FEDERAL - STATE PLANNING DOCUMENTS INFORMATION DIGEST

MINNESOTA DEPARTMENT OF NATURAL RESOURCES
ST. PAUL, MINNESOTA JUNE, 1973

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INTRODUCTION

Since 1967, Minnesota has made substantial progress toward the preparation of a statewide framework water and related land resources plan. In addition, the State has participated in Federal-State planning programs. These activities have been pursued largely in connection with grants for comprehensive water and related land resources planning as authorized by Title III of the Federal Water Resources Planning Act of 1965.

During fiscal years 1968 and 1969, the Water Resources Coordinating Committee, Minnesota State Planning Agency, prepared and published a 456 page Technical Bulletin No. N2, entitled Background Information for Framework Statewide Water and Related Land Resources Planning in Minnesota. The Bulletin contains summarized information on:

1969 economic and population conditions
Availability of water and related land resources
Previous resource development
Water laws, policies and government
1969 problems and planning data needs.

A second volume, entitled Minnesota Water and Related Land Resources - First Assessment was prepared during fiscal years 1969 and 1970 by the Committee. The Assessment inventories available information (projected 1969 to 2020) concerning the statewide:

Economy and population
Water and related land resources availability, demands opportunities, needs problems
Possible solutions to problems.

The Committee's principal planning activity for fiscal year 1971 involved the production of a third publication Alternate Programs and Projects for Managing Minnesota's Water and Related Land Resources Through the Year 2020. In this volume, existing and possible future (1970-2020) problems, are summarized. Water and related land resources programs and projects recommended by Federal-State regional planning organizations are identified. The time table, planning policies, and costs associated with these programs and projects are identified. Factors to be considered in selecting programs and projects, such as environmental concerns and costs sharing for Federal programs, are discussed. Finally, existing State planning policy questions and information deficiencies are identified.

A number of the most important planning policy questions were listed in Alternate Programs and Projects for Managing Minnesota's Water and Related Land Resources Through the Year 2020. Legislators, administrators, and citizen groups were asked to indicate what position water resources planners should take on the policy questions. The Committee in fiscal year 1972, began a project to appraise the explicit and implicit reactions that were made to planning policy questions during the period November 1, 1970 through June 20, 1971, and, thereby, set the stage for the completion of the work toward development of the statewide framework water and related land resources plan.

In a fiscal year 1972 Committee report, entitled Minnesota Water and Related Land Resources: Policies for Planning, all bills introduced and bills passed during the 1971 session of the Legislature pertaining to the planning policy questions were

assembled and studied. Legislative committee hearings and registration files for lobbyists were reviewed for information concerning the planning policy questions. Statements related to the planning policies made by Governor Anderson and other key members of the present Administration and Executive Branch were assembled and studied. Documents prepared by special interest groups and pertaining to the planning policy questions were reviewed. Comments on the planning policy questions were solicited from appropriate State, Federal and local officials. Key legislators of the 1971 session of the Legislature were interviewed to ascertain the intent of legislation hearing on the planning policy questions.

A second major fiscal year 1972 effort was directed at the question of need for a statewide water and related land resources information system for Minnesota. A fifth document in the series published by the Committee embodies the findings of the Committee relative to the issue of a continuous statewide information system. The report entitled Minnesota Water and Related Land Related Resources: Information Systems analyzed available data and recommended the establishment of a statewide system.

At the close of fiscal year 1972, an effort to scope-down water and related land resources planning to a sub-State region was instituted. The Minnesota river basin, viewed as the basin having the most acute water resources problems in the State, was selected as the focus for this effort. A document entitled Water and Related Land Resources Planning Information, Problem and Alternative Solutions Digest for Southern Minnesota River Basin, Minnesota digesting all available information pertaining to the basin, including recommendations for action programs to manage resources, was prepared early in fiscal year 1973.

The information pertaining to Minnesota in the appendices generated through January 1971 by the Upper Mississippi River Comprehensive Basin Study Coordinating Committee, Missouri Basin Inter-Agency Committee, Souris-Red-Rainy River Basins Commission, and Great Lakes Basin Commission, was digested and partially reviewed from a State viewpoint (see Minnesota Water and Related Land Resources First Assessment, June 1970. Water Resources Coordinating Committee, State Planning Agency and Alternative Programs and Projects for Managing Minnesota's Water and Related Land Resources Through the Year 2020, January 1971, Water Resources Coordinating Committee, State Planning Agency). Since January 1971, additional appendices have been generated by the Federal-State organizations mentioned above in connection with the completion of framework and level B plans for river basins.

Statewide water and related land resources planning responsibilities were transferred during 1972 to the Bureau of Planning, Department of Natural Resources. During fiscal year 1973, the Department of Natural Resources with the assistance of a consultant, digested and reviewed from a State viewpoint appendices generated since January 1971. All potentially feasible programs and projects identified by Federal-State organizations through fiscal year 1973 were reviewed in context with State policies enunciated by the State legislature through its 1973 session. Programs and projects were segregated into three categories: Category 1 - programs and projects which appear to be consistent with State policies, Category 2 - programs and projects which appear to be inconsistent with State policies, and Category 3 - programs and projects for which additional information is required before a decision can be made as to whether or not they are consistent with State policies. This report is a brief digest of information contained in documents generated by Federal-State organizations through fiscal year 1973. The purpose of this report is to provide the reader with insight into the content of Federal-State documents.

During fiscal year 1973, the broad economic social and political statewide impacts associated with various mixes of structural and nonstructural flood damage reduction measures was appraised. The studies on the Minnesota river basin as described in the report entitled "An Economic Analysis of Flood Damage Reduction Alternatives in the Minnesota River Basin," by Alan Hopeman, Water Resources Research Center, Univ. of Minn., Bulletin 58 were extended to the Cannon, Zumbro and Root rivers basin; Mississippi river main stem; Mississippi river headwaters; Red river basin; and other basins in the State. Information in Federal-State organizations' appendices was summarized. The broad statewide economic, social and political impacts associated with Federal water quality standards was appraised.

A report was prepared covering the following matters: the relationship of a policy to place emphasis on waste dilution and groundwater as the major water supply for the Twin Cities Metropolitan area to Federal and State policies and programs for water quality management; the economic costs of developing and maintaining large groundwater supplies; the economic costs of various degrees of waste treatment; the possibility that the development of large groundwater supplies may encourage increasing dispersion and independence of local governmental units; feasibility and costs associated with the development of additional surface water supplies from potentially feasible reservoir sites upstream from the Twin Cities; and feasibility and costs associated with the development of additional water supplies by piping water in the Mississippi River from some appropriate point downstream from the Twin Cities.

All bills introduced and bills passed during the 1973 session of the Legislature pertaining to water and related land resources policies were assembled and studied. Based on a study of 1973 legislation conclusions were reached with respect to the planning policies inherent in the State statutes and possible emerging planning policies.

A report was prepared covering such matters as: possible impacts on Minnesota's future economic and population position due to projected large irrigation projects in North Dakota and the Missouri River Basin; possible impacts on Minnesota due to the Taxes Water Plan, NAWAPA Plan, diversions of water from the Rainy River or the Lake of the Woods, stabilization of water levels in the Great Lakes, diversions of waters into and out of the Great Lakes; and interrelation between Federal-State plans for the Missouri river basin and the upper Mississippi river basin. Another report covered a brief history of wetland drainage in Minnesota, a description of past wetland preservation programs, a description of potentially feasible future wetland preservation programs, an analysis of the impacts of potentially feasible future wetland preservation programs, and an analysis of the wetland-drainage controversy.

A statewide water and related land resources plan does not yet exist. There is no frame of reference for judging whether proper relations exist between local, State, regional, national, and international plans. Despite the lack of a statewide plan and largely because resource availability has in the past exceeded water and related land resources demands and needs, undesirable but not critical problems have emerged in Minnesota. With the prospect that, within 50 years, water and related land resource demands and needs may approach or exceed the availability of resources in some areas, the State cannot expect to continue to avert critical problems without a comprehensive statewide plan. Without accelerated planning programs, the most important water and related land resources problems or the most cost-effective methods of attacking them cannot be accurately determined. The success of efforts to correct problems cannot be evaluated.

Past progress in the preparation of a statewide framework water and related land resources plan and participation in Federal-State planning programs, as

it is, has not kept pace with desirable time tables largely because of difficulties surrounding planning policies decisions. In part, the weaknesses of the State's planning efforts are due to the lack of the existence of comprehensive statewide policies for water and related land resources planning, development and management. Understanding and appreciation of social-economic-political planning considerations lags behind knowledge of physical planning aspects. In addition and in connection with the environmental movement, many traditional assumptions have been questioned during the past 3 years, and attitudes toward population, economic and technology growth, and the use of natural resources are no exceptions. Public opinion regarding the balance between growth and environmental quality is still in the process of being crystallized.

It is argued on one hand that a statewide framework water and related land resources plan cannot be completed until planning policies are adopted by the Legislature and the Executive Branch. While on the other hand, it is argued that planning policies cannot be formulated until the impacts of a plan are known and public opinion concerning such issues as economic growth versus environmental quality is crystallized. Thus, it seems obvious that before decisions can be made concerning planning policies, the impacts of several alternative plans must be debated. The best procedure for resolving the plan - policy dilemma seems to be: 1) to prepare alternative plans based on several sets of planning policies (alternative futures) which emcompass all existing and possible emerging policy choices, 2) to identify economic and environmental impacts associated with the alternative plans, 3) to crystalize public opinion concerning desirable planning policies through public hearings, and 4) to identify the set of planning policies and associated plan which satisfy public opinion and State policies.

Future demands for water and related land activities have in the past been based upon a single projection of the important variables affecting water requirements. Future water demands will depend, however, on a number of variables including: (1) factors affecting demands for food and fiber for domestic use and for export, including the life styles and eating habits of people, (2) government programs dealing with resource development and distribution, such as achievement of environmental goals including meeting water quality standards, and farm price support and agricultural production controls, (3) the rate of technological advance, (4) municipal, industrial, and recreational water uses, and (5) the price of water to the various users. Any attempt to anticipate and identify future water resource problems must consider, among other things, changes in the rate of growth and distribution of the population and the economy, absence of existence of important government programs affecting water use, level of technology, eating habits of consumers, and laws dealing with environmental and water quality.

It is difficult if not impossible to attach values to many of these variables 50, 30, 20, or even 10 years in the future, And, it is even more difficult and probably impossible to assign a single value or "best" estimate to these same variables at some future time period. Thus, the problems of meeting future water requirements in terms of a range of possible outcomes, or alternative futures should be investigated. In formulating planning policies, the State should not be bound by any particular projection or forecast of the future. Rather, alternative forecasts should be made to ascertain the effects of alternative courses of action. The concept of alternative futures, should become a part of the basic framework of future water resources planning and decision making.

Three alternative futures will be investigated. One alternative future will be labeled "Developmental Alternative Future." The goals, assumptions, criteria and policies of alternative future 1 will be essentially those associated with Federal-State planning documents. The population and economy projections would be largely extrapolations of past trends. The plan associated with alternative future 1 will essentially consist of an integration of the plans formulated by Federal-State River Basin Commissions. Another alternative future will be labeled "Environmental Quality Alternative Future." The goals, assumptions, criteria and policies of alternative future 2 will be predicted upon population and economy projections which incorporate population and economy stabilization concepts and stress a high degree of environmental quality. It is probable that alternative futures 1 and 2 will be considered extremes. The third alternative future will be labeled "Balanced Developmental and Environmental Quality Alternative Future." The goals, assumptions, criteria and policies of alternative future 3 will be predicted upon emerging attitudes toward population and economic growths and that the objective to enhance economic development has no inherently greater claim on water and related land resources than the objective to enhance the quality of the environment. This report should assist the State in preparing the plan associated with alternative future 1.

PLANNING OBJECTIVES AND ASSUMPTIONS AND ELEMENTS OF PLANS

The planning objectives and assumptions adopted by each of the 4 Federal-State organizations differ somewhat in detail. However, in general, the planning objectives and assumptions of all Federal-State organizations are similar to those described below.

Economic and population projections are predicted upon assumptions. Also assumptions, criteria, and rationale are involved in the translation of economic and population projections into demands and needs for water and related land resources. Future problems are identified by comparing demands and needs and resource availability. Problems are those that would occur if no additional water and related land resources facilities were provided other than those that existed in 1969. Solutions to problems involve the provision of facilities over and above those available in 1969. Major objectives and assumptions, upon which the identification of problems and alternative solutions is based, are summarized below.

Objectives

The overriding goal and objective behind the preparation of a framework plan is to provide a broad guide to the best use, or combination of uses, of the water and related land resources of the region to meet foreseeable short and long-term demands and needs. Water and related land resources in appropriate instances must be preserved and enhanced to maintain or improve the quality of the region's environment. Natural resource development and management must keep pace with the economic and population growth of the region. The economic and population position of the region must be maintained or improved in part by the proper development and management of water and related land resources. Due consideration must be given to national, regional, State, local and private interests, keeping in mind reasonable and realistic principles concerning the sharing of the Nation's wealth.

Specific goals and objectives inherent in the framework plans are listed below:

- Development and management of water and related land resources to assure a supply adequate to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes from surface or groundwater sources or from a combination of these two;

- reduction of flood damage through floodplain management, flood protection, flood prevention, flood control, and flood-warning practices;

- contribution to the establishment, diversification, and stabilization of an economic base having capability to sustain acceptable living standards within communities and to provide employment opportunities;

- implementation of land-use practices that effectively reduce siltation and loss of the land base through activities associated with farming, mining, construction, forestry, and other development actions of man;

- improvement of water quality through control of municipal and industrial waste discharge, agricultural pollution, and littering, to permit and encourage additional use of the available water supply;

- maintenance and improvement of an environment that offers a diversity of recreational, cultural, and aesthetic experience in keeping with the resource capability;

- retention of those basic features which contribute to the historic uniqueness and character of the State; and

- application of the multiple-use concept to water and related land resources in a way that will permit utilization of the resource base in an efficient and balanced manner to serve the greatest number of people.

River Basin Commissions consider four objectives: national and regional economics, environmental quality and social well being. The national objective is attained when the outputs from a water and related land resource program are expected to equal or exceed the costs required to implement the program, or when outputs meet stated national objectives. National policy does not oppose a reasonable amount of interregional, interstate, local and private competition. The national objective is a major consideration in framework statewide planning, not only because it provides a measure of well-being of all the people and a basis for public investments, but also because it is a useful aid in assessing the extent of departure that may be necessary to meet other objectives such as regional, local, private, and environmental quality.

Regional, State, and local economic objectives provide for the preservation and/or enhancement of economic and social values generally through policies of income redistribution. Income redistribution as a goal assures a continuing or increased portion of the Nation's and/or State's income being allocated to a particular region, State, or locality.

The environmental quality objective is the preservation and enhancement of cultural and aesthetic values by postponing development of resources so that they may be available for their best use when needed. The environmental quality objective focuses on enhancement as well as the preservation aspects of quality and generally results in a lower level of investment in water and related land resources development. The attainment of the environmental quality objective often subordinates economic development by imposing quality standards and restricting or restraining development.

The objectives of national income, regional development, State development, environmental enhancement, and well-being of people provides the framework within which the effects of water and related land projects may be evaluated. The details of these objectives are continually changing as national, regional, and State goals are defined and new objectives emerge. Benefits and costs are identified as the beneficial or adverse effects of projects or program activities toward attainment of these objectives. Plans for water and related land resource use and development are formulated in recognition of their contribution to all of these objectives. Evaluation practices assure that these contributions are identified and fully measured.

In order to assure that full consideration be given to each of these objectives they are made explicit in operational terms for each program and project. Concomitantly, the contributions that programs and projects make to these objectives are measured. This permits the development and application of techniques for formulating project plans and programs in the context of multiple objectives. By displaying both favorable and adverse project effects on stated national, regional, State, and local water development and other objectives, a better basis of choice for selecting among alternatives is provided all groups of decision makers - Federal, State, and local governments, concerned citizen groups, and private enterprise.

National income measures a nation's output as the aggregate earnings of labor and property which arise from current and future production. The increase in national income attributable to a project or program is the measure of its contribution to this objective.

Development of water and land resources increases the productivity of natural resources and may increase the productivity of labor and capital used with these resources. Increases in crop yields, enhancement of land use, expansion in recreation use, and peaking capacity for power systems are examples of direct increases in productivity from water and related land development that contribute to national income. Additionally, there may be further national income gains from putting otherwise unemployed resources to work in related activities and from taking advantages of economies of scale and other externalities.

Droughts, floods and fluctuating water supplies cause disruption in economic activity. Reduction in direct economic losses through water and related land resource projects will reduce losses to other dependent activities and contribute to economic stability and steady flows of income.

The regional development objectives embrace several related components such as: increased regional income, increased regional employment, improved regional economic base, improved income distribution within the region, and improved quality of services within the region. Income gains in a region would include national income gains accruing to the region. Not all national income gains arising from a project in a region will necessarily accrue to that region. Where national policy and goals seek to bring about an improved geographic distribution of economic development through expansion of economic activity in a region, the effects of projects or program activities toward achieving such goals will be considered as regional development benefits. These regional development objectives are closely related to the well-being objective of personal income distribution.

The State development objectives embrace several related components such as: increased state income, increased state employment, improved state economic and population base, improved income distribution within the State, and improved quality of services within the State.

Environmental objectives include the conservation, preservation, creation, or restoration of natural, scenic, and cultural resources in order to enhance or maintain the quality of the environment. These objectives are closely allied to all efforts to conserve natural resources, including: the preservation or enhancement of aesthetic areas including open and green space, wild rivers, lakes, beaches, shores, mountains and wilderness areas, estuaries, or related areas of unique natural beauty; the protection of areas of archaeological, historical, or scientific value; the protection or improvement of water quality including the control of pollution from all forms of waste, drainage and heat and the prevention of erosion and the restoration of eroded areas, with particular emphasis on the treatment of watersheds, and critical erosion areas including gully, streambank, roadside, and beach erosion. A major consideration of environmental objectives is to conserve natural resources so that they will be available when needed and the freedom of choice by future users will not be impaired.

In addition to national income, regional development, State development, and environmental objectives, other well-being objectives consider the personal, group, and community effects of the project or program activity. Since some of these well-being objectives have a location impact, there is a close relation to regional development objectives. Included are such objectives as security of life and health, national defense, personal income distribution, and inter-regional employment and

population distribution. Security of life and health are enhanced by reducing risk of floods or other disaster to human life and by reducing the hazards to health associated with water development and use. National defense objectives are served by providing critical water supplies, goods, or transportation requirements, or by providing needed reserve capacities and protection against interruption of the flow of goods at the time of critical need. Objectives of personal income distribution are determined by national policies that specify arrangements for distribution of project benefits and costs among groups of beneficiaries. The distribution of population and employment over the state, regions, and nation is of concern and the effects of projects on such distribution should be indicated so that such effects can be related to national, regional, and state policy considerations.

Assumptions

The following assumptions have been used in projecting population and economic growth, water and related land resources demands, needs and opportunities and future problems and alternative solutions.

- no major nuclear conflict will occur during the projection period (1969-2020);
- government policy will be to maintain full employment (96 to 97 percent) without serious inflation;
- the quality and quantity of available water on a gross State basis will not be a factor limiting economic and population growth;
- there will be a modest drop of age - specific birth rates from the level of the 1950's;
- there will be completed average family size of about 3.2 children for all women who will have reached child-bearing age by 1975 and a leveling off to 3.1 children thereafter (upper Mississippi river basin and Missouri river basin);
- there will be completed average size of about 2.8 children for all women who will have reached child-bearing age by 1973 (Red river basin, Rainy river basin, and Great Lakes basin);
- most of the projected increase in population will occur in expanding urbanized areas;
- labor participation rates for women are expected to increase but labor participation rates for men will decrease because of the declining relative proportion of men between the ages of 35 and 65;
- there will be sufficiently high levels of economic activity and job opportunities to bar excessive labor force withdrawal (such as during a major depression) while precluding emergency which would prompt excessive labor force entry (such as during a full-scale war);
- the future trend in working hours will be similar to that of recent years, including the likely effect of longer vacations and increased part-time employment;
- man-hour productivity will continue to increase in accordance with post-war trend lines;

- future technical relationships among output, employment, and capital stock will approximate past trends;

- in the future, persons will not save an appreciably greater portion of their incomes than in the past;

- future estimates of employment can be made based on historical data concerning Bureau of Census population estimates and Bureau of Labor Statistics labor-force participation rates;

- a State which had a larger share of a given industry in the past will be expected to continue to hold a larger share in the future. To the extent that a given state had a larger share of rapidly growing as opposed to slowly growing or declining industries, that State would be expected to show greater increases in future employment;

- higher per-capita income will slightly increase per capita consumption of food until 1980 after which per-capita consumption is assumed constant, the greatest change will be in consumption of specific items such as beef and poultry products;

- export of food and feed grains over the period 1969 to 2020 will approximately double;

- projected agricultural yields and costs assume increased adoption of presently known technology;

- the State's share of the nation's food supply over the projection period will remain relatively stable;

- without additional water and related land resource development, increases in crop yields and livestock-feeding efficiency lag agricultural demands. The result is a gradual diminishing of idle and nonharvested land until after 2000. Projections for 2020 indicate that about 15 percent of the State's established agricultural demands could not be met without additional water and related land resources development and/or without stepping up the rate of technological advance in crop yields and/or livestock feeding efficiencies. Less than a 20 percent increase in yields over those projected for 2020 is necessary to meet all food, feed and fiber demands for the State without any additional water and related land resources developments;

- there will be over a 50 percent reduction in rural farm population between 1960 and 2020 and about a 50 percent decline in farm employment;

- the value of crops, livestock, and livestock products is projected to increase by an index of 143 in 1980, 190 in 2000 and 241 in 2020, using 1959 as a base;

- cropping pattern is not projected to change radically with resource development. Drainage, flood plain management, and conservation practices offer more opportunities for increasing agricultural production efficiency than does irrigation;

- rural and urban flood-plain areas are prime areas for future municipal, industrial, commercial, and agricultural expansion. Structural flood control and flood prevention works should be constructed to permit as much further development of flood plains as demanded. Flood-plain zoning and other

non-structural flood-plain management measures should be applied only to flood-plain areas which cannot be protected by structural works. Large-scale flood-plain zoning of both rural and urban flood-plain areas will not be acceptable to society; and

- large-scale local protection works (levees and channel improvements) are rejected as solutions to flood problems of a basin because they offer no regional flood damage reduction. Instead, programs and projects involving principally dam and reservoirs are deemed preferable to provide both local and regional structural flood-damage reduction.

Elements of Plans

The six major elements of plans are as follows:

Projections of economic and population development. Economic and population base studies start with information from a nationwide study by the Office of Business Economics of the Department of Commerce and the Economic Research Service of the Department of Agriculture, to prepare economic projections, including population and growth in major economic sectors, to the years 1980, 2000, and 2020.

Translation of economic and population projections into needs for water and related land resources uses. The economic projections are made for employment, income, and output for major economic sectors. In addition, information is collected on efficiency of water use in different economic sectors, on costs of substitutes and other factors that affect rates of water use in relation to economic activity. Relating projected economic activity and population growth to water use and pollution loadings is a responsibility of field planners.

Appraisals of the availability of water supplies, including quantity and quality. The use of mathematical models and computers has provided substantial improvement in this technique in recent years and is utilized to the extent practicable in the framework plan.

Appraisals of the availability and characteristics of related land resources. This involves the classification of soils and relating them to potential agricultural use, including irrigation capabilities. Also included are urban land changes, outdoor recreation and wildlife needs, greenbelts, and other potential uses.

Outline of the characteristics of projected water and related land resources problems. Based on the collection of the foregoing data, the critical problem areas are identified, and the characteristics of the problems are brought in focus.

Alternative approaches that appear appropriate for solution for the foregoing problems. This analysis is based on the general knowledge of development opportunities and costs, reasoned approximations, available data, and judgment of experienced planners. Those basins or parts of basins that have problems are described, including the possible solutions. Areas where no problems are expected in the immediate future are also indicated.

GREAT LAKES BASIN

Population And Economy

The 1970 population of the Great Lakes basin in Minnesota was 237,848; it was 247,899 in 1960. The largest municipalities and their 1970 populations are as follows: Duluth - 100,578; Hibbing - 16,104; Virginia - 12,450; Cloquet - 8,699; Chisholm - 5,913; Eveleth - 4,721; Two Harbors - 4,437; Hoyt Lakes - 3,634 and Silver Bay - 3,504. The population of all of these municipalities, except Hoyt Lakes, declined during the period 1960 - 1970. The population of the basin is projected to increase to about 353,000 in 2020.

Industrial activity in the basin, although diversifying into new areas of food and kindred products, garments and modular housing components, is still dominated by iron and taconite ore mining, processing and shipment; steel rolling and finishing; iron works, and industrial equipment fabrication. Duluth is the major industrial center for this type of industrial activity, which is also important to numerous Iron Range communities - Silver Bay, and Two Harbors. Other mining activities primarily sand and gravel, are widespread throughout the basin. Manufacturing of forest products and of paper and allied products is the other major mainstay of the basin economy. Manufacture of hardboard and formed fiber products, building insulation products, currugated containers, wood stick matches, and quality paper products are vital business activities in the Duluth and Cloquet areas.

The taconite industry has served to stabilize the basin economy particularly along the Iron Range. Major installations for mining and processing taconite ores include those located near Mountain Iron, near Forbes, near Hoyt Lakes and at Silver Bay. Taconite now accounts for more than 70 percent of total metal mining employment.

The garment industry has shown very promising growth characteristics in Duluth and along the Iron Range in Virginia, Eveleth, Gilbert and Hibbing. Mobile home and modular home construction units represent another high-potential business area, which logically draws upon Duluth's established industrial base.

Tourism is a major economic activity in Duluth and along the North Shore. An estimated 480,000 tourists visited Duluth in 1970. The convention business, showing continued improvement in recent years, has been further stimulated by the opening of excellent new facilities in Duluth.

The total employment participation rate (employment/population) in the basin was 0.32 in 1960 and it is projected to increase to 0.37 in 2020.

Climate and Water Resources

The climate of the basin is continental in the interior, while a modified maritime climate prevails near the lake shore. Average annual temperatures range from 35 to 40 F. The average annual precipitation over the basin is 27 to 32 inches; average annual snowfall over most of the basin varies from 40 to 50 inches. The average length of the growing season ranges from about 80 to 120 days.

The Great Lakes basin in northeastern Minnesota has a total drainage area of 11,434 square miles. Lake Superior has a surface area of 2,212 square miles in

Minnesota. The shoreline of Lake Superior in Minnesota stretches for 189 miles from Duluth to Grand Portage.

The average, maximum and daily minimum flows of the St. Louis river at Scanlon near Duluth are: 2,192 cfs, 37,900 cfs and 109 cfs, respectively. In the southern reach of the St. Louis river, it is questionable whether streamflow is sufficient to handle waste discharges, even assuming adequate treatment of municipal and industrial sources. In the upper reaches of the basin, low flow along the St. Louis river and its tributaries can pose a more serious problem in view of the large municipalities and extensive mining activities along the Mesabi Iron Range.

There are 14 lakes in the basin whose areas are 1,000 acres or more. Lake Superior dominates with 1,415,700 acres. Other large lakes include: Island Lake - 8,280 acres; Brule Lake - 5,204 acres; Whiteface Reservoir - 4,980 acres and Boulder Lake - 4,450 acres.

The groundwater resources in the basin are quite variable. In many areas, the glacial drift is too thin and discontinuous to provide adequate supplies of groundwater. In the St. Louis river subbasin, there are extensive areas of unconsolidated sand and gravel which, in general, yield large quantities of water. Much of the Lake Superior subbasin, including Duluth, lies within the Arrowhead groundwater province. Groundwater supplies in this province, for greater than domestic uses, are generally difficult to find because of the thin drift cover and the impervious basement. Low yield supplies can be obtained from scattered fractures within the bedrock. Glacial drift aquifers provide the only reliable groundwater supplies.

Most of the eastern portion of Carlton County and northeastern portion of Pine County lies within the East-Central groundwater province. Groundwater resources in this province occur mostly in the red drift. Surficial mapping indicated about one-third of this province is underlain by sands with moderate to high groundwater yields. Till deposits elsewhere in this groundwater province have generally low yields. The western portion of St. Louis County lies within the western groundwater province. The natural iron ore bodies along the Mesabi Range yield medium to high amounts of groundwater.

Inland in the Lake Superior subbasin, most municipal water supplies are obtained from groundwater. There is sufficient groundwater to adequately supply increased demands of the municipalities for their projected growth. Duluth uses Lake Superior for its municipal water supply, at a rate of approximately 16 mgd. A 23-mile long water line has been constructed from Duluth to Cloquet to convey Lake Superior water for domestic and industrial water supplies. Proctor and Midway Park are also supplied by Duluth. Two Harbors, Silver Bay, Beaver Bay, Grand Marais and a few other small communities withdraw water from Lake Superior. Otherwise, the remaining population in the Lake Superior subbasin obtain their water supply from wells. In the St. Louis river subbasin, 87 percent of domestic water supply is obtained from groundwater sources. In the Nemadji river subbasin, all domestic water is supplied by private wells.

On the lower St. Louis river, the Minnesota Power and Light Company operates 4 hydroelectric facilities, located between Cloquet and Fond du Lac. In addition, the Northwestern Paper Company generates hydroelectric power for its plants on the St. Louis river at Cloquet. These plants have a total installed capacity of 88,860 kilowatts.

Five storage reservoirs, 4 on the Cloquet river and 1 on the Whiteface river watershed, are used to regulate streamflow for operation of the power dams. These reservoirs have a total storage capacity of 332,160 acre feet.

Land Use and Minerals

The land use in the basin in 1970 (in thousands of acres) was as follows: urban buildings - 162.5 acres; cropland - 258.3 acres; pasture and range - 62 acres; forest land - 5,981.5 acres and other - 115.6 acres. Of the forest land, 5,347.6 acres were commercial and 633.9 acres were non-commercial. About 20 percent of the drainable land is drained, about 35 percent of the agricultural land is treated, and about 60 percent of the forest land is treated.

Taconite production is projected to increase from 47.6 million long tons per year in 1980 to 108 million long tons per year in 2020. Copper and nickel production is projected to increase from 0.27 million short tons per year in 1980 to 0.72 million short tons per year in 2020.

Alternative Programs For Development Of Water And Related Land Resources

Four alternative objectives were considered in designing programs for the development of the water and related land resources in the basin. These objectives are identified as follows: Normal Growth, representing the traditional national economic development because the latter is a reflection of a continuation of past trends; Limited Growth, which reflects the traditionally titled environmental quality in that as growth of population and the economy is limited, there is more emphasis on the enhancement and preservation of the natural resources; Accelerated Growth, which connotes encouragement of development in a part of the basin or the entire basin by bringing to bear unused or external resources which will increase the population in the area and increase the economic growth; and Preferred Growth, which projects the rate of growth of the population and the economy considered by the residents to be optimum. The overriding objective is to enhance the social wellbeing of people. This may be done by aiding in the improved distribution of employment, population and income; helping to provide for educational, cultural, and recreational opportunities; and by improving the security of life, health and property.

The normal growth objective includes an assumption that the economy tends toward an equilibrium condition in which production and consumption are balanced by the forces of a competitive economy. The objective also assumes that the generation of changes in income flows by public investment is triggered by alterations in the use of economic resources the level and composition of output, and patterns of consumption. Another basic assumption is that the national economy will remain in a state of equilibrium. Also, implicit in the objective is an assumption that past trends will be followed with respect to the values of the parameters of: the population of the working age, the labor force participation rate, the employment rate, the proportion of employment in the private economy, the hours per person per year in the private economy, and the product per man-hour in the private economy.

The limited growth objective is responsive to society's concern for a reduced consumption of limited natural resources and a conviction that this reduction in use

can come through a reduction in population and a reduction in unit consumption. Such a limited growth objective permits a greater emphasis on the conservation, preservation, creation, restoration, or improvement of the quality of natural and cultural resources and ecological systems, and the maintenance of the natural environment as a source of present enjoyment and as heritage for future generations. This is the kind of concern found in the National Environmental Policy Act of 1970.

Population projections for 2020 for the basin based on the accelerated, normal and limited growth objectives are 963,000, 353,000 and 253,000, respectively. Per capita income projections are $18,395.00, $13,516.00, and $9,621.00, respectively.

Alternative programs based on accelerated, normal and limited growth objectives for the development of the basin's water and related land resources are presented in Table 1. Programs will meet 100 percent of the basin's needs for municipally supplied, self-supplied industrial, rural domestic and livestock, irrigation, mining and thermal power cooling water withdrawals; municipal waste discharges; industrial waste water discharges; outdoor recreation; sport fishing; recreational boating; commercial navigation; wildlife management; outdoor recreation - intensive and outdoor recreation - extensive. About 37 percent of agricultural land treatment needs will be met together with 14 percent of cropland drainage needs, 56 percent of forest land treatment needs, 4 percent of shoreland erosion needs, 21 percent of streambank erosion needs, 100 percent of urban flood damage reduction and 54 percent of rural flood damage reduction.

Costs of Normal Growth Objective Programs for Development of Water and Related Land Resources

The estimated costs of normal growth objective programs for development of water and related land resources in the basin are as follows:

INITIAL INVESTMENTS 1970 - 2020 (1970 dollars)			ANNUAL OPERATION AND MAINTENANCE COSTS (2020)		
Fed. $	Non - Fed. $	Total $	Fed. $	Non - Fed. $	Total $
181,900,000	186,000,000	367,900,000	3,000,000	12,000,000	15,000,000

Total investments are greatest in the following program elements: forest land treatment thermal power cooling, outdoor recreation - intensive, commercial navigation, recreational boating, wildlife management and municipal waste water discharges. Non-Federal investments are greatest in the following program elements: thermal power cooling, forest land treatment, outdoor recreation - intensive, recreational boating, commercial navigation, wildlife management and municipal wastewater discharges. Federal investments are greatest in the following program elements: commercial navigation, forest land treatment, recreational boating, outdoor recreation - intensive, wildlife management and municipal waste water discharges.

Both Federal and non-Federal operation and maintenance costs are greatest in the following program elements: municipal waste water discharges, outdoor recreation - intensive, recreational boating, thermal power cooling, commercial navigation, mining water withdrawals and municipal water withdrawals.

TABLE I

Alternative Programs For The Development Of The Great Lakes Basin's Water And Related Land Resources

Description of Water and Related Land Resources Development Program Elements	Program Quantities Normal Growth Objective	Accelerated Growth Objective	Limited Growth Objectives
Water Withdrawals			
Municipally Supplied	23.0 mgd	156 mgd	9 mgd
Self-Supplied Industrial	15.0 mgd	106 mgd	5 mgd
Rural, Domestic & Livestock	1.8 mgd	6 mgd	2 mgd
Irrigation	15.2 mgd	66 mgd	5 mgd
Mining	72.8 mgd	600 mgd	24 mgd
Thermal Power Cooling	1,769.6 mgd	3,500 mgd	55 mgd
Non-Withdrawal Water Uses			
Municipal Wastewater Discharges	42.2 mgd	344 mgd	19 mgd
Industrial Wastewater Discharges	34.9 mgd	727 mgd	36 mgd
Outdoor Recreation	6,925,000 recreation days	30,800,000 recreation days	6,070,000 recreation days
Sport Fishing	1,500,000 angler days	2,400,000 angler days	487,000 angler days
Recreational Boating	970,000 boat days	2,480,000 boat days	716,000 boat days
Commercial Navigation	159.9 million tons/yr	248 million tons/yr	103 million tons/yr
Related Land Uses & Problems			
Agricultural Land Treatment	79,200 acres	79,200 acres	79,200 acres
Cropland Drainage	7,900 acres	7,900 acres	7,900 acres
Forest Land Treatment	2,162,400 acres	2,162,400 acres	2,162,400 acres
Shoreland Erosion	0.5 miles	0.5 miles	0.5 miles
Streambank Erosion	38 miles	38 miles	38 miles
Floodplains - Urban	100 acres	136 acres	72 acres
Wildlife Management	735,900 acres	735,900 acres	735,900 acres
Outdoor Recreation - Intensive	4,500 acres	21,500 acres	2,200 acres
Outdoor Recreation - Extensive	800 acres	800 acres	800 acres
Floodplains-Rural	60,900 acres	60,900 acres	60,900 acres

Requirements for Water and Related Land Resources Development

Withdrawals for water supplies in the basin in 1970 were as follows: municipal - 25.8 mgd, industrial - 68 mgd and rural 5.2 mgd. Projected withdrawals for water and supplies in 2020 are: municipal 52.5 mgd, industrial - 83 mgd and rural - 7 mgd.

The development of water resources within the basin in the past has been limited to a few hydroelectric developments, municipal sewer and water facilities, and reservoir facilities to supply water for iron and taconite processing. Water-supply shortages are not anticipated with respect to municipal supplies. Most municipal supplies are obtained from the groundwater in the basin, and it is felt that there is sufficient groundwater to adequately supply increased demands of the municipalities for their projected growth. Large quantities for either self-supplied industrial water, including that for mineral processing, and the water for thermal power cooling will probably come from Lake Superior.

There are 37 municipal waste sources and 98 industrial waste sources in the basin. The municipal sources include 19 with secondary treatment facilities, 15 with primary treatment only, and 3 with no sewers and treatment. Significant types of industrial sources are: irrigation, cooling and miscellaneous - 27 sources; iron ore mines and concentrators - 16 sources; electric power plants - 11 sources, and slaughterhouse/locker plants - 11 sources.

Addition of secondary treatment to 12 municipalities with only primary treatment facilities is required. All sewage treatment facilities in the basin require either urgent or definite near-term corrective action to expand, upgrade or otherwise improve existing operations. Several locations are expected to add tertiary treatment facilities.

The major pollution problems in the basin are traceable to: effluents from the mining and forest products industries, and the lack of secondary, or in many cases, tertiary treatment, by both municipal and industrial wastewater treatment systems. The single largest source of industrial effluent comes from the Reserve Mining Company (Silver Bay) taconite plant which discharges approximately 60,000 long tons of taconite tailings daily into Lake Superior. All other taconite plants in the basin use closed systems for effluent discharge, i.e., on-shore tailings basins.

Forestry and forest product manufacturing also use and discharge large amounts of water which, without proper treatment, can cause severe and extensive pollution. The St. Louis river has high water quality above Cloquet, and poor water quality below Cloquet to its mouth. Two large wood processing firms (Northwest Paper Company and Superwood Corporation), as well as some smaller companies, are located on this reach of the river. Progress is being made toward improving the treatment facilities of these two firms; continued effort in accordance with their stipulations is critical to the improvement of this stretch of the St. Louis river and beyond into Lake Superior.

The basin has a higher percentage of primary-treatment-only communities than has any other basin in the State. Phosphorus removal has been recommended for all the municipalities in the basin. The combined action of upgrading to secondary treatment and of providing for phosphorus removal for municipalities in the basin is of major importance for preserving water quality.

The recreational demand in the basin in 1970 was about 7 million recreation days; it is projected to increase to 17 million recreation days in 2020. Recreation programs include: berthing facilities, launching sites, navigational aids, and harbors of refuge. On inland waters, the programs primarily provide launching sites, access, and some berthing facilities. Needs include: greater utilization of the recreational potential on Lake Superior and along its shore and greater recreational use of existing designated wilderness areas while still preserving important wilderness qualities.

Recreational obstacles include low water levels for recreational canoeing, overuse of facilities within the Boundary Water Canoe area, adverse environmental impacts of mining operations, and heavy dependency upon the tourist industry. Much of the recreational land needs can be met by increased development of existing public forests and parks and by acquisition of lands in and near the Duluth - Superior area.

The Voyageurs National Park, an authorized addition to the National Park System encompassing about 219,000 acres, must be developed together with the proposed Grand Portage National Monument and the North Country Trail. New lands will need to be acquired to satisfy some of the recreational needs where opportunities are not now available. Acquisition and development of additional lands for 2 State parks, Baptism River and Judge Magney State Parks, is needed. Provision of additional access sites on Lake Superior and its tributaries is needed together with the reclamation of polluted beaches along the Lake Superior shore in the Duluth - Superior area. Lakeshore development around lakes has not created any problems except for a few lakes near Duluth.

In 1967, the basin sustained about 532,000 fishing trips for cold water species and 1,534,000 for warm water species. There was a deficiency of about 6,000 acres of lakes and 820 miles of streams to meet the demand. By 1985, this need is anticipated to have expanded nearly 5 times. One of the most important factors affecting the production of sport fish in the basin is the low productivity of waters. In many of the streams which support stream trout, the limiting factor is poor wintering habitat.

Sport fishery needs could be met by programs which include intensive management of reclaimed trout lakes, management of other lakes for other species, introduction of salmon and steelhead into Lake Superior and tribuary streams with spawning run development, management and stocking of stream fishery waters, and continued vigilence against the sea lamprey.

In 1970, there were about 57,000 hunters in the basin; 68,000 hunters are projected for 2020. Degradation and loss of habitat is occurring from surface mining operations and the associated structural facilities. The expected increase in acres devoted to this practice will eventually result in a significant portion of the basin being devoted to this single purpose use. This is a serious use conflict because the basin, due to it's high environmental quality, is much more suited to outdoor recreational use. The economic benefits of this use are traded for economic benefits derived from mining which, due to its permanence, also precludes the basin returning to recreational use at a later date.

Populations of white-tailed deer and ruffed grouse, the major game species are probably underharvested in the remote northern reaches of the basin due to limited access by public roads. Shore areas of Lake Superior close to public roads are heavily hunted.

The largest remaining concentration of timber wolves in the United States, with the exception of Alaska is found in the basin. Although Minnesota does not consider the wolf an endangered species (population is currently placed at 750 animals), the U. S. Bureau of Sport Fisheries and Wildlife does officially regard this animal (eastern timber wolf) as rare and endangered. Wolf numbers are limited directly by availability of their principal prey, deer, and thus indirectly by the carrying capacity of deer habitat. The U. S. Forest Service believes that the high demand for wolves for trophies, pelts, pups, exhibits, and scientific purposes has resulted in an increasing number of persons searching for timber wolf dens each spring, thereby creating a problem on those portions of National Forest lands where access is not limited.

The moose population has been declining slightly in recent years. This decline appears to be due to some winter losses and lowered productivity caused by habitat limitatons. The population is at or above the carrying capacity of the range, due to changes in forest succession.

A conflict between forest management and wildlife management is avoided when cutting operations in aspen and other hardwood stands attempt to regenerate aspen rather than release a thick understory of small hardwood trees. The maintenance of aspen and its associated undergrowth as a component of forest habitat is necessary if white-tailed deer and ruffed grouse are to be perpetuated.

The long-term trend for big game is downward, due primarily to the effects of natural succession away from a young, uneven-aged, mixed hardwood conifer forest toward the even-aged homogeneous spruce-fir climax forest. Timber harvest activity and wildlife management programs tend to arrest this trend and may create the variety in the vegetation necessary to sustain suitable game populations. All of the big game in the area (white-tailed deer, moose, black bear, and timber wolf), do best when the forest is broken up into a mosaic of stands of different age and species composition. The carrying capacity of the habitat is sustained for deer and moose populations and wolf populations are thus kept healthier too.

Habitat conditions for ruffed grouse, snowshoe hare, and woodcock have deteriorated for the same reasons given for big game. However, the trend toward a climax spruce-fir forest results in improved habitat for spruce grouse. Habitat for all wildlife species can be improved by forestry and wildlife management practices that create a greater diversity of habitat types.

Waterfowl populations are limited in spite of the abundance of water in the basin. Low fertility of soil and water limits the production of waterfowl food. The most favorable habitat for waterfowl consists of small flowages, beaver ponds. and lake bays.

Duluth-Superior harbor is located between and adjacent to Duluth and Superior, formed by the waters of St. Louis river and bay and Superior bay, and protected from Lake Superior by sand and gravel barriers or points of land, known as Minnesota Point and Wisconsin Point. Ships enter the harbor from Lake Superior, either through the Duluth Ship Canal located in the northern portion of the harbor or through the Superior Entry in the southeastern part of the Harbor. Piers of concrete and timber construction line the entrance channels and Superior Entry is protected from Lake storms by two breakwaters in the form of an arrowhead. The improved portion of the Harbor consists of 17 miles of dredged channels anchorage

areas or maneuvering basins providing 27-foot depths for iron-ore traffic, 23-foot depths for coal and grain traffic, and 20-or 21-foot depths in tributary channels. Superior Front Channel, with 27-foot depths provides an artery between entrances. Small pleasure-craft may also use numerous small bays projecting from the Harbor.

The shipping of ore from Duluth-Superior dominates the traffic picture of that port. For the past 30 years, the proportion of total shipping through the port for this product has been consistently above 75 percent. Grain shipments have increased in recent years and in 1969 generally exceeded 10 percent of the total port traffic. Coal and coke, the principal receipt, had been diminishing gradually through the years, from about 20 percent in the 1930's, to less than 10 percent in 1969.

Duluth - Superior harbor is served by 60 major docks, 32 which are in Duluth and 28 in Superior. Most of these are active, although few are operating at full capacity. The 1970 total shipments and receipts were about 80 million tons; they are projected to increase to 159.9 million tons in 2020.

Taconite Harbor, Silver Bay, Two Harbors, and Duluth-Superior harbors ship 63 percent of the iron ore traffic on the Great Lakes. In addition, Duluth - Superior ships 25 percent of the grain, 12 percent of the overseas general cargo and also handles scrap iron, fats and oils in international trade, plus coal, limestone, salt, steel products, gypsum and petroleum products in domestic movements. The bulk and overseas general commerce is expected to generate $35 million, $1.2 billion and $1.6 billion in total (direct and secondary) income in 1980, 2000 and 2020 respectively, and could support 104,000 families in 1980 and 178,000 families by 2020. The volume of commerce, employment generated and percent of total population that could be supported by the total income indicate that the basin is highly dependent on the mining, processing, and shipment of iron ore and pellets, on the transshipment of grain and on receipts and shipments of other bulk and general cargo. This traffic can only be sustained by a highly efficient and economical transportation system.

Federal expenditures through 1969 at Two Harbors and Duluth-Superior have totaled $27 million, including $8 million for maintenance. Maintenance costs are now averaging more than $200,000 annually. Provision of a 31 foot depth to accommodate supercarriers (vessels between 730 and 1,000 feet long) is not expected to require strengthening of dock structures but will require dredging as follows: Silver Bay, ($200,000); Taconite Harbor ($600,000) and Duluth-Superior ($17,000,000.)

Needed commercial navigation programs are extension of the season and accommodation of the new supercarriers. Projections of future waterborne traffic will be influenced positively by higher population and industrial growth (iron ore and copper industries), extension of season, and use of superships in the Lakes above the Welland Canal, and strong port promotion policies Low sulfer western coal is expected to begin moving through Duluth - Superior harbor bound for the lower lakes. This movement has already started through Thunder Bay (400,000 tons).

Possible negative influences are: lower rates of growth for population and industry; transportation of ore by rail or pipeline; competition from foreign ores, eastern ports and the Seaway (breakeven point is now the Cleveland area); and requirement of expensive land disposal of taconite tailings. Therefore, satisfying the national and regional economic development objectives will require continued support of the iron ore trade from western Lake Superior. Satisfying the

environmental objective may require expensive alternate means of disposal of tailings which would weaken the economies of Minnesota ores over foreign ore and deal a severe blow to the basin.

Power requirements in the basin are projected to be 17 times as high in 2020 as they were in 1970.

RAINY RIVER BASIN

Population and Economy

In 1960, most of the Rainy river basin's people were living in 15 incorporated places. The three largest towns are International Falls, Ely and Baudette, with a 1960 population of approximately 16.3 thousand. The total population of the basin in 1960 was about 40,400; in 1970, it was about 37,000. Population projections indicate expected future population levels of about 40,000 in 1980, 41,600 in 2000 and 44,700 in 2020.

Approximately 7,200 persons were employed in Koochiching and Lake of the Woods Counties in 1960. Projections of future employment indicate a growth rate of about 0.4 percent per year, giving an expected 2020 total employment of 9,100. The largest single employer in these two counties was the paper and allied products industry, employing about 2,000 persons. The employment level of the paper and allied products industry is expected to decline to 1,300 persons. Increases in employment are anticipated in industries such as the services and trade sectors. In 1967, earnings in the paper and allied products industry accounted for about 42 percent of earnings. Employment in forest-based industries, including forest management, was 3,460 persons. In 1962, agricultural earnings constituted about 6.8 percent of total earnings. Hay is the basin's dominant crop.

The basin's total personal income is projected to increase from $45 million in 1967 to $281 million in 2020. Per capita income was 80 percent of the national average in 1962 and it is projected to increase to 93 percent of the national average in 2020.

Climate and Water Resources

The climate of the basin consists of mild, pleasant summers and cold, snowy winters. The mean annual temperature varies from 35 to 39 F. The average annual precipitation is 21 to 30 inches; average annual snowfall is 50 to 60 inches.

The basin comprises a drainage area of 11,292 square miles in northern Minnesota. The maximum daily flow in the Rainy river at International Falls has been 47,900 cfs and the minimum daily flow has been 40 cfs. The average flow of the Rainy river into the Lake of the Woods is over 10,000 cfs At International Falls - Fort Frances, the Minnesota and Ontario Paper Company operates a hydroelectric plant which generates 5,600 kw. A 4,000 kw hydroelectric plant is located at Winston.

There are 65 lakes with areas of 1,000 acres or more in the basin. Lake of the Woods is, by far, the largest with 317,010 acres.

In general, low streamflow conditions are highly localized and do not jeopardize any of the basin's municipal and industrial water supplies There are no known major aquifers in the basin in the sense that aquifers with large proven water supplies have been identified. Small groundwater supplies may be obtainable from lenses of sand and gravel outwash, and in some places from fractures in the crystalline Precambrian rocks.

Land Use

About 5.8 million acres of the basin's total land area is forest, 231 thousand acres is cropland and 35 thousand acres is pasture or range. Urban and built-up area occupies 41 thousand acres, and other developments such as recreation and wildlife utilize 363 thousand acres. The total water area is approximately 722 thousand surface acres. The basin's major land uses expressed as a percent of the total land area are: forest land - 81 percent, urban and built-up - 1 percent cropland - 3 percent, water areas -11 percent, other lands - 3 percent and pasture and rangeland - 1 percent.

About 26.5 thousand acres currently being used for pasture and range land is suitable for crop production if converted to cropland. However, about 7.5 thousand acres currently being used for crop production could be converted to uses such as forest and pasture or range land. In 1968, private interests had approximately 200 acres of farm land under irrigation. The basin has an estimated 15,000 acres of land with soil and land characteristics such that they could be irrigated.

Mineral Resources

The only important mineral resource currently being utilized in the basin is a small to moderate amount of sand and gravel construction aggregate. The low-grade copper-nickel material in the Ely area is considered only a marginal deposit, even though vast tonnages are available for underground mining.

Alternative Programs for Development of Water and Related Land Resources

Two alternative programs for the development of the basin's water and related land resources are presented in Table 2. Each program is designed to meet a particular set of needs, but neither program is recommended as such.

Alternative program A is responsive primarily to a regional economic growth objective. In addition to identifying those measures needed to maintain the current rate of growth, alternative program A contains program elements which, if implemented would contribute to increases in regional Income, employment and general economic stability and to the enhancement of environmental and social well-being conditions of concern to the region. Alternative program A is not an "anti-environment" program. In selecting those elements included, those alternatives which would have the least deterimental impact on the natural environment were chosen as a matter of course.

Alternative program B is responsive principally to the maintenance and/or enhancement of environment objective. Environmental quality is enhanced by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the basin. Components of the environmental objective include the following: management, protection, enhancement, or creation of areas of natural beauty and human enjoyment such as open and green space, wild and scenic rivers lakes, beaches, shores, mountain and wilderness areas, and estuaries; management, preservation, or enhancement of especially valuable or outstanding archaeological, historical, biological (including fish and wildlife habitat), and geological resources

and selected ecological systems. Enhancement of selected quality aspects of water, land, and air by control of pollution; prevention of erosion and restoration of eroded areas with particular emphasis on the treatment of watersheds, mined areas, and critical erosion areas including gullies, streambanks, roadsides, and beaches; and minimizing nonreversible decisions.

Particular emphasis was placed on identifying those water and related land resources management and development measures which tend to: broaden the economic base; increase employment opportunities; maintain and enhance the health, well-being and security of the people by reducing hazards from water pollution and floods; maintain a strong agricultural economy by emphasizing watershed management, soil conservation practices, and irrigation; and improve the quality of life by preserving and enhancing environmental and aesthetic values of the region including lakes, parks, recreation facilities, fish and wildlife habitat and the most significant scenic and historic sites.

Alternative program A will meet 100 percent of the basin's needs for municipal and industrial (including self-supplied industrial), livestock, mining and private irrigation water. Components included would reduce urban flood damages by 97 percent. There are no provisions for the reduction of rural flood damages. Drainage of agricultural lands would proceed at the current rate. Land treatment is programmed to be 99 percent installed. Needs for wildlife habitat would be fully met.

No irrigation or agricultural drainage development is included in alternative program B. No provision is made for the reduction of flood damages beyond calling for floodplain management at Cook.

Both programs call for the development of new and/or enlarged waste treatment works for those communities whose present sewage treatment plants are not capable of providing adequate treatment through 2020. Development of these facilities will provide adequate treatment for 39,400 people or about 90 percent of the basin's 2020 population and will reduce the organic load to the basin's streams to about 2,000 population equivalent. Each program also proposes that a number of smaller communities replace their present waste treatment facilities with a new on-site private waste disposal system for each dwelling or business unit. With a combined population of only about 4,470, these communities are considered too small to warrant the development of community waste treatment systems. Both programs recognize the need to provide additional waste treatment facilities to accommodate increases in effluent arising from an expanding paper and pulp industry as well as from a growing milk processing industry. Both programs emphasize the importance of providing adequate waste treatment and improved water quality to enhance the basin's fish and wildlife resources.

TABLE 2. Alternative Programs for the Development of the Rainy River Basin's Water and Related Land Resources

Description of Water and Related Land Resources Development Program Elements	Program Quantities	
	Alternative A	Alternative B
Surface Water Control		
Single Purpose Reservoirs		
Develop storage for use in irrigation.	19,400 acre ft.	- 0 -
Develop storage for use by the pulp and paper industry and the mining industry; develop small dams and ponds to provide livestock water; and develop waterfowl habitat areas through the construction of low-head dams.	117,200 acre ft.	117,200 acre ft.
Instream Control		
Channel Improvement to reduce urban flood damages.	10 miles	- 0 -
Ground Water Development		
Municipal and Industrial		
Develop wells and pipelines to provide water for municipal and industrial use.	1,550 acre ft.	1,550 acre ft.
Rural Water Supply		
Develop wells throughout the basin to provide water for stock watering purposes.	850 acre ft.	850 acre ft.
Related Land Programs		
Drainage		
Develop drainage facilities on agricultural and forest lands.	147,900 acre ft.	- 0 -
Environmental and Resource Enhancement		
Protection and Management		
Continued management and treatment of agricultural and forest lands - Cropland 139,000 acres, Pasture and Rangeland 250,000 acres and Forest Land, 2,603,000 acres.	2,767,000 acres	2,767,000 acres
Waste Water Management		
Expansion or modification of waste treatment plants to meet municipal needs, expansion or modification of waste treatment plants to meet industrial needs, improved waste treatment at existing paper and pulp mills to meet needs develop new and/or improved facilities to adequately treat the wastes produced by the milk processing industry, develop on-site waste disposal systems for small communities, and develop new and/or improved toilet facilities in Natural Forest areas.	27,700 population served	27,700 population served

TABLE 2. (continued)

Description of Water and Related Land Resources Development Program Elements	Program Quantities	
	Alternative A	Alternative B
Water Supply Treatment		
Municipal - Install conventional water treatment plants	9,600 population served	9,600 population served
Fish and Wildlife Facilities		
Wetlands - Acquisition of wetland habitat through State Wildlife Management areas, preservation and development of wildlife habitat through the Agricultural Conservation programs, and preservation of wildlife habitat through land retirement under the Cropland Adjustment Program.	178,300 acres	287,300 acres
Access Sites - Develop access sites on lakes	- 0 -	12
Access Roads - Develop roads and highways and trails in State and National Forests to provide improved access to fish and wildlife resources.	2,553 miles	2,553 miles
General - Preservation and protection of all natural wild rice growing areas, Development of fish and wildlife habitat areas in National Forests preservation and protection of the basin's fishing resources through improved management of the resource in the National Forests and preservation and protection of wildlife habitat through restoration and improved maintenance of logging dams in the National Forests.		
Outdoor Recreation		
Special Use Lands - Develop intensively developed lands plus acquisition of buffer zones.	1,210 acres	296,800 acres
Trails and Roads - Develop trails	150 miles	150 miles
Nonstructural Management Programs		
Floodplain Management - Initiate floodplain management and regulation at Cook to preclude future flood prone developments	100 acres	100 acres
Shoreland Management - Initiate shoreland zoning or some other form of land use control to protect lake and adjacent shoreline environments.		
Additions and Modifications to Existing Projects or Developments		
Water Supply Systems - Increase capacity of existing treatment plants at Babbit, Littlefork and Orr	0.53 mgd	0.53 mgd

Costs of Alternative Programs for Development of Water and Related Land Resources

The estimated costs of alternative programs for development of water and related land resources in the basin are as follows:

Program	Initial Investments (1967 - 2020, 1967 Dollars) Fed. $	Non-Fed. $	Total $
Alternative A	175,977,400	71,629,200	247,606,600
Alternative B	175,291,600	67,270,700	242,562,300

Program	Annual Operation and Maintenance Costs (2020) Fed. $	Non-Fed. $	Total $
Alternative A	2,299,100	466,500	2,765,600
Alternative B	2,468,100	258,400	2,716,500

The greatest Federal investments would be for the following programs: fish and wildlife facilities - access roads; protection and management - forest land; outdoor recreation - special use lands; and fish and wildlife facilities - wetlands. The greatest non-Federal investments would be for the following programs: protection and management - forest land; waste water management - municipal, industrial and rural; single purpose reservoirs for water supplies and irrigation; and drainage.

The greatest Federal operation and maintenance costs would be associated with the following programs: fish and wildlife facilities - access roads and fish and wildlife facilities - wetlands. The greatest non-Federal operation and maintenance costs would be associated with the following programs: single purpose reservoirs for water supplies and irrigation; waste water management - municipal, industrial and rural; outdoor recreation - special use lands; and outdoor rrecreation - trails and roads.

Requirements for Water and Related Land Resources Development

Municipal and industrial water supply withdrawals are projected to increase from 1.98 mgd in 1968 to 4.36 mgd in 2020. About 2.38 mgd will have to be developed in excess of the developed base supply in 1968 to meet requirements. Industrial (self-supplied) water supply withdrawals are projected to increase from 54.05 mgd in 1968 to 157.09 mgd in 2020. About 103.04 mgd will have to be developed in excess of the developed base supply in 1968 to meet requirements. Domestic water supply requirements are expected to decline through 2020 due to the projected decrease in rural and non-farm population. Livestock rural water supply withdrawals are projected to increase from 2,637 acre-feet in 1968 to 4,764 acre-feet in 2020. About 2,127 acre-feet will have to be developed in excess of the developed base supply in 1968 to meet requirements.

Approximately 200 private acres were irrigated in 1968 with 260 acre-feet of water. By 2020, about 15,200 acres could be irrigated with 19,760 acre-feet of water. About 19,500 acre feet of water will have to be developed in excess of the developed base supply in 1968. Water for private irrigation will generally be supplied by surface water sources.

Above the dam at the outlet of Rainy Lake, in the basin, the bacterial and physical characteristics are such that the water is suitable for all domestic uses. Below the dam, the bacterial and physical characteristics of the water indicate that the river has been degraded by discharges to the stream of paper and pulp mills wastes and inadequately treated municipal waste. There are over 50,000 surface acres in the Boundary Waters Canoe Area which recently have exhibited algal blooms every year. About 10,000 acres can presently be classed as severe and limiting for recreation uses. The Rainy river between International Falls and Baudette has been degraded by municipal and industrial wastes and does not support a good sports fishery. Below Baudette, the quality improves and a good fishery is maintained. A possible future water-quality problem in the basin could be caused by mineral exploration and the proposed expansion of existing mining operations.

The most serious water quality problem occurs at International Falls where the combination of municipal and industrial wastes causes degradation of the Rainy river for many miles downstream. The Minnesota municipalities in this area have constructed adequate waste treatment plants, but industrial installations are very inadequate. A second cause of concern exists in the municipal waste disposal practices of Little Fork river drainage and the Rainy river and Lake of the Woods drainage below International Falls. Four of the five municipal waste treatment plants in these drainages are primary plants and therefore do not meet Minnesota requirements.

The Forest Service has not been able to keep abreast of the demand for public recreation areas. Only about one-fourth of the campsites have adequate latrines and the Forest Service estimates that possibly 75 percent of all seepage pit toilets in the forest contribute to water pollution in some degree. Many campsites have no toilet facilities.

There are 19 municipal and 29 industrial waste sources in the basin. A total of 7 municipalities require urgent or definite near-term corrective action. In 3 instances, this action involves upgrading from primary to secondary treatment; in 4 cases, improvement of existing secondary treatment facilities. There are 3 municipalities which require future improvement prior to 1980.

Land required for mining was about 20 acres in 1968 and is projected to increase to 55 acres in 2020. About 35 acres will have to be developed in excess of the developed base supply in 1968 to meet requirements. About 424 acre-feet of water was required for mining in 1968 and mining water withdrawals are projected to increase to 1,221 acre-feet in 2020. About 797 acre-feet will have to be developed in excess of the developed base supply in 1968 to meet requirements.

In most of the basin, flood occurrences have been of minor consequence since the basin is lightly populated and occupation of the floodplains has been limited. Nevertheless, serious flooding of fertile agricultural lands frequently recurs along some of the western tributaries of Lake of the Woods. High lake stages, especially when accompanied by high winds, have caused flood damages to shoreline properties on several of the larger lakes, particularly Namakan Lake, Rainy Lake, and Lake of the Woods.

Average annual urban flood damages with all existing projects in places are projected to increase from $43,000 in 1968 to $58,000 in 1970. Average annaul rural flood damages with all existing projects in place are projected to increase from $106,000 in 1968 to $175,000 in 2020.

In 1968, acreage which had been adequately drained were as follows: cropland - 60,000 acres, pasture and rangeland - 6,000 acres, forest and woodland - 27,043 acres and other 3,000 acres. Land acreages which are characterized by a minor wetness condition and are considered feasible for drainage are as follows: cropland - 88,761 acres, pasture and rangeland - 11,236 acres, forest and woodland - 779,728 acres and other - 4,016 acres. The following acreages will have to be developed in excess of the developed base supply in 1968 to meet requirements: cropland - 28,761 acres, pasture and rangeland - 5236 acres, forest and woodland 752,685 acres and other 1,016 acres.

In 1968, acreage which had been adequately treated for erosion control were as follows: cropland - 69,000 acres, pasture and rangeland - 7,000 acres and forest and woodland - 3,240,000 acres. Acreages requiring treatment for erosion control are as follows: cropland - 231,000 acres, pasture and rangeland - 35,000 acres and forest and woodland - 5,843,000 acres. The following acreages will have to be treated in excess of the treated base supply in 1968 to meet erosion control requirements: cropland - 162,000 acres, pasture and rangeland - 28,000 acres and forest and woodland - 2,603,000 acres.

Demands for outdoor recreation are projected to increase from 1,046,000 recreation days in 1968 to 2,587,000 recreation days in 2020. The developed supply for recreation land is increasing from 170 acres in 1968 to 250 acres in 2020. Required developed land for recreation is projected to increase from 230 acres in 1968 to 560 acres in 2020. About 310 acres of recreation land will have to be developed in excess of the developed base supply to meet requirements. The developed recreation water surface supply in 1968 (316,431 acres) exceeds requirements by 299,431 acres. Developed supply of trails increases from 10 miles in 1968 to 14 miles in 1980 and then decreases to 10 miles in 2020. Trail requirements are projected to increase from 70 miles in 1968 to 160 miles in 2020. About 310 miles of trails will have to be developed in excess of the developed base supply to meet requirements.

The demand for hunting is projected to increase from 510,000 hunter-days in 1968 to 671,000 hunter-days in 2020. Developed supply for hunter-days will increase to 236,000 hunter-days. About 435,000 hunter-days will have to be provided in excess of the developed base supply to meet requirements. The demand for fishing is projected to increase from 1,653,000 fisherman-days in 1968 to 2,246,000 fisherman-days in 2020. The developed supply for fisherman (2,993,000 fisherman-days) exceeds the requirements.

There is a deficit of large trees which limits product suitability and the quality of forest stands. Sawtimber stands occupy only 365-thousand acres while medium-sized trees in poletimber stands grow on 2.3-million acres. Young seedling and sapling stands account for 1.6-million acres or one-third of the commercial forest land. Ideally, a better balance of size classes should be available. Management attention could provide a better structuring of young stands and accelerate growth into the larger classes. Accomplishments in tree planting, timber stand improvement, wildlife habitat development, recreation improvement and watershed protection and management have provided for adequate treatment on about 3.2-million acres, or slightly over half of all forest lands. By 2020, 950-thousand acres more will undoubtedly be adequately treated. Priority watershed protection and environmental maintenance measures on Federal forest lands include channel clearing and improvement, streambank protection, multiple-purpose and water level control structures, recreation improvements, human-and solid-waste disposal, and

wildlife and wetland developments.

The electric power requirements in the basin are projected to increase from 288 million kwh in 1965 to 4,855 million kwh in 2020. Reak requirements are projected to increase from 56,000 kw in 1965 to 912,000 kw in 2020.

RED RIVER BASIN

Population and Economy

The population of the Red River basin was 236,850 in 1970 and 241,534 in 1960. Over 32 percent of the basin population is concentrated within 7 municipalities with 1970 population as follows: Moorhead - 29,687, Fergus Falls - 12,443, Thief River Falls - 8,618, Crookston - 8,312, East Grand Forks - 7,607, Detroit Lakes - 5,797 and Breckenridge - 4,200. Population changes 1960-1970 were: Moorhead - +29.4 percent, Fergus Falls - -9.4 percent, Thief River Falls - +20.5 percent, Crookston - -2.7 percent, East Grand Forks - +8.7 percent, Detroit Lakes - +2.9 percent and Breckenridge - -3.1 percent. During the period 1960-1970, population increased in only 3 counties and decreased in the 18 other counties in the basin. There are 114 municipalities in the basin: 64 percent are under 500 population and 80 percent are under 1,000 population. The general tendency is for larger municipalities to continue to grow and for smaller communities and rural areas to decrease in population.

The population of the basin is projected to increase to about 297,000 in 2020. Total employment is projected to be about 113,250 in 2020 distributed in economic sectors as follows: agriculture, forestry and fisheries - 6,100; mining - 250; construction - 7,500; non-commodity - 86,000; and manufacturing - 13,400. The per capita income is projected to be 87 percent of the national average in 2020.

The primary industry in the basin is agriculture. Small grains, sugar beets, potatoes and soybeans are the principal crops grown. Other industries are service industries and those related to the processing or distribution of the basin's agricultural products. Included among these industries are beet sugar plants, flour mills, meat packing plants and farm machinery manufacturers. Service industries include machine shops, bakeries, foundaries, print shops, etc. Wildlife and recreation facilities in the basin represent a major source of income.

The basin's economy is projected to grow at a rate below that of the nation but to increase in magnitude. The total demand for food and fiber produced in the basin will more than double by 2020 because of anticipated growth in population and exports. The ratio of total employment to total population for the basin will approach, but not necessarily reach, the national ratio of 40 percent by 2020.

Climate and Water Resources

The climate of the basin is markedly continental in type with cold winters and relatively warm summers. The mean annual temperatures throughout the basin range from 37 to 43° F. The average growing season is 180 to 190 days per year, or 20 to 30 days less than in southern Minnesota. Average annual precipitation is 19 to 24 inches; average annual snowfall is 30 to 40 inches.

The basin comprises a drainage area of 17,729 square miles in northwestern Minnesota. The Red river begins at the junction of the Bois de Sioux and Otter Tail rivers at Breckenridge. Major sub-basins and areas are: Two Rivers-Jo river - 1,232 square miles, Roseau river - 1,128 square miles, Red Lake river - 5,661 square miles, Middle-Snake-Tamarac rivers - 1,286 square miles - Wild Rice Marsh Sandhill rivers - 2,465 square miles, Buffalo river - 1,189 square miles, Otter Tail river - 1,922

square miles, Mustinka-Bois de Sioux rivers - 1,429 square miles, and Red river main stem (direct drainage) - 1,417 square miles.

There are wide variations in flows in the Red river and its tributaries, from zero or very low flow conditions to widespread damaging floods. Discharges of the Red river at Emerson, Manitoba are: average - 2,970 cfs, minimum daily - 0.9 cfs, and maximum instantaneous - 95,500 cfs.

Surface water is used for municipal water supplies by several major communities: East Grand Forks, Breckenridge, Crookston, Thief River Falls and Fergus Falls. Moorhead uses both ground and surface water supplies. Smaller communities using surface water include Hallock, Oslo, Stephen and Frazee.

There are 53 large lakes with areas of 1,000 acres or more in the basin, mostly concentrated in Otter Tail and Becker Counties. Red Lake (288,800 acres) is by far the largest lake.

There are 3 reservoirs on Red river tributaries in Minnesota. The Red Lakes and Lake Traverse reservoirs are of particular importance in flood control and flow regulation. The 3 reservoirs have a combined usable storage of 2,062,400 acre feet.

There are 7 hydro-electric plants in the basin, 2 on the Red Lake river and 5 on the Otter Tail river. The combined installed capacity of the plants is 4,125 kw.

Groundwater is obtained primarily from aquifers in Pleistocene glacial drift. Outwash and ice-contact deposits near the southeastern edge of the basin are quite thick and probably contain the largest acquifers, both in area and estimated groundwater storage. Buried lenses and stringers of sand and gravel scattered throughout the basin yield water generally adequate only for small domestic supplies. Glacial Lake Agassiz deposits cover much of the basin and they are generally too fined grained to be important as a source of groundwater. Some of the lakeshore deposits of glacial Lake Agassiz are coarse grained and form important acquifers.

Major drift aquifers underlie only about 18 percent of the basin. In view of the limited areal extent of major drift aquifers, most of the basin is dependent on bedrock and minor drift aquifers for groundwater supplies. Bedrock aquifers, which underlie the glacial drift, yield small quantities of water, generally of inferior quality.

Alternate Programs for Development of Water and Related Land Resources

Two alternative programs for the development of the basin's water and related land resources are presented in Table 3. Each program is designed to meet a particular set of needs, but neither program is recommended as such.

Alternative program A is responsive primarily to a regional economic growth objective. In addition to identifying those measures needed to maintain the current rate of growth, alternative program A contains program elements which, if implemented, would contribute to increases in regional income, employment, and general economic stability and to the enhancement of environmental and social well-being conditions of concern to the region. Alternative program A is not an

"anti-environment" program. In selecting those elements included, those alternatives which would have the least deterimental impact on the natural environment were chosen as a matter of course.

Alternative program B is responsive principally to the maintenance and/or enhancement of environment objective. Environmental quality is enhanced by the management, conservation, preservation, creation, restoration, or improvement of the quality of certain natural and cultural resources and ecological systems in the basin.

Components of the environmental objective include the following: Management, protection, enhancement, or creation of areas of natural beauty for human enjoyment such as open and green space, wild and scenic rivers, lakes, beaches, shores, mountain and wilderness areas, and estuaries; management, preservation, or enhancement of especially valuable or outstanding archaeological, historical, biological (including fish and wildlife habitat), and geological resources and selected ecological systems; enhancement of selected quality aspects of water, land, and air by control of pollution; prevention of erosion and restoration of eroded areas with particular emphasis on the treatment of watersheds, mined areas, and critical erosion areas including gullies, streambanks, roadsides, and beaches; and minimizing nonreversible decisions.

Particular emphasis was placed on identifying those water and related land resources management and development measures which tend to: broaden the economic base; increase employment opportunities; maintain and enhance the health, well-being and security of the people by reducing hazards from water pollution and floods; maintain a strong agriculture economy by emphasizing watershed management, soil conservation practices, and irrigation; and improve the quality of life by preserving and enhancing environmental and aesthetic values of the region including lakes, parks, recreation facilities, fish and wildlife habitat and the most significant scenic and historic sites.

Structural measures for reducing flood damages to existing developments are considered essential to the economic and social well-being of urban areas.

Alternative program A will meet 100 percent of the basin's needs for municipal and industrial, industrial-self-supplied, and rural water supplies; and private irrigation, mining, fish and wildlife; and recreation facilities. Program A includes components which, if implemented, would significantly reduce urban flood damages by 2020; rural flood damages would be reduced by 67 percent in 2020. Program A calls for the drainage of agricultural lands at the current ongoing rate. Land treatment is programmed to be 85 percent installed by 2020.

Alternative program B differs from alternative program A in that no irrigation or agricultural drainage development is included. Urban flood damage would be reduced by only 28 percent in 2020; rural flood damage reduction reaches a high of 4 percent by 2020.

Both programs call for the development of new and/or enlarged waste treatment works for those communities whose present sewage treatment plants are not capable of providing adequate treatment through 2020. Development of these facilities will provide adequate treatment for about 85 percent of the basin's 2020 population. Each program also proposes that a number of smaller communities replace their present waste treatment facilities with a new on-site private waste

disposal system for each dwelling or business unit. Both programs recognize the need to provide additional waste treatment facilities to accomodate increases in effluent arising from a expanding food processing industry.

Cost of Alternative Programs for Development of Water and Related Land Resources

The estimated costs of alternative programs for development of water and related land resources in the basin are as follows:

	Initial Investments (1967 - 2020, 1967 dollars)		
Program	Fed. $	Non-Fed. $	Total $
Alternative Program A	95,000,000	94,000,000	189,000,000
Alternative Program B	66,000,000	66,000,000	132,000,000

	Annual Operation and Maintenance Cost $ (2020)		
Program	Fed. $	Non-Fed. $	Total $
Alternative Program A	1,900,000	4,400,000	6,300,000
Alternative Program B	4,500,000	2,300,000	6,800,000

The greatest total investments are associated with continued management and treatment of cropland, pasture, rangeland and forestland. Investments for water supply, drainage flood control, recreation, waste disposal, and fish and wildlife programs follow in order of magnitude. The greatest Federal investments are associated with continued management and treatment of cropland, pasture, rangeland and forest land; flood control; water supply; drainage; and recreation in that order. The greatest non-Federal investments are associated with drainage, land treatment, water supply and waste disposal programs.

The greatest total operation and maintenance costs are associated with private irrigation, fish and wildlife, water supply, recreation, and land treatment programs in that order. The greatest Federal operation and maintenance costs are associated with fish and wildlife and flood control programs. The greatest non-Federal operation and maintenance costs are associated with private irrigation, fish and wildlife, land treatment, waste treatment and water supply programs in that order.

TABLE 3. Alternative Programs for the Development of the Red River Basin's Water and Related Land Resources

Description of Water and Related Land Resources Development Program Elements	Program Quantities	
	Alternative Program A	Alternative Program B
Surface Water Control		
Multiple Purpose Reservoirs		
Develop storage near Twin Valley (Wild Rice river) to be used jointly for flood control, fish and wildlife, and recreation	47,000 acre ft.	0
Single Purpose Reservoirs		
Develop storage on Red Lake river above Crookston for flood control	177,000 acre ft.	0
Develop small dams and ponds to provide livestock water	10,000 acre ft.	10,000 acre ft.
Develop surface acres for waterfowl habitat	0	30,000 acres
Instream Control		
Develop urban levees at Perley, East Grand Forks, and Oslo to reduce urban flood damage	8 miles	0
Develop rural levees along the Red river main stem to reduce flood damages	160 miles	160 miles
Groundwater Development		
Irrigation		
Develop wells for irrigation of land under private development	113,000 acre ft.	0
Municipal and Industrial		
Develop wells and pipelines for use in smaller communities (1,000-10,000 population)	7,000 acre ft.	7,000 acre ft.
Develop wells and pipelines for use in communities having populations of less than 1,000	3,000 acre ft.	3,000 acre ft.
Develop wells and pipelines for self-supplied industrial use	1,300 acre ft.	1,300 acre ft.
Rural Water Supply		
Develop wells for stockwatering purposes	10,000 acre ft.	10,000 acre ft.

TABLE 3. (continued)

Description of Water and Related Land Resources Development Program Elements	Program Quantities: Alternative Program A	Program Quantities: Alternative Program B
Mining		
Develop wells for mining purposes	6,000 acre ft.	6,000 acre ft.
Related Land Programs		
Drainage		
Develop drainage facilities for agricultural lands	3,500,000 acres	0
Irrigation		
Irrigation through private development of groundwater	100,000 acres	0
Environmental and Resource Enhancement		
Protection and Management		
Continued management and treatment of cropland, pasture and rangeland and forest land	7,500,000 acres	7,500,000 acres
Waste Water Management		
Expansion or modification of existing municipal and industrial waste treatment facilities. Develop on-site waste disposal systems for small communities	120,000 population served	120,000 population served
Water Supply Treatment		
Install conventional water treatment plants	60,000 population served	60,000 population served
Fish and Wildlife Facilities		
Waterfowl production areas, fee and easement acquisition- 35,913 acres; State Wildlife Management Areas - 489,301 acres; National Wildlife Refuges - 500 acres; Wetland Water Bank - 1,074,035 acres; Agricultural Conservation Program - 308,370 acres; public access to public land - 60 acres; wild rice areas - 7,975 acres; wildlife habitat, Indian - 725 acres; trout management - 625 acres; commercial fish, Indian - 10 acres	790,000 acres	1,917,504 acres
Outdoor Recreation		
Special Use Lands		
Develop intensively developed lands plus buffer areas	10,000 acres	10,000 acres
Trails		
Develop trails	1,000 miles	1,000 miles

TABLE 3. (continued)

Description of Water and Related Land Resources Development Program Elements	Program Quantities: Alternative Program A	Program Quantities: Alternative Program B
Nonstructural Management Programs		
Floodplain Management	10,000 acres	10,000 acres
Additions and Modifications to Existing Projects or Developments		
Water Supply Systems		
Increase capacity of existing treatment plant at Grand Forks	3.75 mgd	3.75 mgd.

Requirements for Water and Related Land Resource Development

Generally the basin has adequate water supplies. The major problem is protection of the supplies. A small amount of irrigation is practiced in the basin, 1.2 mgd irrigating about 2,800 acres. Industrial water requirements were about 4.6 mgd in 1965 and they are projected to increase to about 13 mgd in 2020. Municipal water requirements are projected to increase from 11 mgd in 1965 to 28 mgd in 2020.

The fishery of the Red river has been largely eliminated due to water pollution. At present it is not suitable for any recreational activity, which involves water contact; below Fargo-Moorhead. Several lakes in the Detroit Lakes area have experienced catastrophic aquatic weed and algae growth in recent years as a result of excessive nutrient enrichment. The most serious waste-treatment problem is that caused by the four sugar-beet-processing mills of the American Crystal Sugar Company located at East Grand Forks, Crookston and Moorhead, and Drayton, North Dakota. Sugar beet process wastes are extremely high in oxygen-demanding organic matter and the bacterial population of the water is also very high. The combination of high strength, high bacterial population, seasonal operation, and large volumes makes for a very difficult situation.

Water quality will be degraded by the return flows from the lands to be irrigated by water imported from the Missouri river basin through the Garrison Diversion Project of the Bureau of Reclamation. As presently conceived, about 25,700 acres in North Dakota will be under irrigation in the Sheyenne valley by 1980 and about 15,400 acres will be irrigated by the same date in the Wild Rice valley. By 2000, 65,500 acres will be irrigated in the Sheyenne valley and 18,500 acres in the Wild Rice Valley. By 2020 over one quarter million acres may be under irrigation in the two valleys.

In 1971, there were 114 municipal and 363 industrial waste sources in the basin. The municipal sources include 3 with tertiary facilities, 55 with secondary treatment facilities, 4 with primary treatment only, 5 with sewers and no treatment, and 47 smaller communities with no sewers and treatment. Major types of industrial sources are milk receiving and processing plants (67) and slaughterhouse/locker plants (67). There were 20 potato processing, grain and potato washing sources. The industrial waste produced exceed those of the population by 10 times. There are a large number of industries for which expanded treatment is required. The most

severe unsolved waste treatment problems are those of the sugar beet and potato processors. In addition to point sources, agricultural wastes are of significance. Livestock feedlots, inorganic fertilizers, pesticides, herbicides, dissolved solids concentration from irrigation, and surface drainage are contributory pollution sources.

Addition of secondary treatment to the 5 sewered municipalities with no treatment, and to 4 with only primary treatment is needed. Of the 55 municipalities with secondary treatment, 20 require either urgent or near-term corrective action to expand, upgrade or otherwise improve existing facilities. Nine additional municipalities require facility improvement by 1980. Approximately 23 smaller communities need to add sewers and treatment before 1980.

The development of the basin due to the growth of the agricultural economy has resulted in encroachment on the very extensive tributary and main stem floodplains. In this region much of the urban encroachment can be attributed to the lack of high-ground areas suitable for development. The most critical flood-prone area extends along the Red river main stem and includes the lower-lying portions of Wahpeton, Breckenridge, Fargo, Moorhead, Grand Forks, and East Grand Forks; the entire communities of Georgetown, Perley, Hendrum, Halstad, Oslo, Robbin, St. Vincent, and Noyes, Minnesota, and of Drayton, Bowesmont, Joliette, and Pembina, North Dakota; and about 560,000 acres of the most fertile farmland in the basin. Fertile farmland bordering the many minor tributaries of the Red river experience flooding both from the local source and from Red river backwater along the downstream reaches of the tributaries.

Damaging floods are known to have occurred on the Roseau river in 1919, 1923, 1927, 1938, 1942, 1948, 1950, 1951, 1956, 1962, 1965, 1966, 1967, and 1969. The entire Village of Roseau (1960 population - 2,146) and about 65,000 acres of primarily agriculture land along the Roseau river between Roseau Village and the upstream limit of Big Swamp are subject to flooding. The Two Rivers watershed flood problems are aggravated by overflow floodwaters from the Roseau river entering the tributary ditches via Big Swamp. During the past 20 years, damaging floods caused principally by snowmelt have occurred in 1950, 1966, and 1969 and very high crop losses resulted from rainstorm floods in June, 1957, the summer of 1958, and June, 1962. The 1950 flood inundated lowlying urban developments at Hallock and Lake Bronson and over 40,000 acres of agricultural land. Floods from snowmelt occur on an average of once in two years during spring breakup in the Tamarac river watershed. Major flooding in the western half of the watershed has occurred during the spring of 1950, 1956, 1962, 1965, and 1969. The floodplain area along the Tamarac river north and west of the Village of Stephen and along the lower end of the northernmost branch, often affected, is estimated at 9,500 acres of which approximately 95 percent is cropland.

A stream gaging station on the Middle river has been in continuous operation since 1950 at Argyle. Floods were recorded in 1950, 1965, 1966, and 1969 from snowmelt runoff. Rainfall flood occurred in July, 1956, June, 1962, and July, 1968. Widespread and damaging flooding of the Snake river and its tributaries plus overland flooding, occurred five times during the past 20 years, including the years 1950, 1965, 1966, and 1969. Floods have adversely affected the towns of Argyle, 1960 population 789; Newfolden, 1960 population 370; Middle River, 1960 population 414; Warren, 1960 population 2,007; and Alvarado, 1960 population 282.

The floodplain at Crookston (1960 population 8,546) the major urban flood problem area of the Red Lake river watershed, includes nearly half the residential area of the City. The major flood of 1950 at Crookston was caused by snowmelt

followed by prolonged rainfall. The April, 1965 flood on the Red Lake river, which was caused by heavy rainfall on frozen soil, produced a crest stage at Crookston just exceeding the 1950 flood peak stage. Successful, though costly, emergency protective works prevented heavy flood damage at the communities along the Red river, except at Robbin, Bowesmont, St. Vincent, and Noyes. Flooding of the Red river and some of its tributaries, including the Red Lake river, occurred again in the spring of 1967 as a result of snowmelt. With sandbagging of low areas and other emergency measures, only minor urban damages were sustained at Crookston and the communities along the Red river. However, over ten-thousand acres of cropland were flooded in the vicinity of Oslo.

Floods resulting principally from snowmelt runoff overtop the Sand Hill River channel banks within the Red river valley and inundate adjacent cropland, thus delaying seeding. Beltrami, a small village (1960 population, 186) is located in the floodplain. Very widespread and extremely damaging floods have occurred in the Wild Rice-Marsh watershed in the years 1882, 1897, 1909, 1943, 1947, 1950, 1965, and 1969. Lesser and more localized flooding has occurred in 1915, 1916, 1936, 1946, 1951, 1956, 1962, 1964, and 1966. Large floods frequently inundate broad rural areas along the Wild Rice and Marsh rivers from the point of diversion above Ada downstream to near Hendrum and Shelly. Frequent flooding occurs throughout the Red river valley area of the Buffalo river watershed. The floodplains encompass low-lying portions of the communities of Barnesville, Georgetown, and Hawley, with 1960 populations of 1,632, 178, and 1,270, respectively. Fertile cropland bordering the drainage ditches and other tributaries within the Red river valley portion of the Otter Tail River watershed comprise a principal flood-prone area. However, the area bordering the Otter Tail River main stem remains subject to limited residual damage from the larger, more infrequent floods.

Average annual flood damages in the basin are projected to increase from $5,324,000 in 1967 to $9,099,000 in 2020. About 26 percent of flood damages are rural; 74 percent are agricultural and other. Projects which have started or have been funded prior to December, 1967 reduce flood damages by about 29 percent.

Outdoor recreation annual demand in the basin is projected to increase 2.3 times by 2020. A present need exists for additional acres of facility development and trails to satisfy unmet demands for outdoor recreation. In the year 2020, 86% of the demand for land-based activities will be unsatisfied with the existing recreation land base. Similarly, 23 percent of the water-oriented demand cannot be satisfied with the existing water base. A large percentage of the available recreation areas are not accessible for day-use from major urban centers. Poor water quality combined with the low flows detracts from the recreational value of the Red river and some of its major tributaries. Massive algae blooms in many of the basin's shallow lakes detract from their recreational value.

Pollution, including sedimentation, is the factor most severely limiting fishing in existing waters. Agricultural, industrial, and domestic pollutants are primary degraders of fish habitat and a serious problem. Among the more significant fish and wildlife problems are the following: the continuing loss of valuable natural wetlands and its disruptive effects upon resident and migratory wildlife; destruction of fish and wildlife habitat through land use changes associated with highways, urban development flood control, drainage, channelization, irrigation, and agriculture; poor land use practices such as overgrazing or failure to protect against natural hazards resulting in erosion (wind and water); siltation of streams, reduction of wetlands, and losses of habitat by flooding; habitat destruction through misuse (or undermanagement) of public land; lack of access to public land for hunting and fishing or associated recreation; unused or under-utilized game or fish populations often resulting from restrictive laws and lack of physical and legal public access;

pollution of fishing waters and inadequate protection of water quantity and quality; over-utilization of slow growing species such as lake trout, sturgeon, and possible other species in waters of low fertility; undeveloped or underdeveloped commercial fisheries; widely fluctuating stream flows that accentuate other limiting factors for fish such as low water quality and high biochemical oxygen demand; undesired eutrophication of lakes accelerated by detergents, agricultural fertilizers, and chemical and organic wastes from associated land and water use; and the need to preserve natural areas for beautification, scientific, and cultural purposes including those of prime importance to threatened species.

Studies reveal several needs that should receive major attention: reduction of accelerating eutrophication rates and man-made pollutants entering streams and lakes; correct or improve the unbalanced distribution of fishing opportunity; reverse the trends of decline of lake trout from deep and relatively infertile lakes; repair and maintain low dams on lakes and streams in forested areas; provide for more and better waterfowl production habitat; reverse the decline of distribution and abundance of rare and endangered species such as lake sturgeon; restore small game production already lost and replace losses estimated for the future from agricultural drainage; protect and preserve Greater Prairie Chicken habitat in the last remaining natural prairies on "beach" lands of Pleistocene Lake Agassiz; and improve economics associated with commercial fisheries.

Wind erosion is a problem in the basin with some sheet erosion in the glacial drift areas and some gully erosion on the small portions of cropland on steeper slopes and along the streams. Much of the level lake basin has a micro-relief which is easily flooded. The water trapped in the shallow basins causes seeding operations to be delayed in the spring and damages standing crops in the remainder of the crop season. Major treatments needed to provide protection to the land are: floodways, residue management, cover crops, annual buffers, field windbreaks, fertilizing, grassed waterways and drainage.

It is estimated that 37 percent of the cropland is adequately treated at the present time. Of the land remaining to be treated, about 54 percent of it needs only residue management and annual cover crops. About 9 percent needs grass in rotation; about 19 percent needs more intensive treatment such as stripcropping, grassed waterways, annual buffers, and field windbreakers; and about 18 percent needs drainage. A very small percentage needs seeding back to permanent grass. It is expected that the proportion of land adequately treated will increase to about 50 percent by 1980, 60 percent by the year 2000, and 70 percent by 2020.

About 39 percent of the pasture and range land is presently considered to be adequately treated. Of the remaining land to be properly treated about 39 percent of the pasture and 51 percent of the range land needs proper management practices such as proper use to maintain the grass in good condition. About 44 percent of the pasture and 39 percent of the range land needs improvement by measures such as fertilization, weed control, interseeding, or reseeding. Some small scattered areas of rangeland need brush control along with good management to improve it. Pasture and range land adequately treated is expected to increase to 50 percent by 1980, 60 percent by the year 2000, and 70 percent by 2020.

Forest lands need some timber stand improvement and protection from grazing to improve timber quality. The remaining stands on commercial forest land are in need of cultural treatment to bring them to the desired level of stocking. There is a deficit of large trees which limits product suitability and the quality of many forest stands. Management attention could provide a better structuring of young stands and accelerate growth into the larger classes.

Forecasts of irrigation development, water use, investment, and impacts for the Souris-Red-Rainy river basin were prepared by the U.S. Bureau of Reclamation for the Optimum utilization of land and water resources to stabilize and improve local and regional agricultural economics through irrigation. Potentially irrigable lands were considered to be suited to development by either private or project methods depending on the availability of the water supply. Project systems are pictured as large scale surface-water storage and distribution works which could probably be constructed only with the investment of public funds. Whereas, private irrigation is accomplished with farm-unit sized systems utilizing primarily groundwater resources. An estimate of potential irrigation development is: North Dakota - 1,203,500 acres, South Dakota - 3,500 acres and Minnesota 343,000 acres.

Water for potential irrigation could be withdrawn from groundwater or diverted from rivers, streams, or lakes. Water supplies available for irrigation are limited in the Souris river and Red river basins and are plentiful in the Rainy river basin. Groundwater which would be available for irrigation has been identified in certain areas of the Souris river and Red river basins. Inventories are incomplete at present. The abundance of good quality surface water, apparent absence of large water-bearing aquifers and the small size of the potentially irrigable area preclude the consideration of groundwater for irrigation in the Rainy river basin. In contrast, the Souris river and Red river basins have large areas of potentially irrigable land but surface water is not available from the Souris river for irrigation development and Red river water supplies could serve only a portion of the potentially irrigable area in the basin. Water for ultimate irrigation development in these two basins must be supplied from the Missouri and Rainy rivers.

The complex system for diverting water from the Rainy river basin might cost $300 million for initial installation. The project is not deemed feasible at this time until after the year 2020.

The electric power requirements in the basin are projected to increase from 1,686 million Kwh in 1965 to 28,615 Kwh in 2020. Peak requirements are projected to increase from 373,000 Kw in 1965 to 5,573,000 Kw in 2020.

UPPER MISSISSIPPI RIVER BASIN

The Upper Mississippi river basin has been subdivided into 5 basins: Minnesota river basin; Cannon, Zumbro and Root rivers basin; Mississippi river headwaters basin, Des Moines river basin and Cedar river basin. The overriding goal and objective behind the preparation of framework plans for these basins is to provide a broad guide to the best use or combination of uses, of the water and related land resources of the basins to meet foreseeable short and long-term demands and needs. Water and related land resources in appropriate instances must be preserved and enhanced to maintain or improve the quality of the basins' environment. Natural resource development and management must keep pace with the economic and population growth of the region. The economic and population position of the basins must be maintained or improved in part by the proper development and management of water and related land resources. Due consideration must be given to national, state, local and private interests, keeping in mind reasonable and realistic principles concerning the sharing of the Nation's wealth.

More specific goals and objectives for the framework basins' plans are listed below:

- Development and management of water and related land resources to assure a supply adequate to meet long-range seasonal requirements for domestic, municipal, industrial, agricultural, fish and wildlife, recreational, power, navigation, and quality control purposes from surface or groundwater sources, or from a combination of these two;

- Reduction of flood damage through floodplain management, flood protection, flood prevention, flood control, and flood-warning practices;

- Contribution to the establishment, diversification, and stabilization of an economic base having capability to sustain acceptable living standards within communities and to provide employment opportunities;

- Implementation of land-use practices that effectively reduce siltation and loss of the land base through activities associated with farming, mining, construction, forestry, and other development actions of man;

- Improvement of water quality through control of municipal and industrial waste discharge, agricultural pollution, and littering, to permit and encourage additional use of the available water supply;

- Maintenance and improvement of an environment that offers a diversity of recreational, cultural, and aesthetic experience in keeping with the resource capability;

- Retention of those basic features which contribute to the historic uniqueness and character of the State; and

- Application of the multiple-use concept to water and related land resources in a way that will permit utilization of the resource base in an efficient and balanced manner to serve the greatest number of people.

Population and Economy

In 1960, the population of the Mississippi river headwaters basin in Minnesota was about 2,000,000. Population projections indicate a level of about 5,600,000 in 2020. Over 70 percent of the people lived in the Minneapolis - St. Paul Standard Metropolitan Statistical Area. Some of the larger municipalities and 1970 populations outside this area are as follows: St. Cloud - 39,691, Willmar - 12,869, Brainerd - 11,667, Bemidji - 11,490, Hutchinson - 8,031, Little Falls - 7,467, Grand Rapids - 7,247, Alexandria 6,973, Litchfield - 5,262, Sauk Rapids - 5,051, Mora - 2,582, Pine City - 2,143, Sandstone - 1,641, Moose Lake - 1,400, Lindstrom - 1,260, Rush City - 1,130, North Branch - 1,106 and Chisago - 1,068. During the period 1960-70, many rural areas experienced a population decrease and most urban populations increased. The Twin Cities Metropolitan Area accounted for the largest increases in urban population.

The center of Minnesota's manufacturing activity has been the Twin Cities. A concentration of production, capital and skills has enabled diversification of types of industries. Percentages of total employment in various categories in 1970 were approximately as follows: agriculture, forestry, fishery and mining - 1 percent; construction - 6 percent; non-commodity - 69 percent; and manufacturing - 24 percent. Projected employment percentages in 2020 are: agriculture, forestry, fishery and mining - less than 1 percent; construction - 7 percent; non-commodity - 73 percent; and manufacturing - 20 percent.

Outside the Twin Cities Metropolitan area agriculture and related industries account for a significant portion of the occupational activity in the basin. Expansion of various industrial activities from the wide base in the Twin Cities which includes petroleum, chemical and primary metal industries has been increasingly evident in counties west and north of the Twin Cities Metropolitan area. The St. Cloud regional area is rapidly developing an important base of various industries: food and kindred products, stone and masonry products, optical goods and printing and publishing.

The pulp and paper industry has large installations at Brainerd, Grand Rapids, Little Falls and Sartell. Iron and taconite ore mining is primarily centered in Itasca County on the Cuyuna Range. Large taconite plants are located near Nashwauk and Keewatin. In many parts of the basin, heavy concentrations of resorts draw increasing numbers of vacationers. Extensions of light industrial manufacturing operations are occurring in Chisago, and southern Pine and eastern Kanabec counties.

Percentages of total employment in various categories in 1970 were approximately as follows: agriculture, forestry, fishery and mining - 14 percent; construction - 6 percent; non-commodity - 55 percent; and manufacturing - 21 percent. Projected employment percentages in 2020 are: agriculture, forestry, fishery and mining - 5 percent; construction - 6 percent; non-commodity - 64 percent; and manufacturing - 25 percent.

Per capita income in the basin is projected to increase from $2,264 in 1960 to $10,300 in 2020. National per capita income was $2,220 in 1960 and is projected to be $10,540 in 2020.

Climate and Water Resources

The mean annual temperature in the basin varies from 38 to 44° F. The average annual precipitation ranges from 22 to 30 inches; average annual snowfall ranges from 40 to 50 inches. Average duration of total crop season ranges from 180 to 220 days.

The basin comprises a drainage area of 23,786 square miles in central and eastern Minnesota. Minimum, maximum and average discharges of the Mississippi river at St. Paul are 632 cfs, 171,000 cfs and 10,080 cfs, respectively. Minimum, maximum and average discharges of the St. Croix river at St. Croix Falls are 75 cfs, 54,900 cfs and 4,057 cfs, respectively. There are 128 lakes in the basin with areas of 1,000 acres or more.

In general, the groundwater in the basin is plentiful and more than adequate to meet present and most future needs. With the exceptions of the City of St. Cloud and the Twin Cities, almost all of the central water supply systems use groundwater. Groundwater is found in unconsolidated glacial sediments and in bedrock formations. Extensive areas of permeable outwash deposits are present throughout the basin. The outwash deposits in the Upper St. Croix basin constitute a potential source of sustained high yields for irrigation and industrial use. There are certain areas within the basin where glacial deposits are fine grained and low yielding, however, the future potential for development of groundwater in the basin is enormous.

In the lower portion of the basin, water supplies come from sandstones and dolomites which are some of the highest yielding bedrock aquifers in the country. Well yields from the Jordan-Prairie due Chien aquifer are consistently high. The Mt. Simon-Hickley, a deeper and thicker acquifer, is also a significant source of well water supply.

Commercial navigation exists in the basin. There is a nine foot deep channel on the lower 23 miles of the St. Croix river from Stillwater to Prescott. Navigation improvements on the Mississippi river consisting of locks and dams and a 9-foot channel extend into Minneapolis.

There were 14 hydroelectric projects located in the basin in 1966.

Land Use

In 1968, urban land use was practiced on 838,000 acres in the basin; urban land use in 2020 is projected to be 1,450,000 acres. Cropland and pasture land use is projected to increase from 6,938,000 acres in 1968 to 7,898,000 acres in 2020. Forest land use was practiced on 7,610,000 acres in 1968; other land use was practiced on 1,458,000 acres in 1968.

Program for Development of Water and Related Land Resources

The program for the development of the basin's water and related land resources are presented in Table 4. The program will meet 92 percent of the basin's needs for water withdrawals uses. The greatest unsatisfied need is for agricultural withdrawals for irrigation. About 59 percent of the instream use needs for

TABLE 4.
Program For The Development Of The Mississippi River Headwaters Basin's Water And Related Land Resources

Description of Water and Related Land Resources Development Program Elements	Program Quantities
Natural Streamflow	
Municipal and Industrial, Withdrawal use	195 mgd
Industrial Self-Supplied, Withdrawal use	72 mgd
Agricultural, Withdrawal use	3 mgd
Thermal Power Cooling, Withdrawal use	1,997 mgd
Water Surface Access, Fish and Wildlife area	74,000 acres
Aesthetic and Cultural Areas	151,000 acres
Groundwater	
Municipal and Industrial, Withdrawal use	223 mgd
Industrial Self-Supplied, Withdrawal use	82 mgd
Agricultural, Withdrawal use	40 mgd
Mining	44 mgd
Recreation, Instream use	314 mgd
Fish and Wildlife, Instream use	314 mgd
Streamflow Control	
Municipal and Industrial, Withdrawal use	111 mgd
Industrial Self-Supplied, Withdrawal use	41 mgd
Recreation, Instream use	1,500 mgd
Fish and Wildlife, Instream use	1,500 mgd
Water Quality Management, Instream use	600 mgd
Recreation, Water surface area	150,000 acres
Flood and Sediment Damage Reduction	
Administration of Flood Plain Zoning, Floodproofing New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan, Flood Insurance Program	50 years
Corrective Damage Reduction, Aesthetic and Cultural area	163,000 acres
Corrective Damage Reduction, Cropland and Pasture	60,000 acres
Preventive Damage Reduction, Aesthetic and Cultural area	214,000 acres
Preventive Damage Reduction, Flood Plain area	214,000 acres
Land Treatment and Management	
Treatment, Cropland and Pasture	900,000 acres
Treatment, Aesthetic and Cultural area	530,000 acres
Erosion Control	1,130,000 acres
Drainage, Cropland and Pasture	1,200,000 acres
Forests Land Management	1,393,000 acres
Land Acquisition	
Streams (Purchase and Easement)	1,190 miles
Recreation	650,000 acres
Aesthetic and Cultural area	202,000 acres
Wetland Preservation	290,000 acres
National Forest Expansion	54,000 acres
Wastewater Treatment	
Secondary Treatment and Advanced Waste Treatment	Meeting Water Quality Standards

recreation, fish and wildlife and water quality management would be met. The program would satisfy about 50 percent of the water surface area needs for recreation and fishing, 92 percent of the recreational land resources needs, 67 percent of the hunting land area needs and 85 percent of aesthetic and cultural area needs. About 81 percent of the floodwater and sediment problem, 85 percent of the erosion problem, 71 percent of the drainage problem and 32 percent of the forest lands management problem would be solved. Water quality standards would be fully met.

Costs of Program for Development of Water and Related Land Resources

The estimated costs of the program for development of the water and related land resources in the basin are as follows:

Initial Investments (1969-2020, 1969 dollars)			Annual Operation and Maintenance Costs (2020)		
Fed. $	Non-Fed. $	Total $	Fed. $	Non-Fed. $	Total $
1,061,426,000	1,303,800,000	2,365,226,000	66,068,000	97,100,000	163,168,00

The greatest Federal investments would be for the following programs: wastewater treatment, streamflow control, land acquisition, land treatment and management and flood and sediment damage reduction. The greatest non-Federal investments would be for the following programs: wastewater treatment, streamflow control, land treatment and management, natural streamflow and flood and sediment damage reduction.

The greatest Federal annual operation and maintenance costs would be associated with the following programs: streamflow control, wastewater treatment, land treatment and management, land acquisition and flood and sediment damage reduction. The greatest non-Federal annual operation and maintenance costs would be associated with the following programs: wastewater treatment, streamflow control, land treatment and management, flood and sediment damage reduction and land acquisition.

Requirements for Water and Related Land Resources Development

Water withdrawals for all purposes are expected to increase from 891 mgd in 1966 to 3,961 mgd in 2020, an elevenfold increase. Municipal and industrial withdrawals are projected to increase from 156 mgd in 1966 to 713 mgd in 2020, while industrial self-supplied withdrawals increase from 135 mgd to 341 mgd. Rural domestic and livestock withdrawals are projected to increase from 41 mgd in 1966 to 83 mgd in 2020. The projected increase from 4 mgd to 228 mgd in irrigation withdrawals could have a significant impact on the water resources in the basin. Water withdrawals for mining use is estimated to increase from 18 mgd in 1966 to 62 mgd in 2020. The 1966 thermal power cooling water withdrawals is 537 mgd; thermal power cooling water withdrawals are projected to be 2,534 mgd in 2020. Proposed closed cycle cooling systems may change this outlook. A water supply problem of large proportion may be anticipated at Minneapolis-St. Paul by 1980.

In the seven county Metropolitan area in 1971 the population in 86 municipalities served by sewers with secondary treatment was 1,631,186; the population in 5 municipalities served by sewers with tertiary treatment was 15,041;

the population in 1 municipality served by sewers with primary treatment was 6,876; and the population in 2 municipalities served by sewers with no discharge was 3,733. Seventeen municipalities with populations less than 500 serving a total population of 4,398 were without sewer systems; 24 municipalities with populations greater than 500 serving a total population of 43,713 were without sewer systems. There were 3 Metropolitan Sewer Board installations: Metropolitan Wastewater Treatment Plant, Blue Lake Wastewater Treatment Plant, and Seneca Road Wastewater Treatment Plant. All 3 plants were under construction in 1971. The Metropolitan Wastewater Treatment Plant served 45 municipalities with a total population of 1,463,519. In addition, 35 municipalities with a total population of 194,972 were served with facilities owned and operated by the Metropolitan Sewer Board.

There were 13 industries whose wastes were not discharged directly to municipal sewerage systems and had separate outlets and significant discharges. Five of these industries had secondary treatment facilities; 5 had primary treatment facilities; and 3 had no treatment facilities. Industry contributed about 60 percent of the total organic waste load in the Seven County Metropolitan area. Only 5 of the Metropolitan Sewer Board's 33 treatment plants met State water quality standards in 1971. The total population of the municipalities served by these plants was 42,049. The Metropolitan Wastewater Treatment Plant met all standards except the one for suspended solids.

Outside the Twin Cities Metropolitan area, 232 municipal and 620 industrial waste sources were identified in the basin. The municipal sources include two with tertiary treatment facilities; 115 with secondary treatment; 11 with primary treatment; 6 with sewers and no treatment; and 98 small communities with no sewers and treatment. Major types of industrial sources are 134 milk receiving and processing plants and 107 slaughterhouse/locker plants. Agriculturai wastes, although moderate in absolute terms, are of significance. Wastewater from wood and paper products manufacturing and mining operation also contributes heavily to the pollutional load on specific water bodies of the basin.

Current and potential improvement needs of 133 sewered communities were made. Addition of secondary treatment to 17 municipalities is required. Fifty of the 115 municipalities with a current level of secondary treatment require either urgent or definite near-term corrective action to expand, upgrade or otherwise improve existing facilities. Future problem areas and dates identified below were projected because existing streamflows will be insufficient to meet flow requirements to assimulate wastes after a secondary degree of treatment: Mississippi river below Grand Rapids - present, South Fork Crow river below Hutchinson - 1980, and Mississippi river below Minneapolis - St. Paul - 1980.

Significant flood damages occur along the Mississippi, St. Croix, Crow, and Rum rivers to agricultural and urban property as well as to railroads, roads, and bridges which occupy the flood plains. The total downstream area without flood plain management subject to flooding is 233,000 acres. Average annual damages of $,468,000 in 1966 are projected to increase to $6,628,000 in 2020. Flood plains in upstream areas of the basin total 230,000 acres. Average annual flood damages are projected to increase from $1,053,000 in 1966 to $3,535,000 in 2020.

Recreation demand is projected to increase from 43,864,000 recreation days in 1966 to 156,744,000 recreation days in 2020. The recreation supply was 26,867,000 days in 1966. There is need for an additional 726,000 acres of Bureau of

Outdoor Recreation Classes 1 and 2 recreation lands by 2020; only 128,000 acres were available in 1968. The demand for aesthetic and cultural areas is projected to increase to 8,080,000 acres in 2020; the supply was 2,152,000 acres in 1968 leaving a need for an additional 5,928,000 acres in 2020. About 100 miles of scenic and/or wild rivers are needed.

Fishing and hunting demand is projected to increase from 3,042,000 fishing and hunting days in 1966 to 3,573,000 fishing and hunting days in 2020. The fishing and hunting supply was 2,913,000 fishing and hunting days in 1968. With an available fishing and hunting area supply of 15,394,000 acres, an additional 3,070,000 acres of fishing and hunting area is needed. Wetland preservation is needed on 290,000 acres.

Erosion problems occur on 1,322,000 acres and 1,689,000 acres have drainage problems. There are 4,487,000 acres of forest lands which require management programs. Land treatment is needed on 900,000 acres.

There are congested harbor and fleeting areas and problems of limited access in the Minneapolis-St. Paul area along the Mississippi river.

MINNESOTA RIVER BASIN

Population and Economy

The 1970 population of the Minnesota river basin was 396,240; the 1960 population was 403,835. The 1970 populations of 8 of the largest municipalities were as follows: Mankato - 30,895, New Ulm - 13,051, Fairmont - 10,751, St. Peter - 8,339, North Mankato - 7,347, Waseca - 6,789, Montevideo - 5,661 and Morris - 5,366. Approximately 51 percent of the basin population is concentrated within 9 southern counties which comprise 35 percent of the land area. Population in the basin decreased by 1.9 percent since 1960. Of the 33 counties included, in whole or in part within the basin, 8 counties gained population and 25 lost. The population in the basin is projected in 2000 to be 760,000 or 1.72 times the population in 1960.

The employment in the basin in 1960 was 143,000; 74,000 was non-commodity producing, 69,000 was commodity producing, 13,000 was manufacturing commodities and 56,000 was nonmanufacturing commodities. The 2020 employment is projected to be 244,000; 188,000 will be noncommodity producing, 56,000 will be commodity producing, 25,000 will be manufacturing commodities and 31,000 will be nonmanufacturing commodities. Per capita income in 1960 in the basin was $1,617; it is projected to be $9,905 in 2020.

The Minnesota river basin is an area of extensive agricultural activity, featuring corn and small grain production, sweet corn and green pea production, dairy farming and livestock feeding. In 1960, about 38 percent of the total employment was in agriculture. In 1969, there were over 1 million cattle and calves, including milk cows and heifers in the basin (more than 25 percent of the State total), and 1.25 million hogs (almost 40 percent of the State total).

There are relatively few large industrial centers in the basin; most industries are located along the lower reaches of the Minnesota river from Mankato to its confluence with the Mississippi river at Minneapolis - St. Paul. The industrial development in the basin is closely associated with those industries which depend upon agriculture for their raw materials, e.g., food processing and canning plants. There are a considerable number of widely distributed plants engaged in food canning and freezing and in poultry packing. Numerous smaller dairy processing and slaughter house plants are distributed throughout the basin.

Climate and Water Resources

The mean annual temperature in the basin ranges from 44 to 46° F. Average annual precipitation ranges from 21 to 30 inches; normal annual snowfall is 40 inches. The average duration of the total crop season ranges from 200 to 220 days.

The Minnesota river drains an area of 14,910 square miles in Minnesota. The maximum instantaneous flow of the Minnesota river at Carver has been 117,000 cfs. and the minimum flow has been 79 cfs. The average flow is 3,174 cfs. There are 39 lakes in the basin with areas of 1,000 acres or more. The 3 largest lakes are Swan Lake - 9,346 acres, Minnewasha - 7,770 acres and Big Stone - 6,028 acres.

The eastern half of the basin generally has adequate groundwater supplies available for present and foreseeable needs. Known sand and gravel aquifers are capable of yielding much more water than is currently withdrawn. Bedrock units,

especially the Jordan-Prairie du Chien aquifer and the Mt. Simon - Hinkley aquifer, are high yielding aquifers.

The unconsolidated sediments in much of the valley of Minnesota river are generally very fine-grained and probably will yield relatively little water to wells. Locally, they are also thin where the bedrock rises almost to the river bed. The thickness of the alluvium and its width in the lower reaches of the river are very great. It may be that studies will indicate that in some reaches the alluvium is a major potential source of water for industry. Generally, the glacial drift aquifers in the basin have been adequate for municipal and industrial use.

The major part of the western half of the basin is underlain by several glacial till sheets ranging up to more than 400 feet in total thickness. Extensive drift deposits are present in most of the major tributaries to the Minnesota river. Locally, these deposits yield large quantities of groundwater. The groundwater yield potential on the uplands depends mostly on the presence or absence of sand bodies in the glacial drift. Several towns use water from Cretaceous sandstones despite its inferior quality, because a source of better quality water is not available.

Land Use

In 1958, the major land use in the basin was as follows: tototal - 10,580,000 acres, urban and built up - 340,000 acres, cropland - 8,501,000 acres, pasture - 776,000 acres, forest - 346,000 acres and other - 617,000 acres, There were 249,000 acres of water area. The projected land use in 2020 is as follows: urban built-up-432,000 acres, cropland - 9,078,000 acres, pasture - 137,000 acres, forest - 316,000 acres and other 617,000 acres.

Mineral Resources

Within the basin, in 1960, dimension stone accounted for about 52 percent of the total mineral value ($10,976,948), sand and gravel about 43 percent, and crushed stone about 6 percent. The quantities of sand and gravel, crushed stone and dimension stone mined were 5,731,000 short tons, 578,000 short tons and 60,500 short tons, respectively. Future production of mineral commodities is projected to increase by about 4 to 6 times by 2020. Reserves are estimated to be sufficient to meet the projected demands.

Program for Development of Water and Related Land Resources

The program for development of the basin's water and related land resources is presented in Table 5. The program will meet 100 percent of the basin's needs for municipal and industrial (including self-supplied industrial), livestock, rural, mining, thermal and power cooling, and 22 percent of irrigation water supplies. There are provisions for fully meeting water quality standards. Low streamflow augmentation is employed to remedy most quality problems not solved by secondary treatment facilities. Streamflow control is programmed to provide water supplies.

Of the 629,000 acres of flood-plain land, a total of 447,000 acres can be protected by a corrective flood control program. Approximately 82,000 acres are presently protected. Urban annual flood damages are expected to be reduced by

about $17,672,000 in 2020. Rural flood damage prevention and management will be applied to 95,000 acres of flood plain by 2020, thus decreasing average annual flood damages by about $3,255,000 in 2020.

Of the 2,226,000 acres affected by erosion, the program recommends that 1,600,000 acres be treated by 2020. Of the 2,748,000 acres requiring drainage, the program recommends that 2,200,000 acres be drained by 2020. It is uneconomical to solve 27 percent of the floodwater and sediment damages, 24 percent of the erosion problem, 20 percent of the drainage problem and 82 percent of the potential forest lands management.

A watersurface area need for recreational use amounting to 86,000 acres by 2020 is met. An expected demand for 21,391,000 water - oriented recreation days by 2020 will be met together with a need to satisfy 17,000 angler days by 2020.

Navigation development for both recreation and commercial use would be considered to Mankato by 2020. The program includes the following projects: 4 dams and reservoirs located on the Minnesota river above New Ulm and above Carver, on the Cottonwood river near New Ulm and on the Blue Earth river near Mankato; 30 miles of local protection works along the Minnesota River and 214 P.L. 566 program areas. The recommended time table calls for the completion by the year 1985 of the 3 dams and reservoirs on the Minnesota river above New Ulm, above Carver and on the Cottonwood river near New Ulm, the local protection works, and P.L. 566 projects. The dam and reservoir on the Blue Earth river near Mankato and additional P.L. 566 projects are to be completed during the period 1985-2020.

Costs of Program for Development of Water and Related Land Resources

The estimated costs of the program for development of water and related land resources in the basin are as follows:

Initial Investments 1967-2020, (1967 dollars)			Annual Operation and Maintenance Costs (2020)		
Fed. $	Non-Fed. $	Total $	Fed. $	Non-Fed. $	Total $
461,427,000	624,818,000	1,086,245,000	34,718,000	59,985,000	94,703,000

The greatest Federal investments would be for the following programs: corrective streamflow control, flood control, meeting water quality standards, land treatment, and land acquisition. The greatest non-Federal investments would be for the following programs: land treatment, corrective flood control, meeting water quality standards, developing streamflow and groundwater development.

The greatest Federal operation and maintenance costs would be associated with the following programs: corrective flood control, streamflow control, land treatment, meeting water quality standards and land acquisition. The greatest non-Federal operation and maintenance costs would be associated with the following programs: land treatment, corrective flood control, streamflow control, meeting water quality standards, and groundwater development.

TABLE 5. Program for the Development of the Minnesota River Basin's Water and Related Land Resources

Description of Water and Related Land Resources Development Programs Elements	Program Quantities
Natural Streamflow	
Municipal and Industrial, withdrawal use	14 mgd
Industrial, Self-Supplied, withdrawal use	19 mgd
Agricultural, withdrawal use	10 mgd
Thermal Power Cooling	136 mgd
Commercial Navigation, instream use	66 mgd
Water surface, recreation area	86,000 acres
Water surface, fish and wildlife area	1,000 acres
Aesthetic and Cultural Area	86,000 acres
Groundwater	
Municipal and Industrial, withdrawal use	37 mgd
Industrial Self-Supplied, withdrawal use	116 mgd
Agricultural, withdrawal use	58 mgd
Mining, withdrawal use	10 mgd
Recreation, instream use	147 mgd
Fish and Wildlife, instream use	147 mgd
Streamflow Control	
Municipal and Industrial, withdrawal use	13 mgd
Industrial Self-Supplied, withdrawal use	63 mgd
Agricultural, withdrawal use	45 mgd
Water Quality Management, instream use	252 mgd
Water Surface Area, Commercial navigation	60 mgd
Flood and Sediment Damage Reduction	
Administration of Flood Plain zoning, Flood proofing New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan, Flood Insurance Program	50 years
Corrective Damage Reduction, Cropland and Pasture	130,000 acres
Corrective Damage Reduction, Aesthetic and Cultural area	365,000 acres
Corrective Damage Reduction, Flood plain area	365,000 acres
Preventive Damage Reduction, Aesthetic and Cultural area	95,000 acres
Preventive Damage Reduction, floodplain area	95,000 acres
Land Treatment and Management	
Treatment, Cropland and Pasture	1,173,000 acres
Treatment, Aesthetic and Cultural area	800,000 acres
Erosion Control	1,710,000 acres
Drainage, Cropland and Pasture	2,200,000 acres
Forest Land Management	27,000 acres
Land Acquisition	
Streams (Purchase and Easement)	289 miles
Wetland Preservation	0
Recreation	350,000 acres
Aesthetic and Cultural	49,000 acres
Wastewater Treatment	
Secondary Treatment and Advanced Waste Treatment	Meeting Water Quality Standards

Requirements for Water and Related Land Resources Development

Approximately 221,000 people are served by the 149 local public central water supply systems in the basin. Only 2 of these systems use surface water. In 1960, total water usage for municipally supplied domestic and commercial needs was 17 mgd; only 0.7 mgd was from surface sources. The total industrial water use by about 70 plants was estimated at 34 mgd. It is projected that in 2020 municipal water withdrawals will total about 73 mgd and industrial water withdrawals will total about 256 mgd. Major water withdrawal increases will probably occur in or about the present centers of population and industrial activity.

Water withdrawals for livestock and rural farm domestic uses are projected to increase from 35 mgd in 1960 to 100 mgd in 2020. Gross water requirements to satisfy economic potential for irrigation in the basin are projected to increase from 1,130 acre feet in 1970 to 515,000 acre feet in 2020.

The following communities are not expected to have any water supply problems through the year 2020 as the available groundwater supplies will be sufficient to meet their future demands: Ortonville, Benson, Glenwood, Morris, Dawson, Montevideo, Redwood Falls, Olivia, Bird Island, Sleepy Eye, Springfield, Arlington, Le Center, Le Sueur, Saint Peter and Waseca. Granite Falls' future water supply needs can continue to be supplied by the Minnesota river through 2020. Marshall and Fairmount are expected to have water supply problems starting in 2020. Water supply problems can be expected in New Ulm by 2000. Mankato is projected to have water supply problems starting in 2000. The projected demand for 460 mgd of irrigation water by 2020 is significant.

The present municipal organic waste load is contributed by 106 community systems in the basin. Industrial organic waste discharges comprise more than 82 percent of the total organic waste discharge. Processing of farm products contributes the bulk of the industrial organic waste load.

In 1971, a total of 177 municipal and 449 industrial waste sources were identified in the basin. The municipal sources include 89 with secondary treatment facilities, 10 with primary treatment only, 9 with sewers and no treatment and 69 communities with no sewers and treatment. A substantial share of industrial waste is currently discharged through municipal waste treatment systems and this is expected to continue in the future.

The principal water quality problems in the basin in 1971 were caused by extensive algal growth, excessive suspended sediment, low levels of dissolved oxygen, and bacterial contamination. The major areas affected were Big Stone Lake and other lakes (algae problems); the entire Minnesota and its tributaries (suspended sediment problems); and low dissolved oxygen and bacterial contamination below Milbank on the Whetstone river, on the Minnesota river below Ortonville, Granite Falls, Redwood Falls, New Ulm, at Chaska; on the Blue Earth river below Vernon Center; and bacterial contamination below Mankato, at the mouth of the Minnesota river and below Buffalo Center on the Blue Earth river. Other water quality problems resulted from animal wastes and thermal discharges. Treatment facilities serving about 79 percent of the sewered community population require significant facility improvement prior to 1980.

Future water quality problems areas are projected where low streamflows are insufficient to meet the flow required to assimilate future waste discharges with a

degree of treatment deemed satisfactory in 1971. River flow is not sufficient to assimilate the waste discharges from Ortonville to the Minnesota river. A problem area is projected for the Minnesota river below New Ulm beginning in 2020. Discharges from 9 major organic waste producing industries and from the City of Mankato will create a problem area on the Minnesota river beginning about the year 2000. Minor problem areas will occur as a result of waste discharges into intermittent streams throughout the basin.

In 1964, the recreation demand in the basin was 18,608,000 recreation days; it is projected to increase to 71,860,000 recreation days in 2020. The recreational acreage in 1964, 214,610 acres, could be expected to furnish 10,446,000 recreation days. Approximately 292,717 acres of recreational land and 47,862 acres of recreational water are needed by 2020.

One of the most disturbing threats to recreation opportunity, particularly water-oriented activities, in the basin is deteriorating water quality. Many recreation resources cannot be used because the public has been denied access. One of the major problems in meeting outdoor recreation demand is the fact that there are inequities in the distribution of the population in relation to recreation resources.

In 1960, the basin's consumptive fishing demand was 3,003,000 angler days and consumptive hunting demand was 806,000 hunter days. Fishing and hunting demands are not projected to increase. In 1960, there were 249,000 acres of fishing water, 10,224,000 acres of potential hunting areas and 106,000 acres of commercial fishing habitat in the basin.

Among the more significant fish and wildlife problems are: the continuing loss of valuable natural wetlands, destruction of fish and wildlife habitat through land-use changes, poor land-use practices, unused or under-utilized game or fish populations, pollution of fishing water and the need to preserve natural areas.

About 22 percent of the basin's land area has erosion problems, needs treatment, and is feasible to treat. Additional progress is needed in the selection of land use and the installation of conservation practices to reduce and control erosion within allowable limits. Areas subject to gully erosion damage total about 150 acres.

Agriculturally, excess water becomes a problem when it interferes with tillage, land preparation, the development of plants, and harvest operations. Crop and pasture areas with drainage problems total about 4,535,000 acres in the basin. About 1,700,000 acres are currently drained, 87,000 acres are not practical to drain and 2,748,000 acres are feasible to drain. In many areas, drainage works are installed but do not have adequate size or ample outlets. In addition to the high-moisture content problem, some soils are subject to flooding and will need flood protection to realize their full productive capacity.

Agricultural irrigation, mainly to supplement below-normal rainfall, is carried on in limited amounts (2,585 acres in 1966) in the basin. Potential acreage for irrigation of combined field and specialty crops total about 2,073,000 acres.

Major floods have occurred in the basin 11 times since 1881. In the upstream areas of the basin, 390,000 acres of land are subject to flooding. Much of the flood damage in the basin is to public and private property at Mankato and North Mankato. Other urban areas subject to appreciable damage are Montevideo, Le Hillier, St. Peter, Henderson, Carver and Chaska. Significant damages also occur to industrial developments between Shakopee and the mouth of the river.

The total downstream flood plain area of the Minnesota river and its tributaries is about 240,000 acres with about 112,000 acres in crops and 83,000 acres in pasture. Downstream average annual flood damages are projected to increase from $4,289,900 in 1966 to $22,487,200 in 2020. Upstream average flood damages are projected to increase from $3,750,000 in 1966 to $10,279,000 in 2020. Projections assume that no additional flood control and prevention works other than those existing in 1966. To date, some flood prevention has been accomplished as soil and water conservation projects and some local protection works have been construction by the U.S. Army Corps of Engineers, counties and cities.

Navigation improvements on the Minnesota river from its mouth at St. Paul for a distance of 14.7 miles upstream were completed in 1968. Improvements include a channel 9 feet deep and 100 feet wide. Commercial traffic on the river increased from 102,200 tons in 1950 to 1,721,600 tons in 1968. About 58 percent of this traffic included shipments of corn, barley, rye, wheat, oats, and soybeans, and 26 percent consisted of bituminous coal receipts.

Industrial expansion may justify navigation development 25 miles up the river or even to Mankato within the next fifty years or so. Investigations are underway to determine the need for and the feasibility of extension of the 9-foot channel beyond mile 14.7 to mile 25.

The present thermal power cooling water use withdrawal is 139 mgd. Projected population increases and increased economic activity will increase thermal power cooling demands to 2,090 mgd in 2020.

CANNON, ZUMBRO AND ROOT RIVERS BASIN

Population and Economy

The 1970 population in the Cannon, Zumbro and Root rivers basin was 313,771; the 1960 population was 285,998. Over 42 percent of the basin population is concentrated within 6 municipalities with 1970 populations as follows: Rochester - 53,766, Winona - 26,438, Faribault - 16,595, Owatonna - 15,341, Red Wing - 12,834 and Northfield - 10,235. There are a total of 80 municipalities in the basin. The basin's population increased by 9.7 percent since 1960, or just slightly less than the overall State population percentage growth. Of the 14 counties included, 9 gained population and 5 lost population. The population in the basin is projected to increase to 600,000 in 2020 or 2.19 times the population in 1960.

Agriculture and related industries comprise a large portion of the occupational activities in the basin. Dairy farming is a major activity. Livestock and poultry production is also extensive. Fillmore is one of the State's leading counties in the production of milk, beet cattle, hogs and sheep. Corn, hay and soybeans are the major crops; oats are also a significant crop, along with sweet corn and green peas for processing. Food processing and kindred industries are located throughout the basin. Faribault and Owatonna are notable centers for processing corn, peas, poultry and dairy products. Processing of dairy products (milk, cream, butter and cheese) is widely distributed in the larger cities (including Rochester and Winona) and in medium-sized municipalities such as Caledonia, Lake City and Spring Valley.

Rochester is the basin's leading center for manufacturing and service-oriented industries. IBM has a major production and service facility for EDP processing equipment and accessories. The Mayo Clinic is the focal point for various medical and hospital service operations; the manufacture of medical and hospital equipment is also a significant activity. A number of food processing operations are located in Rochester. Production of fertilizers, fabricated metal products and construction materials is also important.

Winona features a diversified range of industrial production activities: food and kindred products, including malt beverages and grain milling; fertilizers; fabricated metal products for farm use; metal castings; machinery components; heavy equipment; small household appliances; apparel, etc. Faribault is an important hub for processing of agricultural products: peas and corn; milk, butter, and cheese; poultry; and livestock feeds. Some manufacturing of machinery and EDP equipment components is also carried out. Owatonna is a growing secondary industrial center. Processing of corn, dairy and meat products is a significant activity. Manufacture of farm machinery and equipment, heavy industrial equipment and fabricated metal products is also important.

Northfield's industry does not include any major food processing activities. Rather, it is principally oriented toward manufacture of packaging machinery; plastic products; electronic accessories, foundry and woodworking machinery; and heavy industrial equipment. Several of Red Wing's industries are based upon agricultural resources in the region; grain milling; malting; leather tanning; dairy products; linseed and soybean processing. Manufacturing of shoes and other footwear is also significant, in addition to fabricated metal and plastic products, scientific instruments and wood products.

The number of people employed in 1960 in the basin was 99,000; 62,000 were noncommodity producing, 37,000 were commodity producing, 15,000 were manufacturing commodities and 22,000 were nonmanufacturing commodities. Employment in 2020 is projected to be 223,000; 181,000 will be noncommodity producing, 42,000 commodity producing, 31,000 manufacturing commodities and 11,000 nonmanufacturing commodities. Per capita income in the basin in 1960 was $1,793; it is projected to be $9,817 in 2020.

Climate and Water Resources

Annual average temperature in the basin ranges from 44 to 46° F. Annual average precipitation ranges from 28 to 32 inches. The average duration of total crop season ranges from 210 to 220 days. Normal annual snowfall is 40 inches.

The average discharge, instantaneous minimum flow and instantaneous maximum flow in the Cannon river at Welch are 479 cfs, 2.5 cfs and 36,100 cfs, respectively. The average discharge and minimum and maximum flows in the Zumbro river at Zumbro Falls are 475 cfs, 27 cfs and 35,900 cfs, respectively. The average discharge and minimum and maximum flows in the Root river near Houston are 644 cfs, 65 cfs, and 37,000 cfs, respectively. The average discharge and minimum and maximum flows in the Mississippi river at Winona are 24,810 cfs, 2,250 cfs, and 268,000 cfs, respectively.

The basin generally has adequate groundwater supplies available for present and foreseeable needs. In much of the basin, known sand and gravel aquifers are capable of yielding much more water than is currently withdrawn. The Jordan-Prairie du Chien aquifer and the Mt. Simon-Hinckley aquifer are high yielding bedrock aquifers. The St. Peter Sandstone is the source of many water supplies in the basin.

The valley of the Mississippi river is filled with as much as 200 feet of unconsolidated sediments that range up to 10 miles in width. Within the alluvium are deposits of sand and gravel that yield more than 1,000 gpm to single wells. Yields adequate for most industrial and municipal uses can be developed from the alluvium in most reaches of the river.

The bedrock structure of the basin is a southward plunging elongated trough whose axis trends through the Albert Lea-Austin area in Freebron and Mower counties. The important aquifers are sandstone beds and the Cedar Valley Limestone. Groundwater yields from the Cedar Valley which occurs along the east flank of the trough are low to moderate and are from solution enlarged fractures. Yields are low in the underlying Galena and in the Decorah-Platteville. The St. Peter Sandstone has low to medium yields. The Prairie du Chien-Jordan has high yields to wells; the Mt. Simon-Hinckley aquifer is a moderate to high yielder of relatively soft groundwater.

Land Use

The major land use in 1968 in the basin was as follows: urban and built-up - 151,000 acres, cropland - 2,510,000 acres, pasture - 300,000 acres, forest - 616,000 acres and other - 128,000 acres. Total land area was 3,705,000 acres and total water area was 49,000 acres. Major land use projections for 2020 are: built-up - 261,000 acres, cropland - 2,675,000 acres, pasture - 89,000 acres, forest - 552,000 acres, and other 128,000 acres.

Mineral Resources

Sand and gravel production for 1960 in the basin was 1,678,111 tons with a value of $1,432,246. Future production of sand and gravel in the basin is projected to increase nearly 8 times by 2020 to about 13 million tons annually, and will require a cumulative total of 405 million tons for the 1960-2020 projection period. Reserves of sand and gravel are estimated to be about eight times projected requirements and will be more than adequate to meet these demands.

Crushed stone production for 1960 in the basin was 1,416,482 tons with a value of $1,734,683. Future crushed stone production is projected to increase to about 7 times 1960 levels by 2020 to nearly 10 million tons annually, and will require a cumulative total of nearly 310 million tons for the 1960 - 2020 projection period. Reserves of stone are estimated to be about eight times the projected requirements and, of course, will be more than adequate to meet these demands.

Program for Development of Water and Related Land Resources

The program for the development of the water and related land resources in the basin is presented in Table 6. The program will meet 100 percent of the basin's needs for municipal and industrial (including self-supplied industrial), livestock, rural, mining, thermal power cooling, and 11 percent of irrigation water supplies. There are provisions for fully meeting water quality standards. Low streamflow augmentation is employed to remedy most quality problems not solved by secondary treatment facilities. Streamflow control is programmed to provide water supplies.

Of the 89,000 acres of flood plain land, it is estimated that a total of 88,000 acres can be protected by a corrective flood-control program. Approximately 18,000 acres are presently protected. Urban average annual flood damages would be reduced

by about $6,228,000. The corrective flood control program would reduce damages on an estimated 63,000 acres of crop and pasture land. The flood damage prevention program would be applied to 29,000 acres of flood plain land resulting in decreases in average annual flood damages by $3,643,000.

Of the 818,000 acres having erosion problems, the program recommends that 570,000 acres be treated. Proper management would provide 43,000 hunting days and 1,140,000 recreation days. It is uneconomical to solve 16 percent of the floodwater and sediment damages, 25 percent of the erosion problem, 20 percent of the drainage problem and 83 percent of the potential forest lands management.

Costs of Program for Development of Water and Related Land Resources

The estimated costs of the program for development of water and related land resources in the basin are as follows:

Initial Investments (1967-2020, 1967 dollars)

Fed. $	Non-Fed. $	Total $
200,706,000	266,187,000	466,893,000

Annual Operation and Maintenance Costs (2020)

Fed. $	Non-Fed. $	Total $
14,091,000	22,837,000	36,928,000

The greatest Federal and non-Federal investments would be for the following programs: meeting water quality standards, streamflow control, flood control, land treatment and land acquisition.

The greatest Federal operation and maintenance costs are associated with the following programs: streamflow control, meeting water quality standards, flood control, land treatment and groundwater development. The greatest non-Federal operation and maintenance costs are associated with the following programs: land treatment, streamflow control, wastewater treatment, groundwater development, and flood control.

Requirements for Water and Related Land Resources Development

Sixty-three public central water supply systems presently serve 173,000 population in the basin. All of these systems use groundwater as the source of supply. The present total municipal water use is 14.5 mgd and the total industrial water use is approximately 30.5 mgd. Production of food and kindred products is the major water-using industry, accounting for approximately 60 percent of the total industrial water use. Major industrial water usage is in Winona County (Winona), Olmstead County (Rochester), Goodhue County (Red Wing), Rice County (Faribault), and Steele County (Owatonna). All industrial water, with the exception of water used in power production, is obtained from groundwater. Total municipal and industrial water use is projected to increase 7.3 times by 2020. The increase is projected to be fairly uniform throughout the basin. The major increases will probably occur in or about the present centers of industrial activity.

TABLE 6. Program for the Development of the Cannon, Zumbro and Root River Basins' Water and Related Land Resources

Description of Water and Related Land Resources Development Program Elements	Program Quantities
Natural Streamflow	
Municipal and Industrial, withdrawal use	11 mgd
Industrial Self-Supplied, withdrawal use	31 mgd
Agricultural, withdrawal use	4 mgd
Thermal Power Cooling	101 mgd
Hydropower, instream use	40 mgd
Water surface, recreation area	8,000 acres
Water surface, fish and wildlife area	6,000 acres
Groundwater	
Municipal and Industrial, withdrawal use	68 mgd
Industrial Self-supplied, withdrawal use	175 mgd
Agricultural, withdrawal use	19 mgd
Mining, withdrawal use	3 mgd
Recreation, instream use	221 mgd
Fish and Wildlife, instream use	221 mgd
Streamflow Control	
Hydropower, instream use	100 mgd
Recreation, instream use	150 mgd
Fish and Wildlife, instream use	150 mgd
Water quality management, instream use	212 mgd
Recreation, water surface area	15,000 acres
Flood and Sediment Damage Reduction	
Administration of Flood Plain zoning, Floodproofing New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan, Flood Insurance Program	50 years
Corrective Damage Reduction, Cropland and Pasture	68,000 acres
Corrective Damage Reduction, Flood Plain Area	70,000 acres
Corrective Damage Reduction, Aesthetic and Cultural Areas	70,000 acres
Preventive Damage Reduction, Aesthetic and Cultural Areas	30,000 acres
Preventive Damage Reduction, Floodplain area	30,000 acres
Land Treatment and Management	
Treatment, Cropland and Pasture	300,000 acres
Treatment, Aesthetic and Cultural Areas	285,000 acres
Erosion Control	610,000 acres
Drainage, Cropland and Pasture	360,000 acres
Forest Land Management	54,000 acres
Land Acquisition	
Streams, Purchase and Easement	187 miles
Wetland Preservation	60,000 acres
Recreation	120,000 acres
Aesthetic and Cultural	32,000 acres
Hunting	60,000 acres
Wastewater Treatment	
Secondary Treatment and Advanced Waste Treatment	Meeting Water Quality Standard

Water withdrawals for livestock and rural farm domestic uses are projected to increase from 17 mgd in 1960 to 34 mgd in 2020. Water requirements to satisfy economic potential for irrigation in the basin are projected to increase from 20 acre feet in 1970 to 217,000 acre feet in 2020.

The following communities are not expected to have any water supply problems through the year 2020 as the available water supplies will be sufficient to meet their future demands: Red Wing, Winona, Owatonna and Faribault. Rochester is expected to require an additional source of supply by 2020.

All incorporated communities in the basin with populations of over 1,000 are served by central sewage treatment facilities and all but Wabasha (1960 population 2,500) and Winona (1960 population 24,815) are served by secondary facilities. Both Wabasha and Winona discharge to the Mississippi River. The present municipal organic waste load is contributed by 46 community systems in the basin. Approximately 150,500 people or about 74 percent of the nonfarm population are currently served by sewage systems. At present, industrial discharges account for approximately 80 percent of the total organic waste discharge. This percentage is expected to increase to approximately 82 percent by 2020. The bulk of the industrial organic waste load originates from the processing of farm products. Concentrations of industries are found in Owatonna, Faribault, Red Wing, Rochester and Winona.

A future water-quality low flow problem is projected to occur on the Straight river downstream from Owatonna by the year 1980. A large food processing plant is treating its waste in a seepage pond with no discharge. However, the growth of this industry is projected to be such that by 1980, a discharge will be necessary. The industrial discharges, plus the municipal discharges, will cause a problem area. Flows needed to prevent a problem area from developing are 25 cfs by 1980, 45 to 50 cfs by 2000, and 89 to 90 cfs by 2020.

Municipal and industrial waste discharges from the Faribault area are expected to create a water-quality low flow problem downstream from Faribault by the year 1980. The food-and-kindred-products industry accounts for the majority of the waste load. Flows needed to prevent a problem area from developing are 35 cfs by 1980, 60 cfs by 2000, and 120 cfs by 2020.

The 7-day, 1-in-10 years low flow of the South Fork Zumbro river near Rochester is approximately 22 cfs. This flow, should it occur, is not adequate to prevent a problem from developing at the present time. However, the City of Rochester is presently expanding and improving its sewage treatment plant, which may delay to the year 1980 a problem area from developing. Flows needed to prevent a problem area from developing are 45 cfs at present, 90 cfs by 1980, 175 cfs by 2000 and 330 cfs by 2020.

There are several communities which discharge to intermittent streams or small drainage ditches. Local nuisance conditions may develop as a result of insufficient stream flows. These areas are Spring Valley creek, downstream from Spring Valley, and North Branch Root river, downstream from Chatfield. The 2020 projected populations of both Spring Valley and Chatfield are less than 10,000.

In 1964, the recreation demand in the basin was 14,070,000 recreation days; it is projected to increase to 45,023,000 recreation days in 2020. About 26 percent of the recreation demand in 1964 was unsatisfied. Approximately 153,329 acres of recreation land and 43,804 acres of recreation water are needed by 2020. There were about 47,746 acres of recreation land in 1964.

In 1960, the basin's consumptive fishing demand was 1,326,000 angler days and consumptive hunting demand was 431,000 hunter days. The fishing and hunting demands are projected in 2020 to be 1,529,000 angler days and 504,000 hunter days, respectively. In 1960, there were 67,000 acres of commercial fishing habitat in the basin, 49,000 acres of fishing waters and 3,555,000 acres of potential hunting acres.

About 24 percent of the basin's land area has erosion problems, needs treatment and is feasible to treat. Areas subject to gulley erosion damage total about 130 acres. Crop and pasture areas with drainage problems total 998,000 acres in the basin. About 546,000 acres are currently drained, 4,000 acres are not practical to drain and 448,000 acres are feasible to drain.

Major floods have occurred in the basin 9 times since 1881. Flood plain in the upstream areas of the basin total 49,900 acres. Agricultural damages are appreciable along the Rush river. Sigr ificant damages occur along the Cannon, Zumbro and Root rivers to agricultural and urban property, as well as to railroads and associated bridges which occupy the flood plain. The major urban damage centers are Rochester, Preston, Rushford, Houston and Hokah. Flood damages have been caused to crop and to urban properties at such cities as Cannon Falls, Northfield and Faribault. Major damage centers along the Mississippi river include Winona. The total downstream flood plain area is 39,000 acres, with 15,600 acres in crops, 17,600 acres in pasture and 5,800 acres other.

As of 1967, downstream average annual flood damages in the basin were $1,111,800. In 2020, they may be $7,021,600. Upstream average annual flood damages are $1,588,000; damages are projected to be $4,779,000 in 2020. Average annual flood plain damages along the Mississippi river are projected to increase from $1,565,000 in 1966 to $9,877,600 in 2020. Projected damages assume no additonal flood control and prevention works other than those existing in 1967.

The upper Mississippi river between the Missouri river, and Minneapolis, has been improved for navigation by a system of 28 locks and dams. These locks and dams have changed the river into a series of "steps" which river tows, and other boats, either "climb" or "descent" as they travel upstream or downstream. The lowermost dam, No. 26, is located at Alton, Illinois, 8 miles above the mouth of the Missouri river, and the uppermost dam, at Minneapolis, 853.75 miles above the Missouri river. The dams are spaced at irregular intervals varying from 9.6 to 46.3 miles, the average length of pools being 25 miles. The lift of the locks varies from 5.5 to 49.2 feet with an average lift of 12.9 feet.

At most of the sites a main lock 110 x 600 feet has been constructed, together with the upper gate bay of an auxiliary lock 110 x 360 feet to be completed when required by traffic. Exceptions are as follows:

- St. Anthony Falls Upper Lock -- Single Lock 56 x 400 feet.
- St. Anthony Falls Lower Lock -- Single Lock 56 x 400 feet and upper gate bay of an auxiliary lock.
- Locks No. 1 -- Twin locks 56 x 400 feet.
- Locks No. 2 -- Old lock 110 x 500 feet; New lock 110 x 600 feet.
- Locks No. 14 -- Single lock 110 x 600 feet; Old LeClair Canal Lock 80 x 320 feet.

- Locks No. 15. -- Main Lock 110 x 600 feet; Auxiliary lock 110 x 360 feet.
- Locks No. 19. -- Main Lock 110 x 1,200 feet.
- Locks No. 26 -- Main lock 110 x 600 feet; Old lock, 110 x 360 feet.

The entire authorized 9 foot navigation project, with the exception of the upper 4.6 miles (St. Anthony Falls extension) has been in operation since 1940. The latter project was placed in operation on September 21, 1963. Improvement of the navigation channel in the vicinity of Horse Island and Crescent Bridge, at and downstream from the city of Rock Island, Illinois, was started in 1967. The channel in this reach presents a hazard to navigation because of sharp rock ledges and displaced rock on the channel bottom. The improvement involves rock excavation to widen, deepen, and in some places to realign the navigation channel.

River traffic has increased rapidly since completion of the principal features of the project. Total commerce moved between Minneapolis and the mouth of the Missouri river increased from 2,410,000 tons in 1939 to 46,175,000 tons in 1968. Principal commodities transported are petroleum products, coal and grain, although in recent years tonnage has become more diversified with substantial quantities of iron and steel, chemicals, and other products being moved. A sizable fleet of powerful diesel towboats has been built up, almost completely replacing the old-time paddle-wheel steamboats. Harbors, terminal facilities and riverside industries have been developed at many of the river cities and towns.

The fifty-year life of existing navigation structures on the Mississippi river in the Minnesota river basin will be reached about 1990. The present capacity of the existing channel and lock structures is estimated to be about 25 - 40 million tons. Based on low-to-medium traffic projections this lock capacity may not be reached until after 2020. Based on high traffic projections, this lock capacity may be reached before 2020. Lock and Dam No. 1 at Minneapolis, which has difficult approach conditions, is badly in need of repair and may have to be replaced.

History has shown that difficulties of river transportation due to the lack of adequate channel improvements have tended to reduce river traffic because barge lines with limited carrying capacity could not compete. The development of a 12-foot and possibly a 15-foot channel on the upper Mississippi river may prove feasible within the next 50 years or so. This will involve major modifications to lock structures, or new structures and a combination of pool modifications and dredging. Separate locks for recreation navigation should be given due consideration. The economic feasibility of the 12-foot channel on the lower Mississippi river considering traffic interchange, can be fully realized only if a 12-foot channel is provided on the upper Mississippi river. Projections of commodity movements indicate that interchange shipments will become more dominant in the future. An important factor vital to the future of waterborne commerce and transportation in general is the structure of rates and costs for the various modes of commercial transportation.

The existing 8-month navigation season on the upper Mississippi river requires industries to have large storage areas and maintain large inventories during the winter months. Extension of the navigation season may be feasible and desirable.

DES MOINES RIVER BASIN

The Des Moines river basin includes a drainage area of 1,539 square miles in southwestern Minnesota. The 1970 population in the basin was 35,162; it was 38,123 in 1960. The 1970 populations of leading municipalities are:

Worthington - 9,825, Windom - 3,952, Jackson - 3,550, Slayton - 2,351, Lakefield - 1,820, Fulda - 1,226 and Sherburn - 1,190. The economic base of the basin is largely agricultural; much of the industrial operations are closely related to agriculture.

In addition to poor sustained low streamflow, flooding is an occasional problem on the West Fork of the Des Moines river. There are 6 lakes in the basin with surface areas of 1,000 acres or more. With the exception of Worthington, there is no anticipated shortage of groundwater supply within the basin. Worthington is expected to develop a water supply problem about 1980. Of particular concern through future decades will be adequate flows in the Des Moines river tributaries to assimilate organic waste effluents.

A total number of 65 waste sources were identified in the basin. The 22 municipal sources include 9 with secondary treatment, 1 with sewers and no treatment. The other municipalities are unsewered. The 43 industrial sources include 5 which are handled by wastewater treatment plants. Three of the 9 municipalities with secondary treatment require either urgent or definite near-term corrective action to expand upgrade or otherwise improve existing facilities. Three additional municipalities will require facility improvement before 1980.

CEDAR RIVER BASIN

The Cedar river basin includes a drainage area of 1,034 square miles in southcentral Minnesota. The 1970 population in the basin was 76,150; in 1960, it was 80,047. The 1970 populations of the leading municipalities were: Austin - 25,074, Albert Lea - 19,418, and Blooming Prairie - 1,804. The economy of the basin is primarily based upon the production of various agricultural commodities and the processing of meat products. A number of moderate-to-small scale industries are located in Austin and Albert Lea and other villages.

Low streamflow conditions on the Cedar river at Austin and the Shell Rock river at Albert Lea can pose serious problems in view of the relatively high industrial and municipal waste loadings. There are 6 lakes in the basin with surface areas of 1,000 acres or more. In much of the basin, known aquifers are capable of yielding much more water that is currently withdrawn. No water supply problems are projected in the basin through 2020.

A total of 81 waste sources were identified in the basin. The 22 municipal sources include 11 with secondary treatment, 1 with primary treatment, and 10 with no sewers and treatment. There are 59 industrial sources. Seven out of the 11 municipalities with secondary treatment require either urgent or definite near-term corrective action to expand, upgrade or otherwise improve existing facilities. Two additional municipalities were ranked as probably requiring facility improvement before 1980.

MISSOURI RIVER BASIN

Population And Economy

The 1970 population in the Missouri river basin in Minnesota was 47,205; it was 49,058 in 1960. The populations of the five largest municipalities in 1970 were: Pipestone - 5,328; Luverne - 4,703; Adrian - 1,350; Edgerton - 1,119; and Jasper - 754. Three of the municipalities gained population during the period 1960-70 and the others lost population. There are 23 municipalities in the basin whose population comprises 39 percent of the basin. The non-municipal population lost 7.3 percent during the period 1960-70. Projected population in the basin is about 68,000 in 2020.

The economy of the basin has a primary agricultural base. Livestock raising and feedlot operations are of particular importance. Crop production is widespread throughout the basin. Corn, oats, soybeans, hay and flax are the leading crops. To a large extent, the manufacturing activities are related to agribusiness. Local industry has included fertilizers, dairy products, poultry and egg products, oils and greases, soft drinks, farm structures and equipment, and boats and marine accessories. Other types of industries in the basin include: water conditioning equipment, fire trucks, fire fighting equipment and truck bumpers and grille guards, modular structures and ultrasonic cleaning equipment and concrete products. The outlook for the basin economy is for very modest growth, based upon stable continuance of current agriculturally-oriented service operations and further expansion of new areas of product manufacturing.

Climate and Water Resources

The basin climate is typically mid-continental, with cold winters and warm summers. The average annual temperature ranges from 45 to 46° F. The average duration of the total crop season is about 205 days. The annual average precipitation ranges from 22 to 27 inches and the average annual snowfall over the basin is 40 inches.

The Missouri river basin in Minnesota comprises a drainage area of 1,782 square miles. The composite picture for streamflow in the basin is that of relatively low average flow on major streams (125 cfs, or less), and larger tributaries (50 cfs, or less). Long-duration periods of low flow are a perennial problem during the late winter and summer months. Ocheda Lake is the only lake with an area of 1,000 acres or more.

Municipalities, industries and farms in the basin make extensive use of groundwater from glacial drift aquifers. Cretaceous sandstones supply moderate amounts of water. The groundwater supply in the basin, although not as abundant as in other parts of the State, is adequate to support smaller scale municipal and industrial uses.

Program For Development Of Water And Related Land Resources

Programs for the development of the basin's water and related land resources are listed below:

- Expansions in water-supply facilities - Municipal and Industrial
- Waste treatment facilities for existing needs - Municipal
- Waste treamtment facilities for existing needs - Industrial

- Expansion of waste treatment facilities - Municipal
- Expansion of waste treatment facilities - Industrial
- Agricultural drainage measures
- Agricultural land treatment measures
- Recreational facilities
- P. L. 566 programs

Costs Of Program For Development Of Water And Related Land Resources

Accurate data concerning initial investments and annual operation and maintenance costs for development of the water and related land resources in the basin are not available. Rough estimates are given below:

Initial Investments 1968-2020, (1968 dollars)			Annual Operation and Maintenance Costs (2020)		
Non-Fed. $	Fed. $	Total $	Non-Fed. $	Fed. $	Total $
30,000,000	15,000,000	45,000,000	2,000,000	300,000	2,300,000

Requirements For Water And Related Land Resources Development

In 1969, there were 17 municipal water supply systems in the basin; all systems used groundwater as the supply source. In 1965, municipal withdrawals were about 1.6 mgd. and industrial use (principally for creamery and rendering works) was about 0.3 mgd. All industries use groundwater. Projected municipal and industrial water requirements in 2020 are 2.9 and 0.85 mgd, respectively. There are no areas in the basin where a major future water supply problem is projected through 2020.

There are 67 waste sources in the basin. The 24 municipal sources include nine with secondary treatment, one with primary treatment, two with sewers and no treatment. The 43 industrial sources include eleven whose effluents are handled by treatment plants. Major types of industrial sources are five milk receiving and processing plants and seventeen slaughterhouse/locker plants. In addition to point sources, agricultural wastes are important; farm animals contribute wastes with a human population equivalent of 2.3 million in the basin.

Addition of secondary treatment to the two sewered municipalities with no treatment and to the one municipality with only primary treatment is needed. Five out of the 9 municipalities with a current level of secondary treatment require either urgent or definite near-term corrective action to expand, upgrade or otherwise improve existing facilities.

Approximately 68,918 acres are subject to flooding in the basin. Average annual flood damages are projected to increase from $831,000 in 1960 to $3,323,000 in 2020 without new flood control and prevention works. Annual gully erosion damages are projected to increase from $1,000 in 1960 to $3,000 in 2020.

Twenty-seven P.L. 566 watershed programs involving land treatment and drainage are needed. Watershed projects should cover about 2/3 of the basin in areas except those in the northwest and southwest. One watershed project, Lakes Okabena and Ocheda on the Little Sioux River, needs to be completed. The project involves 2 desilting basins, 1 FR and recreation structure, 1 fish and wildlife improvement, and 3,783 acre-feet of storage. The estimated sediment yield in the basin ranges from less than 500 tons per square mile per year in the north and east to between 500 and 1,000 tons per square mile per year in the south and west.

The Pipestone National Monument is a major recreation area. There are two State recreation areas with developed land acreages up to 20 acres, one State recreation area with developed land acreages over 21 acres, and one State recreation area with developed land acreages over 100 acres. One new water based recreation facility is needed. A high quality pheasant, partridge and quail habitat in the southeast corner of the basin needs to be developed and maintained together with high quality duck and goose habitat areas in the northwest and southeast corners of the basin. There is a heavy demand for water-based recreation in connection with the Sioux Falls area.

SUMMARY

In the past, there has been considerable activity in Minnesota associated with the development and management of water resources. For example, water supply and sewage treatment plants have been constructed at most cities and villages as well as by many industries. Water-oriented recreation facilities have been provided in connection with parks, waysides, reserves, and monuments, etc. scattered throughout the State. Fish management programs have been extended to many areas and hundreds of wildlife management areas have been developed. Wetland waterfowl production areas are being managed. Agricultural lands have been drained in extensive areas and farmers have made considerable progress in the installation of conservation practices to reduce and control soil erosion. Some flood control and prevention has been accomplished as soil and water conservation projects and as projects of the U.S. Army Corps of Engineers. Extensive improvements of rivers and harbors for navigation are located along the Mississippi River and in the Duluth-Superior area.

Past development and management practices, as substantial as they are, have not kept pace with the steadily growing demands placed upon water resources. Not only does Minnesota have catch up problems to contend with in the future, continuing pressures and demands for enhancement of the environment and improved economic well-being can be expected to create steadily growing demands for water resources. There exists many water resource problems associated with such matters as: pollution of streams, lakes and groundwater; water-oriented recreation; water supply; flooding; navigation; and land use.

On a gross basis, the capabilities of the State's water resources exceed projected demands and needs for at least the next 50 years. As a whole, the State has abundant water resources with an average annual precipitation of 25 inches, average annual runoff of 5 inches, and large reserves of groundwater. However, the State is less fortunate in the distribution and timing of water resources. Rainfall varies from 32 inches in the southeast to 19 inches in the extreme west during a year of normal precipitation. During a drought year that may occur in 2 percent of any given number of years, precipitation varies from only 15 inches in the northeast to 9 inches in the west.

In Minnesota there are 15,291 lake basins larger than ten acres. Including the State's portion of Lake Superior, lakes cover an area of 4,059 square miles, or about 4.8 percent of the State's area. In addition, the State has approximately 25,000 miles of streams, and contains the headwaters of the Mississippi River. Lakes are not evenly distributed throughout the State. They are most numerous in the northeast and central parts of the State.

Minnesota, except perhaps for areas in the northern and western parts and some local areas, has large supplies of groundwater. Bedrocks in the southeastern part of the State yield small to moderate quantities of water. Glacial deposits, except in northern, western, and southwestern portions of the State, generally contain concentrations of sand and some gravel that are excellent environments for groundwater. The natural quality of water resources is, on a gross basis, favorable for most uses. Lakes in the northeast have a low concentration of salts; whereas, lakes in the southwest have a high concentration of salts. The dissolved solids are less than 500 parts per million in most streams. They are highest in streams in the western part of the State and lowest in the northeastern part.

Projected growth of the State's population and economic activity is based on the belief that a viable economy with substantially full employment may be maintained in the face of both international and domestic problems. The total population of the State is projected to double between 1967 and 2020, from 3,582,000 to about 7,000,000. Increases in population may continue to be concentrated in urban centers, especially the Minneapolis-St. Paul area. In 1967, about 71 percent of the population was concentrated in the southeastern part of the State. By the year 2020 about 82 percent of the State population is projected to be concentrated in the urbanized southeastern sector of Minnesota. Future water and related land resources problems have been identified based upon these population and economy projections.

Water and Related Land Resources Problems

Water Quality

A review of planning documents prepared by Federal-State regional organizations and the Minnesota State Planning Agency indicates that the most serious water resources problems in Minnesota are those associated with water quality. Estimated costs, during the period 1971-2020, for potentially feasible water quality programs and projects greatly exceed costs for individual programs and projects associated with other water resources functional areas: water supply; recreation, fish and wildlife; flood control; navigation; and land treatment, drainage, irrigation and forests.

Despite the fact that upgrading of treatment works and construction of facilities for untreated wastes has been proceeding at a rapid rate as approved water quality standards are being enforced, in 1972 Minnesota had serious and undesirable water quality problems. Recent progress in the construction of waste treatment plants has prevented much serious deterioration in water quality in the face of significant increases in population and industrial production.

The Federal Environmental Protection Agency estimates that, except for some watersheds in northeastern and eastern Minnesota, streams in the State in 1970 were locally polluted (10-19.9 percent stream miles violate Federal water quality criteria), extensively polluted (20-49.9 percent stream miles violate Federal water quality criteria), or predominantly polluted (50 percent stream miles violate Federal water quality criteria). Streams in much of the State were locally polluted. Pollution conditions were most serious in watersheds in northwestern Minnesota.

The sources of harmful substances which enter streams and make them less desirable for other uses are many and varied. The most common is the discharge of organic matter with high bacterial content from municipal sewer systems, carrying wastes from homes and other human habitations and from industrial plants. Food processing industries, such as canneries, sugar refineries, packing plants, and creameries, have large volumes of organic wastes which must be disposed. Pulp and paper mills have both chemical and fiber wastes, the disposal of which is difficult. Steam-electric generating plants raise the temperature of reaches of streams and cause thermal pollution. Nuclear power plants may discharge minute but harmful radioactive materials into streams. Agricultural runoff with sediment, pesticides, herbicides, and feed lot wastes cause problems. Harmful oil spills sometimes occur, Minnesota has a special pollution problem resulting from the increased mining of ores which require beneficiation or separation of the valuable mineral from the

worthless rock. Large volumes of water are used to transport the tailings in disposal areas. Disposal of taconite tailing in Lake Superior is a problem. Solid waste disposal and septic tanks are polluting water resources.

Polluting problems such as low dissolved oxygen levels; high total coliform bacertia densities, and degradation of aesthetics result in damages to the legitimate water uses for recreation, municipal and industrial water supply, irrigation, and fish and wildlife propagation. Pollution is a problem below most principal river communities and industries.

Many lakes have problems of pollution. Urbanization, industrialization and agricultural activities have unbalanced nature's delicate system. The use of lakes for human, industrial, and boat waste disposal is only one of the many influences. Agricultural drainage, increased sedimentation resulting from poor land development practices and even waste water treatment itself also contribute to lake problems.

In the seven county Metropolitan area in April 1971, only 5 of the Metropolitan Sewer Board's 33 treatment plants met State water quality standards. The Metropolitan Wastewater Treatment Plant met all standards except the one for suspended solids. There were 2,644 identified waste sources in the outstate portion of Minnesota. (i.e. outside the seven county metropolitan area); of these sources 728 were municipal and 1,916 were industrial. Treatment facilities serving about 894,000 people or about 85 percent of the outstate sewered community population required significant facility improvement prior to 1980.

The percentage of total population of sewered municipalities served by sewage treatment was 85.2 in 1956, 91.7 in 1957, 98.3 in 1963, 99.2 in 1967, 99.4 in 1969, and 99.6 in 1971. The percentage of total population of sewered municipalities served by secondary treatment was 65.2 in 1957, 89.4 in 1967, 90.3 in 1969, and 92.5 in 1971. In 1968, the urban population with adequate municipal treatment works totaled 769,000; the urban population with less than adequate municipal treatment works was 1,324,000. An urban population of 277,000 had no municipal treatment works.

The number of industries discharging wastes through separate outlets were estimated to be 700 in 1945, 717 in 1948, 1,124 in 1957, 935 in 1962, and 732 in 1967. The estimated number of these for which some forms of treatment was provided are: 230 in 1945, 247 in 1948, 503 in 1957, 479 in 1962, and 453 in 1967. The estimated numbers of these for which no treatment was provided are: 470 in 1948, 621 in 1957, 456 in 1962, and 279 in 1967. Thus, the number of industries discharging through separate outlets was the same in 1967 as it was in 1948; the number of these industries providing some form of treatment in 1967 was about twice that in 1948. Since 1948, there has been a substantial increase in the percentage of industries with separate outlets providing some form of waste treatment. In addition, there have been substantial improvements in methods of treatment. However, industrial loading of municipal treatment systems has increased.

The total State population (1970 census) was 3,805,069. As of January 1, 1971, there were 854 municipalities in the State with a total population of 2,914,669. There were 232 municipalities without sewer systems with a total population of 153,570; 532 municipalities with sewer systems served a total population of 2,761,099; 23 municipalities had a sewer system without treatment with a total population of 11,693; 508 municipalities had a sewer system with

treatment (451 treatment plants) serving a total population of 2,749,406; 458 municipalities had secondary treatment (403 treatment plants) serving a total population of 2,553,962; and 15 municipalities had tertiary treatment facilities serving a total population of 58,763.

Future water-quality problems will occur because of population and economic growth when waste loads, even after secondary treatment, exceed the assimulative capacities of streams. Projected major water quality problem areas include: South Fork Crow River near Hutchinson, starting in the year 1980; Mississippi River at Minneapolis-St. Paul, starting in the year 1980; Cannon River near Faribault, starting in the year 1980; Straight River near Owatonna, starting in the year 1980; Minnesota River near Mankato, starting in the year 2000; Minnesota River near New Ulm, starting in the year 2020; headwaters of small streams in the Iron Mining Range urban areas, starting in the year 1980; and Ada, Barnesville, and Detroit Lakes, in the Red River Basin, starting in the year 1975. Future return flows from irrigation projects in North Dakota will cause water quality problems along the Red River. Alternatives for solving future water quality problems are: advanced waste treatment; low streamflow augmentation; and holding ponds with regulated discharges.

Groundwater is an unseen but vital reservoir of fresh water for the State. Over 90 percent of the communities in Minnesota are dependent upon groundwater for municipal use. Groundwater provides a high quality water requiring little or no treatment for over 2,500,000 people or about 66 percent of the State's population.

A number of examples of contamination of groundwater have been documented by the State Health Department and the Pollution Control Agency. A majority of the groundwater pollution problems can be grouped into classes. There are problems resulting from individual sewage disposal systems, from agricultural practices and from municipal waste disposal practices. Other problems are caused by industrial waste disposal practices, petroleum products spills and leaks and from the use of disposal wells. In some of the instances cited, there is data to show that pollution of the groundwater has taken place. In other situations the disposal practice may have been stopped before any reported contamination because of the high potential of pollution which existed.

Water Supply

All public water supply systems in the State of Minnesota have been evaluated in relation to the chemical characteristics of new water supplies serving communities within the State, insofar as these are known at the present time and contained in the report entitled "Public Water Supply Data - 1971, State of Minnesota," published by the Division of Environmental Health, Minnesota Department of Health. In several instances data are given on the finished water supplies, and treatment processes employed are characterized. An examination of these data show that when compared to water quality parameters identified by the Task Group on Water Quality of the American Water Works Association and the Drinking Water Standards, marked deficiencies in the quality of the supply are noted. These deficiencies help characterize the degree of treatment required to meet these proposed parameters. This is particularly important in this State because a greater portion of water supply systems utilize the ground water as the source of supply. However, in terms of population served by ground or surface supplies, the numbers are about equal and slightly in favor of surface water supplies.

Chemical characteristics related to health effects reported include nitrate nitrogen, sodium, and fluorides. Additionally other chemical characters affecting the aesthetic properties of a water (taste, color, odor) include iron, manganese, chloride, sulfates, and total solids as well as hardness. Since many of the supplies currently do not meet the recommended Drinking Water Standards, with respect to one or more of these parameters and even more of them will fail to meet the goals proposed by the American Water Works Association for water quality, the adequacy of current treatment, if it exists, can be seriously questioned.

In some instances present methods of water treatment are not responsive to the removal of some of these contaminants. It will be necessary to examine the validity and usefulness of some of the procedures under current investigation for the treatment of public water supplies if the people of Minnesota are to be supplied with the quality to which they are entitled.

In 1965, the amounts of water withdrawn for public supplies, rural supplies, irrigation supplies, and self-supplied industrial supplies were 260, 120, 6, and 1,400 million gallons per day (mgd). The State's average per capita use of water was about 108 gallons per day. Of the 1,786 mgd withdrawn for the above mentioned supplies, about 276 mgd was consumed. Although all basins in the State will experience substantial growths in withdrawals, the greatest withdrawal increases will occur in the Upper Mississippi river basin. The largest single areas of water will occur in the Lake Superior watershed and the Twin Cities Metropolitan Area. Total water withdrawals, except for thermoelectric and hydroelectric power uses, in the State are projected to increase from 1,159 mgd in 1960 to 3,290 mgd in 2020 or about 2.8 times. Consumption is projected to increase from 162 mgd in 1960 to 287 mgd in 2020 or about 1.8 times. Total water withdrawals in the Twin City Metropolitan area are projected to increase from about 230 mgd in 1960 to 760 mgd in 2020. Per capita municipal water use in the State is projected to rise to 118 gallons per day in the year 2020.

Projected water supply demands, data on extended dry-weather lowstream flow, and data on the availability of groundwater were utilized to make judgments as to the need for future development of new water supply sources in various areas of the State and to identify potential water supply problems. Major water supply problems are projected for the following places: Minneapolis-St. Paul, starting approximately 1980; Marshall, starting approximately 2020; New Ulm, starting approximately 2000; Worthington, starting approximately 1980; and Iron Range area, starting approximately 1980. The water supply demands of the rest of the State can be met by more fully utilizing developed sources and by expanding water supply capabilities. Water supply problems can be solved by impounding available surface waters and/or, locating new groundwater sources. A few long pipelines to sources may need to be provided. The greatest potential water supply problems are projected to occur at Minneapolis-St. Paul and the Iron Range area. Properly developed, the State has adequate water supplies, even during extended dry periods, to meet all foreseeable domestic, municipal, industrial and irrigation demands.

One important water problem in Minnesota concerns water supplies for the Minneapolis-St. Paul metropolitan area and the Iron Range area. The water supply withdrawals at Minneapolis-St. Paul may exceed streamflow in the Mississippi River during extended dry periods sometime within the next 20 years. The possible viable solutions to this problem are: reduced withdrawals of water, greater use of groundwater resources, importation of surface water from the St. Croix River or Mississippi River below Minneapolis-St. Paul, impoundment and release of surface waters behind one or more dams on the Minnesota river or its tributaries,

impoundment and release of surface waters behind one or more dams on the Mississippi river or its tributaries above Minneapolis-St. Paul, and a combination of two or more of these solutions.

As the result of the expanding taconite industry, water-supply problems in the Iron Range area are anticipated during extended dry periods within the next 20 years. The possible viable solutions to this problem are: reduction in withdrawals of water, greater use of groundwater resources, importation from Lake Superior or from the Rainy river, and a combination of two or more of these solutions.

Floods

Major floods have occurred from 7 to 11 times during the past 100 years in the Minnesota River Valley; Upper Mississippi River Valley; Cannon, Zumbro and Root River Valleys; and Red River Valley. Based on available information, there is evidence that there has been a reduction of frequency of loss of life from floods. At the same time the frequency of major property damage from floods has increased with increased development and use of flood plains. Without flood plain management or new flood control and protection works, total average annual flood damage potential for Minnesota is projected to increase from $22 million in 1966 to about $80 million (1968 dollars) in 2020. Average annual flood damages were greatest in the Minnesota River Basin and Red River Basin, and least in the Missouri River Basin in 1966. Overall, upstream and downstream flood damages were about equal. Downstream flood damages are projected to be 1.7 times as great as upstream flood damages by the year 2020. About 4 million acres in the State are subject to inundation. Flood damages in the Great Lakes basin and Rainy river basin are limited and small. Urban Flood Damage centers are most numerous in the Upper Mississippi river basin. It is estimated that present flood damage reduction programs reduce the average annual flood damage in Minnesota by about 28 percent. Existing flood damage reduction projects consist mostly of channel improvements, dikes, pumping facilities, and land treatment.

At the current rate of Federal and non-federal expenditures, and without flood plain management, flood control and prevention will not keep pace with the increase in flood damages that can be anticipated as a result of intensive use and development of flood plains. About 53 potentially feasible flood control projects in the State have been identified by the U.S. Army Corps of Engineers. Many of these projects are multi-purpose and provide such benefits as recreation facilities, pollution dilution and water supply, in addition to flood control. Projects are located mostly in the Upper Mississippi River and Red River Basins and involve several large dams and reservoirs. The U.S. Soil Conservation Service has identified 684 potentially feasible multipurpose P.L. 566 flood prevention projects in all parts of the State, except the northeast part. These projects encourage much additional floodplain development, and favor regional flood damage reduction.

Drainage and Irrigation

In the 1950-59 period, 205 open-ditch projects were completed in the State to drain lands for agricultural purposes. Projects involved 2,333 miles of open ditches. In addition, 47 closed or tile projects were constructed, involving 936 miles of tile for improved drainage. The benefited agricultural area was about 11 million acres. About 10 million acres had benefited by previous drainage. Areas drained are concentrated in the Red river basin, Minnesota river basin, and in southern counties

in the State. The U.S. Soil Conservation Service has identified the following land areas as having a drainage problem with respect to agriculture: Lands suitable for crop land having excess water as a major problem, 17,754,900 acres and lands suitable for cropland having excess water as a secondary problem 1,013,000 acres. Studies indicate that of the 46,210,397 acres inventoried in the State by the U.S. Soil Conservation Service: 40 percent have erosion problems, 27 percent need treatment and are feasible to treat, and 12 percent have been protected by treatment. The most serious erosion problems are in the southwestern part of the State. Protection by treatment is appreciable in the southeastern part of the State. There are about 15,143,500 acres of cropland, 2,489,400 acres of pasture and 16,075,434 acres of forest and woodland that require conservation treatment and that would be feasible to treat in the State. The U.S. Soil Conservation Service has identified 8,304,200 acres that require watershed project action. About 35,004 farmers or 25.2 percent of all farmers have been assisted in completing a plan for soil and water conservation for their farms.

The use of water for irrigation in Minnesota has grown from a minimum number of acres in the 1930's to about 17,000 acres in 1964. Supplemental irrigation may increase substantially in the future, especially in the field of speciality crops as potatoes and vegetables. An inventory was made by the U.S. Bureau of Reclamation of arable lands in the Souris-Red-Rainy river basin to determine their irrigability. Potential irrigable lands with surface water supplies total: 1,065,500 acres in North Dakota, 285,000 acres in Minnesota, and 3,500 acres in South Dakota. Potential irrigable lands with groundwater supplies total 138,000 acres in North Dakota and 58,000 in Minnesota. With no large supplies of surface water available for potentially irrigable lands in North and South Dakota, development of these lands depends upon the importation of water. The potentially irrigable lands are in addition to the lands to be irrigated through the Garrision Division Unit that utilizes Missouri river water importation. North Dakota is searching for water to irrigate its lands, since additional Missouri river water is not likely to be made available for State use. The Rainy river or Lake of the Woods in Minnesota is a source that could provide the quantity and quality of water for irrigation in Minnesota and North and South Dakota, as well as water for diluting return irrigation flows in the Red river. To serve the potential irrigable lands 1,500,000 acre-feet of water would have to be imported annually from the Lake of the Woods (international waters). The U.S. Bureau of Reclamation has conceived a plan to serve potential irrigable lands utilizing the Rainy river. A complex system would import Rainy river water to lands in North Dakota and Minnesota. The immense development plan would involve gravity diversion of Rainy river water from the natural storage of the Lake of the Woods.

Recreation, Fish and Wildlife

The recreation resources of the State are mainly the lakes. The lake resource is enhanced for recreation where it is associated with rough terrain, northern hardwood or pine forests, or sandy soil for prime beaches. In some areas, noticeably around Brainerd, density of lake homes equals that of some Twin City suburbs, without adequate sewer provisions. Lakeshore property is being purchased faster than homes are being built, indicating speculators are buying up such land. About one-fourth of all outdoor recreation is and will continue to be dependent on water. Land next to water is essential for access to and full enjoyment of water-oriented recreation.

The amount of recreation participation on an average Sunday during the warm weather season was developed into a demand figure in terms of activity occassions-participation in any activity for more than a half-hour in one day. The indication is that recreation activity will increase at a much faster rate than the population increases. In 1967, boating, canoeing, swimming, waterskiing, and sailing demands on an average summer Sunday totaled 373,056; 32,739; 1,119,598; 102,137; and 655,433 activity occasions, respectively. Corresponding projections for 1985 are 904,183; 81,719; 2,987,713; 323,649; and 1,538,929 activity occasions, respectively. The fishing participation rate per capita in 1967 was 7.8 activity occassions and is projected to increase slightly in the future. There was 285,482 big-game hunters in 1966. Projections indicate that in 1980 there will be approximately 340,000 big-game hunters. Small-game hunters totaled 233,156 in 1965 and are projected to total 325,000 in 1980. Waterfowl management plans will provide opportunities for about 150,000 duck hunters. The projected 1980 demands for recreation in Minnesota will be 1.87 times the 1960 demand. Thereafter, demand is expected to increase to 3.06 times the 1960 demand by the year 2000, and to 4.25 times by the year 2020.

Many lakes have problems of pollution; weed growth; algae, sedimentation; lake level fluctuations; undesirable lake shore development; limited public access and facilities for the public; inadequate small boat harbors; water supply and sanitation; excessive boating; preservation of scenic values; inadequate fish management, including fish production and fish control; inadequate beaches and poor beach conditions; preservation of wildlife habitats; dredging and disposal of dredged materials; unknown ownership of lake shore property; lack of variety of recreational facilities; preservation of historic sites; erosion of lake shores; inadequate resort facilities; short resort season; and use for water supply. Wetlands needed for wildlife management are being lost at a rapid rate due to draining and other practices. Many of the State's lake problems have been intensified by man's economic progress.

Swimming is the number one water oriented recreation activity in the State. The concentrated use of the swimming beaches in urban areas is contributing to the pollution of the waters, thus creating a health problem. The littering of some beaches and swimming areas with debris constitutes a safety hazard. There are also localized deficits in water-oriented recreational opportunities. Although the greatest demand for swimming is in the metropolitan areas, there are many communities throughout the State to which swimming facilities are remote.

Undesirable developments on shorelands of rivers or lakes where such encroachments will increase pollution of the lake, cause soil erosion or destroy natural fish and wildlife habitat or the aesthetic values should be prevented. Existing programs of acquisition of natural fish spawning areas to include acquisition of selected, undeveloped shorelands best suited for conservation purposes should be extended. This includes fish and wildlife habitat, protection of highly erodable soils, and protection of lands of prime scenic quality. The State must adopt rigid policies for protection of state-owned lands bordering recreational lakes or streams from encroachments of power lines, roads, dumping grounds and timber cuttings, and encourage local governments to do likewise.

Minnesota has many sites of outstanding scenic beauty such as the rock shores of Lake Superior, the bluffs along the Mississippi river valley, and waterfalls of unique quality such as the Pigeon river falls on the Minnesota Canadian border. These are just a few samples of the natural landscape, its geology, botany and wildlife that need preservation. Minnesota is also rich in history - Indian explorations

and pioneer settlements, for example. The most unique historic sites must be preserved if the memorials are to be recognized now and in the future.

Navigation

Existing navigation facilities on the Mississippi river, with favorable channel conditions and proper distribution of up-and-down-bound traffic, can economically handle from 25 to 40 million tons of traffic annually. Traffic is projected to increase from about 9 million tons in 1969 to 27 million tons in 2020. Upward river traffic has accounted for about 70 percent of the total in recent years. Transportation of coal, petroleum products and grain accounts for most of the traffic. River terminals in Minnesota are located on the lower Minnesota River and at Minneapolis, St.Paul, Red Wing, and Winona on the Mississippi River. The Duluth-Superior harbor is served by 60 major docks. The shipping of iron ore dominates the traffic picture of the harbor. Grain shipments and coal and coke receipts are next in volume of traffic.

Average traffic in the Duluth Harbor is projected to increase from about 67 million tons in 1969 to 90 million tons in the year 2020. The 50-year life of existing navigation structures on the upper Mississippi River will be reached about 1990. Lock and Dam No. 1 at Minneapolis may need to be replaced. Industrial expansion in the lower Minnesota river basin may justify navigation development 25 miles up the river or even to Mankato within the next 50 years. The development of a 12 foot and possibly a 15 foot channel on the Upper Mississippi River may prove feasible within the next 50 years. Extension of the navigation season on the Upper Mississippi river may be feasible. The feasibility of a waterway connecting Lake Superior and the Mississippi river is being considered.

Electric Power

In 1970 the electric power utilities serving the State provided approximately 23.5 billion kilowatt-hours of power and they supplied a peak demand of 4,175 megawatts. Unless past and current trends are altered, it is not unreasonable to project annual electric power consumption approaching 69 billion kilowatt-hours by the year 1985, 187 billion kilowatt-hours by the year 2000, and a staggering 497 billion kilowatt-hours by the year 2020 - only fifty years from now. Peak demands are projected to increase from 4,175 megawatts in the year 1970 to 76,932 megawatts in the year 2020. Electric power consumption may continue to double approximately every eleven years. If present trends continue, industry could foreseeably consume over 50 percent of the State's electric power by the year 2020.

If unlimited expansion of electrical energy is to continue, many new generation and transmission facilities will have to be constructed in Minnesota or adjacent areas. In the next fifteen years the construction of 15 new generation facilities is a possibility in the State; beyond 1985, plant construction may continue to accelerate. And, the megawatt capacity of newer units promises to increase. Larger units could exceed 1,000 megawatts in capacity by 1985 as compared to the present unit capacity of 550 megawatts. Only 10 years ago units were being constructed with less than 100 megawatts of capacity and units of 2,000 megawatts are on the drawing boards.

The size and number of possible new power facilities pose serious potential threats to the environmental quality of Minnesota. Cumulative air pollution, water

pollution, solid waste disposal, transportation of fuel, land use, and radiation hazards and risks could accelerate even with stringent controls. Although the State is making rapid progress in abating pollution created by existing power plants, much remains to be accomplished. Thus, the State is faced with serious catch up as well as possible future environmental degradation problems associated with continuing rapid growth of electric power demand.

In the past, electric power generating units have required large quantities of water for once-through cooling purposes. Future units and those under construction will be capable of closed-cycle operation using cooling towers and/or cooling ponds. These units could require sizable dependable water supplies and cooling ponds can require 1,000 acres or more.

Costs of Potentially Feasible Water and Related Land Resources Development Programs

Accurate data concerning past and potentially feasible initial investments and annual operation and maintenance costs for water and related land resources development programs are not available. First approximations and rough estimates (probably conservative) are summarized in Tables 7 and 8. Initial investments through 1968 have totaled about $2.5 billion, whereas, initial investments 1969 to 2020 may be about $4.8 billion. Annual operation and maintenance costs were about $87 million in 1968; they may be about $321 million in 2020. Investments and costs given above are constant 1968-69 dollars.

TABLE 7. Estimated Investments and Operation and Maintenance Costs Through 1968 for Water and Related Land Resources Development

Category of Resource Development and Management	Initial Investments Through 1968			Annual Operation and Maintenance Costs (1968)		
	Fed.	Non-Fed.	Total	Fed.	Non-Fed.	Total
	(million 1968 dollars)					
Water Supply	10	755	765	neg.	46.0	46.0
Water Quality	15	510	525	neg.	7.5	7.5
Recreation, Fish, Wildlife and Forests	95	175	270	4.0	20.0	24.0
Flood Control	49	14	63	0.5	0.3	0.8
Navigation	379	9	388	4.0	neg.	4.0
Land Drainage, Irrigation and Treatment	250	206	456	neg.	4.5	4.5
Total	798	1,669	2,467	8.5	78.3	86.8

TABLE 8. Estimated Investments and Operation and Maintenance Costs Associated with Potentially Feasible Water and Related Land Resources Development Programs

Basin	Initial Investments (1969-2020, 1969 dollars)		
	Fed. $	Non-Fed. $	Total $
Great Lakes	181,900,000	186,000,000	367,900,000
Rainy River	175,977,400	71,629,200	247,606,600
Red River	95,000,000	94,000,000	189 000,000
Mississippi River Headwaters	1,061,426,000	1,303,800,000	2,365,226,000
Minnesota River	461,427,000	624,818,000	1,086,245,000
Cannon, Zumbro and Root riv.	200,706,000	266,187,000	466,893,000
Missouri River	30,000,000	15,000,000	45,000,000
Total	2,206,436,400	2,561,434,200	4,767,870,600

Basin	Annual Operation and Maintenance Costs (2020)		
	Fed. $	Non-Fed. $	Total $
Great Lakes	3,000,000	12,000,000	15,000,000
Rainy River	2,299,100	466,500	2,765,600
Red River	1,900,000	4,400,000	6,300,000
Mississippi River Headwaters	66,068,000	97,100,000	163,168,000
Minnesota River	34,718,000	59,985,000	94,703,000
Cannon, Zumbro and Root rivers	14,091,000	22,837,000	36,928,000
Missouri River	2,000,000	300,000	2,300,000
Total	124,076,100	197,088,500	321,164,600

Federal sector investments 1969 to 2020 are about 47 percent of the total and non-Federal sector investments are about 53 percent of the total. Non-federal public local-sector investments are 62 percent of non-federal investments, private sector investments are 28 percent of non-federal investments and public State sector investments are 10 percent of non-Federal investments.

Federal sector annual operation and maintenance costs in 2020 are about 39 percent of the total and non-Federal sector costs are about 61 percent of the total. Information concerning impacts of programs costs on local and State population growth, industries, firms, employment, consumers and taxpayers, and trade; and incidence of costs is not documented.

Classification of Potentially Feasible Water and Related Land Resources Development Programs

A review of identified potentially feasible programs and projects for solving existing and future water and related land resources problems in Minnesota was made in context with existing State water and related land resources policies. Programs and projects were segregated into three categories: Category 1 - Programs and projects which appear to be consistent with State policies, Category 2 - Programs and projects which appear to be inconsistent with State Policies, and

Category 3 - Programs and projects for which additional information is required before a decision can be made as to whether or not they are consistent with State policies. Judgements concerning quantities in program or project descriptions could not be made with available information, therefore, they are not to be considered a part of the review mentioned above. The results of the review are presented in Table 9.

TABLE 9.
Classification of Potentially
Feasible Water and Related Land Resources Development Programs

Basin and Description of Water and Related Land Resources Development Program Elements	Classification[a] Category 1	Classification[b] Category 2	Classification[c] Category 3
GREAT LAKES BASIN			
Water Withdrawals			
Municipally Supplied	X		
Self-Supplied Industrial	X		
Rural, Domestic & Livestock	X		
Irrigation			X
Mining	X		
Thermal Power Cooling	X		
Non-Withdrawal Water Uses			
Municipal Wastewater Discharges			X
Industrial Wastewater Discharges			X
Outdoor Recreation	X		
Sport Fishing	X		
Recreational Boating	X		
Commercial Navigation	X		
Related Land Uses & Problems			
Agricultural Land Treatment	X		
Cropland Drainage			X
Forest Land Treatment	X		
Shoreland Erosion	X		
Streambank Erosion	X		
Floodplains - Urban			X
Wildlife Management	X		
Outdoor Recreation - Intensive	X		
Outdoor Recreation - Extensive	X		
Floodplains-Rural			X

[a] Program and project consistent with State policies.
[b] Program and project inconsistent with State policies.
[c] Program and project requiring additional information.

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
RAINY RIVER BASIN			
Surface Water Control			
Single Purpose Reservoirs			
Develop storage for use in irrigation.			X
Develop storage for use by the pulp and paper industry and the mining industry; develop small dams and ponds to provide livestock water; and develop waterfowl habitat areas through the construction of low-head dams.			X
Instream Control			
Channel Improvement to reduce urban flood damages.			X
Ground Water Development			
Municipal and Industrial			
Develop wells and pipelines to provide water for municipal and industrial use.	X		
Rural Water Supply			
Develop wells throughout the basin to provide water for stock watering purposes.	X		
Related Land Programs			
Drainage			
Develop drainage facilities on agricultural and forest lands.			X
Environmental and Resource Enhancement			
Protection and Management			
Continued management and treatment of agricultural and forest lands, Cropland, Pasture and Rangeland and Forest Land.	X		
Waste Water Management			
Expansion or modification of waste treatment plants to meet municipal needs, expansion or modification of waste treatment plants to meet industrial needs, improved waste treatment at existing paper and pulp mills to meet needs, develop new and/or improved facilities to adequately treat the wastes produced by the milk processing industry, develop on-site waste disposal systems for small communities, and develop new and/or improved toilet facilities in National Forest areas.	X		

TABLE 9 (continued)

Resources Development Program Elements	Category 1	Category 2	Category 3
Water Supply Treatment			
Municipal - Install conventional water treatment plants	X		
Fish and Wildlife Facilities			
Wetlands - Acquisition of wetland habitat through State Wildlife Management areas, preservation and development of wildlife habitat through the Agricultural Conservation programs, and preservation of wildlife habitat through land retirement under the Cropland Adjustment Program.	X		
Access Sites - Develop access sites on lakes	X		
Access Roads - Develop roads and highways and trails in State and National Forests to provide improved access to fish and wildlife resources	X		
General - Preservation and protection of all natural wild rice growing areas, Development of fish and wildlife habitat areas in National Forests, preservation and protection of the basin's fishing resources through improved management of the resource in the National Forests, and preservation and protection of wildlife habitat through improved maintenance of logging dams in the National Forests.	X		
Outdoor Recreation			
Special Use Lands - Develop intensively developed lands plus acquisition of buffer zones.	X		
Trails and Roads - Develop trails	X		
Nonstructural Management Programs			
Floodplain Management - Initiate floodplain management and regulation at Cook to preclude future flood prone developments	X		
Shoreland Management - Initiate shoreland zoning or some other form of land use control to protect lake and adjacent shoreline environments.	X		
Additions and Modifications to Existing Projects or Developments			
Water Supply Systems - Increase capacity of existing treatment plants at Babbitt, Littlefork and Orr	X		

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
RED RIVER BASIN			
Surface Water Control			
Multiple Purpose Reservoirs			
Develop storage near Twin Valley (Wild Rice river) to be used jointly for flood control, fish and wildlife, and recreation			X
Single Purpose Reservoirs			
Develop storage on Red Lake river above Crookston for flood control			X
Develop small dams and ponds to provide livestock water	X		
Develop surface acres for waterfowl habitat	X		
Instream Control			
Develop urban levees at Perley, East Grand Forks, and Oslo to reduce urban flood damages	X		
Develop rural levees along the Red river main stem to reduce flood damages	X		
Groundwater Development			
Irrigation			
Develop wells for irrigation of land under private development	X		
Municipal and Industrial			
Develop wells and pipelines for use in smaller communities (1,000-10,000 population)	X		
Develop wells and pipelines for use in communities having populations of less than 1,000	X		
Develop wells and pipelines for self-supplied industrial use	X		
Rural Water Supply			
Develop wells for stockwatering purposes	X		
Mining			
Develop wells for mining purposes	X		

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
Related Land Programs			
Drainage			
Develop drainage facilities for agricultural lands			X
Irrigation			
Irrigation through private development of groundwater	X		
Environment and Resource Enhancement			
Protection and Management			
Continued management and treatment of cropland, pasture and rangeland and forest land	X		
Waste Water Management			
Expansion or modification of existing municipal and industrial waste treatment facilities. Develop on-site waste disposal systems for small communities	X		
Water Supply Treatment			
Install conventional water treatment plants	X		
Fish and Wildlife Facilities			
Waterfowl production areas, fee and easement acquisition; State Wildlife Management Areas; National Wildlife Refuges; Wetland Water Bank; Agricultural Conservation Program; public access to public land; wild rice areas; wildlife habitat, (Indian Lands) trout management; commercial fish, (Indian Land)	X		
Outdoor Recreation			
Special Use Lands			
Develop intensively developed lands plus buffer areas	X		
Trails			
Develop trails	X		
Nonstructural Management Programs			
Floodplain Management	X		
Additions and Modifications to Existing Projects or Developments			
Water Supply Systems			
Increase capacity of existing treatment plant at Grand Forks	X		

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
MISSISSIPPI RIVER HEADWATERS BASIN			
Natural Streamflow			
Municipal and Industrial, Withdrawal use	X		
Industrial Self-Supplied, Withdrawal use	X		
Agricultural, Withdrawal use	X		
Thermal Power Cooling, Withdrawal use	X		
Water Surface Access, Fish and Wildlife area	X		
Aesthetic and Cultural Area	X		
Groundwater			
Municipal and Industrial, Withdrawal use	X		
Industrial Self-Supplied, Withdrawal use	X		
Agricultural, Withdrawal use	X		
Mining	X		
Recreation, Instream use	X		
Fish and Wildlife, Instream use	X		
Streamflow Control			
Municipal and Industrial, Withdrawal use	X		
Industrial Self-Supplied, Withdrawal use	X		
Recreation, Instream use			X
Fish and Wildlife, Instream use			
Water Quality Management, Instream use			X
Recreation, Water surface area			X
Flood and Sediment Damage Reduction			
Administration of Flood Plain Zoning, Floodproofing, New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan	X		
Flood Insurance Program	X		
Corrective Damage Reduction, Aesthetic and Cultural area			X
Corrective Damage Reduction, Cropland and Pasture			X
Preventive Damage Reduction, Aesthetic and Cultural area			X
Preventive Damage Reduction, Flood Plain area			X
Land Treatment and Management			
Treatment, Cropland and Pasture	X		
Treatment, Aesthetic and Cultural area	X		
Erosion Control	X		
Drainage, Cropland and Pasture			X
Forests Land Management	X		

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
Land Acquisition			
Streams (Purchase and Easement)	X		
Recreation	X		
Aesthetic and Cultural area	X		
Wetland Preservation	X		
National Forest Expansion	X		
Wastewater Treatment			
Secondary Treatment and Advanced Waste Treatment	X		
MINNESOTA RIVER BASIN			
Natural Streamflow			
Municipal and Industrial, withdrawal use	X		
Industrial Self-Supplied, withdrawal use	X		
Agricultural, withdrawal use	X		
Thermal Power Cooling	X		
Commercial navigation instream use	X		
Water Surface recreation area	X		
Water Surface, fish and wildlife area	X		
Aesthetic and Cultural area	X		
Groundwater			
Municipal and Industrial withdrawal use	X		
Industrial Self-Supplied, withdrawal use	X		
Agricultural, withdrawal use	X		
Mining, withdrawal use	X		
Recreation, instream use	X		
Fish and Wildlife, instream use	X		
Streamflow Control			
Municipal and Industrial, withdrawal use	X		
Industrial Self-Supplied, withdrawal use	X		
Agricultural, withdrawal use	X		
Water Quality Management, instream use			X
Water Surface Area, commercial navigation			X
Flood and Sediment Damage Reduction			
Administration of Flood Plain Zoning, Flood Proofing New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan,	X		
Flood Insurance Program	X		
Corrective Damage Reduction, Cropland and Pasture			X
Corrective Damage Reduction, Aesthetic and Cultural area			X

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
Corrective Damage Reduction, flood plain area			X
Preventive Damage Reduction, aesthetic and cultural area			X
Preventive Damage Reduction, floodplain area			X
Land Treatment and Management			
Treatment, Cropland and Pasture	X		
Treatment, aesthetic and cultural area	X		
Erosion Control	X		
Drainage, Cropland and Pasture			X
Forest land Management	X		
Land Acquisition			
Streams (Purchase and Easement)	X		
Recreation	X		
Aesthetic and Cultural	X		
Wastewater Treatment			
Secondary Treatment and Advanced Waste Treatment	X		
CANNON, ZUMBRO AND ROOT RIVERS BASIN			
Natural Streamflow			
Municipal and Industrial, withdrawal use	X		
Industrial Self-Supplied, withdrawal use	X		
Agricultural, withdrawal use	X		
Thermal Power Cooling	X		
Hydropower, instream use	X		
Water surface, recreation area	X		
Water surface, fish and wildlife area	X		
Groundwater			
Municipal and Industrial, withdrawal use	X		
Industrial, Self-Supplied, withdrawal use	X		
Agricultural, withdrawal use	X		
Mining, withdrawal use	X		
Recreation, instream use	X		
Fish and Wildlife, instream use	X		
Streamflow Control			
Hydropower, instream use			X
Recreation, instream use	X		
Fish and Wildlife, instream use	X		
Water quality management, instream use			X
Recreation, water surface area	X		

TABLE 9 (continued)

Resources Development Program Elements	Category[1]	Category[2]	Category[3]
Flood and Sediment Damage Reduction			
Administration of Flood Plain Zoning, Floodproofing, New Structures, Flood Plain Information and Hazard Studies, Emergency Flood Protection Plan	X		
Flood Insurance Program	X		
Corrective Damage Reduction, Cropland and Pasture			X
Corrective Damage Reduction, Flood Plain area			X
Corrective Damage Reduction, Aesthetic and Cultural area			X
Preventive Damage Reduction, Aesthetic and Cultural area			X
Preventive Damage Reduction, Floodplain area			X
Land Treatment and Management			
Treatment, Cropland and Pasture	X		
Treatment, Aesthetic and Cultural areas	X		
Erosion Control	X		
Drainage, Cropland and Pasture			X
Forest Land Management	X		
Land Acquisition			
Streams, (Purchase and Easement)	X		
Wetland Preservation	X		
Recreation	X		
Aesthetic and Cultural	X		
Hunting	X		
Wastewater Treatment			
Secondary Treatment and Advanced Waste Treatment	X		
MISSOURI RIVER BASIN			
Expansion in water-supply facilities - Municipal and Industrial	X		
Waste treatment facilities for existing needs - Municipal	X		
Waste treatment facilities for existing needs - Industrial	X		
Expansion of waste treatment facilities - Municipal	X		
Expansion of waste treatment facilities - Industrial	X		
Agricultural drainage measures			X
Agricultural land treatment measures	X		
Recreational facilities	X		
P.L. 566 programs			X