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THESIS

Presented to the Faculty of the
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MASTER OF BUSINESS ADMINISTRATION

by

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College, Alaska

May, 1968

A COST STUDY FOR AN

ALTERNATIVE SOURCE OF WATER FOR

THE CITY OF FAIRBANKS, ALASKA, 1968

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ABSTRACT

The purpose of the study is to conduct a detailed investigation of an alternative water source and to examine whether this source could be utilized at a lower annual cost than the present source. The study takes into account the economic background of Fairbanks, the cost involved for treatment of the present source and the capital and treatment cost estimated for the utilization of the recommended source.

The findings of the study are (1) the proposed system realizes an annual cost higher than the present system, i.e., the immediate utilization of the proposed water source is not recommended; (2) when consideration is being given for long term expansion of the Municipal Utilities water system, the proposed system should be re-examined; (3) the recommendation is made that a source, such as the one proposed in the study, be considered as the future water supply for the University of Alaska.

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CHAPTER I

INTRODUCTION

Water supply and distribution systems are seldom complete, continually wearing out and becoming obsolete and outgrown. The result is that preliminary surveys and design investigations for revising, maintaining and extending existing systems are a continuing activity.[1] The present Fairbanks water system is no exception. In that community with a population of 13,311 (an expansion of 125 percent over the 1950 population) the 1953 water system was being operated at or beyond its "optimum" capacity in order to meet the flow requirements of the City by 1962.[2] A major geographic expansion of the Fairbanks water system occurred in 1963. Operating revenues and new customers have increased steadily since 1963 as is shown in Table 1 of Chapter IV. This growth along with Fairbanks population trends and increased demands on the present water system have led to this study.

Purpose

This study's purpose is to conduct a detailed investigation of an alternative water source and examine its economic feasibility with the express goal of reducing water production costs in Fairbanks, Alaska.

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[1] H. E. Babbitt, J. J. Doland, J. L. Cleasby. Water Supply Engineering. (New York: McGraw-Hill Book Company, Inc., 6th ed., 1962).

[2] Linck, Stevens, and Thompson Consulting Engineers. Water Works Improvements for the City of Fairbanks, Alaska Municipal Utilities System. (Fairbanks, Alaska: 1961).

Method of Research

This study is primarily descriptive in nature. The data were collected through interviews with Municipal Utilities System personnel, consulting engineers, and construction material suppliers. Pertinent published and unpublished materials consisting of engineering texts, reports, journals and research monographs were also used. Design computations are presented to show the feasibility of the project. An analysis is also made for determination of the project's practicality. The implications drawn from this analysis are derived from the use of generally accepted analytical tools.[3]

Organization

The study is organized into six chapters with appendices containing the quantitative data found following the chapter in which the data are analyzed and discussed. Chapter I, the Introduction, includes the purpose of the study, method of research, and a chapter organization of the study. Chapter II follows with a condensation of the full report, titled Summary and Implications. Chapter III is background information, a survey discussion of the history, climate and economic base for Fairbanks. The body of the study is found in Chapters IV through VI. Chapter IV is descriptive of the present water system. This is followed by the study project's engineering and cost allocations, Chapter V. The concluding chapter, Chapter VI, analyzes the project's cost in relation to the present water system and suggests further areas for study.

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[3]See E. L. Grant and W. G. Ireson, Principles of Engineering Economy. (New York: The Ronald Press Company, 4th ed., 1964).

CHAPTER II

SUMMARY AND IMPLICATIONS

Summary

The planning and expansion of water supply and distribution systems is a continuing activity, and the Fairbanks water system is no exception. This study has examined (1) the economic background of Fairbanks; (2) the existing water system; (3) an alternative water source in terms of the treatment required, the capital expenditures involved and the feasibility of the proposed supply.

The Fairbanks Trade Area is expanding at a rate of about 4 percent annually. This rate is about one half that prevailing during the last 25 year period. The Municipal Utilities System, therefore, is not enveloped in a static economy, i.e., both the economy and the community are growing. Planning for the future expansion of services is essential in a growing area such as this. As a part of the planning process for expanding public utility services, the overall cost is a serious consideration. In this respect, this study was undertaken to determine whether an alternative source of water could be utilized at a lower cost than the present source. Another consideration of prime importance is the water quality in this area, i.e., there is a high hardness and iron content in the water supplies native to this area. An alternative water source, relatively low in hardness (112 ppm) and iron (0.3 ppm) content, is located near the Tanana River in the vicinity of section block 26 (see Figure 7). This source is recommended. The treatment necessary to ready this source for domestic consumption is (1) aeration, (2) filteration, and (3) chlorination. The total annual treatment cost ($130,647) for the proposed system is $21,000 lower than the cost for the present treatment process. The savings is realized in the proposed system by lower annual chemical cost and by taking advantage of drawing warm water (about 36°F) from a strata 400 feet below the Tanana River bottom. The savings is realized in the utilization of the warm water because no additional heat is required before pumping the water to the main treatment plant, i.e., if heat addition was required the overall cost for water treatment could increase.

An annual capital cost is established for both the present and the proposed system. A comparison of the total annual cost for each system reveals that the annual operation cost of the present system ($151,700) is $38,545 lower than the annual operation cost for the proposed system ($190,245).

Implications

In view of this study's findings, the implications are--

1. The system proposed in this study realizes an annual cost considerably higher than the present system.
2. Serious consideration should not be given to the immediate utilization of the proposed water source. However, when consideration is being given for long term expansion

of the Municipal Utilities water system, the proposed system should be reexamined. A key parameter to be examined at that time is the investigation of the proposed water source to determine whether the chemical analysis used as a basis in this study is still applicable.

3. The recommendation is made that a source, such as the one proposed in this study, be considered as the future water supply for the University of Alaska.

CHAPTER III

BACKGROUND

The City of Fairbanks (the State's second largest community)[1] is located 400 miles north-northeast of Anchorage and 100 miles south of the Arctic Circle in the Interior of Alaska. Fairbanks lies on the northern edge of the broad, flat Tanana River Valley on the banks of the Chena River approximately 10 miles above the Chena's confluence with the Tanana River.[2] The establishment of the city on major routes of river travel in 1901 aided in Fairbanks' rapid growth with the discovery of important gold placers in the immediate vicinity in 1902.[3] Intermittent growth in the Fairbanks area was characteristic in the early years of settlement. Large population influxes followed each gold discovery, later followed by equally rapid declines as the deposits were exhausted. By the time the 1910 Census was taken, the city's population was estimated as 3,956 with approximately 10,000 miners, in addition, living in camps surrounding Fairbanks.[4] The city's location made it a natural transportation point for Interior Alaska and a steady and

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[1] Anchorage is the State's largest community with a population of 121,700 in 1967.

[2] See Ernest Wolff and Robert C. Haring, Natural Resource Base of the Fairbanks North Star Borough, Alaska, (College, Alaska: University of Alaska, 1967), pp. 33-60.

[3] George W. Rogers, The Future of Alaska Economic Consequences of Statehood, (Washington: Resources for the Future, Inc., 1962).

[4] Clarence C. Hulley, Alaska 1741-1953, (Portland, Oregon: Binifords and Marks, 1953), p. 282.

permanent growth took place after 1920 as Fairbanks became a major trade and service center for the area to the north and west. Although Fairbanks is isolated from large markets, national and world economic activity, its geographic setting has served to promote and sustain development in other respects by providing a base for specialized military and scientific activities. World War II changed the economic structure of Fairbanks, i.e., employment in the gold industry (the basic industry for Fairbanks at that time) was drastically curtailed by the Federal Government during the war, two military bases were established in the area and the newly completed military highway connecting Alaska with the continental United States had its northern terminus in Fairbanks.[5] The initial construction of the military installations and the further expansion of these facilities in the 1950's have shifted the area's economy from one based on gold and transportation to an economy based on military and construction activity. The specialized locational and climatic factors native to Fairbanks have led to the establishment of government installations for activities in polar space research and Arctic weather research. Transportation facilities serving Fairbanks assure its continuance as the natural trade and supply center for the Interior of Alaska. The Government-owned and operated Alaska Railroad terminates in Fairbanks and several arterial routes radiate from Fairbanks connecting it with Anchorage, Valdez and other points. The military highway mentioned previously (now

[5]See Leo Loll, (ed.) "Gold Mining in Alaska," Alaska Review of Business and Economic Conditions, (College, Alaska: University of Alaska, March, 1965); George W. Rogers, op. cit., p. 12.

known as the Alaska Highway) connects the community with Canada and the "lower 48." Scheduled and non-scheduled air service connects Fairbanks with national, international and local (northern and western regions of the state) air traffic.

Population

The population of Fairbanks is currently estimated at 19,000 people with an urban community civilian population of 28,700 people.[6] There are, in addition, about 10,000 military personnel residing in the area, which brings the total population of the Fairbanks community to nearly 40,000 people. Since 1920, the Fairbanks population as well as the population in the surrounding area have increased steadily. The population influx was due to the construction and subsequent expansion of military bases, government research facilities and state administrative and educational facilities.

Employment

The major segment of the labor force is employed by government agencies, i.e., Federal (including military), State and local. The principal concentrations in employment occur at the military bases, Federal space research facilities and the University of Alaska. The categories, military and government, account for one-third of the labor force in the City of Fairbanks and nearly two-thirds of that in the

[6] See R. C. Haring and C. Correia, Economic Base of the Fairbanks North Star Borough, Alaska, (College, Alaska: University of Alaska, June, 1967), pp. 42-45.

Fairbanks Trade Area.[7] Most of the remainder engaged in construction and service-type industries. The somewhat more autonomous sectors, the extractive and manufacturing industries, which employ one-third of the national labor force, employ less than 3 percent in either Fairbanks or its Trade Area. Manufacturing industries that have developed are those which characterize all cities of comparable size such as food production for the local market, printing and publishing, and production of construction materials, such as dimensional lumber and cement blocks. Employment data compiled by the State Department of Labor indicate a substantial expansion in total employment between 1960 and 1965, with an increase of approximately 25 percent in the total number employed. The increases were mainly in the government and service categories which indicate no basic change in the structure of the economy.

Future Economic Development

Future growth for the Fairbanks community will be influenced by the expansion of governmental research facilities and an increase in tourism. The expansion of commercial facilities induced by employment and population increases in the Trade Area of Interior Alaska will also affect the growth of Fairbanks. Development of agriculture, forest or mineral resources and marked expansion in manufacturing are not forseen. Estimates of employment opportunities indicate that growth will proceed at a lesser rate than in the past. Population growth at a rate of 2.7

[7] Ibid., p. 23: See also U.S. Army Corps of Engineers, Fairbanks Flood Control, Fairbanks, Alaska, (Anchorage, Alaska: U.S. Army Engineer District, Alaska Corps of Engineers, December, 1967), p. B-2.

percent annually, which is one-half of that prevailing during the last 25 year period appears reasonable. Economic growth associated with this estimated population projection will increase in the order of 4 to 4.5 percent annually.

Locational and Climatology Characteristics

The City of Fairbanks, located in the Interior of Alaska, is well sheltered from maritime influences on practically all sides. The temperatures over this area are characterized by large seasonal variations. Each day during the months of June and July the sun is above the horizon for a period of from 18 to 21 hours. The daily average temperature for these months ranges from the lower seventies to an extreme high of 99°f recorded in July 1919. Conversely, for the period of November to March, daylight ranges from 10 hours to less than 4 hours each day. Normal daily temperatures for this period fall below 0°F with an all time low of -66°F recorded in January 1934. (See Figure 1 for mean values of climatic parameters.)

Precipitation follows a fairly regular seasonal pattern. Light showers begin in May and build up through the summer months to a maximum in August. A noticeable decline in rainfall takes place between September and December with the first snow occurring in October and increasing to a maximum in January. The average snowfall in February and March is about half of that occurring in January with an annual snowfall average of about 60 inches.[8]

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[8] See Ernest Wolff and Robert C. Haring, *op. cit.*, pp. 18-23.

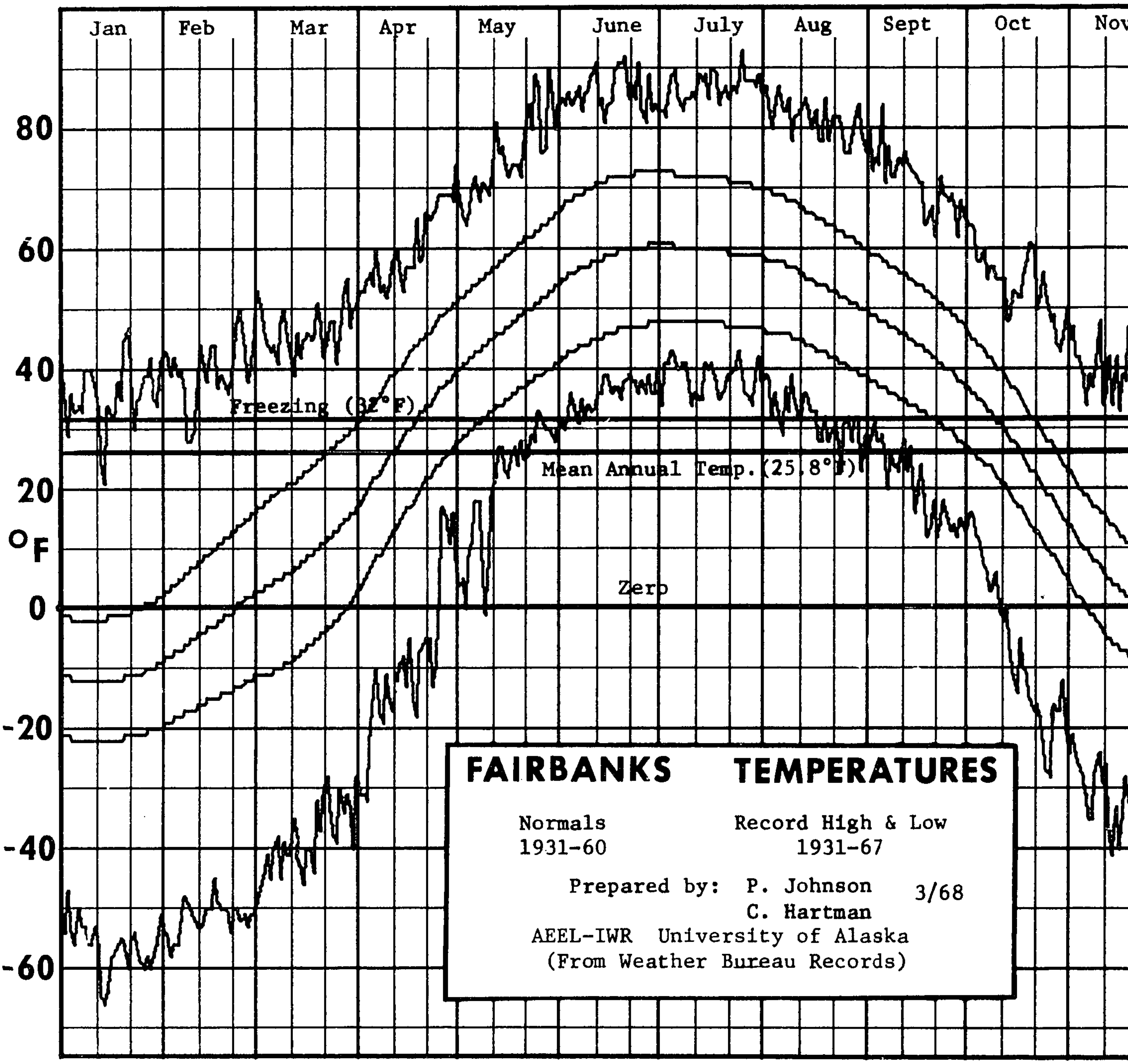
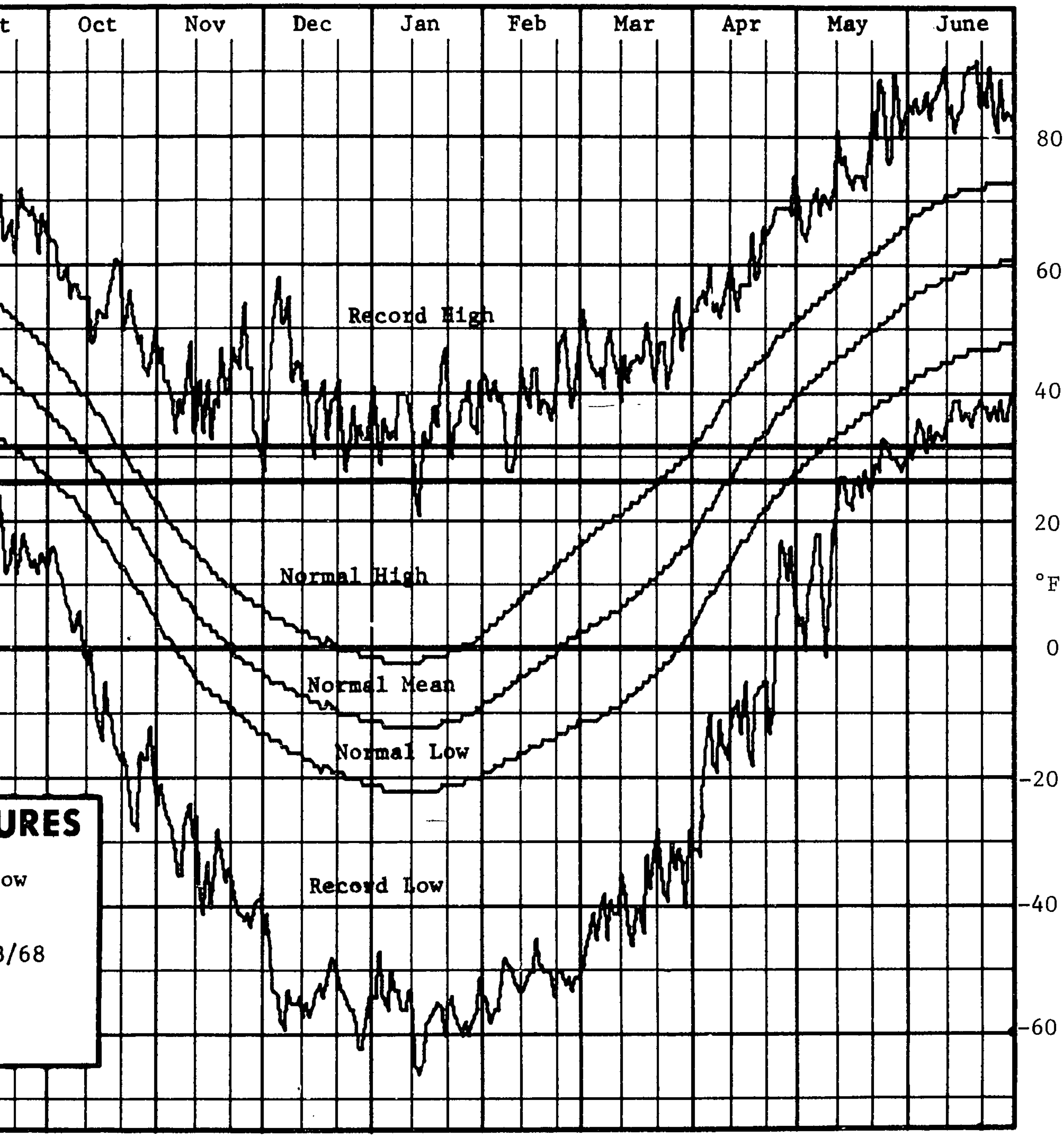


Figure 1 Mean Values of Cli



ean Values of Climatic Parameters

CHAPTER IV

EXISTING WATER SYSTEM

General

The city's water distribution system dates back to 1953 when the Municipal Utilities System undertook the construction of mains, pumping stations, and a water treatment plant. Additions to this water system were made in 1954, 1955, 1960 and most recently in 1963. The system now provides services for 2,530 customers, an increase of 96 percent over 1961 when there were only 1,300 services for the area.

Design of the water system is concerned primarily with the prevention of freezing occurring in both the mains and services during the months from December through May. During this period seasonal frost may reach depths exceeding six feet in an average winter. To prevent freezing, the treated water is distributed through a continuous circulation type system at a temperature of about 55°F and at a flow rate of 2.5 fps (feet per second) with pump stations delivering pressures in the mains at 80 to 100 psi (pounds per square inch).[1] The basic pumping station design incorporates a two-speed electric motor driven centrifugal pump and a gasoline engine driven centrifugal pump arranged in parallel as a standby unit for use in the event of repairs or a power outage on the main line pump. The distribution mains are of both wood stave and

[1]See R. Sage Murphy, Single-Main Recirculating Water Distribution Systems for Arctic Communities, (College, Alaska: Institute of Water Resources, University of Alaska, 1968, in press).

insulated steel construction. The insulated steel has performed the most satisfactory without the deterioration and maintenance encountered in the former when used under high pressures. The steel pipe is asphalt coated inside and covered outside with layers of asphalt and 23.5 pound paper to a thickness of 9/16 inch.

Water Treatment Plant

The present water treatment plant has a total processing capacity of 3 mgd (million gallons per day) with provision for expansion to 5 mgd. The plant units include a combined solids-contact type flocculator clarifier system, three rapid sand filters, a clearwell with an effective capacity of 1,900,000 gallons, and improved chemical handling facilities and mechanical equipment. Condenser piping in the adjacent power plant maintains a raw water temperature of about 55°F at the treatment plant. The raw water is treated for removal of iron, hardness and occasional turbidity in addition to being disinfected for protection against bacterial contamination. Selected water production data are presented in Tables 1, 2, 3, and 4 of Appendix A. The treatment and distribution design capacity is for a population of 28,000 within the present city limits with provision for expansion of the system as population and area trends develop. Areas now served by the present system are the downtown area, Slaterville, The Railroad Industrial area, West and East Weeks Field, Moreland Acres and Taku Subdivisions and South Fairbanks. The area encompassed by the present system is presented in Figure 2.

Source of Water Supply

The present water source is from wells located near the plant in a gravel strata 100 feet below the Chena River. (See Figure 2 for location of treatment plant and wells). Total hardness is about 180 ppm (parts per million) and iron is present in amounts up to 5.6 ppm. (See Table 6 for a chemical analysis of the raw water). Present wells produce approximately 6,000 gpm (gallons per minute). This is equivalent to about 8.5 mgd. Of this quantity about 1.5 mgd is diverted from the power plant condensers into the treatment plant for purification and distribution and the remaining 7.0 mgd is not utilized, i.e., it is discharged into the Chena River.

APPENDIX A TO CHAPTER IV

TABLE 1

SELECTED STATISTICS

WATER PRODUCTION FOR THE CITY OF FAIRBANKS

1964 - 1967

SOURCE	1967	1966	1965	1964
Metered Sales (thousands of gallons)	355,958	336,260	312,518	303,324
Operating Revenues	$724,489	$639,453	$604,508	$587,409
Customers	2,530	2,395	2,329	2,260
Maintenance Expense	$ 40,723	$ 34,069	$ 34,262	$ 34,349

SOURCE: Municipal Utilities System, City of Fairbanks, Alaska.

TABLE 2

SELECTED WATER TREATMENT PLANT PRODUCTION DATA

1965 - 1967

SOURCE	1967	1966	1965
Total Gallons Treated	460,650,000	394,031,000	390,400,000
Water to Distribution System (in gallons)	435,000,000	377,350,000	355,400,000
Water used for Filter Wash (in gallons)	3,250,000	1,728,000	2,150,000
Peak Daily Demand	1,817,000	1,565,000	1,318,000
Minimum Daily Demand	1,022,000	965,000	790,000
Average Daily Demand	1,238,000	1,043,000	971,000
Chemicals Used: (in pounds)			
Lime, Hydrated	457,900	433,500	407,550
Ferric Sulfate	89,865	78,650	83,050
Sodium Silicate	39,750	29,760	57,900
Sodium Silicofluoride	5,041	4,693	4,769
Chlorine	11,235	9,123	11,170
Chemical Costs: (dollars per hundred pound)			
Lime, Hydrated	$ 3.54		
Ferric Sulfate	6.14		
Sodium Silicate	6.16		
Sodium Silicofluoride	14.71		
Chlorine	13.00		

SOURCE: Municipal Utilities System Water Treatment Plant, City of Fairbanks, Alaska.

TABLE 3

WATER PRODUCTION COSTS FOR THE CITY OF FAIRBANKS

1965 - 1967

	1967 $/1000 gallons	1966 $/1000 gallons	1965 $/1000 gallons
PRODUCTION:			
Power	$0.02	$0.04	$0.11
Labor	0.02	0.02	0.03
Miscellaneous	0.00	0.01	0.01
TREATMENT:			
Power	0.07	0.05	0.07
Labor	0.21	0.22	0.27
Chemical	0.12	0.10	0.08
Miscellaneous	0.05	0.05	0.06
DISTRIBUTION:			
Labor	0.13	0.19	0.19
Accounting	0.12	0.12	0.13
Sales	0.00	0.00	0.01
Administration & Overhead	0.11	0.08	0.11
Miscellaneous	0.15	0.14	--
FIXED COSTS:			
Depreciation	0.52	0.52	0.50
Franchise Taxes	0.11	0.16	0.17
Social Security & Misc.	--	--	0.02
Interest	0.46	0.50	0.47
TOTAL	$2.09*	$2.20**	$2.26***
TOTAL MAINTENANCE COST (as part of the above)	0.11	0.10	0.11

* Costs are based on a total yearly production of 355,958,000 gallons.

** Costs are based on a total yearly production of 336,260,000 gallons.

*** Costs are based on a total yearly production of 312,518,000 gallons.

SOURCE: Municipal Utilities System, City of Fairbanks, Alaska; Brown, E.S., Feasibility Study of Water Supply Alternatives for the University of Alaska. College: unpublished E.M. Thesis, University of Alaska, 1967.

TABLE 4

FORECASTED ANNUAL MUNICIPAL UTILITIES SYSTEM METERED WATER SALES AND CUSTOMERS

1968 - 1980

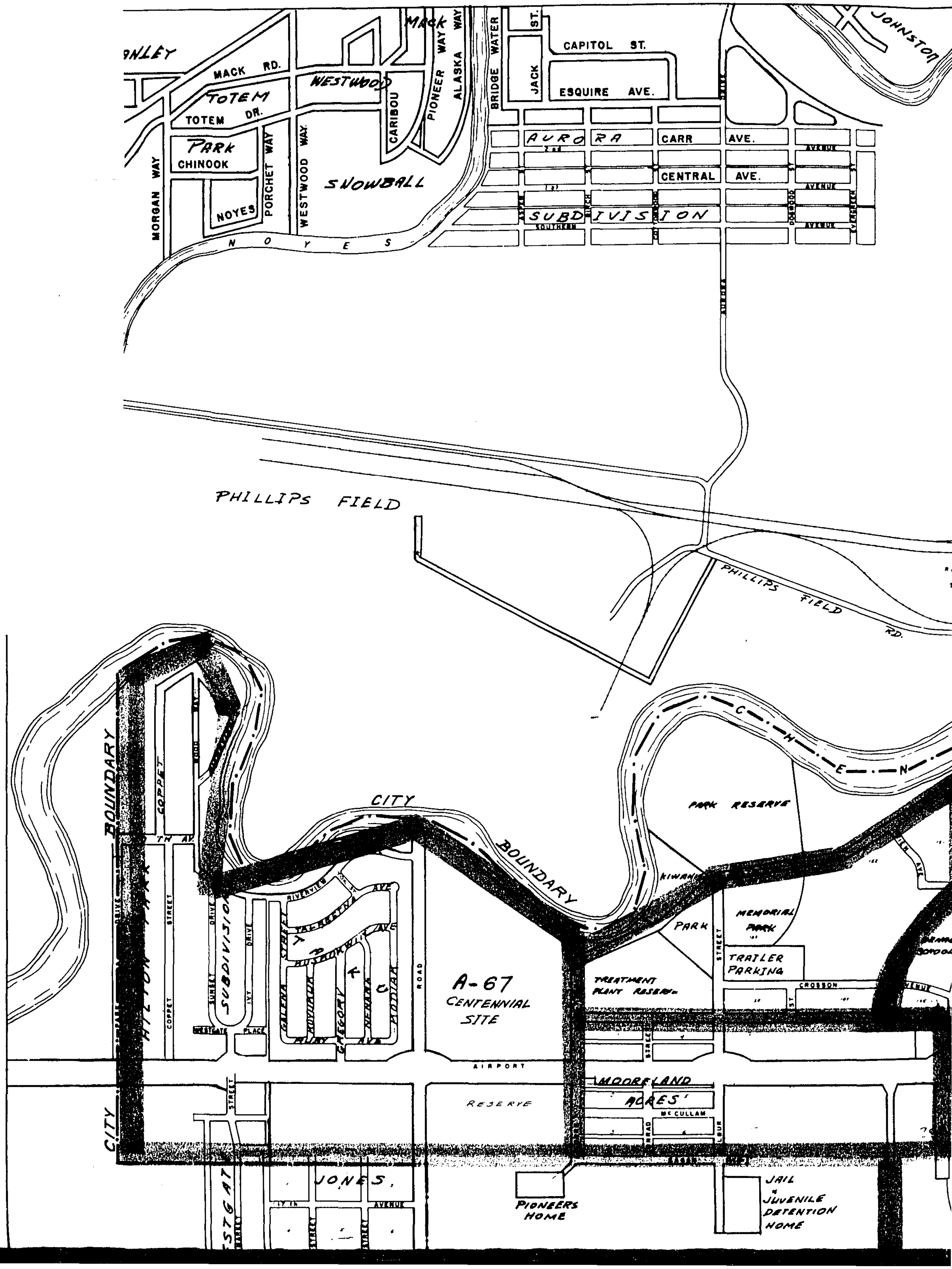
CATEGORY	1968	1969	1970	1971	1975	1980
Metered Sales (in thousands of gallons)	372,426	390,590	408,755	426,919	499,577	590,399
Customers	2,597	2,685	2,773	2,860	3,211	3,649

Trends: Straight line, least squares, by category T = a + bx, x = 0.5 in 1966

(a) Metered Sales (in thousands of gallons) T = 327,015 + 18,164.4x

(b) Customers T = 2387.5 + 87.6x

SOURCE: Author's Computation.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PIONEER WAY
ALASKA WAY
BRIDGE WATER
SNOWBALL
N O Y E S
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JACK
CAPITOL ST.
ESQUIRE AVE.
JOHNSTON
AURORA
CARR AVE.
CENTRAL AVE.
SUBDIVISION
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PHILLIPS FIELD RD.
CITY BOUNDARY
C H E N
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KIWANIS
PARK
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TREATMENT PLANT RESERVE
HILTON PARK
COPPER
SUBDIVISION
RIVERVIEW
TAMARACK
A-67
CENTENNIAL SITE
ROAD
AIRPORT
RESERVE
MOORELAND ACRES
McCULLAM
CROSSON
WESTGATE PLACE
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RUBY AVE
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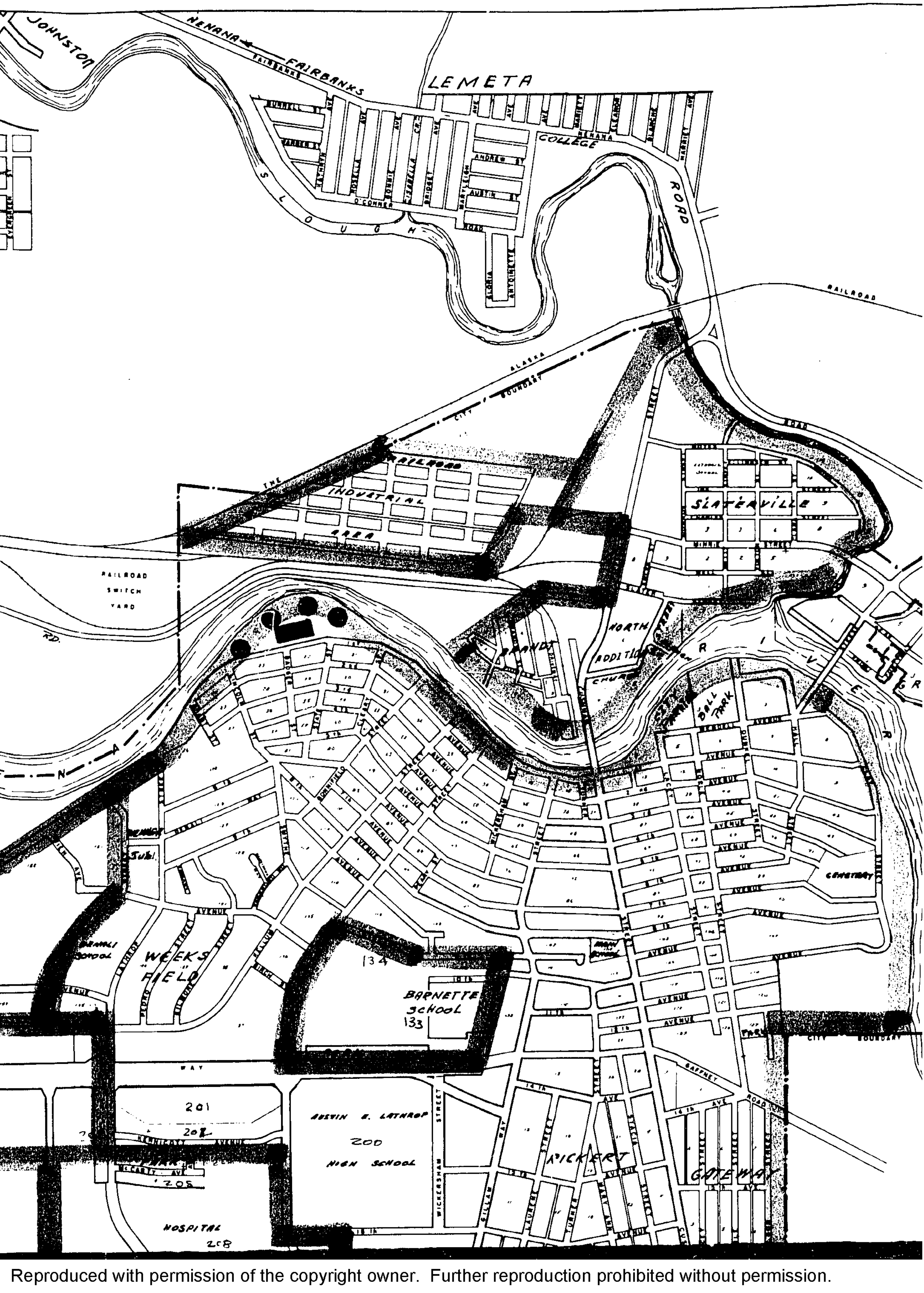
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RAILROAD INDUSTRIAL AREA
RAILROAD SWITCH YARD
SLATERVILLE
NORTH ADDITION
BRANDT
BALL PARK
RIVER
CEMETERY
WEEKS FIELD
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AUSTIN E. LATHROP HIGH SCHOOL
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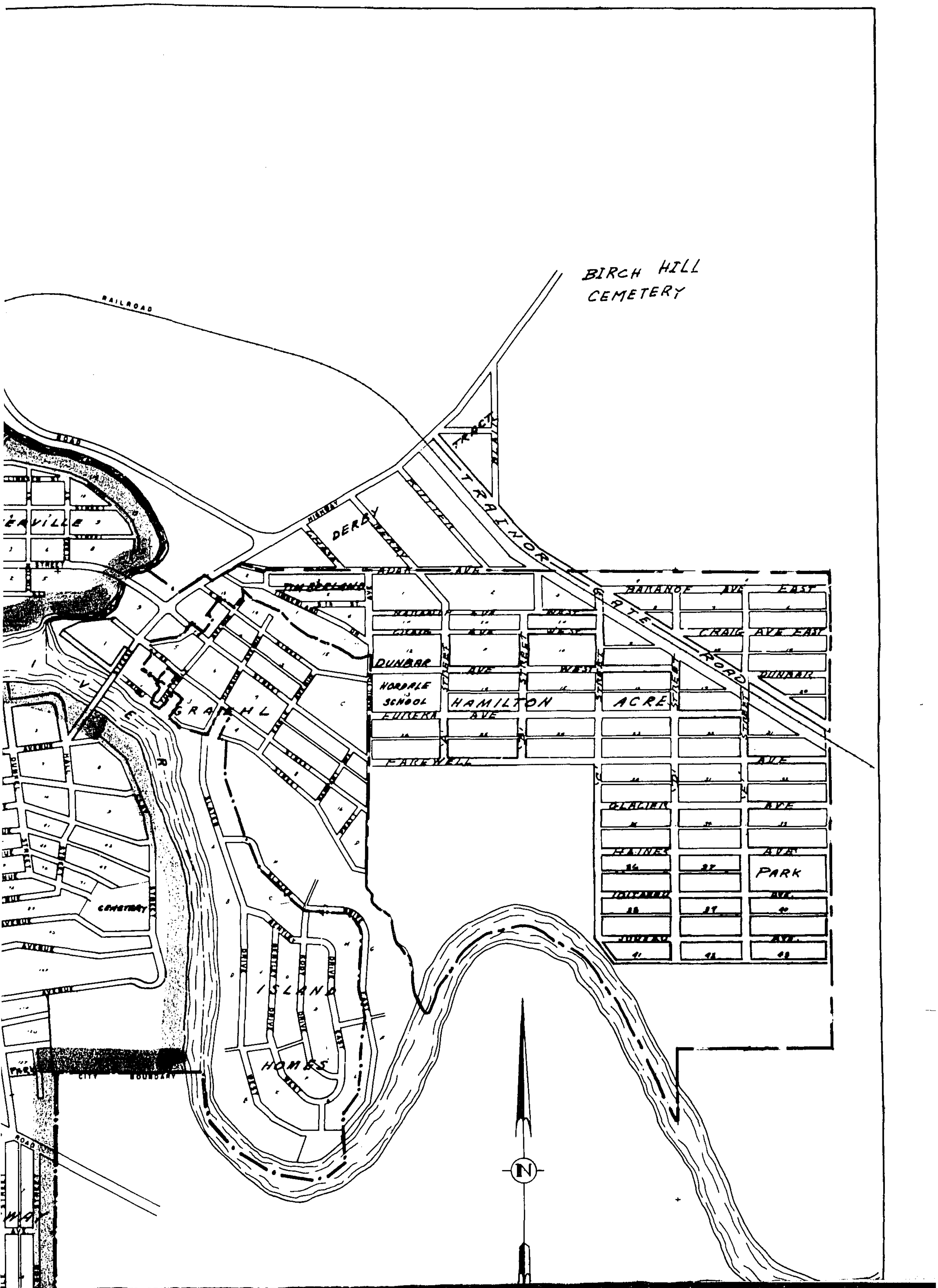
RICKERT
GATEWAY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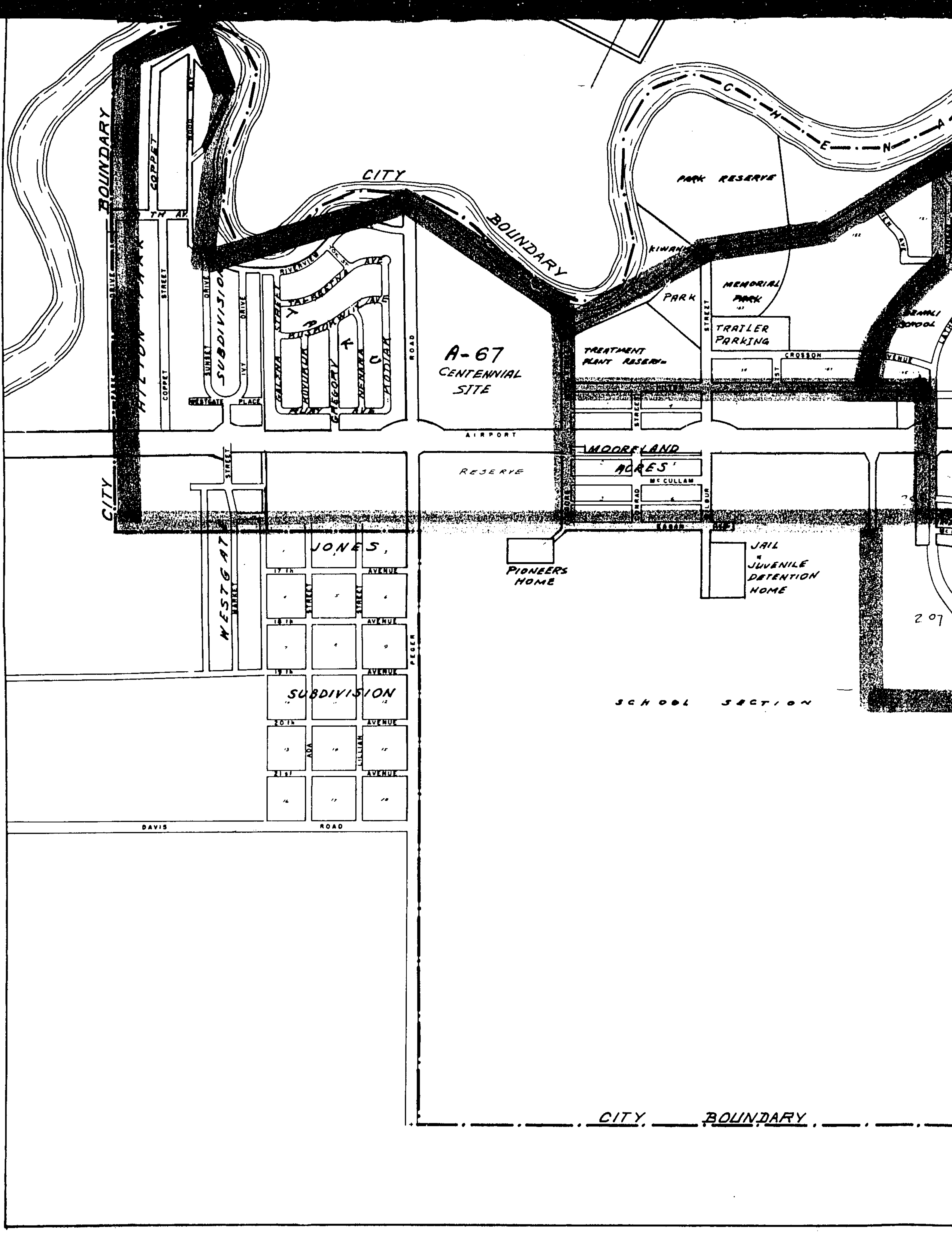

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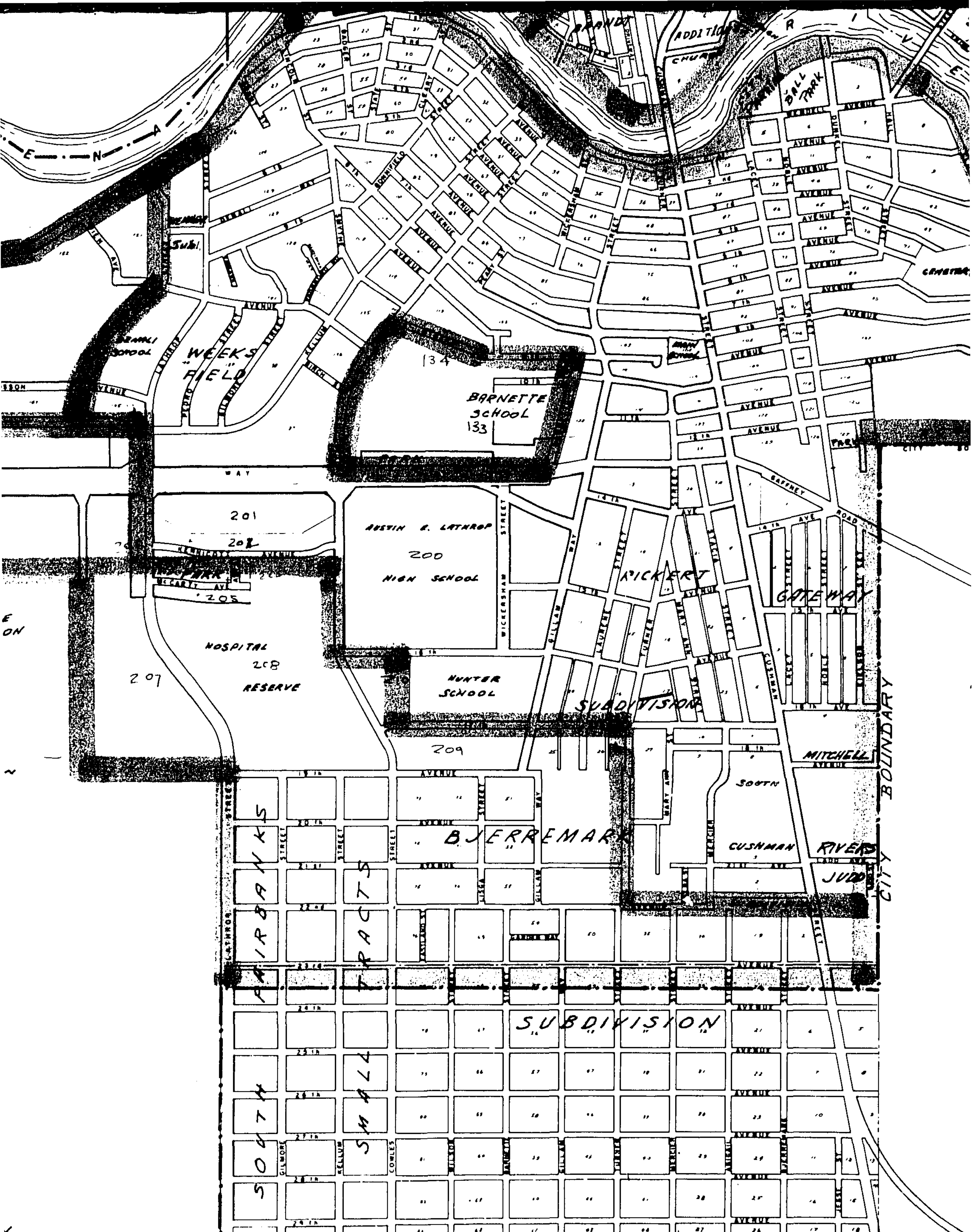

WEEKS FIELD
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HIGH SCHOOL
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HUNTER SCHOOL
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RICKERT
SUBDIVISION
GATEWAY
MITCHELL
SOUTH
CUSHMAN
RIVERS
JUDD
CITY BOUNDARY
BJERREMARK
SUBDIVISION
SOUTH FAIRBANKS
SMALL TRACTS
BALL PARK
CEMETERY
ADDITION
MAIN SCHOOL
GAFFNEY ROAD
WICKERSHAM STREET
GILLAM WAY
CUSHMAN STREET
LATHROP STREET

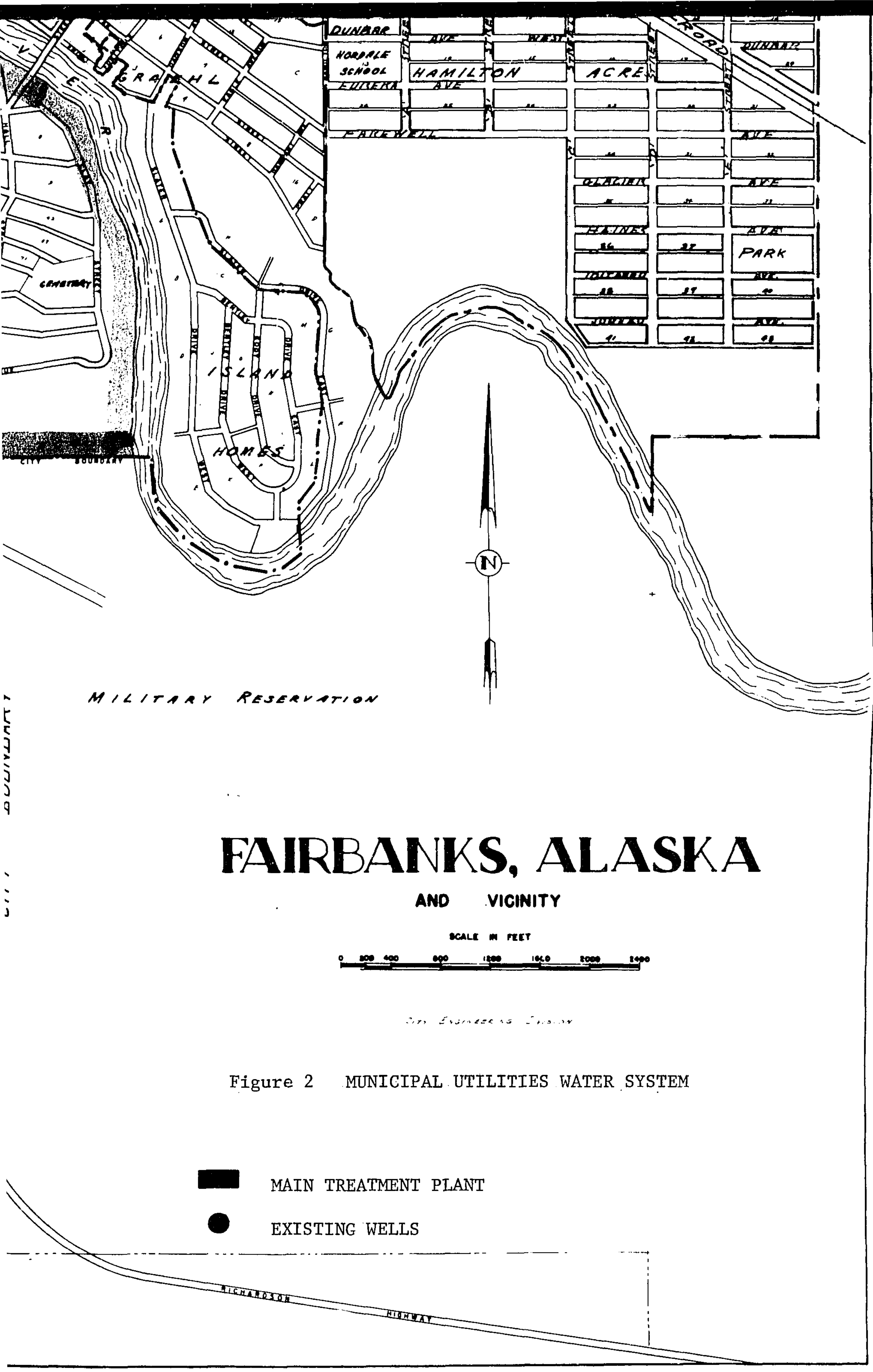

Figure 2 MUNICIPAL UTILITIES WATER SYSTEM

CHAPTER V

THE PROPOSED PROJECT

The study project's presentation is comprised of (1) recommending an alternative source of water supply for the City of Fairbanks, (2) the method for treatment of this water, and (3) the capital expenditure involved to make the proposed system operative.

Recommended Source of Water Supply

The location of possible sources of water supply for Fairbanks is considered in this section and a water supply source is recommended. Relatively uninhabited water shed areas are available in the Fairbanks area, e.g., Chena River Upstream Storage and the Silver Creek drainage area. However, the capital cost involved in developing entrainment and pumping facilities and long transmission pipelines do not make serious investigations feasible at this time.[1] In 1961 a consulting engineering firm, Linck, Stevens and Thompson, investigated the possibility of developing a surface intake on the Chena River at the treatment plant, but reported that no additional benefit would be gained from such a device. The quality of the water with respect to bacteria pollutants and turbidity would not be as good as that obtained from existing wells, i.e., treatment costs for the former would be much higher. The use of Ranney collector wells located near the Chena River

[1] See U.S. Army Corps of Engineers, Fairbanks Flood Control, Fairbanks Alaska, (Anchorage, Alaska: U.S. Army Engineer District, Alaska Corps of Engineers, December, 1967).

were also considered at that time.[2] Investigations disclosed that the river bottom and adjacent strata are very porous. This is indicated by the rise in turbidity in the existing wells as the silt load in the river increases.[3] Under the preceeding conditions, it was determined that a Ranney collector would have no advantages over the present system and would be more expensive to develop. During 1962, chemical analyses of water from wells in the Fairbanks area were run by the treatment plant personnel. Table 5 gives a representative sample of the water hardness and iron content for different locations in Fairbanks. Of the samples taken in 1962, the wells with the lowest carbonate and iron content were those wells used by the treatment plant for the city's water supply. This low carbonate and iron content is assumed to be due to surface runoff which passes through the Chena River's porous bottom and into the city's wells, i.e., a portion of the water pumped from the wells is primarily surface water. At the time the 1962 water samples were taken no analyses of nearby ground water or water from the Tanana River were run. A distinction should be made between ground water and surface water. Surface water is that water on the land surface that is visible in lakes, ponds, rivers, and streams. The water below the earth's surface

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[2]The Ranney water collector is a dug well about 13 feet in diameter that has been sunk as a caisson. Screens (perforated pipe) are driven radially and approximately horizontal from this well. The length of the horizontal screens varies from 100 to 300 feet. Such wells have great capacities, some up to 25 mgd.

[3]See Linck, Stevens and Thompson Consulting Engineers, Water Works Improvements for the City of Fairbanks, Alaska Municipal Utilities System, (Fairbanks, Alaska, 1961); conversations with treatment plant personnel revealed that the turbidity in the well water increases as the silt load in the river increases.

is called ground water because of its physical location in the ground. Separate names for surface and ground water are useful to describe where the water is, not because they are different kinds of water.

During the mid-forty's a consulting engineering firm, Black and Veatch, conducted preliminary surveys for a water supply and distribution system in Fairbanks. Their investigation revealed an adequate water source in the area of section block number 26 at the end of South Cushman. (See the attached Fairbanks (D-2) quadrangle for geographic orientation.) Test wells driven in this area tested at approximately five mgd (a well depth of 250 feet) which is adequate to supply a minimum population of 31,000 at 160 gpcpd (gallons per capita per day), a high value for Fairbanks. Note that in Table 2 the maximum peak consumption in Fairbanks was only 1.8 mgd in 1967. A comparison of the chemical analysis for the city's raw water wells and the Black and Veatch exploratory well is presented in Table 6. The exploratory well's hardness is 112 ppm. This is comparable with the hardness of the Tanana River at 110 ppm. A comparison of the hardness of the treated water distributed by the City with the hardness of the exploratory well reveals that the hardness of the latter is 8 ppm lower than that now being distributed.

The water source recommended in this study draws water from the strata 250 to 400 feet below the bottom of the Tanana River in approximately the same location as the supply source determined by the Black and Beatch study. The method of treatment will be based on the 1945 chemical analysis of the water. (This is presented in Table 6.)

Conversations with U.S. Public Health personnel at the University of Alaska revealed that the 1945 chemical analysis of the water is the most accurate available.

For development of the recommended water supply, it is advisable that three small test holes be drilled to bedrock to determine the formations and type of water available at lower depths. Since no tests holes or wells are sunk into bedrock in this vicinity, the maximum well depth cannot be determined at this time. However, available literature suggests this depth to be from 200 to 500 feet. All wells are to be sunk sufficiently deep to penetrate ample water bearing strata. The production of the necessary water supply will be from four 30 inch gravel pack wells, using 18 inch perforated casing and driven opposite the water bearing gravel formations.[4] The log of Exploratory Well Number 1 is presented in Table 7. Deep-well turbine pumps (motor driven) will perform the pumping operation. The following is the consultant's summary of the pump tests performed on the exploratory wells--

> The results of the pump test indicate that there is an abundance of water in this area and that it can be obtained with a very low drawdown, which will tend to hold pumping costs to a minimum. This low drawdown also indicates that the water flows very freely through the water bearing formations...[5]

An estimated maximum daily requirement of 4.0 million gallons (a conservative figure when considering the consumption projections in

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[4] The gravel wall, placed during the well's construction, encompasses the entire screen. The cost of gravel pack wells is usually greater than typically screened wells, but the resulting increase in capacity and prolonged life justify the increased cost.

[5] Black and Veatch Consulting Engineers, Report Covering Exploratory Work for Wells, (Fairbanks, Alaska: Black and Veatch Consulting Engineers, March, 1945).

Table 4) requires a 2,800 gpm well capacity. This requires the capacity of three wells at a rate of 1,000 gpm for each well. A fourth well is necessary as a standby unit in the event repairs are required on one of the other three wells. The drawdown determined by Black and Veatch for each individual well is between 10 and 20 feet, a very low figure.[6]

Ground water supplies have certain advantages over surface supplies[7]--

1. They are usually clearer.
2. They contain fewer bacteria.
3. If taken from one or two wells they will usually have more uniform mineral content.
4. They usually have a more uniform (constant) temperature during the summer.

The temperature of ground water at a depth of 50 feet has the same average temperature as the area above it, i.e., if the temperature above ground is around 32°F then the water to a depth of 50 feet is also 32°F. Water from a depth of greater than 50 feet has a temperature higher than the average temperature of the region above it. The temperature increases an average of 1 degree for each 60 feet in depth below 50 feet. Thus, at a depth of about 400 feet below the earth's surface, the temperature of the water would be about 6 degrees warmer than at a depth of 50 feet.

Some disadvantages of ground water are[8]--

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[6] The distance from the original water surface to the surface of the water in the well is known as the drawdown. When replenishment of the ground water surrounding a well is at a rate less than the rate of withdrawing water from the well, the drawdown will increase.

[7] See Charles P. Hoover, Water Treatment and Supply, (Washington: National Lime Association, 1951).

[8] Ibid., p. 7.

1. Calcium and magnesium compounds are present in larger quantities than in surface waters found in the same localities.
2. Iron and manganese are present in many well supplies.
3. Hydrogen sulphide is often present.
4. The cost of pumping well water is usually greater than the cost of pumping surface water.
5. The mineral content from two or more wells may be entirely different even though located on the same plot of land.

The calcium and magnesium compounds are objectionable because they cause hardness. For example, when the water is hard, more soap must be used to clean clothing or some other article. Iron and manganese stain items they come in contact with, e.g., a brown stain is left on clothing, dishes and other household items when these minerals are present in the water supply. Hydrogen sulphide has a disagreeable taste and odor, i.e., a rotten egg smell. This is not encountered in the source under study. Deep-well turbine type pumps have helped to lower pumping costs when a comparison is made with the cost of pumping with other type pumps.[9]

The yield of a well is dependent upon the porosity of the water bearing formation, the size and type of material the soil is composed of, the depth of the well into the water bearing strata, the diameter of the well, and the temperature of the water. Since most of this information is not known, the yield of a well is usually calculated by actual pumping. This is the method used to determine the quality of the strata proposed for use by this study.

[9] For example, the efficiency of air-lift pumps at depths of from 100 to 500 feet is about 30 percent; in comparison, the efficient of deep-well turbine pumps is about 75 percent.

Water Treatment

The method for treatment presented in this section is to use an aeration process to precipitate out the iron and manganese contained in the water and to then filter out the precipitate at the main treatment plant. The final operation before distribution to the city's mains is to add chlorine for bacteria disinfection. Ground water containing carbon dioxide, iron and manganese may be treated by the aeration process. This process reduces the carbon dioxide and oxidizes the iron, causing the iron to precipitate as an insoluble ferric compound which can be removed readily by filtration--

$$\underset{\text{Ferrous oxide}}{4FeO} + O_2 = \underset{\text{Ferric oxide}}{2Fe_2O_3}$$

Manganese, when present in small quantities, is also precipitated by aeration. Chemical analysis (see Table 6) shows manganese to be present in the proposed source, an amount of 0.2 parts per million. An objection to aeration is that oxygen-free water, under some circumstances, may be more corrosive when aerated. An asphalt coating on the lining of the transmission and distribution pipe should inhibit corrosive actions which might otherwise occur. The present distribution pipe is asphalt lined and the proposed transmission line will be comparable.

Aeration may be accomplished by various means. Basically, it may be done by (1) allowing water flows or falls through the air; (2) letting air bubble through the water in an open tank; (3) pumping air into and dissolving it in water under pressure in a closed tank. When both the climatic environment and the cost for installation and operation are considered the second method is the most practical. This method will be effective even during the winter months. Detention time in the aeration tank will be approximately one hour.[10] This is a sufficient detention time to allow for the oxidation and complete precipitation of the iron. A preliminary estimate from the distributor of the Air-Aqua Oxidation System places installation cost at roughly $8,000. (See schematic diagram below.) A 7-1/2 hp (horsepower) compressor motor is the only operation cost for the aeration system.

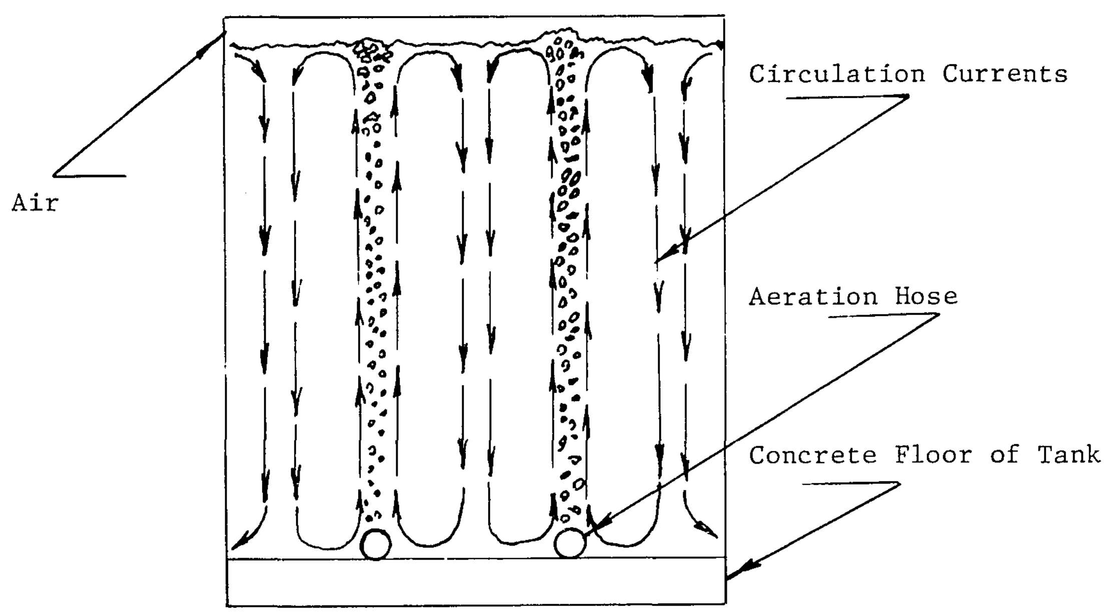

Figure 3 Typical Schematic of Aeration System

The second phase in the treatment process is to filter the aerated water at the main treatment plant. The water will pass through the rapid

[10] See M. M. Ghosh, J. T. O'Connor, and R. S. Engelbrecht, Precipitation of Iron in Aerated Ground Waters, (New York: Sanitary Engineering Division, American Society of Civil Engineers, February, 1966), pp. 199-213.

sand filters for the removal of the fine iron and manganese precipitate.[11]

The third and final stage of treatment before distribution to the city's water mains is to add chlorine for bacteria disinfection.

Capital Expenditures

The capital expenditures required to make the proposed system operative are presented in this section. They are (1) new well construction, (2) an aeration tank, (3) a pumping station, (4) a transmission pipeline, (5) new mechanical facilities at the power plant, and (6) an electric transmission line. The capital expenditure is estimated to be $742,760. This is summarized--

Wells (four required)	$248,000
Aeration tank	67,250
Pump Station	109,500
Pipeline	302,000
Power Plant Mechanical	4,000
Electric Transmission Line	12,000
Total estimated project cost	$742,750

The water will be obtained by pumping from three 30 inch gravel pack wells. Each well will have an 18 inch diameter casing driven opposite the water bearing gravel formations. The initial cost of each well, complete with pumphouse enclosure and a 40 hp drive motor, is estimated to cost approximately $62,000 in present dollar value.[12] The operation cost for these wells should closely approximate Municipal

[11] Ibid., p. 199.

[12] All dollar amounts will be in present value unless otherwise specified.

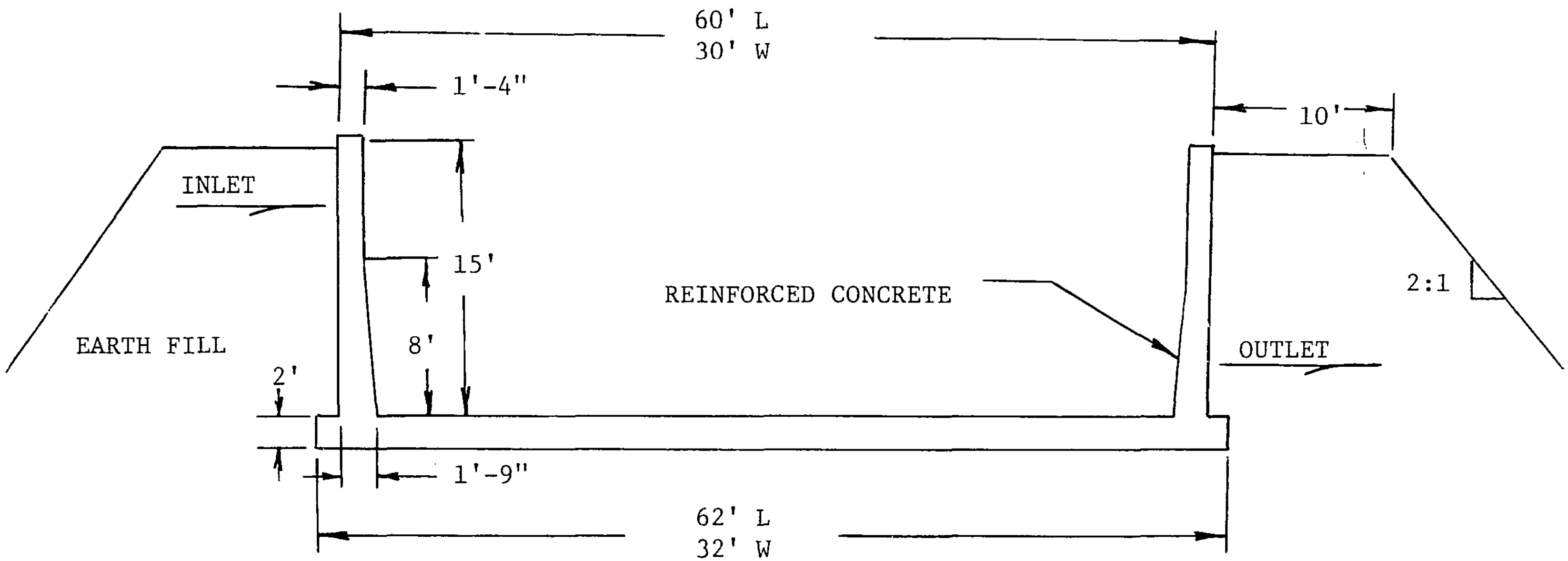

Figure 4 Concrete Aeration Tank

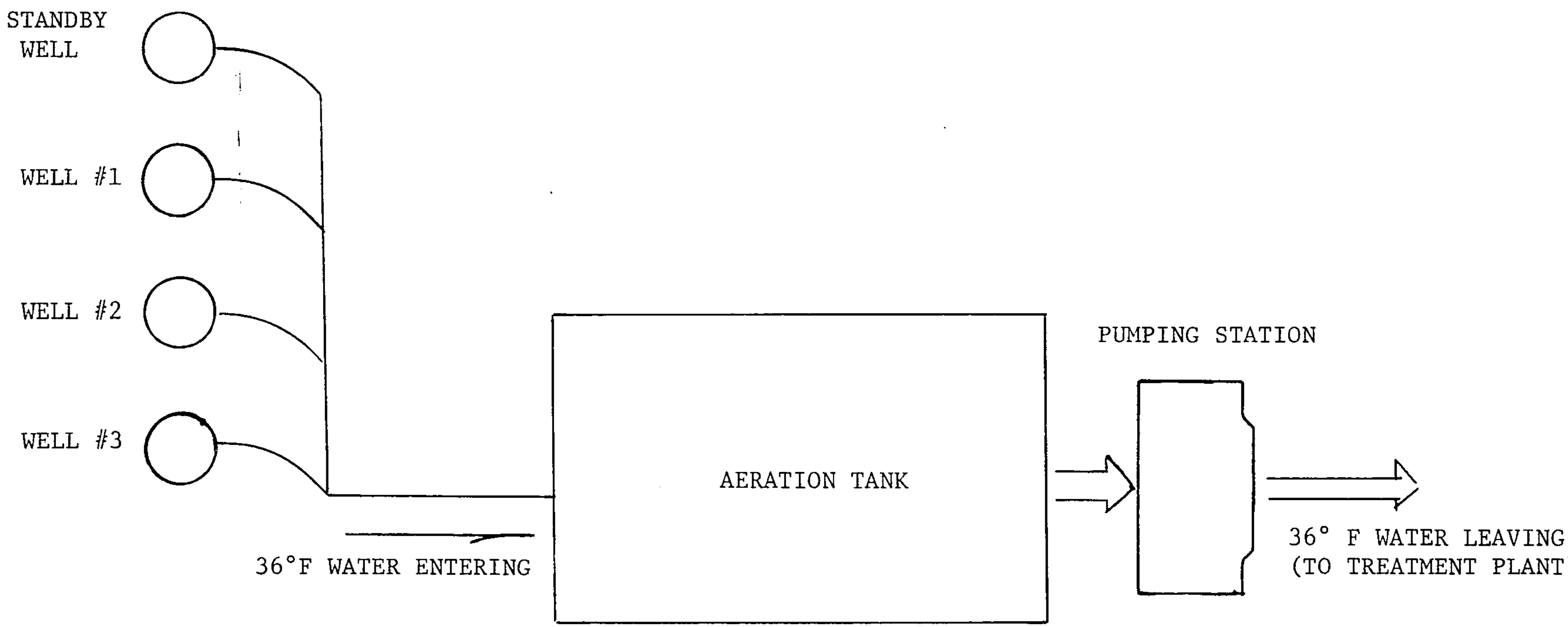

Figure 5 The Proposed System

Utilities present pumping costs. The gravel pack wells with interior screens (see Figure 6) are used to increase the area of contact between the aquifer and the well, thereby diminishing the velocity of entering water and increasing the specific capacity of the well.[13] Although the construction of these wells is initially high (costing $24,000 per mgd) their large capacity, relative freedom from trouble, and long life (estimated to be about 15 years in Fairbanks) made their use favorable.[14] The deep-well turbine type pump (motor driven) has been chosen to perform the pumping operation. This is a vertical-shaft pump rather than a horizontal-shaft type. The American Water Works Assocation describes a turbine pump as[15]--

> A vertical turbine pump is a vertical-shaft centrifugal or mixed-flow pump with a rotary impeller or impellers, with discharge from the pumping element coaxial from the shaft...

The advantages of using this type pump are that it has (1) a high discharge head, i.e., the ability to move large volumes of water; (2) a low floor space requirement, e.g., a smaller pump house would reduce construction costs; (3) quiet operation; (4) the flexibility of locating the pump drive motor at an elevation high enough to avoid flooding. Some literature suggest that maintenance difficulties may be encountered.

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[13] H. E. Babbitt, J. J. Doland and J. L. Cleasby, Water Supply Engineering, (New York: McGraw-Hill Book Company, Inc., 6th ed., 1962).

[14] See F. S. Friel, Water and Sewage Works, May, 1966, p. 194; this dollar amount is considerably higher under Alaska construction conditions.

[15] American Water Works Association Specifications A 101-55, Journal of American Water Works Association, July, 1966, p. 705.

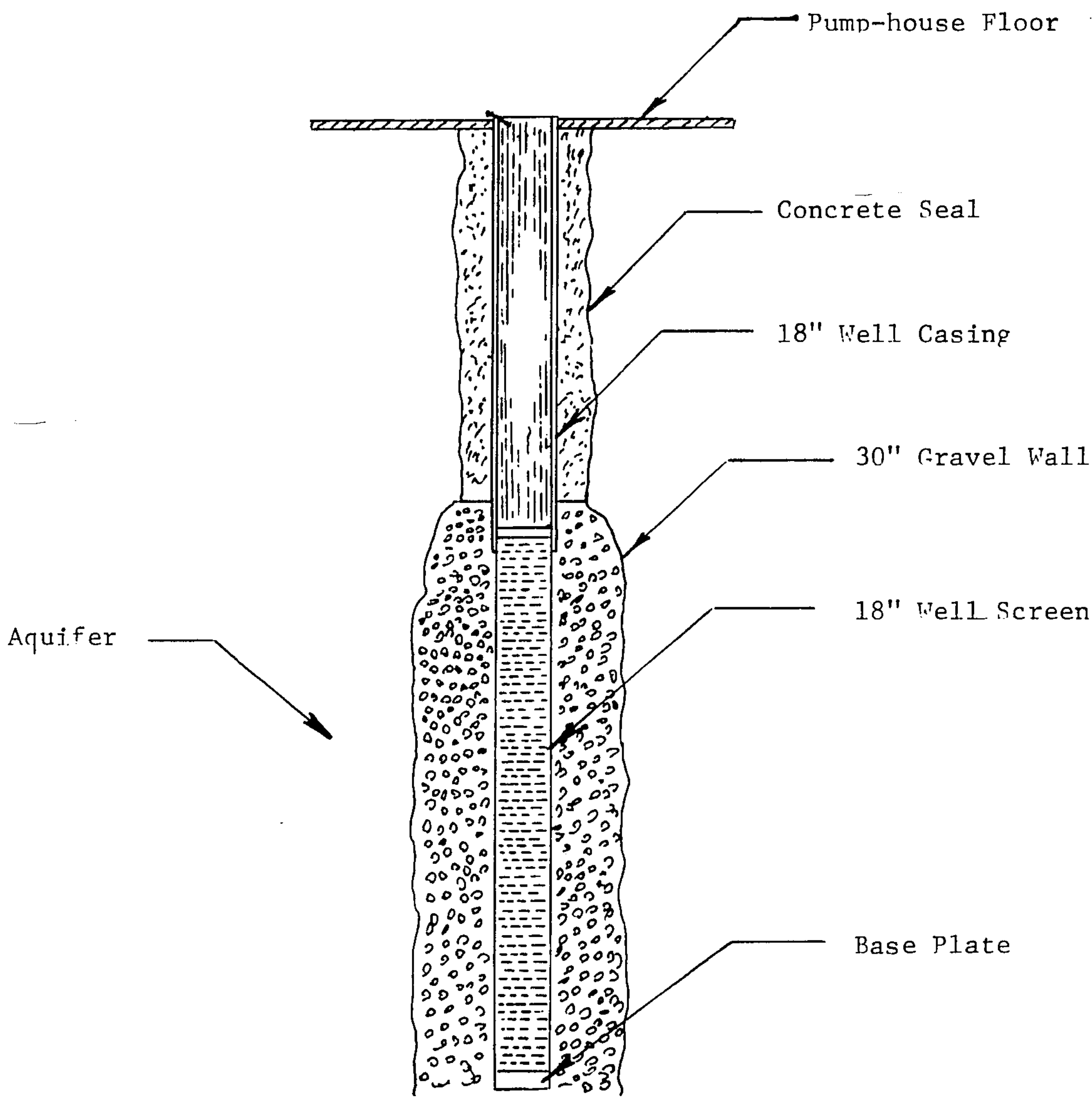

Figure 6 Typical Cross-section of a 30" Gravel-Pack Well with an 18" Casing

However, a survey of the pumps being used on the City's wells revealed that they are relatively maintenance free.

The design of a pump for deep well use must take into account the drawdown in the well so that the rate of discharge and the lift required may be obtained. Imperical formula have been established to show the relation between controlling conditions in pumping operation, they are[16]--

$$D = \frac{235\ Q^{0.154} H^{0.256}}{N^{0.678}}$$

$$N = \frac{N_s H^{0.75}}{Q^{0.5}}$$

D = outside diameter of pump casting, in inches.
H = total head for one pump stage, in feet of water.[17]
N = specific speed, in rpm (revolutions per minute).
Q = rate of discharge of the pump series (this is the speed at which one pump of the series would run when discharging 1 gpm under a head of 1 foot at the highest efficiency).

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[16] See H. E. Babbitt, J. J. Doland, J. L. Cleasby, op. cit., pp. 206-208.

[17] The total head (H), in feet of water, is the sum of the distance lifted and the friction head created from lifting the water for each stage. In the development of discharge pressure, it may be inefficient to develop the entire pressure with a single impeller, as either the diameter or the speed, or both, may be undesirably great. Increased pressure can be obtained by leading the discharge from one impeller into the suction of another since the discharge pressure from a centrifugal pump is the sum of the initial pressure at the inlet and the pressure added by the impeller. Each time this is done a stage is added to the pump. To determine the friction Head (H_f) the following equations are used--

$$N_R = \frac{Vdp}{u} \quad ; \qquad H_f = \frac{fLV^2}{d\ 2g}$$

From Table 8 it is seen that an 18 inch diameter well casing coupled with a four stage deep-well turbine type pump (driven by a 40 hp motor) is the desirable combination for the pumping operation required for each well.

Once the raw water leaves the pump discharge it flows into a reinforced concrete aeration tank where the iron and manganese contained in the water are precipitated into insoluble compounds. The tank's capacity is approximately 200,000 gallons. This places the detention period in the tank at about one hour when the water is withdrawn from the tank at a rate of 2.800 gpm. (See also the section on water treatment.) During the winter months a temporary cover may be placed over the aeration tank to limit heat loss from the water in the tank. (See Table 11 for calculations of head loss when a temperature of -50°F is experienced over the tank.) The loss, even without a cover, is only 0.17°F during the one hour detention period. The initial cost, complete with aeration unit, an insulated cover, inlet and discharge facilities and an earth embankment (see Figure 4), is estimated at $67,250. The cost allocations are--

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N_R = Reynolds Number (represents the ratio of the inertia forces to the viscous forces, a dimensionless number)
v = velocity, in feet per second.
d = diameter of the pipe, in feet.
p = mass density of fluid, in slugs/cubic feet.
u = absolute viscosity, in pound seconds/square feet.
H_f = friction head, in feet of water.
f = friction factor of the pipe.
L = length of pipe, in feet.
g = acceleration due to gravity, in feet/second/second.

Complete concrete aeration tank (340 cy. @ $150/cy.)	$ 51,000
Aeration equipment complete with standby compressor	8,000
Mechanical	1,500
Earth embankment and backfill (3,000 cy. @ $1.25/cy.)	3,750
Temporary insulated cover for winter	3,000
TOTAL	$ 67,250

A pumping station will adjoin the aeration tank and will take direct suction at the tank. Provision is provided for adding 5.5 million Btu (British thermal unit) of heat to raise the temperature of the water a maximum of four degrees when necessary. A centrifugal pump, having a capacity of 3,000 gpm at 51 feet theoretical head with 50 hp rating, will deliver the product through an 18 inch transmission line to the treatment plant. A central control panel in the pumping station will monitor the wells, aeration unit and pumping. A standby gasoline distribution pump and a 300KW diesel generator are to be located in the pumping station. The initial cost of the pumping station is estimated to be $109,500. The cost allocations are--

Pumping station physical structure	$ 33,000
5.5 million But head source (including a standby supply of coal for one month)	15,500
Distribution pumps (including standby unit)	9,000
Electrical	11,000
Mechanical	14,000
300KW Diesel Generator standby unit	27,000
TOTAL	$109,500

An eighteen inch steel transmission line was chosen to deliver the product from the aeration tank pumping station to the treatment plant, a distance of about 20,000 feet. The initial cost of the transmission line is about $302,000

Problems encountered in the design of transmission lines involving freezing of flowing water in buried lines require knowledge of the distance water will flow before the temperature lowers to freezing. By providing a sufficient quantity of above-freezing water, the loss of heat to the surrounding frozen soil can be balanced to provide an outlet temperature slightly above freezing. Heat can be added to the water in the pipe to keep it in the +32° to 40°F range, or the environment around the pipe can be warmed. The latter is not practical for the present study. Economy dictates that only the optimum amount of heat should be added to the system for operation, i.e., heat should not be wasted as this also is money wasted. The following formula is used to determine the velocity required to prevent freezing of flowing water in an insulated pipe[18]--

$$V = \frac{s(K_i)}{112{,}000(r_p 2)(\ln r_i/r_p)(\ln T_i - T_s/T_2 - T_s)}$$

V = velocity of flow, feet/second
s = length of pipeline, feet
K_i = thermal conductivity of insulation, Btu/ft-hr, °F
r_p = radius of pipe, feet
r_i = radius of outer edge of insulation, feet
T_i = inlet water temperature, °F
T_s = temperature of surrounding frozen soil, °F
T_2 = outlet water temperature, °F

This equation assumes that (1) the temperature of the frozen ground surrounding the pipe is constant for the period of flow over the entire length of the pipe, (2) the effect of frictional heat developed by the

[18]See Department of the Army Technical Manual #TM5-852-6, Methods for Determination of Depths of Freeze and Thaw in Soils, (Washington: Department of the Army, January, 1966).

water flow is negligible, (3) the thermal resistance and heat capacity of the pipe wall are negligible, and (4) the temperature distribution of the water in the pipe is uniform at each cross-sectional area. An annual ground temperature of 27°F is used in the design calculations. This temperature was established by consulting with Dr. Harold Peyton, Engineering Consultant, Arctic Environmental Engineering Laboratory at the University of Alaska. Two inches of insulation, having a K factor of 0.2 Btu/ft hr. °F, is used as the design criterion in the calculations shown in Table 10. This table illustrates the flow necessary to prevent freezing when the annual ground temperature is 27°F and the inlet water temperature ranges from 34° to 36°F with an outlet temperature of 33°F. These water velocities are representative of a system under operation. The velocities derived by the formula are doubled, in actual practice, to provide a margin of safety in the system. If the raw water coming from the wells (a depth of 400 feet is assumed) is 36°F when it enters the aeration tank, the heat loss occurring during the detention period of one hour is negligible, i.e., the water leaving the tank is only slightly less than 36°F. (See Table 11 for heat loss calculations.) This would indicate that the heat source located in the pumping station would only be used on an emergency standby basis. Analysis of the available data indicates that an actual operation velocity of 3.5 feet/second (2,800 gpm) is more than adequate to prevent freezing in the pipe. The eighteen inch pipe was chosen after the economic comparison of different size pipes was made. (See Table 12.) The comparison was based on initial cost and the cost for pumping at a rate of 2,800 gpm for a period of twenty years. These costs are summarized--

Pipe Size	Total Cost =	Initial Cost +	Pumping Cost
20 inch diameter	$468,120	$370,000	$ 98,120
18 inch diameter	465,380	302,000	163,380
14 inch diameter	566,040	237,400	228,640
12 inch diameter	777,940	225,400	522,540

The cost allocations for the transmission line are--

18 inch std. 0.375 wall steel pipe		$ 8.00/L.F.
Freight @ $0.04/# (71#/ft.)		2.84/L.F.
Insulation		1.26/L.F.
Excavation		3.00/L.F.
	TOTAL	$15.10/L.F.
Total Cost for 20,000 L.F.		$302,000

After the product leaves the transmission line it will be chlorinated at the treatment plant and then pumped through the power plant condensers where its temperature will be raised to about 55°F. The warmed water will next be sent through the treatment plant rapid sand filters to remove the iron and manganese precipitate. New mechanical facilities, e.g., valves, tees, reducers, etc., are required at the power plant to handle this procedure. The cost of the mechanical facilities is about $4,000. This estimate was established after consulting with power plant engineering personnel on the extent to which existing piping would have to be altered to handle the new source of water.

An electric transmission line must be constructed from the city limits at 23rd and Cushman to the aeration facilities, a distance of a little over one mile. City engineers estimate this cost at about $12,000.

APPENDIX A TO CHAPTER V

TABLE 5

WATER ANALYSIS FAIRBANKS AREA

1963

Location	Hardness (Parts per million)	Iron
616 Bentley Drive (Jack Adams)	188	5
Airport Road (Boatel)	274	7.5
540 Baranoff (Brene Canaday)	170	7
2115 Central in Aurora (O. Ennes)	390	5
210 Eureka (E. O. Hansen)	185	2
348 Well in Slaterville (S. Jurek)	120	3
2-1/2 mi. Richardson Highway	150	5
5 Mi. Badger Road (D. Baird)	170	3
515 College Road (G. Dufseth)	240	15
2130 Airport Road (C. Fulton)	665	10
Mack Road (S. Hansen)	410	20
109 Dawson in Graehl (B. Kelly)	240	7.5
Mack Road (P. Anderson)	102	10
Dale Road & Ravenwood	220	7.5
706 Bentley Drive (Polar Engr.)	220	10
University Avenue (H. Goldizen)	270	7
Totem Drive (C. Hauge)	132	25
2024 Eagen in Mooreland Acres	255	5

SOURCE: Municipal Utilities System, Fairbanks, Alaska.

TABLE 6

RAW WATER CHEMICAL ANALYSIS EXPLORATORY WELL, 1945

MUNICIPAL UTILITIES WELL 1967

Parts per Million	Exploratory Well	Municipal Utilities Well
Ph	7.6	6.7 - 6.9
Color	5	---
Turbidity	4	---
Solids:		
Suspended	4	---
Dissolved	169	---
Mineral	152	---
Organic	17	---
Silica	7	---
Iron	0.32	3.8 - 5.6
Manganese	0.2	---
Calcium	38	128 - 130
Magnesium	6	48 - 54
Sodium	8	---
Bicarbonate	149	144 - 154
Sulfate	17	---
Chloride	1	---
Nitrate	trace	---
Fluorine	0.2	trace
Arsenic, Lead, Zinc	nil	---
Alkalinity (As $CaCO_3$)	112	144 - 154
Total Hardness	112	176 - 184
Carbonate Hardness	112	---
Non-carbonate Hardness	0	---
Hypothetical Combinations:		
Calcium Carbonate	96	---
Magnesium Carbonate	22	---
Sodium Sulphate	25	---
Sodium Chloride	1.6	---
Silica	7	---
Organic Matter	17	---
Iron	0.32	3.8 - 5.6
Manganese	0.2	---

--- These values were not available for the Municipal Utilities Well.

SOURCE: Kelso, J. A. Report of Analysis, (Edmonton, Alberta Canada: University of Alberta, February 1945); Heine, Drawin, Municipal Utilities Water Treatment Plant, Fairbanks, Alaska.

TABLE 7

LOG OF EXPLORATORY WELL NUMBER 1

1945

Depth Below Drill House Floor	Formation
0 - 5	Sandy Silt
5 - 12	Sand and Gravel
12 - 20	Sand
20	Top of Permafrost
20 - 28	Gravel
28 - 34	Sand
34 - 46	Pea Gravel
46 - 61	Fine Gravel
61 - 64	Sand and Gravel
64 - 70	Sand and Gravel
70	Bottom of Permafrost
70 - 88	Fine Gravel
88 - 94	Fine Sand
94 - 115	Sand
115 - 121	Gravel
121 - 127	Coarse Gravel
127 - 139	Fine Sand
139 - 154	Sand and Gravel
154 - 166	Fine Sand
166 - 169	Sand and Gravel
169 - 175	Coarse Gravel
175 - 189	Fine Sand and Gravel
189 - 190	Coarse Gravel
190 - 201	Fine Sand and Gravel
201 - 202	Coarse Gravel
202 - 204	Fine Sand
204 - 205	Gravel
205 - 214	Sand
214 - 229	Gravel
229 - 235	Sand
235 - 241	Fine Gravel
241 - 250	Sand
250 - 268	Sand and Fine Gravel
268 - 270	Sand
270 - 274	Sand and Fine Gravel
274 - 288	Fine Sand
288 - 300	Sand
300 - 302	Gravel
302 - 307	Sand

SOURCE: City of Fairbanks Engineer's Office.

TABLE 8

DESIGN CALCULATIONS FOR WELLS

$H = \text{Lift distance} + H_f$

$H_f = \frac{fLV^2}{d\ 2g}$

f = 0.02
L - 400 feet
Q = 2.24 cubic feet/second @ 1000 gpm
d = 1 foot
g = 32.2 feet/second/second

$N_R = \frac{Vpd}{u}$

p = 1.94 slugs per cubic feet
u = 3.75 x 10^{-5} pound seconds/square feet
V = 1.3 feet/second

$N_R = \frac{1.3\ (1)(1.94)}{3.75 \times 10^{-5}} = 6.7 \times 10^4$, from this we may obtain f from a standard friction table, f = 0.02

$H_f = \frac{0.02(400)(2.24)^2}{64.4} = 0.62$ feet of water

H = 400 feet since H_f is relatively small

$N = \frac{N_s H^{0.75}}{Q^{0.5}} = \frac{1750(400)^{0.75}}{1000^{0.5}} = 4920$ rpm $\qquad N_s = 1750$ rpm

The value, N = 4920 rpm, is too high. Next try a four stage pump with 100 foot lifts per stage. $N = \frac{1750(100)^{0.75}}{1000^{0.5}} = 1750$ rpm. This is the value desired.

$D = \frac{236\ Q^{0.154} H^{0.256}}{N^{0.678}} = 14$ inches.

In order to facilitate an increase of about 200 gpm in future pumping an 18 inch casing is recommended.

The Motor Horsepower is calculated as-- $HP = \frac{Q(62.4\ \#/\text{cubic foot})(H)}{\frac{550\ \text{foot-pounds/second}}{HP}}$

$H_p = \frac{2.24(62.4)(100)}{550} = 25$ hp

Considering a 75 percent efficiency and a future increase of about 200 gpm, the size motor required is one of 40 hp.

TABLE 9

DESIGN CALCULATIONS FOR CENTRIFUGAL PUMPS IN PUMPING STATION FOR SELECTED SIZES OF PIPE

18 inch pipe

$$H_f = \frac{fLV^2}{d\ 2g}$$

$$H_f = \frac{0.02(20{,}000)(3.5)^2}{1.5(2)(32.2)} = 51 \text{ feet of water}$$

$$HP = \frac{Q(62.4\ \#/\text{cu. ft.})(h)}{550 \text{ foot-pounds/second/hp}}$$

$$HP = \frac{6.3(62.4)(164)}{50} = 36 \text{ hp}$$

f = 0.02
L = 20,000 feet
Q = 6.3 cu. ft./second
@ 2,800 gpm
d = 1.5 feet
g = 32.2 feet/second^2
V = 3.5 feet/second

Considering a 75 percent efficiency the motor size required is one of 50 hp.

20 inch pipe

$$H_f = \frac{0.017(20{,}000)(2.9)^2}{96.6} = 30 \text{ feet of water}$$

$$HP = \frac{6.3(62.4)(30)}{550} = 22 \text{ hp}$$

f = 0.017
Q = 6.3 cu. ft./second
d = 1.66 feet
V = 2.9 feet/second

Considering a 75 percent efficiency the motor size required in one of 30hp.

14 inch pipe

$$H_f = \frac{0.017(20{,}000)(5.9)^2}{96.6} = 123 \text{ feet of water}$$

$$HP = \frac{6.3(62.4)(123)}{550} = 88 \text{ hp}$$

f = 0.017
Q = 6.3 cu. ft./second
d = 1.16 feet
V = 5.9 feet/second

Considering a 75 percent efficiency the motor size required is 120 hp.

12 inch pipe

$$H_f = \frac{0.017(20{,}000)(7.9)^2}{96.6} = 220 \text{ feet of water}$$

$$HP = \frac{6.3(62.4)(220)}{550} = 155 \text{ hp}$$

f = 0.017
Q = 6.3 cu. ft./second
d = 1.0 feet
V = 7.9 feet/second

Considering a 75 percent efficiency the motor size required is 210 hp.

SOURCE: The Author's Calculations.

TABLE 10

DETERMINATION OF VELOCITY TO PREVENT FREEZING IN AN 18 INCH PIPE FOR SELECTED TEMPERATURES

K = 0.2
L = 20,000 l.f.

Ground Temp. = T_s = 27°F
Inlet Temp. = T_i = 34°F
Outlet Temp. = T_2 = 33°F

r_i = .75 pipe

r_p = .917 w/insulation

$$V = \frac{20,000\ (-2)}{112,000(.75)^2(\ln \frac{.917}{.75})(\ln \frac{34-27}{33-27})}$$

$$V = \frac{4}{63(.1989)(.157)} = 2.04;$$ use 4 ft./sec.

K = 0.2
L = 20,000 l.f.

Ground Temp. = T_s = 27°
Inlet Temp. = T_i = 35°
Outlet Temp. = T_2 = 33°

$$V = \frac{4,000}{(63,000)(.1959)(.2852)} = 1.12;$$ use 2.5 ft/sec.

Ground Temp. = T_s = 27°
Inlet Temp. = T_i = 36°
Outlet Temp. = T_2 = 33°

K = 0.2
L = 20,000 l.f.

$$V = \frac{4}{63(.1989)(.40547)} = 0.79;$$ use 1.5 ft./sec.

$A = \Pi/4(1.5)^2 = 1.77\ ft^2$

Q = VA

Summary:

T_i = 36°F	T_i = 35°F	T_i = 34°F
V = 1.5 ft/sec.	V = 2.5 ft/sec	V = 4 ft/sec.
Q = 2.66 ft^3/sec.	Q = 4.43 ft^3/sec.	Q = 7.1 ft^3/sec.
= 1,910 gpm	= 1,980 gpm	= 3,180 gpm

SOURCE: The Author's Calculations.

TABLE 11

HEAT LOSS FROM AERATION TANK WHEN TEMPERATURE ABOVE GROUND IS -50°F

Heat Loss[17] = $Q = U(A)(T_i - T_o)$, Btu/hr.

- A = surface area, sq. ft.
- U = $1/R$ = heat conductance, Btuh/sq. ft.
- R_t = total resistance
- R_c = x/k = resistance to heat transfer by conduction
- k = thermal conductivity, Btu/ft. hr. °F
- T_i = temperature of water in tank
- T_o = temperature of material outside tank
- x_o = Thickness of material in inches

For Concrete: $R = 1.28 = x/k$; when $x = 12$ in., $k = 9.4$ Btu in./hr °F ft^2

Heat loss from walls of tank--

$Q = U(A)\ (T_i - T_o)$	$A = 2700$ ft^2
$= 0.59(2700)(36-27)$	$R = x/k = 16$ in.$/9.4 = 1.7$
	$U = 1/R_t = 0.59$
$= 14{,}337$ Btu/hr.	$T_i = 36$°F
	$T_o = 27$°F

Heat loss through floor--

$Q = 0.392(1800)(36-32)$	$A = 1800$ ft^2
$= 2{,}822$ Btu/hr.	$R = 24/9.4 = 2.56$
	$U = 1/2.56 = 0.392$
	$T_i = 36$°F
	$T_o = 32$°F

Heat loss through top (no cover)--

$Q = 1.7(1800)36-(-50))$	$A = 1800$ ft^2
$= 263{,}160$ Btu/hr.	$U = 1.7$
	$T_i = 36$°F
	$T_o = -50$°F

Heat loss through top (with cover)--

$Q = 0.318(1800)(36-(-50))$	$A = 1800$ ft^2
$= 49{,}226$ Btu/hr.	$U = 1/(1/1.7 + 6/0.2 + 1.5/0.8)$
	$= 0.318$

Total heat loss without top: 280,319 Btu/hr.
Total heat loss with top: 66,385 Btu/hr.

To find temperature drop Δt:

$-66{,}385$ Btu/hr. $= \Delta t(1{,}668{,}000)$ — 200,000 gal. = 1,668,000#
$= \Delta t = -0.17$°F
$-280{,}319$ Btu/hr. $= \Delta t(1{,}668{,}00\#)$
$\Delta t = -0.17$°F

SOURCE: The author's calculations; also see W. H. Severns and J. R. Fellows, Air Conditioning and Refrigeration. (New York: John Wiley and Sons, Inc., 1962)

TABLE 12

ECONOMIC SIZE PIPE FOR SELECTED DIAMETERS

Initial Cost	20 inch	18 inch	14 inch	12 inch
Cost per L.F.	$11.00	$ 8.00	$ 5.86	$ 5.43
Freight cost/L.F.	3.15	2.84	2.18	1.98
Excavation cost/L.F.	3.00	3.00	3.00	3.00
Insulation cost/L.F.	1.35	1.26	1.26	1.26
Total cost/L.F.	$18.50	$15.10	$11.87	$11.27
Total cost/20,000 L.F.	$370,000	$302,000	$237,400	$225,400
Cost of power/year (2,800 gpm)	4,906	8,169	11,432	26,127
Cost of power/20 year	98,120	163,380	228,640	522,540
Selected Information				
Pump motor size	30 hp	50 hp	120 hp	210 hp
Motor hp in KW	24.4 KW	37.3 KW	89.5 KW	156.6 KW
KW hrs. used/year	196,224	326,748	784,020	1,371,816
Cost/KW hr. = $0.025				

SOURCE: Author's Computations.

CHAPTER VI

ANALYSIS OF PROPOSED PROJECT

This chapter analyses the project's costs in relation to the present water system. The operation costs incurred in the study project stem from several sources. They are (1) the yearly cost for pumping water from the wells, i.e., the cost of electric power, (2) the operation of the aeration tank compressor, (3) the cost associated with pumping the product through the eighteen inch transmission line to the treatment plant, (4) the chemical used in the treatment process, i.e., the cost of chlorine, and (5) minor maintenance and miscellaneous expenses, e.g., the routine lubrication and adjustment of the pumps and other equipment. This is summarized--

Annual Power Cost:	
Wells	$19,710
Aeration System	1,314
Pipeline	8,322
General	1,314
Chemical (Chlorine)	1,600
Maintenance and Miscellaneous (includes labor)	6,000
Total Annual Operation Cost	$38,260

An electric rate of $0.25/KW-hr. is used to compute the annual power cost. (See Table 14 for computations.) This is the electric rate used by the Municipal Utilities System for "in house" power consumption. The annual chemical cost for chlorine is estimated at $1,600. This allows for an increase of about 1,000 pounds of chlorine over the amount used in 1967 (see Table 2). The author's experience in the construction industry played a large part in determining an estimate for maintenance and miscellaneous expenses.

The cost of the complete system must be depreciated over its useful life. Depreciation represents the physical using up or wearing out of an asset over a designated life span. There is a different useful life for each part of the system. The pumping station structure itself, the transmission and well pumps, the pipeline, the pump motors, and the wells all have an estimated useful life. A depreciation rate should be determined for an aggregate of all items comprising the system. Otherwise an excessive amount of bookkeeping would be required to depreciate each item on an individual basis. A useful life of twenty years and a debt service interest rate of 5 percent are used. These values were established after consulting with Municipal Utilities engineering personnel. The annual cost for depreciation and debt service, using a twenty year life and an interest rate of 5 percent, is $59,598.[1]

Annual Cost of Capital Investment--

Initial capital expenditure $742,750
Twenty year life span
Interest rate, 5 percent
(A zero salvage value is assumed)
Capital Recovery Factor, 0.08024

$742,750 (crf - 5% - 20) =
$742,750 (0.08024) = $59,598 Annual Cost

[1]See E. L. Grant and W. G. Ierson, Principles of Engineering Economy, (New York: The Ronald Press Company, 4th ed., 1964), pp. 76-91.

Annual Cost of the Proposed System--

Annual Operation Cost	$38,260
Annual Cost of Capital Investment	59,598
Total Annual Cost	$97,858

An analysis of the proposed project's annual cost is made in conjunction with the Municipal Utilities' 1967 annual cost (see Table 13) for production and treatment. The water production costs shown in Table 13 are aggregate amounts. This required that some assumptions be made, e.g., electric power costs for both water treatment and distribution are combined. The assumptions are (1) the amount of power used annually for treatment is about $3,000,[2] (2) the labor costs for treatment would be the same under both systems, (3) the miscellaneous cost for treatment would also be the same for both systems.

Summary of Production and Treatment Costs for the Existing and Proposed Systems--

	Present System	Proposed System
PRODUCTION		
Power	$ 5,695	$ 19,710
Labor	6,240	4,000
Miscellaneous	1,691	2,000
TREATMENT		
Power	3,000	10,950
Labor	73,000	73,319
Chemical	42,759	1,600
Miscellaneous	18,996	18,996
SUBTOTAL	$151,700	$130,647
ANNUAL CAPITAL COST	--	59,598
TOTAL COST (ANNUAL)	$151,700	$190,245

[2] The major portion of the power cost for treatment, as shown in Table 13, is for the operation of the eight distribution pumping stations.

In addition to the former assumptions a value for depreciation of that portion of the present water system, which would be applicable for comparison with the proposed system, cannot be determined from the information available from the Municipal Utilities System Annual Reports. The reason for this is that a depreciation figure for the present system is available only in a lump sum amount and not shown separately for the treatment plant and wells. If however, an annual capital cost is calculated from the construction costs estimated for the treatment plant and wells built in 1963, a fairly realistic value for depreciation and debt service may be determined.[3]

Treatment Plant	$1,100,000
Wells	240,000
Total Capital Outlay	$1,340,000

Initial capital expenditure $1,340,000
Twenty year life span
Interest rate, 3 percent
Capital Recovery Factor, 0.06722
(A zero salvage value is assumed)

$1,340,000 (crf - 3% - 20) =
$1,340,000 (0.06722) = $ 90,075 Annual Cost

The present system then has an annual cost for depreciation and debt service, using a twenty year life and an interest rate of 3 percent, of $90,075. This annual cost changes the preceeding total annual cost considerably (see preceeding page), i.e., instead of the previous cost comparisons of $151,700 for the existing system and $190,245 for the

[3]See Linck, Stevens and Thompson Consulting Engineers, Water Works Improvements for the City of Fairbanks, Alaska Municipal Utilities System, (Fairbanks, Alaska, 1961), p. 94.

proposed system the annual cost is now $241,775 for the existing system as compared to $190,245 for the proposed system. This is valid only for comparison in 1963. At that time, the proposed system was the more favorable.

Revised Summary of Production and Treatment Costs for the Existing and Proposed Systems--(if considered in 1963)--

	Present System	Proposed System
PRODUCTION		
Power	$ 5,695	$ 19,710
Labor	6,240	4,000
Miscellaneous	1,691	2,000
TREATMENT		
Power	3,000	10,950
Labor	73,319	73,319
Chemical	42,759	1,600
Miscellaneous	18,996	18,996
SUBTOTAL	$151,700	$130,647
ANNUAL CAPITAL COST	90,075	59,598
TOTAL COST (ANNUAL)	$241,775	$190,245

In view of the preceeding discussion, consideration should not be given to the immediate utilization of the proposed water source. However, serious thought should be given to the proposed system especially when the long term expansion of the Municipal Utilities water system is considered. During the course of this study, conversations with knowledgeable people revealed that future expansion of the water system would make use of intake structures to be placed in the Chena River adjacent to the treatment plant. Careful analyses should be made to determine whether the capital costs encountered plus the increased costs for the treatment of the raw Chena River water are higher or more economical, when such devices are used, than the project proposed by this study. Finally, the recommendation is made that a source, such as the one proposed in this study be considered as the future water supply for the University of Alaska. Areas close to the Tanana River, such as the area south of Van Horn Road, should be examined to determine a potential source for water

TABLE 13

TOTAL WATER PRODUCTION COSTS FOR THE CITY OF FAIRBANKS

1966 - 1967

	1967	1966
PRODUCTION:		
Power	$ 5,695.00	$ 13,030.65
Labor	6,240.27	8,721.77
Miscellaneous	1,690.59	1,890.18
TREATMENT:		
Power	25,827.20	18,160.27
Labor	73,319.64	73,752.36
Chemical	42,758.97	35,086.87
Miscellaneous	18,996.03	17,251.81
DISTRIBUTION:		
Labor	46,320.02	63,529.42
Accounting	42,756.70	41,848.80
Sales	447.11	337.64
Administration & Overhead	37,408.15	28,909.28
Miscellaneous	54,723.11	45,506.06
FIXED COSTS:		
Depreciation	186,454.00	173,688.00
Franchise Taxes	38,775.00	53,046.00
Social Security & Misc.	--	--
Interest	162,787.00	167,254.00
TOTAL EXPENSES	$774,198.79	$741,808.13

SOURCE: Municipal Utilities System, City of Fairbanks, Alaska.

1967 total yearly production -- 355,958,000 gallons.

1966 total yearly production -- 336,260,000 gallons.

TABLE 14

ANNUAL OPERATIONS COSTS

POWER COSTS:

Pumping Station

Motor size 50 hp; KW = 50(0.7457) = 38KW
Operation cost/year = 38KW (24 hr/day) (365 day/year) ($0.025/KW hr)
= $8,322

Aeration Tank

Motor size 7-1/2 hp; KW = 7-1/2 (0.7457) = 6KW
Operation cost/year = 6KW (24) (365) ($0.025) = $1,314

Wells

Motor size 40 hp; KW = 40 (0.7457) = 30KW, for 3 wells = 90KW
Operation cost/year = 90KW (24) (365) ($0.025) = $19,710

Other

Total KW = 6
Operation cost/year = 6 (24) (365) ($0.025) = $1,314

Chemical Cost

Chlorine cost/pound = $0.13; total pounds used = 12,300
Annual cost = ($0.13/#) (12,300#) = $1,600

Maintenance	$2,000
Labor	$3,000
Miscellaneous	$1,000

SOURCE: Author's Computations.

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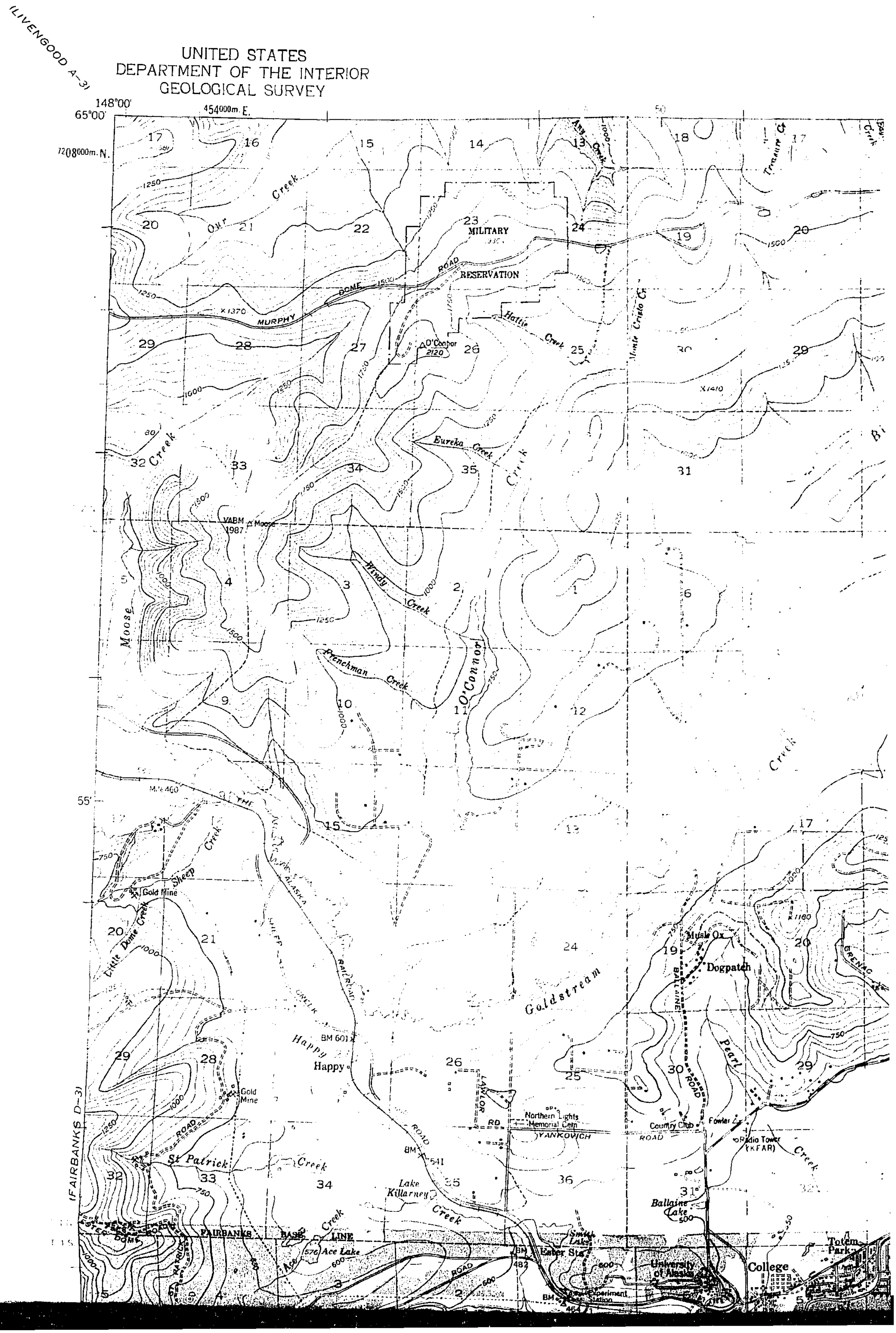
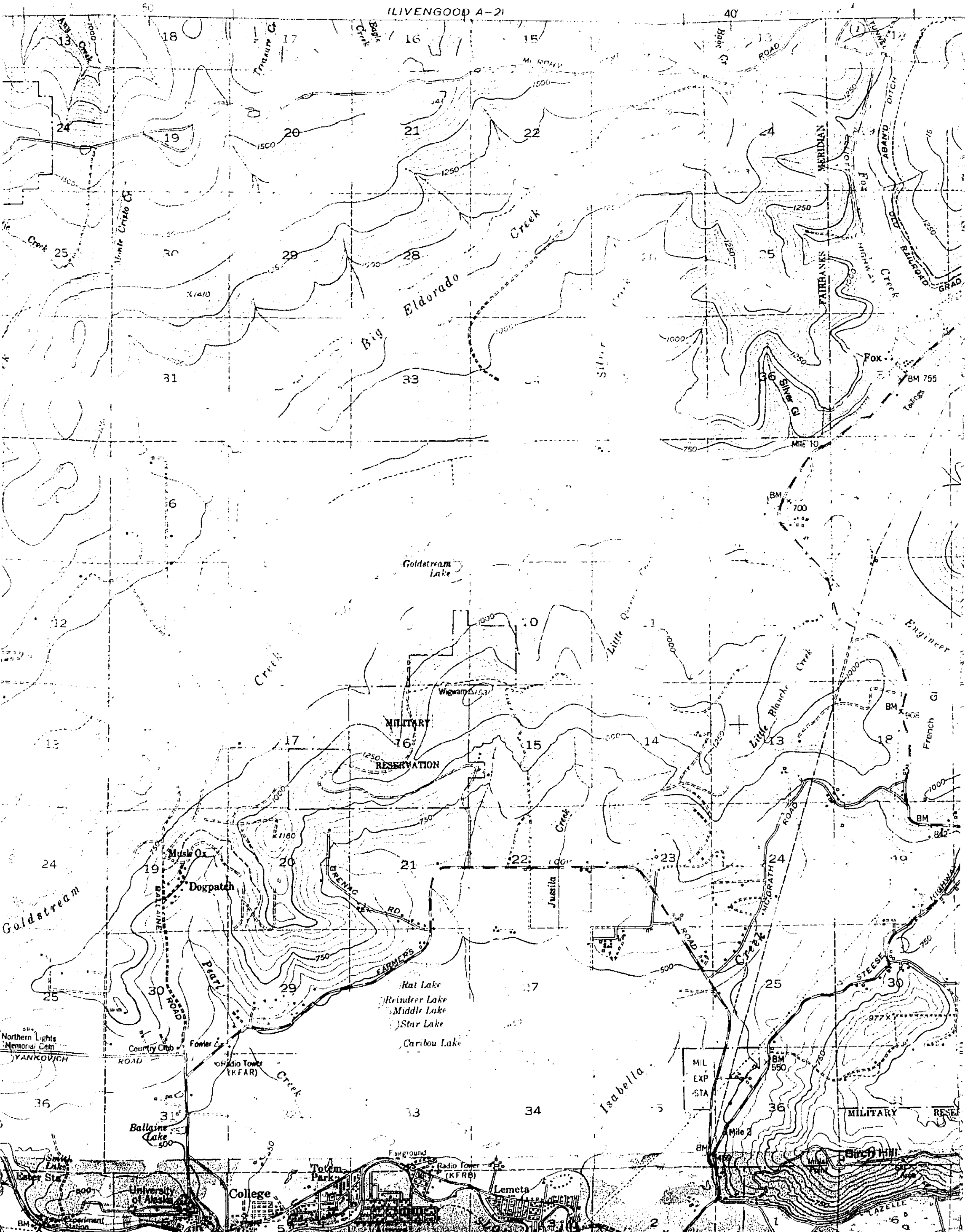
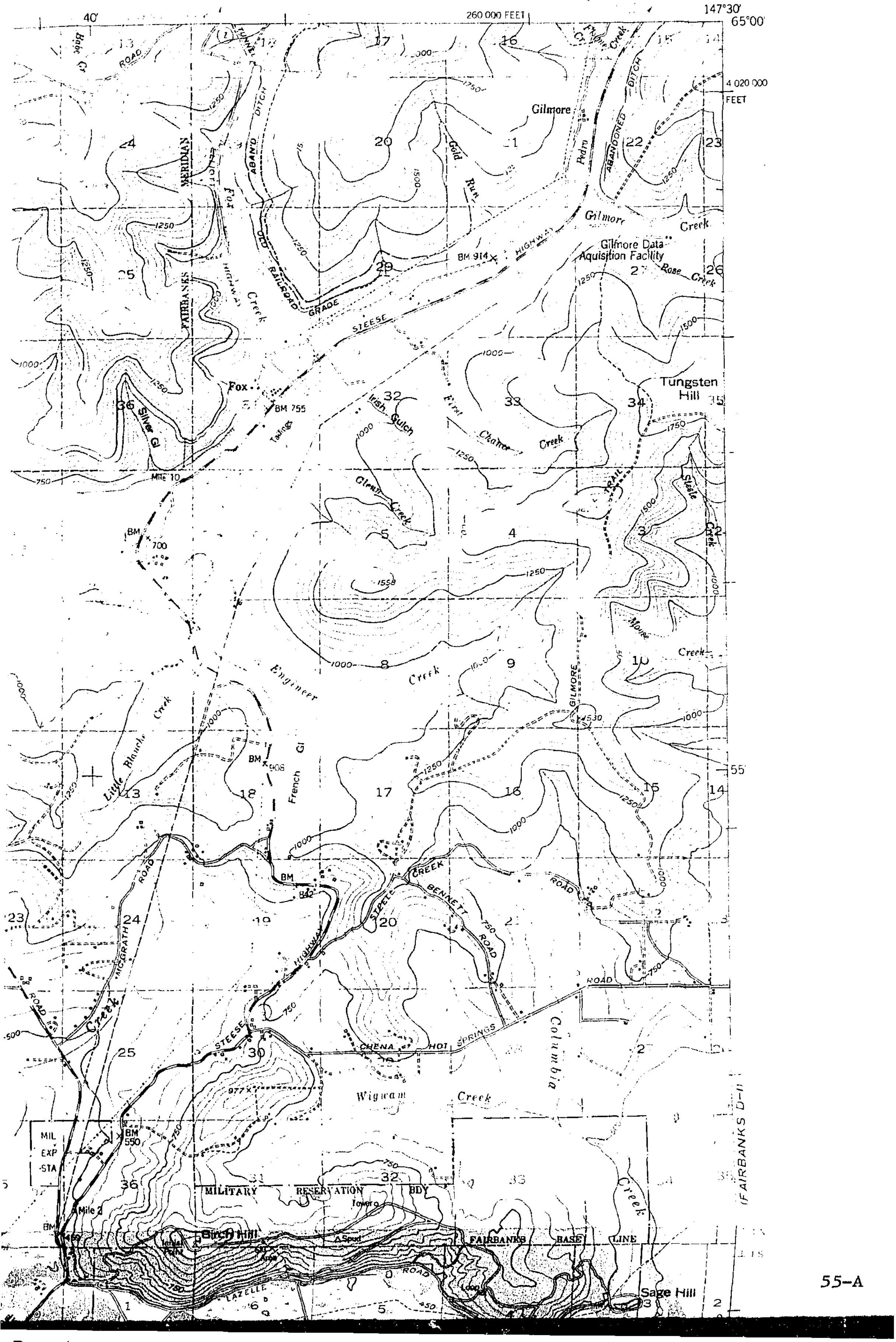
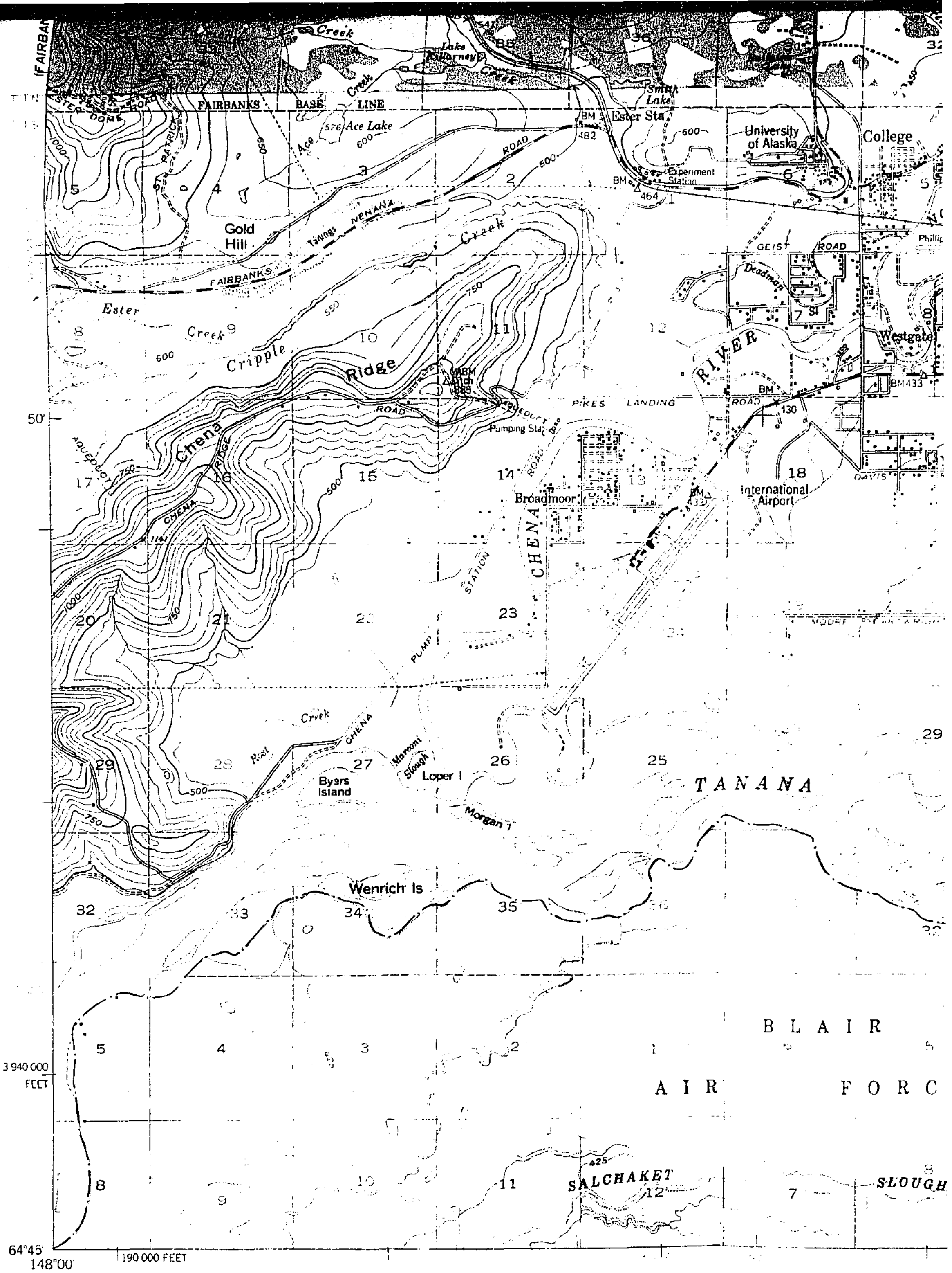




(LIVENGOOD A-2)
Big Eldorado Creek
Monte Cristo Cr
Treasure Cr
Eagle Creek
Silver Creek
MERIDIAN
FAIRBANKS
HIGHWAY
Fox Creek
Fox
OLD RAILROAD GRADE
ABAND DITCH
Silver Gl
Mile 10
BM 755
BM 700
Goldstream Lake
Little Queen Creek
Little Blanche Creek
Engineer Creek
French Gl
BM 908
Wigwam
MILITARY RESERVATION
Goldstream Creek
Musk Ox
Dogpatch
BALLAINE ROAD
Pearl Creek
Jussila Creek
FARMERS RD
GRENAC RD
McGRATH ROAD
STEESE HIGHWAY
Rat Lake
Reindeer Lake
Middle Lake
Star Lake
Caribou Lake
Isabella Creek
Northern Lights Memorial Cem
YANKOVICH ROAD
Country Club
Fowler
Radio Tower (KFAR)
Ballaine Lake
MIL EXP STA
BM 550
Mile 2
MILITARY RESERVATION
Birch Hill
Smith Lake
Exter Sta
University of Alaska
Experiment Station
College
Totem Park
Fairground
Radio Tower (KFRB)
Lemeta
FARMERS LOOP

FAIRBANKS (D-2) QUADRANGLE
ALASKA-NORTH STAR BOROUGH
1:63 360 SERIES (TOPOGRAPHIC)





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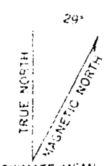
Map not field checked

Universal Transverse Mercator projection, 1927 North American datum
10,000-foot grid based on Alaska coordinate system, zone 3
1000-meter Universal Transverse Mercator grid ticks, zone 6, shown in blue

Gray land lines represent unsurveyed and unmarked locations predetermined by the Bureau of Land Management
Folios F-6, F-7, F-9, and F-10, Fairbanks Meridian

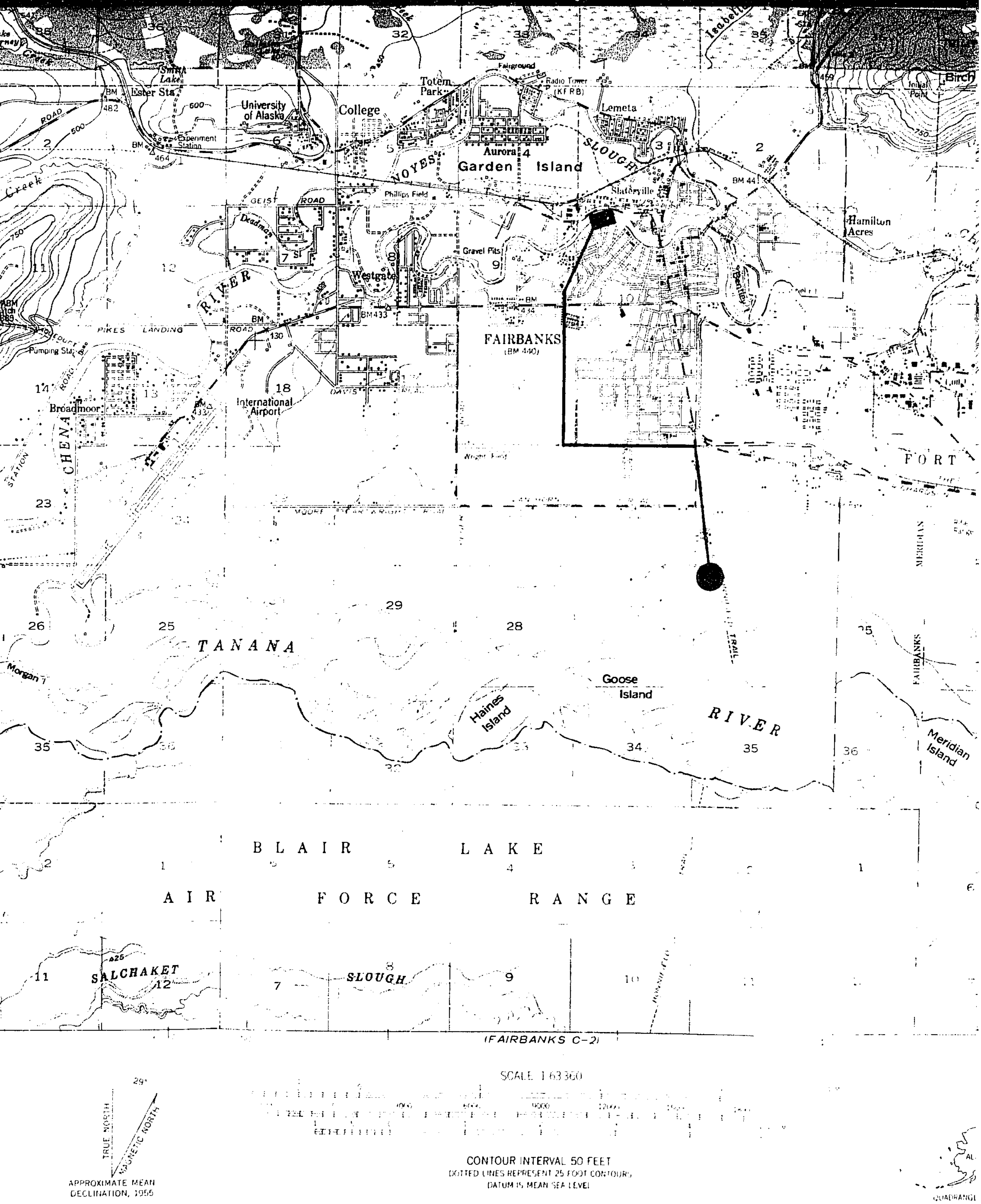
Swamps, as portrayed, indicate only the wetter areas, usually of low relief, as interpreted from aerial photographs

Red tint indicates areas in which only landmark buildings are shown



APPROXIMATE MEAN DECLINATION, 1955

FAIRBANKS, ALASKA
A FOLDER D



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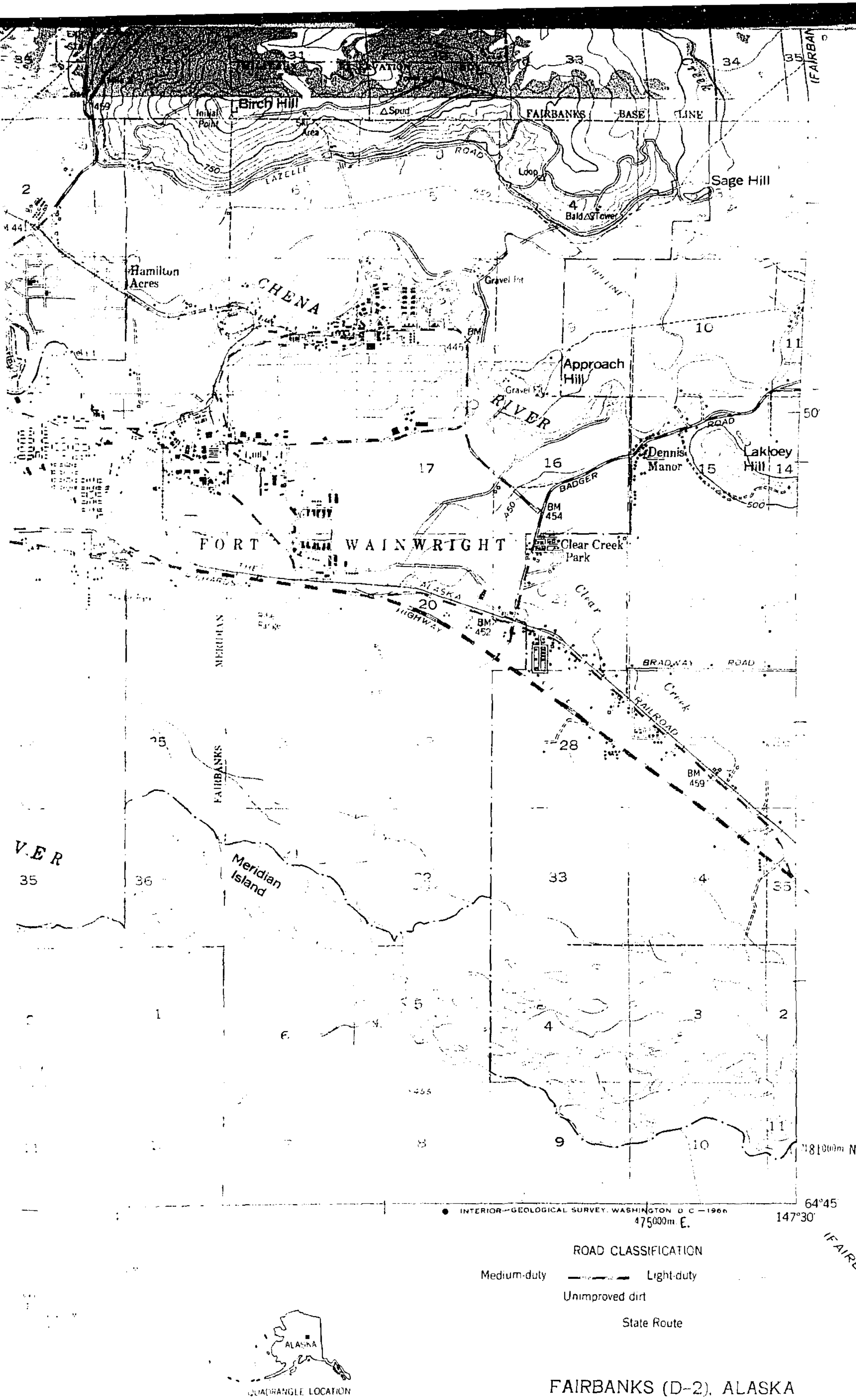

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Figure 7

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