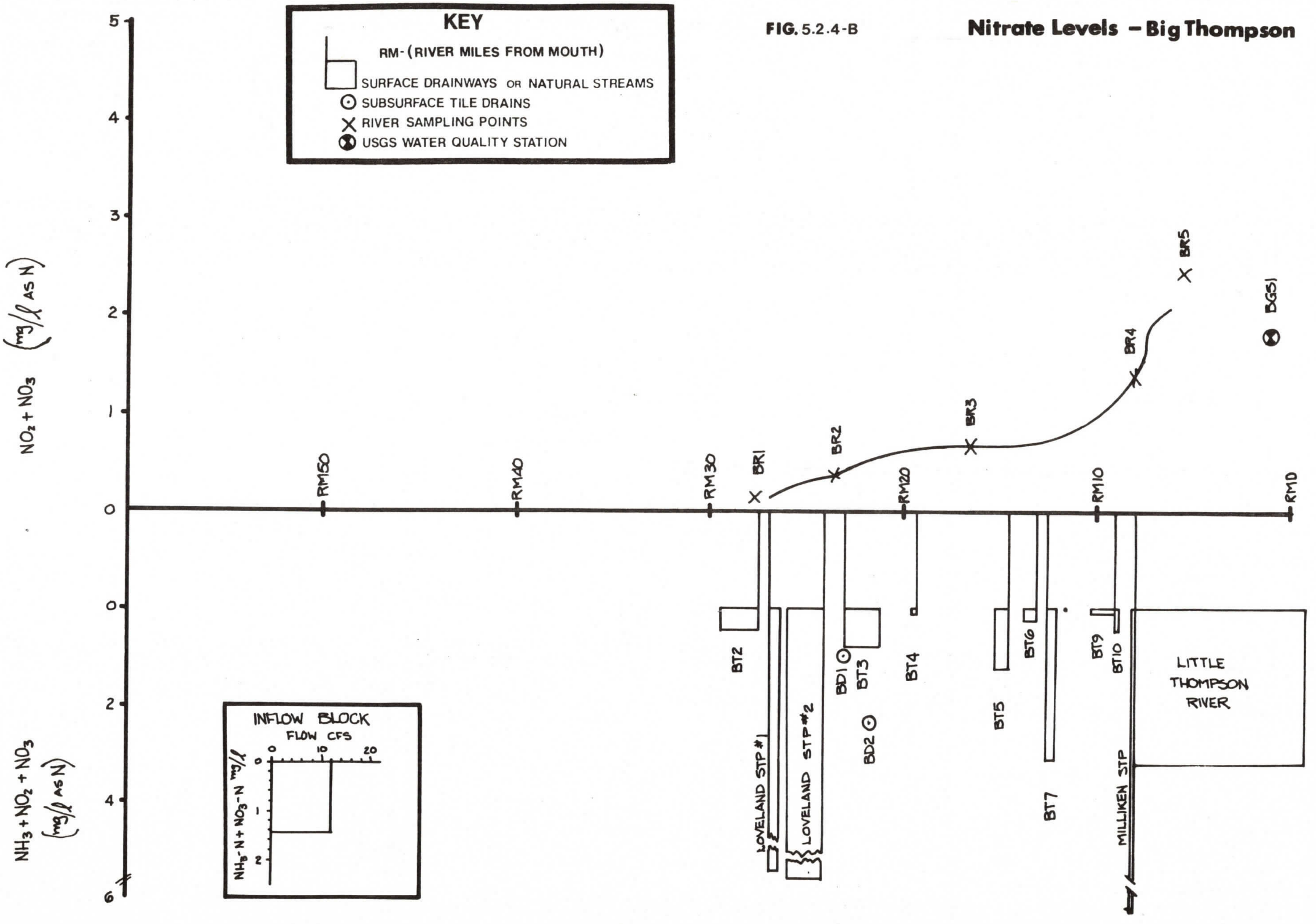


FIG. 5.2.4-A **Nitrate Levels - Cache La Poudre**

Nitrate Levels – Big Thompson

FIG. 5.2.4-B



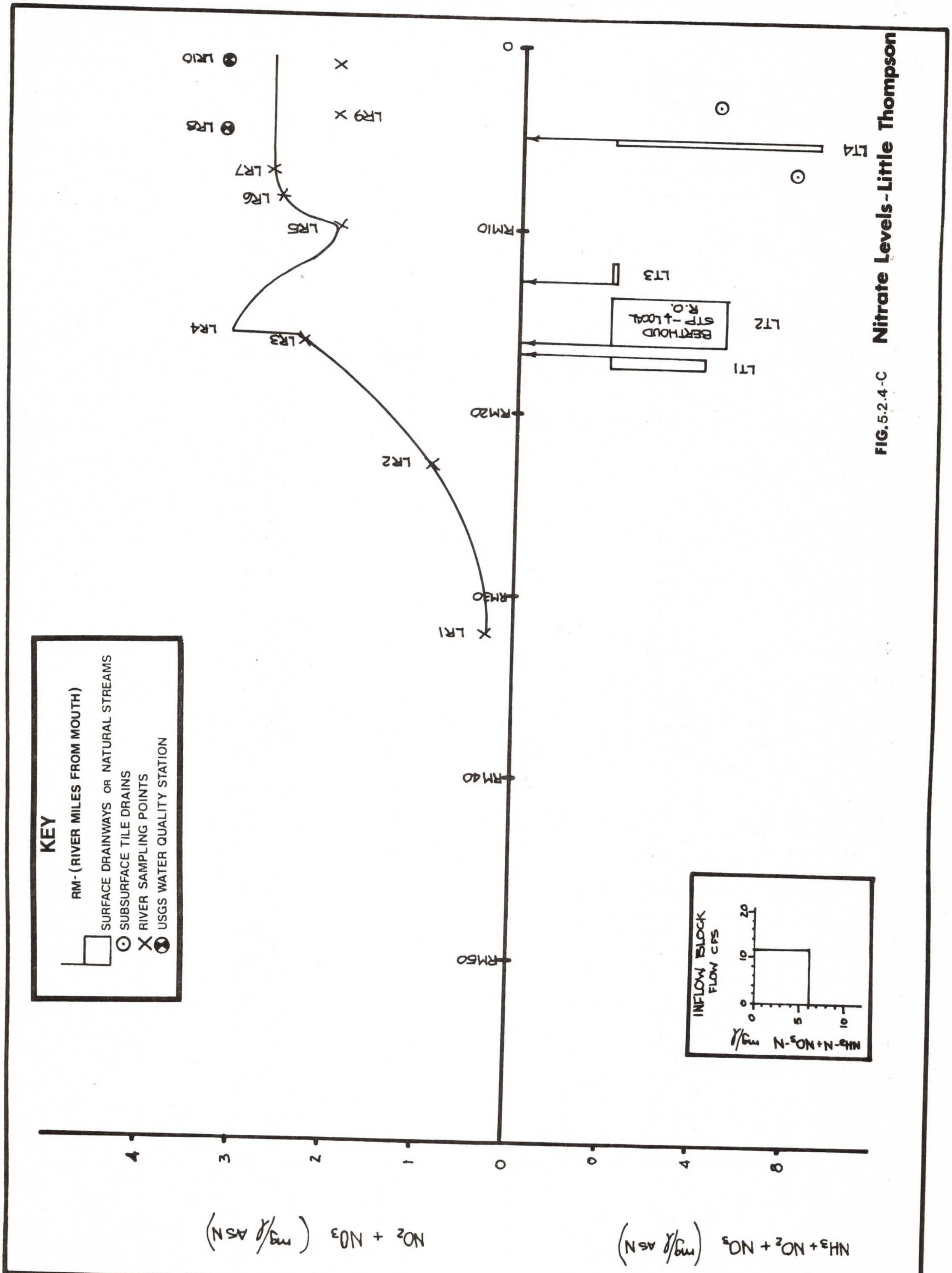
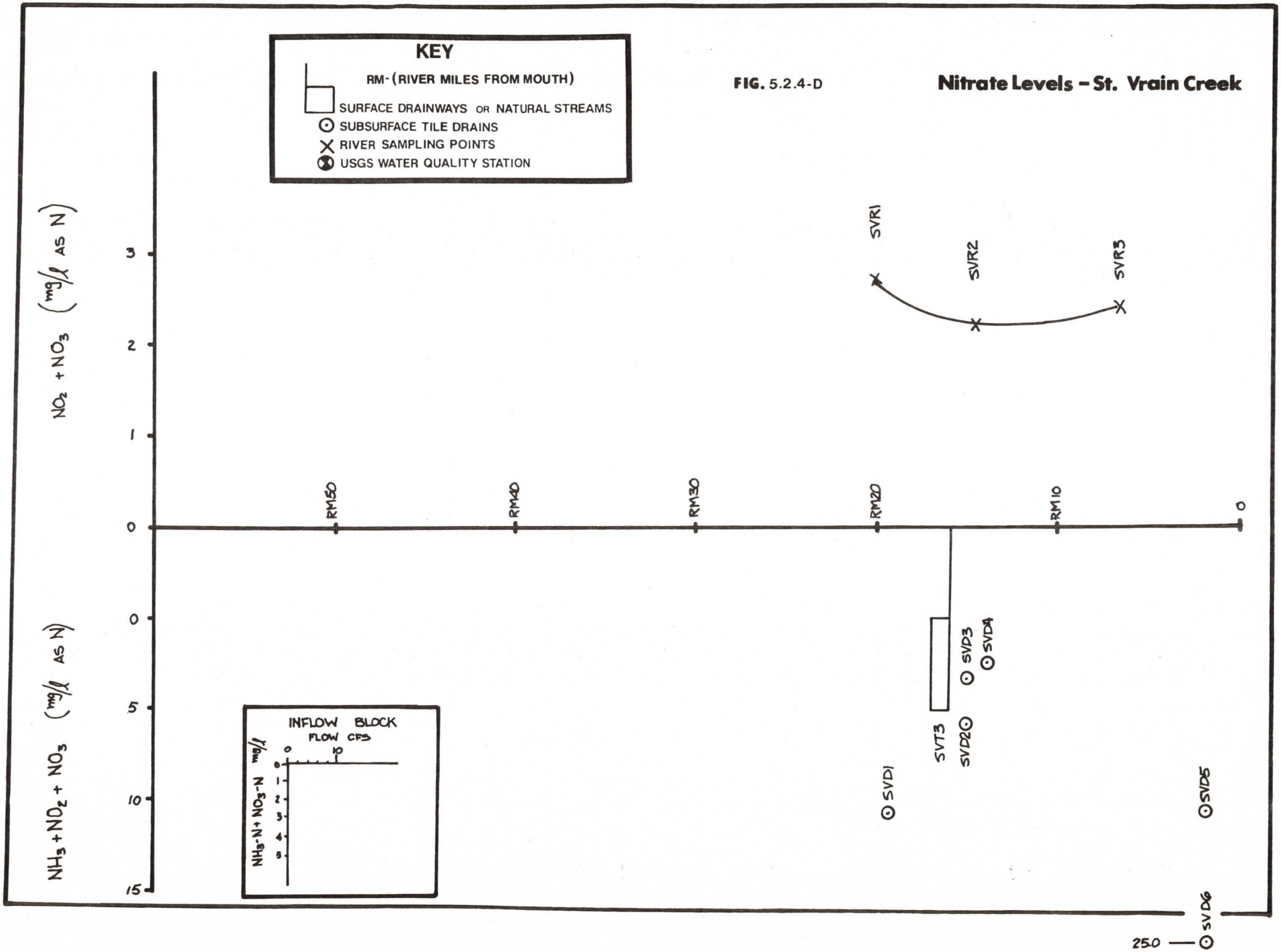


FIG. 5.2.4-C Nitrate Levels-Little Thompson

Nitrate Levels – St. Vrain Creek

FIG. 5.2.4-D



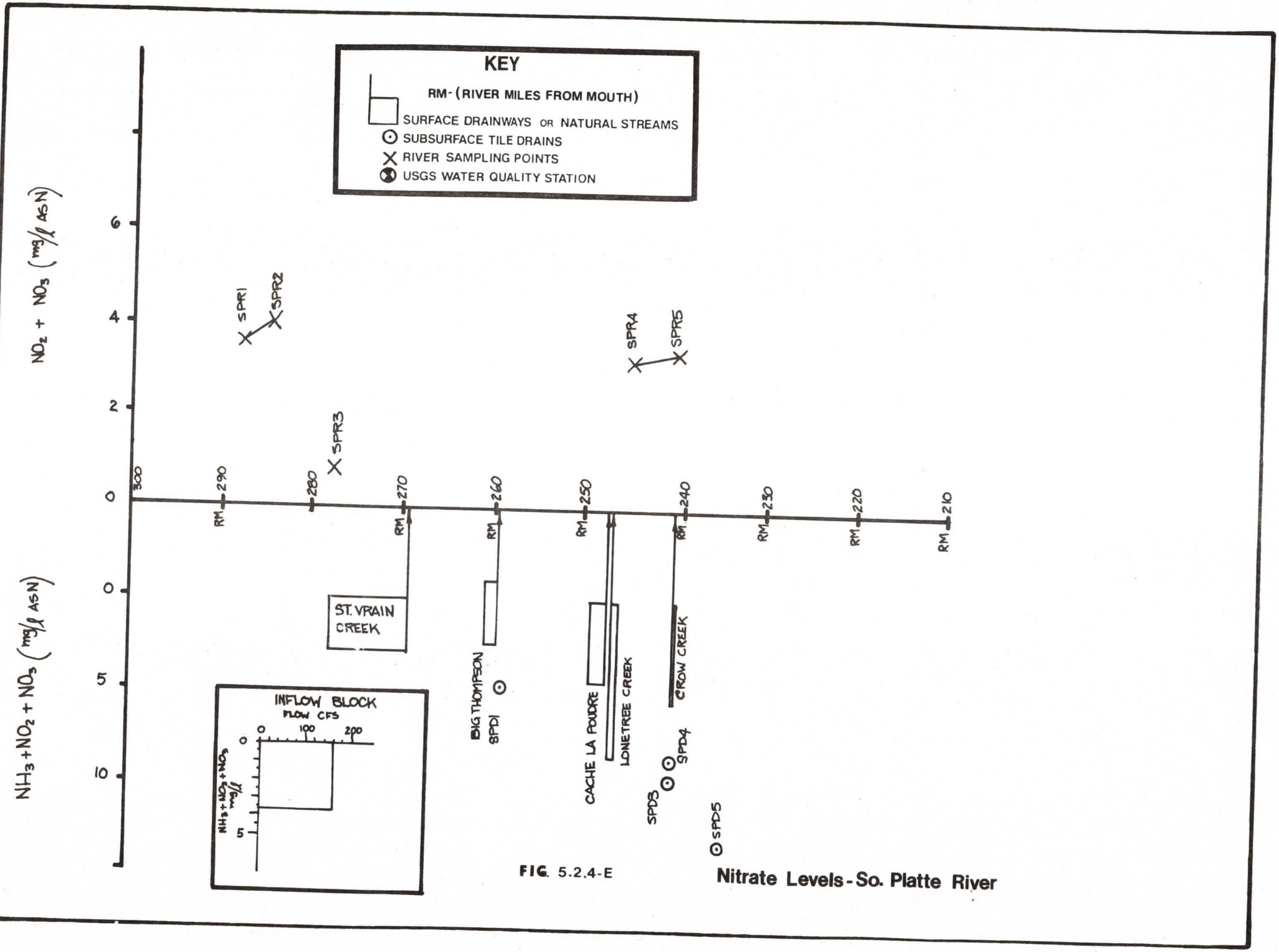


FIG. 5.2.4-E Nitrate Levels - So. Platte River

6.0 IMPACT OF REGULATORY MEASURES

Impetus for installing systems on confined livestock feeding operations to manage wastewater and runoff has largely been created by recent legislation at the Federal level. Responsibility for program enforcement lies with the State. A number of feeders have constructed facilities of their own accord to improve sanitary conditions or facilitate operation of their feedlot or dairy.

6.1 FEDERAL REGULATIONS FOR CONFINED ANIMAL FEEDING OPERATIONS

On February 14, 1974, EPA promulgated effluent limitations, guidelines, and new source performance standards for the feedlot category of point sources. [Federal Register, 1974]. The regulations were issued pursuant to sections 301, 304(b) and 306 of the Federal Water Pollution Control Act Amendments of 1972. The regulation defines the term "feedlot" to mean "a concentrated animal or poultry growing operation for meat, milk, or egg production, or stabling, in pens or houses wherein the animals or poultry are fed at the place of confinement and crop or forage production is not sustained in the place of confinement". The applicability of the regulations was defined to pertain only to feeding operations in excess of 1,000 animal units.

Regulations promulgated in the Federal Register, Vol. 39, No. 32, February 14, 1974, specify that definitions of probable recurrence intervals of rainfall be those developed by the National Weather Service in Technical Paper Number 40, "Rainfall Frequency Atlas of the United States", May, 1961, and subsequent amendments, or equivalent regional or state rainfall probability information developed therefrom. The isohyets in Figures 6.1-A and 6.1-B depict the magnitude of rainfall events in the Larimer-Weld regional area with a probable recurrence interval of once in ten years and once in twenty-five years, respectively. [U.S. Department of Commerce, 1967].

In a lawsuit filed in the Federal District Court for the District of Columbia, the National Resources Defense Council (NRDC) challenged the exercise of the Environmental Protection Agency Administrator's discretion in not establishing a program whereby National Pollutant Discharge Elimination System (NPDES) permits be issued to <u>every</u> point source. The District Court ruled in favor of NRDC. On June 10, 1975, EPA was issued a final order requiring the agency to propose and promulgate regulations to extend the NPDES permit system to include all point sources, including concentrated animal feeding operations in the size range less than 1,000 animal units, previously omitted.

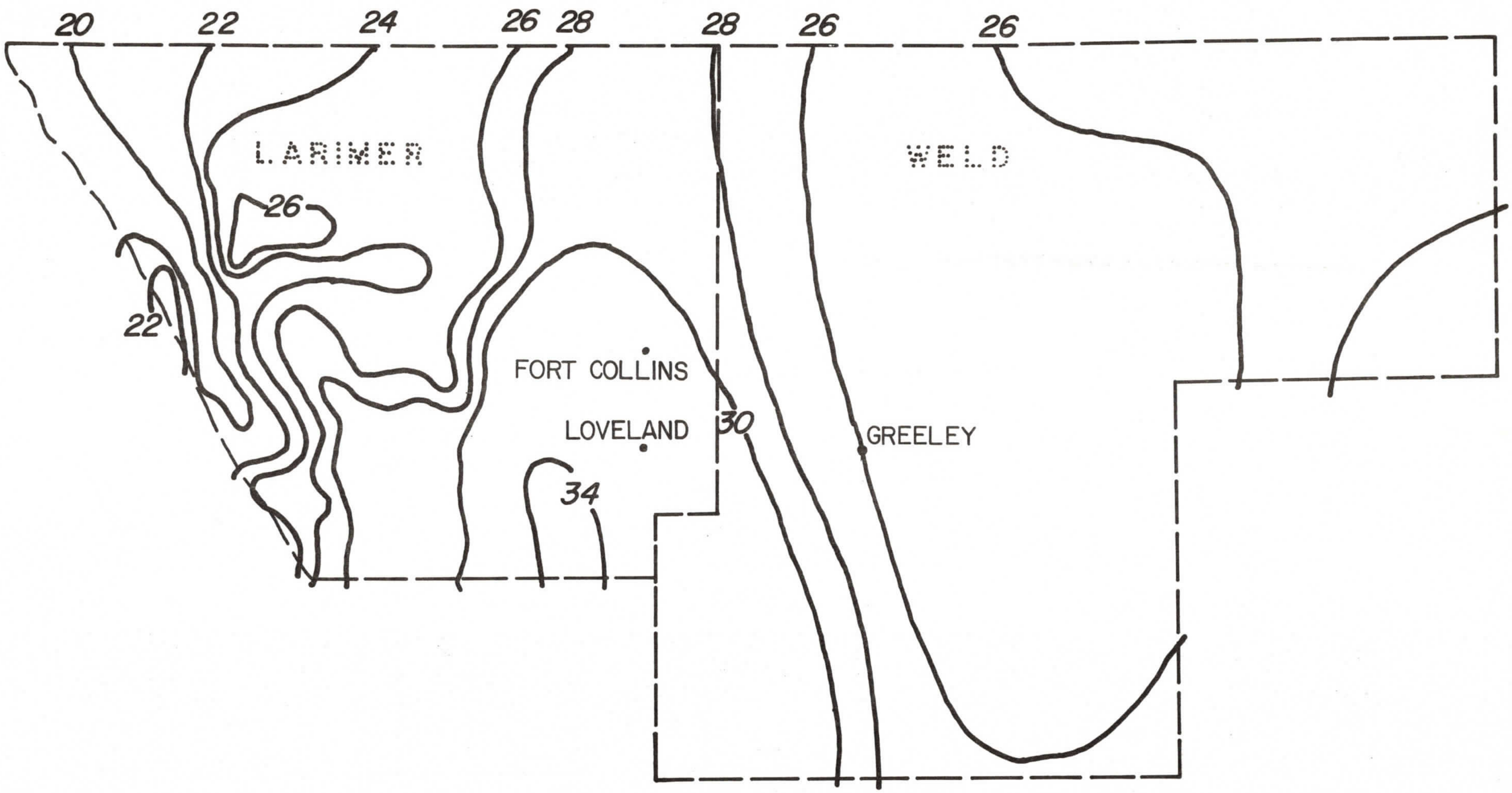


FIGURE 6.1-A. ISOPLUVIALS OF 10-YR. 24 HR. PRECIPITATION IN TENTHS OF AN INCH (a)
LARIMER-WELD COUNTIES, COLORADO

(a) Ref. U.S. Dept. of Commerce, 1967

TOUPS CORPORATION

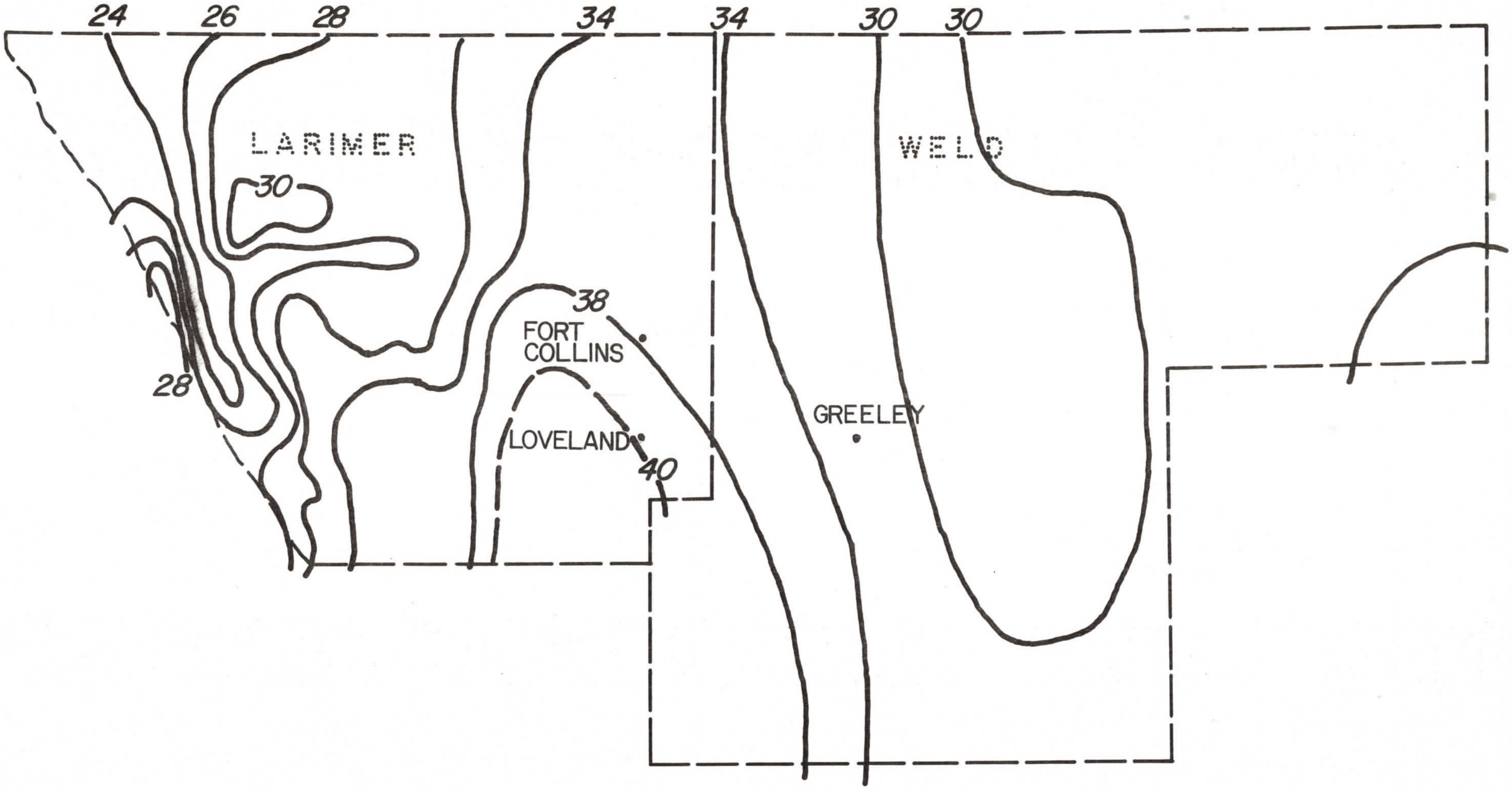


FIGURE 6.1-B. ISOPLUVIALS OF 25-YR. 24-HR. PRECIPITATION IN TENTHS OF AN INCH (a)
LARIMER-WELD COUNTIES, COLORADO

(a) Ref. U.S. Dept. of Commerce, 1967

TOUPS CORPORATION

Declaration of new NPDES regulations for feedlots took place on March 18, 1976 [Federal Register, 1976]. Basic structure of the feedlot program was expanded to include operations with a capacity less than 1,000 animal units. Details of the program are summarized in Table 6.1-A. Animal equivalency was defined according to the following criteria:

1,000	Beef Cattle
700	Dairy Cattle
2,500	Swine
10,000	Sheep
55,000	Turkies
100,000	Chickens (if the operation has continuous overflow watering)
30,000	Chickens (if the operation has a liquid manure handling system)
5,000	Ducks
500	Horses

Subsequent to promulgation of the feedlot directives of March 18, 1976, the Permits Section, Enforcement Division, Environmental Protection Agency, Region VIII, issued guidelines titled "New Strategy for Issuing Permits for Feedlots in Region VIII". [Shankland & Burm, 1976]. The outlined strategy provides direction for the drafting of NPDES permits for feedlots in those states not having delegation of the NPDES Permit Program. States in Region VIII that administer the Permit Program, including Colorado, have been urged to use a similar approach [Frenette, 1976]. Table 6.1-B summarizes the degree of treatment considered to correspond to Best Practicable Control Technology (BPCT) and Best Available Technology (BAT) as applied to various sized confined feeding operations in EPA Region VIII. The strategy and supporting rationale developed by Region VIII to administer the NPDES Permit Program to feedlots greater than and less than 1,000 head capacity are presented herein.

6.1.1 Feedlots Greater Than 1,000 Animal Units

Most of the NPDES permits issued in Colorado have been for operations of 1,000 or more animal units. Approximately 60 permits in Weld County and 10 permits in Larimer County have been approved to date. Permit conditions for facilities of 1,000 unit capacity were based on the "Effluent Guidelines and Standards, Feedlots Point Source Category" promulgated February 14, 1974 [Federal Register, 1974]. For existing discharges, NPDES permits require compliance with Best Practicable Control Technology (BPCT) on/or before July 1, 1977. Implementation of Best Available Technology (BAT) is to occur on/or before July 1, 1983.

TABLE 6.1-A. BASIC STRUCTURE OF FEEDLOT PROGRAM PROMULGATED MARCH 18, 1976

FEEDLOTS WITH 1,000 OR MORE ANIMAL UNITS (a)	FEEDLOTS WITH LESS THAN 1,000 BUT WITH 300 OR MORE ANIMAL UNITS (a)	FEEDLOTS WITH LESS THAN 300 ANIMAL UNITS (a)
Permit required for all feedlots with discharges (b) of pollutants.	Permit required if feedlot-- 1) Discharges pollutants through a manmade conveyance (b), or 2) Discharges pollutants into waters passing through or coming into direct contact with animals in the confined area. (b) Feedlots subject to case-by-case designation requiring an individual permit only after onsite inspection and notice to the owner or operator.	No permit required (unless case-by-case designation as provided below). Case-by-case designation only if feedlot-- 1) Discharges pollutants through a manmade conveyance, or 2) Discharges pollutants into waters passing through or coming into direct contact with the animals in the confined area; and After onsite inspection, written notice is transmitted to the owner or operator

(a) The term "animal unit" means a unit of measure for any feeding operation calculated by adding the following numbers: the number of slaughter and feeder cattle multiplied by 1.0, plus the number of mature dairy cattle multiplied by 1.43, plus the number of swine weighing over 55 pounds multiplied by 0.4, plus the number of sheep multiplied by 0.1, plus the number of horses multiplied by 2.0.

(b) Feedlot not subject to requirement to obtain permit if discharge occurs only in the event of a 25-year 24-hour storm event.

SOURCE: FEDERAL REGISTER, Thursday, March 18, 1976, EPA, State Program Elements Necessary For Participation in the National Pollution Discharge Elimination System -- Concentrated Animal Feeding Operations.

TABLE 6.1-B. DEFINITION OF EFFLUENT GUIDELINES AND STANDARDS

	ANIMAL UNIT CATEGORY	
	Less Than 1,000 (a)	More Than 1,000 (b)
BPCI (c)		
Containment Facilities	Not Defined	10-Year, 24-Hour Precipitation Event
Compliance Date	-	July 1, 1977
BAT (d)		
Containment Facilities	10-Year, 24-Hour (e) Precipitation Event	25-Year, 24-Hour Precipitation Event
Compliance Date	On/Or Before July 1, 1983	On/Or Before July 1, 1983

(a) Permit conditions based on State program elements necessary for participation in the NPDES, Confined Animal Feeding Operations, March 18, 1976. [FEDERAL REGISTER, 1976].
(b) Permit conditions based on Effluent Guidelines and Standards, Feedlots Point Source Category, February 14, 1974. [FEDERAL REGISTER, 1974].
(c) Best Practicable Control Technology.
(d) Best Available Technology
(e) Defined in "New Strategy for Issuing Permits in Region VIII", [Shankland & Burm, 1976].

The strategy presently used by the Permits Section, Enforcement Division, EPA Region VIII, requires that new discharges meet the standards of performance for new sources from the on-set of operation, which equates to immediate employment of BAT.

6.1.2 Feedlots Less Than 1,000 Animal Units

The NPDES regulations for concentrated animal feeding operations promulgated on March 18, 1976, did not define BPCT, BAT, and Standards of Performance for new sources for feedlots smaller than 1,000 animal units. [Federal Register, 1976]. Because of time involved in normal permit processing, most of the new permits for feedlots in this size range could not become effective until sometime after January 1, 1977. Generally one to two years is required for permit applicants to provide necessary waste retention controls. Hence, for most operators compliance with BPCT would occur after the July 1, 1977, date legally specified by Public Law 92-500.

In view of the foregoing situation, it did not seem reasonable for EPA, Region VIII, to define BPCT for feedlots with less than 1,000 animal units. [Shankland & Burm, 1976]. Rather, BAT was defined. The compliance date identified in individual permits is to be based on engineering judgment of a reasonable amount of time to construct appropriate containment facilities, not to exceed July 1, 1983. Definition of BAT for feedlots possessing a capacity of less than 1,000 animal units was less stringent than that developed for the larger operations. This relates at least in part to the economic burden associated with implementation of pollution abatement measures.

6.2 STATE REGULATIONS FOR CONFINED ANIMAL FEEDING OPERATIONS

The Colorado Department of Health has recently prepared a draft copy of proposed guidelines for the control of runoff from livestock confinement areas. [Colorado Department of Health, January, 1977]. Purpose of the document is to provide direction for the design and construction of runoff containment facilities which will satisfy state and Federal requirements. Technical design criteria is also developed. The proposed guidelines indicate that volume of containment facilities be sized to accommodate runoff generated by a precipitation event rather than total rainfall tributary to the feedlot. The Soil Conservation Service has devised various curves which describe the relationship between rainfall and direct runoff. The SCS method of sizing retention facilities is preferred by the Colorado Department of Health because of the technique's conservative nature. In addition, solids capacity of 25 percent is provided.

6.3 ANIMAL WASTE SYSTEMS IN THE REGION

Since 1970, a tremendous effort has been expended by livestock feeders to control wastewater and runoff from their facilities. Details of systems in the region are highlighted herein.

6.3.1 Presently Installed Systems

The Soil Conservation Service is providing technical assistance to farmers and feeders in planning, designing, and installing complete waste management systems. Facilities are tailored to the requirements of individual owners or operators. Wastes are utilized or disposed of in ways that negate the occurrence of nuisance conditions or water quality degradation. Complete waste systems may include components which accomplish the following [Loomis, 1976]:

- Divert native water away from areas where wastes are concentrated;
- Provide controlled drainage of runoff from confined feeding areas;
- Prevent leaching of contaminants to groundwater;
- Collect degraded runoff;
- Treat, utilize, and dispose of collected runoff in an appropriate manner.

Feeders may approach SCS for guidance, or may elect to utilize the services of private engineering consultants.

Presently installed control systems inventoried in Larimer and Weld Counties are identified in Tables 6.3-A and 6.3-B, respectively. A total of nearly 100 facilities exist. Nature of feeding operations served by systems are summarized by county in Table 6.3-C.

Per head costs representative of containment facilities in terms of feedlot capacity are summarized in Tables 6.3-D and 6.3-E for Larimer and Weld Counties, respectively. Feeders identified in the tabulations are those for which data was readily available. A total listing of operators with control systems was previously presented in Tables 6.3-A and 6.3-B.

TABLE 6.3-A

LARIMER COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
1	?	Dairy	?	?	3,190	1973
2	SE1/4 SE1/4 Sec. 34 & SW1/4 SW1/4 Sec. 35 T8N, R68W	Dairy	Inventory Avg: 300	?	6,801	1972
3	E1/2 SE1/4 Sec. 19, T5N, R68W	Dairy	Capacity: 80	1.65 AF	3,800	1973
4	Sec. 29, T7N, R68W	Beef	Capacity: 4,200	?	?	1976
5	NE1/4 Sec. 33, T4N, R69W	Goats	Capacity: 150	0.91 AF	3,200	1973
6	SE1/4 Sec. 11, T8N, R68W	Hogs	Capacity: 360	15,750 Gallons (Concrete Tank)	?	1976
7	NW1/4 Sec. 22, T10N, R68W	Hogs	Inventory Avg: 2,000	?	4,376	1972
8	NW1/4 Sec. 26, T4N, R64W	Dairy	Inventory Avg: 75	0.58 AF	2,000	1973
9	S1/2 Sec. 22, T8N, R68W	Beef	Inventory Avg: 1,000	9.0 AF	3,200	1972
10	N1/2 NE1/4 NE1/4 Sec. 30, T9N, R68W	Dairy	Capacity: 50	1.02 AF	840	1972
11	W1/2 NE1/4 Sec. 5, T4N, R69W	Dairy	Inventory Avg: 75	?	?	1971
12	SE1/4 Sec. 30, T6N, R68W	Dairy	Inventory Avg: 650	5.52 AF	12,000	1974
13	W1/2 Sec. 33, T4N, R64W	Beef	Inventory Avg: 100	?	2,000	1973

TABLE 6.3-A

LARIMER COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
14	NW1/4 Sec. 2, T6N, R68W	Beef	Inventory Avg: 4,000	?	?	1976
15	S1/2 N1/2 & N1/2 S1/2, SE1/4 Sec. 31, T4N, R68W	Dairy	?	?	?	1973
16	SE1/4 NW1/4 Sec. 10, T6N, R68W	Dairy	Inventory Avg: 200	1.3 AF	1,487	1973
17	S1/2 NE1/4 Sec. 1, T7N, R68W	Beef Lambs	Capacity: 3,000 Capacity: 5,000	4.3 AF	6,000	1974
18	1 Mi. N & 1 Mi. W of Waverly	Hogs	Capacity: 6,000	?	?	?
19	N1/2 NE1/4 Sec. 9, T6N, R68W	Hogs	Capacity: 600	9,000 Gallons (Concrete Tank)	11,260	1973
20	N1/2 NW1/4 Sec. 34, T8N, R69W	Dairy	Inventory Avg: 150	4,320 Gallons (Concrete Tank)	5,000	1972
21	NW1/4 Sec. 33, T8N, R69W	Dairy	?	8,760 Gallons (Concrete Tank)	13,000	1976
22	NE1/4 Sec. 26, T4N, R69W	Dairy	Inventory Avg: 250	?	2,000	1974

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
23	E1/2SW1/4 & SE1/4 Sec. 22, T6N, R67W	Beef	Inventory Avg: 600	?	?	?
24	NE1/4 Sec. 19, T5N, R67W	Beef	Inventory Avg: 1,500	7.44 AF	7,500	1974
25	NW1/4 Sec. 20, T7N, R64W	Hogs	Capacity: 2,000	?	?	1976
26	Sec. 30, T1N, R66W	Beef	Inventory Avg: 5,200	13.5 AF	?	1973
27	SW1/4 Sec. 22, T1N, R64W	Dairy	Capacity: 60	0.63 AF	2,500	1973
28	?	?	?	?	?	1971
29	SE1/4 Sec. 15, T6N, R66W	Beef	Inventory Avg: 3,000	4.8 AF	6,000	1972
30	S1/2 Sec. 25, T5N, R67W	Beef	Inventory Avg: 6,000	10.38 AF	7,800	1972
31	NW1/4 Sec. 17, T7N, R65W	Beef	Inventory Avg: 2,000	?	?	?
32	SE1/4 Sec. 19, T8N, R65W	Beef	Capacity: 5,000	?	?	?
33	SE1/4 Sec. 19, T9N, R65W	Beef	Inventory Avg: 10,000	?	?	1973

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
34	NW1/4 Sec. 21, T7N, R67W	Lambs & Beef	Capacity: 50,000 Lambs 500 Beef	41.2 AF	14,000	1973
35	SE1/4 Sec. 35, T7N, R67W	Dairy	Inventory Avg: 95	0.28 AF	1,800	1972
36	SE1/4 Sec. 29, T7N, R64W	Dairy	Inventory Avg: 700	2.6 AF	5,000	1972
37	NE1/4 NE1/4, Sec. 15, T5N, R64W	Dairy	Inventory Avg: 250	1.45 AF	4,135	1972
38	SW1/4 Sec. 2, T4N, R67W	Beef	Capacity: 3,200	11.0 AF	3,000	1973
39	SW1/4 Sec. 1, T3N, R68W	Beef	Capacity: 14,000	?	?	?
40	NE1/4 Sec. 26, T7N, R66W	Beef	Inventory Avg: 3,555	?	?	?
41	SW1/4 Sec. 14, T6N, R65W	Beef	Inventory Avg: 2,000	2.6 AF	3,500	1974
42	SW1/4 NW1/4, Sec. 17, T7N, R65W	Beef	Inventory Avg: 1,500	?	?	?
43	1 Mi. N of Adams Co. Line, 1 Mi. E of U.S. 85	Beef	Inventory Avg: 250	?	2,100	?
44	NW1/4 Sec. 18, T4N, R66W	Beef	Capacity: 10,000	?	7,000	1972

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
45	SW1/4, NE1/4, Sec. 26, T7N, R67W	Dairy	Inventory Avg: 140	1.32 AF	3,000	1974
46	SW1/4 Sec. 4 & NW1/4 Sec. 9, T5N, R65W	Beef	Inventory Avg: 14,500	?	25,000	1970
47	SW1/4 Sec. 31, T6N, R64W; NW1/4 Sec. 6, T5N, R64W	Beef	Capacity: 30,000	?	?	1974
48	NE1/4 NW1/4 Sec. 2, T6N, R67W	Beef	Inventory Avg: 700	1.25 AF	2,000	1971
49	SW1/4 Sec. 3, T7N, R66W	Beef	Capacity: 700	1.12 AF	2,000	1975
50	SW1/4 Sec. 31, T5N, R67W	Dairy	Inventory Avg: 400	2.8 AF	4,500	1972
51	?	Dairy	Capacity: 500	5.2 AF	8,500	1976
52	SE1/4 NE1/4, Sec. 21, T6N, R64W	Beef	Inventory Avg: 200	?	3,000	1971
53	NW1/4 Sec. 17, T6N, R66W	Beef	Inventory Avg: 1,500	4.16 AF	6,834	1976
54	NW1/2 NW1/4, Sec. 14, T7N, R66W	Beef	Capacity: 1,000	2.16 AF	2,000	1976

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
55	Sec. 17, T3N, R67W	Beef	Capacity: 2,500	34.4 AF	?	?
56	E1/2 NE1/4, Sec. 28, T4N, R64W	Hogs	Inventory Avg: 800	0.6 AF	1,000	1975
57	2 Mi. N of Greeley on Hwy 85, 1/2 Mi. W on Monfort Road	Beef	Inventory Avg: 325	?	?	?
58	Sec. 35, T4N, R64W	Beef	Capacity: 3,300	?	?	?
59	SE1/4 Sec. 30, T2N, R64W	Hogs	Capacity: 48	?	?	?
60	?	?	?	?	?	1972
61	Portions of Sec's. 16, 21, 28 & 29, T3N, R67W	Beef	Inventory Avg: 6,500	21.5 AF	3,200	1972
62	NW1/4 Sec. 35, T7N, R66W	Lambs	Inventory Avg: 33,000	?	?	1975
63	NE1/4, Sec. 2, T6N, R67W	Beef	Inventory Avg: 650	2.54 AF	?	1971
64	SE1/4 Sec. 23, T7N, R67W	Beef	Capacity: 2,500	1.79 AF	2,079	1976

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
65	NE1/4 Sec. 19, T7N, R66W	Beef	Inventory Avg: 2,000	0.75 AF	3,000	1972
66	NE1/4 NW1/4, Sec. 9, T5N, R66W	Dairy	Inventory Avg: 100	0.14 AF	2,230	1972
67	2 Mi. N & 5 Mi. W of Greeley on Kodak Rd.	Beef	Capacity: 4,500	?	?	?
68	1-1/2 Mi. S & 2 Mi. E of Gill	Beef	Inventory Avg: 4,000	?	?	?
69	SW1/4 Sec. 1, T4N, R66W	Beef	Inventory Avg: 18,000	?	?	?
70	SE1/4 Sec. 32, T5N, R67W	Hogs	Inventory Avg: 158	0.053 AF	3,280	1972
71	Sec. 9, T4N, R65W Gilcrest Lot	Beef	Inventory Avg: 75,000	?	100,000	?
72	Sec's. 23, 24, 25 & 26 T5N, R64W Kersey (Kuner) Lot	Beef	Inventory Avg: 75,000	?	100,000	1973
73	1-1/2 Mi. NE of Greeley	Beef	Capacity: 900	0.66 AF	1,500	1972
74	?	Beef	Capacity: 950	1.23 AF	?	?
75	?	Hogs	?	?	?	?

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
76	?	?	?	?	?	1973
77	NE1/4 NE1/4 Sec. 30, T3N, R67W	Beef	Capacity: 6,100	11.55 AF	14,000	1976
78	SW1/4 SE1/4 Sec. 31, T5N, R67W	Dairy	Inventory Avg: 250	1.52 AF	3,000	1973
79	NE1/4 Sec. 13, T5N, R65W	Dairy	Capacity: 50	?	?	1972
80	Near LaSalle	Dairy	?	?	?	?
81	N1/2 NE1/4 Sec. 18, T7N, R65W	Beef	Capacity: 3,200	3.92 AF	3,860	1976
82	NW1/4 Sec. 33, T4N, R66W	Beef	Capacity: 4,000	?	?	1975
83	E1/2 Sec. 29, T4N, R66W	Beef	Inventory Avg: 900	?	?	?
84	SE1/4 Sec. 20, T4N, R67W	Beef	Capacity: 1,500	?	4,175	1972
85	?	Dairy	?	?	?	1974
86	SW1/4 Sec. 10, T6N, R	Beef	Inventory Avg: 1,200	1.3 AF	6,000	1972

TABLE 6.3-B

WELD COUNTY

INSTALLED WASTE/RUNOFF CONTROL FACILITIES

OWNERSHIP CODE #	LOCATION	ANIMAL TYPE	SIZE	WASTE CAPACITY	COST ($)	YEAR
87	SE1/4 Sec. 6, T6N, R65W	Beef	Capacity: 3,000	?	2,500	1976
88	S1/2 SE1/4 SW1/4 Sec. 29, T7N, R64W	Hogs	Inventory Avg: 280	0.103 AF	1,600	1971
89	Sec. 20, T1N, R66W	Beef	Inventory Avg: 19,000	?	?	?
90	S1/2 S1/2 NE1/4 Sec. 30, T1N, R66W	Lambs	Inventory Avg: 19,415	?	?	?
91	NW1/4 Sec. 21, T8N, R65W	Dairy	Capacity: 150	1.61 AF	2,500	1975
92	SE1/4 NE1/4, Sec. 9, T5N, R66W	Beef	Inventory Avg: 3,200	5.18 AF	2,500	1973
93	NE1/4, Sec. 6, T5N, R64W	Beef	Capacity: 22,000	?	20,000	1972
94	NW1/4 SW1/4 Sec. 6, T6N, R64W	Dairy	Inventory Avg: 120	0.741 AF	?	1972
95	N1/2 NE1/4 Sec. 7, T7N, R65W	Beef	Inventory Avg: 800	4.13 AF	?	1972
96	SE1/4 NW1/4 Sec. 13, T5N, R65W	Dairy	Capacity: 240	1.81 AF	2,500	1972
97	SE1/4 Sec. 8 & NE1/4 Sec. 17, T7N, R66W	Lamb Beef	Capacity: 75,000 Lambs 2,000 Beef	19.88 AF	6,600	1973

TABLE 6.3-C. INSTALLED WASTEWATER/RUNOFF CONTROL FACILITIES

TYPE	COUNTY		TOTAL
	LARIMER (a)	WELD (b)	
Beef	4	47	51
Beef & Lamb	1	2	3
Dairy	12	15	27
Lamb	-	2	2
Hogs	4	6	10
TOTAL	21	72	93 (a) (b)

(a) One goat dairy also.
(b) Three additional operations are of an undetermined nature.

TABLE 6.3-D. LARIMER COUNTY - INVESTMENT COSTS FOR WASTEWATER/RUNOFF RETENTION FACILITIES (a)

TYPE	OWNERSHIP CODE #	$ COST ORIGINAL	$ COST CURRENT (b)	$ COST PER HEAD CAPACITY
Beef	9	3,200(72) (d)	4,900	3.43
Beef	13(e)	2,000(73)	2,840	18.90
Beef & Sheep	17	6,000(74)	7,980	2.30
Dairy	2	6,801(72)	10,400	24.20
Dairy	3	3,800(73)	5,400	47.40
Dairy	8	2,000(73)	2,840	26.50
Dairy	10	840(72)	1,290	17.90
Dairy	12	12,000(74)	15,960	13.15
Dairy	16	1,487(73)	2,110	7.40
Dairy	21(e)	5,000(71)	8,450	39.30
Dairy	22	2,000(74)	2,660	6.20
Dairy (goat)	5	3,200(73)	4,540	302.70
Hogs	7	4,376(72)	6,700	8.40
Hogs	19	11,260(73)	15,990	66.60

(a) For identity of total number of feedlots with retention facilities, see Table 6.3-A.
(b) Based on January, 1977, Construction Cost Index.
(c) Based on equivalency in terms of head of cattle.
(d) Number in parentheses indicates year installed.
(e) Data not plotted.
(f) Concrete tank for waste control (data not plotted).

TABLE 6.3-E. WELD COUNTY - INVESTMENT COSTS FOR WASTEWATER/RUNOFF RETENTION FACILITIES (a)

TYPE	OWNERSHIP CODE #	$ COST ORIGINAL	$ COST CURRENT (b)	$ COST PER HEAD CAPACITY (c)
Beef	24	7,500 (74)(d)	9,980	3.80
Beef	29	6,000 (72)	9,180	2.60
Beef	30	7,800 (72)	11,930	0.80
Beef	38			
Beef	39	3,000 (73)	4,260	1.30
		15,000 (69)	29,250	2.10
Beef	41	3,500 (74)	4,660	1.63
Beef	44	7,000 (72)	10,710	1.10
Beef	46	25,000 (70)	46,250	2.60
Beef	48	2,000 (71)	3,380	2.80
Beef	49	2,000 (75)	2,420	3.50
Beef	53	6,834 (76)	7,650	3.80
Beef	54	2,000 (76)	2,240	2.20
Beef	61	3,200 (72)	4,900	0.60
Beef	63	2,079 (76)	2,330	0.90
Beef	65	3,000 (72)	4,590	1.61
Beef	72	100,000 (73)	142,000	1.20
Beef	73	1,500 (72)	2,300	2.60
Beef	77	14,000 (76)	15,680	2.60
Beef	81	3,860 (76)	4,320	1.40
Beef	84	4,175 (72)	6,390	4.30
Beef	86	6,000 (72)	9,180	6.56
Beef	87	2,500 (76)	2,800	0.90
Beef	92	2,500 (73)	3,550	1.20
Beef	93	20,000 (72)	30,600	1.40
Beef & Sheep	34	14,000 (73)	19,880	3.60
Beef & Sheep	97	6,600 (73)	9,370	1.00
Dairy	27	2,500 (73)	3,550	41.30
Dairy	35	1,800 (72)	2,750	20.20
Dairy	36	5,000 (72)	7,650	7.70
Dairy	37	4,135 (72)	6,330	17.70
Dairy	45	3,000 (74)	3,990	20.00
Dairy	50	4,500 (72)	6,890	12.05
Dairy	51	8,500 (76)	9,520	13.30
Dairy	66	2,230 (72)	3,410	23.80
Dairy	78	3,000 (73)	4,260	7.48
Dairy	91	2,500 (75)	3,030	14.10
Dairy	96	2,500 (72)	3,830	11.20
Hogs	56	1,000 (75)	1,210	3.80
Hogs	70	3,280 (72)	5,020	62.80
Hogs	88	1,600 (71)	2,700	16.90

(a) For identity of total number of feedlots with retention facilities, see Table 6.3-B.
(b) Based on January, 1977, Construction Cost Index.
(c) Based on equivalency in terms of head of cattle.
(d) Number in parentheses indicates year installed.

Cost data are depicted graphically on Figures 6.3-A and 6.3-B. Feedlot and dairy installations are treated independently. It is evident from the figures that economy of scale is generally realized when systems are installed.

Wastewater/runoff control facilities serving feedlots in the two-county region are normally of the "pond" variety. Typical construction costs relate to excavation, diking, and inlet/outlet piping or channalization. Systems installed at dairies may incorporate concrete holding tanks in lieu of earthen basins. Hence, capital costs are commensurately greater.

The total investment by feeders in the two-county region for wastewater/runoff control facilities is summarized in terms of 1977 dollars in Table 6.3-F.

TABLE 6.3-F. TOTAL COST OF PRESENTLY INSTALLED CONTROL SYSTEMS (a)

TYPE	COUNTY		TOTAL $
	LARIMER $	WELD $	
Cattle	35,000	800,000	835,000
Dairy	70,000	60,000	130,000
Lamb	-	60,000	60,000
TOTAL	105,000	920,000	1,025,000

(a) January, 1977 dollars.

A paucity of data regarding cost of facilities installed to serve the hog feeding industry does not permit development of a definitive investment price. However, it is estimated that pork producers in the Larimer-Weld area have spent in excess of $30,000.

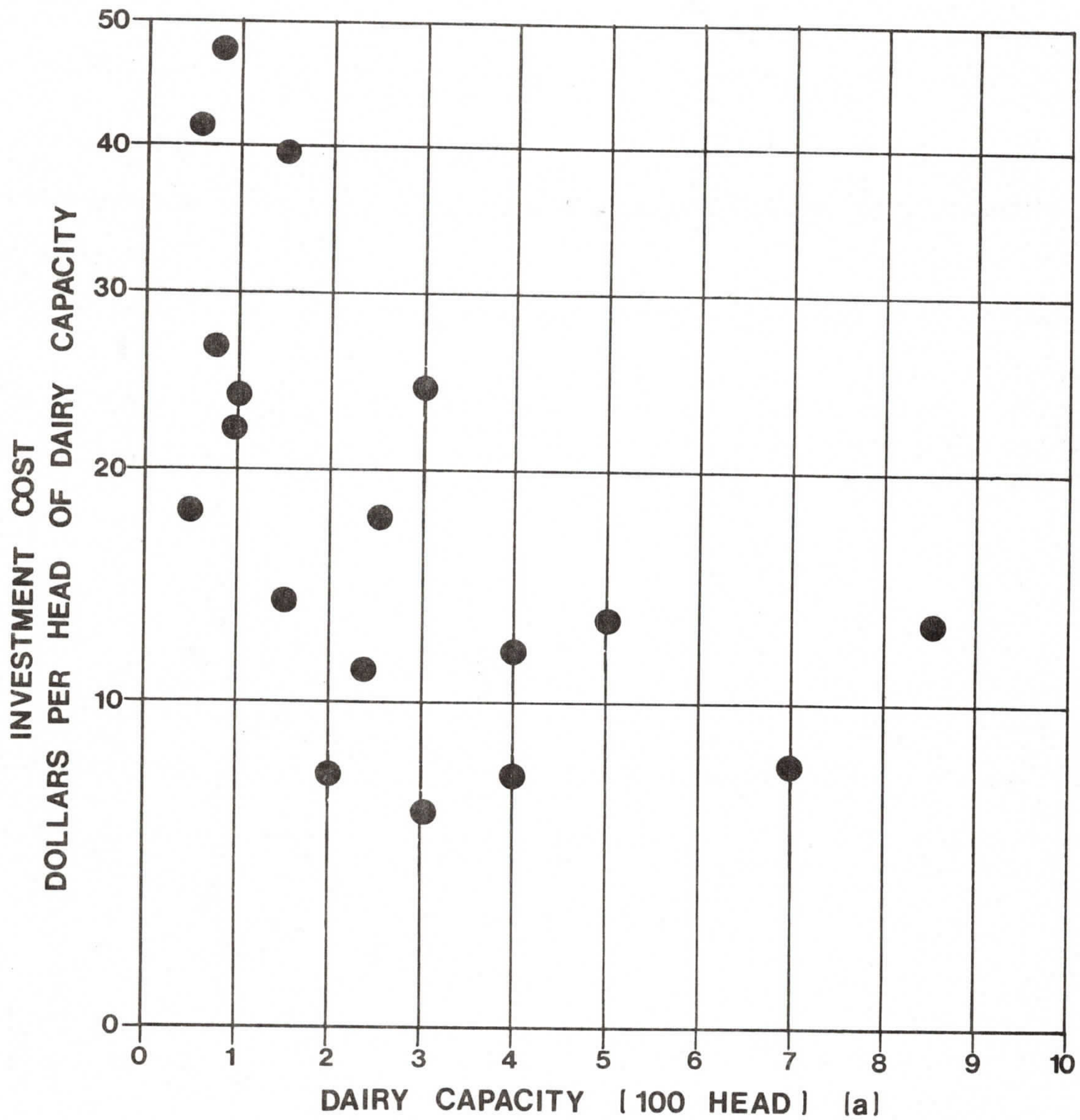


FIG. 6.3-A LARIMER AND WELD COUNTY DAIRIES
INVESTMENT COSTS FOR WASTEWATER/RUNOFF CONTROL FACILITIES

(a) CAPACITIES ARE ACTUAL DAIRY CAPACITIES; CONTROL COSTS ARE COMPUTED IN TERMS OF HEAD EQUIVALENT TO BEEF CATTLE (700 COWS = 1,000 CATTLE)

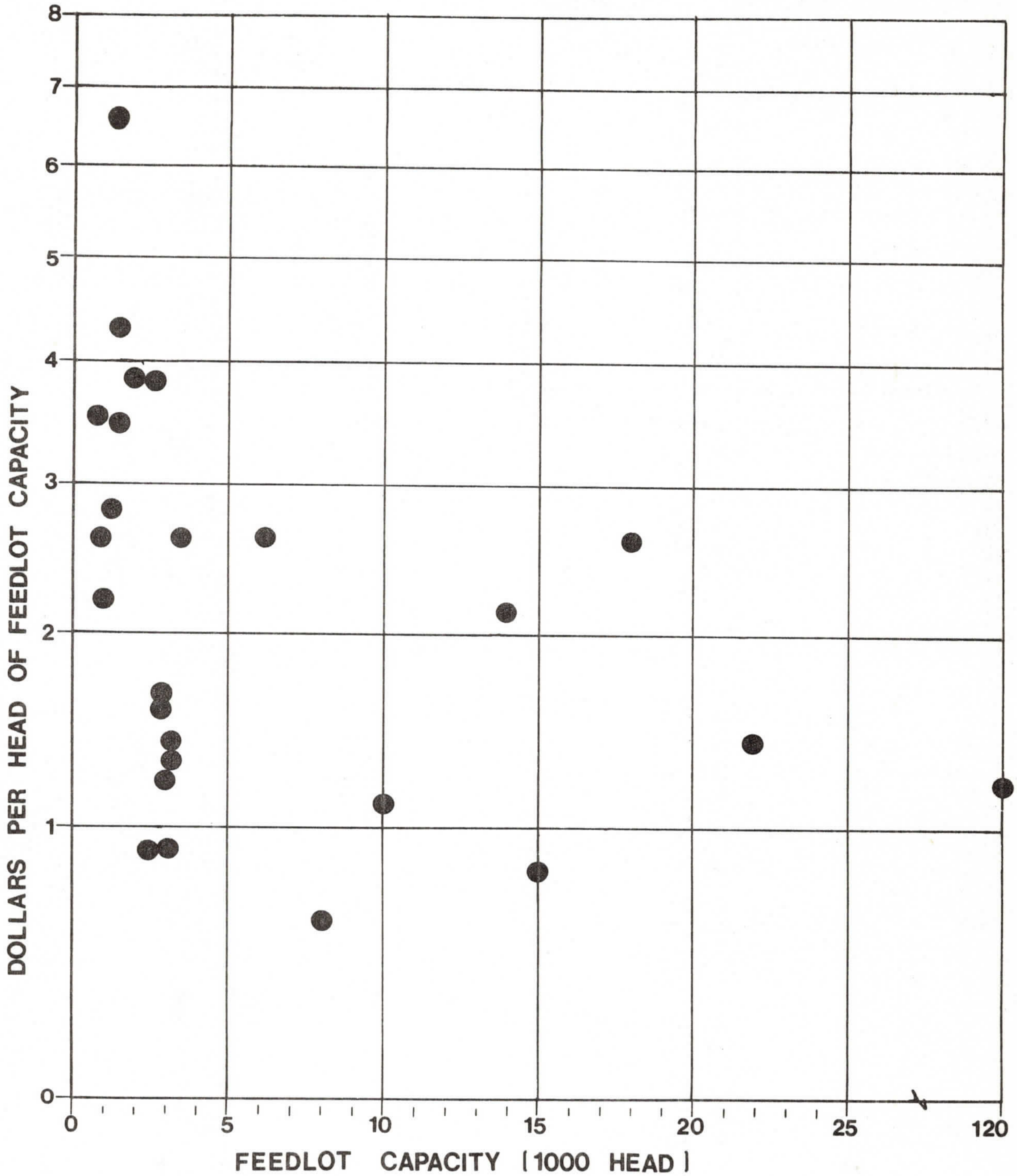


FIG. 6.3-B LARIMER AND WELD COUNTY CATTLE FEEDLOTS INVESTMENT COSTS FOR WASTEWATER/RUNOFF CONTROL FACILITIES

6.4 WATER QUALITY IMPACT OF REGULATORY MEASURES

The analysis developed herein will serve to identify the role implementation of wastewater/runoff control measures has had on reducing the impacts of waste loads generated by feedlots in the region.

Plotted in Figure 6.4-A are the average annual number of days that precipitation events of various amounts can be anticipated at the Greeley station. The figure is derived from data presented in Table 6.4-A. Precipitation data representative of other stations in the regional area is provided in the tabulation for purposes of comparison. Research has demonstrated that a minimum of 0.4 to 0.5 inches of rainfall is necessary to produce runoff from a feedlot. [Kreis, et. al., 1972; Porter, et. al., June, 1975; Powers, et. al., May, 1975]. According to Figure 6.4-A, nine events per year can be expected to generate 0.4 inches or more of rainfall. The range of events is itemized according to size in Table 6.4-B. Associated runoff, also presented in the table, is computed through use of SCS curve No. 91.

The nine average events detailed in Table 6.4-B can be expected to yield an annual total of 1.5 acre-inches of runoff per feedlot acre. Magnitude of the runoff initiated during any given event during the year can be expected to range on the average by a factor of nearly 18.

Characteristics of runoff for feedlots are subject to extreme variation. Governing factors include ration type, feedlot slope, intensity of rainfall, and tributary runoff. For purposes of computing generalized mass emission rates from uncontrolled feedlots, data representative of runoff from two feedlots in the Fort Collins area will be utilized. [Porter, et. al., June, 1975]. Chemical composition of runoff is detailed in Table 6.4-C.

The average of data summarized in Table 6.4-C is utilized in Table 6.4-D to develop generalized mass emission rates of various constituents associated with runoff from uncontrolled feedlot acreage in the Larimer-Weld region. The tabulation depicts wastes in feedlot runoff generated by a 1.24 inch storm in the Greeley area. It also indicates the volume of wastes in runoff induced by all storms expected on the average to impact the Greeley regional area each year.

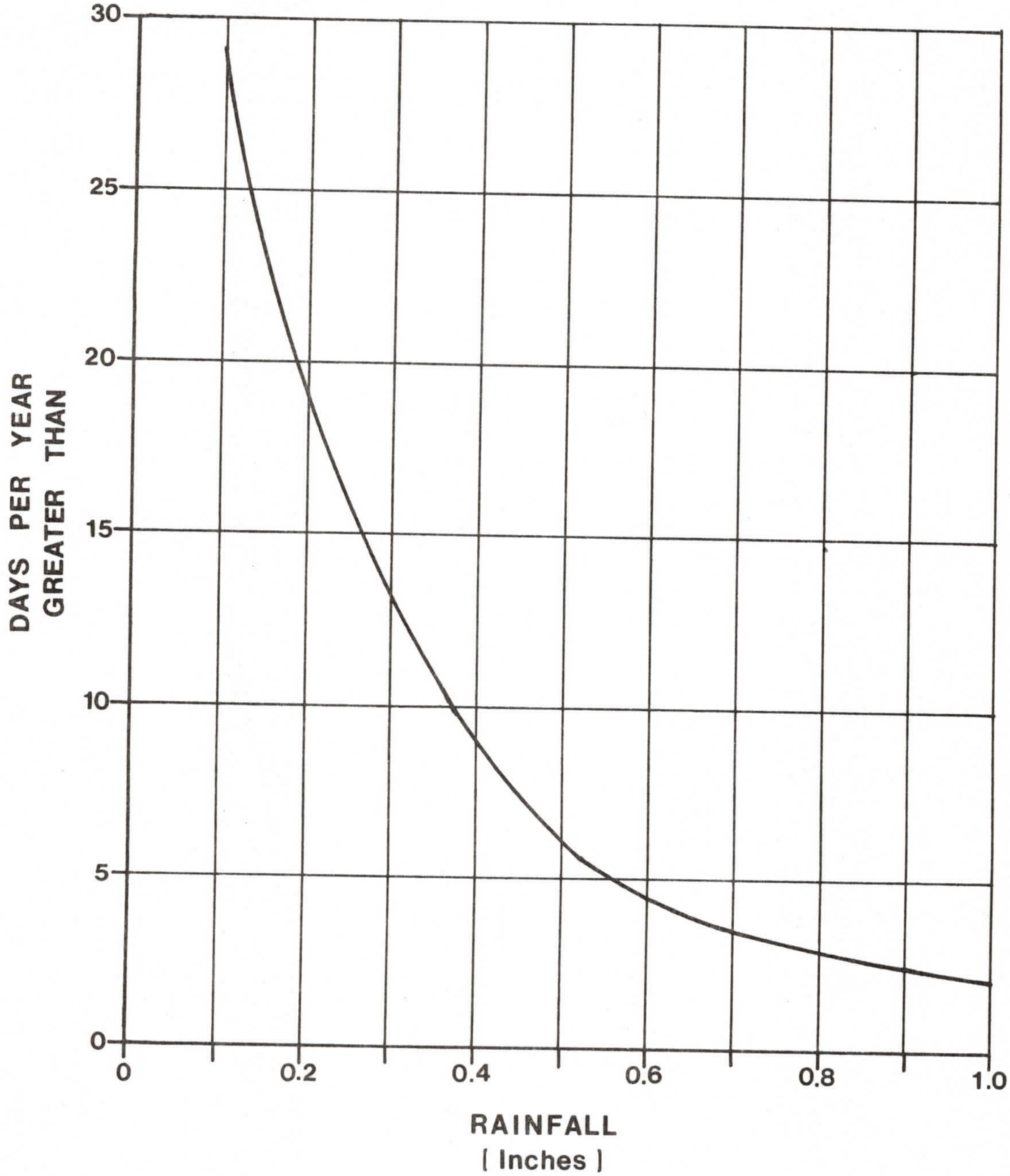


FIGURE - 7.1 - A GREELEY STATION
ANNUAL AVERAGE RAINFALL EVENTS

TABLE 6.4-A. REGIONAL STATION SUMMARY - PRECIPITATION INTENSITY

STATION	PRECIPITATION INTENSITY	MEAN NUMBER OF DAYS												ANNUAL TOTAL
		JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	
Fort Collins	0.10 + Inches	1.2	1.6	3.6	3.9	5.2	4.6	3.8	3.4	2.9	2.8	1.8	1.2	36
	0.50 + Inches	0.1	0.0	0.5	0.6	1.6	0.8	0.9	0.6	0.8	0.9	0.2	0.1	7
	1.00 + Inches	0.0	0.0	0.1	0.2	0.8	0.2	0.2	0.2	0.0	0.2	0.0	0.0	2
Fort Lupton	0.10 + Inches	1.3	1.8	3.0	3.2	4.9	4.6	3.4	3.0	2.5	2.5	1.5	1.1	33
	0.50 + Inches	0.0	0.0	0.4	0.3	1.4	0.8	0.5	0.6	0.9	0.6	0.0	0.1	6
	1.00 + Inches	0.0	0.0	0.1	0.1	0.6	0.4	0.3	0.0	0.2	0.0	0.0	0.0	2
Greeley	0.10 + Inches	1.0	1.1	1.9	2.3	4.7	3.8	3.0	3.2	3.2	2.1	1.5	1.0	29
	0.50 + Inches	0.0	0.0	0.2	0.3	1.5	1.0	0.7	0.5	1.0	0.5	0.0	0.1	6
	1.00 + Inches	0.0	0.0	0.0	0.2	0.4	0.5	0.2	0.1	0.2	0.0	0.0	0.0	2
Longmont (Boulder County)	0.10 + Inches	1.5	1.6	3.1	3.3	5.1	4.5	3.4	3.0	2.9	2.5	1.8	1.5	34
	0.50 + Inches	0.1	0.1	0.2	0.6	1.2	1.2	0.5	0.4	0.8	0.5	0.0	0.1	6
	1.00 + Inches	0.0	0.0	0.0	0.1	0.6	0.4	0.1	0.1	0.3	0.2	0.0	0.0	2
Windsor	0.10 + Inches	0.9	1.4	2.4	2.5	4.5	4.4	2.6	2.9	2.9	2.5	1.6	0.7	29
	0.50 + Inches	0.0	0.0	0.3	0.5	1.6	1.2	0.5	0.5	0.4	0.4	0.1	0.1	5
	1.00 + Inches	0.0	0.0	0.1	0.1	0.8	0.2	0.1	0.1	0.2	0.1	0.0	0.0	2

TABLE 6.4-B. FEEDLOT RUNOFF INDUCED BY AVERAGE ANNUAL RAINFALL EVENTS (a) GREELEY STATION

ANNUAL RAINFALL EVENTS (NUMBER)	RAINFALL (INCHES) (b)	RUNOFF (c) (INCHES)
9	0.4	0.03
8	0.43	0.04
7	0.46	0.05
6	0.50	0.07
5	0.55	0.10
4	0.63	0.14
3	0.76	0.21
2	1.00	0.36
1	1.24	0.53
ANNUAL TOTAL		1.53

(a) Summary of precipitation events 1951-1970.
(b) See Figure 6.4-A.
(c) Based on SCS Curve 91, "Runoff For Inches of Rainfall", applies to feedlots with an earthen base.

TABLE 6.4-C. CONSTITUENTS IN FEEDLOT RUNOFF (a)

Parameter	Feedlot - Slope 0% (b)	6% - 8% (c)
Total solids (g/l)	17.5	204.0
Suspended solids (g/l)	11.8	195.6
Dissolved solids (g/l)	6.6	8.4
EC (umhos/cm at 25° C)	8.59	12.80
pH	7.19	6.75
NO_3 (ppm)	2.96	43.4
NO_2 (ppm)	0.0	0.0
NH_4 (ppm)	358.0	1,130.0
N (total, ppm)	1,153.5	7,370.0
PO_4^{3-} (ppm)	114.0	
P (total, ppm)	92.5	
COD (mg O_2/l)	17,800.0	

(a) Porter, et. al., June, 1975.
(b) Anderson Feedlot.
(c) Ashlind Feedlot.

TABLE 6.4-D. MASS EMISSION RATES - FEEDLOT RUNOFF (a)

PARAMETER	AVERAGE CONCENTRATION (mg/l)	LOAD PER ACRE FROM A 1.24-INCH STORM (POUNDS)	ANNUAL AVERAGE LOAD PER ACRE (b) (TONS)
Suspended Solids	105,000	12,600	18
Dissolved Solids	7,500	900	1.3
Ammonia	750	90	0.13
Total Nitrogen	4,250	510	0.7
Total Phosphorus	95	11	0.02
COD (O_2)	18,000	2,160	3

(a) Earthen base feedlots.
(b) Based on a total annual runoff volume of 1.5 acre-inches.

Table 6.4-E identifies the order of magnitude of average annual wastes transported off the 640 uncontrolled feedlot acres estimated to exist in the region.

TABLE 6.4-E. MASS EMISSION RATES FROM UNCONTROLLED FEEDLOT ACREAGE

PARAMETER	ANNUAL AVERAGE LOAD PER ACRE (TONS)	ANNUAL AVERAGE LOAD, 640 ACRES (TONS)
Suspended Solids	18	11,500
Dissolved Solids	1.3	830
Ammonia	0.13	80
Total Nitrogen	0.7	450
Total Phosphorus	0.02	10
COD	3	1,900

Statistical data indicates that between 835,000 and 950,000 fattened cattle are marketed in Larimer and Weld Counties each year. The exact number fluctuates according to economics of the livestock feeding industry. It is evident from information presented in Tables 6.3-A and 6.3-B, and in Appendices A and B, that over 345,000 cattle are supported on feedlots equipped with conventional wastewater/runoff control systems. This corresponds to nearly 80 percent of the total number of beef produced in the two-county area. Total feedlot acreage in the Larimer-Weld region known to be served by conventional wastewater/runoff control systems is on the order of 2,200 acres.

More than 30,000 head reside on feedlots determined by the State Department of Health to pose no threat of waste runoff to receiving waters because of mitigating factors of soil porosity, terrain, or hydrologic isolation. These head are supported on about 200 feedlot acres. The total number of cattle fattened in the region on facilities with natural or conventional control measures represents approximately 85 percent of the total volume produced annually.

Of the remaining cattle fattened on feedlots not presently known to be provided with control measures, over 70,000 are fed on feedlots already identified by the State Department of Health. In addition, the Department has already identified about 10 feedlots whose capacities are presently unknown. Feedlot acreage supporting these 70,000 head is on the order of 470 acres.

Characteristics of feeders summarized in Appendices A and B demonstrate that the State Department of Health has identified feedlots in the region responsible for cattle inventories of approximately 450,000 head at any given time. Annual production from these facilities is about 900,000 head. When the cattle market provides a good return on investment, an additional 50,000 head per year very likely would be fattened on feedlots presently unidentified in the two-county area. Yearly production of 50,000 head corresponds to an average feedlot inventory of 25,000, requiring about 170 feedlot acres.

Of the uncontrolled feedlots identified by the State Department of Health, a total of 9 possess inventories greater than 1,000 head. Feedlots with inventories in the 300-1,000 range number 64. Operations characterized by head counts of less than 300 total 73. Unless investigated on a site-by-site basis and found to be degrading water quality, the 73 small feedlots will be exempt from the permit program.

It was estimated in Section 2 that a total of 1,250 cattle feedlots with capacities greater than 20 head exist in the two-county area. Approximately 210 feedlots on uncontrolled and conventionally/naturally controlled acreage have been identified by the State Department of Health. It is concluded that presently unidentified feedlots in the region, responsible for production of an estimated 50,000 head per year, number over 1,000. Some of these feedlots are undoubtedly used for only a portion of the year (one pen produced annually). Size of almost all of these operations is considered to be less than 300. This is supported by records of the Weld County Assessor, which identified 634 and 463 active feedlots in 1972 with inventories of 20 to 99 head, and 100 to 499 head, respectively [Sudduth, 1972].

If the natural and conventional wastewater/runoff control systems which presently serve the cattle feeding industry in the region did not exist, the total annual waste load generated would be expected to be about five times the quantities indicated in Table 6.4-E.

7.0 RELATIONSHIP BETWEEN BEST MANAGEMENT PRACTICES AND WATER QUALITY

The 208 planning program will result in increased emphasis on proper waste management. In most instances, returning animal wastes to agricultural soils represents the most appropriate and best management practice if consideration is exercised to avoid degrading soil integrity and water quality. Careful evaluation of soil and plant assimilative capacities, in conjunction with judicious use of on-farm irrigation water management practices, form the basis for proper system operation. [Loomis, 1976].

7.1 EFFECTIVENESS OF REGULATIONS AND PRACTICES

The current program sponsored by the Colorado Department of Health to extend the discharge permit system to confined feeding operations has resulted in the installation of nearly 100 wastewater/runoff containment facilities. Operators most noticeable because of their size, proximity to receiving waters, or actual impact on water quality are generally among those initially directed by the State to install control systems. Other feeders have constructed facilities of their own accord. Remaining operators are being identified and evaluated as constraints of manpower and time allow. Feedlots potentially exerting a major impact on water quality in the two-county region have, or are in the process of, implementing control measures. It was determined in Section 6 that the State has been successful in curtailing annual availability to surface water of wastes associated with feedlot runoff by a factor of 80 percent over mass emission rates that would otherwise occur.

7.2 BEST MANAGEMENT PRACTICES AND WATER QUALITY

Proper management of wastes associated with confined livestock feeding operations can greatly mitigate or negate the potential for water quality degradation. Recommended practices are presented herein.

7.2.1 Feedlot Runoff

Because of the nature and magnitude of their related wastes, feedlots possess the ability to detrimentally impact receiving surface water quality. Such waters include irrigation ditch supplies, reservoirs and impoundments, minor tributaries, and major watercourses. Pollution potential can be greatly minimized by increasing the degree of hydrologic isolation exhibited by a feedlot with respect to local or regional receiving waters. Isolation can be achieved by natural features of terrain, presence of surrounding fields or lands which serve as buffer zones, or extreme porosity of area soils. When these conditions are lacking, physical structures or modifications must be added to the existing environment. Determination of the need for wastewater/runoff control measures at any given feedlot is the subject of an on-going program conducted by the Colorado Department of Health. The State evaluates pollution potential of feeders on an individual basis. Recommendations for control measures are site specific.

7.2.2 Percolation of Corral Wastes

Management and maintenance of feedlot pens or corrals plays an extremely important role in minimizing degradation to local groundwater. If left undisturbed, the anaerobic zone at the manure-soil interface that develops on a continuously used feedlot forms a relatively impermeable layer that inhibits nutrient infiltration to groundwater. It is important that the integrity of the manure seal be maintained. This is especially critical during pen cleaning activities. Mechanical scrapers or front end loaders used to collect manure should be operated to avoid gouging the relatively thin manure pack adjacent to the soil. Any inadvertent damage should be repaired. Holes in the seal produced by pawing or playing animals should also be filled in and compacted.

Groundwater degradation can result from percolation of wastes from abandoned or intermittently used corrals. The sealing character of the manure pack in such lots is destroyed, resulting in a high potential for wastes to be leached to underlying groundwater. It is recommended that accumulated manures in abandoned or intermittently used lots be removed and disposed to agricultural lands. The feedlot base should be scarified to the existing soil surface. The Soil Conservation Service and the University Agricultural Extension Service should conduct an informational program through local news media to encourage part-time or former feeders to voluntarily control the pollution potential of their corrals. Technical assistance in manure scraping, collection, and disposal should be provided by the foregoing agencies as required on an individual basis.

7.2.3 Manure Disposal

Two overriding concerns influence the rate at which manure should be applied to agricultural soils. These include potential deleterious water quality impacts and potential adverse crop response.

Optimum rates of applying manure to land are largely a function of nitrate and salinity fractions of animal wastes. Salinity loading is of major significance in a relatively dry region, such as Larimer-Weld. It is therefore important to analyze the chemical composition of manure before an appropriate land application rate can be determined. Constituents of concern in animal waste are nitrogen, phosphorus, potassium, sodium, calcium and magnesium. Sampling activity should be conducted several times a year and should be oriented toward establishing an average manure composition. Other related factors in land application that need to be investigated are soil type, nutrient needs of the crop, and local climate. Character of an agricultural soil influences the optimum rate at which manure should be applied because it determines the quantity of salt leaching from the root zone, movement of nitrate-nitrogen to groundwater, and nitrogen loss to the air through processes of volatilization and denitrification.

From the standpoint of water quality and soil integrity, the safest manure application rates are the lowest which produce the best agronomic results [Powers, et. al., May, 1975]. Use of fields as manure disposal areas with little or no concern for nutrient benefit poses a potential hazard of salt buildup in the soil and nitrate leaching to groundwater.

7.2.3.1 Surface Water Quality

Quality of runoff leaving a field that has received livestock wastes application is a function of several factors [Powers, et. al., May, 1975]:

- Time of application;
- Presence of vegetative cover;
- Degree of incorporation;
- Amount applied;
- Intensity of rainfall;
- Slope of the field.

Time of the year is an important consideration in manure loading to land. This principally relates to frozen versus non-frozen soil condition. When manure is spread in winter, significant quantities of nitrogen, phosphorus, and potassium can be lost in runoff [Midgley & Dunklee, 1945].

Phosphate is tightly adsorbed on the surface of soil particles. Hence, phosphate fertilizers do not percolate [Viets, 1972]. Phosphate can be eroded away in conjunction with sediment transport or even washed off in solution if it hasn't had the opportunity to infiltrate and be incorporated into the soil complex. Because of its greater solubility in manure, loss of potassium is greater than that of nitrogen and phosphorus. Generally, nutrient transport in surface runoff in the spring are negligible compared to winter losses [Minshall, et. al., 1970; Hensler, et. al., 1971].

The lack of vegetative cover on an agricultural field plays an important part in livestock waste assimilation. Research indicates that runoff from agricultural lands to which manure has been applied is reduced significantly if soils have been plowed. This may relate to the rough field surface [Young, 1973]. Application of livestock wastes to sod covered fields greatly increases the potential for nutrient loss through runoff when compared to waste application on fallow lands. The likelihood of waste transport is believed to relate to the presence of vegetation, which prevents waste constituents from contacting the soil.

Nutrient loss in runoff is decreased greatly when livestock wastes are physically incorporated into the soil profile. Plowed fields receiving manures have demonstrated only slightly higher nutrient losses from snowmelt runoff than lands receiving no manure application [Young, 1973]. Other research has found that nutrient losses in runoff from check plots were greater than from plots receiving manure applications which were subsequently plowed under [Minshall, et. al., 1970]. In a study of fields subject to manure loading and soil incorporation, fewer nutrients were found in irrigation tailwater than were applied by the irrigation water itself [Stewart and Mathers, 1971]. Increasing the rate of manure application also increases the potential for nutrient loss in surface runoff [McCaskey, et. al., 1973].

Likelihood of degrading surface runoff water quality is increased by:

- Application of livestock waste to frozen ground;
- Application of wastes to ground with vegetative cover;
- Failure to incorporate wastes in soils after application.

7.2.3.2 Groundwater Quality

Manure loading to land can lead to groundwater degradation if application rates are excessive. This relates to the fact that nutrients will accumulate in the soil profile in quantities greater than can be assimilated by crops.

Guidelines have been formulated by Kansas State University which recommend specific application rates of solid beef cattle feedlot manure to agricultural lands. [Powers, et. al., May, 1974]. Two disposal strategies are considered:

- When soils are used as a disposal medium only;
- When the nitrogen value of manure is used to satisfy fertilizer requirements of crops.

Manure loading rates are governed by the foregoing alternative management techniques. The following activities are suggested to properly regulate manure disposal:

- Have manure analyzed for nitrogen, potassium, phosphorus, sodium, calcium, and magnesium.
- Have irrigation water analyzed for electrical conductivity and percentage of soluble sodium.
- Determine soil texture of the particular field or disposal area to receive the manure application.
- If the manure is to be used as a source of nitrogen, appropriate application rates should be used to insure availability of desired quantities of nitrogen per acre during any given year. Loading schedules have been developed which identify rates required to provide specific amounts of nitrogen. Nitrogen content of manure is considered in the guide as well as nutrient availability in successive years following initial spreading.
- Rate of application depends on whether manure is to be incorporated into irrigated or non-irrigated soils. Guidelines specify loading rates for each situation.
- A check should be made to see if manure loading rates recommended for fertilization exceed maximum allowable rates for salinity control. These upper limits are based on continuous application rates. Initial rates of two to three times the maximum are normally acceptable if a soil does not border on being saline at the outset. This practice should not continue for more than two years.

- Soil fertility and soil-alkali tests should be conducted annually to identify accumulation of salt and nitrate.

Nitrogen in manure is made available only as manure decays. Thus some is released for several years subsequent to initial application. The rate that manure decays increases as the percentage of nitrogen in the manure increases. Table 7.2.3-A summarizes generalized annual manure application rates necessary to provide desired quantities of available nitrogen per acre. The actual response of manure in soil is highly dependent upon its initial properties. Livestock wastes characterized by large percentages of nitrogen in the inorganic form, or nitrogen in the form of chemicals such as uric acid or urea which are subject to relatively rapid decomposition to inorganic nitrogen, possess a high rate of decay for the first several years. Lower decay rates are associated with wastes that have lost nitrogen through ammonia volatilization, or through leaching after decomposition during storage [Powers, et. al., May, 1975].

The application rates cited in Table 7.2.3-A are based on air-dried manure. However, air-dried manure is rarely found in stockpiles or on feedlots, so dry manure application rates must be adjusted by a factor in order to derive rates for various moisture contents. Multipliers are summarized in Table 7.2.3-B.

As an example of recommended long-term manure loading, consider an agricultural field of corn fertilized exclusively from livestock wastes. Annual nitrogen requirement of corn is on the order of 180 pounds per acre. Assuming an average manure nitrogen content of 1.0 percent and a moisture content of 35 percent, the following application rates should be practiced:

Year	Tons/Acre Dry	Tons/Acre Wet (35%)
1st	45	69.3
2nd	32.1	49.4
3rd	28.2	43.4
4th	25.7	39.6
5th	23.7	36.5
10th	17.4	26.8
15th	14.3	22.0
20th	12.5	19.3

TABLE 7.2.3-A MANURE APPLICATION RATES NEEDED TO INSURE 50, 100, OR 200 POUNDS OF AVAILABLE NITROGEN PER ACRE (a) (Rates on the Dry Weight Basis)

NITROGEN DESIRED (lbs/A)	NITROGEN IN MANURE (percent) (b)	YEAR OF APPLICATION							
		1st (T/A)	2nd (T/A)	3rd (T/A)	4th (T/A)	5th (T/A)	10th (T/A)	15th (T/A)	20th (T/A)
50	3.5	1.0	0.9	0.9	0.9	0.8	0.8	0.8	0.8
	2.5	2.5	1.8	1.7	1.6	1.5	1.4	1.3	1.2
	1.5	4.8	3.7	3.4	3.1	3.0	2.6	2.3	2.1
	1.0	12.5	8.9	7.8	7.2	6.6	4.8	4.0	3.5
100	3.5	1.9	1.8	1.8	1.8	1.7	1.6	1.6	1.5
	2.5	5.0	3.6	3.4	3.3	3.1	2.7	2.5	2.4
	1.5	9.6	7.4	6.7	6.3	6.1	5.1	4.6	4.2
	1.0	25.0	17.8	15.6	14.3	13.1	9.6	7.9	6.9
200	3.5	3.8	3.6	3.5	3.5	3.4	3.3	3.2	3.1
	2.5	10.0	7.3	6.9	6.6	6.3	5.5	5.0	4.7
	1.5	19.1	14.8	13.1	12.6	12.1	10.3	9.1	8.4
	1.0	50.0	35.7	31.3	28.6	26.3	19.3	15.9	13.9

(a) Powers, et. al., May, 1974.
(b) Nitrogen contents are on the dry weight basis. Adapted from Pratt, et. al., 1973.

TABLE 7.2.3-B CONVERSION FACTORS FOR RELATING DRY MANURE TO FEEDLOT MANURE WITH INDICATED MOISTURE CONTENTS

% WATER	FACTOR	% WATER	FACTOR	% WATER	FACTOR
10	1.11	35	1.54	60	2.50
15	1.18	40	1.67	65	2.86
20	1.25	45	1.82	70	3.33
25	1.33	50	2.00	75	4.00
30	1.43	55	2.22	80	5.00

7.2.3.3 Crop Response to Manure Loading

Criteria of achieving maximum crop yields due to accessibility of plant nutrients in the soil generally determine the rate at which most manures should be applied. Hence, nitrogen content of manures is frequently used because this constituent often limits plant growth and because it exists as a major potential source of groundwater degradation if present in excessive quantities. Inorganic nitrogen content of livestock wastes prior to land application determines to a great extent plant availability of nitrogen. Availability is modified by the rate of mineralization of organic nitrogen to inorganic forms in the soil after application to agricultural lands. Factors that control accumulation and movement of nitrate nitrogen, the predominant form utilized by plants, will subsequently control plant availability of nitrogen.

The best criteria on which to base the calculation of manure application rates are an estimation of nitrogen mineralization in conjunction with crop nitrogen uptake, and potential impact of salt addition. Nitrogen loading is of paramount concern in obtaining optimal crop nutrition and minimizing groundwater degradation. It is desirable to determine the amount of nitrogen present in a soil prior to manure application in order to adjust loading rates. These data are available from relatively simple and rapid analyses conducted by soil testing laboratories.

State extension agencies have documented recommended rates of inorganic nitrogen fertilizer required to satisfy the needs of particular crops. This information can be related to nitrogen levels existing in a soil to assist in determining optimal livestock waste application rates. Other factors which must be considered include:

- Estimation of mineralization rate for particular animal wastes;
- Estimation of nitrogen losses from the soil due to volatilization and denitrification.

An individual farmer can determine whether to supply crop nitrogen demands exclusively from livestock wastes or to supplement with inorganic nitrogen fertilizers. A general guide in commercial nitrogen fertilizer application is to reduce the requirement by five pounds for every acre-ton of manure spread [Ludwick, et. al., 1975].

When it is intended that the entire nitrogen need of a crop be satisfied by livestock waste application alone, extremely high manure application rates are generally required for the first few years. Such practice is necessary to build residual soil nitrogen up to appropriate nutrient levels. In initial manure applications of this nature, the potential exists for toxic levels of salt to accumulate in soils and reduce crop growth. Guidelines have been developed which, if adhered to, will prevent this adverse occurrence [Powers, et. al., May, 1975]. The guidelines are based on salt balance computations which consider soluble salt content of the applied livestock waste, salt increment in irrigation water, volume of salt leached from the soil profile, and salt tolerance of the crop.

Crops that can effectively utilize the nutrients made available by high manure loading rates are limited in number. [Ruehr, 1976]. Large quantities of mineral nitrogen resulting from manure decomposition can cause wheat and other small grains to lodge. Nitrate-nitrogen can be utilized from soil depths of 1 yard or more by alfalfa, a deep-rooted legume. However, manure can be incorporated into soils cultivated with alfalfa and grass pastures only infrequently because these crops remain established for several years. Fields that are annually cultivated are readily amenable to application of livestock wastes. Corn and sorghum for grain and silage are the most significant crops that can take advantage of the fertilizer benefits of manure. These crops are best adapted to nutrient uptake because they yield a high degree of dry matter which incorporates nutrients from the soil. Because these crops are grown extensively in the Larimer-Weld region and are a basic source of cattle feed, nutrients from manure can be recycled to livestock in feedlots. Recent research has demonstrated that manure application to sugarbeets produces an undesirable plant response [Giles, 1974]. Because of its relatively slow rate of decomposition, manure fertilization causes soil nitrate to accumulate late in the growing season. Sugarbeet plants utilize stored sucrose to convert nitrate to organic nitrogen compounds. Manure nitrate thus reduces the quantity of recoverable sucrose and consequently the profits for the grower.

Comprehensive research has been conducted at the Agronomy Research Center, Colorado State University, Fort Collins, Colorado, regarding effect of beef cattle manure on soil properties and plant growth [Ruehr, 1976]. Experiments were conducted under field, greenhouse, and laboratory conditions. The purpose of the investigation was to develop guidelines for manure application rates to soils and to elucidate the cause of seedling emergence inhibition on a soil typical of the Fort Collins area (Nunn clay loam). Results and conclusions of the study pertinent to field conditions are most applicable to the data requirements of the 208 Water Quality Planning Program.

Reductions in plant populations observed under field conditions were associated primarily with the increase in soil salinity attributable to manure loading [Ruehr, 1976]. Inhibition of seed germination and emergence relates to the nature of the applied manure, elapsed time after spreading before it was incorporated into the soil, time of planting after manure incorporation, and the proximity of seed to chunks of manure in the soil. Specific causes of decreased emergence include salinity, excessive ammonia, and presence of phototoxic substances. Research indicates that if a phototoxic substance exists, it is quite labile and decomposes easily [Ruehr, 1976]. Ammonium is also subject to rapid decomposition. Hence, soil salinity is the principal constituent which will not dissipate readily with time. Buildup of high soil salinities associated with large applications of cattle manure can be mitigated by proper management of irrigation water. Manure application rates must be reduced if irrigation water is not subsequently applied to soils. This relates to the fact that irrigation supplies help leach soluble salts from the soil profile. This phenomenon can also be accomplished to an extent by native precipitation.

Reduced germination and lowered seedling growth are often incurred if planting takes place shortly after application of livestock waste to the soil. [Powers, et. al., May, 1975]. Soil toxicity is generally attributable to either increased salinity or excessive concentration of ammonium nitrogen resulting from decay of organic matter. Management practices which will curtail or eliminate growth problems include: early application of manure prior to planting time; avoidance of soil overloading; and pre-irrigation with good quality water. To maximize availability of nitrogen, it is especially desirable to apply manures which possess a low nitrogen content well ahead of planting. This relates to the fact that a period of several weeks will elapse when nitrogen will be immobilized rather than mineralized in the soil. Early application will permit mineralization of nitrogen to coincide with the period of actual plant growth.

It is possible to maximize crop yields and minimize pollution potential by effective and timely addition to animal wastes to soils. Excessive concentration of ammonium and other inorganic salts which can inhibit seed germination and reduce crop yield may occur if manure is not spread in a uniform manner. It is desirable to avoid the creation of piles or windrows in a field.

Ammonia concentration of manure is determined by feedlot management; extent of ammonia volatilization is determined by farm management [Ruehr, 1976]. A value judgment must be made by growers regarding whether to:

- Apply manure and incorporate it with the soil at a convenient time without regard to possible ammonia volatilization; or
- Apply and incorporate the manure as rapidly as possible to conserve the ammonia-nitrogen.

Spreading manure at a convenient time tends to decrease the possibility of high ammonia concentrations which could inhibit seed germination. In contrast, immediate manure incorporation captures much of the potential nitrogen available to a crop. However, such practice also increases the availability of total nitrogen, which when converted to nitrate can potentially impact groundwater quality. Incorporating livestock wastes into the soil immediately after application prevents rain and snowmelt from conveying manure constituents into streams, reservoirs, or other receiving waters.

During average conditions of crop growth, application of either chemical fertilizer or livestock manures at optimum rates will yield comparable effects on production. However, the equity in yields appears to change noticeably by extremes of soil moisture. Various studies have demonstrated that during dry years, agricultural soils receiving manure have out-produced those receiving chemical fertilizers [McIntosh & Varney, 1972; Ware & Johnson, 1968]. This is believed to relate to improved soil moisture availability attributed to the presence of manure. The converse was observed to be true in wet years. Chemical fertilizers surpassed manures in promoting crop production. Decreased manure performance was associated with denitrification in the soil and subsequent lowered nitrogen availability.

Guidelines for manure application have been developed as a result of studies conducted at the Agronomy Research Center, Colorado State University, Fort Collins, Colorado [Ruehr, 1976]. Recommendations are summarized herein:

- Annual application rates of 25 to 50 tons per acre on a wet weight basis of beef cattle manure as removed from the feedlot would allow for nearly optimum forage yields with a minimum of nitrate-nitrogen degradation of subsoil; (because of residual manure nutrient value, this loading rate should be reduced on fields subject to a long history of manure loading);
- Rates in excess of 50 tons per acre may cause reduced plant populations due to increased soil salinity, increased nitrate accumulation in the subsoil, and reduced forage production with less efficient use of applied nitrogen;
- If rates over 50 tons per acre are employed, corn forage would be a better crop to cultivate than a sorghum-sudangrass hybrid due to the potentially toxic plant nitrate concentrations in the latter;
- Harvesting corn forage would be better than harvesting only the grain if a grower is concerned about maximum efficiency of nitrogen utilization from applied manure;
- Use of feedlot manure necessitates careful irrigation water management due to increased soil salinity;
- A single large residual application of up to about 325 tons per acre on a wet weight basis can be made, but problems should be anticipated with:
  - Physically incorporating the manure into the soil;
  - Markedly reduced plant populations and yields;
  - Higher irrigation water requirements;
  - Greater potential for nitrate accumulation in the subsoil in subsequent years.

7.2.3.4 Impact on Livestock

Animal health may be endangered if forages high in nitrate nitrogen are injested. Nitrate nitrogen tends to accumulate in plants if the vegetation is subject to moisture stress or if nitrate-nitrogen availability in soils is high. Uptake of nitrate nitrogen by plants is accelerated by the presence of decomposing animal manures which increase the concentration of this ion in the soil solution.

The possibility exists for toxic accumulations of nitrate nitrogen or nutrient imbalances to develop in soils subject to applications of livestock waste. In a study of corn forage grown on soil that had received solid beef feedlot manure, it was recommended that irrigated forage by analyzed for nitrate nitrogen before being fed to livestock if it had [McCaskey, et. al., 1973]:

- Been grown on soils that received greater than 12 tons per acre of dry manure;
- Been grown on soils that had received large single applications of manure;
- Been grown under moisture stress.

7.2.4 Lagoon Water Disposal

Proper management of lagoon water on agricultural lands must proceed from a knowledge of its chemical makeup. It is recommended that water analyses be conducted bi-annually, preferably during early spring and late summer [Powers, et. al., August, 1975]. Of major significance are data representative of electrical conductivity, and sodium and potassium percentages. Quality of irrigation water should also be determined. Electrical conductivity, sodium, and sulfate content are the most important parameters in the Larimer-Weld region.

Concentration of sulfates in irrigation water is of concern because if high enough, it may cause calcium in lagoon water to precipitate. This can create an imbalance between soluble sodium plus potassium versus the soluble calcium plus magnesium, and resultant soil dispersion.

It is always appropriate to collect a sample of soil in the lagoon water disposal area for annual salt-alkali testing. Result records should be reviewed to identify any irregular variations. Problems can be occurring if electrical conductivity of soil water extract becomes excessive, if crop yields decrease, or if agricultural lands begin to exhibit impaired drainage characteristics.

It is essential for an irrigator to properly manage lagoon water applications to prevent salt accumulation in cultivated lands. Lagoon waters typically contain excessive salts and should not be disposed of to soils without adequate dilution with good quality water. If supplemental water is not available, application rates should be limited. Uniform application of liquid livestock waste components collected in lagoons is insured by sprinklers. Performance of properly designed gravity flow irrigation systems is also acceptable.

Guidelines for lagoon water disposal have been developed by Kansas State University which minimize the potential of reducing productivity of receiving agricultural lands [Powers, et. al., August, 1975]. The directives are based on current irrigation water quality standards and feedlot operational data derived from facilities in Kansas. The following management strategy is recommended when lagoon water is to be disposed on soil:

- Obtain an analysis of lagoon and diluting irrigation water;
- Determine the texture of soil on the disposal site;
- Evaluate results of the water quality analysis to determine if the sodium plus potassium content is high enough to cause soil dispersion. Professional advice should be sought if levels are excessive;
- Dilution of lagoon water should proceed according to specific recommended factors developed for various soil and electrical conductivity conditions;
- If good quality water is unavailable for dilution, limited amounts of lagoon water can be applied directly to agricultural soils. Guidelines have been formulated which specify annual recommended limits based upon soil texture and lagoon water salt content. Application of undiluted lagoon water should be used only as a last resort disposal method;
- A salt-alkali test should be performed on disposal area soils annually;
- Disposal of concentrated lagoon water is a special problem which merits professional direction.

APPENDIX A

LARIMER COUNTY INVENTORY
OF CONFINED FEEDING OPERATIONS PER
COLORADO DEPARTMENT OF HEALTH

APPENDIX B

WELD COUNTY INVENTORY
OF CONFINED FEEDING OPERATIONS PER
COLORADO DEPARTMENT OF HEALTH

Appendices A and B have not been included in this report because of their excessive length. Copies of the above referenced appendices are available at the offices of the Larimer-Weld Regional Council of Governments, 201 East Fourth Street, Room 201, Loveland, Colorado, telephone 667-3288.

APPENDIX C

BIBLIOGRAPHY

Amen, Ray. Personal Communication. February, 1977.

Biniek, J. P., "Environmental Crunch on Agriculture -- Economics or Ecology?" Control of Agricultural-Related Pollution in the Great Plains, Seminar, July 24-25, 1972, Lincoln, Nebraska, Water Resources Committee, Great Plains Agricultural Council, Publication No. 60, 1972.

Burford, Jr., John L., and Varani, Fred T., Bio-Gas of Colorado, Inc., Energy Potential Through Bio-Conversion of Agricultural Wastes, Final Report to Four Corners Regional Commission, September, 1976.

California Fertilizer Association, Western Fertilizer Handbook, 1953.

Colorado Department of Agriculture, Colorado Crop and Livestock Reporting Service, in Cooperation with U.S.D.A. Statistical Reporting Service, Colorado Agricultural Statistics, 1975 Preliminary, 1974 Final. July, 1976.

Colorado Department of Health, "Guidelines for Design of Feedlot Runoff Containment Facilities", January, 1977.

Farr, Dick. Personal Communication. February, 1977.

Federal Register, Volume 39, No. 32, Thursday, February 14, 1974.

Federal Register, Volume 41, No. 54, Thursday, March 18, 1976.

Frenette, Roger E., Chief, Permits Administration and Compliance Branch, Enforcement Division, Environmental Protection Agency, Region VIII. Personal Communication to Frank J. Rozich, Director, State of Colorado Health Department, Water Quality Control Division. Letter dated May 17, 1976.

Fretwell, Lance A., Agricultural Statistician, Colorado Crop and Livestock Reporting Service, U.S. Department of Agriculture, Colorado Department of Agriculture. Personal Communication. February, 1977.

Giles, Joseph Fred., "Prediction of Nitrogen Status of Sugar Beets by Soil Analysis", Ph.D. Dissertation, Fort Collins, Colorado, Library, Colorado State University, 1974.

Gray, S. Lee, Huszar, Paul C., and McKean, John R., Economic Consultants, Colorado State University, Fort Collins, Colorado, "Future Economic Trends, Input/Output Analysis", Part 3, Executive Summary. January, 1977.

Hensier, R. F., Erhardt, W. H., and Walsh, L. M., "Effects of Manure Handling Systems on Plant Nutrient Cycling", Livestock Waste Management and Pollution Abatement, Proc. Int. Symposium on Livestock Wastes, American Society of Agricultural Engineers, St. Joseph, Michigan, 1971.

Kreis, R. D., et. al., "Characteristics of Rainfall-Runoff From a Beef Cattle Feedlot", EPA-R2-72-061, 1972.

Loomis, Glen H., Director, Environmental Services Division, Soil Conservation Service, U.S. Department of Agriculture. Co-authored by Gary A. Margheim, Environmental Specialist, Environmental Services Division, SCS. "Some Possible Impacts of Implementing Section 208 on Animal Agriculture", Presented to Environmental Sciences Committee of the American National Cattlemen's Association, Denver, Colorado, July 22, 1976.

Ludwick, A., Soltanpour, P., Reuss, J., Colorado State University Cooperative Extension Service, Guide to Fertilizer Recommendations in Colorado, 1975.

McCaskey, T. A., Rollins, G. H., and Little, J.A., "Water Pollution by Dairy Farm Wastes as Related to Method of Waste Disposal", WRRI Bulletin 18, Auburn University, Auburn, Alabama, 1973.

McIntosh, J. L., and Varney, K.E., "Accumulative Effects of Manure and N on Continuous Corn and Clay Soil - I. Growth, Yield, and Nutrient Uptake of Corn", Agron. J. 64:374-378.1972.

Manges, H. L., Murphy, L.S., Powers, W. L., and Goering, E., "Disposal of Beef Feedlot Wastes Onto Cropland", Paper 72-961 presented at the winter meetings of the American Society of Agricultural Engineers in Chicago, Illinois, December 11-15, 1972.

Mathers, A. C., and Stewart, B. A., "Corn Silage Yield and Soil Chemical Properties as Affected by Cattle Feedlot Manure", Journal of Environmental Quality, 3:143-147. 1974.

Mathers, A. C., and Stewart, B. A., "Nitrogen Transformations and Plant Growth as Affected by Applying Large Amounts of Cattle Feedlot Wastes to Soil", Cornell University Conference on Agriculture Waste Management, January 19-21, 1970.

Meek, B. D., MacKenzie, A. J., Donovan, T. J., and Spencer, W. F., "The Effect of Large Applications of Manure on Movement of Nitrate and Carbon in an Irrigated Desert Soil", Journal of Environmental Quality, 3: 253-258, 1974.

Meyer, J. L., Olson, Earl, and Baier, Dwight, "Manure Holding Ponds Found Self-Sealing", 1972.

Midgley, A.R., and Dunklee, D. E., "Fertility Runoff Losses from Manure Spread During the Winter", University of Vermont Agriculture Experiment Station Bulletin 523, 1945.

Miller, "Infiltration Rates and Groundwater Quality Beneath Cattle Feedlots, Texas High Plains", 1971.

Miner, J. R., and Willrich, T. L., "Livestock Operations and Field-Spread Manure as Sources of Pollutants", Agricultural Practices and Water Quality, Proceedings of a Conference Concerning the Role of Agriculture in Clean Water, November, 1969, Iowa State University, Iowa, November, 1970.

Minshall, N. E., Witzel, S. A., and Nichols, M. S., "Stream Enrichment from Farm Operations", Proc. American Society of Civil Engineers, Sanitary Engineering Division, J. SA 2:513-524, 1970.

Monfort of Colorado, Inc., Public Relations Representative. Personal Communication, February, 1977.

Murphy, L.S., Wallingford, G. W., Powers, W. L., Manges, H. L., "Effects of Solid Beef Feedlot Wastes on Soil Conditions and Plant Growth", Waste Management Research Proceedings of the Cornell Agricultural Waste Management Conference, 449-464, 1972.

Norstadt, F. A., USDA, ARS, Fort Collins, Colorado. Personal Communication, 1977.

Norstadt, F. A., and Porter, Lynn K., "Interactions of Beef Cattle Wastes with Soil", Chapter 47, Environmental Biochemistry, Volume 2, Metals Transfer and Ecological Mass Balances, 1976.

Patrick, W. H., Jr., "Nitrate Reduction Rates in a Submerged Soil as Affected by Redox Potential", International Conference Soil Sci. Trans., 2:495-500, 1960.

Pearsall, W. H., and Mortimer, C. H., "Oxidation-Reduction Potentials in Water-Logged Soils, Natural Waters, and Muds", Journal Ecol., 27:483-501, 1939.

Porter, L. K., et. al., "Pollution Abatement from Cattle Feedlots in Northeastern Colorado and Nebraska", EPA-660/2-75-015, June, 1975.

Powers, W. L., Hay, D. R., Murphy, L. S., Whitney, D. A., Manges, H. L., and Wallingford, G. W., Kansas State University Cooperative Extension Service, Manhattan, "Guidelines for Land Disposal of Feedlot Lagoon Water", Circular C-485, August, 1975.

Powers, W. L., Wallingford, G. W., Murphy, L.S., "Research Status on Effects of Land Application of Animal Wastes", EPA-660/2-75-010, May, 1975.

Powers, W. L., Wallingford, G. W., Murphy, L.S., Whitney, D. A., Manges, H. L., and Jones, H. E., "Guidelines for Applying Beef Feedlot Manure to Fields", Kansas State University Extension Circular C-502, May, 1974.

Pratt, P. F., F. E. Broadbent, and Martin, J.P.,"Using Organic Waste as a Nitrogen Fertilizer", California Agriculture, Agriculture Publications, University of California, Berkeley, California, 1973.

Reddell, D. L., Lyerly, P. J., and Hefner, J. J., "Crop Yields from Land Receiving Large Manure Applications", Paper No. 72-960 on micro fiche presented at winter meetings of the American Society of Agricultural Engineers. Chicago, Illinois, Dec. 11-15, 1972.

Ruehr, Thomas A., "Effect of Beef Cattle Manure on Soil Properties and Plant Growth", Ph.D. Dissertation, Fort Collins, Colorado, Library, Colorado State University, 1976.

Sabey, B., Colorado State University, College of Agriculture, Fort Collins, Colorado. Personal Communication, 1977.

Shankland, Robert D., & Burm, Robert J., Permits Section, Enforcement Division, Environmental Protection Agency, Region VIII, April, 1976.

Stewart, B. A., and Mathers, A. C., "Soil Conditions Under Feedlots and on Land Treated with Large Amounts of Animal Wastes", Proceedings of International Symposium on Identification and Measurement of Environmental Pollutants, Ottawa, Ontario, Canada, June 14-17, 1971.

Stewart, B. A., Viets, F. G. Jr., Hutchinson, G. L., Kemper, W. D., Clark, F. E., Fairbourn, M. L., Strauch, F., Distribution of Nitrates and Other Water Pollutants Under Fields and Corrals in the Middle South Platte Valley of Colorado, USDA, ARS 41-134, December, 1967.

Stout, Cal, Stout-Wall Research, Inc., Personal Communication. February, 1977.

Sudduth, David N., District Conservationist, U.S. Department of Agriculture, Soil Conservation Service, Greeley, Colorado. Personal Communication to Jack Hall, Area Conservationist, Soil Conservation Service, Denver, Colorado. Letter dated May 11, 1972.

Summerfelt, R. C., "Eutrophication in the Great Plains", Control of Agricultural-Related Pollution in the Great Plains, Seminar, July 24-25, 1972, Lincoln, Nebraska, Water Resources Committee, Great Plains Agricultural Council, Publication No. 60, 1972.

Swanson, N. P., "Hydrology and Characteristics of Feedlot Runoff", Control of Agricultural-Related Pollution in the Great Plains, Seminar, July 24-25, 1972, Lincoln, Nebraska, Water Resources Committee, Great Plains Agricultural Council, Publication No. 60, 1972.

U.S. Department of Agriculture, Colorado Department of Agriculture, Colorado Crop and Livestock Reporting Service, "Colorado Cattle on Feed", January 25, 1977.

U.S. Department of Commerce, Bureau of the Census, "1974 Census of Agriculture, Preliminary Report, Larimer County, Colorado", August, 1976.

U.S. Department of Commerce, Bureau of the Census, "1974 Census of Agriculture, Preliminary Report, Weld County, Colorado", July, 1976.

U.S. Department of Commerce, Bureau of the Census, "1969 Census of Agriculture, Part 12, Ranking Agriculture Counties", February, 1973.

U.S. Department of Commerce, Environmental Science Services Administration, Special Services Branch, Office of Hydrology, Weather Bureau and Engineering Division, Soil Conservation Service, "10-Year and 25-Year 24-Hour Precipitation, Colorado", October, 1967.

U.S. Environmental Protection Agency, "Cattle Feedlots and the Environment, Control Guidelines", Seattle, Washington, 1972.

U.S. Environmental Protection Agency, "Development Document for Effluent Limitations Guidelines and New Source Performance Standards for the Feedlots Point Source Category", EPA-440/1-74-004-a, January, 1974.

Viets, F. G., "Cattle Feedlot Pollution", Animal Waste Management, Proceedings of National Symposium on Animal Waste Management, September 28-30, 1971.

Viets. F. G., "Management Strategies for Fertilizer Use", Control of Agricultural-Related Pollution in the Great Plains, Seminar, July 24-25, 1972, Lincoln, Nebraska, Water Resources Committee, Great Plains Agricultural Council Publication No. 60, 1972.

Viets, Frank G., Jr., "The Mounting Problem of Cattle Feedlot Pollution", U.S.D.A., Agricultural Sciences Review 9:1971.

Viets, Frank G., and Hutchinson, Gordon L., Agricultural Research Service, Fort Collins, Colorado, Airborne Ammonia Eutrophies Lakes, August, 1970.

Ware, L. M., and Johnson, W. A., "Poultry Manure for Vegetable Crops - Effects and Value", Bulletin 386, Agricultural Experiment Station, Auburn University, Auburn, Alabama, 1968.

Webster, Bill, and Whitmore, Jim, Webster Feedlots. Personal Communication. March, 1977.

Young, R. A., "Nutrients in Runoff from Manure Spread on Frozen Ground", Transactions of the ASCE, 1973.