NATIONAL PARK SERVICE
UNITED STATES DEPARTMENT OF THE INTERIOR

MASTER DOMESTIC WATER SYSTEMS STUDY

YELLOWSTONE NATIONAL PARK
WYOMING

CONTRACT NO. 4970B10066

1972

WESTERN ENGINEERS - ARCHITECTS, INC.
CASPER, WYOMING

Western Engineers-Architects, Inc.
MAIN OFFICE, 2111 E. 2ND STREET, CASPER, WYOMING 82601
PHONE 307 235-1571

PRINCIPALS
R. LEE DONLEY, P.E. & L.S.
FRANK LUERS, P.E. & L.S.
RUSSELL L. DONLEY, P.E. & L.S.
ADRIAN F. WATERS, L.S.

ASSOCIATES
JIMMIE L. JONES, ARCHITECT
S. A. BOGEN, P.E.
STEVEN T. BAIRD, A.I.A., N.C.A.R.B.
JOSEPH H. YOUNG, N.C.A.R.B.
JOSEPH F. PATRICK, P.E.

ASSOCIATE FIRMS
SALT LAKE CITY, UTAH—364-9922
BAIRD, YOUNG & JONES (ARCHITECTS)

NEW YORK, NEW YORK—684-4104
S. A. BOGEN ENGINEERS (ELECTRICAL & MECHANICAL)

SALT LAKE CITY, UTAH—363-6981
JOSEPH F. PATRICK ENGINEER (STRUCTURAL)

REPLY TO: 2111 E. 2nd St.
Casper, Wyo. 82601

National Park Service
Department of the Interior
Denver Service Center
7200 West Alameda Avenue
Denver, Colorado 80226

Subject: Contract No. 4970B10066, Engineering Services Yellowstone National Park Domestic Water Systems Study

Gentlemen:

We submit herewith 50 copies of our master domestic water systems study in accordance with our contract agreement which states in part: "the surface waters of the Park are some of the best quality in the United States. Because of the high quality of these waters, chemical treatment utilizing coagulation or mechanical turbidity separation, will be utilized only when absolutely required." We have attempted to propose systems placing an emphasis on public health, simplicity, and dependability.

This report evaluates the existing domestic water systems and presents a master plan for improvements based upon present and future needs. The field work in this report was performed on the project site with the able assistance of National Park Service personnel.

It is intended that this report will serve as a guide for detailed planning and project implementation.

This has been a challenging and rewarding project.

Sincerely yours,

Western Engineers-Architects, Inc.

Russell L. Donley

Russell L. Donley, P.E.
Registered Professional Engineer
and Land Surveyor
Wyoming License No. 646

RLD:ell

TABLE OF CONTENTS

	Page No.
LIST OF TABLES	iii
LIST OF FIGURES	vii
LIST OF ABBREVIATIONS	xiv
LIST OF SYMBOLS	xv
ACKNOWLEDGEMENTS	xvi
INTRODUCTION	xviii
SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS	xxii
REPORT	
PART I BASIS OF DESIGN	
Chapter 1. GENERAL INFORMATION	1- 1
Chapter 2. WATER SYSTEM DESIGN DATA	2- 1
Chapter 3. SUPPLY TREATMENT AND SPECIAL PROVISIONS	3- 1
Chapter 4. COLLECTION	4- 1
Chapter 5. DISINFECTION	5- 1
Chapter 6. COAGULATION	6- 1
Chapter 7. FILTRATION	7- 1
PART II DETAILED ANALYSIS	
GENERAL INFORMATION	8- 1
Chapter 8. MAMMOTH HOT SPRINGS AREA	8- 2
Chapter 9. TOWER AREA	9- 1
Chapter 10. OLD FAITHFUL AREA	10- 1
Chapter 11. CANYON AREA	11-11
Chapter 12. LAKE AREA	12- 1
Chapter 13. GRANT AREA	13- 1
Chapter 14. MADISON JUNCTION AREA	14- 1
Chapter 15. NORRIS AREA	15- 1
PART III IMPLEMENTATION	
Chapter 16. PRIORITIES OF CONSTRUCTION	16- 1
Chapter 17. MAINTENANCE & OPERATION	17- 1
APPENDICES	
Appendix A. SUPPLEMENTARY DATA	A- 1
Appendix B. HARDY CROSS NETWORK	B- 1
Appendix C. LABORATORY RESULTS	C- 1
Appendix D. CONSTRUCTION COSTS	D- 1
LIST OF KEY PROJECT PERSONNEL	D-14
REFERENCES	D-15

LIST OF TABLES

Table No.		Page No.
S- 1	Summary of Design Populations and Flows	xxxi
S- 2	Summary of Fire Demand Requirements	xxxii
S- 3	Summary of Estimated Construction Costs	xxxiii
S- 4	Summary of Construction Costs of Recommended Immediate Improvements	xxxiv
1- 1	Domestic Water Facilities - Synopsis	1-5,6,7,8
2- 1	Maximum Design Unit Water Flows	2-12
2- 2	Water Quality Summary (mg/l)	2-13
2- 3	Coliform Bacteria in Source of Supply and Other Selected Waters	2-14,15,16
2- 4	Water Source Quantities	2-17
2- 5	Fire Demand and Storage	2-18
2- 6	Assumed Flows All Systems for Hardy Cross Network Analyses - see Appendix B	2-19
3- 1	Water Groupings for Domestic Supply	3- 9
3- 2	Potential Health and Safety Hazards	3-14,15
3- 3	Man Made Fish Barriers on Existing Intakes	3-16
3- 4	Winter Use of Systems	3-17
5- 1	Existing Chlorination Review	5- 4, 5
7- 1	Filters	7- 5
8- 1	Population and Maximum Flows, Mammoth Hot Springs Area	8-10,11,12
8- 2	Basic Design Data, Mammoth Hot Springs Area	8-13,14
8- 3	Evaluation of Existing System, Mammoth Hot Springs Area	8-15,16
9- 1	Population and Maximum Flows, Tower Area	9- 7
9- 2	Basic Design Data, Tower Area	9- 8, 9
9- 3	Evaluation of Existing Systems, Tower Area	9-10,11
10- 1	Population and Maximum Flows, Old Faithful Area	10- 7, 8
10- 2	Basic Design Data, Old Faithful Area	10- 9,10
10- 3	Evaluation of Existing System, Old Faithful Area	10-11



Digitized by the Internet Archive
in 2012 with funding from
LYRASIS Members and Sloan Foundation

http://archive.org/details/masterdomesticew00west

LIST OF TABLES - contd.

Table No.		Page No.
11- 1	Population and Maximum Flows, Canyon Area	11- 8, 9
11- 2	Basic Design Data, Canyon Area	11-10,11
11- 3	Evaluation of Existing System, Canyon Area	11-12,13
12- 1	Population and Maximum Flows, Fishing Bridge in Lake Area	12- 8
12- 2	Population and Maximum Flows, Lake in Lake Area	12- 9,10
12- 3	Population and Maximum Flows, Bridge Bay in Lake Area	12-11
12- 4	Basic Design Data, Lake Area	12-12,13
12- 5	Evaluation of Existing Systems, Lake Area	12-14,15
13- 1	Population and Maximum Flows, Grant Area	13- 7, 8
13- 2	Basic Design Data, Grant Area	13- 9,10
13- 3	Evaluation of Existing Systems, Grant Area	13-11,12
14- 1	Population and Maximum Flows, Madison Junction Area	14- 5
14- 2	Basic Design Data, Madison Junction Area	14- 6
14- 3	Evaluation of Existing System, Madison Junction Area	14- 7
15- 1	Population and Maximum Flows, Norris Area	15- 5
15- 2	Basic Design Data, Norris Area	15- 6, 7
15- 3	Evaluation of Existing System, Norris Area	15- 8
16- 1	Recommended Construction Priorities	16-10

LIST OF TABLES - contd.

Table No.		Page No.
17- 1	Annual Changes in Existing Maintenance and Operation Costs with Recommended Systems	17- 4
A- 1	Temperature and Precipitation Data	A- 1
A- 2	Measured Unit Water Use	A- 2, 3
A- 3	Selected Stream Flows	A- 4,5,6,7,8
A- 4	Selected Stream Turbidities, Temperature, Discharge and Color	A- 9,10,11,12 13,14,15,16,17, 18,19,20,21,22
A- 5	Existing Tank Schedule	A-23, 24
C- 1	Field Chemical Tests by WEA, Inc.	C- 1,2,3,4
C- 2	Chemical and Geological Laboratories - Water Analysis Reports	C- 5,6,7,8,9, 10,11,12,13,14 15,16,17,18,19
C- 3	Results of Coliform Tests on Treated Waters	C-20,21,22,23, 24
C- 4	Color Removal - Yellowstone Park Waters	C-25,26,27
D- 1	Construction Cost Estimates - Mammoth Hot Springs Area	D- 3, 4
D- 2	Construction Cost Estimates - Tower Area	D- 5, 6
D- 3	Construction Cost Estimates - Old Faithful	D- 7
D- 4	Construction Cost Estimates - Canyon Area	D- 8
D- 5	Construction Cost Estimates - Lake Area	D- 9,10
D- 6	Construction Cost Estimates - Grant Area	D-11

LIST OF TABLES - contd.

Table No.		Page No.
D- 7	Construction Cost Estimates - Madison Junction Area	D-12
D- 8	Construction Costs Estimates - Norris Area	D-13

LIST OF FIGURES

Figure No.		Page No.
1- 1	Vicinity Map	1- 9
1- 2	Major Roads and Park Facilities	1-10
1- 3	Wind and Temperature (July and August)	1-11
1- 4	Average Daily Traffic and Population Distribution (July and August)	1-12
1- 5	Average Daily Population and Monthly Campground and Total Population Count	1-13
1- 6	Winter Use	1-14
2- 1	Relative Population Forecasts	2-20
2- 2	Maximum Water Flow Quantities	2-21
2- 3	Tower Area-V-Notch Weir Measuring Overflow from Spring Box	2-22
2- 4	Canyon Area - Cascade Creek Intake Lowest Flow Observed - 1971	2-22
2- 5	W.E.A.,Inc. Hach Field Test Kit	2-23
3- 1	Canyon Area - Open Reservoir	3-18
3- 2	Grant Area - Duck Lake Intake	3-18
3- 3	Mammoth Hot Springs Area - Panther Creek Intake	3-18
4- 1	Typical Backwashable Infiltration Gallery	4- 6
4- 2	Lake Area - Winter Spring Collection Box	4- 7
4- 3	Old Faithful Intake	4- 7
5- 1	Concentration - time relationship for 99 percent destruction of Escherichia coli and several viruses by HOCl at 0 to 6° C	5- 6
5- 2	Relationships Between Concentrations and Time for 99 percent destruction of E.coli by 3 forms of Chlorine at 2 - 6° C	5- 6
5- 3	Residual Requirement for 100 Percent Kill at High Temperature	5- 7
5- 4	Effect of pH on Quantities of Hypochlorous Acid (HOCl) and Hypochlorite Ion (OCl^-) Present in Water	5- 7
6- 1	Effect of Alum Dosage on Coagulation of Colored Water	6- 5
6- 2	Effect of pH on Coagulation of Colored water with Constant Alum Dosage	6- 5

LIST OF FIGURES - contd.

Figure No.		Page No.
6- 3	Effect of Alum Dosage on Coagulation of Colored Water at Constant pH	6- 5
6- 4	Coagulation of 50 mg/l Kaolin with Aluminum Sulfate and Ferric Sulfate	6- 6
6- 5	Comparison of the Effect of pH on: Curve A, Dose of Aluminum Sulfate Required to Halve Turbidity of 50 mg/l Clay Suspension, etc.	6- 6
7- 1	Diatomaceous Earth Filter	7- 6
8- 1	Mammoth Hot Springs Area - Vicinity Map	8-17
8- 2	Mammoth Hot Springs Area - Existing Water System	8-18
8- 3	Transmission Outlet - Swan Lake Flats	8-19
8- 4	Pressure Reservoir Above Mammoth Terraces	8-19
8- 5	Open Reservoir in Terraces Above Mammoth	8-20
8- 6	Wasted Water Discharge from Reservoir	8-20
8- 7	Deteriorated M.H. Exterior	8-21
8- 8	Deteriorated M.H. Interior	8-21
8- 9	Shallow Concrete Transmission Line	8-21
8-10	Leak in Concrete Transmission Line	8-21
8-11	Glen Creek Intake	8-22
8-12	Typical Fire Hose House (common to most areas)	8-22
8-13	Mammoth Hot Springs Area, Future Development and Recommended Construction	8-23
8-14	Mammoth Hot Springs Area - Schematic of Proposed Collection, Treatment, Transmission and Storage	8-24
8-15	Mammoth Hot Springs Area - Proposed Backwashable Infiltration Gallery	8-25
8-16	Mammoth Hot Springs Area - Schematic Flow Diagram Diatomaceous Earth Filter Plant	8-26
8-17	Convergence of Indian Creek - Gardner Creek	8-27
8-18	Road Support Bridge Above Glen Creek Canyon	8-27

LIST OF FIGURES - contd.

Figure No.		Page No.
9- 1	Tower Area - Vicinity Map	9-12
9- 2	Tower Area - Existing Water System	9-13
9- 3	Roosevelt Lodge Inlet in Lost Creek	9-14
9- 4	Roosevelt Lodge - Chlorination House and Wooden Tanks	9-14
9- 5	Tower Fall Spring	9-15
9- 6	Tower Fall Spring Overflow - 69 gpm	9-15
9- 7	Tower Area - Future Development and Recommended Construction	9-16
9- 8	Tower Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	9-17
9- 9	Tower Area - Proposed Control, Chlorination, Fluoridation and Storage Above Tower Fall	9-18
9-10	Tower Area, Schematic of Proposed Well, Pump Control and Chlorination - Tower Junction - Roosevelt Lodge	9-19
10- 1	Old Faithful Area - Vicinity Map	10-12
10- 2	Old Faithful Area - Existing Water System	10-13
10- 3	Firehole River Intake	10-14
10- 4	Continuous Water Overflow - Old Faithful Storage	10-14
10- 5	Auxiliary Intake # 1	10-15
10- 6	Continuous Flow Into Firehole River from Auxiliary Intake # 2	10-15
10- 7	Old Faithful Area - Future Development & Recommended Construction	10-16
10- 8	Old Faithful Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	10-17
10- 9	Old Faithful Area - Filtration Area Including Filtration, Pre & Post Chlorination and Clear Water Storage	10-18
10-10	Old Faithful Area - Proposed Complete Treatment Plant - Alternate - Including Coagulation, Settling, Filtration, Pre and Post Chlorination and Clear Water Storage	10-19

LIST OF FIGURES - contd.

Figure No.		Page No.
11- 1	Canyon Area - Vicinity Map	11-14
11- 2	Canyon Area - Existing Water System	11-15
11- 3	Valveless Sand Filter for Soda Creek Intakes	11-16
11- 4	Lower Soda Creek Intake on Cascade Creek Tributary	11-16
11- 5	Cascade Creek Intake, Pumphouse and Chlorination	11-17
11- 6	Cascade Creek Pumping Station	11-17
11- 7	Upper Soda Creek Intake - Early Summer Flow	11-18
11- 8	Upper Soda Creek Intake - Late Summer Flow	11-18
11- 9	Canyon Area - Future Development and Recommended Construction	11-19
11-10	Canyon Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	11-20
11-11	Canyon Area - Alternate - Proposed Complete Treatment Plant Including Coagulation, Settling, Filtration, Pre and Post Chlorination and Clear Water Storage	11-21
12- 1	Lake Area - Vicinity Map	12-16
12- 2	Lake Area - Existing Water System - Fishing Bridge	12-17
12- 3	Lake Area - Existing Water System - Lake	12-18
12- 4	Lake Area - Existing Water System - Bridge Bay	12-19
12- 5	Fishing Bridge Tank	12-20
12- 6	Fishing Bridge Spring, Upper Pumphouse and Chlorination	12-20
12- 7	Drainage Ditch Around Lake Springs	12-21
12- 8	Fence Around Lake Springs	12-21
12- 9	Lake Spring Overflow	12-21
12-10	Gallery Spring Flow	12-21
12-11	Open Reservoir - Lake	12-22
12-12	Bridge Bay Steel Tank	12-22
12-13	Lake Area - Future Development and Recommended Construction - Fishing Bridge	12-23
12-14	Lake Area - Future Development and Recommended Construction - Lake	12-24

LIST OF FIGURES - contd.

Figure No.		Page No.
12-15	Lake Area - Future Development and Recommended Construction - Bridge Bay	12-25
12-16	Lake Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	12-26
12-17	Lake Area - Proposed Collection Controls and Clear Water Storage	12-27
13- 1	Grant Area - Vicinity Map	13-13
13- 2	Grant Area - Existing Water System - Grant	13-14
13- 3	Grant Area - Existing Water System - West Thumb	13-15
13- 4	House for Caisson Intake - Grant	13-16
13- 5	Chlorination and Intake - Grant	13-16
13- 6	West Thumb Intake in Duck Lake	13-17
13- 7	West Thumb Pumphouse and Chlorination	13-17
13- 8	Grant Area, Future Development and Recommended Construction - Grant	13-18
13- 9	Grant Area - Future Development and Recommended Construction - West Thumb	13-19
13-10	Grant Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	13-20
13-11	Grant Area - Proposed Filtration Plant	13-21
14- 1	Madison Junction Area - Vicinity Map	14- 8
14- 2	Madison Junction Area - Existing Water System	14- 9
14- 3	Older Spring Collection Manhole with Wood Cover	14-10
14- 4	Pumphouse and Chlorination - Madison Junction	14-10
14- 5	Madison Junction Area - Future Development and Recommended Construction	14-11
14- 6	Madison Junction Area - Schematic of Proposed Collection, Transmission, Treatment and Storage	14-12
15- 1	Norris Area - Vicinity Map	15- 9
15- 2	Norris Area - Existing Water System	15-10
15- 3	Norris Area - Direct Intake	15-11
15- 4	Norris Area - Tank Overflow	15-11

LIST OF FIGURES - contd.

Figure No.		Page No.
15- 5	Norris Chlorine House and Tank	15-11
15- 6	Norris Area - Future Development and Recommended Construction	15-12
15- 7	Norris Area - Castle Creek - Schematic of Proposed Collection, Treatment, Transmission and Storage	15-13
15- 7A	Norris Area - Solfatara Creek - Alternate - Schematic of Proposed Collection, Treatment, Transmission and Storage	15-14
B- 1	Mammoth Hot Springs Area - Sketch of Network Analysis - Commercial Fire Flow	B- 2,B- 2-S
B- 2	Mammoth Hot Springs Area - Sketch of Network Analysis - Domestic Fire Flow	B- 3,B- 3-S
B- 3	Tower Area - Sketch of Network Analysis - Domestic Fire Flow - Tower Junction - Roosevelt Lodge	B- 4,B- 4-S
B- 4	Old Faithful Area - Sketch of Network Analysis - Commercial Fire Flow	B- 5,B- 5-S
B- 5	Old Faithful Area - Sketch of Network Analysis - Domestic Fire Flow	B- 6,B- 6-S
B- 6	Canyon Area - Sketch of Network Analysis - Commercial Fire Flow	B- 7,B- 7-S
B- 7	Canyon Area - Sketch of Network Analysis - Domestic Fire Flow	B- 8,B- 8-S, B- 9-S
B- 8	Lake Area - Sketch of Network Analysis - Commercial Fire Flow	B-10,B-10-S, B-11-S
B- 9	Lake Area - Sketch of Network Analysis - Domestic Fire Flow	B-12,B-12-S
B-10	Lake Area - Sketch of Network Analysis - Commercial Fire Flow Fishing Bridge	B-13,B-13-S
B-11	Lake Area - Sketch of Network Analysis - Domestic Fire Flow - Fishing Bridge	B-14,B-14-S
B-12	Lake Area - Sketch of Network Analysis - Domestic Fire Flow - Bridge Bay	B-15,B-15-S
B-13	Grant Area - Sketch of Network Analysis - Commercial Fire Flow	B-16,B-16-S

LIST OF FIGURES - contd.

Figure No.		Page No.
B-14	Grant Area - Sketch of Network Analysis - Domestic Fire Flow	B-17,B-17-S
B-15	Grant Area - Sketch of Network Analysis - Domestic Fire Flow	B-18,B-18-S
B-16	Grant Area - Sketch of Network Analysis - Domestic Fire Flow - West Thumb	B-19,B-19-S
B-17	Madison Junction Area - Sketch of Network Analysis - Domestic Fire Flow	B-20,B-20-S

LIST OF ABBREVIATIONS

A C	-	asbestos cement
C I	-	cast iron
cfs	-	cubic feet per second
C I P	-	cast iron pipe
DR	-	2" drain unless noted otherwise
elev	-	elevation
gal	-	gallon
gcd	-	gallons per capita per day
gpd	-	gallons per day
gpm	-	gallons per minute
G S	-	galvanized steel
Lab	-	laboratory
M H or M.H.	-	manhole
M & E	-	Metcalf and Eddy, Engineers
mg	-	milligrams
mg/l	-	milligrams per liter
ml	-	milliliter
mgd	-	million gallons per day
M P N	-	most probable number
N P S	-	National Park Service
P R V	-	pressure reducing valve
temp	-	temperature
T I R	-	totalizer, indicator, recorder
T E	-	top elevation
vc	-	vitrified clay
W T P	-	water treatment plant
WEA,Inc.	-	Western Engineers-Architects, Inc.

-LIST OF SYMBOLS-

FIREHYDRANTS

- OLD, GOOD
- OLD, LEAKS
- NEW, GOOD
- NEW, WILL NOT DRAIN
- OLD, WATER STANDING
- NEW, NO VALVE
- FAUCET IN HOSE HOUSE

WATER LINES

- CHECK VALVE
- VALVE & RISER
- VALVE CHAMBER
- METER
- VALVE IN CHAMBER
- (A) ALTITUDE OR AUTOMATIC VALVE
- (P) PUMP
- PROPOSED FACILITY
- (2) VALVE OR METER CHAMBER DETAILED AS No. 2 ELSWHERE ON SHEET.

ACKNOWLEDGEMENTS

The broad and varied parameters of this report required excellent cooperation throughout the Park and the National Park Service Design and Construction Office. Many field, office and laboratory personnel of the Park Service made our work easier and far more complete, because of their excellent and prompt assistance.

Jack K. Anderson, Park Superintendent; Gary Everhardt, Assistant Park Superintendent and Keith Fellbaum, Park Environmental Engineer in the Park and Donald L. Bressler, Chief Engineer; Ralph Stratton, Supervisor of General Engineering and George Gallagher, Engineer of the National Park Service Design and Construction office at Denver are appreciated for the interest shown and cooperation extended during the course of this study. Enough cannot be said for the continuing assistance and advice of Mr. Gallagher and Mr. Fellbaum.

Appreciation is further expressed to Park Service personnel Paul Wood, Liford Dore, Rocky Roggerman, Donald Mace, and Jim Lewis for their many courtesies extended our field crews in all of the areas encompassed by this report. Appreciation is also in order for the National Park Service and concessionaires management, who allowed their assigned personnel to assist us in obtaining records, laboratory tests, and providing data for this report.

John McCutchen, U. S. Public Health Service Sanitary Engineering Consultant, of the National Park Service Design and Construction office was most helpful and encouraging for our total treatment design concept.

INTRODUCTION

The National Park Service had a Master Sewerage Study completed for Yellowstone National Park, Wyoming by Metcalf and Eddy, Engineers in 1968. This report is being successfully implemented at this time and points out the convenience and necessity for master planning.

On June 11, 1971 our firm was retained to prepare studies for the domestic water systems of the following population areas: Mammoth Hot Springs, Tower Fall - Roosevelt Lodge - Tower Junction called Tower, Old Faithful, Canyon, Lake - Fishing Bridge - Bridge Bay called Lake, Grant - West Thumb called Grant, Madison Junction, and Norris. This report presents the results of these engineering studies suggesting a master plan for corrective action and further expansion.

SCOPE

The scope of the work included:

1. Mapping the existing distributions systems onto one sheet.
2. Evaluation of the existing facilities.
3. Projection of population and land use by minor updating of the Metcalf and Eddy report.
4. Investigations of quality, quantity and characteristics of water supply.

5. Analysis of treatment requirements.

6. Analysis of transmission, distribution and storage considering peak domestic demands plus fire flows.

7. Testing all existing hydrants.

8. Establishment of design criteria.

9. Preparation of water system preliminary plans for each area.

10. Suggested implementation of a construction program.

11. Recommendations on maintenance and construction priorities.

12. Presentations of capital and operation and maintenance costs.

FIELD OPERATIONS

From June 15 to October 2, 1971 our engineering field office was in operation at the Canyon government trailer park in Yellowstone Park.

Extensive field work proceeded from this office including: 1. visual inspections of all of the facilities of all systems, 2. fire hydrant testing of all hydrants for flow, pressure, and maintenance, 3. water flow and water quality testing of existing systems, 4. weir setting and quantity measurements for proposed and existing sources, 5. sampling and monitoring of more than 200 independent laboratory analyses, and 6. tracing out and field verifying the location of all mains in all systems 2" diameter and larger.

Coordination meetings were held with National Park Service design, administration, and maintenance personnel during the progress of the work. In addition, representatives of the U. S. Public Health Service, Park Rangers,and key concessionaires personnel were consulted; pertinent maps, photographs, drawings, and documents were examined and design criteria were established.

OFFICE OPERATIONS

Concurrently and subsequent to field operations literature surveys and consultations with equipment manufacturers and other consultants have progressed in Denver and in our Casper office. This engineering report was prepared with emphasis placed on providing simple systems requiring a minimum of maintenance but having adequate control to assure a safe dependable supply of water. Economy, feasibility and local conditions are emphasized as all three are important to the implementation of this report.

ORGANIZATION OF REPORT

A summary of the conclusions and recommendations immediately follows this introduction. The Metcalf and Eddy 1968 report was used as a guide for the organization of this report. The design and background data common to all Park areas and comparisons of population, water demands, fire demands, quality, and storage, by area, are presented in Part I (Chapters 1-7). Detailed analysis and design recommendations for each area are

presented in Part II (Chapters 8-15). Priorities of construction and costs of operation and maintenance are provided in Part III (Chapters 16-17). Tables and illustrations are located at the end of each chapter. Tabulated Hardy Cross network analyses, chemical analyses, detailed construction cost estimates, and other data are located in the appendices. References are presented near the end of the report. Key Western Engineers-Architects, Inc. project personnel are listed at the end of the report.

SUMMARY OF CONCLUSIONS AND RECOMMENDATIONS

CONCLUSIONS

1. Proper maintenance and skilled operation are essential to the successful implementation of the recommended programs.

2. All existing domestic water systems need improvement. The Mammoth Hot Springs area is the most critical. More than 40% of the total recommended expenditures are suggested for this area.

3. The water systems and treatment plants should be combined for the following areas: (1) Tower area being Tower Fall, Roosevelt Lodge and Tower Junction ; (2) Lake area being Lake, Bridge Bay and Fishing Bridge; (3) Grant area being Grant and West Thumb. Other areas should operate independent systems.

4. Tower, Lake and Madison Junction all have an abundant supply of excellent water from springs. The Lake and Madison Junction springs contain excessive fluorides which should be removed for the permanent residents by using individual residents units.

5. Adequate treatment can be most economically achieved by building backwashable infiltration galleries under the surface water supplies at Mammoth Hot Springs, Old Faithful, Canyon and Norris. The water is to be polished by diatomaceous-earth filters at Mammoth Hot Springs, Grant and Norris. The water is to be polished by chlorination and activated carbon filtration at Old Faithful and Canyon.

6. Additional covered elevated water storage is planned at Mammoth Hot Springs, Tower, and Old Faithful.

7. Major new transmission lines are requested at Mammoth Hot Springs, Tower and Grant.

8. Control systems are planned for all areas.

9. A few potential occupational or community health hazards exist and remedial recommendations are included.

10. Clearwell storage is provided at all sources or before community usage occurs.

11. Deficiencies exist in several distribution systems being the most critical at Mammoth Hot Springs. These deficiencies result in inadequate fire protection.

RECOMMENDATIONS

The following improvements are recommended. Items with asteriks indicate construction recommended for earliest implementation:

1. Mammoth Hot Springs Area

   -* Construct backwashable infiltration gallery intake and clearwell on Panther Creek near existing intake to develop a turbidity free supply.

   -* Install a new pressure line from Panther Creek-Gardner River intake to treatment plant area as this line will give an enclosed supply from collection to usage.

   - Construct a diatomaceous-earth pressure filtration plant, which will polish the filtered river intake water.

   -* Construct a clearwell and abandon the existing open reservoir and Glen Creek intake for domestic use. The clearwell will give necessary fire protection and chlorine contact time.

   - Construct transmission and distribution system mains to provide adequate fire protection.

These improvements would: eliminate the Glen Creek intake problems; provide adequate chlorine contact time and fire protection; provide a highly polished filtered water and eliminate substantial leakage losses.

2. Tower Area

   -* Construct underground tank and chlorina-house above Tower Fall, which would give

needed fire storage and chlorination-chlorine contact time.

- Construct pressure transmission line from Tower Fall to Roosevelt Lodge-Tower Junction area. This line will tie all the Tower area systems together.
- Construct pressure transmission line from springs above Tower Fall to new tank. The existing line is shallow and too small for all systems when combined.
- Construct underground storage near existing Roosevelt Lodge storage. This new storage will be for winter usage and for additional fire protection.
- Obliterate Roosevelt Lodge chlorination house and intake system as this is not a dependable system.
- Obliterate Tower Junction spring collection system as the new combined system and winter system will eliminate the need for this spring.
- * Construct well and facilities for winter use as the upper Tower Springs will not be used for several years for winter use.
- Construct distribution system mains. These new mains are necessary for fire flows and to give adequate line depths for winter service.

These improvements would: provide adequate chlorination and chlorine contact time; allow all systems to be combined; eliminate the inadequate Roosevelt Lodge facilities; give the highest quality spring water to all areas; and provide a dependable winter supply for the lower areas.

3. Old Faithful Area
   - * Construct backwashable infiltration gallery intake on Firehole River near existing intake to develop a turbidity free supply.

- Construct chlorination-activated carbon filtration plant for color removal from the Firehole River supply. Tests showed this type of treatment to be successful in removing the color from the Firehole water.

-* Construct a clearwell to provide additional fire protection storage and adequate chlorine contact time.

- Construct distribution system mains for adequate fire flows.

These improvements would: substantially reduce the offensive color units resulting from the Firehole River; provide adequate chlorine contact time; and provide adequate storage and distribution for fire protection.

4. Canyon Area

-* Construct backwasable infiltration gallery on Cascade Creek near existing intake to develop a turbidity free supply.

-* Place existing valveless sand filter back in operation for low flows from Soda Creek which will provide polishing filtration.

- Construct chlorination-activated carbon filtration plant on Cascade Creek to remove colored water. Tests showed this type treatment to be successful in removing the color from the Firehole water.

-* Construct a clearwell to provide adequate chlorine contact time on Cascade Creek.

- Construct new distribution mains for adequate fire flows.

These improvements would eliminate current spring runoff color problems, provide adequate chlorine contact time for the

Cascade Creek waters, filter the Soda Creek waters and meet all fire distribution requirements.

5. Lake Area

-* Obliterate existing upper pumphouse at Fishing Bridge springs as this pumphouse-chlorination system is often flooded and is not a safe source of supply.

- Obliterate existing lower pumphouse and wooden storage tank at Fishing Bridge springs as the combined systems eliminate the need for this small system.

- Construct a new pumphouse-chlorination system with a new line to the Fishing Bridge tank when the proposed Lake expansion can no longer service the entire area.

-* Expand the Lake Spring area to utilize the "winter" spring and reinstall the "gallery" spring to make this supply adequate for the entire area.

-* Construct a clearwell at Lake Springs for adequate chlorine contact time.

- Construct new distribution mains for adequate fire flows.

The improvements would: combine all systems and eliminate some potentially hazardous problems at the Fishing Bridge springs; provide adequate chlorine contact time; simplify the existing scattered systems and meet all fire distribution requirements.

6. Grant Area

-* Provide a surge relief valve at the existing pumpwell to eliminate the current excessive water hammer.

- Construct a new filtration plant to polish the clear Yellowstone Lake Water.

-* Construct a clearwell to give adequate chlorine contact time.

- Construct transmission and distribution lines to tie the Grant-West Thumb areas together and to provide adequate fire flows.

- Obliterate the Duck Lake intake and pumping system as this system is no longer necessary with the systems being combined.

These improvements would: eliminate an existing occupational safety hazard; provide a highly polished water supply; provide adequate chlorine contact time while allowing the existing transmission mains to the high service tanks to be used together which is necessary for adequate fire protection; and provide adequate distribution for fire flows in West Thumb.

7. Madison Junction Area

- Construct a small clearwell for additional chlorine contact time and fire protection.

- Construct additional spring collection system to gather all of the readily available spring water.

-* Install individual fluoridation removal units for permanent residents having children as the fluoride content is excessive.

These improvements would make the chlorine contact time adequate and would protect the children of permanent residents from having mottled teeth. Similar fluoride removal procedures should be

employed for the permanent residents at Lake.

8. Norris Area

-* Construct backwashable infiltration gallery on Castle Creek near existing intake to develop a turbidity free supply.

- Construct a polishing filter for the filtered intake systems.

- Replace the shallow transmission line from the existing Castle Creek intake to the existing storage tank.

These improvements would provide a potable turbidity free water.

9. General Recommendations

-* It is recommended that simple all-weather control systems be installed in each area including metering, recording and equipment automation.

-* It is further recommended that a qualified sanitary engineer review each system right after full start up each spring and get any operational problems on system malfunctions corrected. Perhaps an outside consultant could properly make such an inspection as he could make recommendations without internal considerations.

-* A Park Service qualified sanitary engineer should be assigned to supervise, assist and train operating personnel in the systems management and to provide year to year continuity.

Summaries of populations, flows, storage, and estimated costs are listed in Tables S-1, S-2, S-3 and S-4. In Table S-1 the column titled "Design Flow Used for Report" is the maximum

daily flow required without fire protection considerations. Table S-2 shows that sufficient storage will exist in each area to meet fire demands so that additional source development is not required beyond that developed for the domestic design flow.

TABLE S-1. SUMMARY OF DESIGN POPULATION AND FLOWS

AREA	EXISTING POPULATION	DESIGN POPULATION	1971 MAXIMUM WATER FLOWS EXISTING	MAXIMUM MEASURED FLOW	MAX. WATER FLOWS- FUTURE	DESIGN FLOW FOR REPORT*	
			gpd(computed)	gpd	gpd(computed)	gpd	gpm
Mammoth Hot Springs	1780	2200	1,819,000	2,224,000	1,917,000	2,700,000	1870
Tower	650	1070	50,000	54,300	89,000	159,000	110
Old Faithful	3900	4700	460,000	480,000	585,000	860,000	600
Canyon	4300	5100	395,000	371,000	505,000	767,000	540
Lake	8730	9550	656,000	762,000	754,000	1,274,000	890
Grant	2300	6700	194,000	189,000	673,000	1,050,000	730
Madison Junction	1275	1450	67,000	88,000	77,000	138,000	100
Norris	620	930	42,000	41,500	63,000	113,000	80

* All facilities proposed will produce or deliver 25 to 50% more water for short durations.

TABLE S-2. SUMMARY OF FIRE DEMAND REQUIREMENT

AREA		*FIRE DEMAND-4 HRS.		TOTAL STORAGE
		gpm	gpd	gallons
Mammoth Hot Springs	-Residential	500	120,000	
	-Commercial	1500	360,000	1,100,000
Tower	-Residential or -Commercial	500	120,000	160,000
Old Faithful	-Residential	500	120,000	
	-Commercial	1500	360,000	400,000
Canyon	-Residential	500	120,000	
	-Commercial	1000	240,000	870,000
Lake	-Residential	500	120,000	
	-Commercial	1500	360,000	1,405,000
Grant	-Residential	500	120,000	
	-Commercial	1500	360,000	2,275,000
Madison Junction	-Residential or -Commercial	500	120,000	124,000
Norris	-Residential or Commercial	100	24,000	59,200

*Fire demand was established by recommendations based upon the Park's present and planned fire-fighting capabilities.

In some areas the criteria do not meet the standards of the National Board of Fire Underwriters when maximum populations are considered.(2) As a great percentage of the populations are in campgrounds without fire-protection and as the tourist season is short the design criteria was felt appropriate.

TABLE S-3. SUMMARY OF ESTIMATED CONSTRUCTION COSTS*

AREA	COLLECTION	TREATMENT	TRANSMISSION	DISTRIBUTION	STORAGE	TOTAL
Mammoth Hot Springs	$151,550	$254,500	$784,800	$148,000	$270,000	1,608,850 (2,091,500)*
Tower	14,000	66,400	175,700	29,300	44,000	329,400 (428,220)*
Old Faithful	115,000	207,000	0	41,400	109,500	472,900 (614,600)*
Canyon	77,000	164,000	47,700	22,300	36,000	347,000 (451,100)*
Lake	31,000	78,300	99,700	44,100	20,000	273,100 (355,000)*
Grant	2,500	149,500	72,700	14,200	52,500	291,400 (378,820)*
Madison Junction	27,500	23,000	0	0	10,000	60,500 (78,650)*
Norris	5,500	58,400	25,900	0	5,000	94,800 (123,200)*
	$424,050	$1,001,100	$1,206,500	$299,300	$547,000	$3,477,950 (4,521,090)*

* Includes 30% for contingencies and engineering.

Cost estimates were made using 1972 equipment prices, 1971 installation costs in Colorado and Wyoming, with particular proportional increases being based upon "Abstract of Bids" furnished by the Park Service for estimating purposes.

TABLE S-4. SUMMARY OF CONSTRUCTION COSTS OF RECOMMENDED IMMEDIATE IMPROVEMENTS

AREA	ESTIMATED CONSTRUCTION COST*
Mammoth Hot Springs	$1,440,600
Tower	182,900
Old Faithful	142,350
Canyon	56,000
Lake	145,100
Grant	54,000
Madison Junction	2,000
Norris	37,600
	$2,060,550

* Costs are from Chapter 16 and Appendix D and include 30% for contingencies and engineering.

REPORT

PART I

BASIS OF DESIGN

Chapter 1. GENERAL INFORMATION

Location and Transportation

Yellowstone National Park, the oldest and largest national park in the United States, is located in the northwest corner of Wyoming. Its north and west boundaries extend slightly into Montana and Idaho. The Park covers an area of 3,500 square miles. Figure 1-1 shows the location of the Park and the highways in the surrounding area. The 5 entrance roads leading into the Park are identified as follows:

1. West Entrance connecting to West Yellowstone, Montana, and Idaho Falls, Idaho.
2. South Entrance connecting to Grand Teton National Park and Jackson, Wyoming.
3. East Entrance connecting to Cody and Sheridan, Wyoming.
4. North Entrance connecting to Gardiner, Livingston and Bozeman, Montana.
5. Northeast Entrance connecting to Billings, Montana.

The closest air terminal is at the Park boundary in West Yellowstone, Montana. Other nearby air terminals are located at Jackson and Cody, Wyoming, and Bozeman, Montana. Air distances to Yellowstone from Salt Lake City, San Francisco, and Minneapolis-St.Paul are approximately 300, 800, and 900 miles, respectively. No railroads pass through the Park, although rail connections are available at Livingston, Montana, Cody, Wyoming, and Idaho Falls, Idaho.

Major Park roads and all entrances are maintained open from May 1 to October 31. More than 90 percent of the visitors

to the Park provide their own vehicular transportation, although public transportation in the form of concessionaire-operated buses is available within the Park. Figure 1-2 shows the location of the major Park roads and facilities.

Climate

During the summer the climate is cool and pleasant, with daily maximum temperatures in the 80s and early morning minimum temperatures in the 30s. Brief thunder showers are common during July and August. Annual precipitation is about 15 in. and falls mostly as snow during the late fall, winter, and spring. Maximum stream flow occurs in late May or June under the influence of melting snowfields. Midwinter temperatures frequently drop as low as -20 degrees Fahrenheit and have been recorded as low as -66 degrees Fahrenheit. Throughout the summer, winds are generally from the southwest at 5 to 10 miles per hour. Figure 1-3 shows representative wind and temperature data for July and August. Additional temperature and precipitation data are also given in Appendix Table A-1.

Topography and Geology

The Park is situated in the center of the Northern Rocky Mountains, and is primarily a high plateau, roughly 7,500 to 8,500 ft. above sea level, surrounded by ranges of mountains with elevations up to 12,000 ft. The plateau is volcanic in origin and overlies a chamber of hot magma, which is the source of heat for

the Park's hydrothermal features. The Park is subject to earth tremors; several strong earthquakes have occurred during the past 50 years. The soil throughout the Park is primarily a glacial till, and the covering vegetation is dominated by expanses of lodgepole pine and meadow grasslands.

The Park is cut by the Continental Divide, and is drained by 3 major rivers--the Yellowstone, the Madison, and the Snake. The Yellowstone and Madison rivers and their tributaries drain approximately 75 percent of the Park's area northward to the Missouri River and eventually to the Gulf of Mexico. The Snake River and its tributaries drain the remaining area south and westward to the Columbia River and the Pacific Ocean.

Park Use

Over 2 million visitors have passed through Yellowstone National Park in each year since 1965. The total number of annual visitors has increased 50 percent over the past decade. Approximately 90 percent of the visitor attendance is concentrated in the months of July and August. Visitor attendance diminishes rapidly before and after this period; with the exception of rapidly increasing over-snow visitation.

Population centers have developed within the Park in areas of outstanding natural attractions. Nine of these areas (Bridge Bay, Fishing Bridge, Lake, Canyon, Grant, West Thumb, Old Faithful, Madison, and Mammoth Hot Springs) register overnight populations in excess of 1,000 persons during the months

of July and August. These areas, plus 2 additional areas (Norris and Tower) which have high daytime visitation, are the focal points of this study.

The National Park Service census for 1971 showed a total overnight population of about 25,000 during the main tourist season. Campground visitors numbered 12,500. Of these, 71 percent come with travel trailers and campers, and 29 percent with tents and other means of camping. Hotel and cabin visitors numbered about 9,000 and employees about 3,500. Average overnight populations for each village and daily traffic counts for each road are shown in Figure 1-4. Typical weekly occupancy data and monthly total population counts are shown in Figure 1-5. Figure 1-6 shows how winter use is rapidly increasing.

The average length of stay in the Park for visitors is between 1 and 2 days. Typical daytime activities of these visitors include trips to the Grand Canyon of the Yellowstone, the several geyser basins (especially Old Faithful) and Mammoth Hot Springs. Equally important among visitor activities are viewing and photographing the scenery and wildlife along the 142 mile Grand Loop Road which connects all the villages and major natural features of the Park. Fishing in the rivers and streams and fishing and boating on Yellowstone Lake are also important activities. Evening activities, food, lodging, campfire talks, and recreations are centered in the villages.

TABLE 1-1. DOMESTIC WATER FACILITIES - SYNOPSIS

EXISTING	PROPOSED
MAMMOTH HOT SPRINGS AREA	
Collection - Indian Creek-Panther Creek and Gardner River-surface	Collection - Indian Creek-Panther Creek filtered Gardner River - standby-surface
Transmission- Concrete gravity line to Swan Lake Flats, here released into Glen Creek-open stream	Transmission- Pressure main-intake to treatment plant
Collection - Glen Creek Intake	Treatment - Diatomaceous earth pressure filters, chlorination, fluoridation
Transmission- Steel line to open and closed reservoirs	Storage - Clearwell at collection - Clearwell at treatment
Treatment - Continuous Chlorination	Transmission- Pressure mains to Village
Storage - Large open reservoir, small tank	Distribution- Mains-adequate fire protection
Transmission- Gravity steel, gravity clay tile, and pressure CIP to Village	
Distribution- Mains-some fire protection	
TOWER FALL	**ALL COMBINED**
Collection - Spring	Collection - Spring
Transmission- Small pressure line	Transmission- Large pressure line
Distribution- Mains-no fire protection	Storage - Tank-above Tower Fall - Tanks-above Roosevelt Lodge
ROOSEVELT LODGE	Treatment - Chlorination, fluoridation
Collection - Lost Creek-direct	Distribution- Mains-adequate fire protection
Storage - Tanks above Roosevelt Lodge	Other - Supplemental winter supply-small well and pump at Tower Junction-Roosevelt Lodge
Distribution- Mains-some fire protection	
TOWER JUNCTION	
Collection - Springs	
Distribution- Mains-some fire protection	

TOWER AREA

TABLE 1-1. DOMESTIC WATER FACILITIES - SYNOPSIS (contd.)

EXISTING	PROPOSED
OLD FAITHFUL AREA	
Collection - Firehole River-surface	Collection - Backwashable infiltration gallery and standby surface
Transmission- Pressure main to tank - Pressure main, tank to village	Transmission- same
Treatment - Continuous chlorination	Treatment - Color removal by chlorination-activated carbon filtration, also post chlorination
Storage - Small tank	Storage - Small tank and large clearwell
Distribution- Mains-good fire protection	Distribution- Mains-adequate fire protection
CANYON AREA	
Collection - Cascade Creek-direct Soda Creek-surface	Collection - Backwashable infiltration gallery-Cascade Creek and standby surface. - Soda Creek - same
Transmission- Pressure main to storage from Cascade Creek Pressure main to storage from Soda Creek	Transmission- Same
Treatment - Cascade Creek-chlorination when pumps on Soda Creek-continuous chlorination	Treatment - Cascade Creek-removal of color by chlorination-activated carbon filtration, also post chlorination, fluoridation (optional) - Soda Creek-filtration, chlorination, fluoridation (optional)
Storage - Two large tanks	Storage - Same and clearwell at Cascade Creek
Distribution- Mains-good fire protection	Distribution- Mains-adequate fire protection
LAKE AREA-all systems combined	
Collection - Fishing Bridge Spring - Lake Spring - Winter Spring at Lake	Collection - Same and - Gallery Spring at Lake
Transmission- Pressure main to Fishing Bridge tank - Pressure main to Lake tanks - Pressure main to Bridge Bay tank	Transmission- Same
Treatment - Continuous Chlorination	Treatment - Chlorination and limited defluoridation on individual basis
	Storage - Same and Clearwell at Lake
	Distribution- Mains-adequate fire protection

TABLE 1-1. DOMESTIC WATER FACILITIES - SYNOPSIS (contd.)

EXISTING	PROPOSED
LAKE AREA-all systems combined (contd.)	
Storage - Fishing Bridge Tank - Two Lake Tanks - Bridge Bay Tank	
Distribution- Mains-fair fire protection	
GRANT AREA	
GRANT	**SYSTEMS COMBINED**
Collection - Inlet in Yellowstone Lake	Collection - Same
Treatment - Chlorination	Treatment - Diatomaceous earth filtration, chlorination and fluoridation (optional)
Transmission- Pressure main-Intake to tank - Pressure main-Tank to Village	Transmission- Pressure main intake to tank and tank to Village combined-Grant - Pressure main Grant to Bridge Bay - Pressure main Bridge Bay tank to Village
Storage - Two large tanks	Storage - Clearwell-Grant - Two large tanks-Grant - Two small tanks-Bridge Bay
Distribution- Mains-good fire protection	Distribution- Mains-adequate fire protection
WEST THUMB	
Collection - Inlet in Duck Lake	
Treatment - Chlorination	
Transmission- Pressure main intake to tank - Pressure main tank to Village	
Storage - Two small tanks	
Distribution- No fire protection	
MADISON JUNCTION AREA	
Collection - Springs	Collection - Same
Transmission- Pressure main-springs to tank	Transmission- Same
Treatment - Chlorination	Treatment - Chlorination and limited defluoridation on individual basis.
Storage - Tank	Storage - Same and Clearwell at Springs
Distribution- Mains-adequate fire protection	Distribution- Same

TABLE 1-1. DOMESTIC WATER FACILITIES - SYNOPSIS (contd.)

EXISTING		PROPOSED
NORRIS AREA		
Collection	- Castle Creek-direct	Collection - Castle Creek-backwashable infiltration gallery
Transmission	- Pressure main-intake to tank - Pressure main-tank to Village	Treatment - Diatomaceous earth filtration and chlorination
Treatment	- Continuous Chlorination	Storage - Same and Clearwell at treatment
Storage	- Tank	Transmission - Same
Distribution	- Mains-adequate fire protection	Distribution - Same

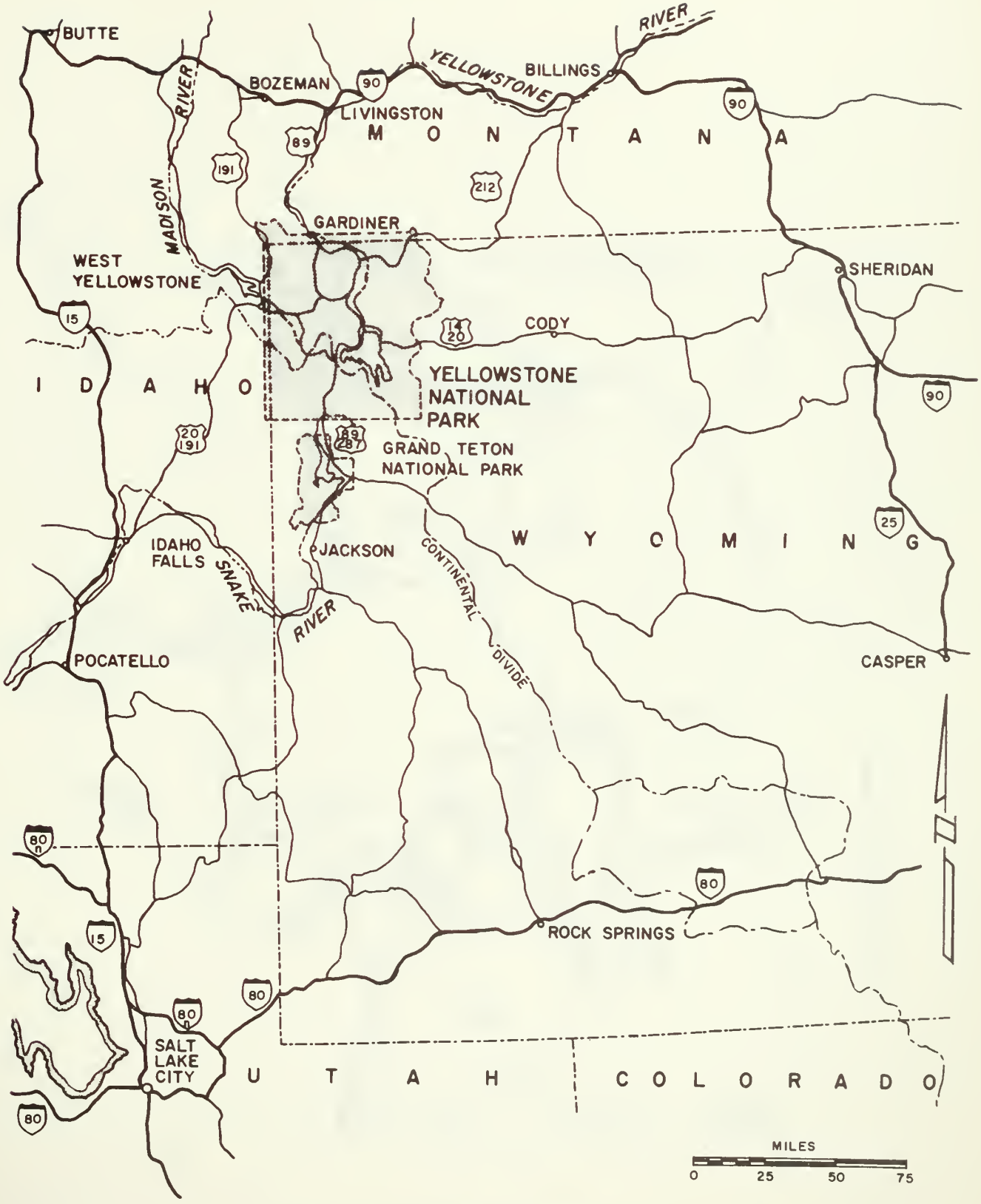


FIG. I-1 VICINITY MAP (1)

Z-21823-3
NOV 18, 1968
N.P.S. YELLOWSTONE
8844.3

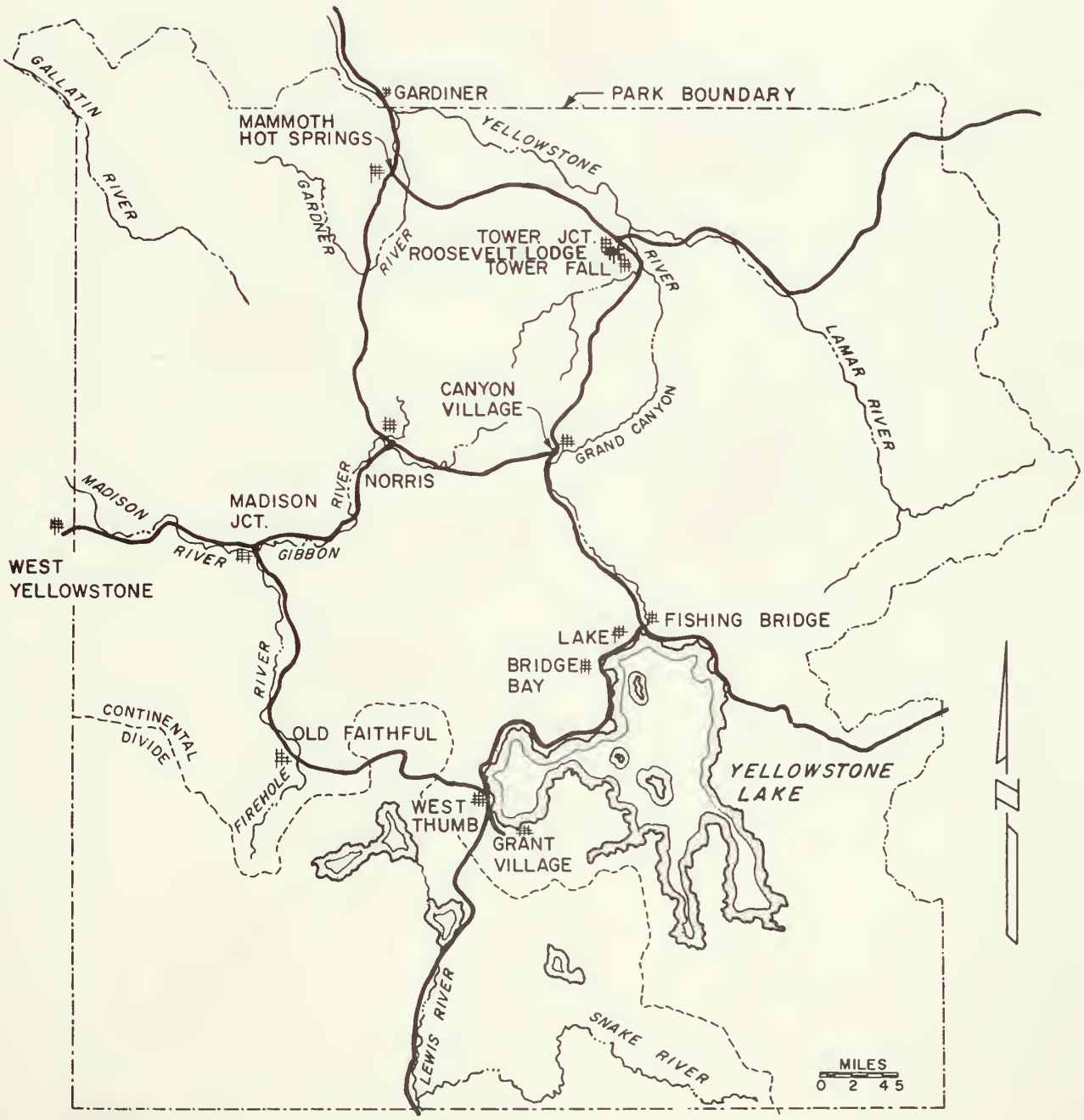


FIG. I-2 MAJOR ROADS AND PARK FACILITIES (I)

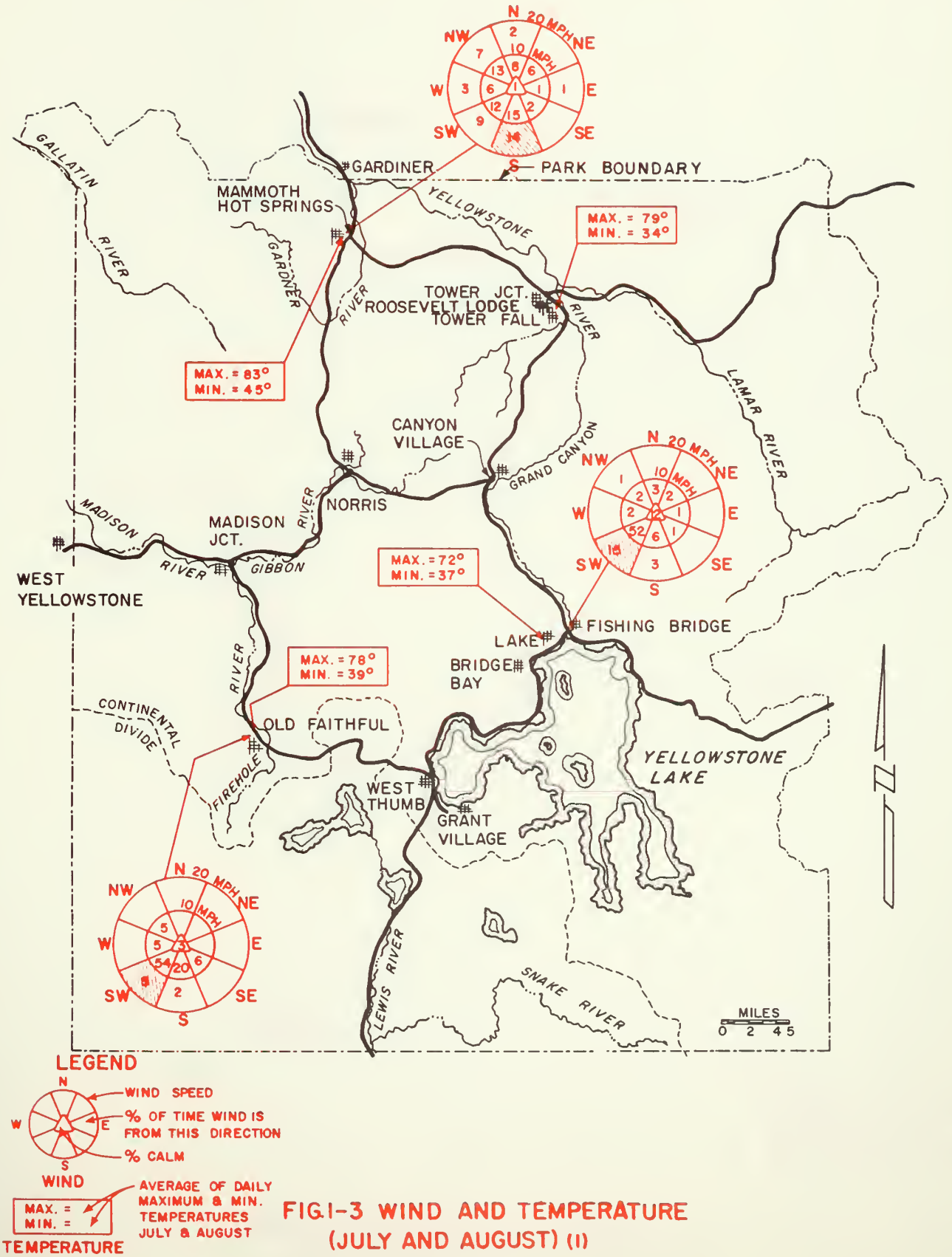


FIG.1-3 WIND AND TEMPERATURE (JULY AND AUGUST) (1)

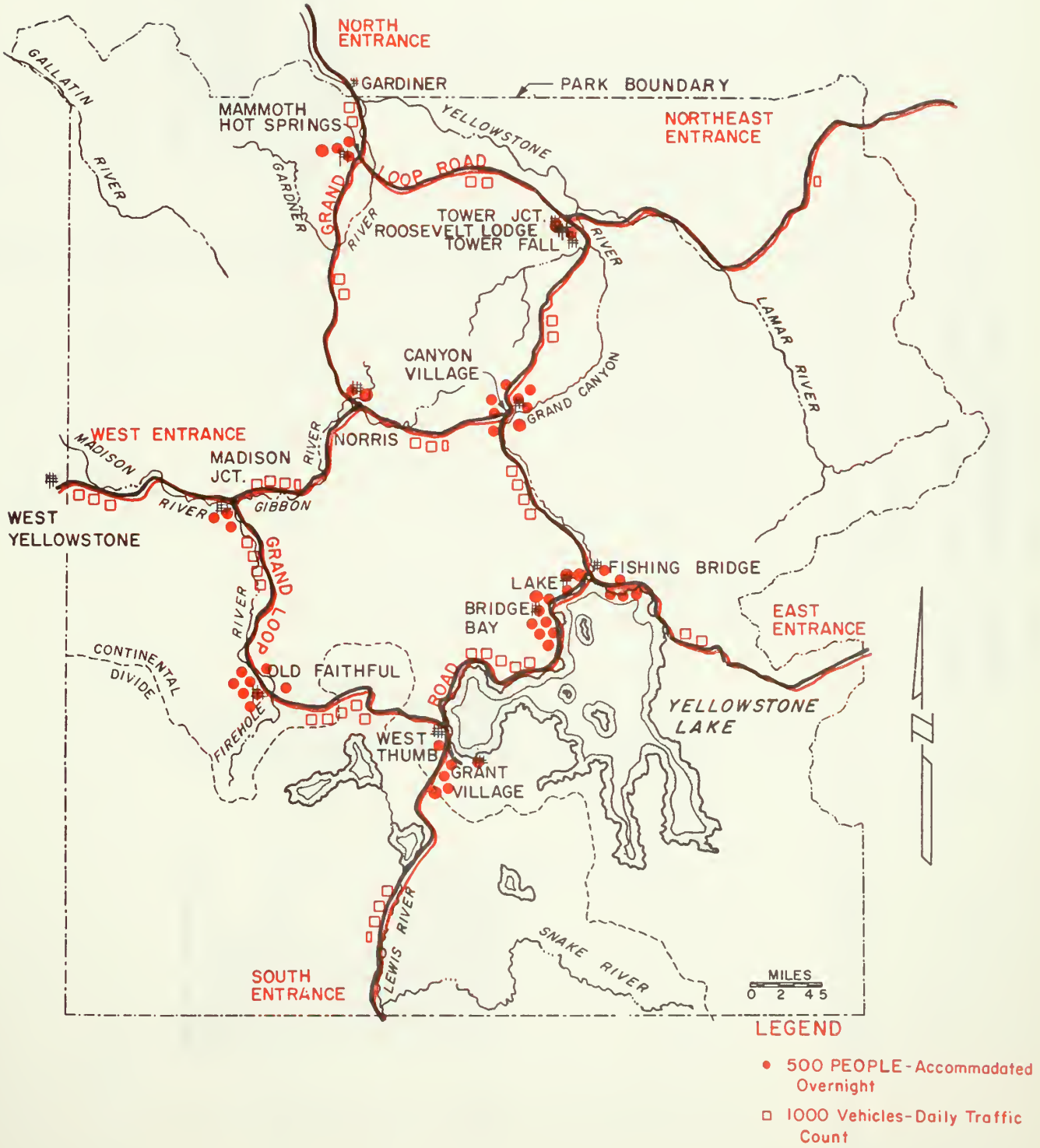


FIG. 1-4 AVERAGE DAILY TRAFFIC AND POPULATION DISTRIBUTION (JULY AND AUGUST)

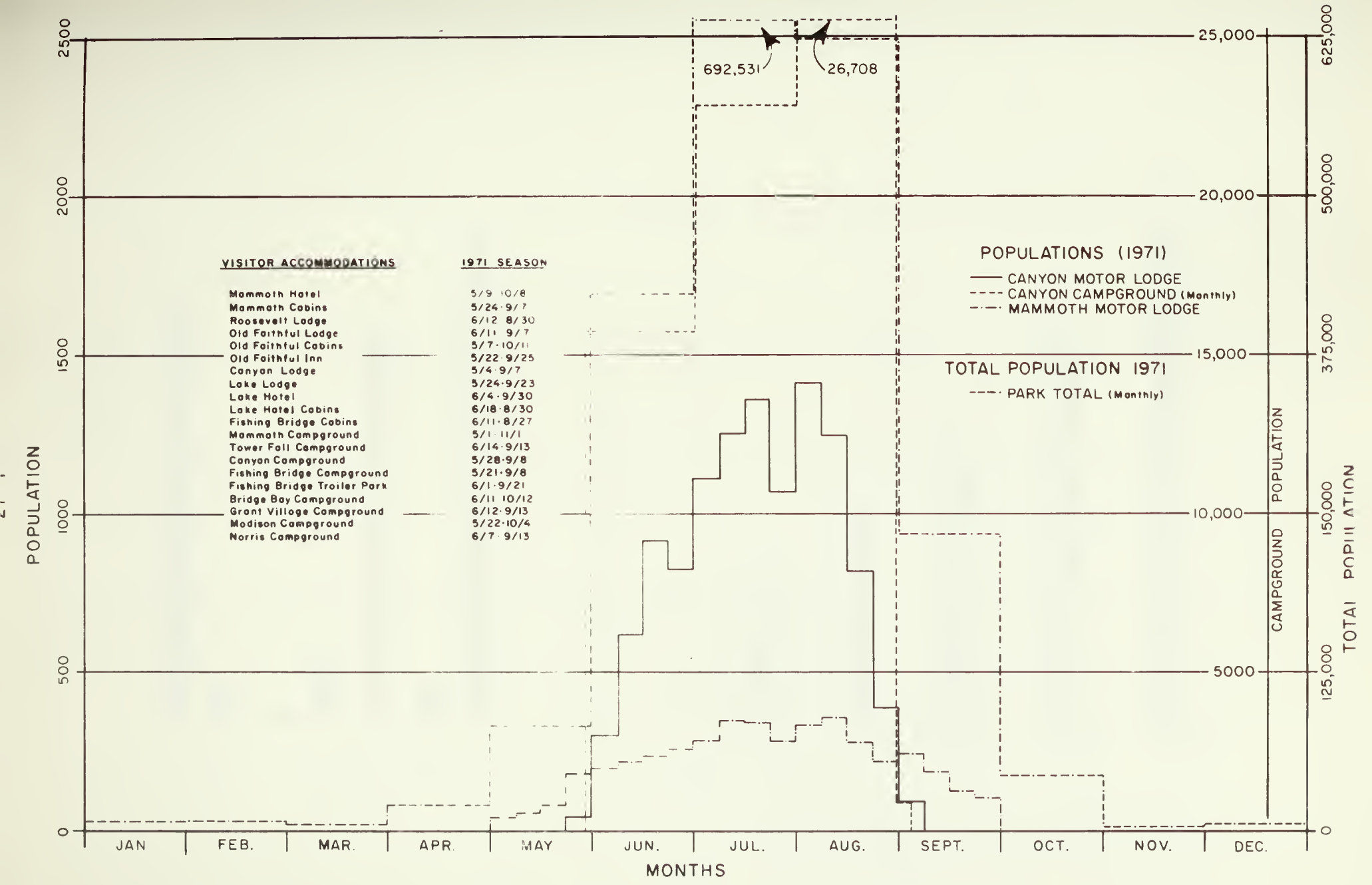


FIG. I-5 AVERAGE DAILY POPULATION AND
MONTHLY CAMPGROUND AND
TOTAL POPULATION

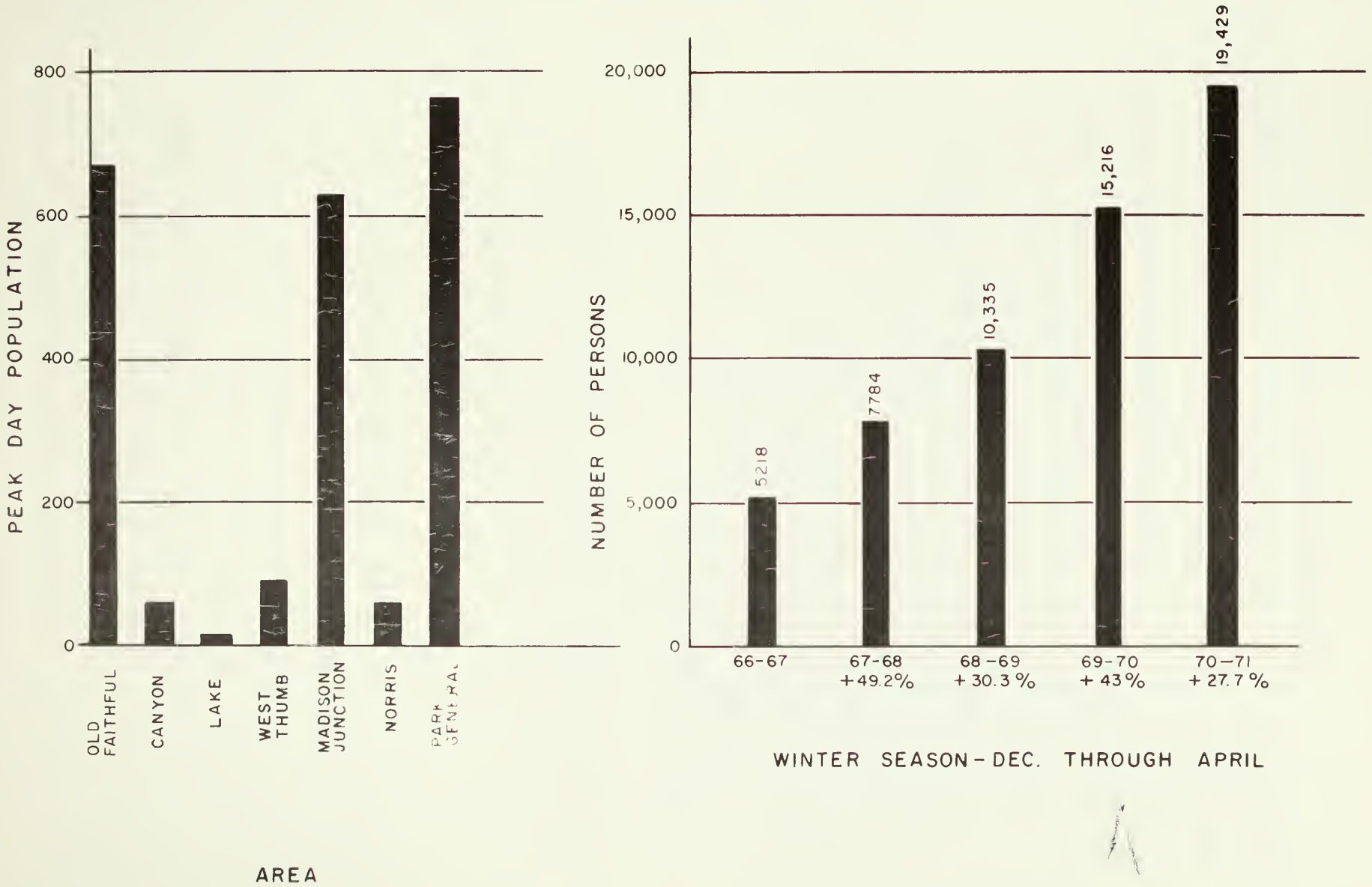


FIG. I-6 WINTER USE

Chapter 2. WATER SYSTEM DESIGN DATA

Each existing domestic water system was carefully mapped and was then evaluated. Design parameters included the following:

Collection of an adequate supply.
Treatment of this supply to make it equal or exceed Public Health Requirements.
Adequate transmission to storage and to the distribution systems.
Storage for adequate domestic and fire flows.
Distribution for adequate domestic and fire flows.

This chapter sets forth the basic design criteria used to estimate the quantity, and quality of the water used in the systems and the hydraulic properties of the existing and proposed components of the systems. Population densities and unit flow allowances were developed and applied following accepted engineering practices.

This chapter further evaluates several treatment-collection alternatives and states the reasons for the first choice recommendations presented in subsequent chapters.

Population (1)

Estimates of present and future populations were determined on the basis of National Park Service quarters assignment lists and campground lists, and of Yellowstone Park Company visitor and employee accommodation lists. These lists tabulated data such as the locations and types of employee residences, trailer sites, and campgrounds, and summarized the number of rentable and employee

quarters and "pillows" at each hotel, motor lodge, and tourist cabin area. From these lists, average and maximum overnight populations were estimated for each area.

In addition, National Park Service census counts were used to establish the existing population and to determine the percentage of occupancy of each lodging facility. These records were based on two 1-day census counts conducted at the peak of the visitor season (late July and early August). The counts tabulated by village the total number of visitors in each hotel, lodge, cabin area, or campground, and listed the number of resident employees by National Park Service, concession, or other category. Future populations were projected using data from the Metcalf and Eddy Report (1) and the updating of that report.

The population data collected from these sources were arranged to correspond to the major study areas. Tables were then prepared for each village to show existing and projected populations by component areas (see Part II). Figure 2-1 shows relative population forecasts for all areas covered by this study. This figure compares the village populations with one another and compares present census data with those in the Metcalf and Eddy Report (1) and this report's design projections. The Old Faithful area decrease from the Metcalf and Eddy total is accounted for by the fact that conversion of this area to a more limited day-use facility is progressing. No other increases or decreases are significant.

Water Demand

Maximum domestic demand flows coupled with the peak fire demand normally determine the total peak demand for a water system.

Table S-2 shows that all fire demands will be equaled or exceeded by storage. Therefor, in all systems, only the peak domestic demand flows are required to meet the system demands.

One of our more difficult problems was the determination of flows for the different areas. With the exception of Fishing Bridge no indicating or totalizing metering is done by the Park Service on any complete area. The following methods were employed to determine water usage requirements:

1. Most concessioner-operated facilities in the Park are connected to the Park Service water systems. These meter readings were especially valuable for determining maximum flows from those facilities. Selected water use figures are tabulated in Appendix Table A-2 taken from the Metcalf and Eddy Report (1) and spot checked for this report. Table 2-1 reflects the maximum design flows generally used throughout the report as shown by "Population and Design Flow" Tables in Part II. Table 2-1 is the result of water use readings, research through published data, correlation with Table A-2 and W.E.A., Inc. experience.

2. Actual flow measurements were taken on every system at a time near optimum use. These maximum measured flows are shown on Fig. 2-2 along with the flows computed based on the individual flow data shown in Table 2-1. Also shown are the design flows used in the report.

Mammoth Hot Springs, Lake and Madison Junction were the areas where the measured flows substantially exceeded the maximum computed flows. In all other areas the flows correlated well. As water metering is limited, the high flows used in the report were expected. The higher of the "Maximum Measured Flow" versus the computed "Maximum

Water Flows-Future" was used as the basis for the computation of the "Design Flow for Report."

The design flow used for the report was computed utilizing the following safety factors:

0 -	100,000 gpd	= 1.8 x maximum flow
500,000 -	1,000,000 gpd	= 1.5 x maximum flow
1,000,000 -	3,000,000 gpd	= 1.2 x maximum flow

The safety factor was employed because:

1. Park traffic was down nearly 10% in 1971 from 1970.
2. As our measurements were not continuous it is highly unlikely that we successfully measured the peak day demand.
3. Sewage flow measurements from the M & E report showed the 1.2 and 1.5 factors to be nearly correct for two applicable areas.(1)

The safety factor is decreased as flows increase because:

1. One campground tap being left open all day in Norris would have a substantially greater effect than the same occurring in Fishing Bridge.
2. Mammoth Hot Springs has constant lawn watering which means that near maximum usage occurs almost daily. Several measurements established this observation. Therefor, a far smaller safety factor is justified.
3. The 1.5 factor covers the four middle sized systems of Old Faithful, Canyon, Lake, and Grant. Lake had a maximum measured flow nearly 20% greater than the computed maximum existing flow. This 20% excess would suggest that the 50% safety factor is realistic.

Flows were measured by several different methods. The method most generally employed was by determining the volume per unit length of drop in a storage tank. All other internal flows into the area were then stopped and the drawdown was measured over extended time periods with intermittent level recordation.

Water Quality, Quantity, and Source of Supply

The waters of Yellowstone are in many respects some of the highest in quality of those found anywhere in the United States. Table 2-2 summarizes the mineral water analyses for the source of supplies used or recommended as alternates for this report. Table C-1 in the Appendix summarizes all of the mineral analyses for practically every potential source considered during this study. Table 2-3 gives the coliform concentrations at most sources used in this report and for some additional selected locations [4]. Table C-2 in the appendix contains detailed analyses of each individual supply and further includes testing for the heavy metals and other potentially harmful minerals for each source of supply. The Environmental Protection Agency (EPA) report contains many complete chemical analyses from many different waters. This EPA report lists the following chemical substances as supplemental to those listed in this report:

Arsenic, Barium, Copper, Cyanide, Lead, Selenium, Phenols, Zinc, Nitrate, and Ra-226.

In no case do the concentrations of these substances approach the maximums established by the Public Health Service Drinking Water Standards. [5]

Tables 2-2 and C-1 show most of the supplies to be soft, cool, with a minimum of mineral content. Table 2-3 shows normally low coliform concentrations. The fluoride content at Lake and Madison Junction is high. The water temperature at Norris in Castle Creek is high. The coliform concentrations in the Firehole River at Old Faithful and in Cascade Creek at Canyon are high.

The quantity of supply for Old Faithful, Grant and Norris is substantial. Table 2-4 shows that Mammoth Hot Springs, Tower, Canyon, Lake, and Madison Junction all have adequate supplies but did require careful quantity review. If the population projections are correct for the different areas and lawn irrigation is used only in the Mammoth Area then the recommended sources should be adequate. The listing for the Mammoth Hot Springs Panther Creek supply includes water diversion from Indian Creek. Figure 2-3 shows one of our V-notch wiers which was utilized in quantity measurements at Tower, Canyon on Soda Creek, Lake, and Madison Junction. Figure 2-4 shows the lowest flow observed in Cascade Creek at Canyon in 1971. USGS reports were also utilized in determining minimum flows. (3) (6) Table A-3 in the appendix lists many Park stream and river flows.

Turbidity is a problem at Mammoth Hot Springs, Old Faithful, Canyon, and Norris. Color is a problem at Old Faithful and Canyon. Table A-4 in the appendix shows many selected samples of stream turbidity and color.(3) EPA also lists some data concerning color and turbidity.(4) Our field office opened just after

the 1971 high turbidity-color season which occurs in late May and early June. Supplemental testing in early June, 1972 allow us to state the following:

> Water supplies for Mammoth Hot Springs, Old Faithful, Canyon and Norris can be collected utilizing back-washable infiltration galleries installed under the streams. Chapter 4-Collection discusses this procedure in detail.

Well development was thoroughly considered as a potential source of supply. Except for the supplemental winter well in the Tower area at Tower Junction no further well development is recommended. The USGS reports show that well development would be most unproductive in most locations. (3) (6)

Storage Design and Fire Protection

Water storage is best computed from cumulative flow diagrams showing the maximum needed to be stored at a constant pumping rate on the peak day. As flow records are not available on any of the Park domestic systems, storage was computed as follows: The total storage should be equal to the maximum fire flow plus the peak domestic flow for the duration of the fire minus the peak capacity that the system can input for the fire duration. Table 2-5 show these computations for all areas. A common maximum storage figure is 30% of the maximum peak day design flow. This storage figure is also represented in Table 2-5. Table A-5 of the appendix gives a detailed existing tank schedule for all areas.

For the areas of Canyon, Lake, Grant, Madison Junction and Norris we recommend only clearwell storage be added to the existing elevated storage. Table 2-5 indicates that Madison Junction and Norris might be slightly short on the computed "maximum storage required." However Madison Junction and Norris storage should be adequate as using the peak domestic flow for storage computations might be slightly excessive. Some authors feel storage computation can be based upon the maximum <u>average</u> daily flow if the delivery and pumping systems are in good order. (2) The proposed Mammoth Hot Springs storage is made relatively high as the transmission lines are long and the safety margins are not large.

Fire flows are computed for a four hour duration as follows:

Area	Residential gpm	Commercial gpm
Mammoth Hot Springs	500	1,500
Tower	500	500
Old Faithful	500	1,500
Canyon	500	1,000
Lake	500	1,500
Grant	500	1,500
Madison Junction	500	500
Norris	100	100

Several considerations beyond those normally mentioned by the National Board of Fire Underwriters became a part of the design fire flows. The Park has good but limited fire protection equipment and a 1,500 gpm maximum flow equals these equipment capabilities in the larger areas. A large portion of the areas population are campgrounds without fire protection thus rendering the standard fire flow formula not applicable. Finally, the

major facilities are open in the Park for only a short duration, thus not justifying a substantially larger expenditure for greater maximum flows.

Hydraulic Design

Practically all of the pipe flows considered were under pressure. As flow is turbulent in pipes used for water supply, the friction factors depend upon the roughness of the pipe and also upon the Reynolds number, which in turn, depends in part upon the velocity in the pipe and its diameter. Therefor a pipe flow formula should have a roughness coefficient which varies with velocity and pipe size. The Hazen-Williams formula was the basis used in the design of our water transmission and distribution systems: (2)

$$v = 1.318\ Cr^{0.63}\ S^{0.54}$$

v = vel. in pipe in feet per second
C = constant depending on pipe roughness
r = hydraulic radius of pipe
s = hydraulic gradient

C values were used as follows:

Description of the Pipe	Valves of C
Extremely smooth and straight AC and cement lined CI	140
Cast Iron - cement lined - old	130
Cast Iron and galvanized iron - old but not in bad shape	100

Fire hydrant spacings were designed and checked to provide 120,000 sq. ft. coverage in residential sections and 100,000 sq. ft. coverage in commercial sections. The network analyses were designed to provide a minimum of 20 p.s.i.g. in the vicinity of a fire. Almost all hydrants were checked for flow, pressure, leakage and

general conditions. The list of Symbols and the detailed Figures in Part II show problems that exist within the areas.

The Hardy Cross method of analysis of flow in a pipe network was used for all system flows. Table 2-6 shows the assumed flows for domestic and fire flows used in all areas. Appendix B shows all of the detailed final input and results in each area. The network analyses were run using our terminal which accessed a General Electric Time Sharing computor network. The software was a "Hydraulic Network Analysis-Users Guide." (8)

Period of Design

General practice in municipal water works design uses the following guides in determining design periods:

Water mains	- 40 to 50 years (desirable)
Pumping and treatment facilities	- 10 to 20 years

Piping is generally designed for the longer periods of service because the additional cost for increased capacity in the initial installation is generally small in comparison with the cost required for future construction. Also, the pipe materials have a life expectancy consistent with this long design period.

On the other hand, pumping and treatment facilities usually require mechanical-electrical equipment which has a much shorter life expectancy. Further, improvements in process design could make present forms of treatment obsolete over a period of a decade or more.

Yellowstone, like other national parks but unlike municipalities, exists in an environment where directions, and limits of

public use can be controlled and channeled towards specific objectives. Realizing that flexibility is an essential element in optimum Park development facilities have been designed, insofar as feasible, to permit future expansion as well as operation at greatly reduced flow rates. Also, all systems are designed for winter usage which dictates the necessity for good operation at minimum flow rates.

TABLE 2-1. MAXIMUM DESIGN UNIT WATER FLOWS

Description	Units	Flow per unit, gpd
Campground (developed)	Per person	50
Lodge or cabins	Per person	50-75
Hotel	Per person	75
Trailer village	Per person	50
Dormitory, bunkhouse	Per person	75
Residence homes, apartments	Per person	200-1000*
Mess hall	Per person	20
Offices and stores	Per employee	25
Visitor centers	Per visitor	5
Cafeteria	Per table seat	150
Dining room	Per table seat	150
Coffee shop	Per counter seat	250
Cocktail lounge	Per seat	20
Laundromat	Per washing machine	500
Hospital	Per bed	200
Gas station	Per station	2,000-5,000
Fish cleaning station	Per station	7,500

* 1000 gpd used in Mammoth Hot Springs Area as lawn watering was included

TABLE 2-2. WATER QUALITY SUMMARY (mg/l)*

AREA	SOURCE OF SUPPLY	SODIUM	POTASSIUM	CALCIUM	MAGNESIUM	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	TOTAL HARDNESS	FLUORIDES**	T°C. @ SOURCE
Mammoth Hot Springs	Panther Creek	12	1	25	10	-	4	6	0	146	-	104	0.2	10
	Gardner River	13	1	43	16	-	64	4	TR	159	-	174	0.1	11
Tower	Tower Fall Spring	24	1	9	4	-	6	4	0	98	-	39	0.4	6
	Winter Well (3)	15	1	14	5	0.1	7	1	0	92		54	0.8	-
Old Faithful	Firehole River	25	3	TR	TR	-	19	6	0	37	-	TR	1.2	14
Canyon	Cascade Creek	13	1	5	2	-	4	4	-	49	-	21	0.4	12
	Soda Creek	14	1	3	2	-	7	6	-	37	-	16	-	14
Lake	Lake Spring	13	3	5	2	-	16	4	0	37	-	21	3.0	9
	Winter Spring	9	2	4	2	-	4	4	0	37	-	18	3.0	9
	Fishing Bridge Spring	5	2	5	2	-	18	4	-	12	-	25	2.9	15
Grant	Yellowstone Lake	19	2	4	3	-	9	10	0	49	-	23	0.3	14
Madison Junction	Springs	30	4	5	3	-	7	20	0	73	-	25	6.0	19
Norris	Solfatara Creek	12	3	3	1	-	6	4	0	37	-	12	1.6	14

* Summary of Chemical and Geological Laboratories Water Analysis Report-Appendix C

** W.E.A. field data used

TABLE 2-3. COLIFORM BACTERIA IN SOURCE OF SUPPLY AND OTHER SELECTED WATERS

AREA AND SAMPLE LOCATION	SAMPLE DATE	TOTAL COLIFORM COUNT/100ml
Mammoth Hot Springs	8/30/71**	
Gardner River Intake		365
Gardner River Intake		293
Panther Creek Intake		184
Panther Creek Intake		171
Tower	8/30/71	
Tower Fall Spring		0
Tower Fall Spring		0
Roosevelt Lodge - Lost Creek		189
Roosevelt Lodge - Lost Creek		175
Tower Junction Spring		0
Tower Junction Spring		0
Old Faithful	8/30/71	
Firehole River Intake		300+*
Firehole River Intake		1000 *
Canyon	8/30/71	
Cascade Creek Intake		1000 *
Cascade Creek Intake		1000 *
Soda Creek Intake		131
Soda Creek Intake		168
Lake	8/30/71	
Lake Spring		43
Lake Spring		8
Fishing Bridge Spring		88
Fishing Bridge Spring		113
Grant	8/30/71	
Yellowstone Lake Intake		20
Yellowstone Lake Intake		31
West Thumb-Duck Lake Intake		190
West Thumb-Duck Lake Intake		176
Madison Junction	8/30/71	
Madison Junction Spring		42
Madison Junction Spring		32
Norris	8/30/71	
Castle Creek Intake		116
Castle Creek Intake		124

* Large number of background colonies; coliform difficult to count.

** Analysis done by NPS Lake Lab.

TABLE 2-3. COLIFORM BACTERIA IN SOURCE OF SUPPLY AND OTHER SELECTED WATERS- contd.

AREA AND SAMPLE LOCATION	SAMPLE DATE	TOTAL COLIFORM COUNT/100 ml
Yellowstone River Below Gardiner	5/13/70(4)	200***
Yellowstone River Below Gardiner	5/16/70	55***
Gallatin River at W.Park Bndry.	5/19/70	260***
Gallatin River at W.Park Bndry.	8/17/70	9
Madison River near W. Entrance	5/27/70	390
Madison River near W. Engrance	5/20/70	53
Soda Butte Creek at Park Bndry.	8/11/70	83
Soda Butte Creek at Park Bndry.	5/16/70	1
Yellowstone River at Fishing Bridge	7/30/70	88
Yellowstone River at Fishing Bridge	5/17/70	1
Gardner River Below Mammoth	7/25/70	93
Gardner River Below Mammoth	5/14/70	1
Gardner River Above Mammoth	5/17/70	40
Gardner River Above Mammoth	5/16/70	1
Lava Creek at Picnic Grounds	5/28/70	31
Lava Creek at Picnic Grounds	7/28/70	9
Slough Creek above Campgrounds	5/28/70	60
Slough Creek above Campgrounds	7/28/70	13
Tower Creek Near Tower Fall	8/11/70	48
Tower Creek Near Tower Fall	7/28/70	2
Yellowstone River Below Fishing Bridge	5/18/70	210
Yellowstone River Below Fishing Bridge	5/15/70	1
Yellowstone Lake in Bridge Bay	8/ 3/70	67
Yellowstone Lake in Bridge Bay	5/14/70	1
Yellowstone Lake Near Dot Island	8/ 3/70	2
Yellowstone Lake Near Dot Island	8/ 1/70	1
Yellowstone Lake Near W. Thumb	8/10/70	210
Yellowstone Lake Near W. Thumb	8/ 3/70	1
Yellowstone Lake at S. Arm	8/ 3/70	1
Yellowstone Lake at S. Arm	7/30/70	1
Yellowstone Lake at Grant	5/26/70	53
Yellowstone Lake at Grant	8/ 3/70	1
Duck Lake	7/27/70	24
Duck Lake	7/26/70	1
Madison River Below Madison Junction	5/27/70	390
Madison River Below Madison Junction	8/15/70	18

*** Hi and low data shown for 1970 results. Many additional samples taken.(4)

TABLE 2-3. COLIFORM BACTERIA IN SOURCE OF SUPPLY AND OTHER SELECTED WATERS-contd.

AREA AND SAMPLE LOCATION	SAMPLE DATE	TOTAL COLIFORM COUNT/100 ml
Gibbon River Below Norris Campground	5/20/70	170
Gibbon River Below Norris Campground	5/29/70	12
Lost Creek Below Roosevelt Lodge	5/28/70	40
Gibbon River Above Norris Campground	8/17/70	84
Gibbon River Above Norris Campground	8/15/70	14
Firehole River at Service Road	5/27/70	130
Firehole River at Service Road	8/12/70	7
Snake River at South Park Bndry.	5/19/70	340
Snake River at South Park Bndry.	7/27/70	22

TABLE 2-4. WATER SOURCE QUANTITIES

AREA AND SOURCE	MINIMUM QUANTITY AVAILABLE		MAXIMUM QUANTITY REQUIRED TO SUPPLY AREA	
	gpm	cfs	gpm	cfs
MAMMOTH HOT SPRINGS				
Panther-Indian Creek	4887	10.89*	1870	4.17
Gardner River-(supplemental only)	5745	12.8 *		
TOWER				
Tower Springs	176**	.392	110	.244
CANYON				
Cascade Creek	1175***	2.62	453	1.01
Soda Creek-upper	59**	0.132	59	.132
Soda Creek-lower	28**	.0625	28	.0625
TOTAL			540	1.204
LAKE				
Lake Spring	385**	.859	385	.859
Winter Spring	125**	.279	125	.279
Proposed Gallery Spring	225**	.501	225	.501
Fishing Bridge Spring	270**	.602	155	.346
TOTAL	1005		890	1.985
MADISON JUNCTION				
Madison Junction Springs	110**	.244	100	.223

* USGS Reports-10/28/66 observations (3)

** V-notch weir (7)

*** Lowest observed flow, 1971-3.7 cfs calculated as rectangular weir (7)

TABLE 2-5. FIRE DEMAND AND STORAGE

AREA	Design Flow		Fire Flow Max. 4 Hour		Max.Flow Input Capac-ity*	Peak 4 hr. Domestic Flow***	Maximum Storage Requir-ed ****	Stg.Using 30% Design Flow	Existing Covered Storage	Proposed Storage
	gpd	gpm	gpd	gpm	gpm	gpm	gal	gal	gal	gal
Mammoth Hot Springs	2,700,000	1870	360,000	1500	2500	2350	324,000	810,000	26,000	900,000
Tower	159,000	110	120,000	500	176**	330	156,960	48,000	30,000	160,000
Old Faithful	860,000	600	360,000	1500	1000	1200	408,000	260,000	35,000	400,000
Canyon	767,000	540	240,000	1000	712	1080	328,320	230,000	750,000	870,000
Lake	1,274,000	890	360,000	1500	1005**	1780	546,000	380,000	1,350,000	1,405,000
Grant	1,050,000	730	360,000	1500	1250	1460	410,400	320,000	2,100,000	2,275,000
Madison Junction	138,000	100	120,000	500	110**	300	165,600	41,000	100,000	124,000
Norris	113,000	80	24,000	100	120	240	52,800	34,000	40,000	44,200

* Max.Flow Input=Design Flow x Percentage Treatment Plant can operate over optimum for short duration

** Table 2-4

*** Peak Domestic 0 - 499 gpm design x 3, 500 - 1000 gpm x 2, 1000 - 2500 gpm x $1.25^{(2)}$

**** (Fire Flow + Peak Domestic Flow - Max. Flow Input) x 240 min. = STORAGE

TABLE 2-6. ASSUMED FLOWS ALL SYSTEMS FOR HARDY CROSS NETWORK ANALYSES- See Appendix B

AREA	Peak 4 Hour Domestic Flow	Residential Fire Flow	Commercial Fire Flow
	gpm	gpm	gpm
Mammoth Hot Springs	2350	500	1500
Tower			
Tower Fall	180	500	500
Roosevelt Lodge)	150	500	500
Tower Junction)			
Old Faithful	1200	500	1500
Canyon	1100	500	1000
Lake			
Fishing Bridge	750	500	750
Lake	1500	500	1500
Bridge Bay	450	500	500
Grant			
Grant	1515	500	1500
West Thumb	150	500	500
Madison Junction	300	500	500
Norris	300	100	100

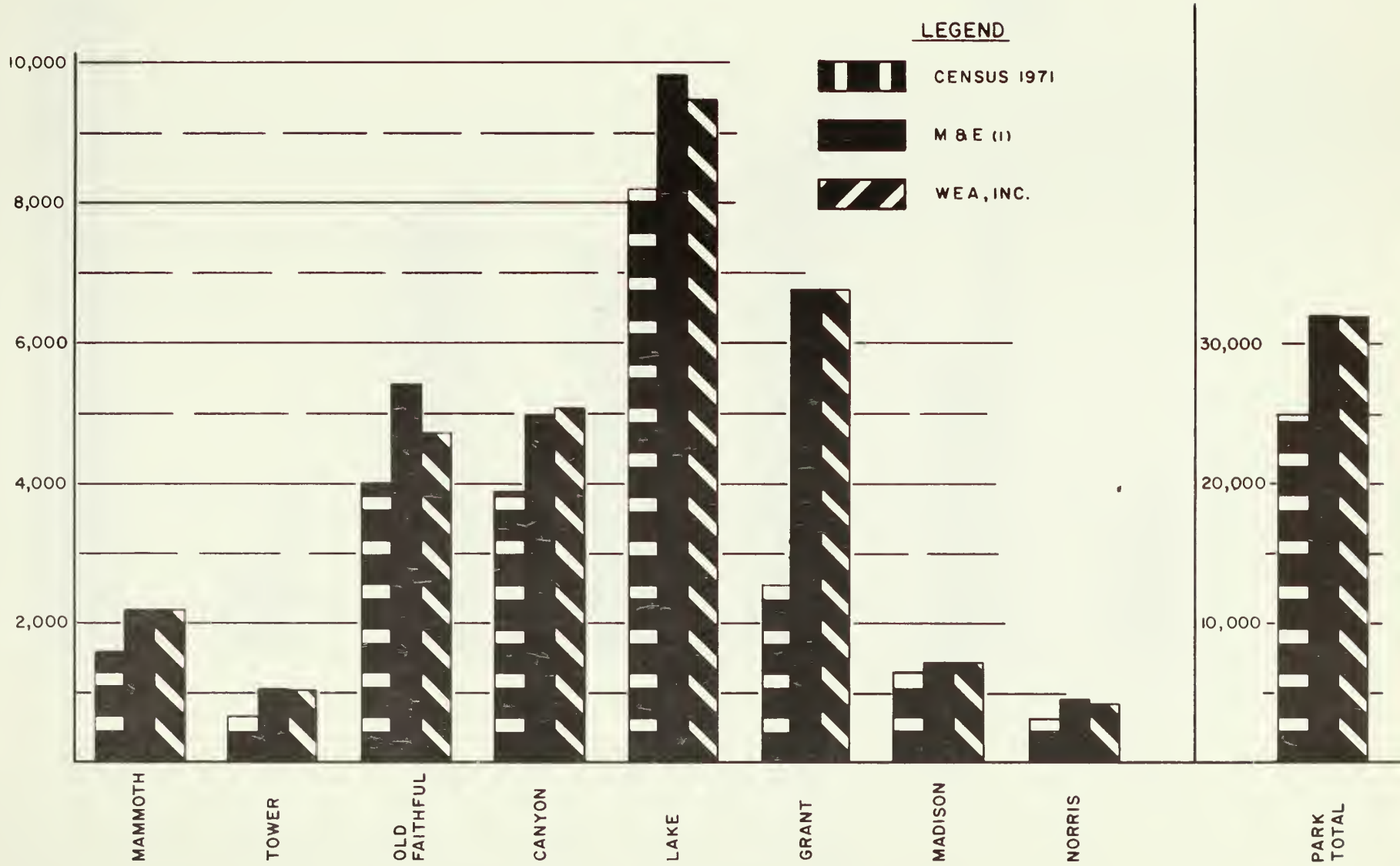


FIG. 2-1 RELATIVE POPULATION FORECAST *

*BASED UPON JULY-AUGUST OVERNIGHT POPULATIONS



FIG. 2-2 MAXIMUM WATER FLOW QUANTITIES



Fig. 2-3. Tower Area - Notch Weir Measuring Overflow from Spring Box



Fig.2-4. Canyon Area - Cascade Creek Intake - Lowest Flow Observed - 1971

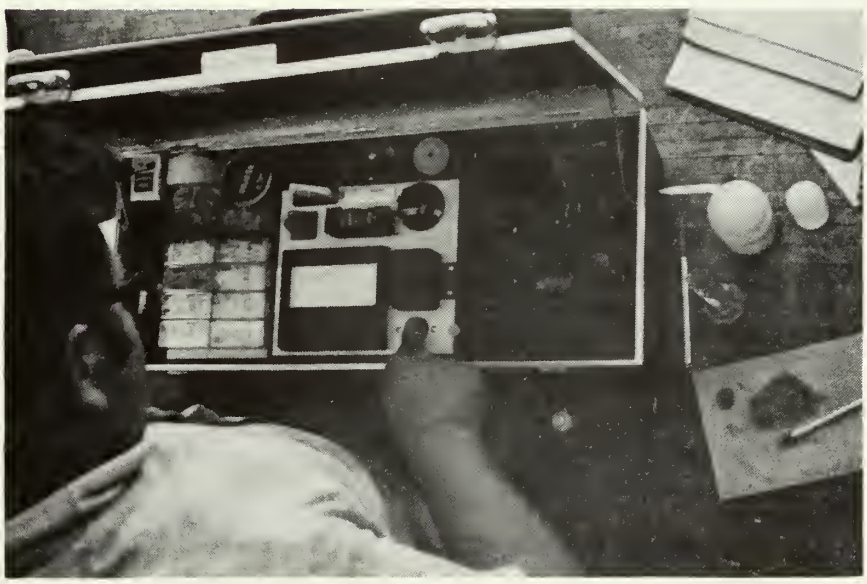


Fig. 2-5. W.E.A., Inc. - Hach Field Test Kit



Chapter 3. SUPPLY, TREATMENT AND SPECIAL CONSIDERATIONS

Domestic water considerations in Yellowstone National Park have some unique characteristics because of the raw water quality, the Parks environment and the varied seasonal operations. Public health, protection of wildlife and environment, land conservation and seasonal operation are considered in this Chapter. Chapters 4, 5, 6 and 7 deal with specific supply and treatment problems.

Public Health

The protection of the public health is the most important consideration in a domestic water supply. Today much attention is being focused on water supply as an aspect of man's environment that can be either (a) a natural resource of great benefit to him or (b) a vehicle by which disease organisms or toxic chemicals can be distributed widely. (9) Great care has been taken in design to make all of the systems extremely safe. This procedure was followed as the two million yearly visitors to the Park are extremely mobile and communicable diseases could thus be rapidly transfered from one part of the country to another.

The Public Health Service recommends that all municipal water supplies, whether they be ground water or surface water, receive treatment by disinfection regardless of the quality of the water. (9) Disinfection is recommended for every system and is discussed in detail in Chapter 5. The "Manual for Evaluating Public Drinking Water Supplies", (9) lists three groupings for water: those useable without treatment, those needing disinfection

only, and those needing complete treatment. The total criteria for each group is listed in Table 3-1.

Referring to Table 2-3 the total coliform count for Tower being 0 meets the Group 1 criteria for not requiring disinfection. However, chlorination is recommended for this area as previously stated. Table 2-3 further show that Lake, Grant, and Madison Junction meet Group II coliform criteria of having a total coliform density of less than 100 per 100 milliliters.

It is recommended that chlorination is adequate for Lake and Madison Junction but that polishing filtration be added to Grant. Chapter 7 - Filtration discusses the reasons for filtration at Grant; for Mammoth Hot Springs, Old Faithful, Canyon, and Norris coliform concentrations fall into the better quality side of Group III which can have concentrations as high as 20,000 100 ml. Group III calls for complete treatment including coagulation, sedimentation, rapid granular filtration and pre and post disinfection. For Mammoth Hot Springs, Old Faithful, Canyon and Norris two filtrations are recommended instead of coagulation. The reason for these deviations from group III coagulation recommendations are discussed in Chapters 4, 5, 6 and 7.

All systems are designed to meet and normally greatly exceed the quality criteria established in the Public Health Service Drinking Water Standards. (5) Fluoridation is recommended for Mammoth Hot Springs and Tower. Fluoridation would be optional at Canyon and Grant as residents do not stay there the year around. As

fluoridation is inexpensive and a proven preventor of dental carries (10) it was felt fluoridating equipment should be given careful consideration for installation in these areas as: 1. Mammoth Hot Springs is the yearly headquarters of the Yellowstone Park Service employees, 2. Fluoridation of outlying areas will give dental protection to the young people in Park Service and concessioner familes throughout the year and 3. By fluoridating all supplies those tourists and other employees coming from fluoridated supplies will continue to consume properly fluoridated water. This becomes of some significance when it is realized that over 50% of the U.S. population is now served by artificially or naturally occurring fluorides. Old Faithful and Norris have naturally occurring fluoride concentration in the proper amounts. Lake and Madison Junction have fluoride concentrations of 3 mg/l and 6 mg/l respectively. These amounts exceed the maximum concentrations allowable and could cause dental fluorosis or mottled enamel.(11)

The methods of fluoride removal which have been tried may be divided into two basic types - those based upon the addition of some material to the water during the coagulation process and those based upon the ion exchange or absorption process.(11) Recent discovery has led to the utilization of reverse osmosis units to remove fluorides. Small household fluoride removal units are recommended for permanent employees who have children for individual installations in Lake and Madison Junction.

The public health aspects of collection will be discussed in Chapter 4. Cross connections are pointed out on the Figures shown in Part II. - Detailed Analysis. Transmission, distribution and storage were designed to comply with the public health suggestions described in the "Manual for Evaluating Public Drinking Water Supplies." (9) Table 3-2 lists the most critical existing potential health and safety hazards noted in the existing systems and makes positive recommendations as to the rectification of these problems. The table does not discuss problems such as inadequate treatment of surface supplies as these will be covered in later chapters.

Protection of Wildlife

Fencing is recommended for all water supply sources as a public health precaution. This fencing will also aid in keeping wild animals away from the supply intakes.

Superintendent Anderson requested that we consider the existing intakes as they are in many cases barriers to fish. Further, it was pointed out that all streams above intakes have been closed to fishing to help in protecting the water from human contamination. Figure 3-3 shows the nearly impassable intake for trout on Panther Creek. Table 3-3 lists man-made barriers to the natural upstream movement of fish and gives recommendations for each structure. After all new facilities and fencing are constructed for each area fishing could be allowed upstream from the intakes.

For Mammoth Hot Springs, Old Faithful, Canyon and Norris backwashable infiltration galleries under the streams are being recommended. For fish protection backwashing of these filters should be accomplished with chlorine free water.

Preservation of Environment

Several major considerations concerning domestic water systems and the environment include: location of facilities, type of structures selected, type of tanks, the way pipeline right-of-ways are restored, power and control transmission line installation and a scenic consideration of Rustic Falls.

New facilities were located as far as was practical from populated areas and screened from general view by vegetation or topography. The treatment processes selected lend themselves to a minimum of land use. Chlorination equipment needs to be kept above ground, therefor aesthetic considerations will dictate selection of attractive building design for these facilities. All proposed tanks and clearwells are to be underground installations. An additional benefit of the underground tank is its greater adaptability to winter useage. All new pipelines should be carefully reseeded. Power and control transmission lines should be buried. The existing power line at Madison Junction to the tank failed because of trees falling on it. This failure would be avoided if the lines were buried.

The existing concrete supply line in the Mammoth Hot

Springs area starting at the Gardner River Intake terminates in Swan Lake Flats above Rustic Falls. This supply line allows a large flow of water to supplement the existing Glen Creek flow for passage over Rustic Falls down to the existing Glen Creek Intake. The lowest flow recorded in Glen Creek without the supplemental flow was 1.85 cfs on Oct. 28, 1966. The lowest tourist season flow was 3.21 cfs on Aug. 13, 1968. The average Aug. flow is 5± cfs, July 10± cfs, and in June, 20± cfs.(3) The supplemental supply often carries as much as 8 cfs. It appears that in July and August the supplemental supply adds a large amount to the flow going over the falls. A new pressure main will be utilized for the domestic supply. The old concrete line should be repaired if it is to be continued in service.

Seasonal Operation

Public use of Yellowstone Park is mostly seasonal. There are two months of extensive use in July and August and six months of low activity from November through April, with transitional periods in between. This fluctuation in activity places a unique and critical requirement upon the design and operation of water supply and treatment facilities, in that systems must be started each spring, shut down each fall or be operated at wide capacity variations. This situation presents many problems:

1. Turbidity and color are serious spring runoff problems when consumptive use is relatively

low. About the time a coagulation process would be working properly after start up is about the same time the source of supply would be crystal clear.

2. The time available for rehabilitation and repair each spring is curtailed by lingering snowcover and freezing temperatures on the one hand, and a rapid influx of seasonal visitors on the other. Thus, within a few weeks time each spring, the quantity of water supplied will increase from almost nothing to near full plant capacity.

3. As the peak season draws to a close, the quantity of water useage drops off rapidly, and soon it is required to maintain a minimal process within the facilities. Thus all systems are designed to allow for minimum service.

4. Because of the seasonal nature of the work, it is difficult to obtain and retain qualified treatment plant operators and to maintain continuity of operation from year to year.

5. All new mains should have a minimum of five foot of cover.

The requirement, therefor, is for a simple but extremely flexible process and one that generates into effective treatment in the shortest possible time. One favorable result of the short seasonal use is that high operating costs can be sustained during the seasonal peaks because of their short duration.

A recent continued increase in over-snow vehicle traffic in the Park is resulting in all areas except Norris maintaining some

services in the winter months. Table 3-4 describes the recommended winter use facilities for each area. Norris is included as the recommended improvements would allow winter usage except at the visitor center.

TABLE 3-1. WATER GROUPING FOR DOMESTIC SUPPLY[9]

Group I. Requirements for Water Usable Without Treatment

A. Bacteriological Quality: shall meet PHS Drinking Water Standards.

B. Physical Quality: should meet PHS Drinking Water Standards.

C. Chemical Quality: chemical concentrations should not exceed the following:

Substance	Concentration, mg/liter
Arsenic (As)	0.01
Barium (Ba)	1.0 [a]
Boron (B)	1.0
Cadmium (Cd)	0.01[a]
Carbon Chloroform Extract (CCE)	0.2
Chloride (Cl)	250
Chromium (hexavalent, Cr^{+6})	0.05[a]
Copper (Cu)	1.0
Cyanide (CN)	0.01
Detergents (Methylene Blue Active Substances)	0.5
Fluoride (F)[b]	
50.0-58.3°F	1.8
58.4-70.6°F	1.5
70.7-90.5°F	1.2
Iron (Fe)	0.3
Lead (Pb)	0.05[a]
Manganese (Mn)	0.05
Nitrogen (nitrate plus nitrite)	10.0
Phenols	0.001
Selenium (Se)	0.01[a]
Silver (Ag)	0.05[a]
Sulfate (SO_4)	250
Total Dissolved Solids (TDS)	500
Uranyl ion (UO_2^{++})	5.0
Zinc (Zn)	5.0

[a]Concentrations in excess of values listed shall constitute grounds for rejection of the supply.

[b]Annual average of maximum daily air temperatures.

TABLE 3-1. WATER GROUPING FOR DOMESTIC SUPPLY[9] contd.

Substances not included in the above table that may have deleterious physiological effect or that may be excessively corrosive to the water supply system should not be permitted in the raw water supply.

D. Radioactivity: should comply with the PHS Drinking Water Standards.

E. Pesticides: should not exceed the following limits:

Pesticide	Maximum permissible concentration, mg/liter[a]
Endrin	0.001
Aldrin	0.017
Dieldrin	0.017
Lindane	0.056
Toxaphene	0.005
Heptachlor	0.018
Heptachlor epoxide	0.018
DDT	0.042
Chlordane	0.003
Methoxychlor	0.035
Total organophosphorous and carbamate compounds[b]	0.1
2,4,5-TP	(Individual limits = 0.1 mg/liter; sum of)
2,4,5-T	(any combination of chlorinated phenoxy)
2,4,-D[c]	(aklyl pesticides = 0.1 mg/liter)

[a]For long term exposures.

[b]Expressed in terms of parathion equivalent cholinesterase.

[c]Short period limit only: 2 to 3 days, no more than once or twice a year.

Group II. Requirements for Water Needing Disinfection Only

A. Physical, Chemical, Radioactivity, and Pesticide Requirements: the requirements as shown for untreated raw ground water (Groups I.B, I.C, I.D, and I.E) should be met. If the water does not

TABLE 3-1. WATER GROUPING FOR DOMESTIC SUPPLY[9] contd.

consistently meet all these requirements, consideration should be given to providing additional treatment during periodic decreases in quality that result from high turbidity, tastes, etc.

B. Bacteriological Quality:

1. Total Coliform Density: Less than 100 per 100 milliliters as measured by a monthly arithmetic mean.

2. Fecal Coliform Density: If fecal coliform density is measured, the above total coliform density may be exceeded but fecal coliform density should not, in any case exceed 20 per 100 milliliters as measured by a monthly arithmetic mean. When the fecal coliform vs. total coliform criterion is used for Group II water, the fecal coliform count should never exceed the 20 per 100 milliliters monthly arithmetic mean. This fecal coliform standard only applies when it is being measured on a regular basis.

GROUP III. Requirements for Water Needing Treatment by Complete Conventional Means Including Coagulation, Sedimentation, Rapid Granular Filtration, and Disinfection (Pre and Post).

A. Bacteriological Quality:

1. Total Coliform Density: Less than 20,000 per 100 milliliters as measured by a monthly geometric mean or,

2. Fecal Coliform Density: If fecal coliform density is measured, the above total coliform density may be exceeded, but fecal coliform should not exceed 4,000 per 100 milliliters as measured by a monthly geometric mean.

The same rational applies here as in the Group II waters concerning the use of the fecal coliform

TABLE 3-1. WATER GROUPING FOR DOMESTIC SUPPLY[9] contd.

vs. total coliform criterion. In no case should the fecal coliform count exceed the 4,000 per 100 milliliters monthly geometric mean.

The arithmetic means is used with the Group II waters because the bacteriological data from these waters will be of lesser magnitude than that from the Group III waters; this difference in magnitude between the monthly means of the Group II and Group III waters is best reflected by the arithmetic and geometric means, respectively.

These bacteriological limits may possibly be exceeded if treatment (in addition to coagulation, sedimentation, rapid granular filtration, and disinfection) is provided and is shown to be doing a satisfactory job of providing health protection.

B. Physical Quality: Elements of color, odor, and turbidity contribute significantly to the treatability and potability of the water.

1. Color: A limit of 75 color units should not be exceeded. This limit applies only to nonindustrial sources; industrial concentrations of color should be handled on a case-by-case basis and should not exceed levels that are treatable by complete conventional means.

2. Odor: A limit of 5 threshold numbers should not be exceeded.

3. Turbidity: The limits for turbidity are variable. Factors of nature, size, and electrical charge for the different particles causing turbidity require a variable limit. Turbidity should remain within a range that is readily treatable by complete conventional means. It should not overload the water

TABLE 3-1. WATER GROUPING FOR DOMESTIC SUPPLY[9] contd.

treatment works, and it should not change rapidly either in nature or in concentration when such rapid shifts would upset normal treatment operations.

C. Chemical Quality: Since there is little reduction in chemical constituents with complete conventional treatment, raw water should meet the limits given for Group I.C.

D. Radioactivity: Should comply with PHS Drinking Standards.

E. Pesticides: Should comply with requirements for pesticides as shown for untreated raw ground water in Group I.E.

TABLE 3-2. POTENTIAL HEALTH AND SAFETY HAZARDS

AREA	DESCRIPTION OF HAZARD	RECOMMENDATIONS
MAMMOTH HOT SPRINGS	1. Open reservoir	1. Abandon when new intake, pressure transmission line and storage are complete.
	2. Inadequate chlorine contact time	2. Provide new storage at clear-well
	3. Cross connections	3. Plug as soon as possible
TOWER		
Tower Fall	1. No chlorination	1. Chlorinate with new facilities.
	2. Inadequate chlorine contact time	2. Provide storage with new facilities
Roosevelt Lodge	1. Inadequate hypochlorination	1. Obliterate when new facilities provided
	2. Wooden roofs on tanks in bad condition	2. Repair one tank, raze other when new facilities provided
Tower Junction	1. No chlorination 2. No chlorine contact time	1. Obliterate spring when new & 2. facilities provided
OLD FAITHFUL	1. Inadequate chlorine contact time	1. Limit incoming water so that existing storage will retain water longer
		2. Provide new storage at clear-well
	3. Two standby systems - not chlorinated	3. Make a positive break between existing and standby system so that cross connection cannot occur

AREA	DESCRIPTION OF HAZARD	RECOMMENDATIONS
CANYON	1. Inadequate chlorine contact time on Cascade Creek	1. Provide new storage at clearwell
	2. Open winter reservoir	2. Abandon or cover
LAKE		
Fishing Bridge	1. Surface water floods spring area and pumphouse	1. Obliterate when new facilities provided
Lake	1. Inadequate chlorine contact time	1. Provide new storage at clearwell (not as serious a problem as the surface sources).
	2. Excessive fluorides	2. Defluoridate drinking water for permanent year around employees who have children on individual basis
GRANT		
Grant	1. Severe water hammer is an occupational safety hazard	1. Immediately install a 6" surge relief valve
West Thumb	1. Sometimes inadequate hypochlorination 2. Duck Lake experienced crustaceans-mid July 1971	1. & 2. Obliterate when Grant-West Thumb systems are combined
MADISON JUNCTION	1. Excessive fluorides	1. Defluoridate drinking water for permanent year around employees who have children on individual basis.

TABLE 3-3. MAN MADE FISH BARRIERS ON EXISTING INTAKES

AREA AND INTAKE	RECOMMENDATION
MAMMOTH HOT SPRINGS	
1. Indian Creek	1. Replace existing intake with new intake allowing fish passage.
2. Panther Creek	2. Remove when new intake installed.
3. Gardner River	3. Remodel to provide for upstream fish passage.
4. Glen Creek	4. Not required for domestic supply with new facilities. However it is located in a high gradient stretch that serves as a velocity barrier to fish even if intake not present.*
OLD FAITHFUL	
1. Firehole River	1. When remodeling continue to provide upstream fish passage.
CANYON	
1. Cascade Creek	1. Remodel to provide for upstream fish passage.
2. Soda Creek-Upper	2. Not a fishery. No improvement required except fencing.
3. Soda Creek- Lower	3. Not a fishery. No improvement required except fencing.
NORRIS	
1. Castle Creek	1. Remove when new intake installed.

* Aug. 1971 - Memorandum from Fishery Management Biologist, Yellowstone to Superintendent

TABLE 3-4. WINTER USE OF SYSTEMS

AREA	RECOMMENDED SYSTEM
MAMMOTH HOT SPRINGS	Same as in Table 1-1 - Proposed
TOWER	Service provided for Roosevelt Lodge and Tower Junction only Intake - well and pump Treatment - chlorination - (natural fluorides adequate) Storage - Proposed underground reservoir Control - Telemetering - tank level - pump start - stop
OLD FAITHFUL	Same as in Table 1-1 proposed
CANYON	Same as in Table 1-1 proposed except the following facilities will not be used: Soda Creek Intake (trib.to Sulfur Creek) Trib. to Cascade Creek Intake Upper treatment house Transmission line - Soda Creek Intake to storage Gravity valveless filter When new facilities are completed the gravity valveless filter and the Soda Creek source should not be utilized until the turbidity is less than 10 J.U.
LAKE	Same as in Table 1-1 Proposed except Fishing Bridge Spring will not be needed.
GRANT	Same as in Table 1-1 Proposed except West Thumb existing tank to Village line will need to be drained.
MADISON JUNCTION	Same as in Table 1-1 - Proposed.
NORRIS	Same as in Table 1-1 Proposed where transmission and distribution lines are of an adequate depth.



Fig. 3-1. Canyon Area Open Reservoir



Fig. 3-2. Grant Area - Duck Lake Intake



Fig. 3-3. Mammoth Hot Springs Area - Panther Creek Intake
note: Difficult Fish Passage and Deteriorated Concrete

Chapter 4. COLLECTION

Stream surface water supplies are used for Mammoth Hot Springs, Old Faithful, Canyon, and Norris. Yellowstone Lake is the recommended source for the Grant area. Springs supply the areas of Tower, Lake, and Madison Junction. It is recommended that Mammoth Hot Springs, Old Faithful, Canyon and Norris utilize backwashable infiltration gallery collection systems. The result of this change from surface to under river collection would allow classification of these systems as "Infiltration Galleries". Part II of the "Manual for Evaluating Public Drinking Water Supplies" states that ground water does not require coagulation and further "An Infiltration Gallery is essentially a horizontal well that collects water along its entire length. Such galleries--------are sometimes constructed beneath the surface water." (9)

Infiltration Galleries

The proposed backwashable infiltration galleries built under the streams are recommended where turbidities are low, below 60 J.U., and last for a short duration of less than two months during low water useage periods.

The backwashable infiltration galleries are in common use throughout the world.(12) W.E.A.,Inc. experience with high country runoff has shown the system to have some distinct advantages for collecting water:

1. The natural stream flow carries most of the turbidity on downstream.

2. The resulting filtered water has turbidity units of less than 5 J.U. even when the river or stream turbidity is quite high.

3. When the stream bed seals and infiltration decreases a gentle backwashing will restore the gallery to maximum capacity. Such a system was installed in the Big Horn River for the Town of Thermopolis in 1961. The design capacity was 3500 gpm and after 11 years of operation the capacity has not changed. The Big Horn River has suspended sediment loadings for short durations of as high as 20,000 J.U.

4. The need for coagulation of turbidity is eliminated.

5. The simplicity, low initial cost, adaptability for automation and extremely low maintenance costs preclude consideration of any type of system involving coagulation.

Color normally cannot be removed or substantially reduced by a backwashable infiltration gallery, (13),(14),(15)

With the exception of service facilities the area surrounding the gallery for a minimum of 100 feet or a "safe" distance should be void of buildings and dwellings and should be protected by a fence to prevent trespass of animals and unauthorized persons. The chief objection to infiltration galleries is that with continued use the capacity decreases. A properly designed backwashable system eliminates this problem. Design is similar to that used for rapid sand filtration if the system is installed as shown in Figure 4-1 except the backwash rate is reduced. The backwash water should not be chlorinated for Park supplies.

Table 3-1 shows that underground supplies not meeting Group 1.A. bacteriological quality but meeting Group 1.B. Phsical Quality, C. Chemical Quality, D. Radioactivity, and E. Pesticides should be considered Group II waters if the following bacteriological criteria are met:

1. Total Coliform Density: Less than 100 per 100 milliliters as measured by a monthly arithmetic mean.

2. Fecal Coliform Density: If fecal coliform density is measured, the above total coliform density may be exceeded, but fecal coliform density should not; in any case, exceed 20 per 100 milliliters as measured by a monthly arithmetic mean. When the fecal coliform vs. total coliform criterion is used for Group II water, the fecal coliform count should never exceed the 20 per 100 milliliters monthly arithmetic mean. This fecal coliform standard only applies when it is being measured on a regular basis.

Table 2-3 indicates the bacteriological criteria might not always be met when utilizing the backwashable intake. For this reason we are recommending additional polishing filtration and careful disinfection be employed as is discussed in Chapter 5. Disinfection and Chapter 7. Filtration.

Springs

Tower, Lake and Madison Junction are all supplied by gravity springs. All of the springs experience a decrease in flow in late summer. This decrease is not substantial and the area springs

recommended in this report all are quite stable with good histories.

Table 2-4 lists the minimum measured spring capacity for 1971. The development quantities for the Lake Gallery Spring and the expansion at Madison Junction were conservatively computed from actual measurements.

Proper spring development should include:

1. Housing in permanent buildings or structures with water tight walls. For surface springs, the walls should extend into the aquifer.
2. Direct surface drainage should be diverted away from the spring.
3. The entire area within 100 feet of the spring should be fenced to prevent trespass of animals or unauthorized persons. Any portion of surface drainage diversion ditches lying above the spring should be within the fenced area.

Surface Water Intakes

Mammoth Hot Springs, Old Faithful and Canyon may take waters directly from the Gardner River, the Firehole River, and Cascade Soda Creeks respectively. These intakes may be maintained for standby service particularly in the winter. Grant will continue to take waters directly from five feet off the bottom of Yellowstone Lake 700 feet from the shore.

For the most part all of the above existing intakes are constructed to ensure continuous raw water flow despite floods, icing, plugging with debris or sand, high winds, power failure,

damage by boats, or any other occurrences. (9) The intakes should be made inaccessible to trespass. The Old Faithful Intake needs some revision for the prevention of icing problems. Intake revisions for fish passage are shown on Table 3-3.

The Yellowstone Lake Intake at Grant is almost trouble free. The Lake would be classified as a Class B. reservoir which encompasses "water being impounded from an area not heavily inhabited and allowed to flow from storage in a natural stream to a point of withdrawal and requiring a treatment in varying degree in addition to disinfection." (16) As no sewage effluents will be discharged in the Lake and as the water quality of the Lake is high the Class B rating is justified. As the Lake is a surface supply and does contain some coliform count, we are recommending polishing filtration and disinfection of the intake water.

Algae was observed in Yellowstone Lake in abundance and has on occasion appeared as an unsightly growth.(1) However, no algae was ever observed in the Grant intake caisson. The inlet is apparently sufficiently deep to avoid any serious algae problems. Discussions with the system operator verified our observations. The Duck Lake Intake for which obliteration is recommended is sufficiently near the surface and close to the shore to be subject to contamination problems. Bathers were observed at this intake (Figure 3-2) this summer which stresses the importance of making intakes inaccessible to trespass. For trespass considerations we recommend placing six additional buoys for 100 feet around the Grant intake.

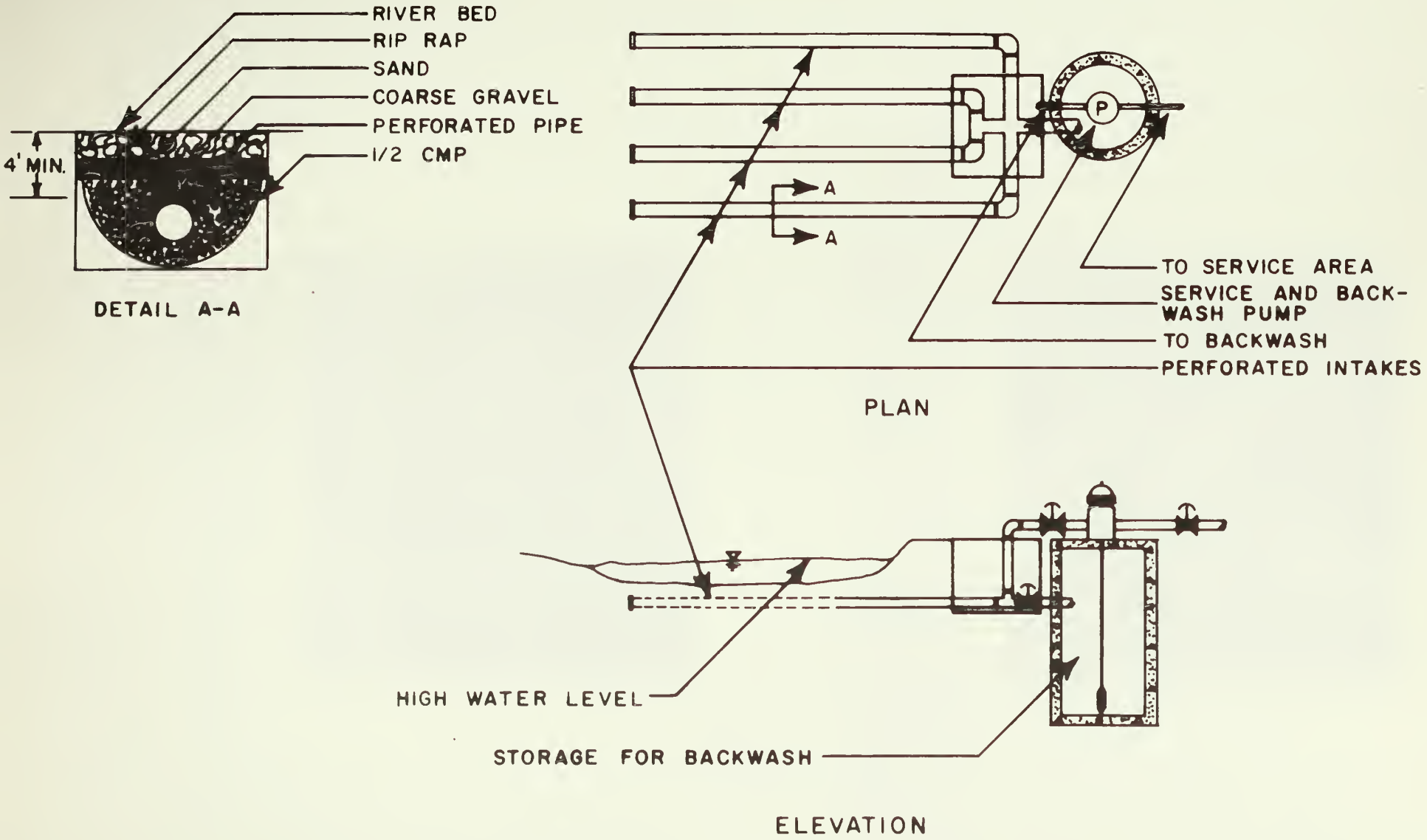


FIG. 4-1 TYPICAL BACKWASHABLE INFILTRATION GALLERY



Fig. 4-2. Lake Area - Winter Spring Collection Box

note: Properly raised cover on one manhole - not on other. Both covers lockable. No fencing. No surface drainage. Good concrete housing.



Fig. 4-3. Old Faithful Intake

note: Wood baffle for ice prevention needs to be made more permanent.

Chapter 5. DISINFECTION

Standard Methods defines the coliform group as "including all of the aerobic and facultative anaerobic, gramnegative, non-spore-forming, rod shaped bacilli which ferment lactose with gas formation within 48 hours at 35° C." (17) Escherichia coli is characteristically an inhabitant of human and animal intestines and is frequently referred to as "fecal coli". Esch. coli may be considered indicative of recent fecal pollution. The presence of any type of coliform organism in treated drinking water suggests either inadequate treatment or access of undesirable materials to the water after treatment. Because of their relative ease in detection the coliform organisms are used as the major indicators of pollution in drinking water. (5)

Chlorination was selected as the disinfecting process for every system. Chlorine is readily available, adequate for the treatments involved and many of the existing Park chlorinators are nearly new and will be useable in the recommended systems.

The AWWA Water Quality and Treatment (13) states "Except for chlorine ---------- most other of the water disinfectants herein mentioned have one or more serious limitations that preclude their general acceptance and adaptability for municipal potable water treatment operations."

The existing chlorination practices in all areas will be assessed and the proposed chlorination processes will be reviewed as to their effectiveness in killing coliform organisms and enteric viruses in this Chapter.

EXISTING CHLORINATION

All areas chlorinate except Tower Fall and Tower Junction. Due to the highly transient populations in the Park disinfection is recommended for all areas. Roosevelt Lodge and West Thumb use hypochlorination. Both of these systems experience the problems inherent in hypochlorination systems and are not satisfactory. (2) All of the remaining systems use dependable gas chlorination systems which will be useable in the proposed systems. The Park Service water system operators are conscientious in maintaining good chlorination. Table 5-1 reviews the chlorination in each area and lists some of the deficiencies the systems have in meeting all public health criteria and the safety requirements recommended by the Chlorine Institute.(18) Chlorine is continually wasted at many installations because automatic devices necessary to stop flow when tanks are full do not exist or are not in good repair.

PROPOSED CHLORINATION

Temperature, chlorine residual, chlorine contact time and pH are important parameters in chlorine disinfection design. Table C-1 in the appendix shows pH varying from 6.6 to 8.3 with most being a low 7 and temperature at the source varying from 6° to 22° C. with the mean being 13°C. Temperatures in the winter and spring will often be between 0°C. and 4°C. Berg shows in Figure 5-1 that E. Coli will be 99 percent destroyed by an 0.1 ppm HOCL residual in 10 minutes for cold water, but that the coxsackle A 2 virus will take 45 minutes for the same kill factor under the same conditions. (19) Figure 5-2 further shows that if chlorine exists as hypochlorite ion (OCI^-) that at a 0.1 ppm concentration E. coli

will be killed in 120 minutes. Figure 5-4 shows the effect of pH on the quantities of HOCI or OCI^- present in the water. (19)

Kelly and Sanderson (21) showed that the inactivation of enteric viruses (polio virus I:MK500 and Mahoney and Coxsackie B-5 in water at pH 7 and 25° C. requires a minimum free residual chlorine of 0.3 mg/l for at least 30 minutes. At higher pH levels or lower temperatures, either more chlorine or a longer contact time is required.

Clark and Chang (20) did extensive work to show that a free chlorine residual of about 1.0 ppm if maintained for 30 minutes would effectively destroy enteric viruses but that a 0.2 - 0.3 ppm with low temperature waters could take substantially longer. However, as the pH is normally below pH 8 then chlorine should be an effective virus killer. (19) (20)

Based on the above findings we are recommending a minimum of four hour detention times for all water supplies in the Park except springs where a two hour detention time is recommended. Also, a free chlorine residual of 0.4 mg/l should be maintained in the contact chambers.(9) Thirty minutes contact time at 0.4 mg/l is recommended by the Public Health Service Manual (9), for normal installations. However, as Park waters can be quite cold and further, as we feel new virology discovery and techniques will soon show that longer contact times are desirable, then we feel our longer recommended contact times are justified. Fortunately the additional clearwells recommended are normally necessary for increased storage. No increased storage was necessary at Canyon, Lake, Grant, and Norris and the clearwells in these areas are recommended primarily for chlorine contact time.

TABLE 5-1 EXISTING CHLORINATION REVIEW

AREA	TYPE OF CHLORINATOR	SCALES	SCALES RECESSED INTO FLOOR	WINDOW IN DOOR	WINDOW IN BUILDING	OUTLET FAN	LIGHT ON-FAN ON DOOR OPEN-FAN ON	DANGER-POISON GAS-SIGN ON DOOR
MAMMOTH HOT SPRINGS	W & T A 741-gas	yes	yes	no	yes	no	no	yes
TOWER								
1. Roosevelt Lodge	W & T hypochlorinator	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
OLD FAITHFUL	W & T-A 741-gas	yes	yes	no	yes	no	no	yes
CANYON								
1. Cascade Crk	W & T-A 741-gas	yes	no	no	yes	no	no	yes
2. Soda Crk	W & T-A 741-gas	yes	no	yes	yes	no	no	no
LAKE								
1. Fishing Bridge	W & T-A 741-gas	yes	yes	no	yes	no	no	yes
2. Lake	W & T-A 741-gas	yes	no	no	yes	no	no	no
GRANT								
1. Grant	W & T-A 741-gas	yes	no	no	yes	no	no	yes
2. West Thumb	hypochlorinator	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.
MADISON JUNCTION	W & T-A 741-gas	yes	no	no	yes	no	no	no
NORRIS	W & T-A 741-gas	yes	yes	no	yes	no	no	no

N.A. - not applicable

TABLE 5-1 EXISTING CHLORINATION REVIEW -contd.

AREA	CHLORINE CONTINUALLY WASTED	GENERAL BUILDING APPEARANCE	POWER WATER SUPPLY
MAMMOTH HOT SPRINGS	yes	Good, fairly new, log	Booster pump
TOWER			
1. Roosevelt Lodge	yes	Old, wood	None required
OLD FAITHFUL	yes	Good, fairly new, log	Pressure drop across valve
CANYON			
1. Cascade Crk	no	Good, new, block-painted	Booster pump
2. Soda Crk	yes	Good, concrete block-painted	Booster pump
LAKE			
1. Fishing Bridge	yes	Wood frame, old, floods in spring	System water pressure
2. Lake	yes	Good, concrete block-painted	System water pressure
GRANT			
1. Grant	no	Good, new, block-painted	Booster pump
2. West Thumb	no	All right, wood frame	None required
MADISON JUNCTION	no	Good, wood frame	High Service Pump
NORRIS	yes	Good, concrete block-painted	Pressure drop across valve

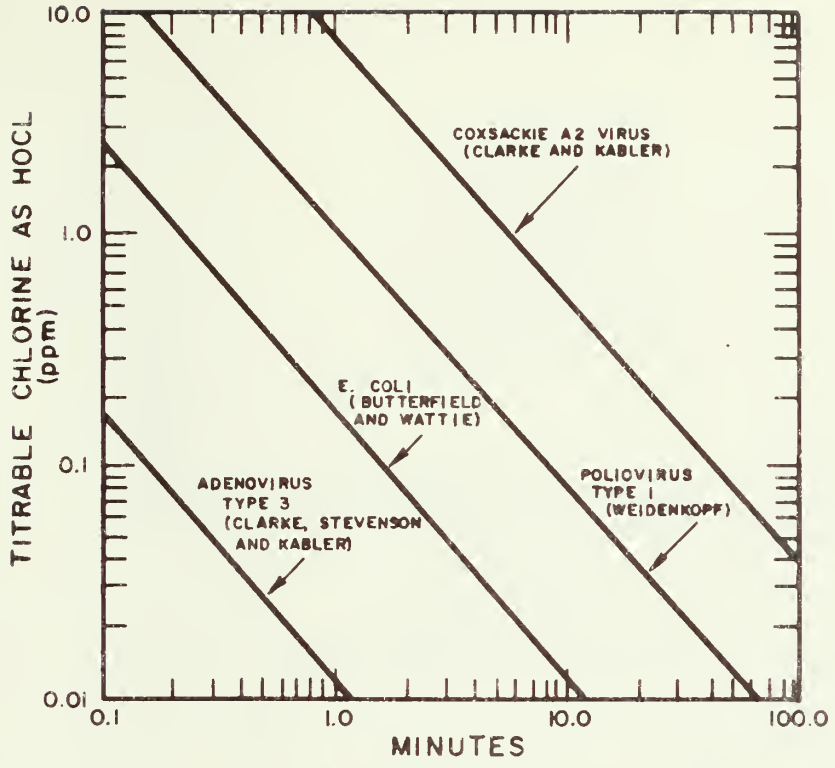


FIGURE 5-1. CONCENTRATION-TIME RELATIONSHIP FOR 99 PERCENT DESTRUCTION OF ESCHERICHIA COLI AND SEVERAL VIRUSES BY HOCL AT 0 TO 6°C.[18]

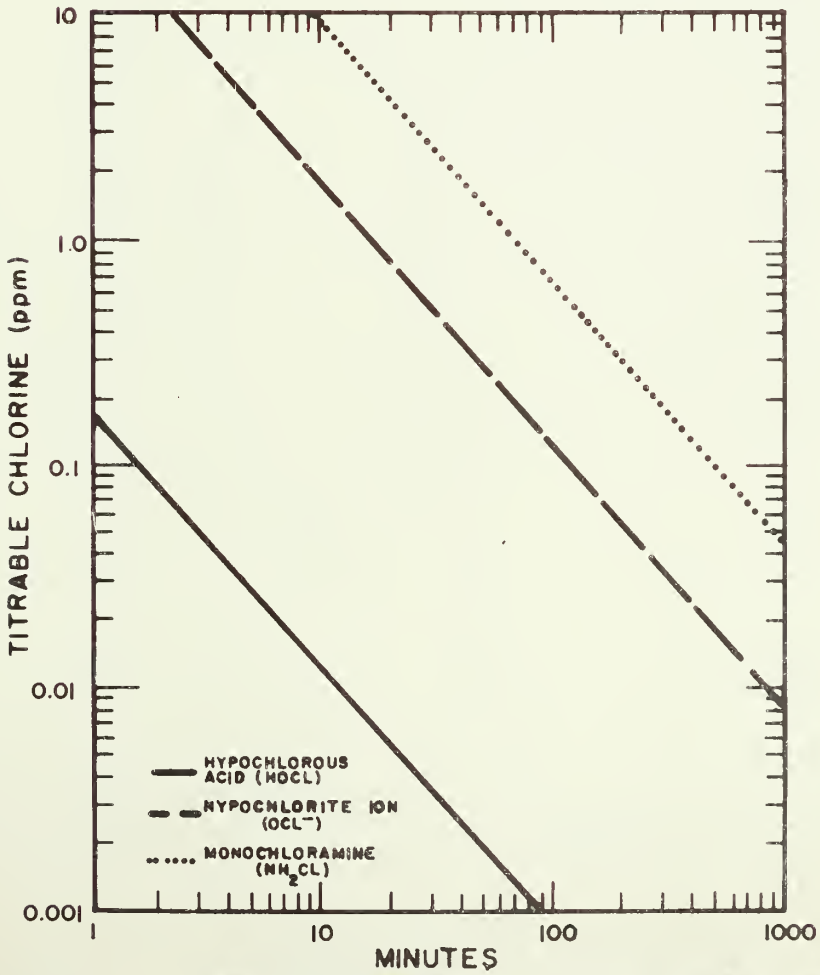


FIGURE 5-2 RELATIONSHIP BETWEEN CONCENTRATION AND TIME FOR 99 PERCENT DESTRUCTION OF E. COLI BY 3 FORMS OF CHLORINE AT 2 TO 6°C.[18]

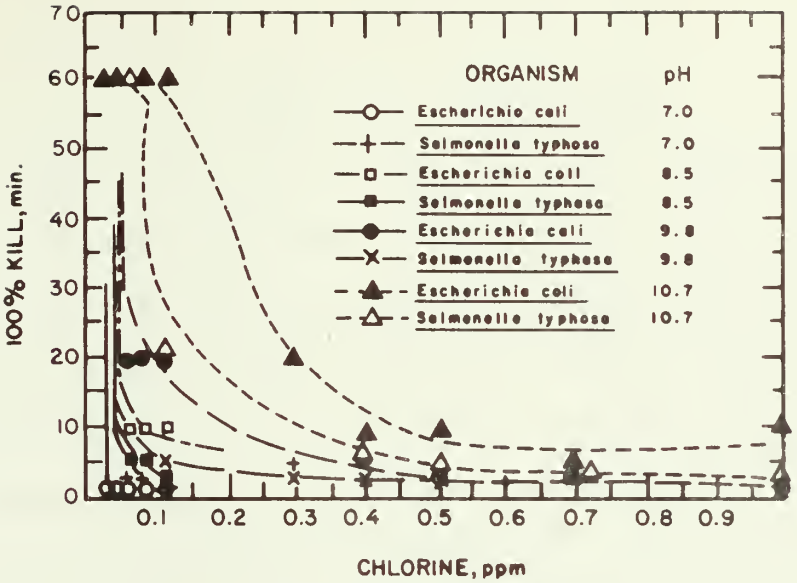


Figure 5-3 Residual Requirement for 100 Percent Kill at High Temperature. (9)

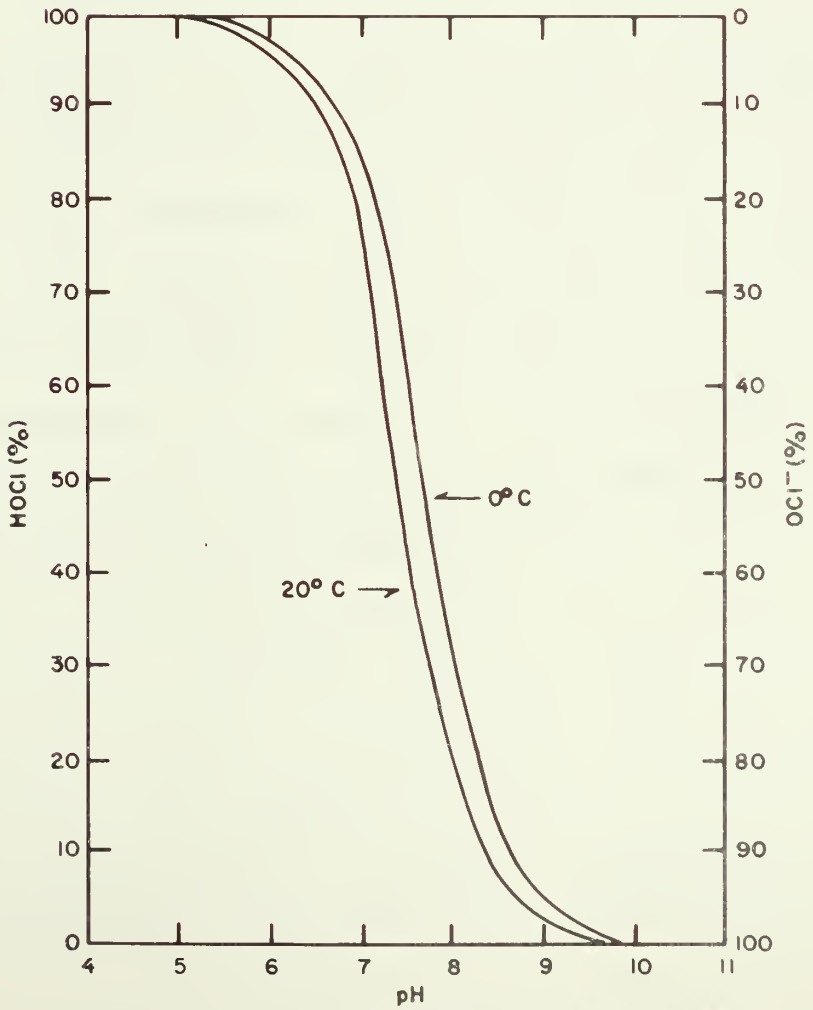


Figure 5-4 Effect of pH on Quantities of Hypochlorous Acid (HOCl) and Hypochlorite Ion (OCl—) Present in Water. (18)

Chapter 6. COAGULATION

Coagulants may be defined as those substances which are capable of removing colloidal impurities from water and coagulation is the process by which such removal is brought about. Particles in the colloidal phase will usually fall between 0.5 mu (millimicron) and 100 mu; above the higher figure they merge into the suspensions and emulsions which may be separated more or less readily by physical means. (14)

Colloids may be precipitated by ions of opposite charge. Generally the precipitating power of a bivalent ion will be 50-60 times as great as a monovalent ion and the precipitating power of a trivalent ion will be 600-700 times as great as that of a monovalent ion. It is this remarkable fact which throws most light on the action of soluable aluminum and ferric salts as coagulants in water treatment. Donley (22) demonstrated that a polyelectrolyte with multiple charges can have significantly greater precipitating power than a trivalent ion.

Researchers have shown that the electrokinetic or zeta potential of the particle, pH, and other chemical characterisitcs of the solution all effect coagulation. (23) (24) (25) The chemical reactions are carried out in extremely low concentrations and good coagulation plant operation requires ingenuity, resourcefulness and scientific ability. Park personnel would face the handicap of a short season in a coagulation plant. Color and turbidity are prevalent often for only a one month duration and never for more than two months. Our experience and that of the water works in-

dustry have shown that a good floculating process may take one to two weeks to be operating properly. The result of this slow start up could mean that about the time the coagulation units are working properly the supplies will be clear. Recent process discoveries such as the Roberts Manhattan Process have greatly aided proper plant control and should be incorporated in any coagulation-filtration plant design. Because of the above considerations we are recommending that all areas that are not supplied by springs go to infiltration galleries which would be followed by polishing filtration except Grant which is a Lake supply followed by filtration. Old Faithful and Canyon have alternate coagulation-filtration processes recommended. Costing was done for coagulation-filtration versus the recommended processes and these studies showed that coagulation-filtration is the most expensive of possible alternatives.

COLOR REMOVAL

On Sept. 3, 1971 after a sudden cloudburst we measured 50 color units on the platinum-cobalt scale in the Firehole River. The maximum limit for color should be 15 color units (5) and less than 3 color units would be desirable. (26) The Firehole is the source of supply for Old Faithful and the employees and tourists all complain of the high color concentrations in May and June. Unfortunately, color is one of the more difficult particles to remove. 90% of color particles are 3.5 to 10 mu in size where clay particles are more apt to be 1 u. (13) It is generally agreed that the organic compounds producing color in water are derived mainly from soil humus which in turn, is produced by the

decay of vegetation. Color particles are invariably negatively charged and are hydrophilic in nature. These properties of small size, hydrophilic nature, and strong negative charge dictate a mechanism of removal entirely different from coagulation of turbidity.

Color removal is generally best in the pH range of 4 to 6. The relationships between pH, alum dosage, color removal and zeta potential are given in a series of graphs presented here as Figures 6-1, 6-2, and 6-3. [25] The chemical characteristics of the water will often adversely effect color coagulation. The Firehole water may prove difficult to coagulate as it is quite soft, cool, and will have a minimum of turbidity present.

Other forms of color removal besides coagulation have been tried with varying degrees of success. One of the more successful methods has been to heavily chlorinate (often break point chlorinate) the colored water. The City of Miami and Fort Lauderdale have successfully treated water having 55 and 80 color units respectively by chlorinating with about 8 mg/l dosages. [14] Chlorination followed by activated carbon filtration was tested in June, 1972 with a high degree of success on Old Faithful and Canyon water supplies. The activated carbon absorbed most of the color from the Firehole River and Cascade Creek sources and further removed the chlorine tastes. Fortunately, Super chlorination was effective in oxidizing color in these waters as it sometimes has little effect (often below 20 percent) on the colors of other waters. [15] Table C-4 lists the results of the chlorination-activated carbon filtration tests.

Extensive research points to one fact in coagulation - testing must be accomplished before final design.

TURBIDITY REMOVAL

Turbidity in surface waters consists largely of clays and other mineral particles. The size range of most of these particles is 0.2 to 5.0 u, which places them in the upper size range of true colloids and in a size range which would settle under gravity in sufficient time. Coagulation of such suspensions in contrast to color is accomplished relatively easily, once the proper pH and chemical dosages are obtained. In general, coagulation of dilute clay suspensions is controlled more by the coagulants and the chemical composition of the water than by the nature of the suspended solids. Figures 6-4 and 6-5 show the effect of pH and strength of coagulant on turbidity removal. [27] No source of supply requires turbidity removal as backwashable infiltration galleries are recommended.

RECOMMENDATIONS

General

Water samples were collected in early June to obtain representative color and turbidity samples. Moffett [28] states "Today, no water plant should be built without a complete process study prior to physical design."

Old Faithful and Canyon

Tests were run on the Firehole River and Cascade Creek colored waters using chlorination-activated carbon filtration which were totally successful. These successful tests negated the necessity for coagulation testing.

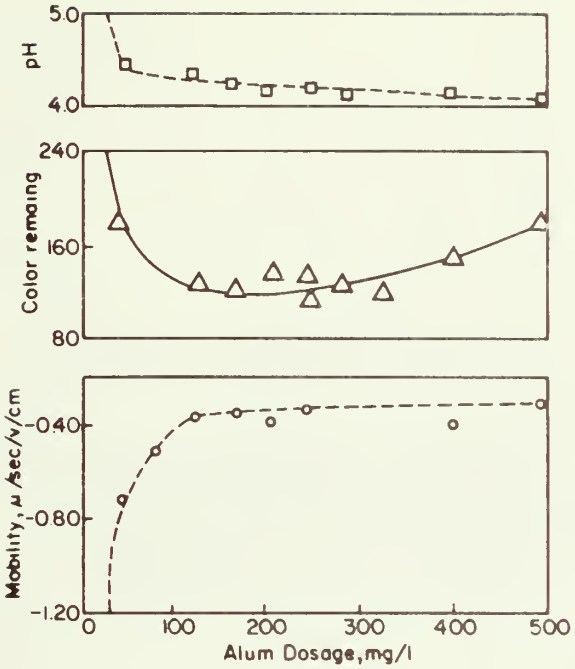


Fig 6-1 Effect of Alum Dosage on Coagulation of Colored Water. Curves Show the Effect of Alum Dosage on Floc Mobility, Color Removal, and pH. Color Removal was Poor with All Dosages, the Best Sample Showing a Residual Color of 120 Units.

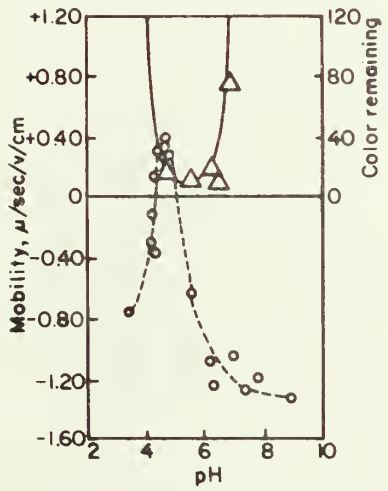


Fig. 6-2 Effect of pH on Coagulation of Colored Water with Constant Alum Dosage. A Constant Alum Dosage of 120 mg/l was Used, and pH was Adjusted with $Ca(OH)_2$. Excellent color Removal was Obtained within a Norrow pH zone of 5.0-5.7. Particle Charge First Decreased, then Reversed Almost Exactly at the Beginning of the pH Zone of Optimum Color Removal.

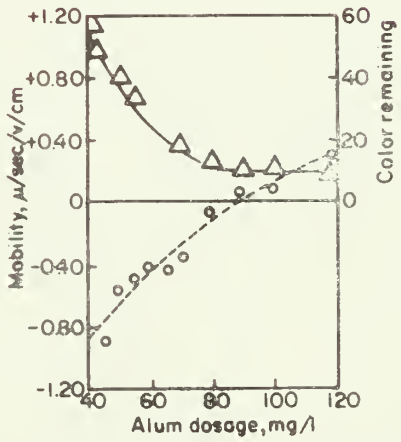


Fig. 6-3 Effect of Alum Dosage on Coagulation of Colored Water at Constant pH. The pH was Maintained Constant at 4.85 with Addition of HCl or $Ca(OH)_2$, While Alum Dosage was Varied. Color Reduction was Increased as Alum Dosage was Increased. Particle-Charge Reversal Occured Almost Exactly at the Alum Dosage for Optimum Color Removal.

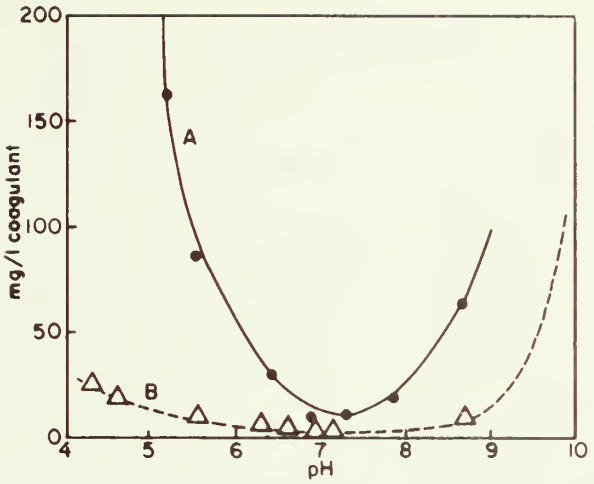


Fig. 6-4 Coagulation of 50mg/l Kaolin with Aluminum Sulfate and Ferric Sulfate. Comparison of pH Zones of Coagulation of Clay Turbidity by Aluminum Sulfate, Curve A, and Ferric Sulfate, Curve B. Points on the Curves Represent the Coagulant Dosage Required To Reduce Clay Turbidity to One-Half its Original Value. (27)

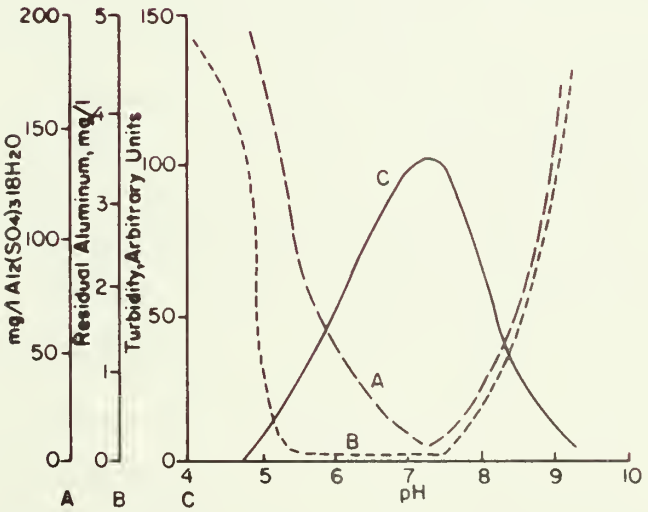


Fig 6-5 Comparison of the Effect of pH on: Curve A, Dose of Aluminum Sulfate Required to Halve Turbidity of 50mg/l Clay Suspension: Curve B, Aluminum Solubility as Indicated by Residual Aluminum After Coagulation with 200 mg/l $Al_2(SO_4)_3 \cdot 18 H_2O$; Curve C, Flocculation of $Al(OH)_3$ as Indicated by the Turbidity 1 Minute After Mixing the Reagents. (27)

Chapter 7. FILTRATION

Table 7-1 presents dual media, mixed media, high rate sand, diatomaceous earth and rapid sand filters, their respective estimated costs in the Park and some physical characteristics of each filter. The costs include a complete filtration plant and building but do not include coagulation costs. High rate filters have made it possible to eliminate the flocculation and settling sections of plants where certain design criteria exist. These are: (29)

1. Raw water turbidity must usually be below 35 ppm. However, some types of turbidity can successfully be treated in concentrations of up to 100 ppm.
2. The raw water supply must not be subject to rapid changes in the amount of turbidity.
3. At no time during the year can there be special problems, such as bacteria, algae, industrial wastes, etc., that require contact time with chlorine, carbon or other corrective chemicals.

With the recommended intake facilities all Park supplies studied meet the above criteria. D.E. (Diatomaceous earth) filtration was selected for Mammoth Hot Springs and Norris. Particle size and cost makes D.E. a good polishing filter which were the over-riding considerations. Activated carbon filtration was selected for Old Faithful and Canyon. Process testing dictated that chlorination-activated carbon filtration was successful in color reduction and was less expensive and far more trouble free than a coagulation-filtration process. The proposed Old Faith-

ful and Canyon treatment processes are:

1. Under-river infiltration to reduce turbidity.
2. Heavy chlorination to reduce color.
3. Activated carbon filters to reduce color and take out chlorine taste.
4. Sand to polish water.
5. Post chlorination.

DUAL AND MIXED MEDIA FILTERS

Conventional rapid sand filters accomplish the removal of particulate matter in the top 3" to 6" of the bed. For practical purposes, little or no removal takes place below 6" in the bed. Multi-media filters, on the other hand, filter throughout the depth of the anthracite bed. This section of the filter bed is designed to have large pores and high porosity for the storage of floc. The underlying sand bed is used as a polishing filter to remove any particulate matter that penetrates the full depth of the anthracite. It is this difference in filtration depth that makes the properly designed multi-media filter so effective in producing quality effluents with long runs while operating at high flow rates and handling large floc loads. The mixed media filter could be substituted for the D.E. filters but do not have as good bacteria or virus removal characteristics.

DIATOMACEOUS EARTH FILTERS

The filter medium used in diatomite filters is manufactured from diatomaceous earth deposits which consist of siliceous fossil remains of dead diatoms. Figure 7-1 shows three of the four steps of D.E. filtration. The final step is back-

washing either by compressed air or with water. The particle size of diatoms assures that final turbidities should be less than O.I.j.u. The D.E. plant is easily automated. Sufficient D.E. plants now exist and D.E. design is sufficiently refined to prove D.E. is an acceptable treatment practice.

Some question might arise as to the public health criteria of using the following total process:

1. Backwashable infiltration gallery.
2. Polishing D.E. filter with pre and post chlorination.
3. Four hour chlorine contact time.

As previously discussed the infiltration gallery should be classified as a ground water supply. However, the gallery may have limited effectiveness in removing coliform organisms. The D.E. filter even without pre and post chlorination will have good efficiency in removing coliform organisms. (30) Early U.S. Public Health Service Bulletins (31) established the relationship of various treatment processes to coliform removal. These studies showed that slow sand filters would reduce coliform counts to between 30 and 40 per 100 ml when the raw water count was 5000. The same studies showed that with a raw coliform loading of 1000 the filter effluent would approximate 10. Total treatment including coagulation and settling would result in effluent coliform loadings of between 20 and 30 and 6 respectively when using the same raw water loading. Recent studies (32) (33) show that D.E. filters can give "complete" coliform removals up to influent coliform levels of several thousand per 100 ml and further that the

D.E. filter has excellent results in virus removal. By using pre and post chlorination 4 hour contact time, and D.E. filtration, residual bacteria and virus would be eliminated. D.E. filtration can be expected to cost 1¢ to 2¢ per 1000 gallon. Disposal of the backwash material must be considered for each installation.

ACTIVATED CARBON FILTERS

Activated carbon is a form of charcoal that has been so treated as to make it highly absorbent of various materials. It has a fairly high affinity for absorbing chlorine. Powdered carbon is seldom used for dechlorination as carbon beds are normally the more successful media. Essentially activation processes consist of the source materials (bituminous coals, etc.) being carbonized under controlled conditions and the resulting carbon being treated with an oxidizing gas, such as steam or air, at elevated temperatures. (34)

The Firehole River and Cascade Creek can be successfully treated for color removal with chlorination followed by activated carbon filtration. The activated carbon also removes the high chlorine residuals. The carbon can be fed as a slurry or used as part of a multi media filter. Recent published articles (35)(36) have discussed most of the advantages and disadvantages of carbon beds. Two important points seem to be that:

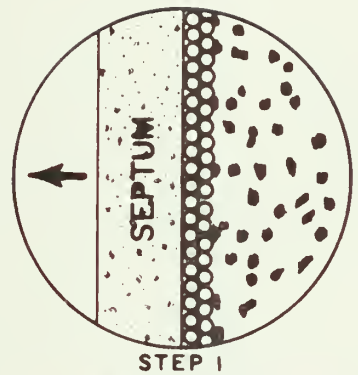
1. more efficient use can be made of carbon in the bed form than in the slurry form; and
2. there is no need to continually check for the proper dose with carbon beds.

For the above reasons we are recommending that activated carbon be used as a carbon bed filter.

TABLE 7-1. FILTERS

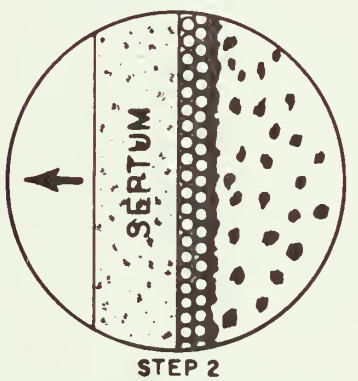
	FILTER	GRAVITY OR PRESSURE	MEDIA **	PARTICLE SIZE **	FLOW RATE GPM/ft^2	COST PARK for 1 mgd
1.	Dual Media	Normally Gravity	Anthracite Sand	microms-u 800-1200 300	4	$280,000
2.	MIXED MEDIA*	Normally Gravity	Anthracite Sand Garnet	800-1200 300 100	4	280,000
3.	Hi Rate Sand	Pressure	Sand Garnet	300 100	4	100,000
4.	Diatomaceous Earth	Pressure or Vacuum	Diatoms with Septum	10-20	1	100,000
5.	Rapid Sand	Normally Gravity	Sand Gravel	300	2	290,000

* Micro Floc Patent
** Media and Particle size are examples only - and can be varied



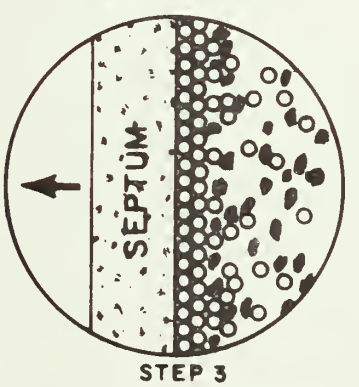
STEP 1

Diatomite Precoat on Septum
(Normal Flow.)



STEP 2

Filtered Solids Clogging Precoat
(Reduced Flow.)



STEP 3

Cake Kept Open by Continuous
Feed.(Normal Flow.)

FIG. 7-1 DITOMACEOUS EARTH FILTER

PART II

DETAILED ANALYSIS

GENERAL

Chapters 8-15 will describe and evaluate the existing systems and make firm recommendations for improvements. Some detail covered elsewhere in the report will not be restated. The readers attention is called to the following tables for detailed analysis of different systems aspects that are pertinent to design but are not covered in detail in Part II:

Table 2-2. Water Quality Summary (mg/l)
Table 2-3. Coliform Bacteria in Source of Supply and Other Selected Waters
Table 3-3. Man Made Fish Barriers on Existing Intakes
Table 3-4. Winter Use of Systems
Table 5-1. Existing Chlorination Review
Table A-5. Existing Tank Schedule

Also some general statements are applicable to all areas and are stressed here:

1. All systems should be metered having TIR facilities. (Totalizing, Indicating, Recording)
2. A maintenance survey should be conducted each spring and equipment in disrepair should be repaired.
3. Power and telemetering lines should be placed under ground whenever possible where these lines effect the water systems.
4. Standby gasoline power plants are recommended and priced at all new systems.

All areas have different alternative systems that would be acceptable. Most of our technical reasons for selection are detailed in Part I. Some alternates are discussed and priced in Part II.

Chapter 8. MAMMOTH HOT SPRINGS AREA

The Mammoth Hot Springs area is located along the northern section of the Grand Loop Road at its junction with the North Entrance Road as shown in Figure 8-1. The primary visitor attractions include the large hot springs and colorful terraces. The village is the permanent Park headquarters for the National Park Service and is the only year-round residential and tourist area in the Park.

During the main tourist season, the Mammoth Hot Springs area accommodates about 7 percent of the total overnight population. Visitor accommodations include the Mammoth Inn with hotel and tourist cabins and the campground. Employee accommodations include a trailer village, several dormitories, and both seasonal and permanent apartments and residences. The 1971 census figures reported an overnight population of 1,700 for Mammoth Hot Springs, of which 650 were listed as employees. Overnight population during the winter season averages over 200.

Many of the permanent apartments and residences, and nearly all of the administration and maintenance offices, occupy masonry structures constructed during the army administration around the turn of the century. These structures are now considered to be historical sites and are to be preserved. The section of the present Grand Loop Road that curves through the area will be relocated.

DESCRIPTION OF EXISTING WATER SYSTEM

A major portion of the water system was constructed during the 1920's and 1930's. The principal exception to this is the relatively new adequately sized mains in the employee residence area. The entire existing system is shown in Figure 8-2.

The maximum required flow for a peak day is 2,700,000 gpd or 1870 gpm. This high water requirement (1230 gcd) is caused from no metering of lawn water use, an extremely porous soil and around the clock lawn watering. Table 8-2 gives the design criteria for the proposed system.

The existing system is described as follows:

> Water is taken from four separate sources: Indian Creek, Panther Creek, the Gardner River and Glen Creek. Historically a major portion of this water was used for the 24" penstock that feeds the power house. This power house is still in existence and can be used. The Indian Creek diversion sends water by open channel flow to Panther Creek. The older Panther Creek Intake and newer Gardner River Intake, from a location near their convergence, transmit water by gravity flow in a concrete pipeline to Swan Lake Flats. Figure 8-3 shows the high summer flow from this pipeline that supplements Glen Creek. Glen Creek water with the supplemental flow is transported in an open stream over Rustic Falls to the Glen Creek Intake. From the Glen Creek Intake large steel lines carry the water to the large open reservoir, or the water can by-pass the reservoir and go directly to Mammoth. By gravity flow the water is withdrawn from the open reservoir, is chlorinated continuously, and passed through a 26,000 gal. concrete reservoir at a flow rate of 2,530 gpm. From the concrete reservoir the flow continues in steel transmission lines to a small high pressure reservoir just above the terraces. This pressure reservoir, shown in Figure 8-4, is a series of chambers that have the following functions:

1. Water is withdrawn under pressure in a C.I. line around the east side of the lower open reservoir to Mammoth.

2. Water is withdrawn by gravity in V.C. tile to another pressure tank immediately west of the open reservoir.

3. Water is withdrawn under pressure in a C.I. line to the east to the few services located on the bench.

Figures 8-5 and 8-6 show respectively the open reservoir and the excess water being wasted out of this reservoir. The excess water that Mammoth is not using comes from the pressure reservoir immediately west of this open reservoir. From this final pressure reservoir C.I. mains transmit the water into the Mammoth distribution system. The distribution system is principally on two elevation levels with two pressure reducing vales separating the two levels. The upper level operates at a pressure between 70 and 80 p.s.i. and the lower level between 80 and 140 p.s.i.

EVALUATION OF EXISTING SYSTEM

The Park Service realized the complexities and inadequacies of the existing system and made the Mammoth Hot Springs Area our number one priority. The principal problem is that no good, dependable source is near the community(3) and that large quantities of water must be transmitted great distances. Table 8-3 presents an evaluation of the existing system which is expanded upon with the ensuing discussion.

The Glen Creek intake is located about half way down the Glen Creek Canyon. During annual high spring runoff the turbulent water carries large trees and boulders which makes annual repair and operation a continuing expensive problem. The shallow concrete transmission line from the Gardner River Intake to Swan Lake Flats is old (built in the 1930's) and in places badly

deteriorated. Thirteen cfs is taken into this line at the upper intake and eight cfs is discharged, thus 5 cfs is lost through leakage. Figures 8-7 through 8-10 point to the condition of this line. Several potential cross connections between chlorinated and unchlorinated sources exist throughout the system and are shown on Figure 8.2. The old wrapped 18" steel line that carries water from the small upper 26,000 gal. tank to the upper pressure reservoir is not transporting water under pressure but is being used as a gravity supply line. The line seems be in good condition but is shallow and exposed at one location.

The large open reservoir near the Glen Creek intake is no longer satisfactory for domestic supply. The small tank near the open reservoir provides about ten minutes chlorine contact time before the water is transported to the community. In the spring the large open reservoir and small tank cannot settle out all of the turbidity and sufficient quantities remain to cause justified complaints. The chlorinator runs constantly and all unused chlorinated waters are passed into the lower open reservoir and thus wasted. Heavy chlorinating is required as no system exists to adequately control the flows into Mammoth. The treatment system is inadequate as:

1. A short chlorine contact time exists.
2. A surface supply is treated only with chlorination.
3. Turbidity gets into the domestic supply in the spring.
4. Chlorine has to be continuously wasted.

The detailed analysis for the distribution system appears in Appendix B. The older upper level is generally inadequate to provide peak domestic and fire flows. The lower level has adequately sized mains. All fire hydrants were checked and their condition is detailed on Figure 8-2. Many of the hydrants are old but in good condition. Lawns are watered 24 hours each day and this water use is almost entirely unmetered. This excessive watering causes the vast domestic flow quantities in the summer months. Fire hydrants spacing is adequate for fire protection.

RECOMMENDED CONSTRUCTION

Figures 8-13 and 8-14 show the horizontal and vertical location of proposed improvements. Figures 8-15 and 8-16 show the proposed infiltration gallery and D.E. filtration plants. Figures 8-17 and 8-18 are included to give the reader an idea of the types of construction problems that will be encountered. The recommended improvements will:

Provide a safe, potable supply.

Provide a new filtration plant and needed covered storage.

Eliminate potential health hazards.

Eliminate excessive water lost through leakage.

Provide a totally enclosed source from intake to consumer.

Eliminate chlorine waste.

Provide a turbidity free water.

Provide an adequate fire protection system.

The features of the plan include:

1. Reconstruct the Indian Creek Intake to be a permanent concrete installation that allows fish passage.

2. Reconstruct the Gardner River Intake for proper fish passage.

3. Construct a new backwashable infiltration gallery under Panther Creek and eliminate the existing Panther Creek Intake. This would provide a filtered ground water supply for Mammoth.

4. Construct a 100,000 gal. clearwell for backwash and service to the community in conjunction with the infiltration gallery.

5. Construct an additional surface water intake on the Gardner River for winter standby useage. The existing Gardner River Intake will be used for supplemental water for Rustic Falls.

6. Construct a new pressure transmission line from the new Panther Creek Intake to the new filtraplant. This line would parallel the existing gravity line shown on Figure 8-18, would run for a short distance in the highway in Glen Creek Canyon (Figure 8-18.) and then for the remaining distance follow an old roadbed to the treatment plant. The old road bed routing is an excellent routing down this difficult terrain.

7. Construct a D.E. pressure filtration plant and large clearwell to provide a highly polished finish water. Chlorination and fluoridation would be a part of this construction.

8. Construct many new transmission and distribution lines to provide flows for fire protection when domestic use is also high. Fire protection is currently inadequate in the employee trailer village and in the park headquarters area.

9. Proposed connections which may require new metering are important to provide looping for adequate fire flows.

10. Test the existing steel line from the new filtration plant to the proposed pressure reducing valve to make certain this line can carry adequate pressures.

11. Excessive lawn watering is a severe problem. If individual metering cannot be accomplished then no one should be allowed to water between the hot daylight hours of 9 a.m. and 5 p.m.

12. A complete control system should be provided to perform all processes automatically. Table 8-2 describes how this system would function. Most processes and tank levels will be monitored at the filtration plant area to provide local, easily accessible control for all system features.

13. Completely separate all of the domestic system from the penstock-power plant system.

The estimated total costs for all systems in this area are $2,091,500. The recommended immediate improvements are $1,440,600. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

The existing gravity line from the Panther Creek-Gardner River Intakes will not be used in the proposed domestic system improvements. The existing Gardner River intake will be used to maintain flow in this gravity line to furnish water for Rustic Falls and the Mammoth Power Plant.

The new supply system will not provide water for the hydroelectric plant.

ALTERNATIVES CONSIDERED

Alternatives considered for the Mammoth Hot Springs are included:

1. Utilization and extensive remodeling of the existing Glen Creek Intake. This was the lowest cost source improvement considered but was still quite expensive. Due to the sometimes low flow in Glen

Creek supplemental water would still be required at times. Finally, and the reason for the rejection of this alternate, is that protection from continuous maintenance problems could not be guaranteed because of the boulders and debris associated with high spring runoff.

2. Lava and Lupine Creek were considered as potential supply sources above the Lava Creek Campground. Studies showed this to be a more expensive system than that proposed as:

   A. Over 4 miles of quite expensive pressure main construction was required.

   B. Because of elevation considerations the pressure main would need to be a 14 inch.

   C. The exceptionally good routing down Glen Creek Canyon (Golden Gate Canyon) did much to lower the proposed routing costs. No such good routing was found for the Lava-Lupine Creek transmission.

   D. The Sheepeater Canyon Bridge across the Gardner River is an expensive difficult Crossing.

   E. Finally the Panther-Indian Creek turbidity is less and easier to control than would be the spring runoff in Lava-Lupine Creeks.

3. Mixed media filtration would be an acceptable alternative to D.E. filtration.

4. Though not utilized in the domestic system report, it is recommended that the gravity concrete line, from the intake to Swan Lake Flats, be repaired throughout most of its length by relining, by pulling a new polyethelene tube through the existing pipe, or by replacement.

TABLE 8-1. POPULATION AND MAXIMUM FLOWS, MAMMOTH HOT SPRINGS AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
				Existing	Future
	Existing	Future	gcd	gpd	gpd
NPS Trailer Court					
32 sites and 9 Wingfoot units	125	135	50	6,250	6,750
Upper and Lower Cliff houses	30	40	1000	30,000	40,000
Sub Total	155	175		36,250	46,750
Hamilton coffee shop area					
Coffee shop and cafeteria	--	--	--	15,000	15,000
Dormitories	40	50	75	3,000	3,750
Sub Total	40	50		18,000	18,750
Hotel area					
Service station	--	--	--	2,000	2,000
General store and dormitories	22	32	75	1,650	2,400
Hotel	270	360	75	20,250	27,000
Cabins	230	290	50	11,500	14,500
Dormitories	200	250	75	15,000	18,750
Print shop	--	--	--	5,000	5,000
Laundry	--	--	--	20,000	20,000
Cafteria, coffee shop	--	--	--	50,000	50,000
Residences	13	20	1,000	13,000	20,000
Sub Total	735	952		138,400	159,650

TABLE 8-1. POPULATION AND MAXIMUM FLOWS, MAMMOTH HOT SPRINGS AREA-contd.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gpd	Existing gpd	Future gpd
Photo shop area					
Photo shop	--	--		500	500
Residences	45	45	1,000	45,000	45,000
Sub Total	45	45		45,500	45,500
NPS administration and residence area					
Residences and apartments	100	130	1,000	100,000	130,000
Offices and shops	--	--	--	12,000	12,000
Dormitories	10	20	75	750	1,500
Clinic	--	--	--	7,000	7,000
Sub Total	110	150		119,750	150,500
Ranger headquarters area					
Offices and shops	--	--	--	500	500
Mess hall	--	--	--	6,000	6,000
Dormitories	25	50	75	1,875	3,750
Sub Total	25	50		8,375	10,250
Residential area	230	250	1,000	230,000	250,000
Campground	440	500	50	22,000	35,000
Lawns and Parks*	--	--	--	1,200,000	1,200,000
Sub Total	670	750		1,452,000	1,485,000

* Includes all lawns and parks not included in residences.

TABLE 8-1. POPULATION AND MAXIMUM FLOWS, MAMMOTH HOT SPRINGS AREA-contd.

DESCRIPTION		POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
		Existing	Future	gcd	Existing gpd	Future gpd
	TOTAL	1,780	2,172	5,600	1,818,275	1,916,000
	Say:	1,780	2,200		1,819,000	1,917,000

Actual maximum measured total flow - 2,224,000 gpd

TABLE 8-2 BASIC DESIGN DATA, MAMMOTH HOT SPRINGS AREA

ITEM	EXISTING	DESIGN
POPULATION	1,780	2,200
WATER FLOW		
Peak, g.p.d.	2,224,000	2,700,000
Peak, g.p.m.		1,870
INTAKE		
Backwashable Infiltration Gallery		
Filter rate gpm/ft^2 - avg.		2
Design capacity - continuous - gpm		2,000
Maximum capacity - gpm		2,500
No. of filters		4
Gardner River - standby		
Intake rate maximum - gpm		4,500
Pumping - 2 ea. - total - gpm at 30' T.D.H. for backwash		2,500
TREATMENT		
Ground water source - no turbidity		
Diatomaceouse earth - pressure filters		
Rate - gpm/ft^2		1
Rate - gpm avg.		2,000
Rate - gpm max.		2,500
Chlorination - pre and post on D.E. filters		
Contact time - hours		4
Fluoridation - mg/l residual		1-1.5
STORAGE		
Infiltration Gallery - gals.		100,000
Service - backwash and to system - underground		
Filtration Plant - clearwell - gals.		800,000
Service - chlorine contact time, control and to system - underground		

TABLE 8-2. BASIC DESIGN DATA, MAMMOTH HOT SPRINGS AREA-contd.

ITEM	EXISTING	DESIGN
DISTRIBUTION		
For Hardy Cross Network Analysis		
Peak 4 hr. domestic flow - gpm		2,350
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commercial fire flow - gpm		1,500
PEAK FLOWS FOR STORAGE DESIGN*		
Maximum flow input - gpm		2,500
Maximum 4 hr. fire flow - gpm		1,500
Peak 4 hr. domestic flow - gpm		2,350
CONTROL SYSTEM		
Backwashable Infiltration Gallery and Clearwell:		
1. Backwash each line separately for set time.		
2. Backwash cycle starts when backwash clearwell drops, i.e. infiltration rate less than flow to filter storage.		
3. Gravity flow to service to stop when filtration plant storage is full.**		
4. Transmit backwash clearwell level to Filtration Plant.		
5. T.I.R. outlet flow from backwash clearwell.		
Filtration Plant and Storage		
1. Auto-valves to control pressure and flow input.		
2. T.I.R. flow in and out.		
3. Fully automatic D.E. filtration plant (use one 500 gpm filter for winter use) but stagger useage.		
4. Receive and record backwash clearwell level.		
5. Filtration plant storage lets water in from pressure line on storage level control.		
6. Record filtration plant storage level.		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Pressure sensing control equipment.

TABLE 8-3. EVALUATION OF EXISTING SYSTEM
MAMMOTH HOT SPRINGS AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
GENERAL	All gravity flow		
INTAKE			
1. Indian Creek	Wooden, old	Poor	
2. Panther Creek	Deteriorated concrete, old	Fair	
3. Gardner River	Good concrete, fairly new	Good	
4. Glen Creek	Average to good concrete and steel	Good	
TRANSMISSION LINES			
1. Gravity line Gardner R. intake to Swan Lake Flats	Concrete, old, different sizes	Poor	Shallow
2. Low pressure line - Glen Creek to Lower Reservoir	Steel, wrapped, old	Good to fair	Sometimes shallow
3. Short line upper pressure reservoir to lower pressure reservoir	V.C., old	Good	
4. Pressure lines, upper pressure reservoir to Distribution	C.I., old and new	Good	
STORAGE			
1. Upper large reservoir	Uncovered open lake		Inadequate
2. Upper underground tank	Concrete, old, 26,000 gal.	Good	
3. Upper pressure reservoir	Concrete, old	Good	
4. Lower pressure reservoir	Concrete, old	Good	

TABLE 8-3. EVALUATION OF EXISTING SYSTEM

MAMMOTH HOT SPRINGS AREA

(contd.)

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
TREATMENT			
1. Chlorination - gas	Continuous with booster	Good	Inadequate
DISTRIBUTION SYSTEM			
1. Upper level	C.I. and G.S. - old	Fair	Inadequate
2. Lower residential level	C.I. - fairly new	Good	



LEGEND

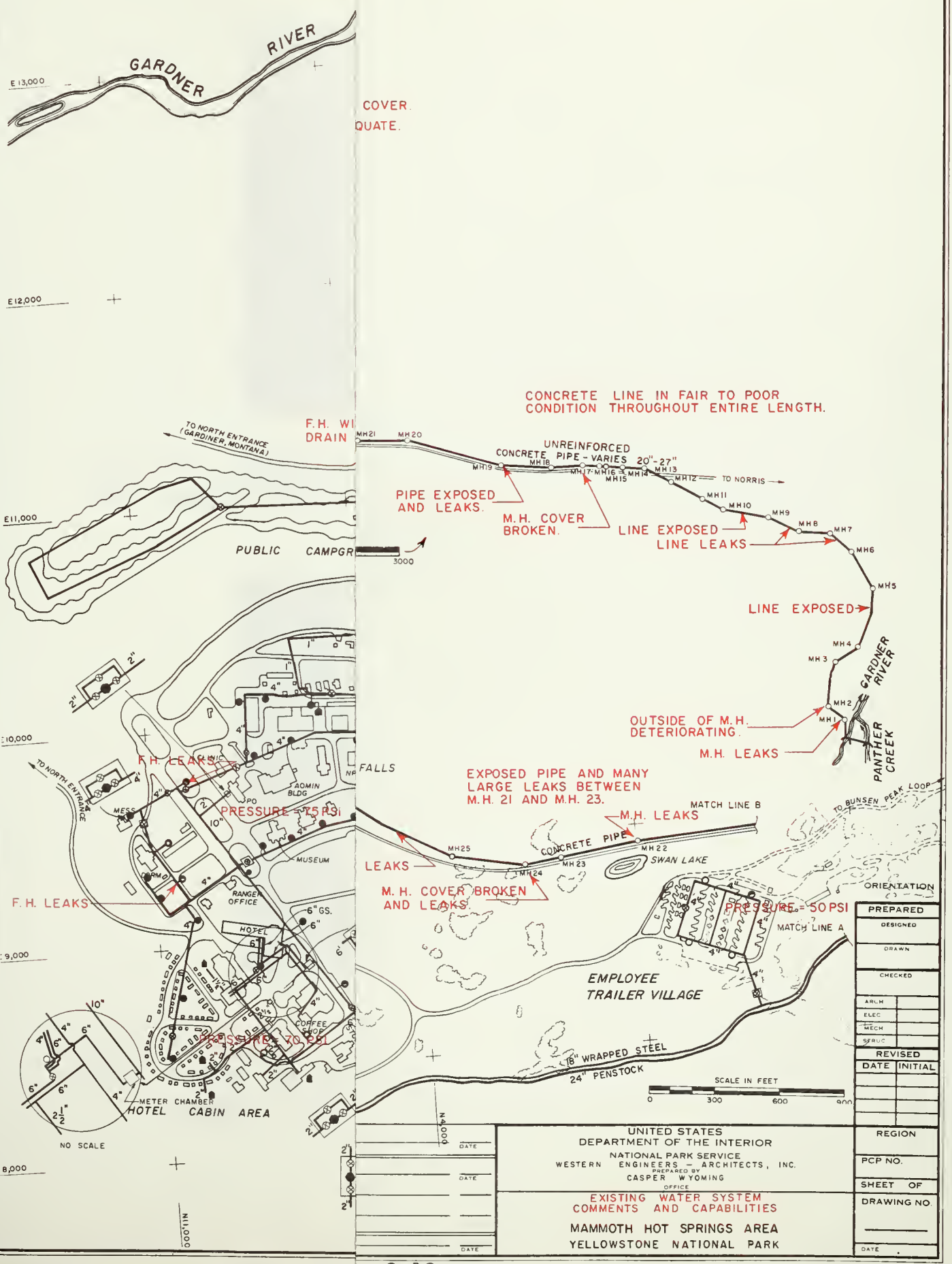
- PROPOSED WTP
- EXISTING INTAKE
- EXISTING WATER LINE
- PROPOSED WATER LINE
- PROPOSED STORAGE
- PROPOSED INTAKE
- SERVICE AREA

SCALE IN MILES

0 1 2 3

N

FIG. 8-1 MAMMOTH HOT SPRINGS AREA VICINITY MAP


GARDNER RIVER
E 13,000
COVER.
QUATE.
E 12,000
E 11,000
E 10,000
E 9,000
8,000
N 11,000
N 4000
CONCRETE LINE IN FAIR TO POOR CONDITION THROUGHOUT ENTIRE LENGTH.
F.H. WI
DRAIN
TO NORTH ENTRANCE (GARDINER, MONTANA)
MH21
MH20
UNREINFORCED CONCRETE PIPE - VARIES 20"-27"
MH19
MH18
MH17
MH16
MH15
MH14
MH13
MH12
TO NORRIS
MH11
MH10
MH9
MH8
MH7
MH6
MH5
MH4
MH3
MH2
MH1
PIPE EXPOSED AND LEAKS.
M.H. COVER BROKEN.
LINE EXPOSED
LINE LEAKS
LINE EXPOSED
GARDNER RIVER
OUTSIDE OF M.H. DETERIORATING.
M.H. LEAKS
PANTHER CREEK
PUBLIC CAMPGR
3000
FALLS
EXPOSED PIPE AND MANY LARGE LEAKS BETWEEN M.H. 21 AND M.H. 23.
MATCH LINE B
M.H. LEAKS
TO BUNSEN PEAK LOOP
CONCRETE PIPE
MH25
MH24
MH23
MH22
SWAN LAKE
LEAKS
M. H. COVER BROKEN AND LEAKS.
F.H. LEAKS
PRESSURE = 75 PSI
PRESSURE = 50 PSI
MATCH LINE A
ORIENTATION
EMPLOYEE TRAILER VILLAGE
18" WRAPPED STEEL
24" PENSTOCK
SCALE IN FEET
0
300
600
900
ADMIN BLDG
MUSEUM
RANGER OFFICE
HOTEL
COFFEE SHOP
MESS
PO
FORMO
F.H. LEAKS
PRESSURE = 70 PSI
METER CHAMBER
HOTEL CABIN AREA
NO SCALE
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
MAMMOTH HOT SPRINGS AREA
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

MAMMOTH HOT SPRINGS

NOTE.
1. ALL MAINS HAVE 4' OR MORE COVER
2. FIRE HYDRANT COVERAGE IS ADEQUATE

GARDNER RIVER
SEWAGE TREATMENT PLANT
DUMP AREA
INCINERATOR
SLUDGE BED
SEPTIC TANK
CHLORINE BLDG
E13,000
E12,000
E11,000
10,000
9,000
8,000
TO NORTH ENTRANCE (GARDINER, MONTANA)
YARD
SCHOOL
PRESSURE - 85 PSI
F.H. WILL NOT DRAIN
EMPLOYEE RESIDENCES
DR
HOUSE SERVICE
LOST LAKE
F.H. WILL NOT DRAIN
PRESSURE REDUCING VALVE
GARAGE
POWER HOUSE
NOTE 2", 4", 8" lines in this area do not connect.
PRESSURE REDUCING VALVE
F.H. LEAKS
PUBLIC CAMPGROUND
F.H. LEAKS
F.H. LEAKS
PRESSURE 175 PSI
NPS OFFICE
ADMIN BLDG
CHAPEL
PARK HEADQUARTERS
MUSEUM
HAYNES PHOTO
RANGER OFFICE
HOTEL
CAPITOL HILL
F.H. LEAKS
VALVE CHAMBER COVER LOOSE
OPAL TERRACE
PRESSURE 70 PSI
SERVICE STATION
METER CHAMBER
HOTEL CABIN AREA
NO SCALE
CURIO SCOFT
TERRACE
AREA
24" PENSTOCK
LOWER CLIFF HOUSE
UPPER CLIFF HOUSE
BARN
CEMETERY
HOUSE SERVICE
GRAND LOOP ROAD
EXCESS WATER RELEASED
RESERVOIR
PRESSURE RESERVOIR
HIGH PRESSURE RESERVOIR
10" G.V.
18" TILE
TO MORRIS JUNCTION
32 M.
LINE EXPOSED
GRAND LOOP ROAD
MATCH LINE A
OPEN DOMESTIC RESERVOIR
26,000 GAL CONCRETE WATER RESERVOIR
CHLORINE HOUSE
BEAVER POND
18" DR
PENSTOCK
DOMESTIC
24" BY-PASS
TO CONCRETE RESERVOIR
TO OPEN RESERVOIR
TO OPEN RESERVOIR
ROAD
GRAND LOOP
ALUM CREEK
SCALE IN FEET
0 1000 2000 3000
CONCRETE LINE IN FAIR TO POOR CONDITION THROUGHOUT ENTIRE LENGTH
MATCH LINE B
UNREINFORCED CONCRETE PIPE - VARIES 20"-27"
MH21 MH20 MH19 MH18 MH17 MH16 MH15 MH14 MH13 MH12 MH11 MH10 MH9 MH8 MH7 MH6 MH5 MH4 MH3 MH2 MH1
TO NORRIS
PIPE EXPOSED AND LEAKS.
M.H. COVER BROKEN.
LINE EXPOSED
LINE LEAKS
LINE EXPOSED
OUTSIDE OF M.H. DETERIORATING
M.H. LEAKS
GARDNER RIVER
PANTHER CREEK
RUSTIC FALLS
EXPOSED PIPE AND MANY LARGE LEAKS BETWEEN M.H 21 AND M.H. 23.
M.H. LEAKS
MATCH LINE B
CONCRETE PIPE
MH25 MH24 MH23 MH22
SWAN LAKE
LINE LEAKS
M.H. COVER BROKEN AND LEAKS
PRESSURE - 50 PSI
MATCH LINE A
EMPLOYEE TRAILER VILLAGE
BUNSEN PEAK LOOP
ORIENTATION
18" WRAPPED STEEL
24" PENSTOCK
SCALE IN FEET
0 300 600

RECOMMENDED	
CONCURRED	
APPROVED	
UNITED STATES DEPARTMENT OF THE INTERIOR	REGION
NATIONAL PARK SERVICE	PCP NO.
WESTERN ENGINEERS — ARCHITECTS, INC PREPARED BY CASPER WYOMING OFFICE	SHEET OF
EXISTING WATER SYSTEM COMMENTS AND CAPABILITIES	DRAWING NO
MAMMOTH HOT SPRINGS AREA YELLOWSTONE NATIONAL PARK	

PREPARED
DESIGNED
DRAWN
CHECKED
REVISED
DATE | INITIAL

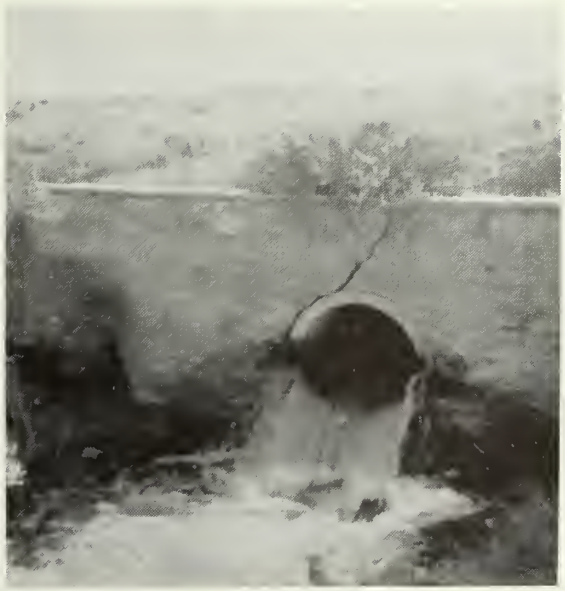


Fig. 803. Transmission Outlet - Swan Lake Flats - 8 c.f.s.
note: deteriorated concrete



Fig. 8-4. Pressure Reservoir Above Mammoth Terraces
note: covers not raised or locked
interior concrete in good condition



Fig. 8-5. Open Reservoir in Terraces Above Mammoth

note: water in lower left is wasted supply not needed for Mammoth



Fig. 8-6. Wasted Water Discharge from Reservoir

note: flow observed from 970 gpm minimum to 1500 gpm maximum this study - picture shows 970 gpm



Fig.8-7. Deteriorated M.H. Exterior

note: concrete gravity transmission line

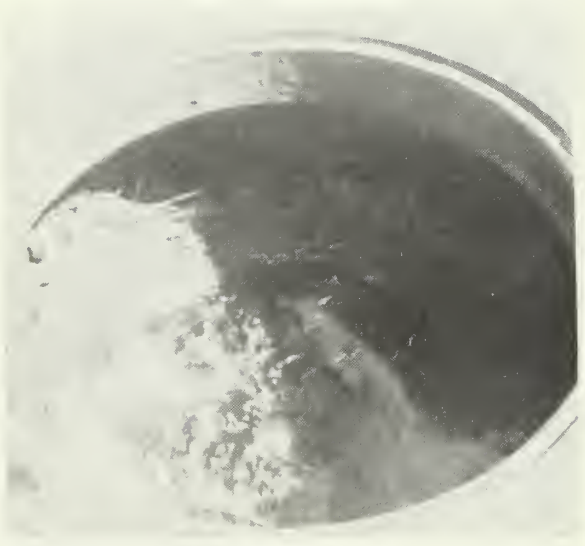


Fig. 8-8. Deteriorated M.H. Interior

note: concrete gravity transmission line



Fig.8-9. Shallow Concrete Transmission Line

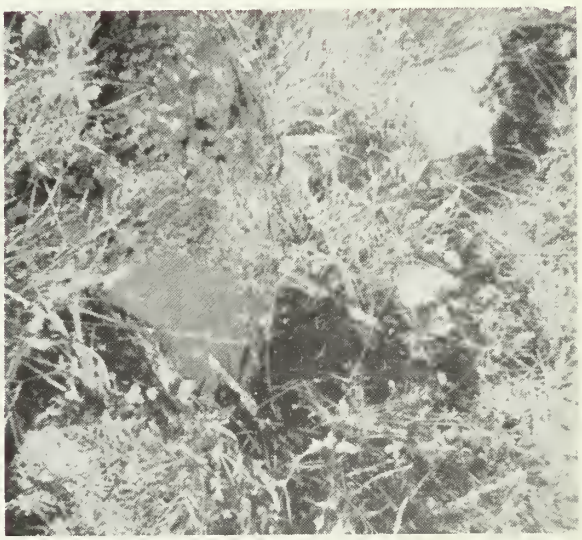


Fig. 8-10. Leak in Concrete Transmission Line

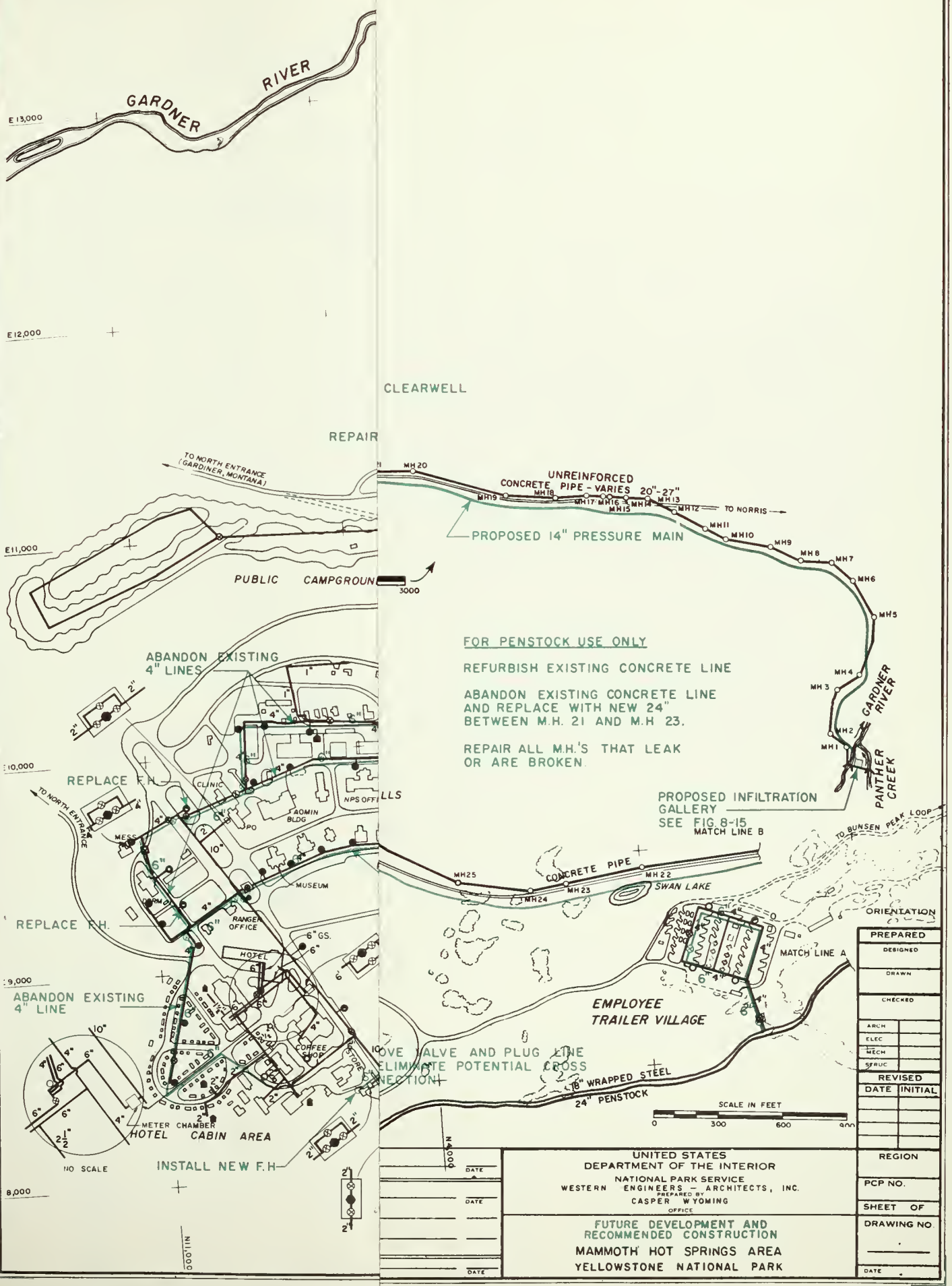




Fig. 8-11. Glen Creek Intake
note: high flow to left and steep gradient to right



Fig. 8-12. Typical Fire Hose House
note: common to most areas


GARDNER RIVER
E 13,000
E 12,000
E 11,000
E 10,000
E 9,000
E 8,000
CLEARWELL
REPAIR
TO NORTH ENTRANCE (GARDINER, MONTANA)
PUBLIC CAMPGROUN
3000
MH 20
UNREINFORCED CONCRETE PIPE - VARIES 20"-27"
MH19
MH18
MH17
MH16
MH15
MH14
MH13
MH12
TO NORRIS
MH11
MH10
MH9
MH8
MH7
MH6
MH5
MH4
MH3
MH2
MH1
GARDNER RIVER
PANTHER CREEK
PROPOSED 14" PRESSURE MAIN
FOR PENSTOCK USE ONLY
REFURBISH EXISTING CONCRETE LINE
ABANDON EXISTING CONCRETE LINE AND REPLACE WITH NEW 24" BETWEEN M.H. 21 AND M.H 23.
REPAIR ALL M.H.'S THAT LEAK OR ARE BROKEN.
ABANDON EXISTING 4" LINES
REPLACE F.H.
REPLACE F.H.
ABANDON EXISTING 4" LINE
INSTALL NEW F.H.
CLINIC
NPS OFF
ADMIN BLDG
P.O.
MESS
MUSEUM
RANGER OFFICE
HOTEL
COFFEE SHOP
STORE
METER CHAMBER
HOTEL CABIN AREA
NO SCALE
PROPOSED INFILTRATION GALLERY
SEE FIG. 8-15
MATCH LINE B
MH25
CONCRETE PIPE
MH24
MH23
MH22
SWAN LAKE
TO BUNSEN PEAK LOOP
ORIENTATION
MATCH LINE A
EMPLOYEE TRAILER VILLAGE
OVE VALVE AND PLUG LINE
ELIMINATE POTENTIAL CROSS
NNECTION
18" WRAPPED STEEL
24" PENSTOCK
SCALE IN FEET
0
300
600
900
N 4000
100' MIN
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
DATE
DATE
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
MAMMOTH HOT SPRINGS AREA
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

MAMMOTH HOT SPRINGS

GARDNER RIVER

SEWAGE TREATMENT PLANT

SEPTIC TANK

SLUDGE BED

CHLORINE BLDG

DUMP AREA

INCINERATOR

E 13,000

E 12,000

E 11,000

10,000

9,000

8,000

YARD

SCHOOL

REPAIR F.H

OR

REPAIR F.H

HOUSE SERVICE

EMPLOYEE RESIDENCES

LOST LAKE

TO NORTH ENTRANCE (GARDINER, MONTANA)

PUBLIC CAMPGROUND

REPAIR F.H

PRESSURE REDUCING VALVE

GARAGE

POWER HOUSE

NOTE: 2", 4", & 8" lines in this area do not connect.

ABANOON EXISTING 4" LINES

REPLACE F.H

REPLACE F.H

REPLACE F.H

CLINIC

ADMIN BLDG

NPS OFFICE

CHAPEL

TENTATIVE BYPASS ROAD LOCATION

HEADQUARTERS

MUSEUM

PARK

HAYNES PHOTO

CAPITOL HILL

REPLACE F.H

RANGER OFFICE

HOSP

ABANOON EXISTING 4" LINES

ABANOON EXISTING 4" LINE

FACILITIES TENTATIVELY SCHEDULED FOR FUTURE OBLITERATION

OPAL TERRACE

COFFEE SHOP

STORE

SERVICE STATION

METER CHAMBER

HOTEL CABIN AREA

NO SCALE

INSTALL NEW F.H

CURIO ACATE

TERRACE

AREA

PROPOSED FILTRATION PLANT AND CLEARWELL SEE FIG. B-16

24" PENSTOCK

LOWER CLIFF HOUSE

UPPER CLIFF HOUSE

BARN

CEMETERY

HOUSE SERVICE

GRAND LOOP ROAD

REMOVE VALVE AND PLUG LINE

ABANOON EXISTING 10" LINE AND PRESSURE RESERVOIRS

PRESSURE RESERVOIR

HIGH PRESSURE RESERVOIR

REPLACE WITH PRESSURE REDUCING VALVES SEE FIG. B-14

PRESSURE TEST EXISTING LINE BEFORE USING AS 70 PSI MAIN IN PROPOSED SYSTEM

TO NORRIS JUNCTION

REMOVE VALVE AND PLUG LINE TO ELIMINATE POTENTIAL CROSS CONNECTION. 16" DR

PENSTOCK

DOMESTIC

24" BY-PASS

TO CONCRETE RESERVOIR

TO PROPOSED 800,000 GAL CLEARWELL

TO OPEN RESERVOIR

TO OPEN RESERVOIR

26,000 GAL CONCRETE WATER RESERVOIR

CHLORINE HOUSE

ABANOON FOR DOMESTIC USE

BEAVER POND

MATCH LINE A

OPEN DOMESTIC RESERVOIR

ABANDON FOR DOMESTIC USE

PROPOSED 14" HIGH PRESSURE TRANSMISSION LINE (ALONG OLD ROAD BED)

MLEN CREEK

SCALE IN FEET 0 1000 2000 3000

MATCH LINE B

UNREINFORCED CONCRETE PIPE - VARIES 20"-27"

TO NORRIS

PROPOSED 14" PRESSURE MAIN

FOR PENSTOCK USE ONLY

REFURBISH EXISTING CONCRETE LINE

ABANOON EXISTING CONCRETE LINE AND REPLACE WITH NEW 24" BETWEEN M.H. 21 AND M.H 23.

REPAIR ALL M.H.'S THAT LEAK OR ARE BROKEN

MH1 MH2 MH3 MH4 MH5 MH6 MH7 MH8 MH9 MH10 MH11 MH12 MH13 MH14 MH15 MH16 MH17 MH18 MH19 MH20 MH21

GARDNER RIVER

PANTHER CREEK

RUSTIC FALLS

PROPOSED INFILTRATION GALLERY SEE FIG. B-15

MATCH LINE B

MH23 MH24 MH25

CONCRETE PIPE

MH22

SWAN LAKE

TO BUNSEN PEAK LOOP

ORIENTATION

MATCH LINE A

EMPLOYEE TRAILER VILLAGE

REMOVE VALVE AND PLUG LINE TO ELIMINATE POTENTIAL CROSS CONNECTION

16" WRAPPED STEEL 24" PENSTOCK

SCALE IN FEET 0 300 600 900

RECOMMENDED _____ DATE

CONCURRED _____ DATE

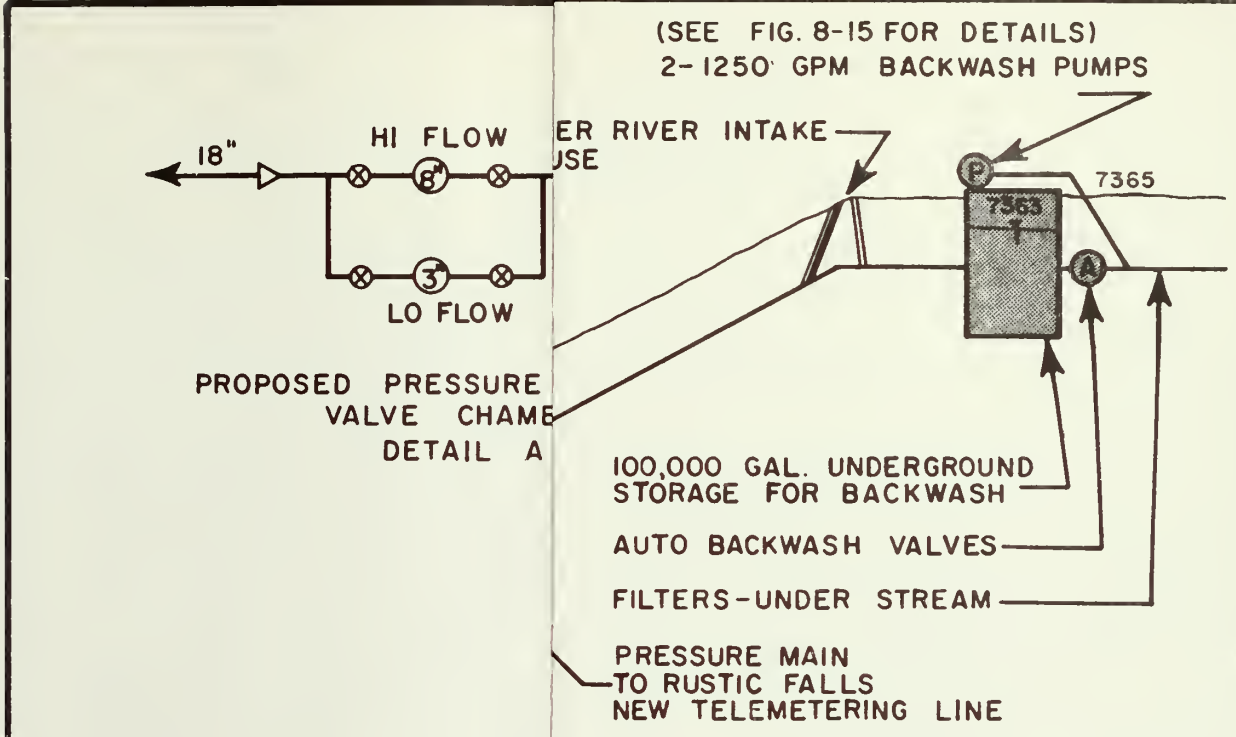
APPROVED _____ DATE

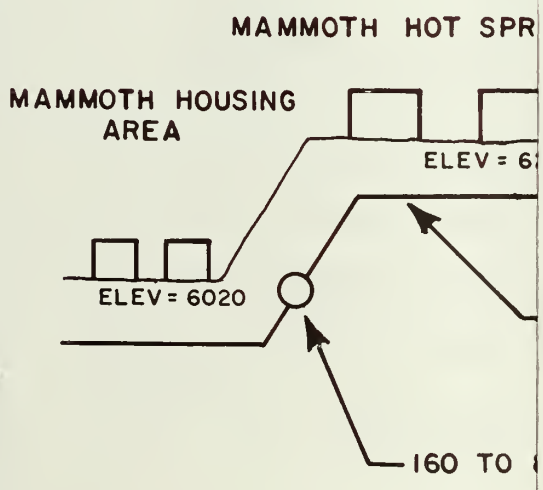
UNITED STATES DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
OFFICE CASPER WYOMING

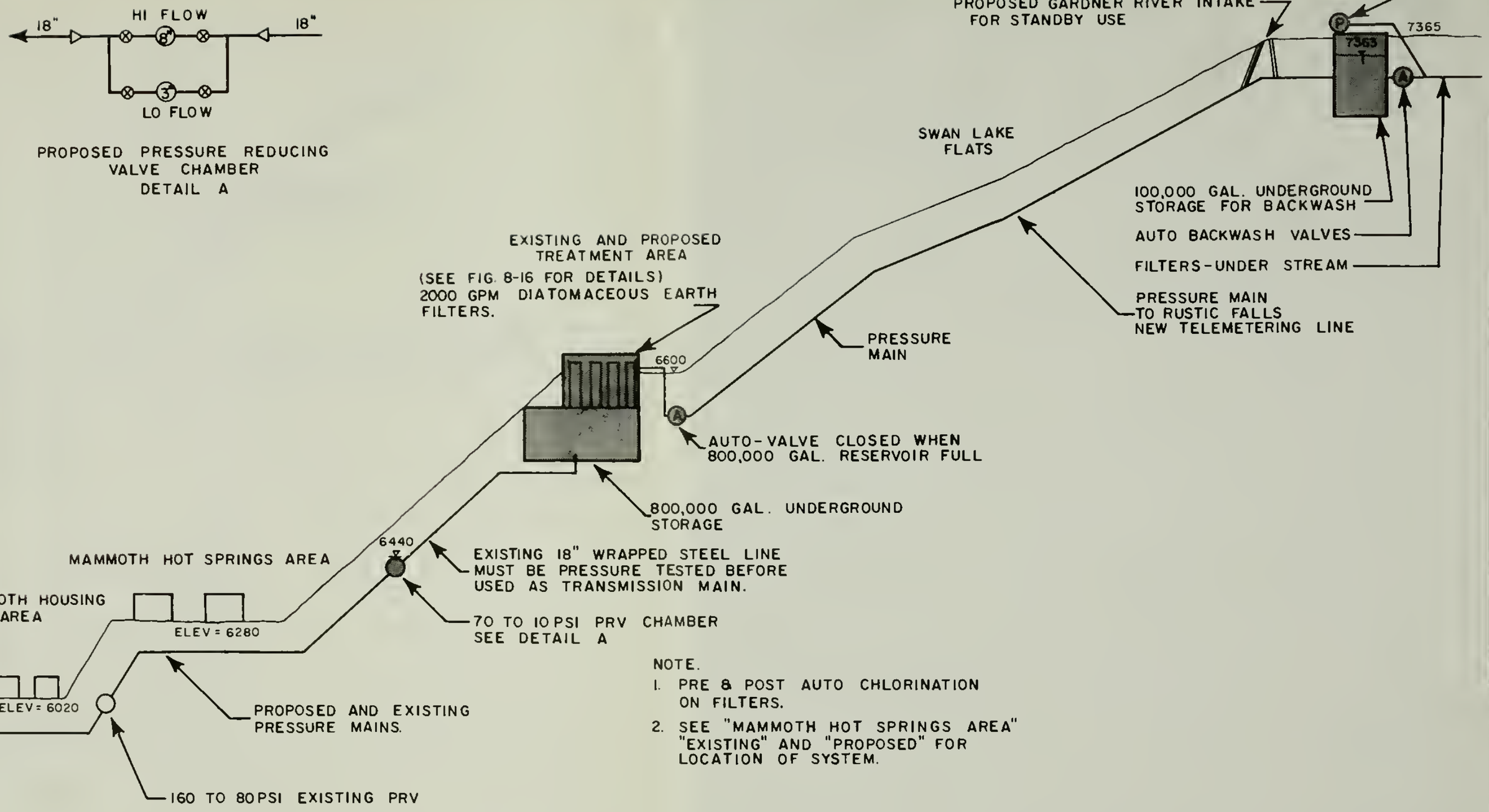
FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
MAMMOTH HOT SPRINGS AREA
YELLOWSTONE NATIONAL PARK

PREPARED
ORIGINED
DESIGN
CHECKED
REVISED
DATE | INITIAL

REGION
PCP NO.
SHEET OF
DRAWING NO


(SEE FIG. 8-15 FOR DETAILS)
2-1250 GPM BACKWASH PUMPS
ER RIVER INTAKE
USE
18"
HI FLOW
8"
3"
LO FLOW
PROPOSED PRESSURE
VALVE CHAME
DETAIL A
7365
7363
100,000 GAL. UNDERGROUND
STORAGE FOR BACKWASH
AUTO BACKWASH VALVES
FILTERS-UNDER STREAM
PRESSURE MAIN
TO RUSTIC FALLS
NEW TELEMETERING LINE

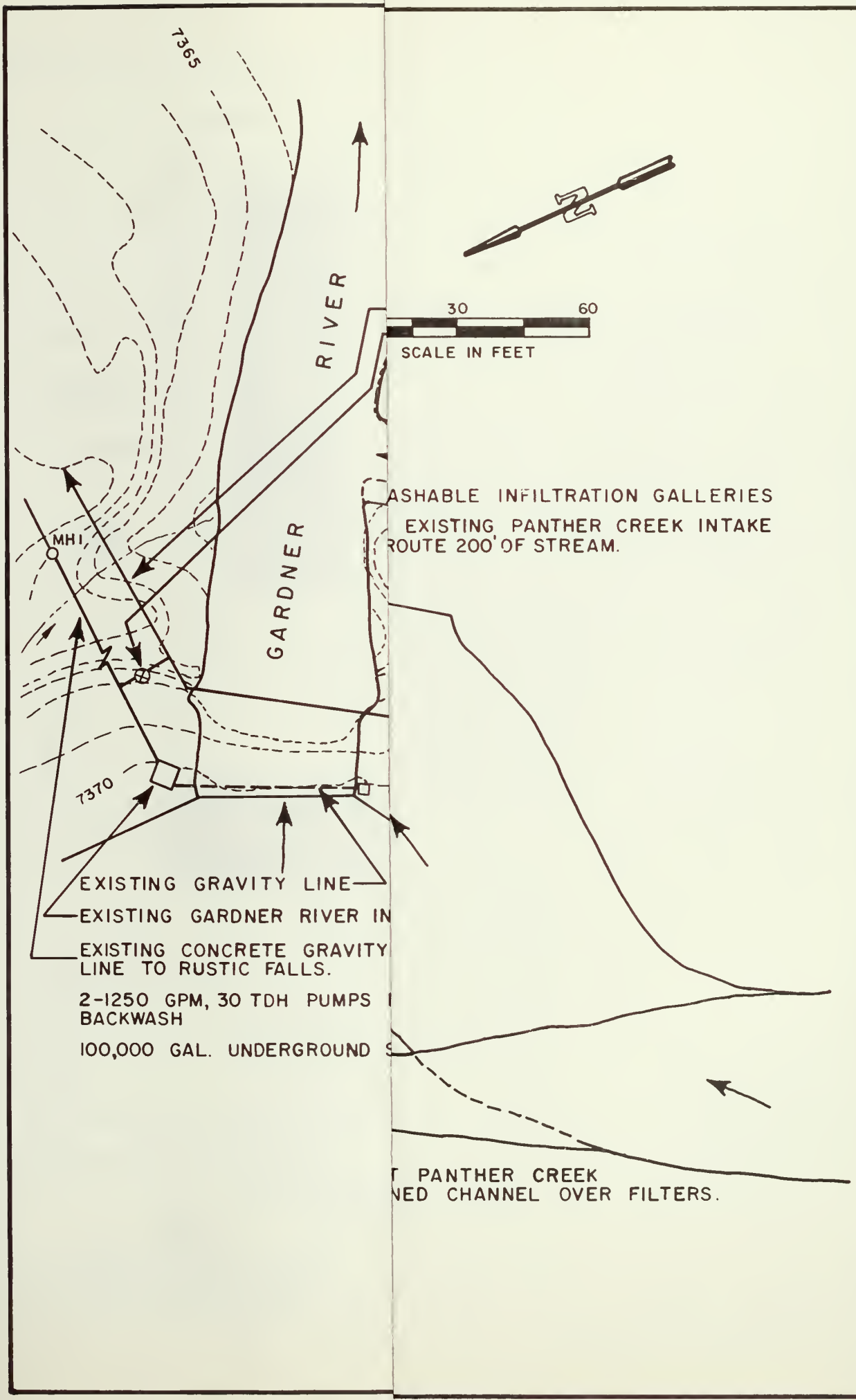

MAMMOTH HOT SPR
MAMMOTH HOUSING
AREA
ELEV = 6
ELEV = 6020
160 TO



NOTE.

1. PRE & POST AUTO CHLORINATION ON FILTERS.
2. SEE "MAMMOTH HOT SPRINGS AREA" "EXISTING" AND "PROPOSED" FOR LOCATION OF SYSTEM.

FIG. 8-14 MAMMOTH HOT SPRINGS AREA SCHEMATIC OF PROPOSED COLLECTION, TREATMENT, TRANSMISSION, AND STORAGE


7365
RIVER
30
60
SCALE IN FEET
ASHABLE INFILTRATION GALLERIES
EXISTING PANTHER CREEK INTAKE
ROUTE 200' OF STREAM.
MH1
GARDNER
7370
EXISTING GRAVITY LINE
EXISTING GARDNER RIVER IN
EXISTING CONCRETE GRAVITY
LINE TO RUSTIC FALLS.
2-1250 GPM, 30 TDH PUMPS
BACKWASH
100,000 GAL. UNDERGROUND
T PANTHER CREEK
NED CHANNEL OVER FILTERS.

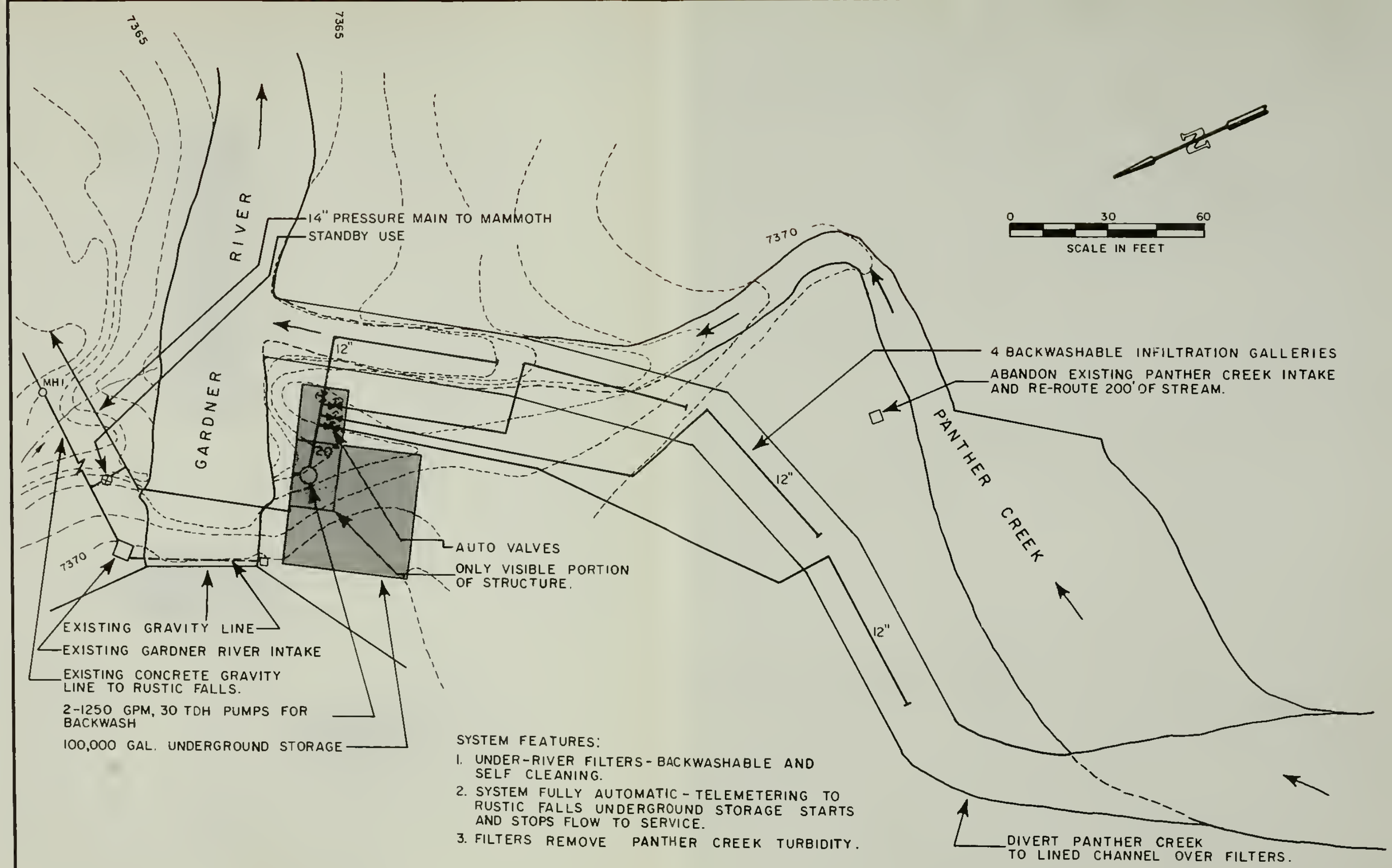


FIG. 8-15 **MAMMOTH HOT SPRINGS AREA**
PROPOSED BACKWASHABLE INFILTRATION GALLERY

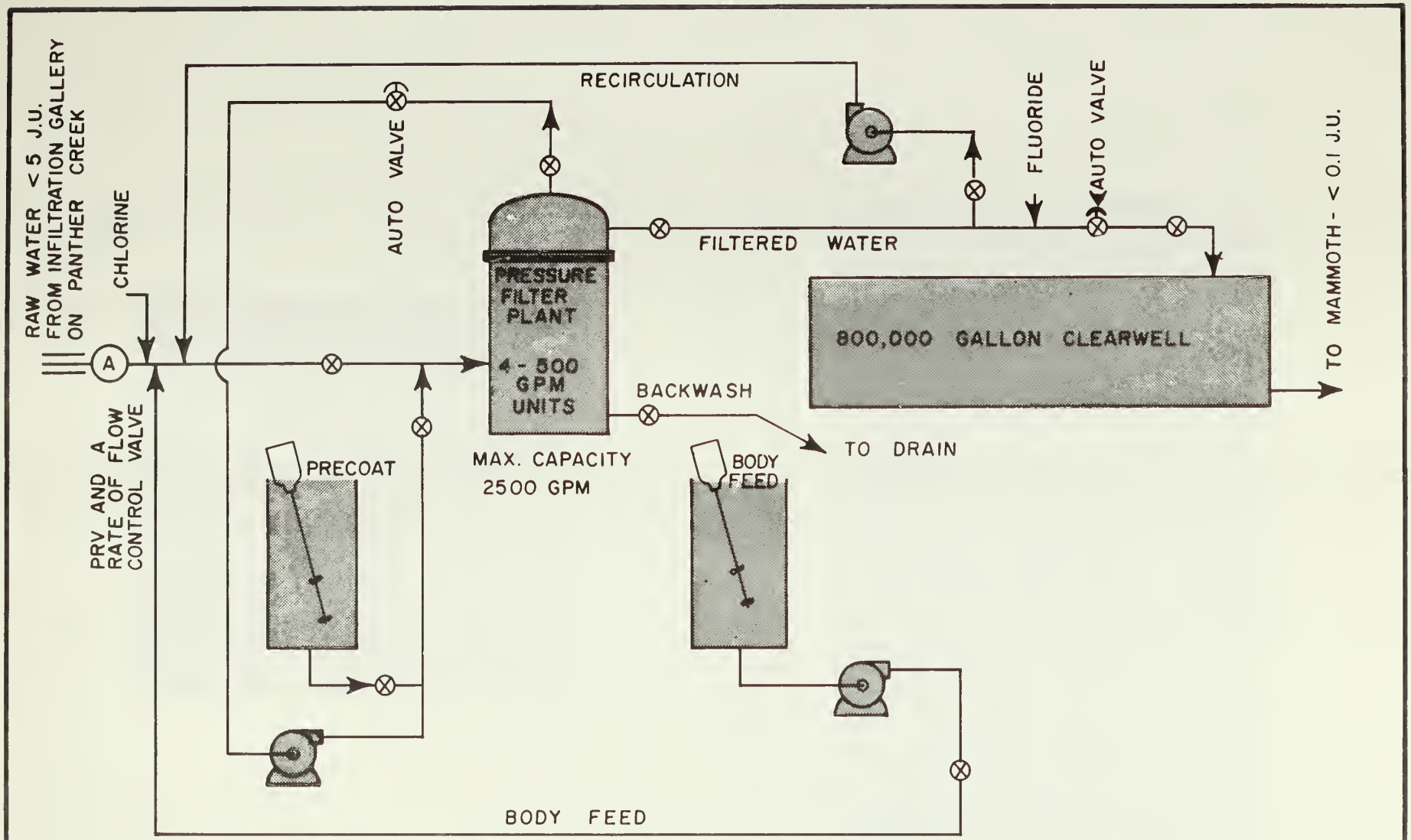


FIG. 8-16 MAMMOTH HOT SPRINGS AREA
SCHEMATIC FLOW DIAGRAM
DIATAMACEOUS - EARTH FILTER PLANT



Fig. 8-17. Convergence of Indian Creek - Gardner River
note: shows existing intakes and proposed location infiltration gallery

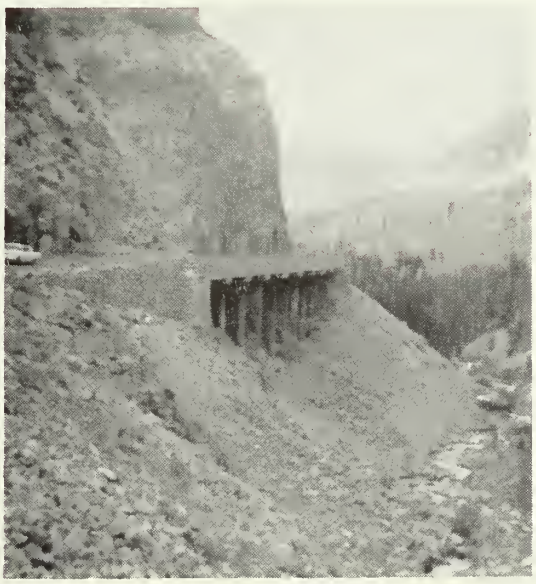


Fig. 8-18. Road Support Bridge above Glen Creek Canyon
note: proposed pressure line will need to be supported on side of this bridge

CHAPTER 9. TOWER AREA

The Tower area, shown on Figure 9-1, consists of three small developments, Tower Junction, Roosevelt Lodge and Tower Fall. Tower Fall is located about 2.5 miles from the other two communities. They are on the Grand Loop Road in the vicinity of the junction-with the Northeast Entrance Road. Major attractions in the area include Tower Fall, the Black Canyon of the Yellowstone River, the Narrows, and Roosevelt Lodge.

Because of their close proximity to one another, their similar characteristics, and their interrelated development programs, it was considered both feasible and advantageous to group the three developments into a single study area. As distances are not too great, operating economies and improved control should prove best with a central system rather than three separate systems.

The Tower area accommodates about 3 percent of the Park's total overnight population. The 1971 census reported a total overnight population of 650, of which 72 were employees. Visitor accommodations include a campground at Tower Fall and the Roosevelt Lodge cabins at Tower Junction. Employee accommodations include a dormitory at Tower Fall and bunkhouses at Tower Junction. Stagecoach and horse concession operations are located at Roosevelt Lodge and the area has a dude ranch atmosphere. Tower Fall is a major Park tour stop.

Development plans may call for moderately increasing the size of the Tower Fall campground and for replacement of the

old cabins at Roosevelt Lodge with new units.

Table 9-1 shows population and design flows for this area. Winter use was considered for Tower Junction and Roosevelt Lodge. The new distribution lines in this area will aid in providing winter use services.

DESCRIPTION OF EXISTING WATER SYSTEM

The entire existing system is shown in Figure 9-2. There have been no appreciable leakage problems in the Tower area but the lines, though in good condition, are mostly quite shallow. Each community has its own separate system. The maximum flow required for all systems combined is 159,000 gpd or 110 gpm. Table 9-2 gives the design criteria for the proposed system.

The existing systems are described as follows:

Tower Fall - Water for Tower Fall is taken from a spring and by gravity flows to a small concrete underground tank where the water not used by the community is allowed to overflow. From this tank the water is transported to the Tower Fall community.

Tower Junction - Water for Tower Junction is taken from a spring and by gravity flows through the Tower Junction community.

Roosevelt Lodge - Water for Roosevelt Lodge is taken from Lost Creek (Figure 9-3), is chlorinated by use of a hypochlorinator and flows into 30,000 gal. of existing wood storage. (Figure 9-4) From storage the water services Roosevelt Lodge.

The mains for all areas are C.I. and G.S. Pressures run from 80 p.s.i. to over 120 p.s.i. at Tower Fall and 30 to 65 p.s.i. at Tower Junction-Roosevelt Lodge.

EVALUATION OF EXISTING SYSTEM

There are several major problems inherent in the three small community systems which include: Maintenance of three different intakes; no chlorination (except by hand feed) of the two spring sources; the Tower Junction Spring and Roosevelt Lodge tank are not on the same elevation thus making it difficult to tie the systems together; the low supply of spring water for Tower Junction; and the difficult intake and turbidity problem at Roosevelt Lodge. Table 9-3 presents an evaluation of the existing systems which is expanded upon with the ensuing discussion.

The existing 4" G.S. line from the Tower Fall Spring to the pressure tank carries 89 gpm which is adequate to supply the combined area for some time. The spring does overflow 87 gpm (Figures 9-5 and 9-6) which is available for future use but will require a new transmission line. The spring should be protected as described in Chapter 4.

The 10,000 gal. Roosevelt Lodge wooden tank is small and in bad repair and is not needed with the combined system and the new underground storage tank. The hypochlorination system will no longer be needed. Lost Creek will be elimi-

nated as a source of supply which will be advantageous as the turbid spring waters and inadequate intake cause some severe maintenance problems and justified complaints from water users. In addition the existing chlorination system is inadequate as chlorination is the only treatment for this surface water supply.

There is no provision for chlorination at Tower Fall and Tower Junction. Some bad coliform tests at Tower Junction in 1970 prompted some additional hand chlorination in 1971. All systems should be adequately chlorinated.

The distribution systems are shallow and also inadequate for peak domestic and fire flows. (See Appendix B). The storage is also inadequate in all areas. All fire hydrants were checked and their condition is detailed on Figure 9-2. Most of the hydrants are in good condition with many being new.

Waters are allowed to run to waste at the Tower Fall pressure tank and the Roosevelt Lodge tank overflow. Chlorine is wasted continuously at Roosevelt Lodge as there is no way except manually to control tank overflow.

RECOMMENDED CONSTRUCTION

Figures 9-7 and 9-8 show the horizontal and vertical location of proposed improvements. Figure 9-9 shows the storage, treatment and control items proposed above Tower Fall. Figure 9-10 shows the proposed well and winter use system for

Tower Junction and Roosevelt Lodge. The recommended improvements will:

- Combine all three systems.
- Provide a safe dependable supply.
- Eliminate turbid waters at Roosevelt Lodge.
- Provide needed storage for fire protection and chlorine contact time.
- Eliminate chlorine waste.
- Provide a useable winter system.
- Provide new mains large enough for fire flows and deep enough for winter use.

The features of the plan include:

1. Protect the Tower Fall Spring source and eliminate the Tower Junction-Roosevelt Lodge source. The winter well source could be built before the long transmission line and would be adequate to supply Roosevelt Lodge during the high spring runoffs.

2. Construct a new six inch transmission line from the spring to the new underground storage above Tower Fall. This line would be adequate to carry all the waters the spring can develop.

3. Construct a new 120,000 gal. underground storage tank with chlorination, fluoridation, T.I.R. metering and control above Tower Fall.

   This station would allow all excess flow to overflow at the spring source. Power and a road will be needed. By combining the systems the storage above Tower Fall greatly reduced the required storage in the lower communities.

4. Construct a new six inch transmission line from the storage tank through Tower Fall to Roosevelt Lodge.

5. Construct several new distribution lines to provide adequate flows for fire protection and adequate depth for winter use.

6. Construct a winter use well for Tower Junction and Roosevelt across the highway near the Tower Junction ranger station. The chlorination and control station should be located near the ranger station.

7. A complete control system should be provided to perform all processes automatically. Table 9-2 describes how this system would function for the combined systems and the winter use system.

The estimated total costs for all systems in this area are $428,220 with $134,000 being recommended for immediate improvement. Chapter 16 describes the construction priorities and Appendix D. lists construction costs.

ALTERNATIVES CONSIDERED

Alternatives considered for the Tower Area included:

1. Development of sufficient well water to supply present and future demands for Tower Junction and Roosevelt Lodge. Such a system might be adequate but there is a question as to the reliability of these underground sources.(3) Also, an additional 80,000 gal. elevated tank would be required plus several new wells and connection lines to the east of the highway. More well testing might show that this system is more feasible than the recommended system.

2. Additional springs and Lost Lake all being located west of Tower Junction, were examined but none could provide an adequate supply.

TABLE 9-1. POPULATION AND MAXIMUM FLOWS, TOWER AREA

DESCRIPTION	POPULATION		Per Capita Flow	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
TOWER FALL AREA					
Campground 53 sites*	325	650	50	16,250	32,500
Dormitories	25	30	75	1,875	2,250
Mess Hall	--	--	--	375	750
Visitor comfort station	--	--	--	10,000	12,500
Store	--	--	--	1,000	1,000
Sub Total	350	680		29,500	49,000
ROOSEVELT LODGE					
Guest units	250	300	25- 75**	6,250	22,500
Employee units	25	60	50	1,250	4,500
Store and dining room	--	--	--	7,500	7,500
Sub Total	275	360		15,000	34,500
TOWER JUNCTION					
Ranger station	20	20	200	4,000	4,000
Service station	6	10	--	1,000	1,000
Sub Total	26	30		5,000	5,000
TOTAL	651	1,070		49,500	88,500
SAY:	650	1,070		50,000	89,000

Actual Maximum Measured Total Flow 54,300.

* 50 percent of campsites assumed to have 2 family occupancy.

** Most units are economy cabins; estimated water use is 25 gcd now ; 75 gcd for future modern units.

TABLE 9-2. BASIC DESIGN DATA, TOWER AREA

ITEM	EXISTING	DESIGN
POPULATION		
Tower Fall	350	680
Tower Junction	26	30
Roosevelt Lodge	275	360
WATER FLOW-COMBINED AREAS		
Peak, gpd	54,300	159,000
Peak, gpm		110
INTAKE		
Tower Fall Spring - gpm		176
TREATMENT		
Ground Water Source - spring		
Chlorination		
Contact time - hours		4
Fluoridation - mg/l residual		1-1.5
STORAGE		
Tower Fall Reservoir - gal.		120,000
Service - control and system underground		
Tower Junction - Roosevelt Lodge		
Existing wood - gal.		20,000
Service- standby - on ground		
Underground concrete - gal		20,000
Service - standby - winter		
DISTRIBUTION- for Hardy Cross Network Analysis		
Peak 4 hr. fire flow - res. and commercial - gpm		500
Peak 4 hr. - domestic-Tower Fall		180
Peak 4 hr. - domestic-Tower Junction & Roosevelt Lodge		150
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm (Table 2-4)		176
Max. 4 hr. fire flow- gpm		500
Peak 4 hr. domestic flow - gpm		330

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

TABLE 9-2. BASIC DESIGN DATA, TOWER AREA-contd.

ITEM	EXISTING	DESIGN
CONTROL SYSTEM		
1. Tower Fall tank - transmission line inlet stops flowing, Tower Fall Spring overflows		
2. TIR meter flow into tank		
3. Record tank level		
SPECIAL WINTER USAGE CONSIDERATION - TOWER JUNCTION - ROOSEVELT LODGE		
Water Flow - gpm		25
Source - well - gpm		25
Pump - gpm		25
Treatment		
Chlorination - gas		
Storage		
Underground concrete - gal.		20,000
Service - control system		
Control System		
1. Tank level indicator and telemetry** Start-stop Hi Service Pump		
2. T.I.R. meter flow from well		
3. I.R. tank level at control-treatment house		

** Pressure sensing control equipment

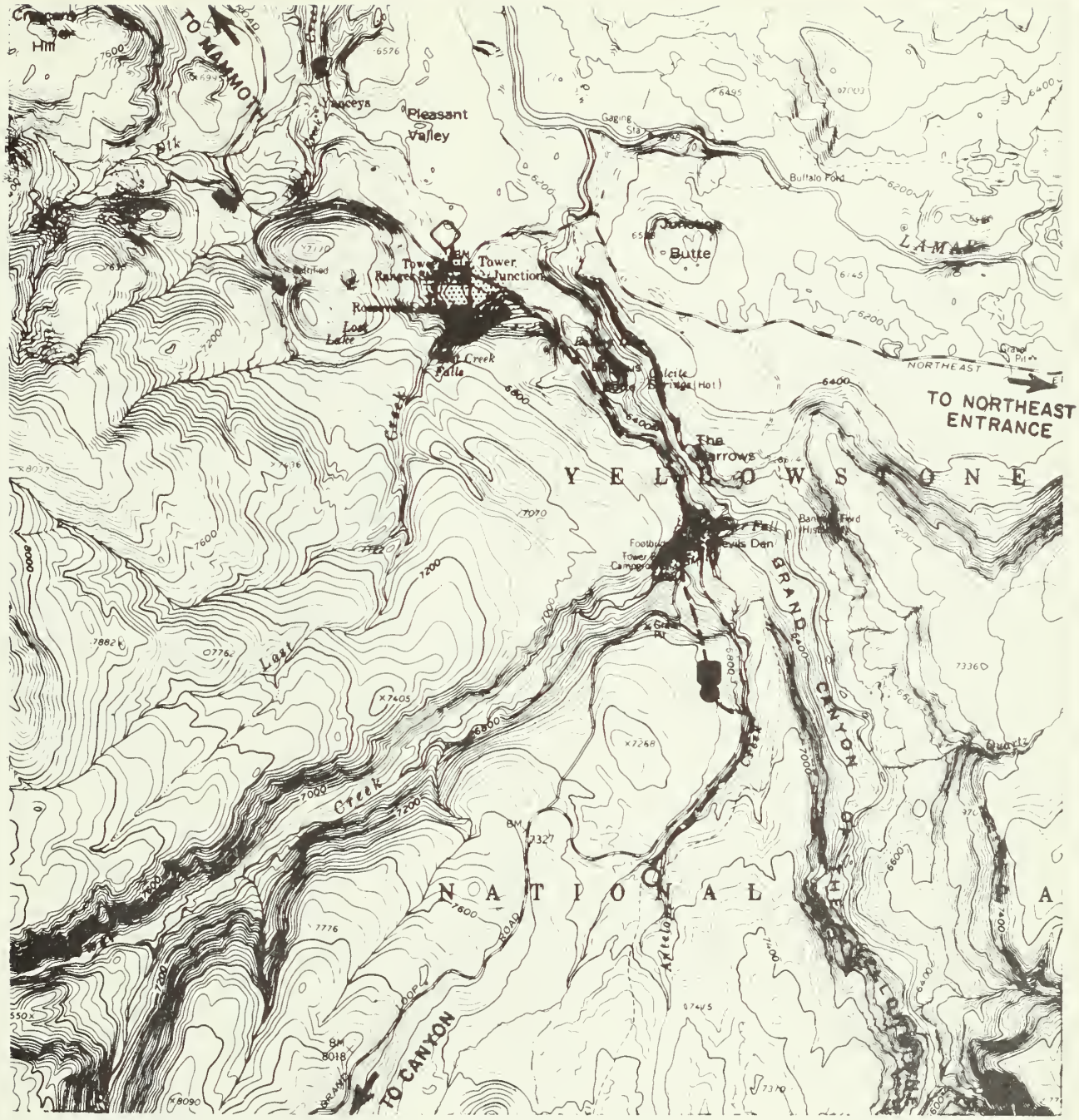
TABLE 9-3. EVALUATION OF EXISTING SYSTEMS

TOWER AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
TOWER FALL			
Source - spring	Concrete structure - fairly new	Good	
Transmission-Pressure line - Spring to Pressure tank to Development	G.S.	Good	Shallow
Pressure Reservoir	Concrete structure - small	Good	
Distribution System	G.S. and some C.I.	Fair	Shallow
ROOSEVELT LODGE			
Source - Lost Creek	Direct Intake, small concrete box difficult to maintain - high turbidity in spring runoff	Fair	Inadequate
Treatment - liquid chlorination	Continuous chlorination	Fair	Inadequate
Tanks			
20,000 gal. wood	New wood tank - has some leaks in roof	Good	
10,000 gal. wood	Old wood tank - bad repair, particularly roof	Poor	
Distribution System	G.S. and some C.I.	Fair	Shallow

TABLE 9-3. EVALUATION OF EXISTING SYSTEMS
TOWER AREA -contd.

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
TOWER JUNCTION			
Source - spring	Concrete structure	Good	5 gpm
Distribution system	G.S. and C.I.	Fair	Shallow
STORAGE OVERALL			Inadequate
TREATMENT OVERALL			Inadequate
GENERAL	All gravity flow		



LEGEND

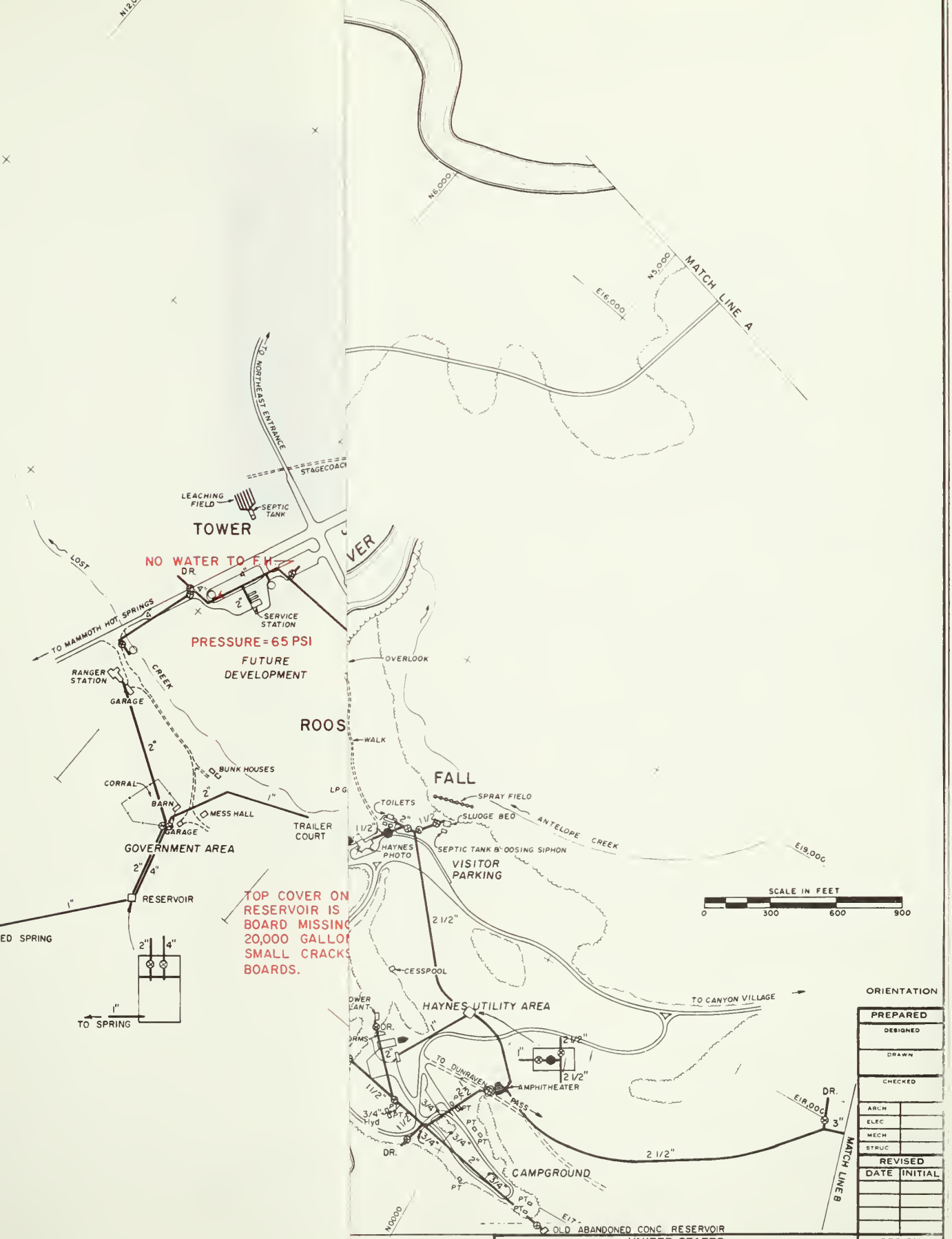
- EXISTING INTAKE
- PROPOSED WATER LINE
- EXISTING TANK
- PROPOSED WELL
- PROPOSED STORAGE
- SERVICE AREA
- PROPOSED TREATMENT

SCALE IN MILES

0 1 2 3

N

FIG. 9-1 TOWER AREA
VICINITY MAP



PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

REGION

PCP NO.

SHEET OF

DRAWING NO

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
TOWER AREA
YELLOWSTONE NATIONAL PARK

DATE

DATE

DATE

DATE

TOWER AREA

YELLOWSTONE RIVER

SULPHUR LAKE

GRAND LOOP ROAD

MATCH LINE A

HORSE CONCESSION AREA

CORRAL

BARN

SHED

CABINS

STAGECOACH

NORTHEAST ENTRANCE

TRAIL

LEACHING FIELD

SEPTIC TANK

TOWER JUNCTION

CESSPOOL

NO WATER TO F H DR

SERVICE STATION

PRESSURE = 65 PSI

FUTURE DEVELOPMENT

TO MAMMOTH HOT SPRINGS

LOST CREEK

RANGER STATION

GARAGE

ROOSEVELT LODGE

HAYNES PHOTO

SHOWER

WASH HOUSE

LPGAS

DUPLEX HOUSES

MESS HALL

TRAILER COURT

CABIN AREA

BRIDGE

EXISTING LINE TO INTAKE AND RESERVOIR PARTIALLY EXPOSED.

2- WOOD STAVE WATER RESERVOIRS- 30,000 GAL TE = 6460

CHLORINE HOUSE

LOST CREEK INTAKE 6520

GOVERNMENT AREA

RESERVOIR

CASED SPRING

TO SPRING

TOP COVER ON 10,000 GALLON RESERVOIR IS CRACKED AND HAS BOARD MISSING. TOP COVER ON 20,000 GALLON ALSO HAS SOME SMALL CRACKS BETWEEN THE BOARDS.

NOTE.
ALL EXISTING LINES IN TOWER FALL, TOWER JUNCTION, AND ROOSEVELT LODGE AREAS ARE SHALLOW

T.E. = 6960 PRESSURE RELIEF RESERVOIR

OVERFLOW

TO TOWER

RELIEF

MATCH LINE B

SCALE IN FEET 0 1000 2000 3000

EXISTING LINE SHALLOW AND PARTIALLY EXPOSED

TO CANYON

TE 7000 SPRING BOX

THE NARROWS

OVER HANGING CLIFF

TOP OF CLIFF

TOWER FALL

TOWER CREEK

TOWER FALL

WALK

TOILETS

SPRAY FIELD

SLUDGE BED

ANTELOPE CREEK

SEPTIC TANK & DOSING SIPHON

HAYNES PHOTO

VISITOR PARKING

SCALE IN FEET 0 300 600 900

CESSPOOL

HAYNES UTILITY AREA

POWER PLANT

DORMS

TO CANYON VILLAGE

TO AMPHITHEATER

AMPHITHEATER

CAMPGROUND

OLD ABANDONED CONC RESERVOIR

OVERLOOK

ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
BALM	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY CASPER WYOMING OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
TOWER AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO

SHEET OF

DRAWING NO

DATE



Fig. 9-3. Roosevelt Lodge Inlet in Lost Creek



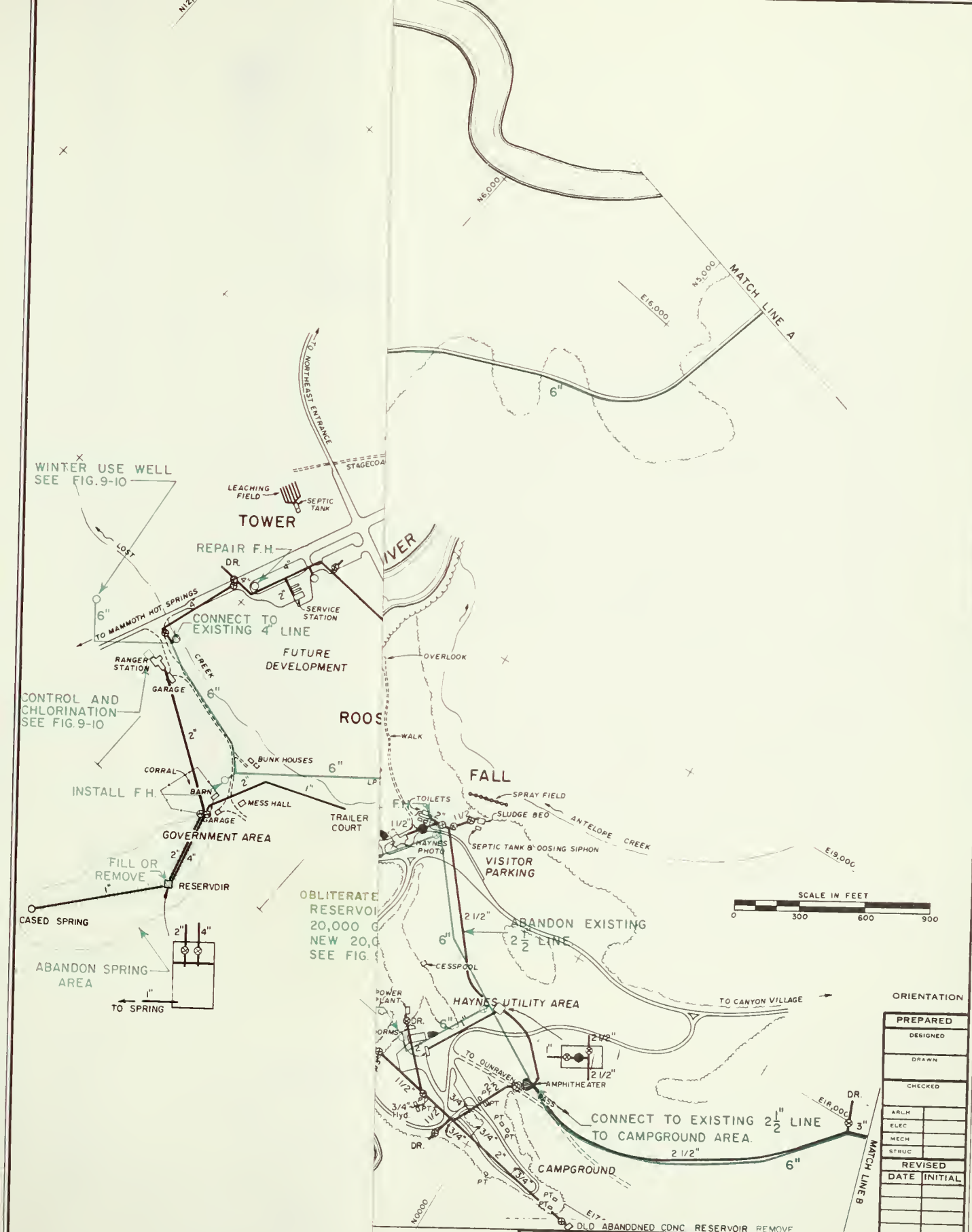
Fig. 9-4. Roosevelt Lodge Chlorination House and Wooden Tanks



Fig. 9-5. Tower Fall Spring



Fig. 9-6. Tower Fall Spring Overflow - 69 gpm



ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARLH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

DATE
DATE
DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
TOWER AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

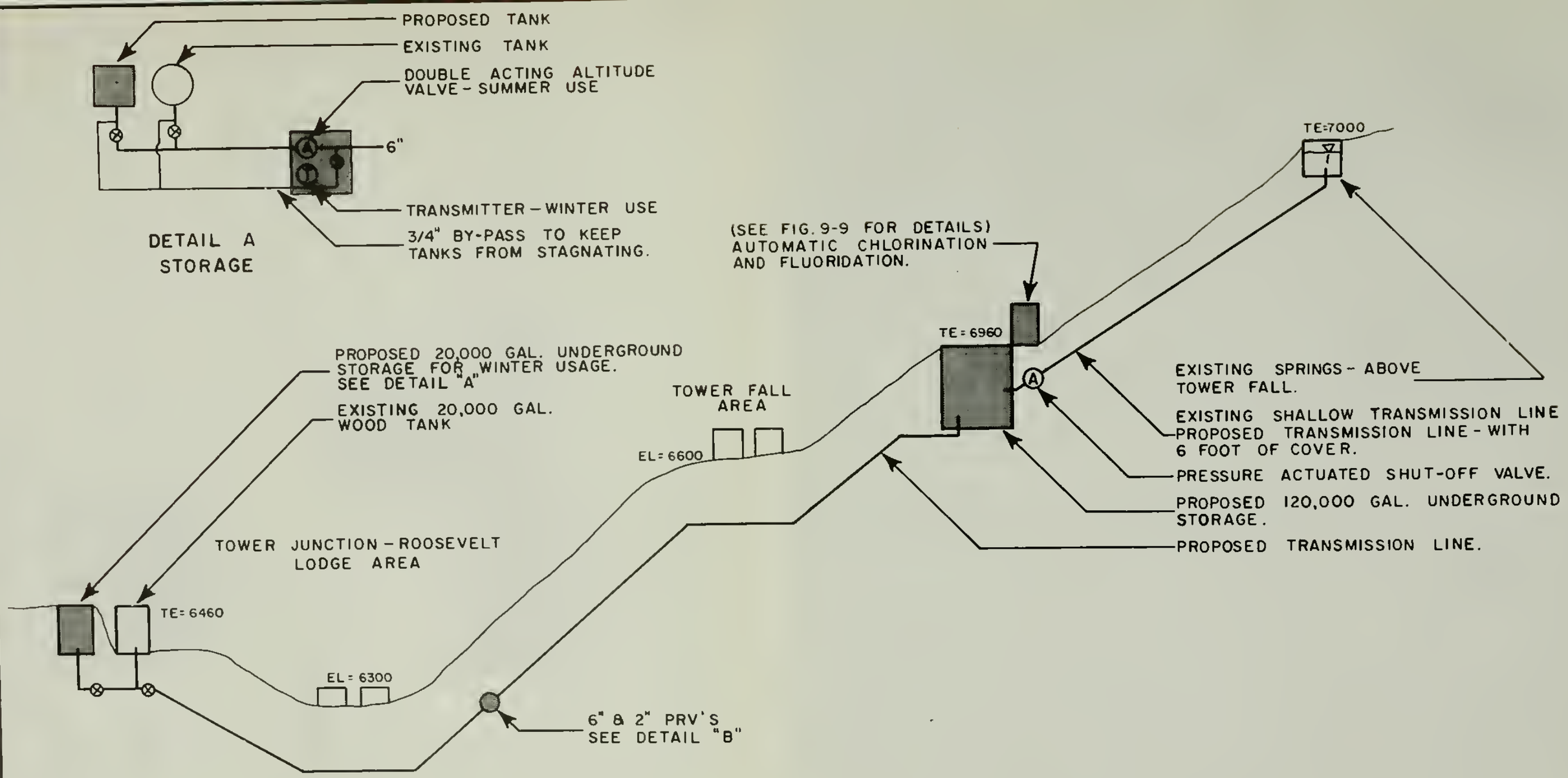
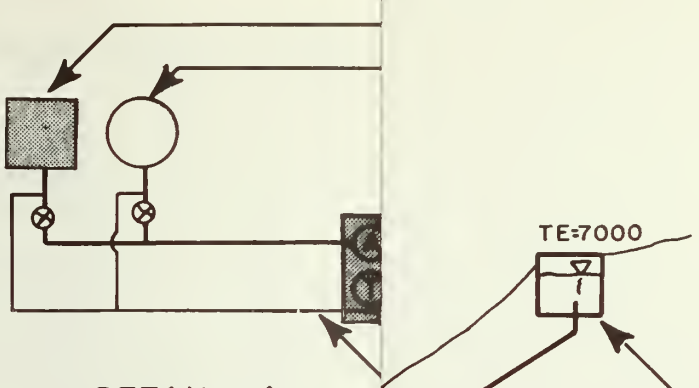


FIG. 9-8 TOWER AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE



DETAIL A
STORAGE

TE=7000

TING SPRINGS - ABOVE
ER FALL.

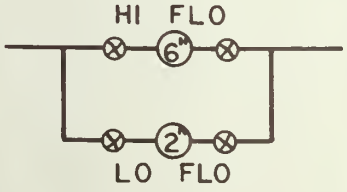
TING SHALLOW TRANSMISSION LINE
POSED TRANSMISSION LINE - WITH
OOT OF COVER.

SSURE ACTUATED SHUT-OFF VALVE.

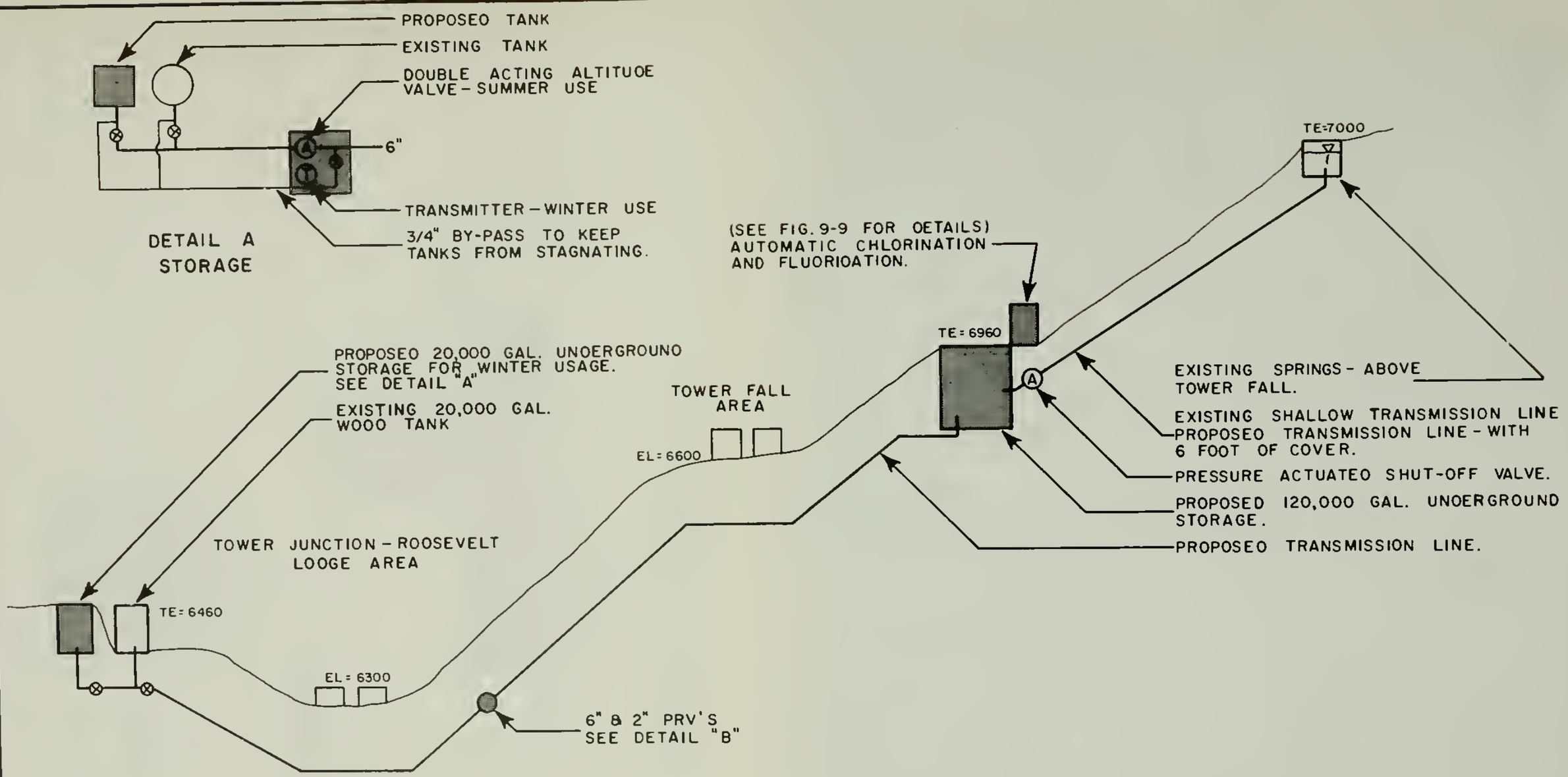
POSED 120,000 GAL. UNDERGROUND
RAGE.

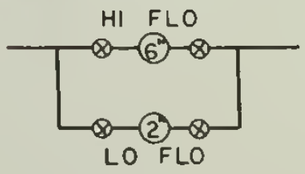
TOWER JUN
LO
POSED TRANSMISSION LINE.

TE= 6460



DETAIL B
PRESSURE REDUCING VALV





DETAIL B
PRESSURE REDUCING VALVES

FIG. 9-8 TOWER AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE

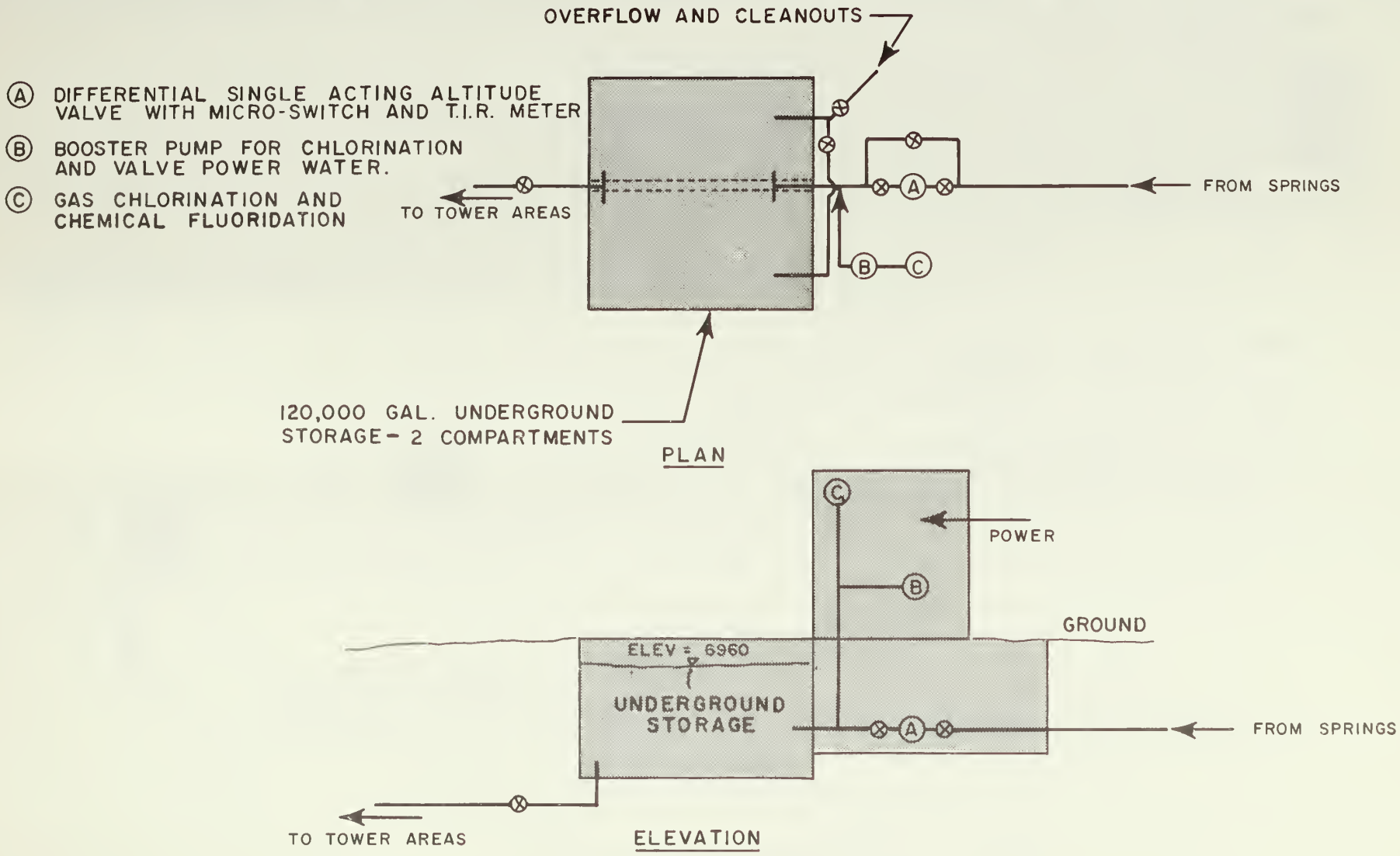


FIG. 9-9 TOWER AREA
PROPOSED CONTROL, CHLORINATION, FLUORIDATION, AND STORAGE ABOVE TOWER FALL

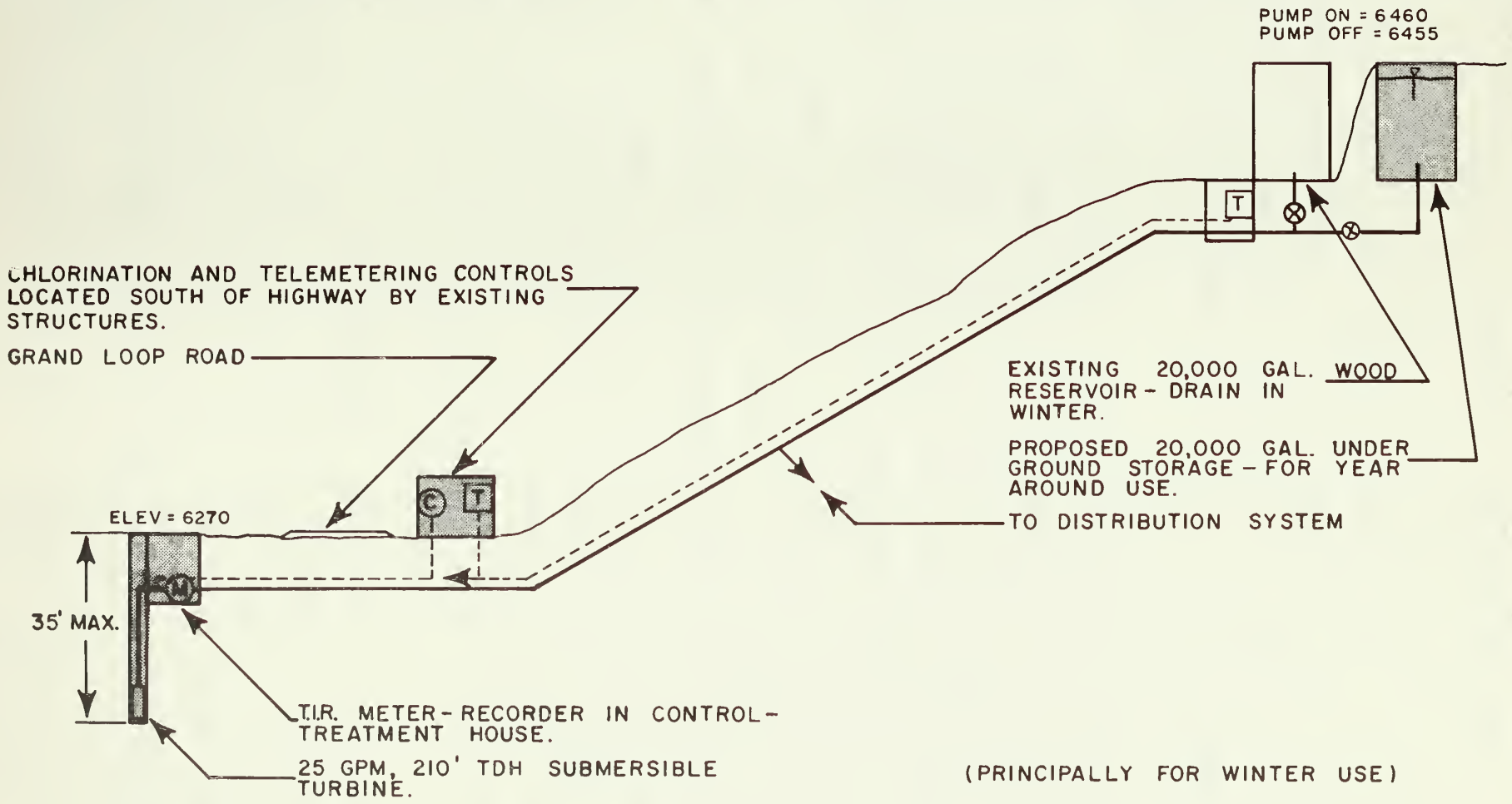


FIG. 9-10 TOWER AREA
SCHEMATIC OF PROPOSED WELL, PUMP,
CONTROL AND CHLORINATION
TOWER JUNCTION - ROOSEVELT LODGE

CHAPTER 10. OLD FAITHFUL AREA

The Old Faithful area, located on the southwest corner of the Grand Loop Road (see Figure 10-1.), is the most heavily visited attraction in Yellowstone Park. The principal natural feature is the upper geyser basin, which has more than 50 active geysers, highlighted by the world famous Old Faithful geyser.

During the 1971 season, the Old Faithful area provided overnight accommodations for approximately 16 percent of the Park population. The overnight census figures of 3,100 visitors and 900 employees were down from the previous seasons, due primarily to the closing of the campground facilities.

The existing guest accommodations are the Old Faithful Inn, the Old Faithful Lodge, and the campers' cabins. Each of the three groups can accommodate about 1,000 guests.

A bypass road has just been completed which carries traffic around the primary community areas. Other changes include the construction of a new visitor center, increased visitor parking facilities and new residential and maintenance facilities for park service and concessioner personnel.

It is the long-range intention of the National Park Service to make Old Faithful primarily a day-use area with limited overnight accommodations. Table 10-1 summarizes the population and water flow data for this area. Winter service is possible as the newer lines have adequate cover for winter use.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required domestic flow for a peak day is 860,000 gal. or 600 gpm. Table 10-2 lists the design criteria for the proposed system. The single most critical problem for this area is that the Firehole River in the spring is highly colored and this color is currently transported directly into the water supply.

Most of the four inch and smaller lines have been installed for over 40 years and are shallow. The newer, larger mains are normally C.I. and are adequately deep. A new 12 inch techite main was completed in 1971 between the Firehole River Intake and the existing storage tank. Figure 10-2 shows the entire existing system.

A trace of the system follows: Water is taken directly from the Firehole River to an underground storage tank which is 167 feet in elevation above the Old Faithful community. The transmission lines from the intake to the tank and the tank to the community are large and adequate. Immediately before reaching the tank the water is chlorinated. Power water for chlorination is provided by a pressure drop across a pressure reducing valve. The distribution system is a conglomerate of large, small, deep, and shallow mains. Pressures in the system range between 50 and 75 p.s.i.

EVALUATION OF EXISTING SYSTEM

Table 10-3 gives a brief evaluation of the existing system which is expanded upon with the ensuing discussion.

The Firehole River Intake (Figure 10-3) is a satisfactory installation except for the ice and debris inflow inhibitor which is a temporary item.

Treatment is inadequate as the chlorine contact time is less than one hour even with flows manually curtailed. While almost all chlorine houses were kept neat and clean, the Old Faithful chlorine house was the cleanest facility of this type seen in the Park. The natural fluoride content is adequate.

Storage is inadequate for both chlorine contact time and fire protection. As no controls exist to stop water from entering the storage reservoir, water and chlorine are continuously wasted from two overflows. (Figure 10-4) Treatment is considered inadequate as a surface source is only receiving chlorination.

The detailed flow analysis of the distribution system appears in Appendix B. Most of the system is adequate for peak domestic and fire flows. The network analysis did show that fire protection deficiencies do exist around the Old Faithful Inn and Lodge. All fire hydrants were checked and their condition is detailed on Figure 10-2. Fire hydrant coverage is adequate. Most of the smaller, older lines are too shallow for winter use. Enough new construction has transpired in recent years that sufficiently deep, larger mains do exist for winter supply.

Two auxiliary intakes are maintained as periodic problems have in the past necessitated their use. Figure 10-5 shows Auxiliary Intake #1 and Figure 10-6 shows the continuous outflow

into the Firehole River from Auxiliary Intake # 2. This outflow can be turned immediately into the distribution system. Neither intake has adequate chlorination equipment or chlorine contact time. Neither intake is adequately protected from contamination.

RECOMMENDED CONSTRUCTION

Figure 10-7 and 10-8 show the horizontal and vertical location of proposed improvements. Figure 10-9 shows a chlorination-activated carbon filtration plant for the removal of color. Figure 10-10 shows a complete treatment plant for the removal of color which is an alternate system. The recommended improvements will:

- Provide a safe, potable, supply which will be low in turbidity.
- Provide chlorination-activated carbon treatment for color removal. Extensive testing showed the chlorination-activated carbon filtration to be quite effective in color removal. For winter use and periods of low color concentrations the chlorine dosage could be substantially reduced prior to the carbon filters, thus allowing the filters to have an exceptionally long life.
- Provide adequate storage for chlorine contact time and for fire protection.
- Eliminate chlorine waste.
- Provide an adequate fire protection system.

The features of the plan include:

1. Construct a backwashable infiltration gallery in the Firehole River which will provide a filtered source of supply that will remove most of the turbidity but little of the color.

2. Construct a chlorination-activated carbon treatment plant including pre and post chlorination and a large clearwell. This plant would remove color. The activated carbon would remove the chlorine taste and further reduce the color. The clearwell would provide adequate chlorine contact time for color removal and bacteria-virus removal and additional storage for fire protection.

3. Construct some new distribution lines to provide adequate fire protection in the Old Faithful Inn and Lodge areas. These lines would also aid in winter useage. Fire protection in these areas is currently inadequate.

4. A complete control system should be provided to perform as is described in Table 10-2.

5. Disconnect and obliterate the existing auxiliary intakes so that no chance for a cross connection can exist. The need for these intakes should be eliminated as:

   A. The new techite line is adequately covered and greatly reduces the former line freezing problems.

   B. The backwashable-infiltration gallery will reduce maintenance and flow interruption problems.

   C. The new storage will give added protection for uninterrupted supply.

6. Proposed connections which may require new metering are important to provide looping for adequate fire flows.

The estimated total costs for the complete system are $614,600 of which $142,350 is recommended for immediate improvement. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

ALTERNATIVES CONSIDERED

Several other supply sources were investigated and rejected as being either inadequate or too expensive. One treatment alternative is shown in Figures 10-10. Briefly the total process would include:

1. Remodel the Firehole River Intake to install a permanent debris and slush diverter. This installation should help alleviate the annual slush maintenance problems.

2. Construct a complete treatment plant including coagulation, settling, filtration, pre and post chlorination and a large clearwell. This plant would remove color. The clearwell would provide adequate chlorine contact time and additional storage for fire protection.

The complete treatment system was rejected for the following reasons:

1. Chlorination-activated carbon testing showed excellent results in color removal. Initial color of 35 units was reduced to less than 5 units with a one hour or shorter chlorine oxidation time followed by activated carbon filtration.

2. Coagulation processes would require more highly skilled operators which were not felt justified for the short durations when highly colored water becomes a problem.

3. The coagulation-filtration process including intake remodeling would cost $260,000 more than the proposed system and would be more expensive to operate and maintain, and would not produce as good a finished supply as the selected process.

The chlorination-activated carbon process should have a comparable initial and operating cost to potassium permanganate followed by manganese treated green sand. This latter process should be tested before being implemented but could prove successful in color removal.

TABLE 10-1. POPULATION AND MAXIMUM FLOWS, OLD FAITHFUL AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW gcd	MAXIMUM WATER FLOWS	
	Existing	Future		Existing gpd	Future gpd
Lodge area					
Cabins	1,000	1,060	50	50,000	79,500*
Employee dorms and cabins	150	165	75	11,250	12,375
Dining room, lounge, and lunch room	--	--	--	30,000	45,000
Sub Total	1,150	1,225		91,250	136,875
Campground area					
NPS apartments	35	35	200	7,000	7,000
NPS bunkhouse	15	34	50	750	1,700
Sub Total	50	69		7,750	8,700
Cabin and concessioner area					
Cabins	900	1,100	50-75	45,000	82,500 *
Dorms and employee cabins	370	450	75	27,750	33,750
Lunch rooms, cafeteria, and bar	--	--	--	70,000	70,000
Laundromat	--	--	--	15,000	15,000
Sub Total	1,270	1,550		157,750	201,250
Inn area					
Inn	850	1,000	75	63,750	75,000
Dormitories	320	380	75	24,000	27,500

* Existing cabins are scheduled for removal. If more permanent facilities are built the water demand could increase to 75 gcd.

TABLE 10-1. POPULATION AND MAXIMUM FLOWS, OLD FAITHFUL AREA-contd.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Inn area (contd.)					
Dining room, lunch rooms, and bar	--	--	--	80,000	80,000
Laundry	--	--	--	15,000	15,000
Sub Total	1,170	1,380		182,750	197,500
Government area					
Trailer court	200	200	50	10,000	10,000
Apartments	50	150	200	10,000	30,000
Sub Total	250	350		20,000	40,000
TOTAL	3,890	4,634		459,500	584,325
Say:	3,900	4,700		460,000	585,000

Actual Maximum Measured Total Flow - 480,000 gpd

TABLE 10-2. BASIC DESIGN DATA, OLD FAITHFUL AREA

ITEM	EXISTING	DESIGN
POPULATION	3,900	4,700
WATER FLOW		
Peak, gpd	480,000	860,000
Peak, gpm		600
INTAKE		
Firehole River - direct: Capacity equal to new 12" techite transmission - gpm - standby		2,480
Backwashable Infiltration gallery - gpm		700 avg 1,000 max
TREATMENT		
Filtration - Activated charcoal gpm gpm		 750 avg 1,000 max
Chlorination - Pre and Post on filters		
STORAGE		
Existing clearwell - gal. service - to system - underground		35,000
Clearwell under or near filters - gal service - chlorine contact time, color oxidation control and to system		365,000
DISTRIBUTION - for Hardy Cross Network Analysis		
Peak 4 hr. domestic flow - gpm		1,200
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commercial fire flow - gpm		1,500
PEAK FLOWS FOR STORAGE DESIGN*		
Flow Input - gpm		1,000 max
4 hr. Fire Flow - gpm		1,500 max
Peak 4 hr. Domestic Flow - gpm		1,200

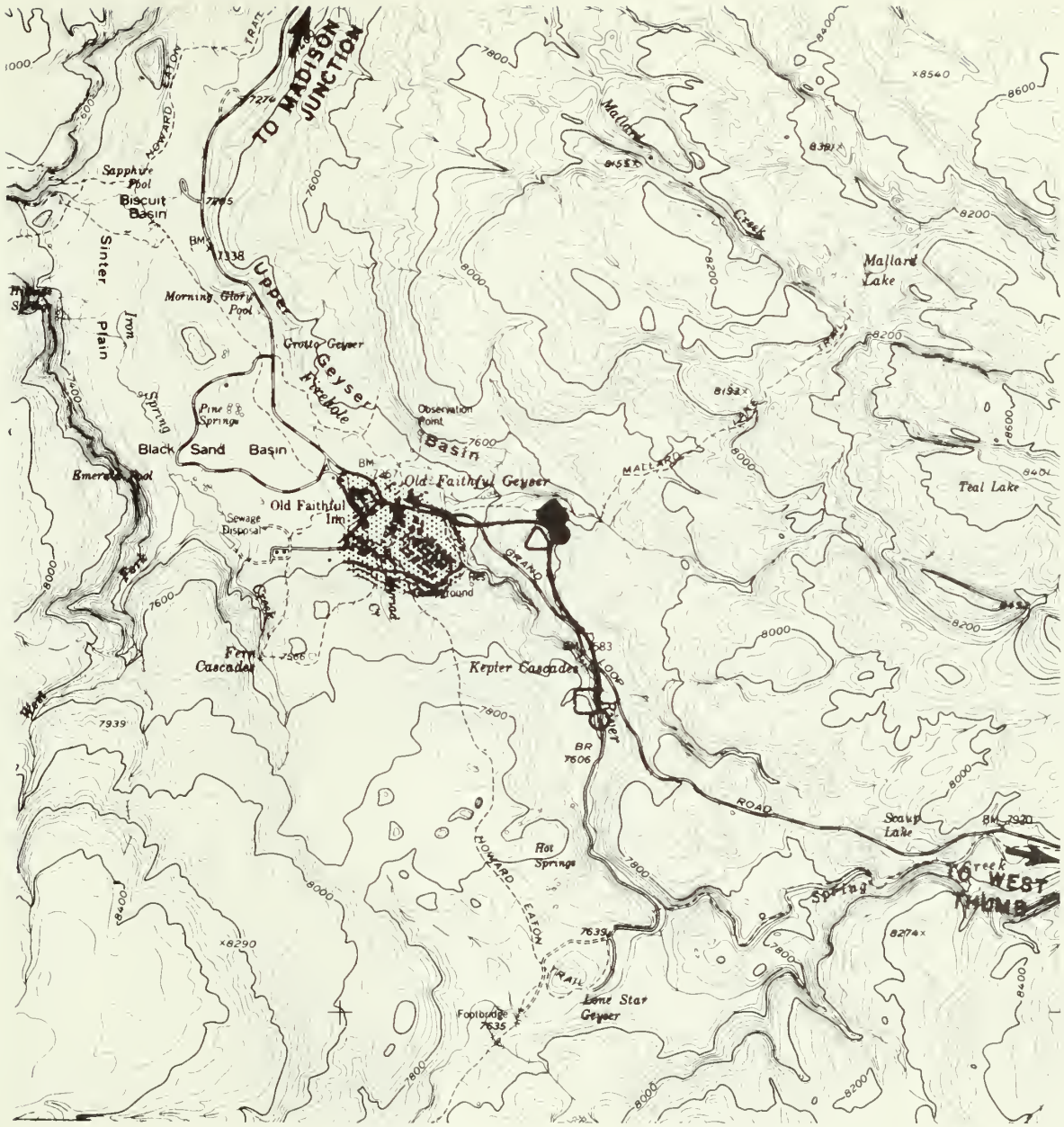
* Chapter 2 and Table 2-5 discuss the storage design for all areas.

TABLE 10-2. BASIC DESIGN DATA, OLD FAITHFUL AREA-contd.

ITEM	EXISTING	DESIGN
CONTROL SYSTEM		
1. Clearwell full - stop raw water flow		
2. Record clearwell level		
3. T.I.R. flow in and out		
4. Semi or fully automate treatment plant.		

TABLE 10-3. EVALUATION OF EXISTING SYSTEM
OLD FAITHFUL AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
GENERAL	All gravity flow		
INTAKE			
1. Firehole River - direct	Concrete-steel headgate	Good	needs remodeling
TRANSMISSION LINE			
1. Intake to elevated storage	New Class 150 techite	Good	
2. Elevated storage to community	Asbestos cement	Good	
STORAGE			
1. 34,000 gal. elevated	Underground concrete	Good	inadequate
TREATMENT			
1. Chlorination-gas	Continuous-pressure drop across valve	Good	inadequate
DISTRIBUTION SYSTEM			
1. 4" lines and smaller	C.I. and G.S., old	Fair to good	shallow
2. 6" lines and larger	C.I.-recent	Good	adequate
AUXILIARY INTAKE # 1 & 2	Concrete structures	Good	
1. Treatment & storage			inadequate



LEGEND

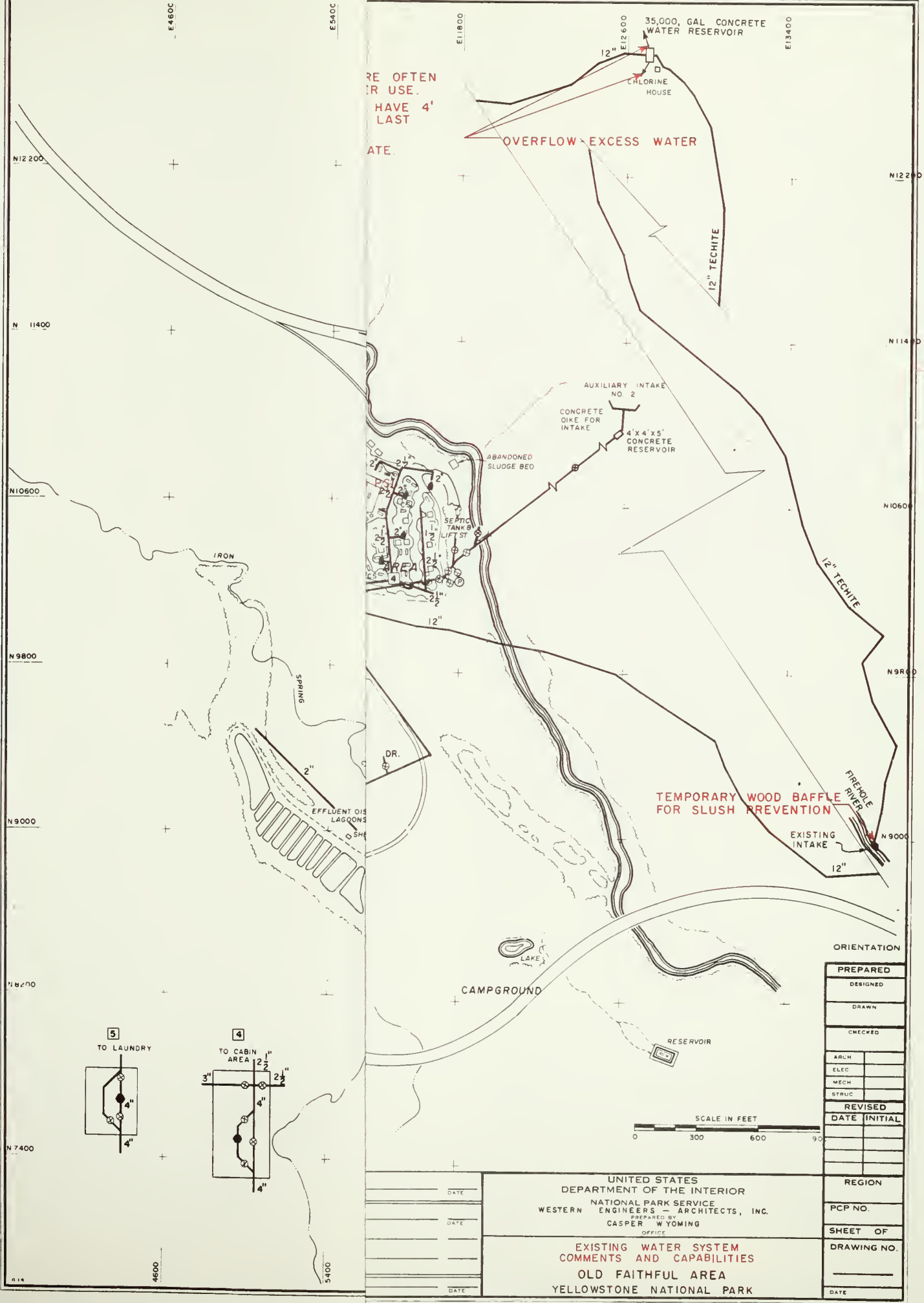
- PROPOSED WTP
- EXISTING INTAKE
- EXISTING WATER LINE
- EXISTING TANK
- SERVICE AREA
- PROPOSED INTAKE
- PROPOSED STORAGE

SCALE IN MILES

0 1 2 3

N

FIG. 10-1 OLD FAITHFUL AREA
VICINITY MAP


RE OFTEN
R USE.
HAVE 4'
LAST
ATE.
35,000, GAL CONCRETE WATER RESERVOIR
12"
CHLORINE HOUSE
OVERFLOW - EXCESS WATER
12" TECHITE
AUXILIARY INTAKE NO. 2
CONCRETE DIKE FOR INTAKE
4'X4'X5' CONCRETE RESERVOIR
ABANDONED SLUDGE BED
SEPTIC TANK & LIFT ST
AREA
IRON
SPRING
DR.
2"
EFFLUENT DISPOSAL LAGOONS
TEMPORARY WOOD BAFFLE FOR SLUSH PREVENTION
FIREHOLE RIVER
EXISTING INTAKE
LAKE
CAMPGROUND
RESERVOIR
5
TO LAUNDRY
4"
4"
4
TO CABIN AREA
1"
2½"
3"
2½"
4"
4"
E11800
E12600
E13400
E4600
E5400
N12200
N 11400
N10600
N 9800
N 9000
N 7400
4600
5400
SCALE IN FEET
0
300
600
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
DATE
DATE
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
OLD FAITHFUL AREA
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

NOTE
1 MOST MAINS 4" AND SMALLER ARE OFTEN SHALLOW - NOT SUITED FOR WINTER USE
2 6" AND LARGER MAINS NORMALLY HAVE 4' OR MORE OF COVER IF PLACED IN LAST 10 YEARS.
3. FIRE HYDRANT COVERAGE ADEQUATE

OLD FAITHFUL AREA

CASTLE GEYSER
OLD SEPTIC TANK
FIREHOLE RIVER
PUMP HOUSE
SERVICE STATION
HAMILTON STORE
PRESSURE = 65 PSI
OLD FAITHFUL GEYSER
THREE SISTERS POOL
STEAM VENTS
INN
DORM
VISITOR CENTER
POST OFFICE
CAFE
LODGE
CABIN AREA
ABANDONED SLUDGE BED
SEPTIC TANK & LIFT ST.
AUXILIARY INTAKE NO 2
CONCRETE DIKE FOR INTAKE
4'X4'X3' CONCRETE RESERVOIR
35,000 GAL CONCRETE WATER RESERVOIR
CHLORINE HOUSE
OVERFLOW - EXCESS WATER
12" TECHITE
IRON SPRING
CREEK
SEPTIC TANK & LIFT STATION
SLUDGE BED
EFFLUENT DISPOSAL LAGOONS
PRESSURE = 70 PSI
TRAILERS
GARAGE
STORAGE
WOODSHOP
UTILITY AREA
CONCESSION AREA
DISPATCH
SU STA
DORM
MT PWR
EMPLOYEE TRAILER COURT
WASH HOUSE
RGR STA
FIRE CACHE
PARKING AREA
LAUNDRY & SHOWER BLDG
SERVICE
TELEG
AUTO REPAIR
PRESSURE = 50 PSI
CABIN AREA
DR.
CAMPGROUND
LAKE
RESERVOIR
TEMPORARY WOOD BAFFLE FOR SLUSH PREVENTION
EXISTING INTAKE
4,5 & 6 CONCRETE RESERVOIR
SMALL CONCRETE DIKE FOR INTAKE
AUXILIARY INTAKE NO 1
4" TO AUXILIARY INTAKE NO 2
REDUCER 12"
TO LAUNDRY
TO CABIN AREA
TO CAFE
TO SEPTIC TANK
TO LAGOON
ORIENTATION
SCALE IN FEET 0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
AREA	
ELEC	
MECH	
ARCH	
REVISED	
DATE	INITIAL
REGION	
PCP NO	
SHEET OF	
DRAWING NO	
DATE	

RECOMMENDED _____ DATE
CONCURRED _____ DATE
APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY CASPER WYOMING OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
OLD FAITHFUL AREA
YELLOWSTONE NATIONAL PARK



Fig. 10-3. Firehole River Intake



Fig. 10-4. Continuous Water Overflow - Old Faithful Storage

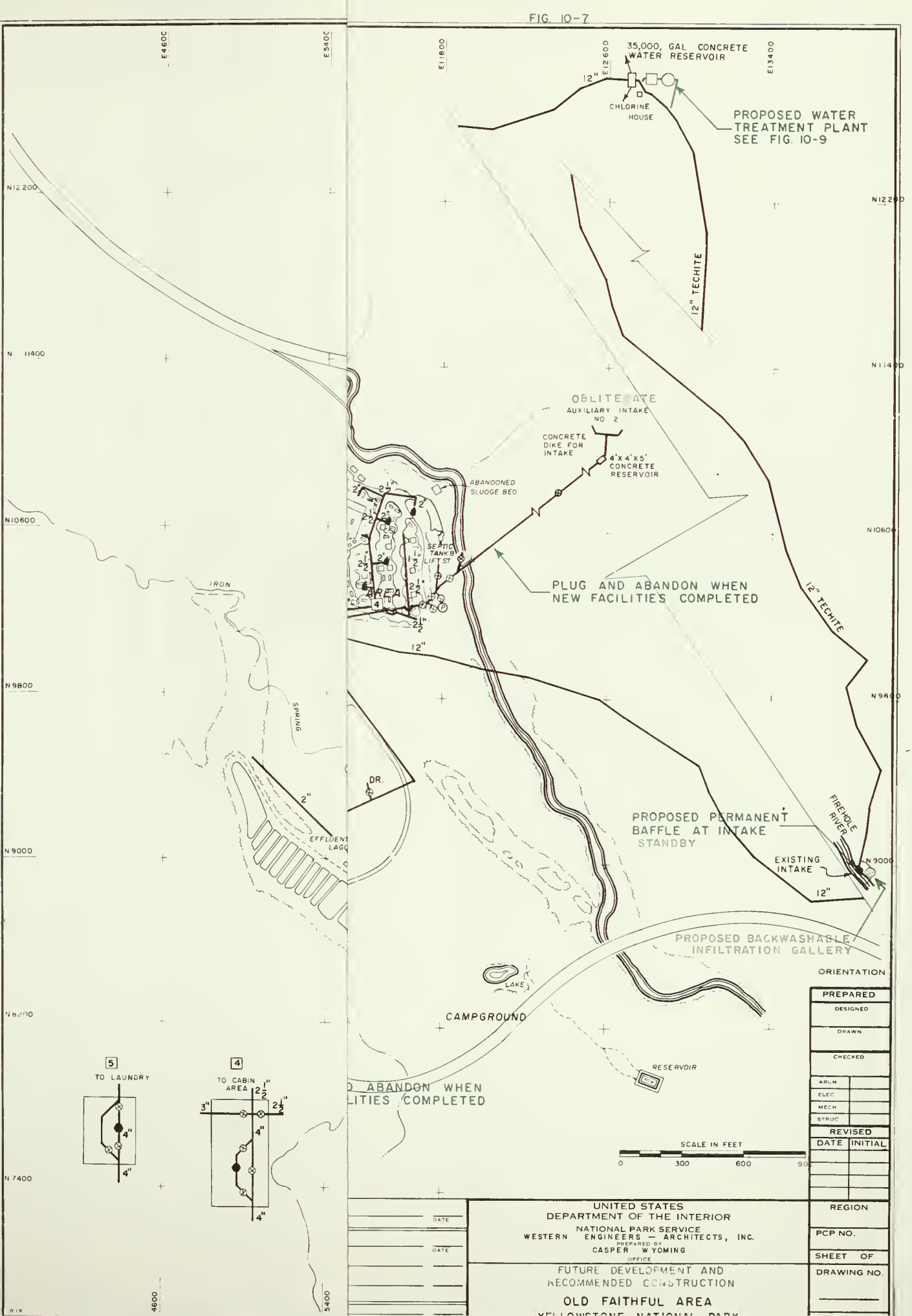


Fig. 10-5. Auxiliary Intake #1



Fig. 10-6. Continuous Flow into Firehole River from Auxiliary Intake #2

FIG. 10-7



PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC

REVISED
DATE | INITIAL

DATE
DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
OLD FAITHFUL AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO.

OLD FAITHFUL AREA

N

CASTLE GEYSER

OLD SEPTIC TANK

FIREHOLE RIVER

CONNECT TO EXISTING 6"

CONNECT TO EXISTING 6"

OLD FAITHFUL GEYSER

OBLITERATE AUXILIARY INTAKE NO 2

CONCRETE DIKE FOR INTAKE

4'x4'x3' CONCRETE RESERVOIR

35,000 GAL CONCRETE WATER RESERVOIR

CHLORINE HOUSE

PROPOSED WATER TREATMENT PLANT SEE FIG. 10-9

12" TECHITE

PUMP HOUSE

SERVICE STATION

HAMILTON STORE

STEAM VENTS

THREE SISTERS POOL

ABANDON EXISTING 4" LINES

INN

DORM

CONNECT AT BYPASS

CONNECT TO EXISTING 6"

LODGE

CABIN AREA

ABANDONED SLUDGE BED

SEPTIC TANK

PLUG AND ABANDON WHEN NEW FACILITIES COMPLETED

IRON

TRAIL

SEPTIC TANK & LIFT STATION

SLUDGE BED

EFFLUENT DISPOSAL LAGOONS

CREEK

PLEX

UTILITY

WOODSHOP

GARAGE

STORAGE

AREA

GAS

DISPATCH

SUPERVISOR

CONCESSION AREA

DORM

MT PWR

EMPLOYEE TRAILER COURT

WASH HOUSE

FIRE CACHE

RGR STA

PARKING AREA

TELEG

AUTO REPAIR

CAFE

LODGE

SERVICE STA

LAUNDRY & SHOWER BLDG

CS

POST OFFICE

CABIN AREA

DR

PROPOSED PERMANENT BAFFLE AT INTAKE STANDBY

EXISTING INTAKE

FIREHOLE RIVER

PROPOSED BACKWASHABLE INFILTRATION GALLERY

CAMPGROUND

LAKE

RESERVOIR

4'x4'x6' CONCRETE RESERVOIR

SMALL CONCRETE DIKE FOR INTAKE

AUXILIARY INTAKE NO 2

OBLITERATE

PLUG AND ABANDON WHEN NEW FACILITIES COMPLETED

ORIENTATION

SCALE IN FEET 0 300 600

[5] TO LAUNDRY

[4] TO CABIN AREA

[3] TO CAFE

[2] TO SEPTIC TANK 2" TO LAGOON

[1] 4" TO AUXILIARY REDUCER INTAKE NO 2 12"

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ENGR	
ARCH	
MECH	
OFFICE	
REVISED	
DATE	INITIAL

RECOMMENDED _____

CONCURRED _____

APPROVED _____

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
DENVER OFFICE
CASPER WYOMING

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION

OLD FAITHFUL AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO

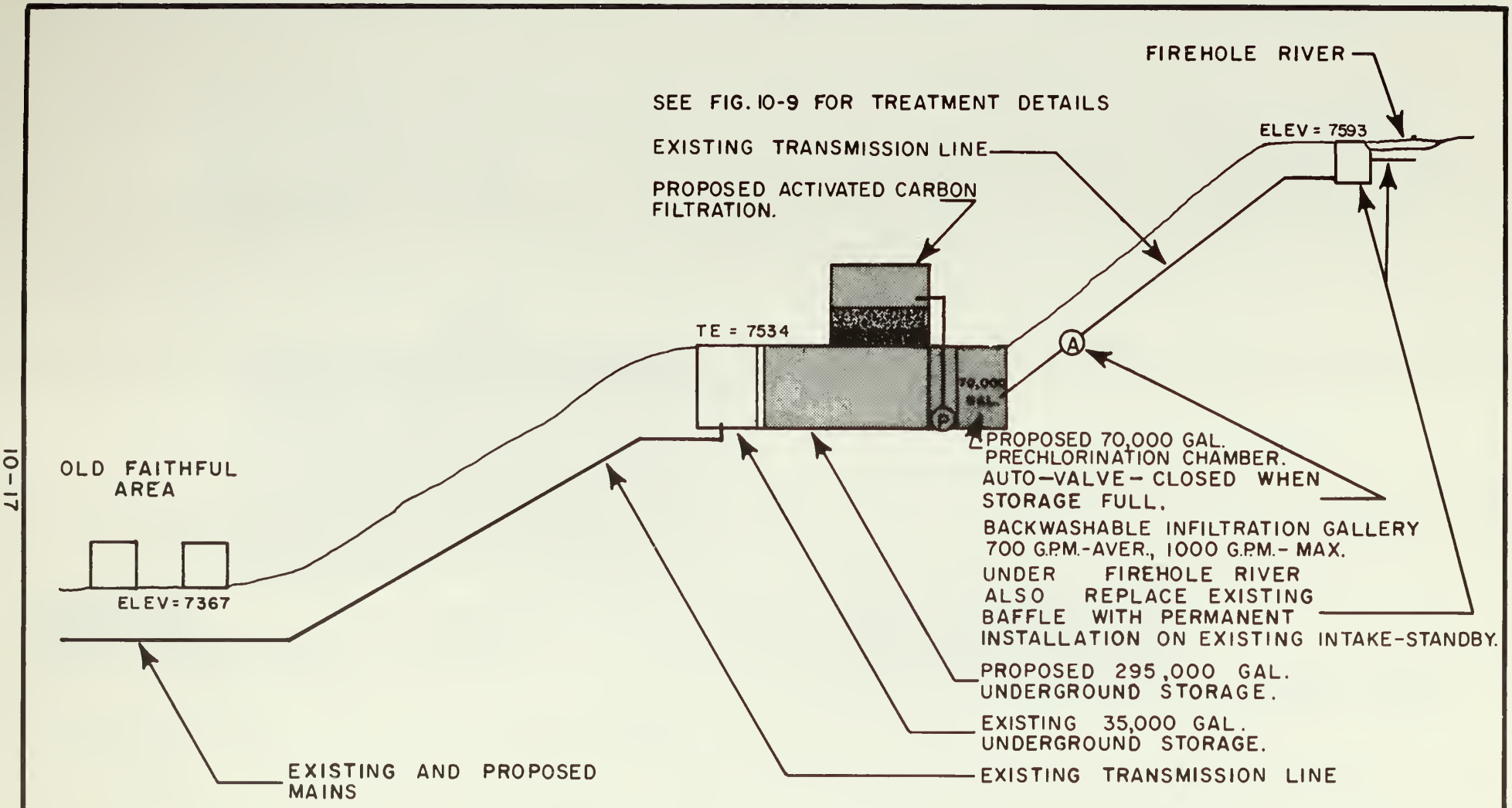
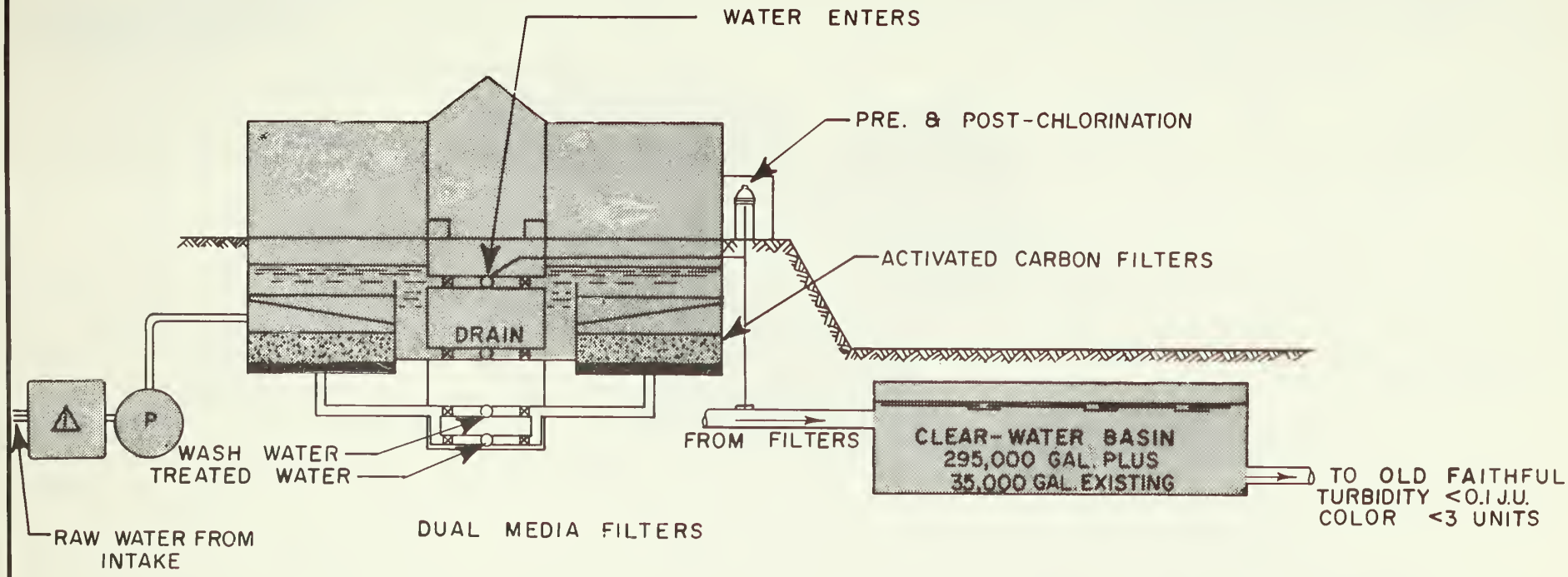


FIG. 10-8 OLD FAITHFUL AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE

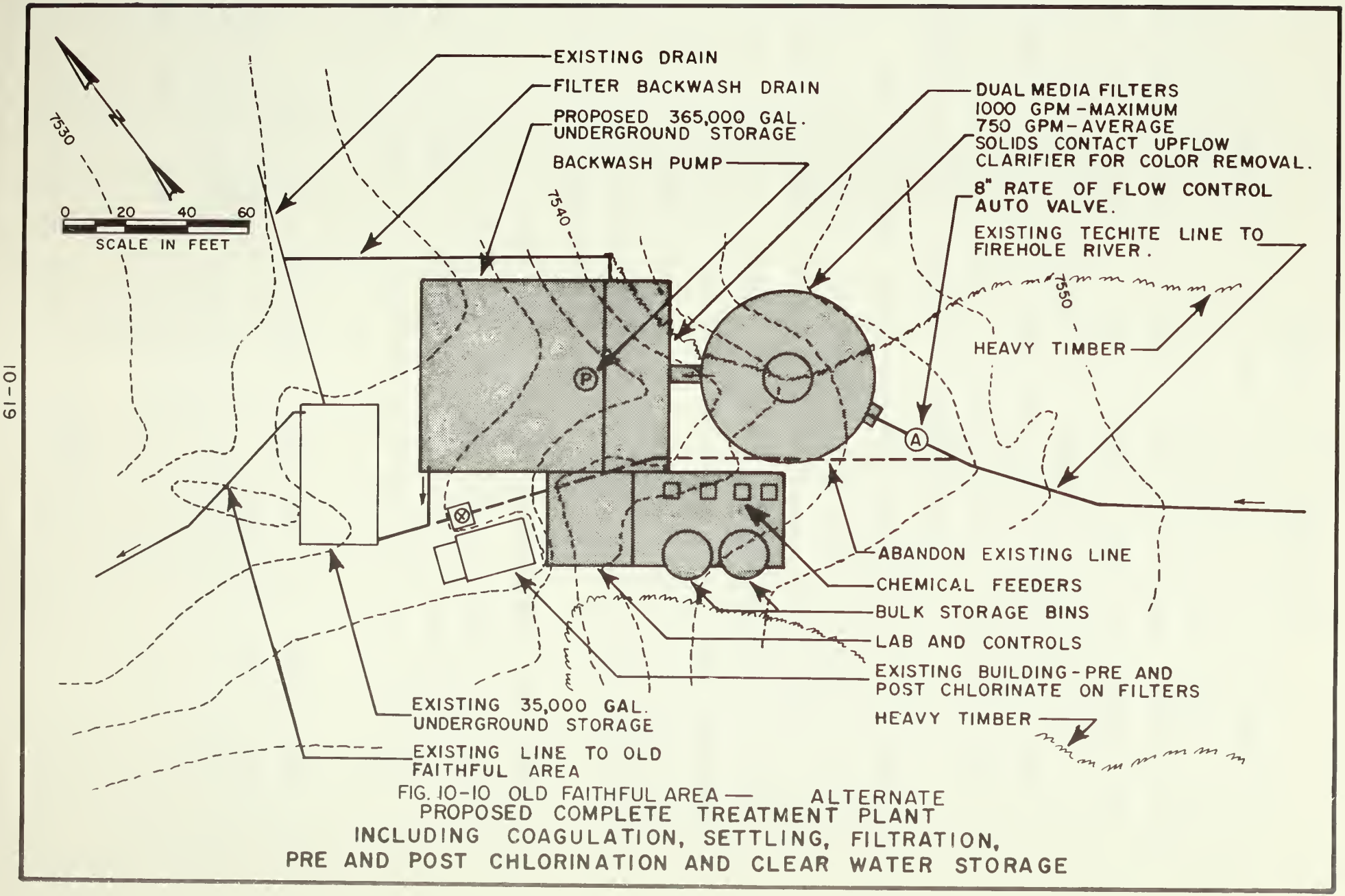
NOTE: PROVIDE: 2-375 g.p.m AVERAGE FILTERS
2-500 g.p.m. MAX. FILTERS
A PORTION OF THE CLEAR WATER BASIN CAN BE CONSTRUCTED DIRECTLY UNDER THE FILTERS.

NOTE: AUTO-VALVES CONTROLLED BY CLEAR-WELL LEVEL WILL LET WATER ONTO FILTERS



⚠ - 70,000 GAL. PRE-CHLORINATION BASIN.

FIG. 10-9 OLD FAITHFUL FILTRATION AREA INCLUDING FILTRATION, PRE & POST-CHLORINATION, AND CLEAR - WATER STORAGE



61-01

FIG. 10-10 OLD FAITHFUL AREA — ALTERNATE
PROPOSED COMPLETE TREATMENT PLANT
INCLUDING COAGULATION, SETTLING, FILTRATION,
PRE AND POST CHLORINATION AND CLEAR WATER STORAGE

CHAPTER 11. CANYON AREA

The Canyon area, as shown in Figure 11-1, is located on the Grand Loop Road close to the geographical center of the Park. According to the 1966 traffic counts, an average of 8,600 trips were made daily in or out of Canyon Junction between June 1 and September 30, representing approximately 10,000 to 15,000 visitors daily or 1-1/2 million visitors seasonally. The 1971 local census for Canyon recorded a daily overnight count of 3,900 persons, of whom 670 were employees.

The existing guest accommodations consist of 598 motor lodge cabin units and 370 camp sites, which account for populations of 1,980 and 1,300 respectively. There are no guest trailer utility hookups or hotel accommodations at Canyon. Nearly all of the facilities now in use have been constructed since 1957 as part of the National Park Service: "Mission 66" project. The programmed construction is more than 95 percent complete at the present time.

Recently opened are a short-order restaurant, and a service station employee dormitory. In addition, one employee dormitory has been added. A government trailer park is being expanded in the government area, and new mess and dormitory facilities may be required.

Population and design flows for the Canyon area are summarized in Table 11-1. As most of the water system has been recently constructed the lines have adequate cover for winter use and winter service is possible.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required domestic flow for a peak day is 767,000 gal. or 540 gpm. Table 11-2 lists the design criteria for the proposed system. The single most critical problem for this area is that Cascade Creek and Soda Creek have high spring runoffs and large amounts of color are currently transported directly into the water supply.

Figure 11-2 shows the entire existing system. A large portion of the system was recently constructed and is in good condition.

The system is described as follows: Water is taken from three sources which compose two completely separate intake systems. The least productive is the gravity flow system which constitutes the upper and lower Soda Creek intakes. The upper intake is located on a tributary to Sulphur Creek about three miles north of Canyon toward Tower. The lower intake (Figure 11-4) which feeds the same transmission line collects part of the headwaters of Cascade Creek. From these intakes the water is transported by gravity to the existing 750,000 gal. elevated storage tanks. These underground concrete tanks also provide chlorine contact time as the Soda Creek waters are continuously chlorinated prior to entering the tanks. A ten foot diameter valveless rapid sand filter by Permutit is installed and in good condition but has not been in use since 1966. (Figure 11-3)

The final source is the Cascade Creek direct intake (Figure 11-5) from which water is pumped by two 20 H.P. centrifugals (Figure 11-6) through a transmission line into the same high service tanks. The transmission line connects to the distribution system before reaching the tanks. The water is chlorinated during pumping by use of a booster pump. The distribution system is mostly new C.I. mains with some notable A.C. and G.S. exceptions. The mains normally have adequate cover. The system pressures range between 65 and 90 p.s.i.

EVALUATION OF EXISTING SYSTEM

Table 11-3 gives a brief evaluation of the existing system which is expanded upon in the ensuing discussion. The Soda Creek Intakes are used for most of the water supply. These intakes are satisfactory when the waters are clear except they are not filtered nor is either intake fenced. The Soda Creek transmission line is shallow and the intakes are sufficiently inaccessible so that they are not a good winter source. Chlorination is continuous as water is constantly overflowing from the tanks thus wasting chlorine. In 1966 the valveless sand filter went into a continuous backwash cycle which could not be stopped and has not been used since. The flow input into the filter should be limited so as not to exceed 156 gpm or 10 J.U. turbidity units.

The Cascade Creek Intake is used only when the Soda Creek facilities cannot produce sufficient waters to supply the

community. The high service pumps are kept in good repair and during peak usage periods, which correspond with low Soda Creek flows, are pressed into service. Cascade Creek like Soda Creek is highly colored during spring runoff and organic color does get into the distribution system during these periods as treatment methods do not exist to eliminate this problem. No chlorine contact time is provided at the pumping station though careful chlorination practices are followed. The intake dam serves as a barrier to fish traveling upstream.

The detailed flow analysis of the distribution system appears in Appendix B. The system is currently inadequate for peak domestic and fire flows. The network analysis did show that fire protection deficiencies do exist, the principal problem being that the main transmission line from the tanks to the populated areas is inadequate. Deficiencies also existed in the government area and the southwest cabin area. All fire hydrants were checked and their condition detailed in Figure 11-2. Fire hydrant coverage is adequate. Winter use should not be a serious problem as mains are adequately deep. An existing open reservoir is currently used in the winter and should be covered or abandoned as quickly as possible.

The only control system is a broken float switch on the elevated tanks which if in service would automatically start-stop the Cascade Creek pumps. The float switch is a difficult control item to maintain in a high country installation because of freezing problems.

RECOMMENDED CONSTRUCTION

Figures 11-9 and 11-10 show the horizontal and vertical location of proposed improvements. A chlorination-activated carbon filtration process was selected after testing as being the most effective trouble free process for color removal. The recommended improvements will:

- Provide a safe, potable supply practically turbidity free.
- Provide a supply extremely low in color. For winter use and periods when the color count is low, the chlorine dosage could be substantially reduced when applied prior to the carbon filters, thus allowing the filters to have an exceptionally long life.
- Provide adequate storage for chlorine contact time.
- Return an existing sand filter to needed service and eliminate chlorine waste.
- Provide an adequate fire protection system.

The features of the plan include:

1. When improvements are sufficiently complete do not use the Soda Creek intakes until the flows are less than 156 gpm and the turbidity is less than 10 J.U. turbidity units.
2. Repair and place back into operation the valveless rapid sand filter in accord with the limits expressed in 1. above.
3. Remodel the Cascade Creek Intake to allow for upstream fish passage.
4. Construct a backwashable infiltration gallery under Cascade Creek which would remove turbidity.
5. Construct a treatment plant including pre and post chlorination, activated charcoal filtration, two large clearwells and pumping. This plant would remove color and provide adequate chlorine contact time.

6. Construct some new distribution lines and connect some lines for looping to provide adequate transmission for fire fighting from the tanks to service for the major population areas and additionally to provide adequate fire protection in the government area and the southwest cabin area. Additional metering may be required as the result of the proposed looping.

7. A complete control system should be provided to perform as is described in Table 11-2.

8. The treatment could also include fluoridation if such is felt desirable.

The estimated total cost for the complete system is $451,100 of which $56,000 is recommended for immediate improvements. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

ALTERNATIVES CONSIDERED

The combination of Cascade Creek and Soda Creek offer a limited source of supply and if growth or a greatly increased demand for water should occur then the adequacy of supply would be in question. Several alternatives were considered including wells, which were inadequate (3), (6) and the Yellowstone River which would be quite expensive.

Figure 11-11 shows an alternate plan which is a complete treatment plant for the removal of color. This plan was felt inferior to the backwashable infiltration gallery under Cascade Creek followed by pre and post chlorination and activated carbon filtration as:

1. The selected process proved, when tested, to reduce the color units to a minimum concentration.

2. Coagulation processes would require more highly skilled operators which were not felt justified for the short durations when highly colored water becomes a problem.

3. The coagulation-filtration process including intake remodeling would cost $188,500 more than the proposed system and would be more expensive to operate and maintain, and would not produce as good a finished supply as the selected process.

The chlorination-activated carbon process should have a comparable initial and operating cost to potassium permanganate followed by manganese treated green sand. This latter process should be tested before being implemented but could prove successful in color removal.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Government area					
NPS trailer park	165	200	50	8,250	10,000
Employee laundries	--	--	--	1,000	1,500
Maintenance yard	--	--	--	500	500
Dormitories	60	100	75	4,500	7,500
Mess hall	--	--	--	900	1,500
Residence homes, apartments	75	100	200	15,000	20,000
Sub Total	300	400		30,150	41,000
Campground area					
Campground (340 sites)	1,300	1,700	50	65,000	85,000
Ranger's house	4	4	200	800	800
Laundromat (40 machines)	--	--		20,000	20,000
Sub Total	1,404	1,404		85,800	105,800
Village area					
Service station	--	--	--	3,000	5,000
Visitor center	--	--	--	6,000	7,500
Employee trailer court	--	100	--	--	5,000
Employee dorms and cabins	600	700	75	45,000	52,500
Motor lodge	1,980	2,000	75	148,500	150,000
Cafeteria, dining room and lounge	--	--	--	45,000	60,000
Coffee shops	--	--	--	30,000	54,000
Short-order restaurant	--	--	--	--	20,000
Sub Total	2,580	2,800		277,500	354,000

TABLE 11-1. POPULATION AND MAXIMUM FLOWS-CANYON AREA - contd.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Horse concession area					
Wranglers' bunkhouse	8	15	50	400	750
Caretaker's residence	5	5	200	1,000	1,000
Wildlife research center	--	15	--	--	1,125
Contractors' bunkhouse	--	15	---	--	750
Sub Total	13	50		1,400	3,625
TOTAL	4,297	5,054		394,850	504,425
Say:	4,300	5,100		395,000	505,000

Actual Maximum measured total flow 371,000 gpd.

TABLE 11-2. BASIC DESIGN DATA, CANYON AREA

ITEM	EXISTING	DESIGN
POPULATION	4,300	5,100
WATER FLOW		
Peak, gpd	395,000	767,000
Peak, gpm		540
INTAKE		
Cascade Creek - direct - gpm - standby		1,175
Backwashable infiltration gallery - gpm		500 avg 750 max
Tributary to Sulphur Creek (called Soda Creek) - direct - gpm		59
Tributary to Cascade Creek (called Lower Soda Creek) - direct - gpm		28
TREATMENT		
Soda Creek Rapid Sand Filtration - existing - gpm		156 max
Chlorination - pre on R.S. filter - existing		
Cascade Creek Filtration - Activated Charcoal - gpm		500 avg 625 max
Chloridation - pre and post on filters		
Fluoridation - mg/l residual - optional		1-1.5
Pumping - 250' TDH - gpm		625
STORAGE		
Upper concrete reservoirs - underground - existing - gal.	750,000	
Service - control, chlorine contact time, and to system		
Clearwells at treatment plant - underground - gal.	120,000	
Service - control, chlorine contact time, color oxidation, and to system		

TABLE 11-2. BASIC DESIGN DATA, CANYON AREA-contd.

ITEM	EXISTING	DESIGN
DISTRIBUTION - for Hardy Cross Network Analysis		
Peak 4 hr. domestic flow - gpm		1,100
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commercial fire flow - gpm		1,000
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm		712
Max. 4 hr. fire flow - gpm		1,000
Peak 4 hr. domestic flow - gpm		1,080
CONTROL SYSTEM		
Soda Creek Intake and Transmission		
1. Tank full - stop flow		
2. TIR flow into tank at Cascade Creek Treatment Plant		
Cascade Creek Treatment Plant		
1. Upper tanks - control pumps **		
2. Record upper tanks level		
3. TIR flow in and out		
4. Clearwell level - flow in		
5. Record clearwell level		
6. Semi or fully automate treatment plant		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Control equipment on elevated tanks to be pressure sensing. This type of control resists winter freezing problems.

TABLE 11-3. EVALUATION OF EXISTING SYSTEM
CANYON AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
INTAKE			
1. Cascade Creek-direct	Concrete dam, pipe under reservoir	Good	Needs remodeling
2. Soda Creek - upper	Concrete dam, inlet box	Good	
3. Soda Creek - lower	Concrete dam, inlet box	Good	
TRANSMISSION LINES			
1. Cascade Creek to elevated storage	A.C.-recent	Good	
2. Soda Creek to elevated storage	G.S.	Good	Shallow
STORAGE			
1. 500,000 gal.elevated	Underground concrete	Good	
2. 250,000 gal. elevated	Underground concrete	Good	
TREATMENT			
1. Cascade Creek			
A. Chlorination - gas	On when Hi-service pumps on-booster pump	Good	Inadequate
2. Soda Creek			
A. Chlorination - gas	Continuous-pressure drop across valve	Good	
B. Rapid sand filter	Valves, auto-backwash-currently out of service 10' dia., Q=156 gpm at 2 gpm/ft^2	Good	

TABLE 11-3. EVALUATION OF EXISTING SYSTEM
CANYON AREA - contd.

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
DISTRIBUTION SYSTEM			
1. Main	C.I., A.C., and G.S.	Good	almost adequate
PUMPING			
1. High service	2 - 2 stage centrifugals, 20 H.P., 150 gpm, 240' TDH	Good	
2. Standby gasoline	1 - 300 gpm, 240' TDH	Good	
CONTROLS			
1. Float control on elevated storage	Start - Stop High Service Pumps	Broken	inadequate



O EXISTING INTAKE

PROPOSED WTP

---- PROPOSED WATER LINE

—— EXISTING WATER LINE

△ EXISTING TANK

▲ PROPOSED PUMPING PLANT

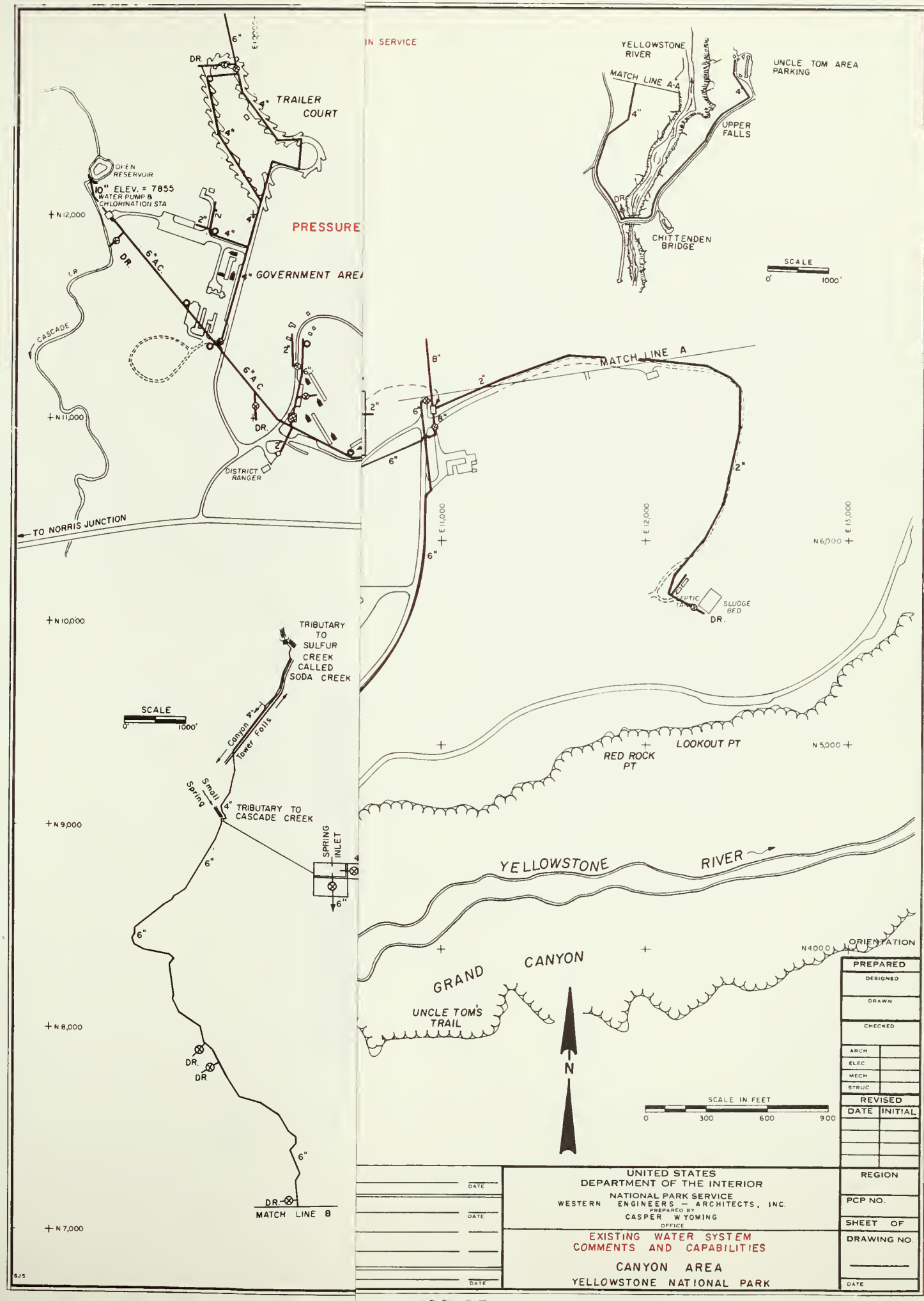
SERVICE AREA

SCALE IN MILES

0 1 2 3

N

FIG. II-1 CANYON AREA
VICINITY MAP


IN SERVICE
6"
DR.
TRAILER COURT
4"
OPEN RESERVOIR
10" ELEV. = 7855
WATER PUMP & CHLORINATION STA
N 12,000
2"
4"
PRESSURE
6" A.C.
GOVERNMENT AREA
CR
CASCADE
N 11,000
DISTRICT RANGER
TO NORRIS JUNCTION
N 10,000
TRIBUTARY TO SULFUR CREEK CALLED SODA CREEK
SCALE
0' 1000'
Canyon to Tower Falls
Small Spring
4" TRIBUTARY TO CASCADE CREEK
N 9,000
SPRING INLET
N 8,000
DR.
MATCH LINE B
N 7,000
YELLOWSTONE RIVER
MATCH LINE A-A
UNCLE TOM AREA PARKING
UPPER FALLS
CHITTENDEN BRIDGE
SCALE
0' 1000'
8"
MATCH LINE A
E 11,000
E 12,000
E 13,000
N 6,000
SEPTIC TANK
SLUDGE BED
RED ROCK PT
LOOKOUT PT
N 5,000
YELLOWSTONE RIVER
GRAND CANYON
UNCLE TOM'S TRAIL
N 4000
ORIENTATION
N
SCALE IN FEET
0 300 600 900
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE INITIAL
DATE
DATE
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
CANYON AREA
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE
GJS

NOTE:
1. ALL LINES HAVE 4' OR MORE COVER
2. FIRE HYDRANT PROTECTION ADEQUATE.

TRAILER COURT

GOVERNMENT AREA

PRESSURE • 85 PSI

FROST PROOF HOSE HYDRANT

DISTRICT RANGER

CANYON JUNCTION

SERVICE STATION

TO NORRIS JUNCTION

TO TOWER FALL

AMPHITHEATER

CAMPGROUND

OPEN

MATCH LINE B

CHLORINE HOUSE

VALVELESS SAND FILTER-NOT IN SERVICE

TE + 8093

500,000 GAL.

CONCRETE WATER RESERVOIRS

250,000 GAL.

6 DR.

6" DR.

TPDO WATER RESERVOIR

WINTER KEEPER RESIDENCE

HORSE CONCESSION

PUMP HOUSE

HAY BARN

FORMER CANYON HOTEL SITE

MATCH LINE A

YELLOWSTONE RIVER

MATCH LINE A-A

UNCLE TOM AREA PARKING

UPPER FALLS

CHITTENDEN BRIDGE

SCALE 0 1000'

TRIBUTARY TO SULFUR CREEK CALLED SODA CREEK

Canyon Falls

Lower Falls

Small Spring

TRIBUTARY TO CASCADE CREEK

SPRING INLET

FROM SODA CREEK

MATCH LINE B

SCALE 1000'

VISITOR CENTER

CANYON VILLAGE

TRANSITE LINE

CANYON MOTOR LODGE

LOOP ROAD

GRAND

TO INSPIRATION POINT

PRESSURE • 65 PSI

CABIN AREA

F.H WILL NOT DRAIN

F.H WILL NOT OPEN

PRESSURE • 89 PSI

MATCH LINE A

ABANDONED SLUDGE BED

ABANDONED SEPTIC TANK

SEPTIC TANK

PARKING

TRAIL

TO LAKE

MATCH LINE A-A

UPPER FALLS

YELLOWSTONE RIVER

LOWER FALLS

GRAND CANYON

UNCLE TOM'S TRAIL

RED ROCK PT

LOOKOUT PT

ORIENTATION

N

SCALE IN FEET 0 300 600 900

PREPARED
DESIGNED
DRAWN
CHECKED
ELEC
MECH
STRUC
REVISED
DATE INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
ASSOCIATED WITH
CASPER WYOMING
OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES

CANYON AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO

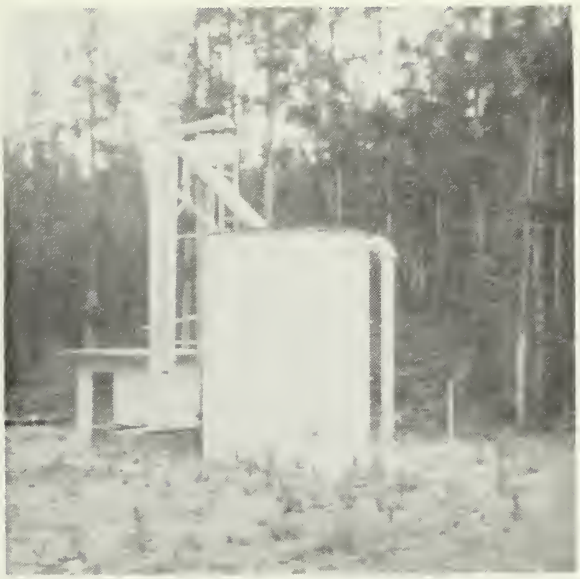


Fig. 11-3. Valveless Sand Filter for Soda Creek Intakes

note: filter not in service since 1966



Fig. 11-4. Lower Soda Creek Intake on Cascade Creek Tributary



Fig. 11-5. Cascade Creek Intake, Pumphouse and Chlorination

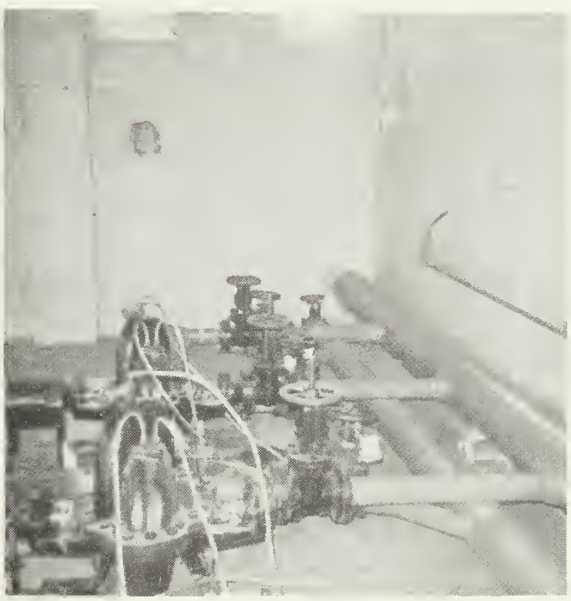


Fig. 11-6. Cascade Creek Pumping Station

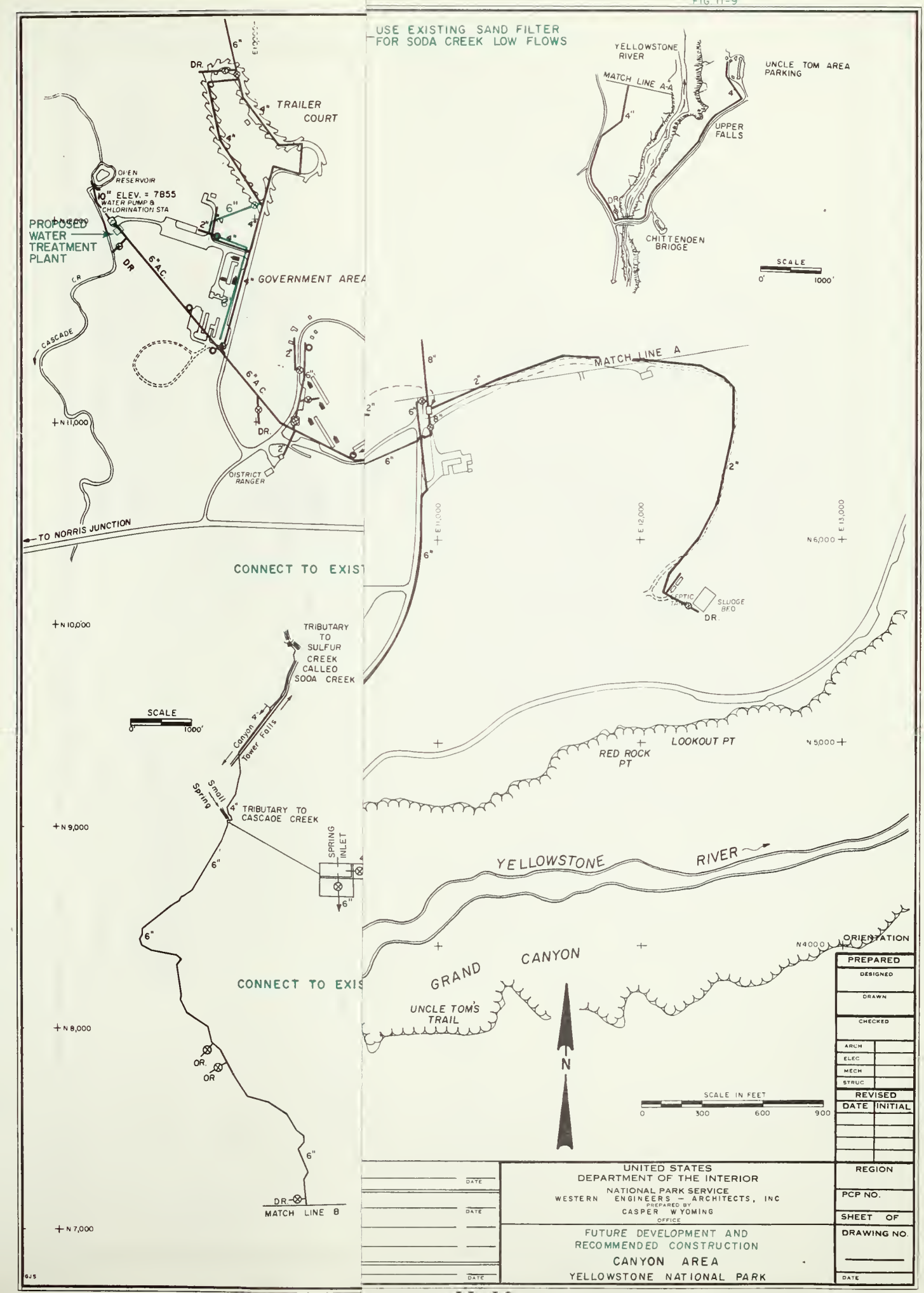


Fig. 11-7. Upper Soda Creek Intake - Early Summer Flow



Fig. 11-8. Upper Soda Creek Intake - Late Summer Flow

note: right hand side - low total flow going over weir



PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
CANYON AREA
YELLOWSTONE NATIONAL PARK

REGION	
PCP NO.	
SHEET	OF
DRAWING NO.	
DATE	

DATE
DATE
DATE

GJS

PROPOSED WATER TREATMENT PLANT
TRAILER COURT
GOVERNMENT AREA
CANYON JUNCTION
TO NORRIS JUNCTION
TO TOWER FALL
CONNECT TO EXISTING 8" LINE
CONNECT TO EXISTING LINES
TRIBUTARY TO SULFUR CREEK CALLED SODA CREEK
TRIBUTARY TO CASCADE CREEK
FROST PROOF HOSE HYDRANT
DISTRICT RANGER
SERVICE STATION
AMPHITHEATER
VISITOR CENTER
CANYON VILLAGE
CAMPGROUND
CABIN AREA
REPAIR F.H.
REPAIR F.H.
TO INSPIRATION POINT
MATCH LINE A
MATCH LINE A-2
MATCH LINE B
CHLORINE HOUSE
VALVELESS SAND FILTER
TE-7893
500,000 GAL
250,000 GAL.
CONCRETE WATER RESERVOIRS
USE EXISTING SAND FILTER FOR SODA CREEK LOW FLOWS
ABANDON FOR DOMESTIC SERVICE AS SOON AS POSSIBLE
TECO WATER RESERVOIR
WINTER KEEPER RESIDENCE
HORSE CONCESSION
BUNK HOUSE
HAY BARN
FORMER CANYON HOTEL SITE
YELLOWSTONE RIVER
MATCH LINE 4-4
UPPER FALLS
UNCLE TOM AREA PARKING
CHITTENDEN BRIDGE
LOOKOUT PT
RED ROCK PT
YELLOWSTONE RIVER
LOWER FALLS
GRAND CANYON
UNCLE TOM'S TRAIL
ABANDONED SLUDGE BED
ABANDONED SEPTIC TANK
SEPTIC TANK
UPPER FALLS
SCALE 1000'
SCALE IN FEET 0 300 600 900
N

RECOMMENDED
CONCURRED
APPROVED

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY CASPER, WYOMING

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
CANYON AREA
YELLOWSTONE NATIONAL PARK

PREPARED
DESIGNED
DRAWN
CHECKED
REVISED
DATE INITIA
REGION
PCP NO
SHEET OF
DRAWING NO

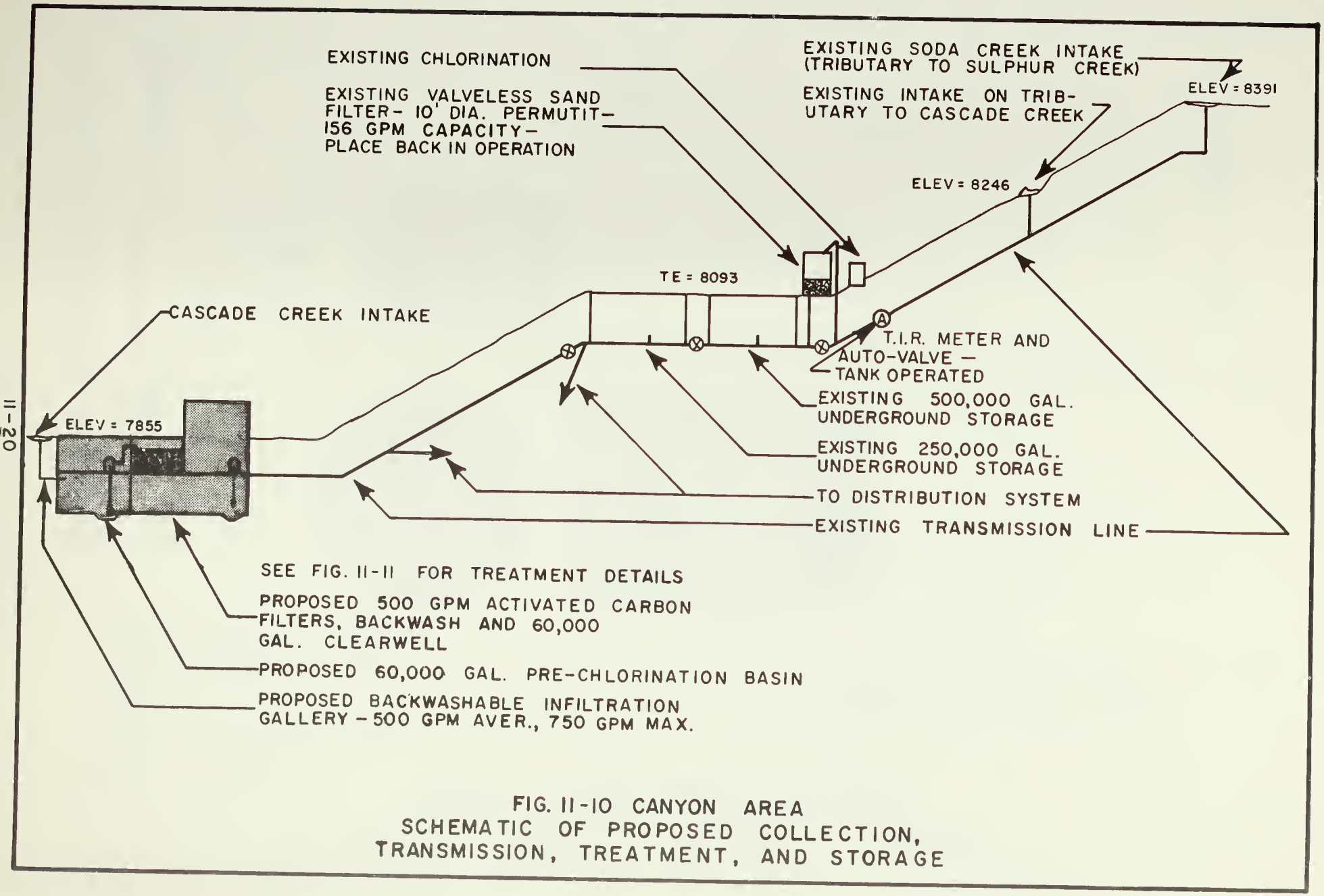


FIG. II-10 CANYON AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE

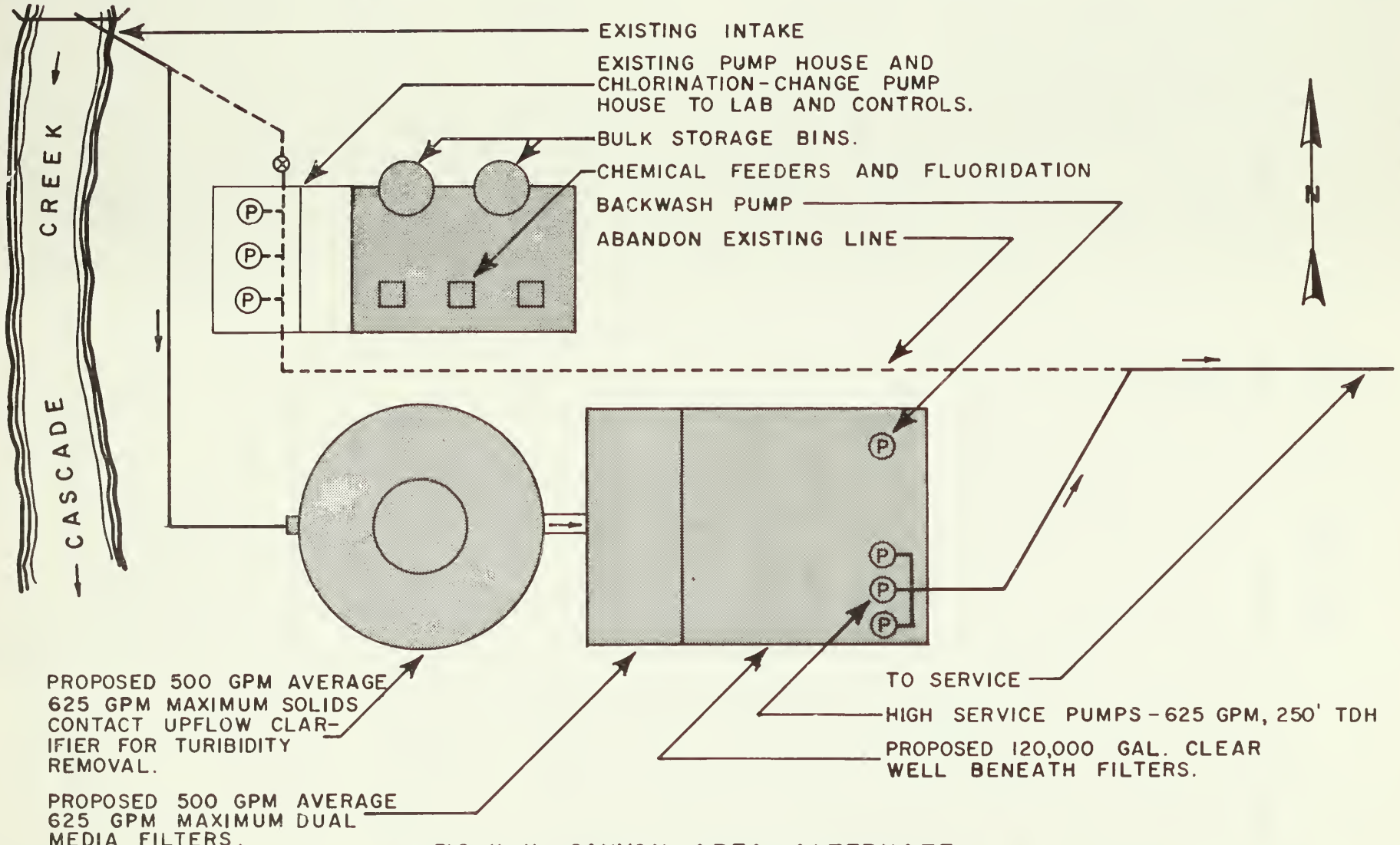


FIG. II-II CANYON AREA - ALTERNATE
PROPOSED COMPLETE TREATMENT PLANT
INCLUDING COAGULATION, SETTLING, FILTRATION,
PRE AND POST CHLORINATION AND CLEAR WATER STORAGE

CHAPTER 12. LAKE AREA

The Lake area encompasses the community of Fishing Bridge, Lake, and Bridge Bay. Because of their close proximity to one another, their similar characteristics, and their interrelated development programs, it was considered both feasible and advantageous to group Bridge Bay, Fishing Bridge, and Lake into a single study area. Also, the existing systems are currently combined and with minor modifications can operate as a unit.

The Lake area accommodates approximately 30 percent of the seasonal population in the Park. It is located along the East Entrance Road and the southeast section of the Grand Loop Road and occupies 4 miles of shoreline on the northern boundary of Yellowstone Lake as shown in Figure 12-1. The primary attraction of the area is boating and fishing. There is a large marina at Bridge Bay. Campgrounds are located at Bridge Bay and Fishing Bridge, and major hotel, lodge, and service facilities are in the center at Lake.

Existing developments in the Fishing Bridge and Lake communities date back to the early 1900's, whereas the Bridge Bay facilities were constructed in the 1960's.

An approximate breakdown of the National Park Service 1971 census for the area gives the following populations:

Bridge Bay	2175 persons
Fishing Bridge	4140 persons
Lake	1900 persons

The existing guest accommodations include hotel, lodge, and cabin facilities at Lake; cabin, campground, and trailer

village facilities at Fishing Bridge; and campground facilities at Bridge Bay. National Park Service and concessioner facilities are located primarily at Lake, but some are also located in the other areas.

To provide the necessary service personnel accommodations, a new dormitory for approximately 100 employees will be constructed in the future. Long-range plans call for the removal of the Lake Hotel and its replacement by 2 story, motel-type units with a total of approximately 400 rooms.

Cabins in the Fishing Bridge area, now approximately 30 years old and generally rated as substandard living accommodations, are being removed as the additional guest facilities at Lake are provided. The campground and trailer park areas are expected to be maintained at their present levels.

Population and design flows for the three communities are summarized in Tables 12-1, 12-2, and 12-3. Winter service is possible as the newer and larger mains have adequate cover for winter use.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required domestic flow for a peak day is 1,274,000 gal. or 890 gpm. Table 12-4 lists the design criteria for the proposed system. This system is unique in that it has already combined three separate systems into one major system. Though many problems exist none will be particularly expensive to solve as the systems are combined and the spring water supply is a good source.

Figures 12-2, 12-3, and 12-4 show the entire existing

systems and how they interconnect for Fishing Bridge, Lake and Bridge Bay respectively. Most of the four inch and smaller mains (with the notable exception of the new Bridge Bay Area) have been installed for many years and are shallow. The newer, larger mains are normally at a depth which provides adequate cover. The systems are described as follows:

Fishing Bridge

For Fishing Bridge water is mostly supplied from the Fishing Bridge spring and is pumped into the Fishing Bridge elevated concrete tank. (Figure 12-5) There are two pumping stations located near the spring that pump continuously. (Figure 12-6) The upper pumping station has a 10 HP centrifugal and the lower station a 7½ HP centrifugal.

Chlorine gas is continuously fed at the upper pumphouse and chlorinates the water flowing to the lower pumphouse and the water being pumped to elevated storage. The upper pumphouse pumps only to elevated storage while the lower pumphouse pumps either to storage or directly to the system depending upon the system demand. From the elevated tank most of the supply goes directly to the Fishing Bridge distribution system. The distribution system is C.I. and G.S. mains with the larger and newer lines having adequate cover. The system pressure is about 75 p.s.i. A transmission line connects the Fishing Bridge and Lake systems. The hydraulics are such that the Fishing Bridge tank can fill to within ten feet of the top from the Lake tanks.

Lake and Bridge Bay

For Lake and Bridge Bay most of the waters are supplied from the Lake Spring, and the winter spring which is located immediately adjacent to the Lake Spring. (Figure 4-2) Both springs are collected in the clearwell at the Lake pumphouse and are chlorinated and pumped with a 30 HP vertical turbine into the Lake elevated storage. Before reaching the tanks the transmission and distribution mains are interconnected. The chlorination process is continuous and the pumping process is almost continuous. The pumping stops on a low level float switch clearwell control. The Bridge Bay system is connected directly to the Lake system by a transmission line which runs from the Lake system to the Bridge Bay elevated steel tank. The Lake ele-

vated tanks are an underground concrete tank and an above ground steel tank, both being at the same elevation. From the Lake and Bridge Bay tank both feed their respective distribution systems. The Lake distribution system is a conglomerate of C.I., A.C., and G.S., being large, small, deep and shallow while in contrast the Bridge Bay system is C.I. and G.S. all being at an adequate depth for winter use. For both systems pressures range between 40 and 80 p.s.i.

EVALUATION OF EXISTING SYSTEMS

Table 12-5 gives an evaluation of the existing systems which is expanded upon in the ensuing discussion.

Fishing Bridge

The Fishing Bridge Pumphouse and chlorination structure are old wood frame buildings built near the spring collection structure. Every spring the snow melt runs several inches deep over these structures causing a potential health problem as the surface runoff mixes with the ground water. The spring area is well fenced and the gas chlorination system is effective and carefully operated. However, the lower pumphouse can pump directly to the system, without any chlorine contact time. The fluoride content in the Fishing Bridge spring is above maximum Public Health Service recommendations and would be a problem for year around residents having small children. The pumps operate continuously as does the chlorinator resulting in a significant waste of power and chlorine. The float switch on the tank is broken so the pumps are not being controlled by tank levels. A pressure sensing control would be more effective as it would not be subject to being broken by ice as is the float switch. The transmission of combined fire flow and domestic water is inadequate from the Fishing Bridge tank to the Fishing Bridge community. The detailed flow analysis of the distribution system appears in Appendix B. Most of the system is adequate for peak domestic and fire flows with the exception of the transmission just mentioned. The concession building and laundry near the visitor trailer village would be better served by looping the system, but maximum fire and domestic flows can be maintained in this area without the looping. All fire hydrants were checked and their condition detailed on Figure 12-2. Fire hydrant coverage is adequate and most hydrants are new. All of the larger mains have adequate cover for winter use as do many of the smaller mains.

Lake

The Lake Springs are fenced (Figure 12-8) and protected from surface drainage by a perimeter ditch. (Figure 12-7) The fence needs maintenance as snow pack breaks it down. Several old spring collection manholes are abandoned but are shut off from the existing spring collection with valves. Mice can and do get trapped in these manholes and the manholes should be removed so that this potential cross connection is eliminated. Figure 12-9 shows the good flap gate on the Lake Spring overflow. The chlorine is carefully and continuously fed into the spring water. The pump continuously pumps this water into the system and elevated storage. The existing clearwell provides some contact time but a two hour contact time should prove more desirable. The float switch on the elevated storage is broken and thus cannot control the tank levels and pumping. The winter spring is not fenced but is an excellent source. Fluoride content in all of the springs is high and should be removed as a dental hygiene program for permanent residents having children. Figure 12-10 shows the flow coming from the gallery spring which is an abandoned spring in the enclosed Lake Spring area that could be reclaimed.

No method now exists to fill the Fishing Bridge tank from the Lake pumphouse. If tank filling were possible from Lake, then sufficient supply could be developed at Lake to abandon the spring facilities at Fishing Bridge for several years. The detailed flow analysis of the distribution system appears in Appendix B. The network analysis did show fire protection deficiencies in the hospital area and in the Lodge Cabin area. All fire hydrants were checked and their condition detailed in Figure 12-4. Fire hydrants coverage is adequate but many gate valves are needed in the hotel area. Winter use should not be a problem as the larger mains have adequate cover. An existing open reservoir (Figure 12-11) has not been used for two winter seasons and should be permanently abandoned or covered.

Bridge Bay

The Bridge Bay system is fed solely by the Lake Spring area. Existing wells are abandoned and should be obliterated. The Bridge Bay tank is in need of interior painting. No method exists to stop the continuous overflow from this tank. (Figure 12-12) An inoperable mercury altitude valve has recently been removed from this tank. The constant overflow results in a power and chlorine loss. The detailed flow analysis appears in Appendix B and shows fire and peak domestic flow deficiency in the concession-marina area. All fire hy-

drants were checked and found adequate for coverage and service. All mains have good cover for winter use.

RECOMMENDED CONSTRUCTION

Figures 12-13, 12-14, and 12-15 show the horizontal location of the proposed improvements for Fishing Bridge, Lake and Bridge Bay respectively. Figures 12-16 and 12-17 show the vertical location of the improvements, some details on the Fishing Bridge tank level control, and some detail on the proposed pumphouse expansion at Lake. The recommended improvements will:

Consolidate all operations and control in the Lake pumphouse and automate the system.

Provide an adequate fire protection system.

Eliminate waste of chlorine and power.

Eliminate the potential health problems.

The features of the plan include:

1. Construct increased storage at the Lake Pumphouse for a two hour chlorine contact time.
2. Construct additional gallery spring collection and pumping capabilities at the Lake spring area and obliterate the Fishing Bridge pumping stations. In conjunction with this install the necessary controls, the altitude valve on the Lake tanks and the control station to fill the Fishing Bridge tank so that the Lake and Fishing Bridge tanks can be filled from one pumping station automatically. The control station for the Fishing Bridge tank is located so that water cannot return to the Lake system unless an unusual demand would occur and thus open the differential pressure reducing valve. (Figure 12-17) This is necessary as the Fishing Bridge tank is ten feet higher than the Lake tanks.
3. Construct a new pumping-chlorination station for the Fishing Bridge spring which will not flood and will pump only into the Fishing Bridge tank. This station will be required only if the fully developed Lake spring area becomes inadequate for total flow.

4. Construct some new transmission and distribution lines to provide adequate fire and peak domestic flows as needed in each community. Some connections of mains and additional metering will be required for proper looping.

5. The new mains in Bridge Bay necessitate a new altitude valve and a change in inlet piping for the existing tank. The tank will serve only for fire protection and excessive domestic flow, thus the altitude valve is by-passed with a constantly flowing 3/4 inch line to keep the tank from stagnating. The tank needs interior painting.

6. Provide individual home defluoridation units for permanent personnel with families having small children.

7. A complete control system should be provided to perform as is described in Table 12-4.

The estimated total cost for the complete system is $355,000 with an immediate recommended expenditure of $145,100. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

ALTERNATIVES CONSIDERED

An existing intake and pumping station can take water directly from Yellowstone Lake. A direct Lake intake would provide an adequate supply but should be installed in a fashion similar to the intake at Grant and further should be followed with a polishing filter. Such a system would eliminate the high fluoride problems, but would also abandon the adequate, highly desirable, spring supply. The Lake intake system with filtration would cost $500,000.

TABLE 12-1. POPULATION AND MAXIMUM FLOWS, FISHING BRIDGE IN LAKE AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Cabin area					
Cabins	1,050	1,000	30	31,500*	30,000
Concession area					
Dormitories	150	190	75	11,250	14,250
Cafeteria	--	--	--	25,000	25,000
Lunch counter	--	--	--	13,250	13,250
Service station	--	--	--	2,000	2,000
Sub Total	150	190	--	51,500	54,500
Campground area					
317 campsites**	1,600	1,600	50	80,000	80,000
Visitor center	--	--	--	5,000	5,000
Residence	9	12	200	1,800	2,400
Sub Total	1,609	1,612	--	86,800	87,400
Visitor trailer park area					
358 spaces	1,470	1,500	50	73,500	75,000
Laundry, 16 machines	--	--	--	8,000	8,000
Sub Total	1,470	1,500	--	81,500	83,000
Government area					
Trailer park	42	50	50	2,100	2,500
TOTAL	4,321	4,352	--	253,400	257,400
Say:	4,300	4,350	--	254,000	258,000

Actual Maximum Measured Total Flow - 264,000 gpd

* Most units are economy cabins; water use is 25 gcd, design max. 30 gcd

** 25 percent of campsites assumed to have 2 family occupancy.

TABLE 12-2: POPULATION AND WATER FLOWS, BAKE IN LAKE AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Hospital and South District office area					
Residences and apartments	50	50	200	10,000	10,000
Dormitories	33	50	75	2,475	3,750
Hospital, 20-30 beds	--	--	--	6,000	6,000
Sub Total	83	100		18,475	19,750
Hotel and cabin area					
Hotel	440	530	75	33,000	39,750
Dining room and lounge	--	--	--	42,000	42,000
Cabins	330	380	75	30,875	28,500
Dormitories	245	300	75	12,250	22,500
Sub Total	1,015	1,210		118,125	132,750
Ranger station and Hamilton store area					
Ranger station	7	7	200	1,400	1,400
Service station	--	--	---	3,000	3,000
Hamilton store (to be moved to Bridge Bay)	--	--	---	8,650	8,650
Dormitory	30	30	75	2,250	2,250
Sub Total	37	37		15,300	15,300
Lodge area					
Cabins	600	1,000	75	45,000	75,000
Dormitories	140	250	75	10,500	18,750
Laundry	--	--	--	20,000	30,000
Cafeteria, snack bar	--	--	--	35,000	48,500
Sub Total	740	1,250		110,500	172,250

TABLE 12-2. POPULATION AND MAXIMUM FLOWS, LAKE IN LAKE AREA-contd.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Government area					
Apartments	28	40	200	5,600	8,000
Employee trailer park	75	175	50	3,750	8,750
Power station	9	10	---	450	500
Bunkhouse and dormitory	65	70	75	3,250	3,500
Sub Total	177	195		13,050	20,750
TOTAL	2,052	2,792		275,450	360,800
Say:	2,100	2,800		276,000	361,000

Actual Maximum Measured Total Flow - 384,000 gpd

TABLE 12-3. POPULATION AND MAXIMUM FLOWS, BRIDGE BAY IN LAKE AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Campground area					
New campground (240 sites)	1,200	1,200*	50	60,000	60,000
Old campground (230 sites)	1,025	1,170*	50	51,250	58,500
Ranger's house	4	4	200	800	800
Sub Total	2,229	2,374		112,050	119,300
Boat rental and marina area					
All purpose building	--	--	--	1,000	3,000
Fish cleaning station	--	--	--	7,500	7,500
Boat service station	--	--	--	5,000	5,000
Sub Total	--	--	--	13,500	15,500
TOTAL	2,229	2,374		125,550	134,800
Say:	2,230	2,400		126,000	135,000

Actual Maximum Measured Total Flow - 114,000 gpd

* 25 percent of campsites assumed to have 2 family occupancy.

TABLE 12-4. BASIC DESIGN DATA, LAKE AREA

ITEM	EXISTING	DESIGN
POPULATION	8,730	9,550
WATER FLOW		
Peak, gpd	762,000	1,274,000
Peak, gpm		890
SOURCE AND PUMPING		
Lake		
Lake Spring - existing - gpm		385
Winter Spring - existing - gpm		125
Gallery Spring - proposed - gpm		225
Pumping @ 190' TDH - gpm		735
Fishing Bridge		
Fishing Bridge Spring - proposed - gpm		270
Pumping @ 140' TDH - gpm		270
TREATMENT AND PUMPING		
Gound Water Source - springs		
Chlorination		
Contact time - hours		2
De-fluoridation -selected units		
STORAGE		
Fishing Bridge Tank - existing - gal.		250,000
Service-control and to system		
Lake Tanks - existing - gal		1,000,000
Service-control and to system		
Lake Clearwell - gal.		75,000
Service-control,chlorine contact time, and to service		
Bridge Bay Tank - existing - gal.		100,000
Service-standby		
DISTRIBUTION - for Hardy Cross Network Analysis		
Fishing Bridge		
Peak 4 hr. domestic flow - gpm		750
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commerical fire flow - gpm		750

TABLE 12-4. BASIC DESIGN DATA, LAKE AREA-contd.

ITEM	EXISTING	DESIGN
DISTRIBUTION - for Hardy Cross Network Analysis-contd.		
Lake		
Peak 4 hr. domestic flow - gpm		1,500
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commercial fire flow - gpm		1,500
Bridge Bay		
Peak 4 hr. domestic flow - gpm		450
Peak 4 hr. residential and commercial fire flow - gpm		500
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm		1,005
Max. 4 hr. fire flow - gpm		1,500
Peak 4 hr. domestic flow - gpm		1,780
CONTROL SYSTEM		
Lake and Fishing Bridge		
1. Elevated storage - start - stop pump** both Lake and Fishing Bridge storage		
2. Record from all three tank locations at Lake.		
3. T.I.R. flow out - Lake and Fishing Bridge, record at Lake.		
4. Lake clearwell full - stop inflow and stop chlorination		
5. Record clearwell		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Control equipment on elevated tanks to be pressure sensing. Steel tanks could be used for winter service with this control system.

TABLE 12-5. EVALUATION OF EXISTING SYSTEMS
LAKE AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
SOURCE			
1. Lake			
A. Lake Spring	Concrete structures - fenced	Good	Almost adequate
B. Winter Spring	Concrete structure - not fenced	Good	Almost adequate
2. Fishing Bridge Spring	Concrete structure - fenced	Good	
TREATMENT			
1. Lake			
A. Chlorination - gas	Continuous - system water pressure	Good	Inadequate
2. Fishing Bridge			
A. Chlorination - gas	Continuous - system water pressure	Good	Inadequate
3. Other	Fishing Bridge pumphouse and chlorination buildings flood	Poor	Inadequate
PUMPING			
1. Lake			
A. High Service Turbine	30 HP, 440 V, 470 gpm at 168' TDH, verticle turbine	Good	Pumps most of time
B. Standby gasoline		Good	
2. Fishing Bridge - upper			
A. High Service Electric	10 HP, 230 V, 127' TDH, 150 gpm - pumps continuously	Fair	Pumps continuously
B. Standby gasoline	150 gpm, 127' TDH	Fair	
3. Fishing Bridge - lower			
A. High Service Electric	$7\frac{1}{2}$ HP, 220/440 V, 90 gpm at 128' TDH	Good	Pumps continuously

TABLE 12-5. EVALUATION OF EXISTING SYSTEMS
LAKE AREA-contd.

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
TRANSMISSION			
1. Lake Springs to Lake Tank	C.I.	Good	
2. Fishing Bridge Springs to Fishing Bridge Tank	3" G.S. 6" C.I.	Good Good	Shallow
3. Lake to Bridge Bay Tank	G.S.	Good	
STORAGE			
1. Lake - 500,000 gal.-elevated	Above ground, steel	Good	
2. Lake - 500,000 gal.-elevated	underground, concrete	Good	
3. F.Bridge-250,000 gal.-elevated	above ground, concrete - old	Fair	
4. Bridge Bay, 100,000 gal.	above ground, steel	Fair	Needs some painting
DISTRIBUTION SYSTEM			
1. Mains 4 inch and smaller	C.I. and G.S. (Bridge Bay lines 4' + of cover)	Fair	Often shallow
2. Mains 6 inch and larger	C.I., G.S. and AC	Good	Normally adequate
CONTROLS			
1. Lake			
A. Tank	Float switch - start - stop high service pump	Broken	Inadequate
B. Clearwell	Float switch - start - stop high service pump	Good	
2. Fishing Bridge	Float switch - start - stop high service pump	Broken	inadequate



LEGEND

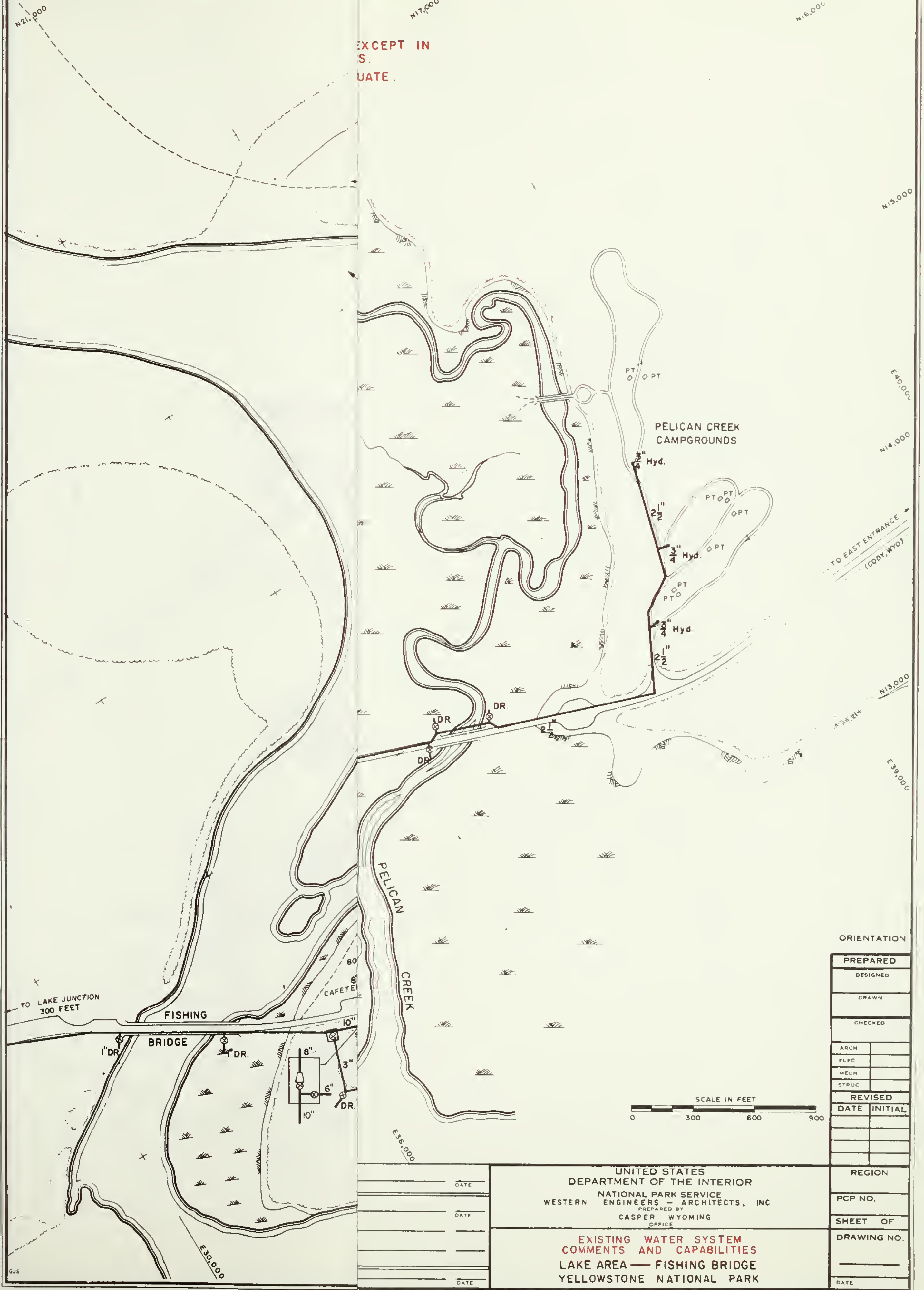
- EXISTING WATER LINE
- PROPOSED WATER LINE
- EXISTING TANK
- PROPOSED PUMPING PLANT
- SERVICE AREA

SCALE IN MILES

0 1 2 3

N

FIG. 12-1 LAKE AREA VICINITY MAP


EXCEPT IN
S.
UATE.
PELICAN CREEK
CAMPGROUNDS
TO EAST ENTRANCE
(CODY, WYO)
PELICAN
CREEK
TO LAKE JUNCTION
300 FEET
FISHING
BRIDGE
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
SCALE IN FEET
0
300
600
900
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS - ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA — FISHING BRIDGE
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

NOTES

1. ALL LINES 4' OR MORE COVER EXCEPT IN CABIN AREA AND SOME SERVICES.
2. FIRE HYDRANT PROTECTION ADEQUATE

YELLOWSTONE RIVER

HOWARD EATON TRAIL TO CANYON VILLAGE

FILTER BEDS

SLUDGE BED

SEPTIC TANK

SEASONAL EMPLOYEES

TRAILER SITES

FISHING BRIDGE

VISITOR TRAILER VILLAGE

CONCESSION BLDG & LAUNDRY

TRAILER DUMP STATION

CABIN AREA

PRESSURE = 80 PSI

NO WATER TO F.H.

PRESSURE = 75 PSI

NO WATER TO H

METER REMOVED

METER

CAFETERIA

BOILER

STORE

SERVICE

RANGER STATION

SHOWERS & LAUNDRY

AMPHITHEATER

VISITOR CENTER & MUSEUM

SEPTIC TANKS

TRAILER DUMP STATION

CAMPGROUND

TO LAKE JUNCTION 300 FEET

FISHING BRIDGE

TO CABINS

TO STORE

YELLOWSTONE LAKE

PELICAN CREEK CAMPGROUNDS

Hyd.

PELICAN CREEK

TO EAST ENTRANCE (CODY, WYO.)

ORIENTATION

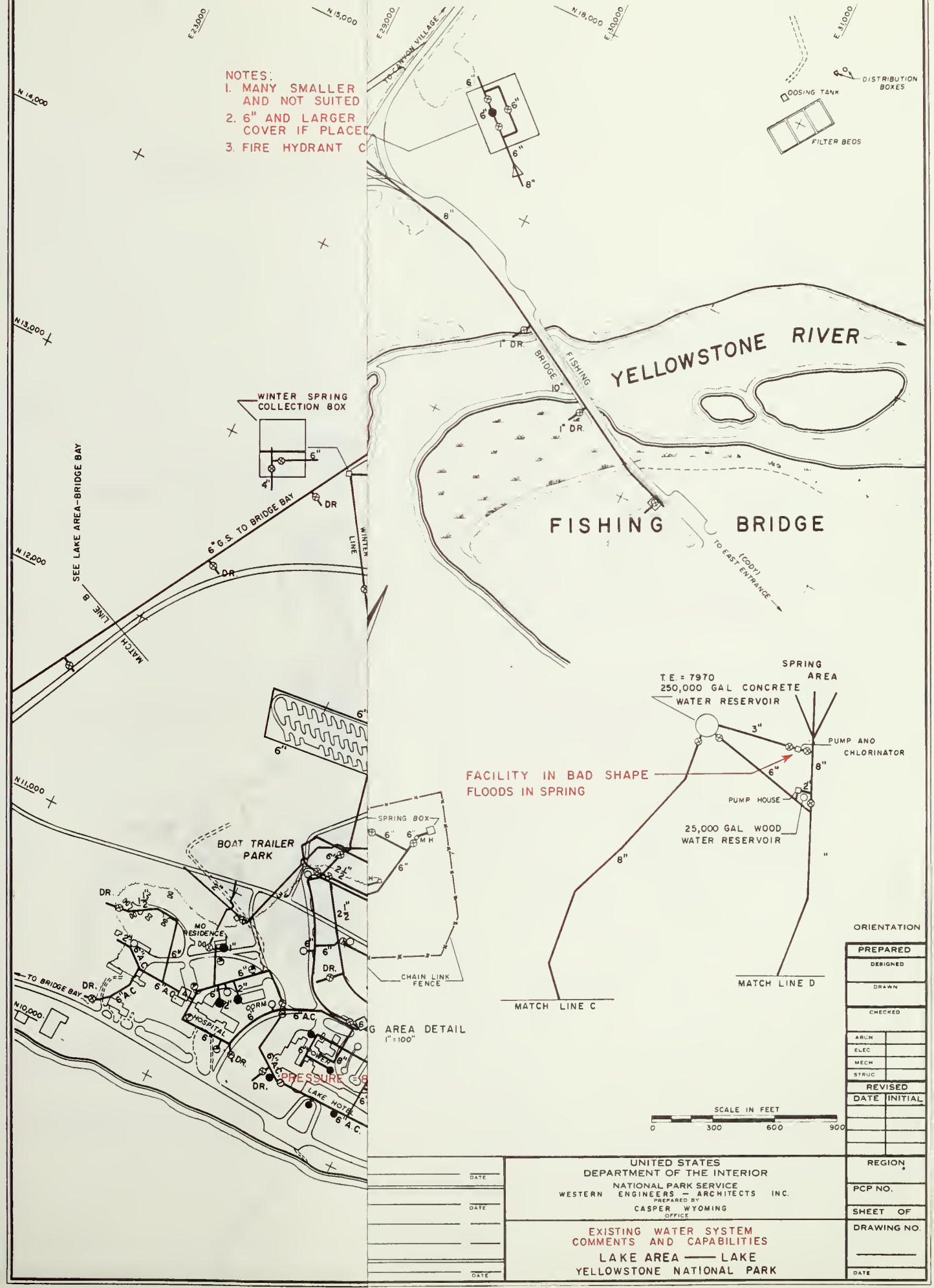
SCALE IN FEET 0 300 600 900

RECOMMENDED		DATE
CONCURRED		DATE
APPROVED		DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
DENVER CASPER WYOMING

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA — FISHING BRIDGE
YELLOWSTONE NATIONAL PARK

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
LD.A.	
S.S.C.	
M.S.C.	
S.T.M.C.	
REVISED	
DATE	INITIAL
REGION	
PCP NO	
SHEET OF	
DRAWING NO	
DATE	


NOTES:
1. MANY SMALLER
AND NOT SUITED
2. 6" AND LARGER
COVER IF PLACED
3. FIRE HYDRANT C
N 14,000
N 13,000
N 12,000
N 11,000
N 10,000
E 23000
N 15,000
E 29000
N 18,000
E 30000
E 31000
TO CANYON VILLAGE
DISTRIBUTION BOXES
DOSING TANK
FILTER BEDS
YELLOWSTONE RIVER
FISHING BRIDGE
1" DR.
10"
FISHING BRIDGE
TO EAST ENTRANCE (CODY)
WINTER SPRING COLLECTION BOX
SEE LAKE AREA-BRIDGE BAY
MATCH LINE B
6" G.S. TO BRIDGE BAY
WINTER LINE
DR.
BOAT TRAILER PARK
SPRING BOX
MH
CHAIN LINK FENCE
MO RESIDENCE
HOSPITAL
TO BRIDGE BAY
LAKE HOTEL
PRESSURE
G AREA DETAIL
1"=100'
SPRING AREA
T.E. = 7970
250,000 GAL CONCRETE
WATER RESERVOIR
PUMP AND CHLORINATOR
FACILITY IN BAD SHAPE
FLOODS IN SPRING
PUMP HOUSE
25,000 GAL WOOD
WATER RESERVOIR
MATCH LINE C
MATCH LINE D
ORIENTATION
SCALE IN FEET
0 300 600 900
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE INITIAL
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA — LAKE
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

NOTES
1 MANY SMALLER MAINS TO 4" ARE OFTEN SHALLOW AND NOT SUITED FOR WINTER USE
2. 6" AND LARGER MAINS NORMALLY HAVE 4' OR MORE COVER IF PLACED IN THE LAST 10 YEARS.
3 FIRE HYDRANT COVERAGE ADEQUATE

T.E. 7960
2-500,000 GAL
WATER RESERVOIRS
STEEL CONCRETE

EXISTING FLOAT SWITCH BROKEN

MATCH LINE C

MATCH LINE D

PRESSURE = 40 PSI

EMPLOYEES COURT

OFF SEASON SEPTIC TANK & LEACHING FIELD

WINTER SPRING COLLECTION BOX

GRAVITY FLOW TO PUMP HOUSE

SPRING BOX

SPRING AREA

SEE DETAIL FOR SPRING AREA

PUMP HOUSE T.E. 7804

6"G.S. TO BRIDGE BAY

SEE LAKE AREA-BRIDGE BAY

ROAD UNDER CONSTRUCTION SUMMER 1971

CLOSED EXCEPT FOR WINTER OPERATION

LODGE CABIN AREA

PRESSURE = 60 PSI

BOAT TRAILER PARK

OPEN
YELLOWSTONE PARK CO. RESERVOIR
NOT IN USE

LAKE

DORMITORIES

HOTEL

H. LEAKS

CABIN AREA

SERVICE STATION

RANGER STA.

LIFT STATION
SLUDGE BED

OFF SEASON LEACHING TRENCH

LAKE INTAKE NOT IN USE

POTENTIAL CROSS CONNECTION

ABANDONED M.H.

CHAIN LINK FENCE

SPRING AREA DETAIL
1"=100'

FACILITY IN BAD SHAPE
FLOODS IN SPRING

T.E. = 7970
250,000 GAL CONCRETE
WATER RESERVOIR

SPRING AREA

PUMP AND CHLORINATOR

PUMP HOUSE

25,000 GAL WOOD
WATER RESERVOIR

MATCH LINE C

MATCH LINE D

YELLOWSTONE RIVER

FISHING BRIDGE

TO EAST ENTRANCE

DOSING TANK

DISTRIBUTION BOXES

FILTER BEDS

LAGOON

PARKING

Y E L L O W S T O N E

LAKE

ORIENTATION

SCALE IN FEET
0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
TOPO	
ELEC	
MECH	
STRUC	

REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

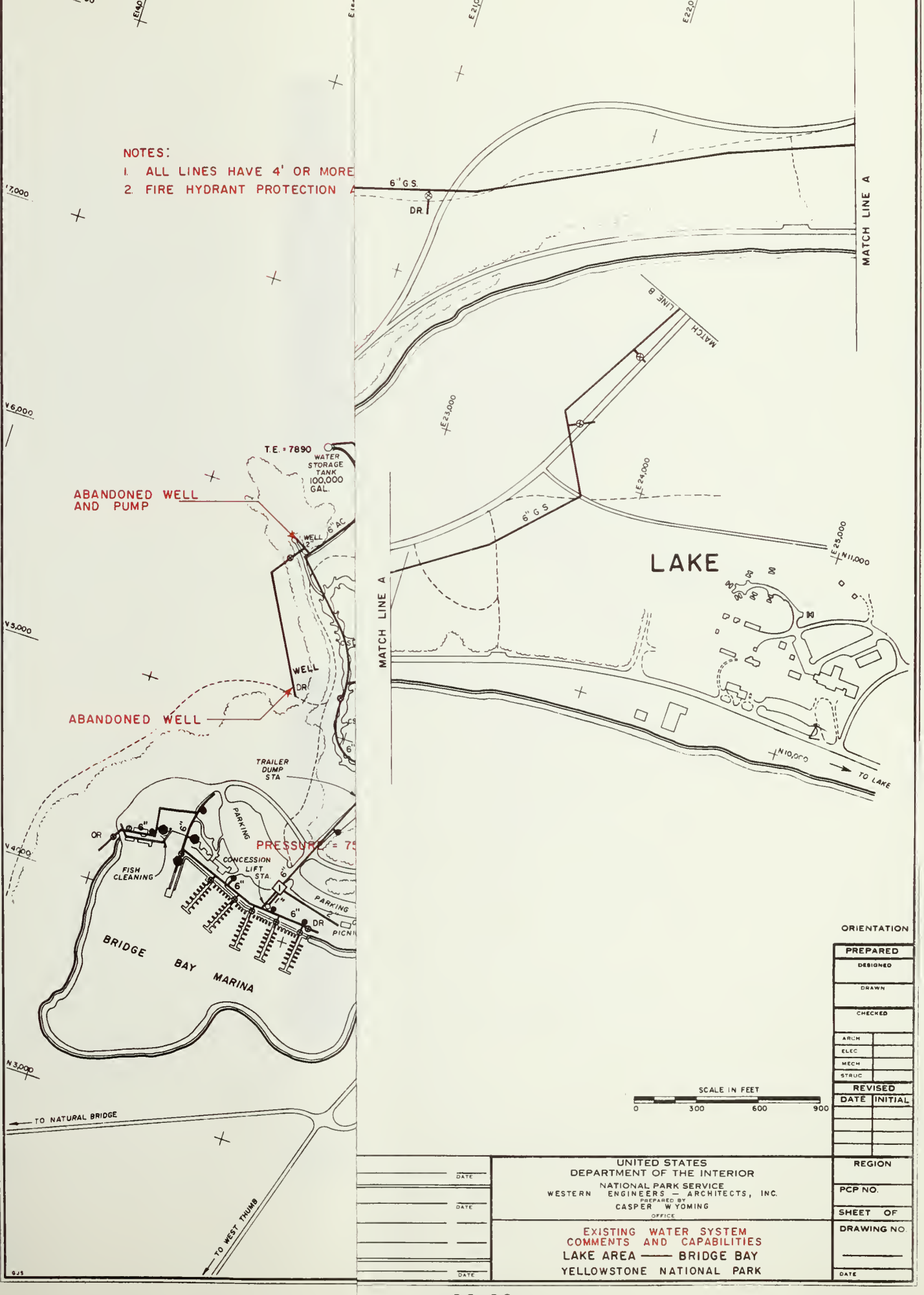
CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS INC
CASPER WYOMING

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA — LAKE
YELLOWSTONE NATIONAL PARK

REGION 1
PCP NO
SHEET OF
DRAWING NO
DATE


NOTES:
1. ALL LINES HAVE 4' OR MORE
2. FIRE HYDRANT PROTECTION A
6" G.S.
DR.
MATCH LINE A
MATCH LINE B
E 23,000
E 24,000
E 25,000
N 11,000
N 10,000
6" G.S.
LAKE
MATCH LINE A
TO LAKE
T.E. = 7890
WATER STORAGE TANK 100,000 GAL.
ABANDONED WELL AND PUMP
6" A.C.
WELL
WELL
DR.
ABANDONED WELL
TRAILER DUMP STA
PARKING
PARKING
CONCESSION LIFT STA.
FISH CLEANING
6"
DR
PICNI
BRIDGE BAY MARINA
PRESSURE = 75
N 6,000
N 5,000
N 4,000
N 3,000
TO NATURAL BRIDGE
TO WEST THUMB
SCALE IN FEET
0
300
600
900
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA —— BRIDGE BAY
YELLOWSTONE NATIONAL PARK
DATE
DATE
DATE

NOTES:
1. ALL LINES HAVE 4' OR MORE COVER.
2. FIRE HYDRANT PROTECTION ADEQUATE

BRIDGE BAY

YELLOWSTONE LAKE

LAKE

ABANDONED WELL AND PUMP

ABANDONED WELL

TE = 7890

WATER STORAGE TANK 100,000 GAL.

PRESSURE = 75 PSI

CAMPGROUND

AMPHITHEATER

HOWARD EATON TRAIL

TO INCINERATOR

TRAILER DUMP STA

RANGER STATION

PARKING

FISH CLEANING

CONCESSION LIFT STA

PICNIC AREA

SEWAGE TREATMENT PLANT

BRIDGE BAY MARINA

CHANNEL

TO NATURAL BRIDGE

TO WEST ENTRANCE

TO LAKE

MATCH LINE A

MATCH LINE B

1" To Lift Sta

SCALE IN FEET
0 300 600 900

ORIENTATION

PREPARED
DESIGNED
DRAWN
CHECKED
REVISED
DATE | INITIAL

RECOMMENDED
CONCURRED
APPROVED

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS - ARCHITECTS, INC
CASPER WYOMING

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
LAKE AREA —— BRIDGE BAY
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO



Fig. 12-5. Fishing Bridge Tank
Shows 3" inlet and old staining



Fig.12-6. Fishing Bridge Spring, Upper Pumphouse and Chlorination
These facilities flood in the spring



Fig. 12-7. Drainage Ditch Around Lake Springs



Fig. 12-8. Fence Around Lake Springs
Note fence broken down at far side.



Fig. 12-9. Lake Spring Overflow
Has flapgate cover



Fig. 12-10. Gallery Spring Flow



Fig. 12-11. Open Reservoir - Lake

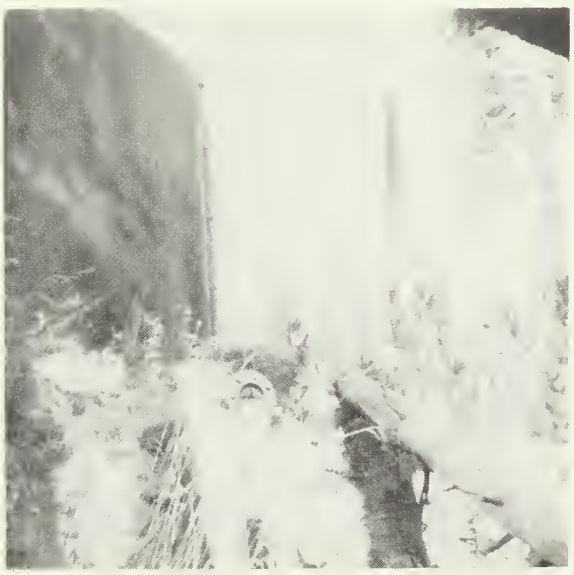
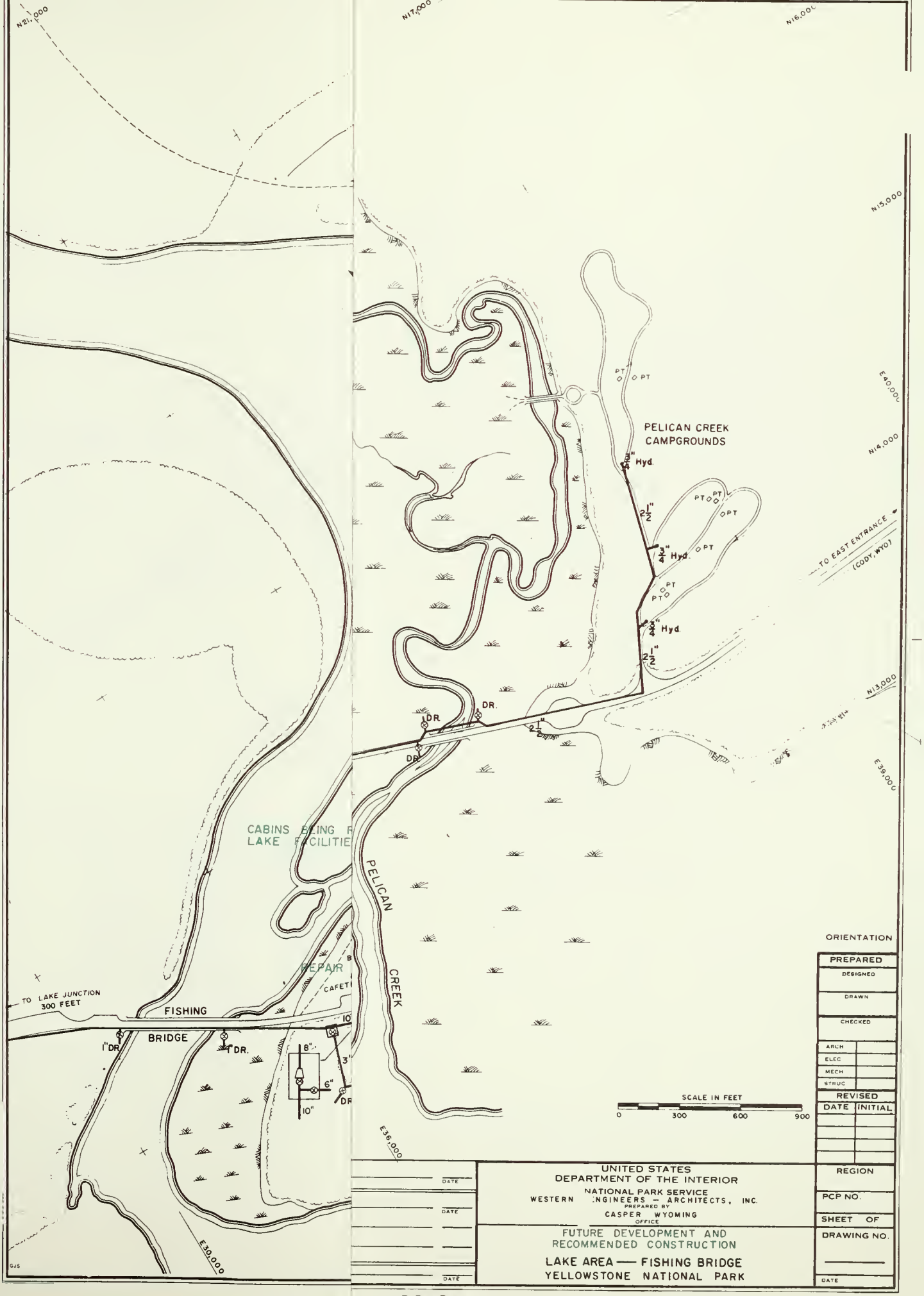


Fig. 12-12. Bridge Bay Steel Tank
note: broken screen-continuous water overflow


N21,000
N17,000
N16,000
N15,000
N14,000
N13,000
E40,000
E39,000
E38,000
E37,000
PELICAN CREEK CAMPGROUNDS
PT
OPT
3/4" Hyd.
2 1/2"
1" Hyd.
TO EAST ENTRANCE (CODY, WYO.)
DR.
1" DR.
CABINS BEING R
LAKE FACILITIE
REPAIR
CAFETI
PELICAN CREEK
TO LAKE JUNCTION 300 FEET
FISHING BRIDGE
8"
3"
6"
10"
SCALE IN FEET
0
300
600
900
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
LAKE AREA — FISHING BRIDGE
YELLOWSTONE NATIONAL PARK
GJS

N21,000 N20,000 N19,000 N18,000 N17,000 N16,000

HOWARD EATON TRAIL TO CANYON VILLAGE

FILTER BEDS

SLUDGE BED

SEPTIC TANK

DR

SEASONAL EMPLOYEES

TRAILER SITES

YELLOW STONE RIVER

FISHING BRIDGE

ADD GATE VALVE

VISITOR TRAILER VILLAGE

METER

CABIN AREA

CONCESSION BLDG & LAUNDRY

TRAILER DUMP STATION

REPAIR F H

CABINS BEING REMOVED AS LAKE FACILITIES DEVELOP

REPAIR

CAFETERIA

STORE

SERVICE

DORM

RANGER STATION

METER REMOVED

SHOWERS & LAUNDRY

NEW GATE VALVES

SEPTIC TANKS

TRAILER DUMP STATION

AMPHITHEATER

VISITOR CENTER & MUSEUM

CAMPGROUND

CONNECT TO EXISTING 6" LINE

TO LAKE JUNCTION 500 FEET

FISHING BRIDGE

PELICAN CREEK CAMPGROUNDS

Hyd.

PELICAN CREEK

TO EAST ENTRANCE (CODY, WYO.)

TO CABINS

TO STORE

YELLOW STONE LAKE

E30,000 E31,000 E32,000 E33,000 E34,000 E35,000 E36,000

N13,000 N14,000 E40,000

ORIENTATION

SCALE IN FEET 0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
LAND	
ELEC	
MECH	
STRUC	

REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

_____ DATE

_____ DATE

APPROVED _____ DATE

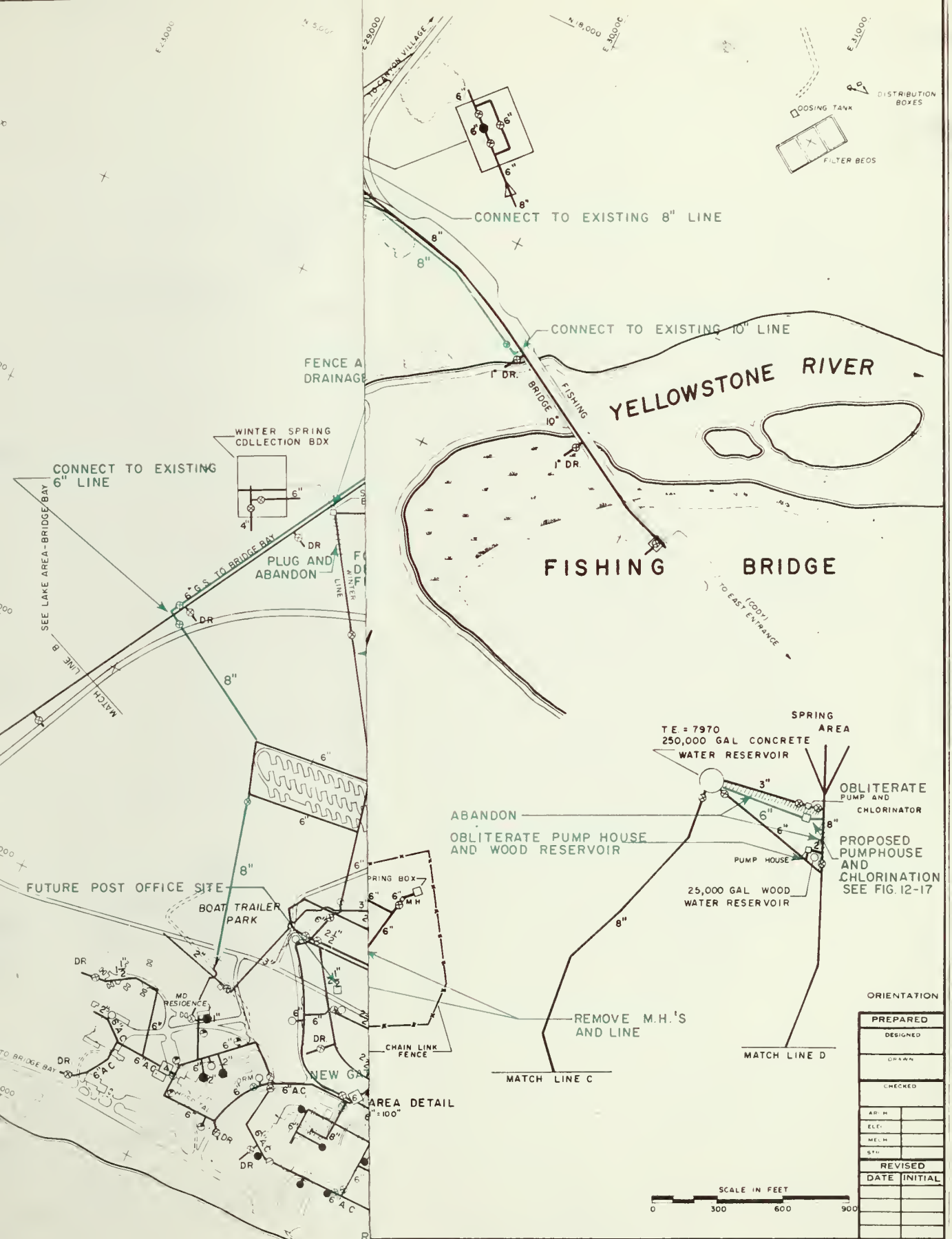
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION

LAKE AREA — FISHING BRIDGE

YELLOWSTONE NATIONAL PARK

REGION	
PCP NO	
SHEET	OF
DRAWING NO	
DATE	



PREPARED
DESIGNED
DRAWN
CHECKED
AR. H
ELEC.
MECH.
STR.

REVISED

DATE	INITIAL

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS INC
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
LAKE AREA — LAKE
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO
DATE

DATE
DATE
DATE

TE = 7960
2-500,000 GAL
WATER RESERVOIRS
STEEL
CONCRETE
TRANSMITTER AND 8" DOUBLE ACTING ALTITUDE VALVE
CONNECT WITH VALVE TO EXISTING LINE
FENCE AND PROVIDE DRAINAGE
WINTER SPRING COLLECTION BOX
CONNECT TO EXISTING 6" LINE
SPRING BOX
SPRING AREA
SEE DETAIL FOR SPRING AREA
PUMP HOUSE TE=7804
PLUG AND ABANDON
FOR IMPROVEMENT DETAILS SEE FIG. 12-17
PLUG AND ABANDON
ROAD UNDER CONSTRUCTION SUMMER 1971
CONNECT WITH CHECK VALVE AND METER
LODGE CABIN AREA
FUTURE POST OFFICE SITE
BOAT TRAILER PARK
OPEN
YELLOWSTONE PARK CO RESERVOIR
ABANOON
LAKE
NEW GATE VALVE
FUTURE MOTEL DEVELOPMENT
CABIN AREA
REPLACE F H
EMPLOYEES COURT
OFF SEASON SEPTIC TANK & LEACHING FIELD
OFF SEASON LEACHING TRENCH
LIFT STATION
SLUDGE BED
OBLITERATE PUMP AND INTAKE
PUMP AND INTAKE (NOT IN USE)
MATCH LINE C
MATCH LINE D
CONTROL STATION SEE FIG 12-17
CONNECT TO EXISTING 8" LINE
CONNECT TO EXISTING 10" LINE
YELLOWSTONE RIVER
FISHING BRIDGE
LAGOON
PARKING
NEW GALLERY SPRING COLLECTION SYSTEM - 225 GPM
SPRING BOX
ABANDONED M H
CHAIN LINK FENCE
SPRING AREA DETAIL
ABANOON
OBLITERATE PUMP HOUSE AND WOOD RESERVOIR
REMOVE M H 'S AND LINE
TE = 7970
250,000 GAL CONCRETE WATER RESERVOIR
SPRING AREA
OBLITERATE PUMP AND CHLORINATOR
PROPOSED PUMPHOUSE AND CHLORINATION SEE FIG 12-17
PUMP HOUSE
25,000 GAL WOOD WATER RESERVOIR
MATCH LINE C
MATCH LINE D
DISTRIBUTION BOXES
DOSING TANK
FILTER BEDS
TO RANGER STA
TO C.S.
TO STORE & SERVICE STA
N
ORIENTATION
SCALE IN FEET
0 300 600 900

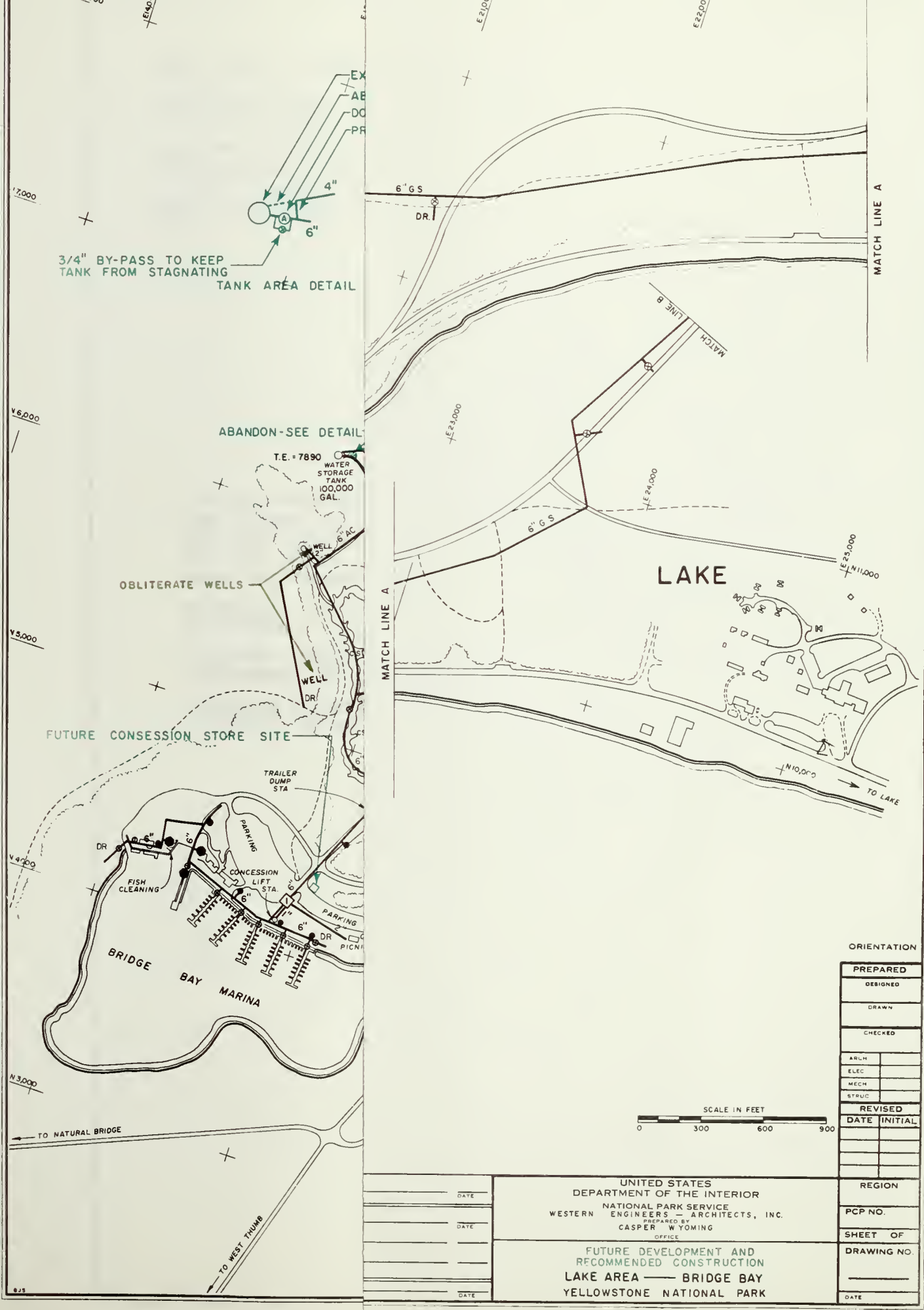
PREPARED	
DESIGNED	
DETAILED	
CHECKED	
REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE
CONCURRED _____ DATE
APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS INC
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
LAKE AREA — LAKE
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO


4"
6"
3/4" BY-PASS TO KEEP TANK FROM STAGNATING
TANK AREA DETAIL
6"GS
DR.
MATCH LINE A
MATCH LINE B
ABANDON-SEE DETAIL
T.E. = 7890
WATER STORAGE TANK 100,000 GAL.
WELL 2"
6" AC
OBLITERATE WELLS
WELL
DR.
FUTURE CONSESSION STORE SITE
TRAILER DUMP STA
PARKING
DR
FISH CLEANING
CONCESSION LIFT STA
PARKING
PICNI
BRIDGE BAY MARINA
LAKE
E 23,000
E 24,000
N 11,000
N 10,000
TO LAKE
TO NATURAL BRIDGE
TO WEST THUMB
N 3,000
ORIENTATION
SCALE IN FEET
0
300
600
900
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
LAKE AREA — BRIDGE BAY
YELLOWSTONE NATIONAL PARK

EXISTING TANK
ABANDON EXISTING LINE
DOUBLE ACTING ALTITUDE VALVE
PROPOSED 4" TIE

3/4" BY-PASS TO KEEP TANK FROM STAGNATING

TANK AREA DETAIL

ABANDON - SEE DETAIL

T.E. 7890

WATER STORAGE TANK 100,000 GAL.

BRIDGE BAY

OBLITERATE WELLS

WELL

CAMPGROUND

AMPHITHEATER

CONNECT TO EXISTING 4" LINE

HOWARD EATON TRAIL

TO INCINERATOR

MATCH LINE A

LAKE

FUTURE CONSESSION STORE SITE

TRAILER DUMP STA

INSTALL NEW VALVE

RANGER STATION

PARKING

FISH CLEANING

CONCESSION LIFT STA

PICNIC AREA

SEWAGE TREATMENT PLANT

BRIDGE BAY MARINA

CHANNEL

TO NATURAL BRIDGE

TO WEST THUMB

YELLOWSTONE LAKE

1" To Lift Sta

2" To C S

TO LAKE

ORIENTATION

SCALE IN FEET 0 300 600 900

PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC

REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

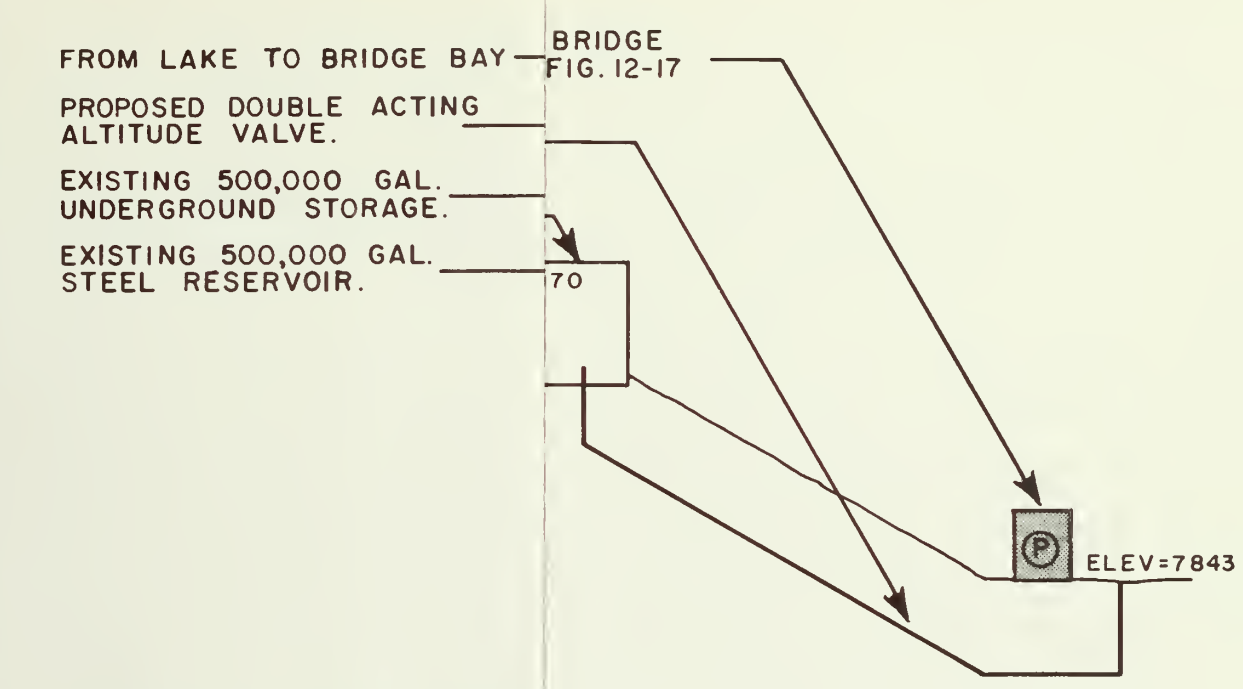
CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
OFFICE CASPER WYOMING

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
LAKE AREA — BRIDGE BAY
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO
DATE



EXISTING PUMPHOUSE, CHLORI
AND 20,000 GAL. CLEARWE
AT LAKE SPRINGS AREA
SEE FIG. 12-17 FOR
PPOPOSED IMPROVEMENTS

PROPOSED 55,000 GAL. CLEARWELL.

EXISTING 100,000 GAL. ST
RESERVOIR - BRIDGE BAY

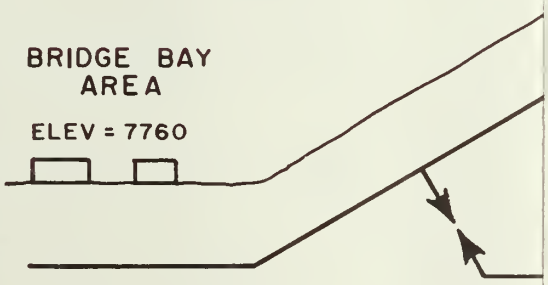
PROPOSED DOUBLE ACTING
ALTITUDE VALVE

OSED TELEMETERING LINE

SED TRANSMISSION LINE
SHING BRIDGE.

SED PRV AND CHECK
- SEE FIG. 12-17
ETAILS.

NG AND PROPOSED
BUTION MAINS.



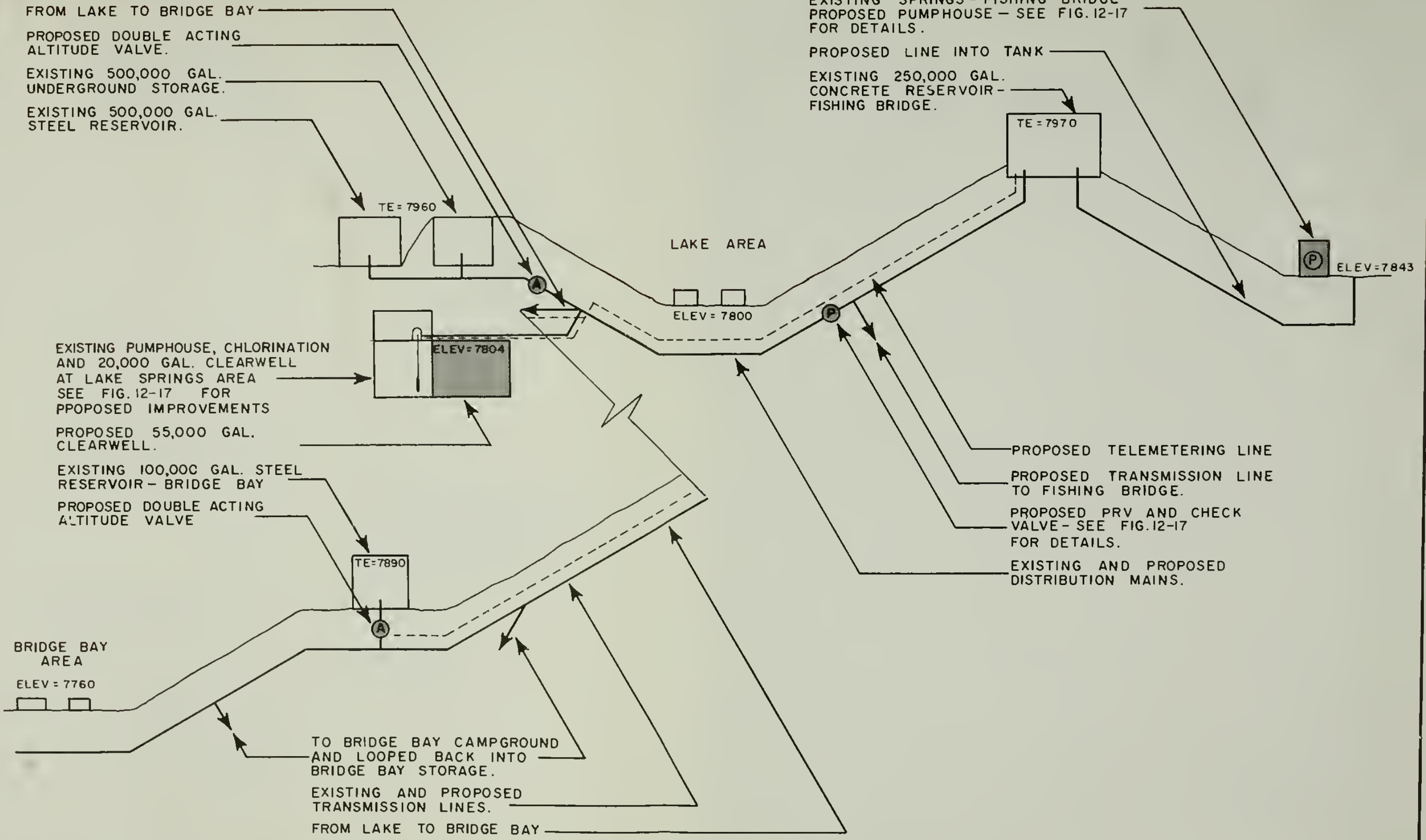
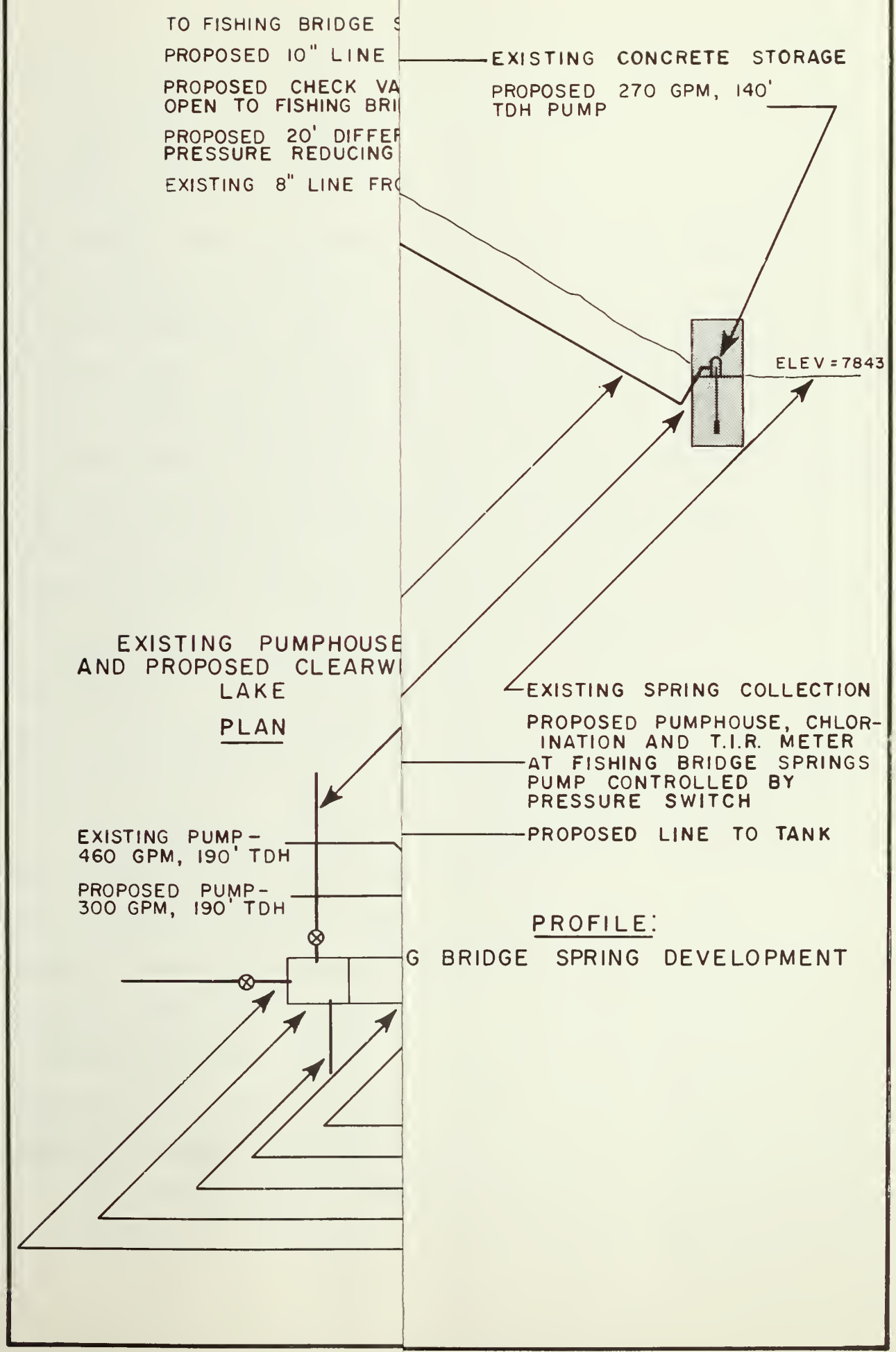
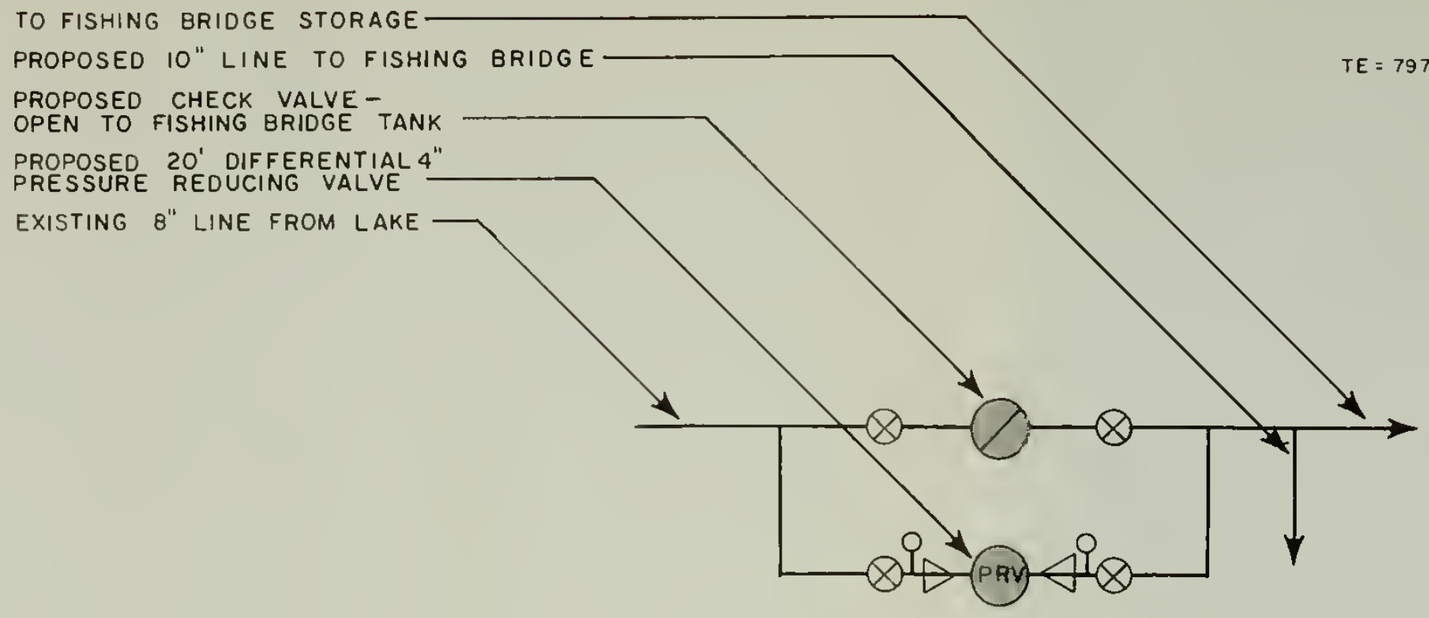


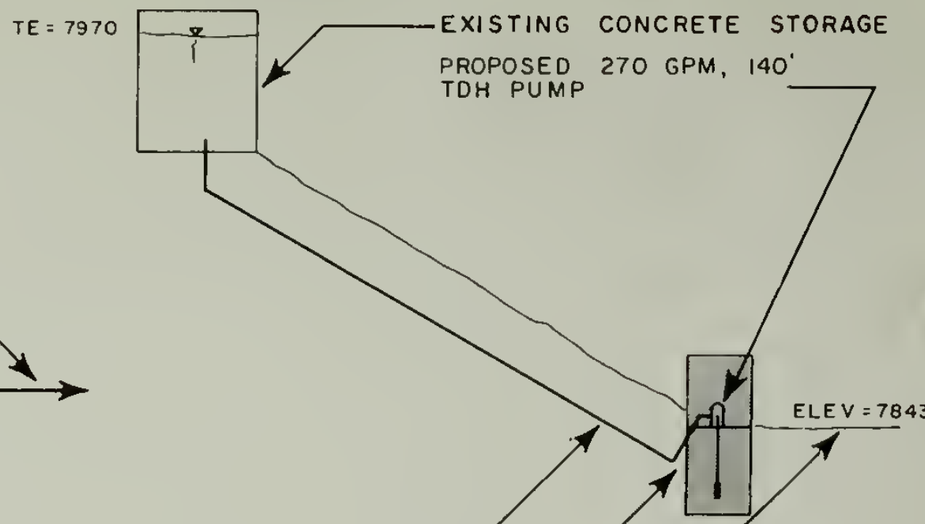
FIG. 12-16 LAKE AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE


TO FISHING BRIDGE S
PROPOSED 10" LINE
PROPOSED CHECK VA
OPEN TO FISHING BRI
PROPOSED 20' DIFFER
PRESSURE REDUCING
EXISTING 8" LINE FR
EXISTING CONCRETE STORAGE
PROPOSED 270 GPM, 140'
TDH PUMP
ELEV = 7843
EXISTING PUMPHOUSE
AND PROPOSED CLEARWI
LAKE
PLAN
EXISTING SPRING COLLECTION
PROPOSED PUMPHOUSE, CHLOR-
INATION AND T.I.R. METER
AT FISHING BRIDGE SPRINGS
PUMP CONTROLLED BY
PRESSURE SWITCH
PROPOSED LINE TO TANK
EXISTING PUMP -
460 GPM, 190' TDH
PROPOSED PUMP -
300 GPM, 190' TDH
PROFILE:
G BRIDGE SPRING DEVELOPMENT



PLAN

CONTROL STATION TO FILL FISHING BRIDGE TANK



PROFILE:

FISHING BRIDGE SPRING DEVELOPMENT

EXISTING PUMPHOUSE AND PROPOSED CLEARWELL LAKE

PLAN

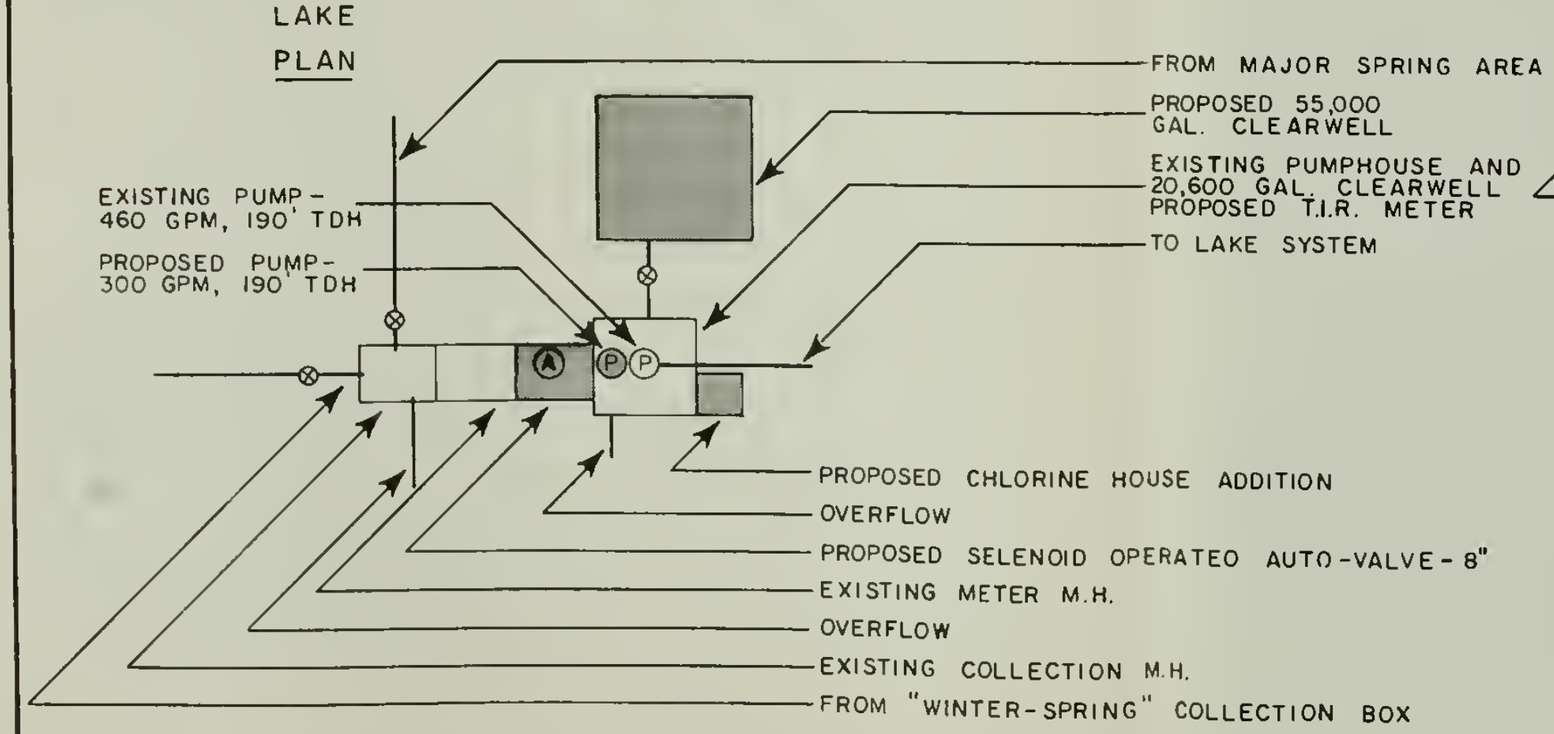


FIG. 12-17 LAKE AREA
PROPOSED COLLECTION, CONTROLS, AND CLEAR WATER STORAGE

CHAPTER 13. GRANT

The Grant area encompasses the communities of Grant and West Thumb and is located along the western projection of Yellowstone Lake near the intersection of the South Entrance Road and the Grand Loop Road. The area is shown in Figure 13-1. Grant Village is the newest visitor accommodation center in the Park, and major construction is still in progress. When completed this village will provide complete visitor services and will permit obliteration of most visitor accommodations at West Thumb. Major visitor attractions in the area are the West Thumb geyser basin, Yellowstone Lake, and a museum at Grant. Recreational facilities at Grant Village are generally water-oriented; a large marina, boat rental service, and boat launching ramps are provided. Present overnight accommodations at Grant include a campground and a National Park Service trailer court. In the future, complete lodge and concessioner facilities will be constructed.

The present overnight population at Grant is approximately 2,300 persons and at West Thumb, approximately 200 persons. The future overnight population of the area is expected to be 6,700 persons, of whom approximately 150 will be in West Thumb. Population and flows are given in Table 13-1. Winter service is possible for Grant but the shallow West Thumb lines prohibit winter use until the recommended new mains are installed.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required domestic flow for a future peak day is 1,050,000 gal. or 730 gpm. As the existing population is

much less than half of the design population a safe design flow now is half of the future peak day amount. Table 13-2 lists the basic design data for this area. Most of the existing system problems are in the older West Thumb system.

The entire existing systems are shown in Figures 13-2 and 13-3 for Grant and West Thumb respectively. The entire Grant system is new while the West Thumb system is old with small and shallow mains.

The systems are described as follows:

Grant

Water is withdrawn from Yellowstone Lake through a new ductile iron intake line into a concrete caisson. (Figure 13-4) The ductile line extends 700 feet into the Lake and takes the water near the bottom at a fifty foot depth. Submersible turbines of 75 and 25 HP, pump water from the caisson to the Grant elevated concrete and steel storage tanks. When the pumps are running the gas chlorination system is working. (Figure 13-5) From the tanks the water flows to distribution. The tanks are an underground concrete tank and an elevated steel tank at the same location but at different elevations. The distribution system is made up of new A.C. and C.I. mains all being at an adequate depth for winter use. The system pressures range between 55 and 90 p.s.i.

West Thumb

Water is withdrawn from Duck Lake through a G.S. line that extends five feet below the surface of the Lake, is chlorinated using a hypochlorinator and is pumped to elevated storage with a 10 HP centrifugal. (Figures 13-6 and 13-7) The storage tanks are two underground concrete reservoirs. From the tanks the water flows to distribution . The distribution lines are small,old, C.I. and G.S. mains that are shallow. The pressures range between 60 and 70 p.s.i. A float switch on the elevated tanks stops the pump when the tanks are full. The pump has to be manually started. A standby pump is well maintained and is operable.

EVALUATION OF EXISTING SYSTEMS

Table 13-3 gives an evaluation of the existing systems which is expanded upon in the ensuing discussion.

Grant

The Grant intake is trouble free and has proven to be most successful. Yellowstone Lake periodically has heavy algae concentrations which have not appeared too date in the water supply. The depth at which water is drawn from the Lake contributes to the success of this intake. As the Grant and Lake area sewage effluents will not be dispersed into the Lake the high quality of the Lake should improve. When the submersible pumps start and stop a severe water hammer occurs, the most severe being when the pump stops. This surge of pressure has caused the chlorine make up water line to break and spray water onto the control panel. This severe surge condition is potentially dangerous and is caused by the long transmission line and existing check valve leading into the elevated steel tank that prevents the tank from acting as a cushion. The large elevated steel tank needs some painting. The Grant tanks are equipped with float switches which would start-stop the pumps but these switches are all broken. The difference in elevation in the tanks causes the operator to use the tanks separately. This is done manually to keep the water fresh in each tank. The steel tank could be used in the summer and the underground tank in the winter. In the summer a small amount of water could be continuously allowed to overflow from the concrete tank thus keeping it fresh and available for standby. A pressure sensing control would be better than the existing float controls as it could not be broken by ice. The detailed flow analysis of the distribution system appears in Appendix B. The intake and outlet lines from the tanks need to be combined to supply peak future domestic and fire flows. All fire hydrants were checked and their condition is detailed on Figure 13-2. The hydrant coverage is adequate and the distribution system is adequate. Winter use should not be a problem.

West Thumb

The West Thumb intake is accessed by a road down a steep hillside that is often impassible in the spring. The intake draws water from just beneath the surface of Duck Lake and is subject to contamination problems.

The health hazards are offset by careful chlorination and adequate contact time in the West Thumb tanks. The tanks are equipped with a float switch that stops the pump on high level, but does not now start the pump at a low level. As the Grant and West Thumb systems are one mile apart it was felt best to eliminate the dual systems and depend entirely upon the Grant Intake. The detailed flow analysis of the West Thumb system appears in Appendix B. This study shows that the existing distribution system with just a feeder line from Grant is not adequate to handle peak domestic and fire flows. For this reason the West Thumb tanks need to be maintained for fire protection. As these tanks are lower than the Grant tanks they should be continuously by-passed with a small flow to prevent stagnation. The network analysis further showed that even with the tanks the system is currently inadequate for fire protection. Fire hydrants could be installed if the store and other facilities remain and the proposed system is totally constructed. Winter use is not desirable as existing mains are shallow unless some of the new mains are installed.

RECOMMENDED CONSTRUCTION

Figures 13-8 and 13-9 show the horizontal location of the proposed improvements for Grant and West Thumb respectively. Figure 13-10 shows the vertical and schematic location of the area improvements and Figure 13-11 shows the proposed D.E. filtration plant. These recommended improvements will:

- Provide a highly polished, safe, potable supply.
- Eliminate a troublesome source of supply at Duck Lake.
- Combine two systems into one and thus reduce operating problems.

The features of the plan include:

1. Place a 6 inch surge relief valve in front of and on the tank side of the existing check valve in the submersible pump house (Figure 13-4) to stop the water hammer.
2. Construct a complete D.E. filtration plant at Grant with clearwell, pre and post chlorination and fluoridation to polish the lake water and provide adequate chlorine contact time. The D.E.

backwash will have to be collected and disposed of as it cannot be discharged back into the lake.

3. Tie the intake and outlet lines together leading into the Grant tanks. By doing this no new transmission lines will be required for peak domestic and fire flows. It was less expensive to tie these lines together and provide more clearwell storage for chlorine contact time than to provide less storage and add an additional transmission line to the tanks.

4. Combine the Grant and West Thumb systems by installing a new transmission line. This tie eliminates the need for separate systems. Some additional transmission line is proposed to continue on to the West Thumb tanks and into the West Thumb community if fire protection and winter use prove justifiable for the cost. Also an altitude valve and by-pass line in the West Thumb tanks can be included if these tanks are to be kept as standby for the West Thumb fire protection.

5. A complete control system should be provided to perform as is described in Table 13-2.

6. Place five additional buoys around the Yellowstone Lake Intake.

7. The treatment could also include fluoridation if such is felt desirable.

The estimated total cost for the complete system is $378,800 with an expense of $54,000 recommended immediately. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

ALTERNATIVES CONSIDERED

The West Thumb community can be served for domestic uses by joining the systems as proposed. To provide automatic service for fire protection from the West Thumb tanks and to provide adequate fire flows will cost $65,000. This expense may not be justified if the major concession facilities are not retained and the community is not used during the winter.

Mixed media filtration could be used in place of D.E. filtration. Chapter 7 discusses filtration in detail. D.E. filtration has the advantage that it is far more successful in bacteria and virus removal over mixed media filters. D.E. disadvantages include slightly higher operating costs and more difficult removal of backwash wastes.

TABLE 13-1 POPULATION AND MAXIMUM FLOWS, GRANT AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Campground area					
399 campsites*	2,000	2,000	50	100,000	100,000
Ranger station	2	5	200	400	1,000
Fish cleaning station	--	--	--	7,500	7,500
Sub Total	2,002	2,005		107,900	108,500
Government area					
Trailer court	54	55	50	2,700	2,750
Dormitories	--	150	75	--	11,250
Apartments	42	40	200	8,400	8,000
Residences	--	20	200	--	4,000
Ranger and fire station	5	5	200	1,000	1,000
Sub Total	101	270		12,100	27,000
Visitor center and marina area					
Laundromat and showers	---	--	--	40,000	40,000
Visitor center	---	--	--	1,500	7,500
Ranger station	5	5	200	1,000	1,000
Fish cleaning stations	---	--	--	7,500	15,000
Marina	---	--	--	1,000	5,000
Sub Total	5	5		51,000	68,500
Lodge area					
Lodge - 800 units	---	2,400	75	--	180,000
Visitor trailer park (250 sites)	---	1,000	50	--	50,000

TABLE 13-1. POPULATION AND MAXIMUM FLOWS, GRANT AREA-contd.

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Concessioner area					
Dormitories	--	875	75	---	65,625
Service station	--	--	--	3,000	3,000
Cafeteria, dining room, and food service center	--	--	--	---	150,000
Sub Total		875		3,000	448,625
West Thumb					
General store	75	75	--	10,000	10,000
Service station	10	10	--	2,000	2,000
Visitor comfort station	--	--	--	5,000	5,000
Employees trailer court	60	60	50	3,000	3,000
Sub Total	145	145		20,000	20,000
TOTAL	2,253	6,700		194,000	672,625
Say:	2,300	6,700		194,000	673,000

Actual Maximum Measured Total Flow - 189,000 gpd

* 25 percent of campsites assumed to have 2 family occupancy.

TABLE 13-2 BASIC DESIGN DATA, GRANT AREA

ITEM	EXISTING	DESIGN
POPULATION	2,300	6,700
WATER FLOW		
Peak, gpd	194,000	1,050,000
Peak, gpm		730
INTAKE		
Yellowstone Lake - existing limited only by booster pump capacity @ 30' TDH gpm		1,250
Duck Lake - obliterate		
TREATMENT		
Good Source		
Diatomaceous Earth - pressure or vacuum filters		
rate - gpm/ ft^2		1
rate - gpm aver.		1,000
rate - gpm max.		1,250
Chlorination - pre and post on D.E. filters		
Contact time - hours		4
Fluoridation - mg/l residual - optional		1-1.5
Pumping at 280' TDH		1,250
STORAGE		
Clearwell at filtration plant - gal. Service - chlorine contact time, control and to system		175,000
Elevated tank at Grant - existing - gal. Service - control and to system		1,500,000
Elevated concrete tank at Grant -existing - gal. Service - winter use, control and to system		500,000
Elevated concrete tank at West Thumb- existing - gal. Service - standby		100,000

TABLE 13-2. BASIC DESIGN DATA, GRANT AREA-contd.

ITEM	EXISTING	DESIGN
DISTRIBUTION - for Hardy Cross Network Anaylsis		
Grant		
Peak 4 hr. domestic flow - gpm		1,515
Peak 4 hr. residential fire flow - gpm		500
Peak 4 hr. commercial fire flow - gpm		1,500
West Thumb		
Peak 4 hr. domestic flow - gpm		150
Peak 4 hr. residential and commerical fire flow - gpm		500
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm		1,250
Max. 4 hr. fire flow - gpm		1,500
Peak 4 hr. domestic flow - gpm		1,460
CONTROL SYSTEM		
1. Elevated Grant Tanks Drop - pumps at filtration plant start**		
2. West Thumb Tanks and Grant Tanks- record level at Filtration plant		
3. TIR flow in and out of filtration plant		
4. Clearwell full caisson pumps off		
5. D.E. Filtration Plant - fully automated		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Pressure sensing control equipment. This equipment would allow the elevated steel tank to be used for winter use.

TABLE 13-3. EVALUATION OF EXISTING SYSTEMS
GRANT AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
SOURCE			
1. Grant - Yellowstone Lake	Caisson and Ductile iron collection line into Lake	Good	Deep
2. West Thumb - Duck Lake	G.S. collection line into Lake	Good	Shallow
TREATMENT			
1. Grant			
A. Chlorination - gas	On when high service pump on Booster pump -severe water hammer is problem	Good	Inadequate
2. West Thumb			
A. Chlorination - liquid	On when high service pump on	Fair	Inadequate
PUMPING			
1. Grant-Submersible turbines-High Service	75 HP, 440 V, 600 gpm 300'TDH-new	Good	
	25 HP, 440 V, 200 gpm 300'TDH-recent	Good	
2. West Thumb - centrifugal and standby gasoline	10 HP, 185 gpm, 127' TDH -old	Good	
TRANSMISSION			
1. Grant intake to Grant tanks	A.C.	Good	
2. West Thumb Intake to W. Thumb tank	C.I.	Good	Shallow
3. West Thumb tank to community	C.I.	Good	Shallow

TABLE 13-3. EVALUATION OF EXISTING SYSTEMS
GRANT AREA-contd.

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
STORAGE			
1. Grant - 1,500,000 gal. elevated	Steel, above ground	Good	Needs some painting
2. Grant - 500,000 gal. elevated	Concrete, underground	Good	
3. West Thumb - 50,000 gal. elevated	Concrete, underground	Good	
4. West Thumb - 50,000 gal. elevated	Concrete, underground, old	Fair	
DISTRIBUTION SYSTEM			
1. Grant Mains	A.C. and C.I.	Good	
2. West Thumb Mains	C.I. and G.S. - old	Fair	Shallow and inadequate
CONTROLS			
1. Grant elevated tanks	Float switches - start-stop high service pump	Not in use	Inadequate
2. Grant surge relief valve	Placed on wrong side of check valve	Not used	Inadequate
3. West Thumb elevated tanks	Float switch - stops pump - start pump not hooked up	Fair	Inadequate



FIG. 13-1 GRANT AREA
VICINITY MAP



ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	

REVISED	
DATE	INITIAL

	DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
GRANT AREA —— GRANT
YELLOWSTONE NATIONAL PARK

REGION

PCP NO.

SHEET OF

DRAWING NO.

DATE

NOTE,
1 ALL LINES HAVE 4' OR MORE COVER
2 FIRE HYDRANT COVERAGE ADEQUATE

EXISTING FLOAT CONTROL BROKEN ON CONCRETE AND STEEL RESERVOIRS

BECAUSE OF ELEVATION DIFFERENCE THE TANKS ARE NOT USED TOGETHER.

1,500,000 GAL STEEL WATER RESERVOIR
80' DIA STEEL TANK
TE = 7980

500,000 GAL CONCRETE RESERVOIR
TE = 7940

8" 10" AC

MATCH LINE C

MATCH LINE B

MATCH LINE A

ROAD UNDER CONSTRUCTION

TO WEST THUMB

THUMB CREEK

GATE

1" DR CAMPGROUNDS

2" GS

INCINERATOR

LAUNCHING RAMP

FISH CLEANING STATION

FOOT BRIDGE

TRAIL

CAMPGROUNDS

TRAILER DUMP STATION

RANGER STATION

AMPHITHEATER

VISITOR CENTER

MARINA

FISH CLEANING

PARKING

LODGE

PROPOSED LODGE UNITS

METER

LAUNDROMAT

PROPOSED CONCESSIONER AREA

GRANT VILLAGE

GOVERNMENT TRAILER COURT

PRESSURE = 55 PSI

GARAGE

SERVICE STATION

MAINTENANCE AREA

F H LEAKS

TRAILER DUMP STATION

SERVICE

RANGER & FIRE STATION

PRESSURE = 90 PSI

EMPLOYEE TRAILER PARK UNDER CONSTRUCTION SUMMER OF 1971

YELLOWSTONE LAKE

10" DUCTILE IRON INTAKE PIPE

EXISTING WATER SUPPLY WORKS UNDERGROUND

SERIOUS WATER HAMMER

ELEV = 7738

PUMP

SEWAGE TREATMENT PLANT

SECONDARY CLARIFIER

TRICKLING FILTER

SLUDGE BEDS

PRIMARY CLARIFIER

DIGESTER

ORIENTATION

SCALE IN FEET

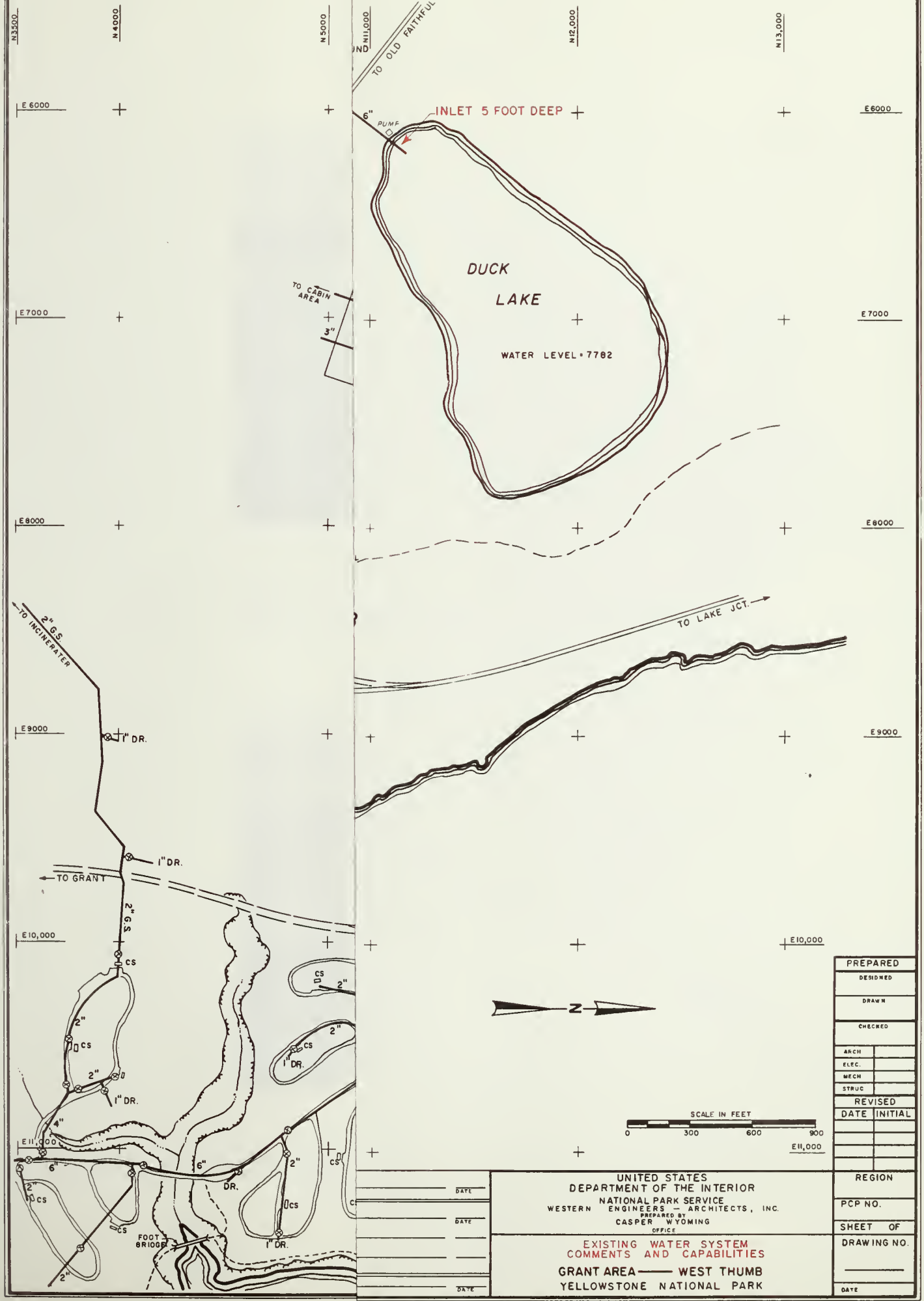
PREPARED
DESIGNED
DRAWN
CHECKED
REVISED
DATE | INITIAL

RECOMMENDED
CONCURRED
APPROVED

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
CASPER WYOMING

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
GRANT AREA — GRANT
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO


N3500
N4000
N5000
N11,000
N12,000
N13,000
TO OLD FAITHFUL
E6000
E7000
E8000
E9000
E10,000
E11,000
6" PUMP
INLET 5 FOOT DEEP
DUCK
LAKE
WATER LEVEL = 7782
TO CABIN AREA
3"
2" G.S. TO INCINERATER
1" DR.
TO GRANT
TO LAKE JCT.
2" G.S.
CS
2"
4"
6"
DR.
FOOT BRIDGE
N
SCALE IN FEET
0
300
600
900
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC.
MECH
STRUC
REVISED
DATE
INITIAL
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE
EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
GRANT AREA —— WEST THUMB
YELLOWSTONE NATIONAL PARK

NOTE
1 ALL EXISTING LINES ARE TO SHALLOW FOR WINTER USE

1

TO CABIN AREA
2"
3"
3"
TO STORE

2-50,000 GAL UNDERGROUND CONCRETE RESERVOIR TE • 7915
TO OLD FAITHFUL
6" DR
6"
PUMP
INLET 5 FOOT DEEP
DUCK LAKE
WATER LEVEL • 7782
ROAD UNDER CONSTRUCTION SUMMER 1971
CABINS
THERMAL
SOUTH ENTRANCE TRAIL
PRESSURE = 65 PSI
WEST THUMB
SERVICE STA
STORE
PHOTO SHOP
THERMAL
TO LAKE JCT
CABINS TO BE REMOVED
LIFT STA
THERMAL AREA
SERVICE AREA
POWER STATION
DUMP
2" GS TO INCINERATOR
1" DR
TO GRANT
2" GS
GATE
THUMB CREEK
FOOT BRIDGE
TRAIL
GRANT VILLAGE CAMPGROUNDS
YELLOWSTONE LAKE

N

PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE | INITIAL

SCALE IN FEET
0 300 600 900

RECOMMENDED ____ DATE
CONCURRED ____ DATE
APPROVED ____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY CASPER WYOMING OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
GRANT AREA —— WEST THUMB
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO
DATE



Fig.13-4. House for Caisson Intake - Grant



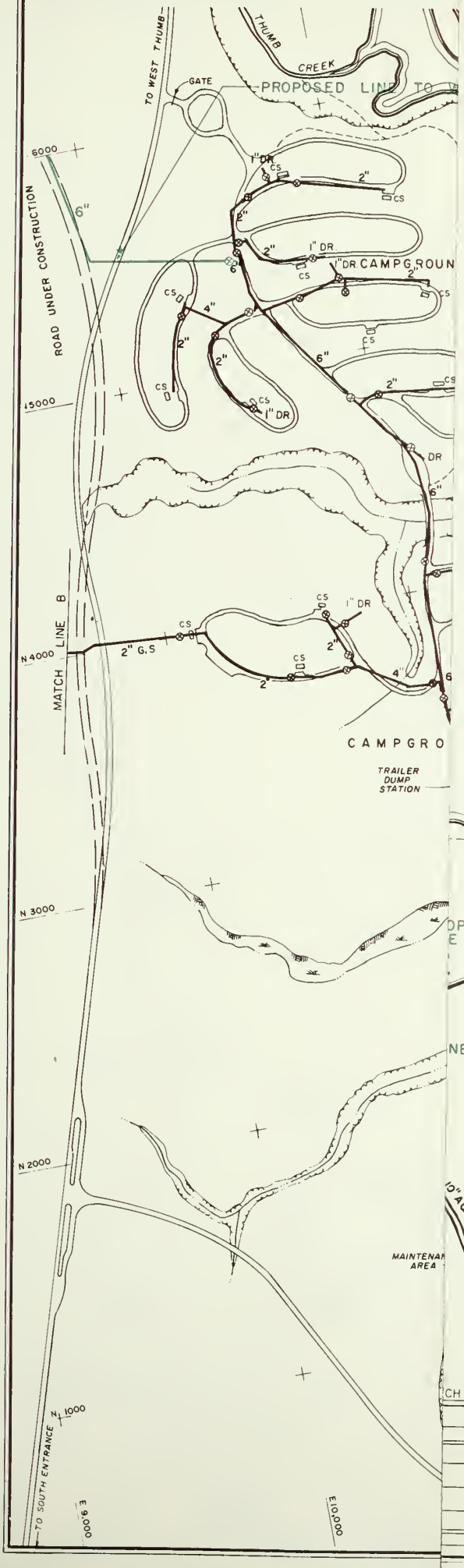
Fig.13-5. Chlorination and Intake - Grant



Fig.13-6. West Thumb Intake in Duck Lake



Fig.13-7. West Thumb Pumphouse and Chlorination
note: gasoline standby pump and overhead power lines


TO WEST THUMB
THUMB CREEK
GATE
PROPOSED LINE TO
ROAD UNDER CONSTRUCTION
6000
6"
1" DR
CS
2"
1" DR CAMPG ROUN
4"
6"
15000
MATCH LINE B
N 4000
2" G.S
CAMPGRO
TRAILER DUMP STATION
N 3000
OPOSED WATER FILTRATION PLANT
E FIG. 13-11
NECT ALL LINES
N 2000
MAINTENAN AREA
TO RESERVOIR
CH LINE C
TO SOUTH ENTRANCE
N 1000
E 9,000
E 10,000
E 17,000
E
MATCH LINE A
TRAIL
SEWAGE TREATMENT PLANT
SECONDARY CLARIFIER
SLUDGE BEDS
TRICKLING FILTER
PRIMARY CLARIFIER
DIGESTER
SCALE IN FEET
0
300
600
900
ORIENTATION
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC
MECH
STRUC
REVISED
DATE
INITIAL
DATE
DATE
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE
FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
GRANT AREA —— GRANT
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO
DATE

PROPOSED LINE TO WEST THUMB

TO WEST THUMB

THUMB CREEK

GATE

ROAD UNDER CONSTRUCTION

CAMPGROUNDS

TRAILER DUMP STATION

RANGER STATION

MATCH LINE B

MATCH LINE A

MATCH LINE C

MATCH LINE D

INCINERATER

LAUNCHING RAMP

FISH CLEANING STATION

FOOT BRIDGE

TRAIL

AMPHITHEATER

VISITOR CENTER

MARINA

FISH CLEANING

PARKING

LODGE

PROPOSED LODGE UNITS

METER

LAUNDROMAT

GRANT VILLAGE

CONCESSIONER AREA

GOVERNMENT TRAILER COURT

GARAGE

SERVICE STATION

MAINTENANCE AREA

SERVICE

RANGER & FIRE STATION

REPLACE F.H.

INSTALL NEW F.H.'S AS FACILITIES ARE CONSTRUCTED.

PROPOSED LODGE AND CONCESSIONER FACILITIES

1,500,000 GAL STEEL WATER RESERVOIR
80' DIA STEEL TANK
TE = 7980

500,000 GAL CONCRETE RESERVOIR
TE = 7940

8" 10" AC

10" DUCTILE IRON INTAKE PIPE

EXISTING WATER SUPPLY WORKS (UNDERGROUND)

ELEV. 7738

PUMP

PROPOSED WATER FILTRATION PLANT
SEE FIG 13-11

CONNECT 10"&8"

CONNECT ALL LINES

SEWAGE TREATMENT PLANT

SECONDARY CLARIFIER

TRICKLING FILTER

SLUDGE BEDS

PRIMARY CLARIFIER

DIGESTER

YELLOWSTONE LAKE

TO SOUTH ENTRANCE

TO WEST YELLOWSTONE

ORIENTATION

SCALE IN FEET
0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
TRANS	
ELEC	
MECH	
STRUC	

REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
CASPER WYOMING

FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
GRANT AREA —— GRANT
YELLOWSTONE NATIONAL PARK

REGION

PCP NO

SHEET OF

DRAWING NO


N3500
N4000
N5000
N11,000
N12,000
N13,000
TO OLD FAITHFUL
OBLITERATE INTAKE PUMPHOUSE AND TRANSMISSION LINE
E6000
E7000
E8000
E9000
E10,000
E11,000
6" PUMP
DUCK
LAKE
WATER LEVEL = 7782
TO CABIN AREA
2"
3"
TO LAKE JCT.
2" G.S. TO INCINERATER
1" DR.
TO GRANT
2" G.S.
CS
2"
4"
6"
DR.
FOOT BRIDGE
N
SCALE IN FEET
0
300
600
900
PREPARED
DESIGNED
DRAWN
CHECKED
ARCH
ELEC.
MECH
STRUC
REVISED
DATE
INITIAL
DATE
DATE
DATE
UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
PREPARED BY
CASPER WYOMING
OFFICE
FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION
GRANT AREA —— WEST THUMB
YELLOWSTONE NATIONAL PARK
REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

N 4000 N 5000 N 6000 N 7000 N 8000 N 9000 N 10,000 N 11,000 N 12,000 N 13,000

E 6000 E 7000 E 8000 E 9000 E 10,000 E 11,000

1

TO CABIN AREA
2"
3"
3" TO STORE

2-50,000 GAL UNDERGROUND CONCRETE RESERVOIR TE • 7915

6" DOUBLE ACTING ALTITUDE VALVE WITH 3/4" BY-PASS TO EACH TANK TO KEEP WATER FROM BECOMING STAGNANT

CONNECT TO EXISTING 4" LINE

6" DR

6" PUMP

OBLITERATE INTAKE PUMPHOUSE AND TRANSMISSION LINE

TO OLD FAITHFUL

DUCK LAKE

WATER LEVEL • 7782

ROAD UNDER CONSTRUCTION SUMMER 1971.

CABINS

CONNECT TO EXISTING 4" LINE

SOUTH ENTRANCE TRAIL

WEST THUMB

INSTALL NEW VALVE

SERVICE STA

INSTALL NEW FH

THERMAL AREA

TO LAKE JCT

2" C.S. TO INCINERATOR

TO GRANT

POWER STATION

CONNECT TO EXISTING 4" LINE

DUMP

SERVICE AREA

CONNECT TO EXISTING 6" LINE

GATE

THUMB CREEK

GRANT VILLAGE CAMPGROUNDS

FOOT BRIDGE

TRAIL

LAKE

YELLOWSTONE

N

SCALE IN FEET
0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

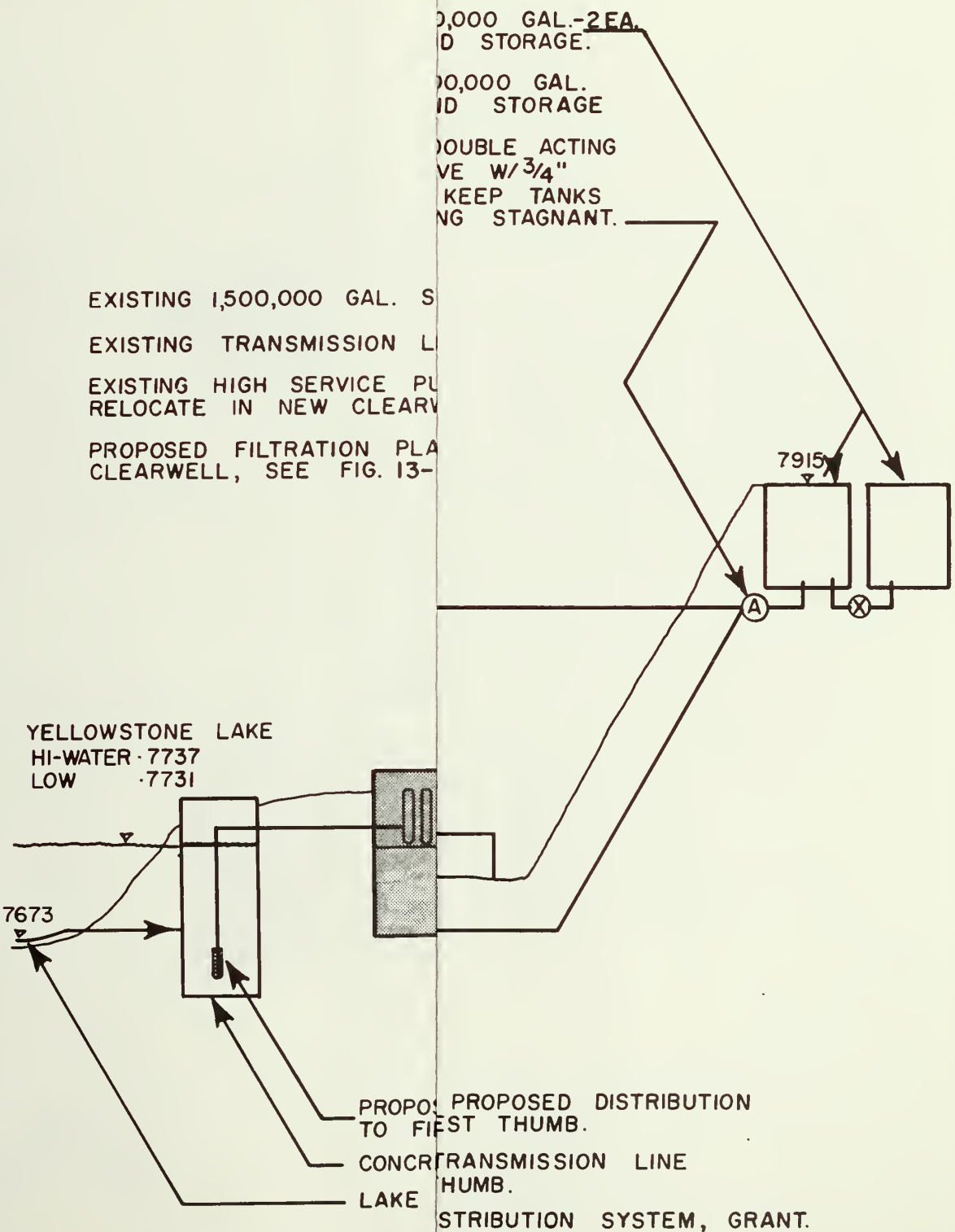
_____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS – ARCHITECTS, INC
PREPARED BY CASPER WYOMING OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
GRANT AREA —— WEST THUMB
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO
DATE


,000 GAL.-2 EA.
D STORAGE.
0,000 GAL.
D STORAGE
OUBLE ACTING
VE W/ 3/4"
KEEP TANKS
NG STAGNANT.
EXISTING 1,500,000 GAL. S
EXISTING TRANSMISSION L
EXISTING HIGH SERVICE PU
RELOCATE IN NEW CLEARV
PROPOSED FILTRATION PLA
CLEARWELL, SEE FIG. 13-
7915
A
X
YELLOWSTONE LAKE
HI-WATER · 7737
LOW · 7731
7673
PROPO
TO FI
CONCR
LAKE
PROPOSED DISTRIBUTION
EST THUMB.
RANSMISSION LINE
HUMB.
STRIBUTION SYSTEM, GRANT.

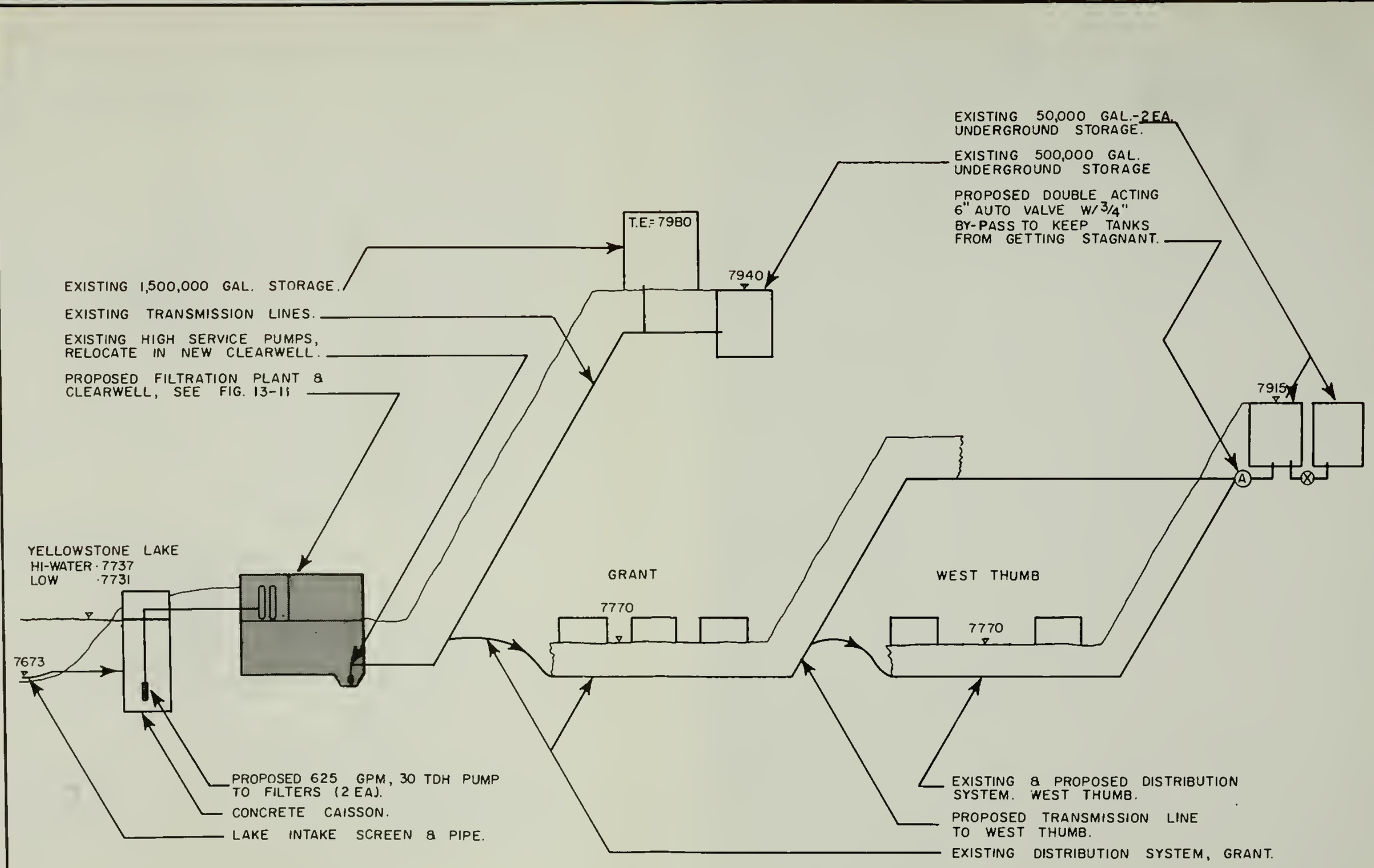


FIG. 13-10 GRANT AREA
SCHEMATIC OF PROPOSED COLLECTION, TRANSMISSION, TREATMENT, AND STORAGE

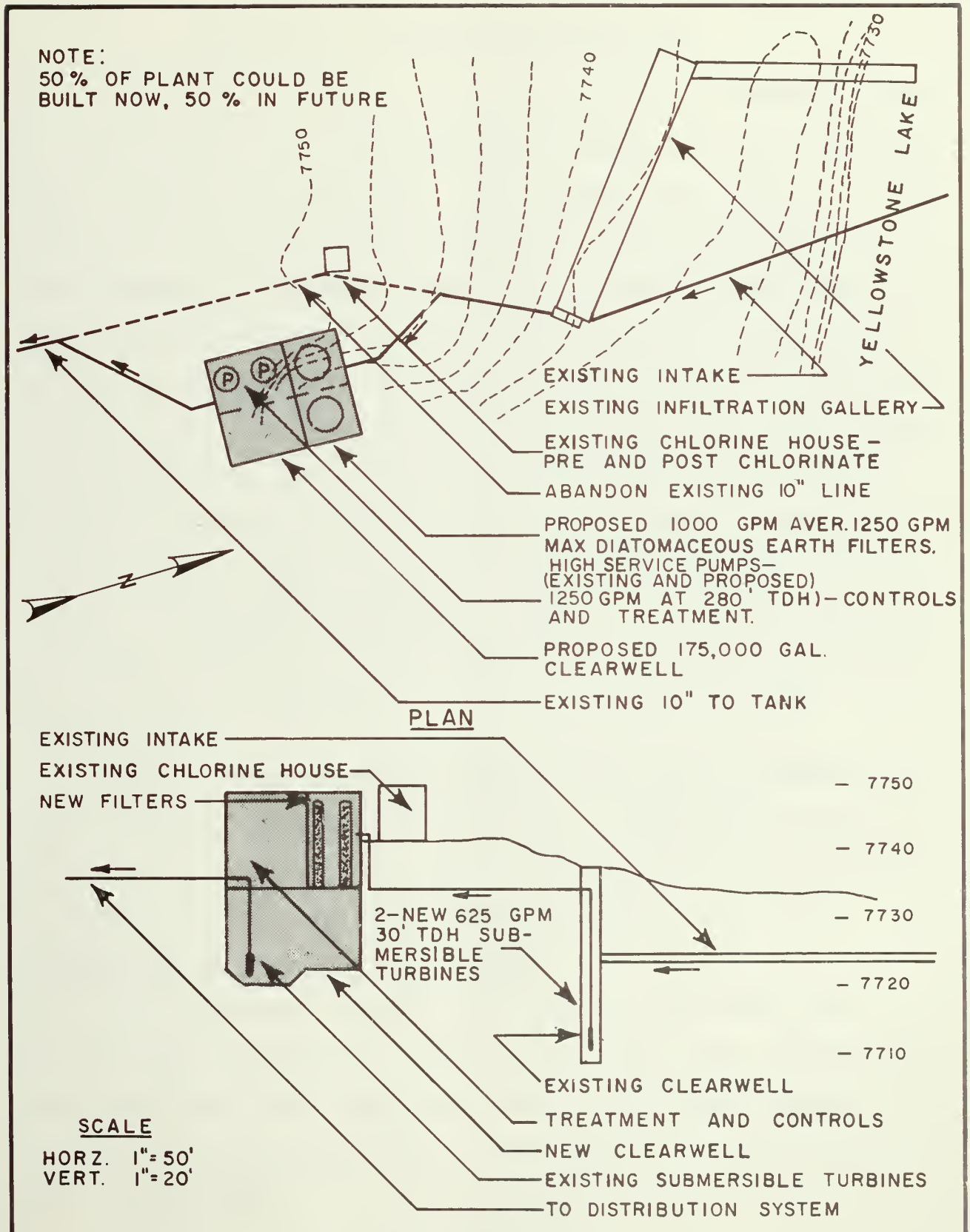


FIG. 13-11 GRANT AREA
PROPOSED FILTRATION PLANT
INCLUDING PRE AND POST CHLORINATION,
TREATMENT AND CLEARWELL STORAGE

Chapter 14. MADISON JUNCTION AREA

The Madison Junction area is located on the Madison River at the intersection of the Grand Loop Road and the West Entrance Road, as shown on Figure 14-1. It was near this site, on September 19, 1870, that a campfire discussion was held which led to the founding of Yellowstone National Park and the development of the National Park System. While not possessing the spectacular visitor attractions of its neighbors, the area is a convenient location for easy travel to all parts of the Park. The Madison area accommodates about 5 percent of the overnight population of the Park. The 1971 census recorded an overnight population of 1,250 persons, of which 50 were employees. Existing facilities include a 300-space campground, a Ranger station, an employee apartment building, a mess hall, a dormitory, and a 13-space trailer court.

There are no plans to increase overnight accommodations or to construct concession facilities. Population and design flows are listed in Table 14-1. Winter service is no problem at Madison as all lines have adequate cover.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required flow for a future peak day is 138,000 gal. or 100 gpm. Table 14-2 lists the basic design data for the area. Madison Junction has fewer problems than any other water system studied. The system is well maintained and operated.

The entire existing system is shown in Figure 14-2. Most of the system is new and all of the system is in good condition. The system is described as follows:

Spring water is collected in a series of underground concrete structures and perforated line and by gravity flows into a small clearwell located below the pumphouse. (Figure 14-3 and 14-4) The water is pumped with a 10 HP centrifugal to the elevated steel tank or directly to the system as the tank and system lines are connected just outside the pumphouse. The steel tank is located above ground. When the pump is running the gas chlorination system chlorinates the clearwell. The pump on-off is controlled by a float switch on the elevated storage. An over-ride low level float stops the pump if the clearwell is low and starts the pump when the clearwell fills. From the tank and pumphouse the water flows to distribution. The distribution system consists of recently constructed C.I. and G.S. mains all being at an adequate depth for winter use. The system pressure range is between 40 and 80 p.s.i.

EVALUATION OF EXISTING SYSTEM

Table 14-3 gives an evaluation of the existing system which is expanded upon in the ensuing discussion.

The Madison Junction springs are a good source of supply. With some modest expansion the springs should be adequate for maximum future use. The springs are not fenced but are immediately adjacent to a well traveled road and should be better protected. A 4 hour chlorine contact time if provided would

help in protection plus add the small amount of additional storage necessary for fire protection. The elevated storage float switch does not currently control winter operation as it has to be disconnected for winter use. A pressure sensing control could replace the float switch and provide year around satisfactory service. By utilizing the pressure sensing control the elevated steel tank would work well in the winter. The tank needs some painting. The detailed flow analysis of this system appears in Appendix B. This study shows that the distribution system is adequate for peak domestic and fire flow. Fire hydrants give adequate coverage for fire protection. The total storage for peak domestic flow and fire protection is slightly inadequate. However, to make fire storage totally adequate would require an additional 41,600 gallons of storage which is not recommended at this time.

Madison Junction does have a serious problem as the springs contain excessive fluoride concentrations which should be removed for permanent residents having children on an individual unit basis.

RECOMMENDED CONSTRUCTION

Figure 14-5 and 14-6 show the horizontal and vertical location of the proposed improvements for Madison Junction.

These recommended improvements will:

- Adequately protect the source.
- Provide additional chlorine contact time and protection.

·Defluoride water for permanent residents on an individual basis.

The features of the plan include:

1. Develop 35 gpm more spring flow to meet the maximum peak demand of the system.

2. Fence the spring source and provide proper drainage for more protection of the supply.

3. Construct a new clearwell for four hour chlorine contact time and for additional fire protection storage.

4. Install individual defluoridation units for all permanent families having children.

5. A complete control system should be provided to perform as described in Table 14-2.

6. Place all power lines to the elevated tank underground to reduce power outages.

The estimated total cost for the complete system is $78,650 of which $2,000 is recommended for immediate construction. Chapter 16 describes the construction priorities and Appendix D lists construction costs.

ALTERNATIVES CONSIDERED

An additional 41,600 gallons of elevated storage at the same top elevation of the existing storage would cost $16,000 and would make the system meet all design parameters. We are not recommending this storage as the storage figure is theoretical for the worst possible condition and will probably never be needed. Future flow records will show conclusively if the storage should be provided.

TABLE 14-1. POPULATION AND MAXIMUM FLOWS, MADISON JUNCTION AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Campground area					
Campground(292 sites)	1,230	1,230	50	61,500	61,500
Group camp (6 sites)	--	150	50	--	7,500
Ranger station	3	3	200	600	600
Sub Total	1,233	1,383		62,100	69,600
Government area					
Apartments	17	24	200	3,400	4,800
Trailer park	26	42	50	1,300	2,100
Sub Total	43	66		4,700	6,900
TOTAL	1,276	1,449		66,800	76,500
Say:	1,275	1,450		67,000	77,000

Actual Maximum Measured Total Flow - 88,000 gpd

TABLE 14-2. BASIC DESIGN DATA, MADISON JUNCTION AREA

ITEM	EXISTING	DESIGN
POPULATION	1,275	1,450
WATER FLOW		
Peak, gpd	88,000	138,000
Peak, gpm		100
INTAKE		
Madison Junction Springs - gpm	75	110
TREATMENT AND PUMPING		
Ground water source - springs		
Chlorination Contact time - hours		4
Defluoridation - on individual unit basis		
Pumping @ 150' TDH - domestic - gpm		105
STORAGE		
Clearwell at Springs - gal. Service - chlorine contact time, control and to system		24,000
Elevated steel tank - existing - gal. Service - control and to system		100,000
DISTRIBUTION - for Hardy Cross Network Analysis		
Peak 4 hr. domestic flow - gpm		300
Peak 4 hr. residential and commercial fire flow - gpm		500
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm		110
Max. 4 hr. fire flow - gpm		500
Peak 4 hr. domestic flow - gpm		300
CONTROL SYSTEM		
1. TIR meter flow out 2. Elevated tank control pump on-off** 3. Clearwell - control flow in 4. Record elevated tank level		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Pressure sensing control equipment. Allows steel tank use in winter.

TABLE 14-3. EVALUATION OF EXISTING SYSTEM

MADISON JUNCTION AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
SOURCE			
1. Springs	Concrete structure, series of manholes, perforated pipe	Good	Almost adequate
TREATMENT			
1. Chlorination - gas	On when high service pump on	Good	Almost adequate
PUMPING			
1. Centrifugal - high service	10 HP, 220 V, 105 gpm, 150' TDH	Good	
2. Standby - gasoline	Old	Good	
TRANSMISSION			
1. Spring to elevated tank	C.I. main	Good	
STORAGE			
1. 100,000 gal. elevated	Steel, above ground	Fair	Needs some painting
DISTRIBUTION SYSTEM			
1. Mains	C.I. and G.S.	Good	
CONTROLS			
1. Clearwell at pumphouse	Float switch stops pumps on low level	Good	
2. Elevated tank	Float switch - start - stop pumps	Good	Almost adequate

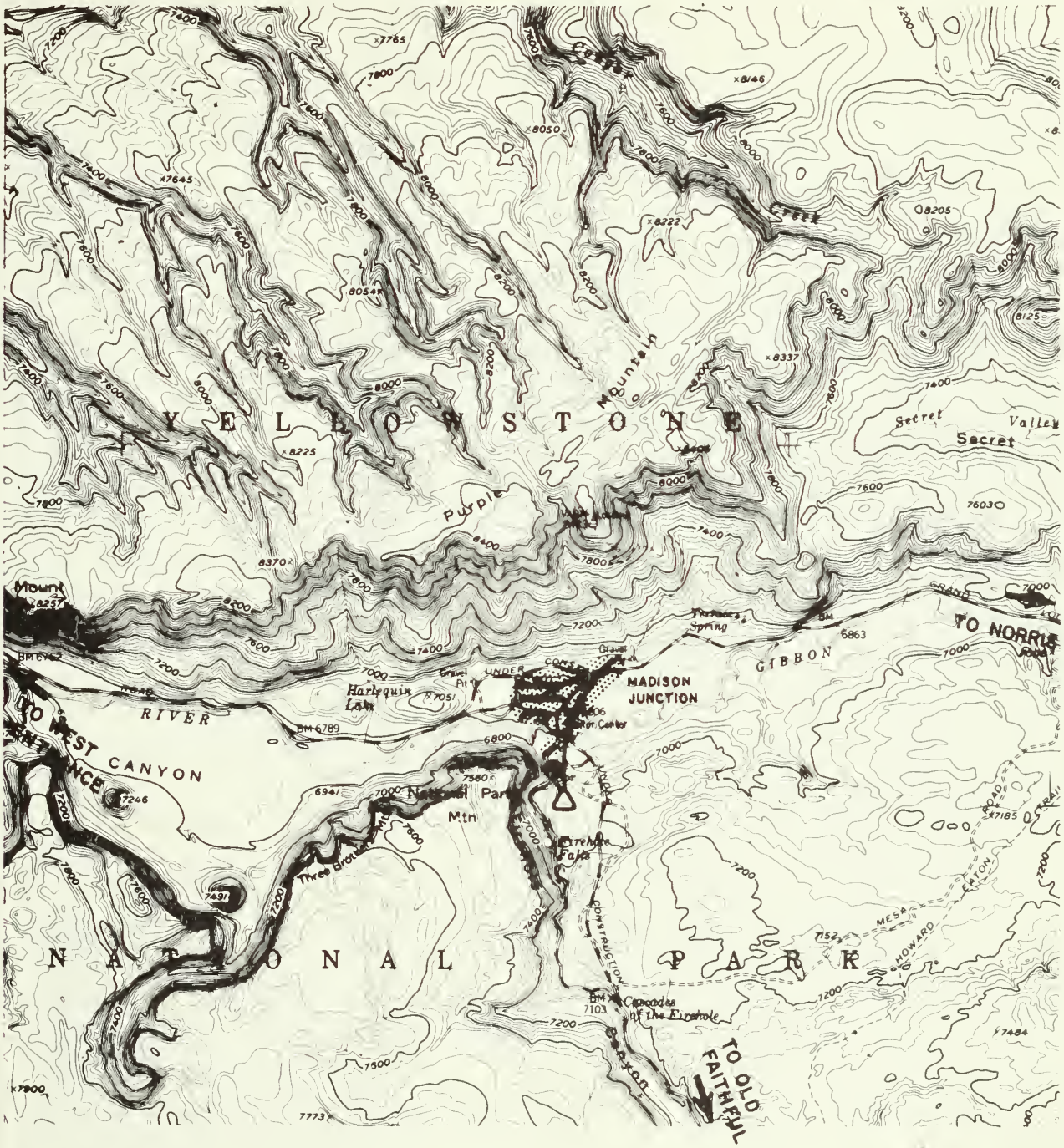


FIG. 14-1 MADISON JUNCTION AREA
VICINITY MAP

E4,000

E11,00

ORE COVER.

ADEQUATE.

N 11,000

N 10,000

JNCTION →

N 9,000

N 8,000

N 7,000

N 6,000

ORIENTATION

SCALE IN FEET

0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

DATE

DATE

DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES
MADISON JUNCTION AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO.

SHEET OF

DRAWING NO

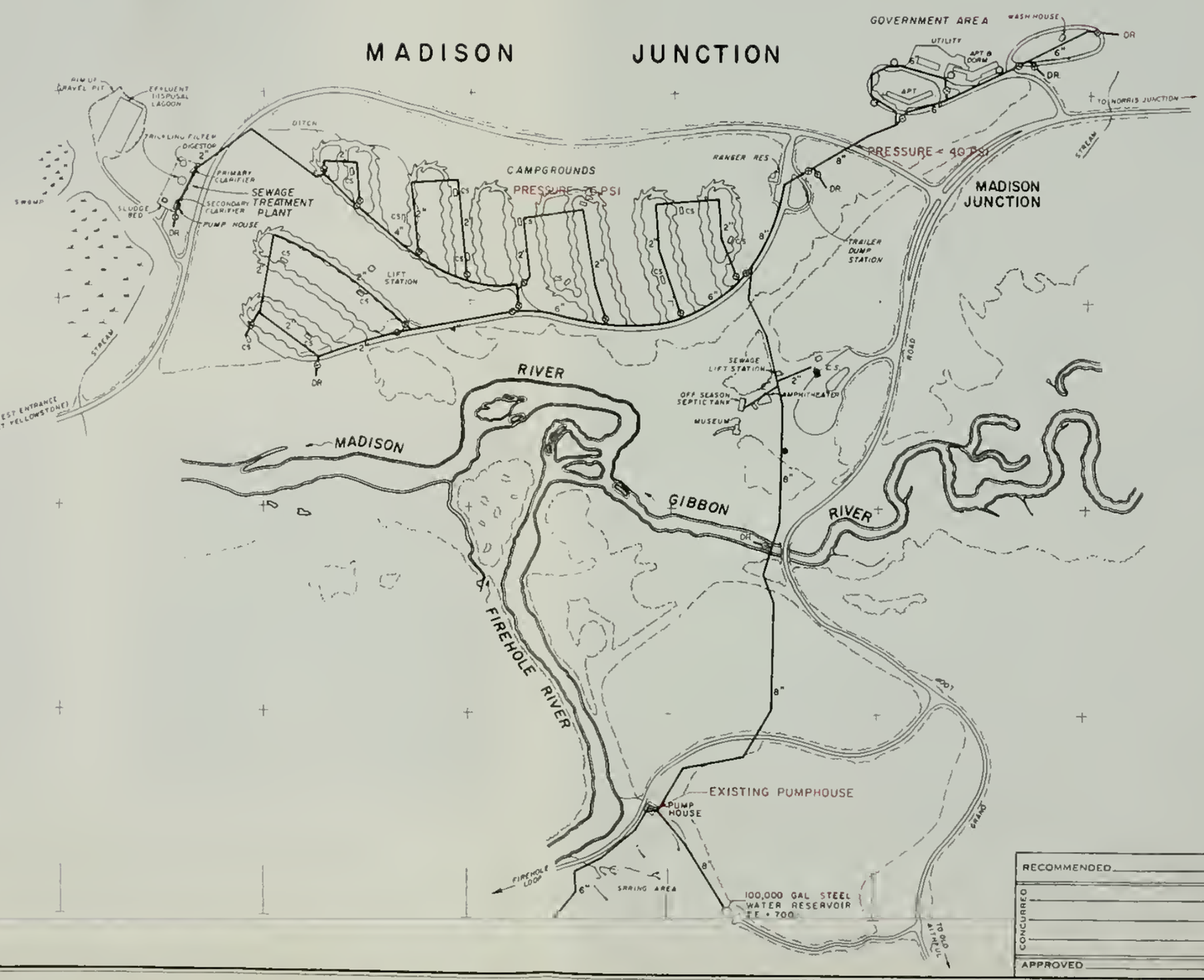
DATE

NOTES

1 ALL LINES HAVE 4' OR MORE COVER.

2 FIRE HYDRANT PROTECTION ADEQUATE.

MADISON JUNCTION



RECOMMENDED	UNITED STATES DEPARTMENT OF THE INTERIOR NATIONAL PARK SERVICE WESTERN ENGINEERS — ARCHITECTS, INC. CASPER WYOMING
CONCURRED	EXISTING WATER SYSTEM COMMENTS AND CAPABILITIES MADISON JUNCTION AREA YELLOWSTONE NATIONAL PARK
APPROVED	

PREPARED · DESIGNED · DRAWN · CHECKED · QUAN · ELEC · MECH · STRUC

REVISED DATE | INITIAL

REGION · PCP NO · SHEET OF · DRAWING NO



Fig. 14-3. Older Spring Collection Manhole with Wood Cover
note: summer use spring supply line above manhole from other springs



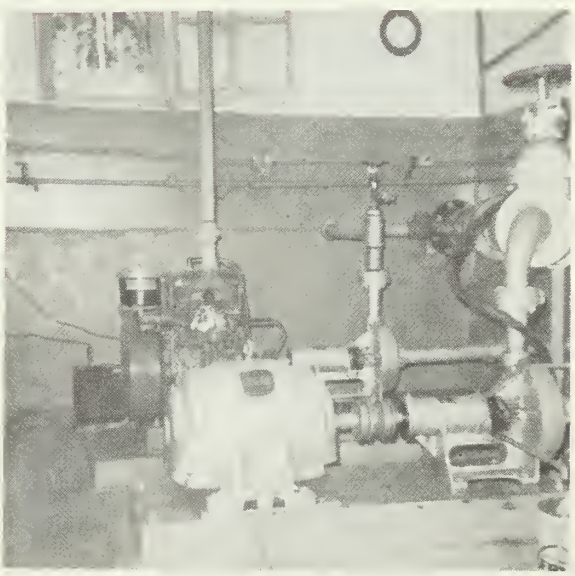


Fig. 14-4. Pumphouse and Chlorination - Madison Junction
note: standby gasoline pump in 2nd picture

E4,000

E11,000

N 11,000

N 10,000

JNCTION →

N 9,000

N 8,000

N 7,000

N 6,000

ORIENTATION

SCALE IN FEET

0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

DATE

DATE

DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND
RECOMMENDED CONSTRUCTION

MADISON JUNCTION AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO.

SHEET OF

DRAWING NO

DATE

E 6,000 E 6,500 E 7,000 E 7,500 E 8,000 E 8,500 E 9,000 E 9,500 E 10,000 E 10,500 E 11,000

N 11,000

N 10,000

N 9,000

N 8,000

N 7,000

N 6,000

N

MADISON JUNCTION

GOVERNMENT AREA

ASH HOUSE

UTILITY

APT. & DORM.

APT.

DR

6"

TO NORRIS JUNCTION

STREAM

DITCH

RANGER RES.

CAMPGROUNDS

8"

TRAILER DUMP STATION

MADISON JUNCTION

ROAD

SEWAGE TREATMENT PLANT

PRIMARY CLARIFIER

SECONDARY CLARIFIER

PUMP HOUSE

TRICKLING FILTER DIGESTION

EFFLUENT DISPOSAL LAGOON

SLUDGE BED

SEWAGE LIFT STATION

AMPHITHEATER

OFF SEASON SEPTIC TANK

MUSEUM

LIFT STATION

RIVER

MADISON

GIBBON

RIVER

FIREHOLE RIVER

GRAND LOOP ROAD

TO WEST ENTRANCE (WEST YELLOWSTONE)

PROPOSED CLEARWELL

PUMP HOUSE

FIREHOLE LOOP ROAD

SPRING AREA

PROPOSED SPRING COLLECTION - 35 GPM

FENCE AND PROVIDE DRAINAGE

100,000 GAL STEEL WATER RESERVOIR TE - 7000

TO OLD FAITHFUL

ORIENTATION

SCALE IN FEET

0 300 600 900

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
LDSCP	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

_____ DATE

_____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION
MADISON JUNCTION AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO

SHEET OF

DRAWING NO

DATE

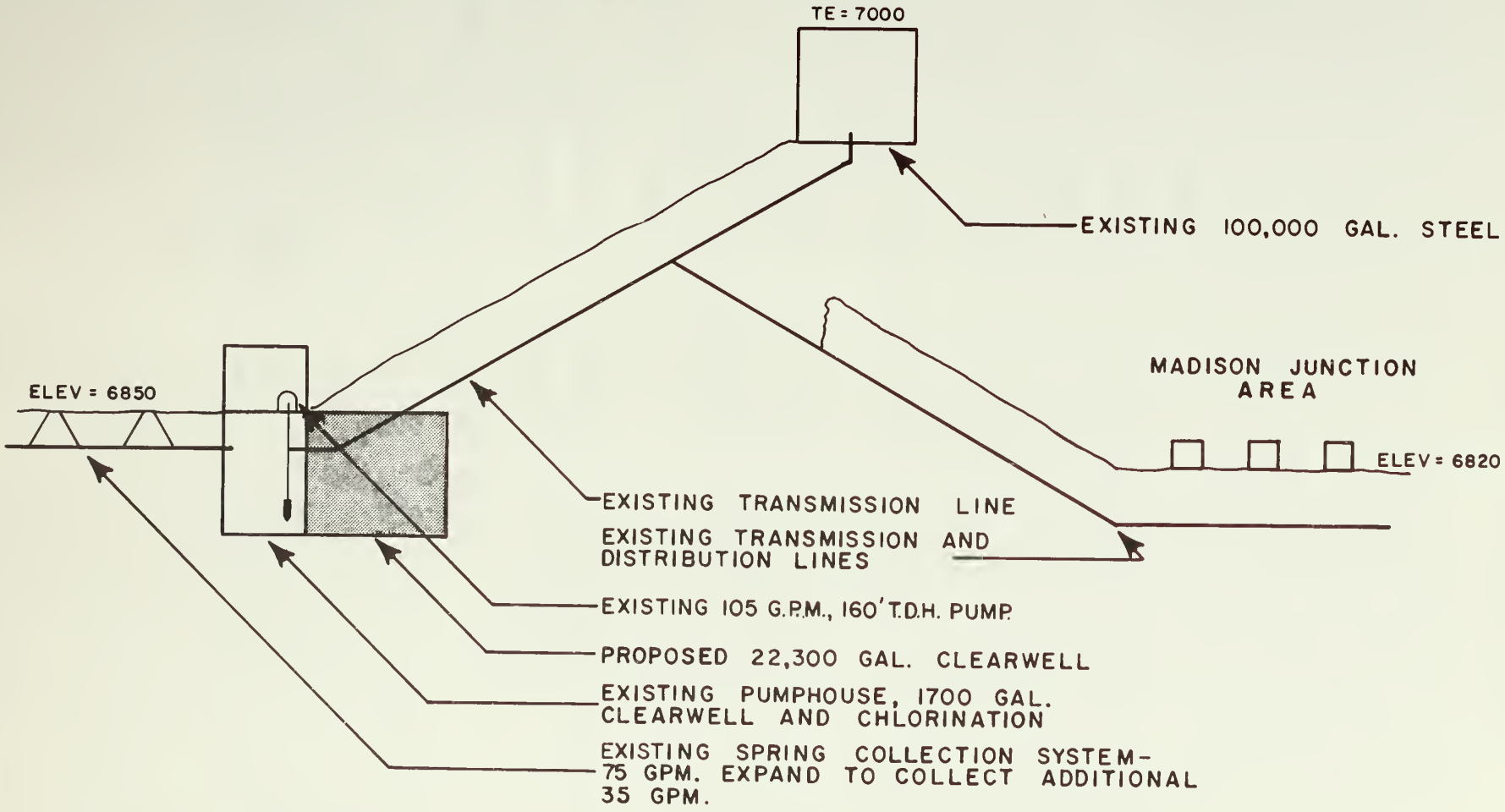


FIG. 14-6 MADISON JUNCTION AREA
SCHEMATIC OF PROPOSED COLLECTION,
TRANSMISSION, TREATMENT, AND STORAGE

Chapter 15. NORRIS AREA

The Norris area, shown in Figure 15-1 is located along the western portion of the Grand Loop Road near its junction with the Norris-Canyon Road. The principal attraction to the area is the Norris geyser basin which has the highest geyser in the world as well as many interesting smaller geysers, steam vents, and hot springs.

The Norris area accommodates only about 3 percent of the overnight population of the Park, but has a high daily visitation. The 1971 census recorded an overnight population of 590 persons of which 20 were employees. Accommodations include the Norris campground and ranger station and a small government employee area.

A visitor museum and ranger-guided tours are provided.

Future development may include a modest expansion of the present campground.

Population and design flows are shown in Table 15-1. Winter use was not a requirement for Norris.

DESCRIPTION OF EXISTING WATER SYSTEM

The maximum required flow for a peak day is 113,000 gal. or 80 gpm. Table 15-2 lists the basic design data for the area. Norris has several problems almost all being connected with the source of supply. Figure 15-2 shows the entire

existing system and Figure 15-3 shows the direct open intake.

The system is described as follows: The intake takes warm (22°C) water directly from Castle Creek and transports this water to an elevated steel storage tank. Before entering the tank the water is continuously chlorinated by utilizing pressure drop across a pressure reducing valve. The steel tank is located above ground. From the tank the water flows to distribution. The distribution system contains C.I. and G.S. mains of which the 4 inch and smaller are shallow, while the 6 inch have adequate cover. The system pressures range between 50 and 80 p.s.i.

EVALUATION OF EXISTING SYSTEM

An infiltration gallery successfully served Norris for several years until recently sealing. As the gallery could not be backwashed it was abandoned and the direct intake was substituted. Turbid flowing waters in the spring cannot be removed and do pass into the system. The Castle Creek intake is in a primitive area. Until 1972 it required a one mile walk to get to the intake. Recently the building of an access road to the intake solved this access problem. The water supply is warm as many warm springs enter Castle Creek. The existing transmission line is too small for any increased flows. Figure 15-4 shows the constant overflow at the Norris tank. Figure 15-5 shows the chlorinating house and tank.

The gas chlorination system is carefully handled but the constant water overflow does use some excess chlorine. The

treatment system is inadequate as a surface supply is treated only with chlorination. The detailed flow analysis of this system appears in Appendix B. This study shows that the distribution system is adequate for peak domestic and fire flow. A fire hydrant is suggested at the recently constructed Norris Soldier Station.

RECOMMENDED CONSTRUCTION

A backwashable infiltration gallery and treatment plant is suggested for Norris on Castle Creek. Figures 15-6 and 15-7 show the horizontal and vertical locations of the proposed improvements. These recommendations will:

- Provide a potable, turbidity free water supply.

The features of the plan include:

1. Providing power and a backwashable infiltration gallery at the source.
2. Providing a D.E. filtration plant with a clearwell.
3. Constructing a larger transmission line from the source to the tank.
4. Providing a complete control system.

The total cost of these improvements would be $123,200, of which $37,600 is recommended for immediate construction. Chapter 16 describes the construction priorities and Appendix D lists construction costs. The slightly more expensive system was selected as the initial cost, by utilizing the existing system to correct severe problems, would be $66,000 less than if the alternate system which utilizes Solfatara Creek had been selected.

ALTERNATIVES CONSIDERED

A completely new intake and treatment plant is an attractive alternative for Norris. Figures 15-6 and 15-7 show the horizontal and vertical location of the proposed improvements. These recommendations would:

- Provide a potable, cool, turbidity free water supply.
- Provide an all weather system.

The features of the plan include:

1. Construct a backwashable infiltration gallery in Solfatara Creek which would provide a cool, 14°C, filtered source of supply that contains an optimum fluoride concentration.

2. Construct a D.E. filtration plant with a clearwell and pre and post chlorination. This plant would polish the water and the clearwell will provide a four hour chlorine contact time. The plant would be complete with all appurtenances including high service pumps.

3. Construct a short transmission line to tie the new filtration plant to the existing system.

4. Eliminate the existing intake and chlorination house. The existing chlorinator can be used in the new facility.

5. Provide a complete control system to function as described in Table 15-2.

The estimated total cost for the complete system is $113,360 of which $93,900 would be recommended for immediate construction.

TABLE 15-1. POPULATION AND MAXIMUM FLOWS, NORRIS AREA

DESCRIPTION	POPULATION		PER CAPITA FLOW	MAXIMUM WATER FLOWS	
	Existing	Future	gcd	Existing gpd	Future gpd
Campground area					
116 sites *	600	900	50	30,000	45,000
Government area					
Trailers and apartments	18	25	100	1,800	2,500
Geyser basin and museum area					
Visitor comfort station	--	--	--	10,000	15,000
TOTAL	618	925		41,800	62,500
Say:	620	930		42,000	63,000

Actual Maximum Measured Total Flow - 41,500 gpd

* 25 percent of campsites assumed to have 2 family occupancy.

TABLE 15-2. BASIC DESIGN DATA, NORRIS AREA

ITEM	EXISTING	DESIGN
POPULATION	620	930
WATER FLOW		
Peak, gpd	42,000	113,000
Peak, gpm		
INTAKE		
Backwashable infiltration gallery filter rate gpm/ft^2		2 avg
Design capacity continuous - gpm		100
Capacity - gpm		160 max
No. of filters - gpm		2
TREATMENT		
Ground water source - no turbidity		
Diatomaceous Earth - pressure of vacuum filters		
rate - gpm/ft^2		1
rate - gpm		100 avg
rate - gpm		160 max
Chlorination - pre and post on D.E. filters		
Contact time - hours		4
Pumping @ 200' TDH - gpm - alternate only		120
STORAGE		
Clearwell @ filtration plant - gal.		5,000
Clearwell @ filtration plant - gal. - alternate only		19,200
Service - backwash, chlorine contact time, and to system		
Elevated steel tank - existing - gal.		40,000
Service - control and to system		
DISTRIBUTION - for Hardy Cross Network Analysis		
Peak 4 hrs. domestic flow - gpm		300
Peak 4 hrs. residential and commercial fire flow - gpm		100

TABLE 15-2. BASIC DESIGN DATA, NORRIS AREA-contd.

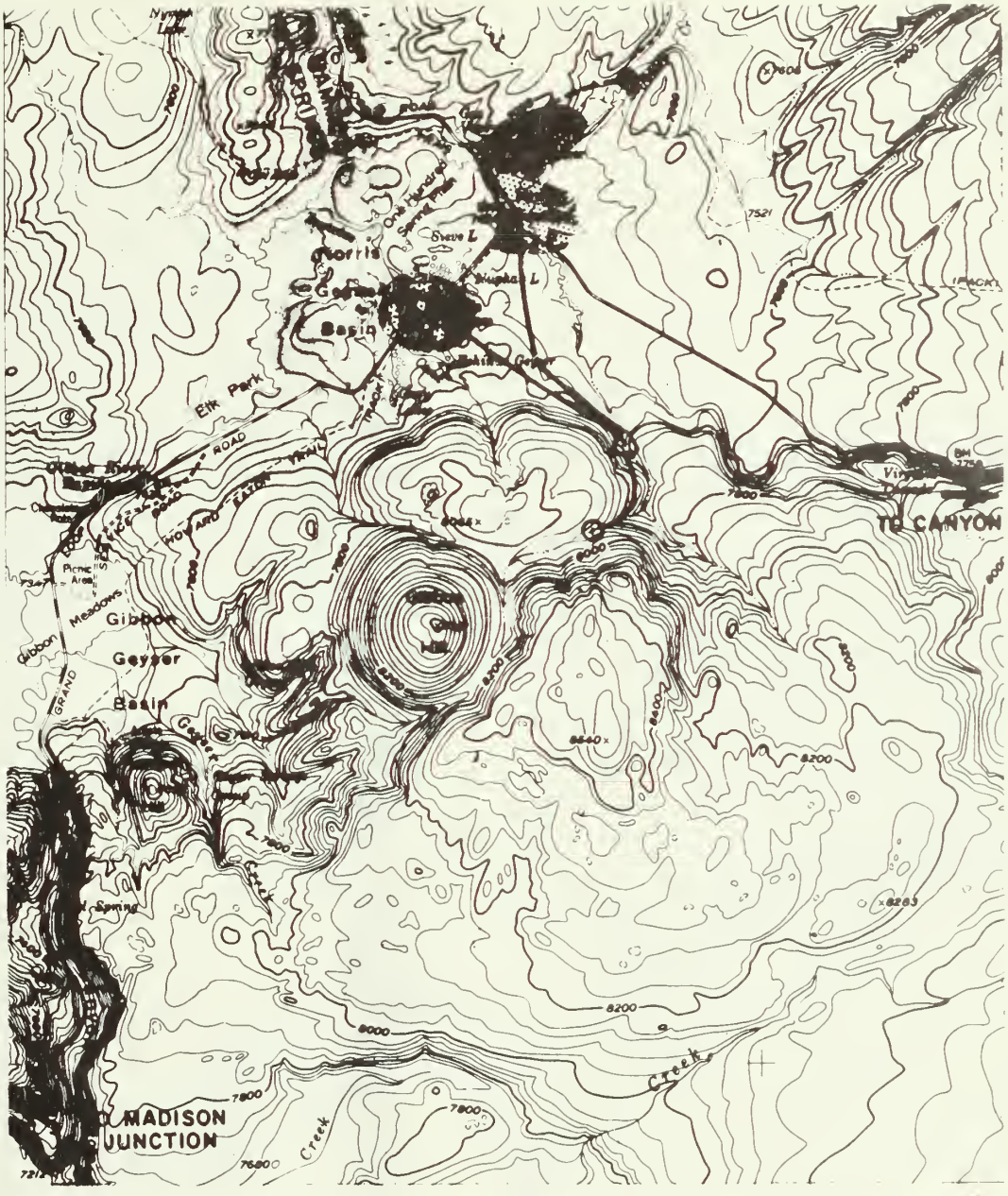
ITEM	EXISTING	DESIGN
PEAK FLOWS FOR STORAGE DESIGN*		
Max. flow input - gpm		120
Max. 4 hr. fire flow - gpm		100
Peak 4 hr. domestic flow - gpm		240
CONTROL SYSTEM		
1. Elevated tank - pump on-off ** alternate.		
2. Receive and record elevated tank level at filtration plant-alternate.		
3. TIR flow		
4. Clearwell level start - stop backwash of infiltration gallery- Flow to service exceeds flow in the gallery.		
5. Fully automate D.E. filtration plant.		
6. Altitude valve on elevated tank.		

* Chapter 2 and Table 2-5 discuss the storage design for all areas.

** Pressure sensing control equipment, alternate system. Would allow winter use.

TABLE 15-3. EVALUATION OF EXISTING SYSTEM
NORRIS AREA

ITEM	GENERAL DESCRIPTION	CONDITION	OTHER
GENERAL	All gravity flow		
SOURCE			
1.Castle Creek - direct	Inaccessible, concrete structure, temporary inlet pipe,warm water	Fair	Inadequate
TRANSMISSION			
1. Intake to elevated tank	G.S. and some PVC	Fair	Shallow
2. Elevated tank to Community	C.I.	Good	
TREATMENT			
1. Chlorination - gas	Continuously, pressure drop across valve	Good	Inadequate
STORAGE			
1. 40,000 gal. elevated	Steel, above ground	Good	
DISTRIBUTION SYSTEM			
1. 4" and smaller	C.I. and G.S.	Fair	Shallow
2. 6"	C.I.	Good	



LEGEND

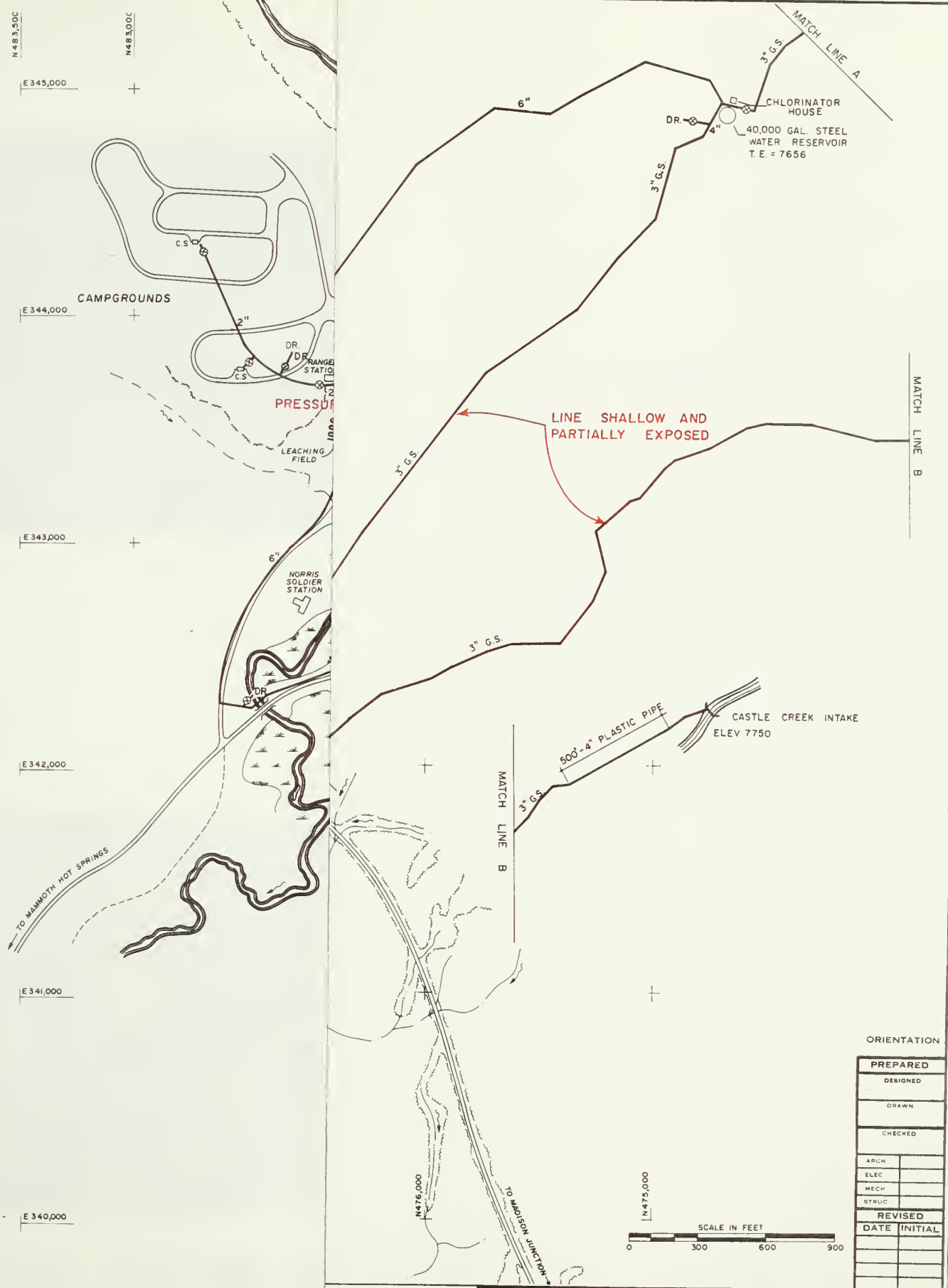
- PROPOSED WTP
- EXISTING INTAKE
- EXISTING WATER LINE
- PROPOSED WATER LINE
- EXISTING TANK
- SERVICE AREA

SCALE IN MILES

0 1 2 3

N

FIG. 15-1 NORRIS AREA
VICINITY MAP



ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	
REVISED	
DATE	INITIAL

DATE
DATE
DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES

NORRIS AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO.
SHEET OF
DRAWING NO.
DATE

NOTE

1. 3" LINE TO VISITOR CENTER AND INTAKE LINE SHALLOW AND PARTIALLY EXPOSED - NOT SUITED FOR WINTER USE.
2. 6" LINE TO GOVERNMENT AREA AND CAMPGROUND HAS 4' OR MORE COVER.

SOLFATARA CREEK

GIBBON RIVER

CAMPGROUNDS

RANGER STATION

PRESSURE = 70 PSI

SEPTIC TANK

LEACHING FIELD

NORRIS SOLDIER STATION

DRY MEADOWS

WET MEADOWS

PICNIC AREA

PRESSURE = 65 PSI GOVERNMENT AREA

TO CANYON VILLAGE

NORRIS - CANYON CUTOFF

GRAND LOOP ROAD

NORRIS JUNCTION

NORRIS JUNCTION

HOWARD EATON TRAIL

FORMER ROAD BED

NUPHAR LAKE

SIEVE LAKE

VISITOR PARKING

MUSEUM

SEPTIC TANK

STEAMBOAT GEYSER

NORRIS GEYSER BASIN

TO MAMMOTH HOT SPRINGS

MATCH LINE A

MATCH LINE B

CHLORINATOR HOUSE

40,000 GAL STEEL WATER RESERVOIR
T.E. = 7656

LINE SHALLOW AND PARTIALLY EXPOSED

CASTLE CREEK INTAKE
ELEV 7750

500'-4" PLASTIC PIPE

TO MADISON JUNCTION

E 305,000 E 304,000 E 303,000 E 302,000 E 301,000 E 300,000

N 483,000 N 482,000 N 481,000 N 480,000 N 479,000 N 478,000 N 477,000 N 476,000 N 475,000

SCALE in FEET 0 300 600 900

ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
CIVIL	
ELEC	
MECH	
ARCHIT	

REVISED

DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS — ARCHITECTS, INC
CASPER WYOMING

EXISTING WATER SYSTEM
COMMENTS AND CAPABILITIES

NORRIS AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO

SHEET OF

DRAWING NO





Fig. 15-3. Norris Direct Intake



Fig.15-4. Norris Tank Overflow



Fig.15-5. Norris Chlorine House and Tank

ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
ARCH	
ELEC	
MECH	
STRUC	

REVISED	
DATE	INITIAL

DATE

DATE

DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS – ARCHITECTS, INC.
PREPARED BY
CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION

NORRIS AREA
YELLOWSTONE NATIONAL PARK

REGION

PCP NO.

SHEET OF

DRAWING NO.

DATE

ELEV. = 7480
PROPOSED WATER FILTRATION PLANT SEE FIG. 15-7A ALTERNATE

SOLFATARA CREEK

PROPOSED ROAD TO PLANT ALTERNATE

FUTURE CAMPGROUND EXPANSION, ABOUT 50 SITES - NOT PROGRAMMED FOR NEXT 5 YEARS

CAMPGROUNDS

RANGER STATION

SEPTIC TANK

LEACHING FIELD

INSTALL F.H.

NORRIS SOLDIER STATION

GIBBON RIVER

DRY MEADOWS

WET MEADOWS

PICNIC AREA

GOVERNMENT AREA

TO CANYON VILLAGE

NORRIS - CANYON - MADISON

GRAND LOOP ROAD

HOWARD EATON TRAIL

NUPHAR LAKE

FORMER ROAD BED

SIEVE LAKE

TO MAMMOTH HOT SPRINGS

N

NORRIS GEYSER BASIN

VISITOR PARKING

MUSEUM

SEPTIC TANK

STEAMBOAT GEYSER

NORRIS JUNCTION

NORRIS JUNCTION

GRAND LOOP ROAD

TO MADISON JUNCTION

CHLORINATOR HOUSE

40,000 GAL STEEL WATER RESERVOIR
T.E. = 7656

CASTLE CREEK INTAKE, LINE AND CHLORINATOR HOUSE

MATCH LINE A

MATCH LINE B

ABANDON AND REPLACE 3" LINE

PROPOSED WATER FILTRATION PLANT SEE FIG 15-7

CASTLE CREEK INTAKE
ELEV 7750

500'-4" PLASTIC PIPE

3" G.S.

4"

6"

DR

E345,000
E344,000
E343,000
E342,000
E341,000
E340,000

N483,500
N482,000
N480,500
N479,000
N477,000
N475,500
N474,000
N473,000

SCALE IN FEET
0 300 600 900

ORIENTATION

PREPARED	
DESIGNED	
DRAWN	
CHECKED	
QUAN.	
SPEC.	
MECH.	
STRUC.	
REVISED	
DATE	INITIAL

RECOMMENDED _____ DATE

CONCURRED _____ DATE

APPROVED _____ DATE

UNITED STATES
DEPARTMENT OF THE INTERIOR
NATIONAL PARK SERVICE
WESTERN ENGINEERS - ARCHITECTS, INC
PREPARED BY CASPER WYOMING
OFFICE

FUTURE DEVELOPMENT AND RECOMMENDED CONSTRUCTION

NORRIS AREA
YELLOWSTONE NATIONAL PARK

REGION
PCP NO
SHEET OF
DRAWING NO.
BASE

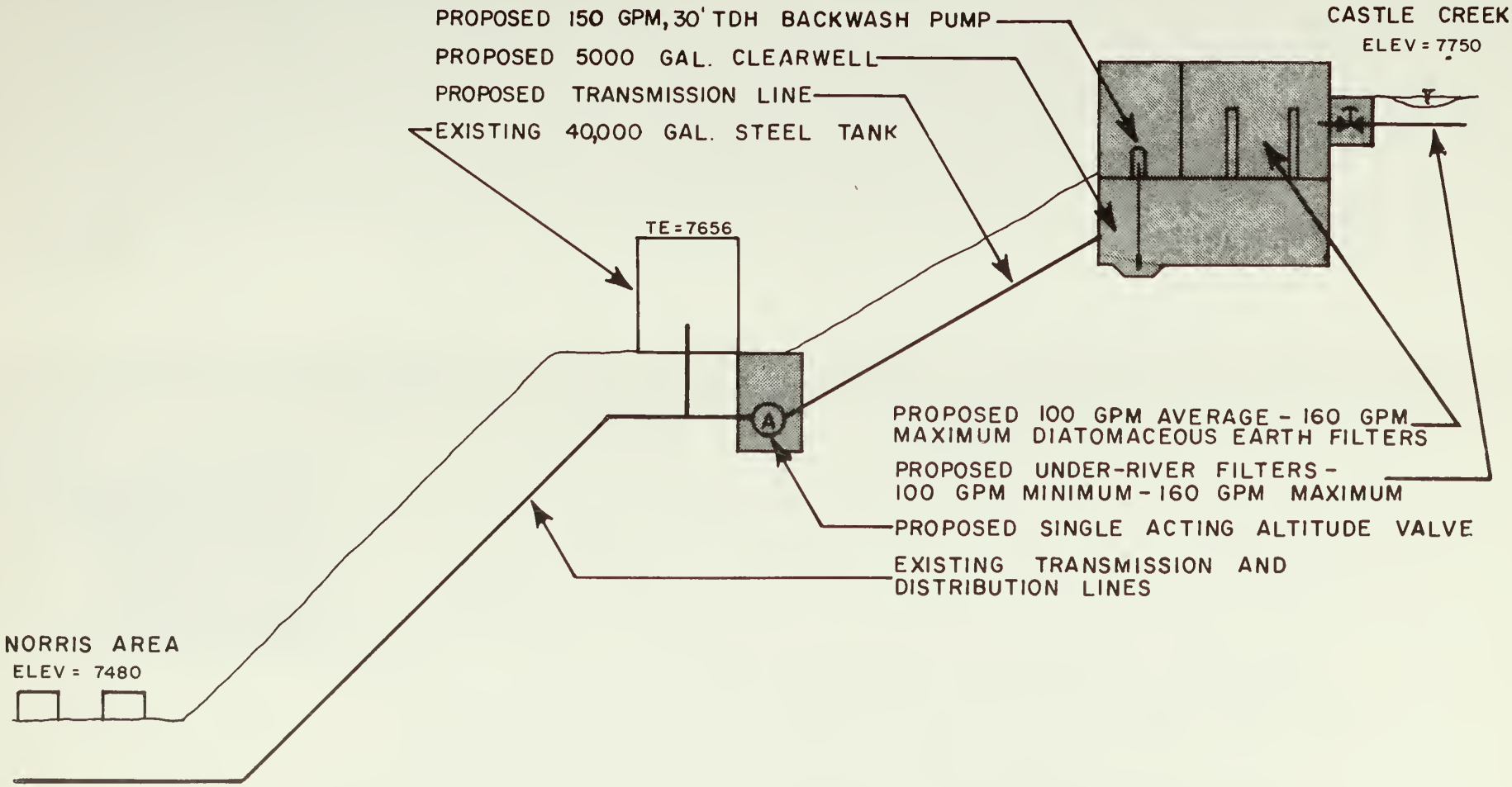


FIG. 15-7 NORRIS AREA - CASTLE CREEK
SCHEMATIC OF PROPOSED COLLECTION,
TREATMENT, TRANSMISSION, AND STORAGE

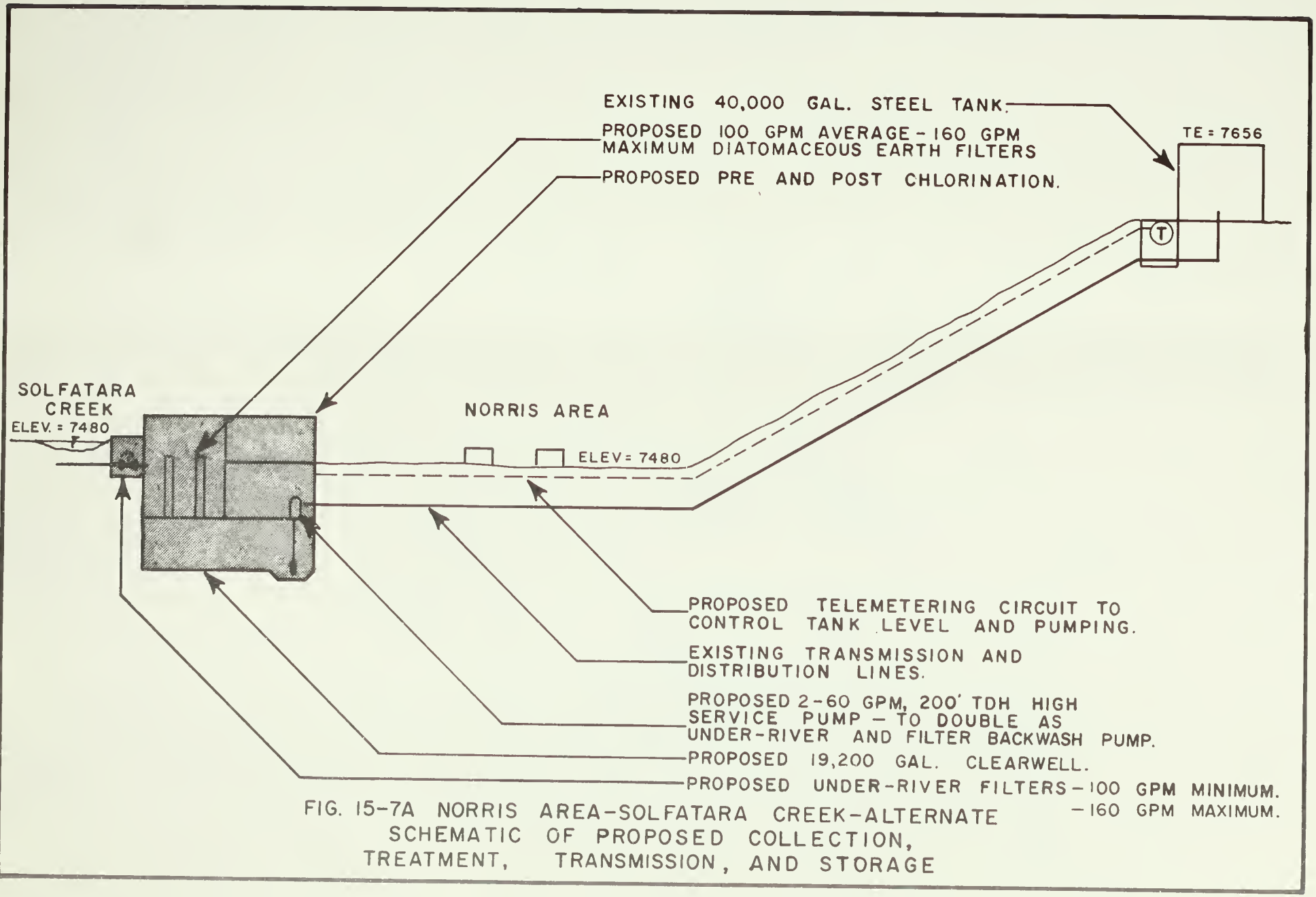


FIG. 15-7A NORRIS AREA-SOLFATARA CREEK-ALTERNATE SCHEMATIC OF PROPOSED COLLECTION, TREATMENT, TRANSMISSION, AND STORAGE

PART III

IMPLEMENTATION

Chapter 16. PRIORITIES OF CONSTRUCTION

Funds generally will not be available to perform all of the recommended program immediately. A number of system deficiencies are potentially hazardous and should be given high priority. Other deficiencies exist in water systems and at times these systems will not meet Public Health Service drinking water standards yet the problems are not considered health hazards. Examples of this are turbid and colored waters. These deficiencies are given a second priority. Also given second priority are some hydraulic problems. The remainder of recommended improvements including adequate fire protection, maintenance, standby generators, polishing filters and other items are all important but are grouped together for final construction.

POTENTIAL HAZARDS TO HEALTH or SAFETY - 1st PRIORITY

Surface waters that receive only chlorination as treatment and have a short or nonexistent chlorine contact time are potentially dangerous even though chlorination is carefully controlled. The following areas fit this criteria: Mammoth Hot Springs, Canyon for the Cascade Creek source, and Old Faithful. Large clearwells are contemplated for each of these areas to provide adequate chlorine contact time. If these clearwells would be constructed so they could fit an overall design plan then they would upon completion eliminate a substantial portion of the public health hazard. The clearwells would cost:

Mammoth Hot Springs	-	$ 312,000
Old Faithful	-	142,350
Canyon	-	47,000

containing less than 10 J.U. the Soda Creek source would normally be filtered, chlorinated and have adequate chlorine contact time. The meter and auto-valve installation on the Soda Creek intake would substantially benefit this operation. The total cost would be $56,000.

Lake

The flooding of the Fishing Bridge spring is a health hazard. Also eliminating the potential cross connections and a longer chlorine contact time at the Lake springs would be desirable. The winter spring should be fenced, drained and not allowed to run to service without chlorination. Some defluoridation should be accomplished for any year-around residents with children.

To correct the above problems would require the following at a cost of $145,000.

1. Construct a new clearwell at the Lake Spring area.
2. Develop the gallery spring.
3. Provide adequate pumping and controls at the Lake Spring area to fill the Fishing Bridge tank and/or the Lake tanks and automate this pumping.
4. Add chlorine house to existing pumphouse to provide space for new pumping and place chlorine equipment in separate room from pumping control equipment.
5. Obliterate Fishing Bridge pumphouse and chlorination house.
6. Provide necessary controls and auto valves to adequately fill and control all tanks from Lake spring area.
7. Fence and provide surface drainage for winter spring at Lake.

8. Defluoridate water supply for individual residences.

Grant

The only critical problem at Grant is the elimination of the water hammer. The Duck Lake source is not desirable and is a case of a surface water receiving only chlorineation for treatment. The contact time at the West Thumb tanks is adequate.

To correct the Grant area problems would require the following improvements at a cost of $54,000.

1. Install a 6 inch surge relief valve between the check valve and the elevated tank to eliminate excessive water hammer. The return flow from this surge relief would enter the intake caisson.
2. Construct a new transmission line between Grant and West Thumb tying to the 4 inch line at the south end of the West Thumb community.
3. Install sufficient controls to start-stop the submersible pumps automatically to keep the Grant tank full.
4. Obliterate the Duck Lake Intake.
5. Provide sufficient altitude valve control to allow the West Thumb tanks to provide supplemental water to West Thumb.

Madison Junction

The only problem that is a serious problem at Madison Junction is the high fluoride concentrations. Proper dental hygiene to prevent fluorosis would require installing home reverse-osmosis or similar defluoridating equipment in those residences of permanent employees having children. Four such units could be installed for a maximum of $2,000.

Norris

The existing system takes a surface supply and provides only chlorination for treatment. Alleviation

of this problem requires construction of a backwashable infiltration gallery as the existing intake facilities would be obliterated. Power would need be run to the source. The altitude valve should be installed when the infiltration gallery is installed. The cost of these improvements is $37,600.

NUISSANCE AND CRITICAL PROBLEMS - 2nd PRIORITY

The nuissance and critical problems not covered in the 1st priority are listed by area in this second priority grouping.

Tower

The Roosevelt Lodge Lost Creek source is still required when the stream is clear in the late summer months as the proposed well would not supply an adequate supply for this community at this time. To avoid using a surface source with just chlorination will require the following improvements at a cost of $153,000.

1. Install a transmission line from the new Tower Fall tank to the Roosevelt Lodge tanks.
2. Place the necessary pressure reducing valves and altitude valves to combine the upper and lower systems.
3. Abandon and destroy the no longer used Roosevelt Lodge facilities.

Old Faithful

The color should be reduced to a tolerable limit at Old Faithful with adequate controls. The following improvements would be the maximum required and would cost $386,100.

1. Construct the backwashable infiltration gallery and power to the gallery.
2. Place permanent baffle for slush removal in Firehole River as a standby source of supply.

3. Construct a chlorination and activated carbon filtration plant with adequate controls for completely automatic operation.

Canyon

The color should be almost completely removed and the total control system installed so that the new plant will function properly. The following improvements would be the maximum required and would cost $260,000.

1. Construct a backwashable infiltration gallery and chlorination-activated carbon filtration plant with adequate controls for completely automatic operation.

Mammoth, Lake, Grant and Norris

The above areas have no second priority items that require attention.

Madison Junction

The spring area should be completely fenced, drained and some maintenance work accomplished for a cost of $26,000.

DOMESTIC WATER SYSTEM CONSTRUCTION PLAN

The following system of priorities for water system improvements is recommended:

1. Correct the priority I deficiencies as rapidly as finances will allows.

2. Correct the priority 2 deficiencies.

3. Complete the recommended construction at the Mammoth Hot Springs Area. Mammoth has the largest, most difficult and complicated system. The D.E. filters would help guarantee a high quality supply at all times for this area. The distribution system in the upper level is the

most inadequate for fire protection of any area studied and may be leaking. Therefor the earliest possible replacement is recommended.

4. Construct the D.E. filter at the Norris Area and complete this system. The D.E. filter will give a highly polished water supply.

5. Construct 50% of the D.E. filter and clearwell at the Grant Area and connect the inlet and outlet transmission tank lines. These improvements would give this area a highly polished finished water and provide adequate fire protection for the Grant Community. The remaining 50% of the filter and clearwell can be constructed when usage demands completion. The remaining West Thumb distribution system improvements could be completed if necessary.

6. Complete the distribution and transmission systems at the Lake Area as improvements are needed in each community to give adequate fire protection. The Fishing Bridge Spring should not be installed unless metering shows it is needed.

7. Construct the remaining improvements at the Tower, Old Faithful and Canyon Areas. These improvements will provide adequate fire flows and add some deeper lines for winter use which will have value in Tower and Old Faithful.

8. Complete most of the remaining improvements at the Madison Junction Area. These improve-

ments would increase the spring capacity, provide a new clearwell, bury the power line to the tank and put in a complete control metering system. Also more defluoridation for additional families might be required. The additional elevated storage can wait for flow studies showing need.

9. Complete the Grant and Madison Junction improvements if flow measurements and other data show that these facilities are needed.

Table 16-1 gives the priority implementation schedule and cumulative costs of the proposed improvements. The program is intended to give a basis for long range planning but should be reviewed each year and revised as necessary to give the most effective implementation of the recommended construction.

Table 16-1. RECOMMENDED CONSTRUCTION PRIORITIES

PRIORITY ITEM	BRIEF DESCRIPTION	ESTIMATED CON-STRUCTED COST*	CUMULATIVE COST
1.	Serious Health Problems	$ 571,950	571,950
1.	Potential Health Problems	1,535,500	2,107,450
2.	Critical and Nuissance Problems	825,100	2,932,550
3.	Complete Mammoth Hot Springs Area	650,900	3,583,450
4.	Complete Norris Area	85,600	3,669,050
5.	Complete most of Grant Area	144,000	3,813,050
6.	Complete Lake Area	210,000	4,023,050
7.	Complete Tower, Old Faithful, Canyon Areas	266,570	4,289,620
8.	Complete most of Madison Junction Area	49,000	4,338,620
9.	Complete Grant and Madison Junction Area	182,470	4,521,090

* Appendix D gives cost breakdowns for individual systems.

Chapter 17. MAINTENANCE AND OPERATION

Proper maintenance and skilled operation are essential to the successful implementation of the recommended programs. The system should be inspected each spring, possibly by an outside consultant, and equipment in disrepair should be repaired.

The seasonal operation will require small flows in the winter. Therefor, modular construction and operation will be required. The advantage to the seasonal operation will be that the units not in use can be easily reconditioned.

GENERAL

The Park Service Environmental Engineer has general supervision over all systems. His authority should be such that he can have jurisdiction over all water systems. This authority would include:

Control of system operations.

Control of treatment processes and required changes in these processes.

Maintenance of equipment.

Replacement of worn out equipment.

INDIVIDUAL SYSTEMS

Each system now has an operator responsible for that system. This operator should be responsible to the Park Service Environmental Engineer. As the new facilities are completed records of flows, tank levels and plant performance should be maintained at the individual system and by the Environmental Engineer.

The systems were all designed for a minimum requirement of full time attention. Simplicity plus automation of function was emphasized to keep operating costs at a minimum.

The following additional help will be required to assist existing operators:

Mammoth Hot Springs, Norris and Tower Area

One additional full time employee for the peak 120 day season could provide and perform all of the new service required for these three areas. Each system should be visited daily with these services performed:

1. Charts checked
2. Equipment checked
3. Treatment checked
4. Trouble shooting and routine maintenance performed.

Old Faithful Area

One new full time qualified operator will be needed for a 90 day season. With the supervision of the existing system operator, this employee could be a quality seasonal employee.

Canyon Area

All statements made at Old Faithful are applicable for Canyon.

Lake, Grant, Madison Junction Areas

No additional personnel should be required for the system improvements in these areas. The new automatic equipment should simplify the operation for Lake and Grant. The Madison Junction system is currently fully automated.

Table 17-1 gives the estimated changes in operation and maintenance costs for all areas. Chlorine was estimated at 20 cents per pound, power costs at 2 cents per kilowatt/hour, new personnel as previously discussed, equipment repair at 5 percent of the installed equipment cost per year, complete water treatment at 10¢ per thousand gallons for a two month period and polishing filtration at 1¢ per thousand gallons. Minus values indicate an anticipated savings over current practices. No increase or deduction was made for maintenance and repair of transmission lines or distribution systems. The equipment repair item is based on a four month operation and is not intended to cover equipment depreciation but only maintenance.

Table 17-1. ANNUAL CHANGES IN EXISTING MAINTENANCE AND OPERATION COSTS WITH RECOMMENDED SYSTEMS

AREA	LABOR and TRANSPORTATION	POWER	CHLORINE	EQUIPMENT REPAIR AND MAINTENANCE	FULL TREATMENT	FILTRATION	TOTAL
Mammoth Hot Springs	$ 3,800	$ 1,320	$-200	$ 7,000	0	$1,300	$13,220
Tower	1,900	120	0	1,400	0	0	3,420
Old Faithful							
(with activated carbon)	3,500	100	700	5,300	0	520	10,120
(with full treatment) alternate	6,900	100	-100	8,600	2,600	0	18,100
Canyon							
(with activated carbon)	3,500	100	0	4,500	0	400	8,500
(with full treatment) alternate	6,900	100	0	6,500	1,700	0	15,200
Lake	0	0	-100	1,700	0	650	3,850
Grant	0	500	0	2,700	0	650	3,850
Madison Junction	0	0	0	400	0	100	400
Norris	1,900	100	0	1,200	0	100	3,300
TOTALS (with activated carbon)	$ 14,600	$ 2,240	$ 400	$24,200	$ 0	$2,970	$44,410
(with full treatment)	21,400	2,240	-400	29,500	4,300	2,050	59,090

APPENDICES

APPENDIX A

SUPPLEMENTARY DATA

TABLE A-1. TEMPERATURE AND PRECIPITATION DATA [1]

Areas and dates	Temperature, degrees Farenheit				Precipitation	
	Max	Ave. max.	Min.	Ave. min.	inches	Days of occurrence
MAMMOTH HOT SPRINGS						
Jan. 1968	45	30	-18	10	3.81	10
Feb. 1968	48	36	- 3	17	0.29	5
Mar. 1968	57	45	5	22	0.75	7
Apr. 1968	66	45	10	22	0.33	9
May 1968	69	57	23	33	1.93	14
June 1968	84	68	24	42	3.82	17
July 1968	89	82	25	47	0.39	4
Aug. 1967	89	83	36	45	0.34(*)	8
Aug. 1968(*)	85	76	24	43	3.87(*)	16(*)
Sep. 1967	90	72	31	41	0.65	6
Oct. 1967	66	54	19	32	2.53	14
Nov. 1967	55	41	- 1	20	1.27	10
Dec. 1967	42	24	-18	7	1.91	13
Total annual					18.02	117
TOWER FALL						
June 1968	81	67	26	34	4.71	15
July 1968	88	79	28	38	1.37	5
Aug. 1968	85	71	25	38	3.98	16
OLD FAITHFUL						
June 1968	79	66	21	36	1.69	12
July 1968	83	78	28	39	0.34	6
Aug. 1-20, 1968	85	69	33	39	4.04	13
LAKE						
June 11-30, 1968	74	63	26	32	1.00	6
July 1968	79	72	27	37	0.78	9
Aug. 1967	79	72	32	37	1.02	8
Sept. 1967	73	61	23	33	1.41	16

(*) A month of abnormal weather; precipitation not included in total.

TABLE A-2. MEASURED UNIT WATER USE(*)

Facility Checked	Unit	Measured unit water use, gpd
Campgrounds		
Grant	Per person	20
Bridge Bay	Per person	20
Lodge or cabins		
Lake Lodge	Per person	45
Old Faithful Lodge	Per person	52(*)
Old Faithful Cabins	Per person	50(*)
Hotels		
Lake Hotel	Per person	76(*)
Mammoth Inn	Per person	78(*)
Old Faithful Inn	Per person	164
Trailer village		
Fishing Bridge	Per person	32
Hospital		
Lake Hospital (25 beds)	Per bed	192
Dormitory or bunkhouse		
Haynes Canyon	Per person	60
Haynes Tower	Per person	64
Haynes Old Faithful	Per person	65
Hamilton's Fishing Bridge	Per person	76
Cafeteria or Dining Room		
Old Faithful Lodge	Per table seat	150(*)
Old Faithful Cabins	Per table seat	150(*)
Lake Hotel	Per table seat	150(*)
Mammoth Inn	Per table seat	150(*)
Mammoth Cafeteria	Per table seat	111-190
Fishing Bridge Cafeteria	Per table seat	300

TABLE A-2. MEASURED UNIT WATER USE (contd.)

Facility Checked	Unit	Measured unit water use, gpd
Coffee shop		
Hamilton's Fishing Bridge Store	Per counter seat	375
Hamilton's Old Faithful Upper Store	Per counter seat	93
Hamilton's Canyon Store	Per counter seat	82
Gas stations		
Old Faithful Upper	Per station	2,000
Old Faithful Lower	Per station	12,000
Canyon	Per station	2,400
Laundromats		
Canyon	Per washing machine	450
Old Faithful	Per washing machine	120
Fish cleaning stations		
Bridge Bay	Per station	8,000
Grant	Per station	5,000-8,000

(*) Estimated.

TABLE A-3. SELECTED STREAM FLOWS

LOCATION		MEAN MONTHLY AND YEARLY DISCHARGE, (*) cfs												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
YELLOWSTONE RIVER at Fishing Bridge (DA = 1,006 sq. mi.)	Max.	607	570	717	801	2,194	6,640	6,238	3,590	1,883	1,231	984	775	1,773
	Ave.	381	375	426	534	1,138	3,764	4,106	2,144	1,184	806	595	460	1,337
	Min.	211	180	217	366	605	2,611	2,423	1,301	848	534	406	277	943
GARDNER RIVER at State Line (DA = 202 sq.mi.)	Max.	105	100	95	160	811	1,158	523	205	169	153	130	114	273
	Ave.	95	91	90	118	474	773	296	157	133	124	108	102	213
	Min.	79	80	79	85	283	436	149	113	96	96	90	85	167
MADISON RIVER at State Line (DA = 420 sq.mi.)	Max.	471	447	460	580	1,212	1,225	673	542	556	513	497	475	585
	Ave.	405	400	393	478	864	812	478	423	420	420	417	412	494
	Min.	332	356	326	396	665	526	361	348	356	354	357	343	411

(*) Based on 15 years of records (1952-1966) from U.S. Geological Survey.
DA = Drainage Area

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK **

STATION NO.	STREAM	LOCATION (N.Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-0368.00	Firehole River above diversion dam, near Old Faithful.	44°26'33" 110°48'15"	5- 2-67	34.5
			5-24-67	155
			6-21-67	275
			6-26-67	177
			7-18-67	98.4
			9-19-67	60.0
			5-22-68	101
			6-12-68	207
			8-14-68	59.1

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES,
YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N. Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-1897.50	Panther Creek above diversion dam, near Mammoth	44°53'36" 110°46'00"	10-28-66	3.44
			8-14-68	9.98
6-1898.10	Indian Creek above diversion dam, near Mammoth.	44°53'20" 110°45'44"	8-14-68	23.2
6-1898.20	Indian Creek diversion, near Mammoth.	44°53'20" 110°45'44"	10-28-66	7.45
6-1898.90	Glen Creek above Rustic Falls above tributary, near Mammoth.	44°55'58" 110°43'36"	10-28-66	1.85
			5-23-67	33.1
			5-24-67	49.7
			6- 4-67	27.8
			6-17-67	20.1
			7- 3-67	11.5
			7-17-67	9.43
			9-20-67	3.10
			5-29-68	12.8
			8-13-68	3.21
6-1899.00	Tributary to Glen Creek above Rustic Falls, near Mammoth	44°55'58" 110°43'36"	5-23-67	46.6
			5-24-67	45.9
			6- 4-67	21.1
			6-17-67	16.8
			7- 3-67	10.2
			7-17-67	14.4
			9-20-67	13.0
			5-29-68	6.43
			8-13-68	15.4

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES,
YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N.Lat.and W. Long.)	Date	DISCHARGE (cubic feet per second
6-0368.50	Old Hotel Spring, near Fountain Paint Pot.	44°33'17" 110°48'03"	10-16-68	.04
6-0369.00	Nez Perce Creek above bridge at picnic area, near Fountain Paint Pot.	44°35'05" 110°46'41"	8-14-68	77.4
6-0369.25	Castle Creek below diversion dam, near Norris Junction	44°42'23" 110°40'23"	9-19-67	1.96
6-0369.27	Castle Creek at turnaround in road, near Norris Junction	44°42'49" 110°40'49"	9-19-67	3.96
6-0369.30	Gibbon River near Norris picnic area, near Norris Junction.	44°43'47" 110°41'20"	8-13-68	30.2
6-1870.35	Tributary to Cascade Creek above diversion dam, near Canyon Village	44°45'37" 110°28'18"	7-25-68	.27
6-1870.50	Cascade Creek above diversion dam, near Canyon Village.	44°44'25" 110°29'59"	7-25-68	4.64
6-1871.00	Tributary to Sulphur Creek above diversion dam, near Canyon Village.	44°45'57" 110°27'52"	7-25-68	.44
6-1890.10	Blacktail Deer Creek above Blacktail pond tributary, near Mammoth	44°57'20" 110°35'28"	9-27-67 8-13-68	3.77 8.11
6-1890.20	Blacktail pond tributary, near Mammoth.	44°57'31" 110°35'40"	9-27-67	.10
6-1890.30	Blacktail Deer Creek below Blacktail pond tributary, near Mammoth	44°57'42" 110°35'26"	9-27-67 8-13-68	4.11 9.12
6-1897.30	Gardner River above diversion dam, near Mammoth	44°53'36" 110°44'56"	10-28-66 7-26-67 9-20-67 8-13-68	12.8 64.4 23.7 33.5

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N.Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth.	44°55'59" 110°43'33"	5- 8-68	23.0
			5- 9-68	20.5
			5- 9-68	28.1
			5-14-68	22.2
			5-17-68	18.3
			5-27-68	19.9
			5-29-68	19.2
			6- 6-68	33.2
			6- 7-68	30.7
			6- 9-68	39.2
			8-13-68	17.8
6-1899.80	Lava Creek above Lupine Creek, near Mammoth	44°56'22" 110°37'36"	5- 2-67	14.4
			5-23-67	95.3
			5-26-67	112
			6- 2-67	147
			7- 3-67	148
			7-17-67	84.9
			8-23-67	39.2
			9-20-67	27.3
			5- 8-68	24.6
			5-10-68	30.2
			5-13-68	38.5
			5-14-68	42.4
			5-21-68	34.4
			5-27-68	38.4
			5-29-68	57.0
			5-29-68	69.7
			5-30-68	83.8
			5-31-68	75.2

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK ** (contd.)

STATION NO.	STREAM	LOCATION (N. Lat. and W. Long.)	Date	DISCHARGE (cubi feet per second
			6- 1-68	70.1
			6- 3-68	103
			6- 4-68	121
			6- 5-68	119
			6- 5-68	116
			6- 6-68	128
			6-10-68	143
			8-13-68	37.2
			10-10-68	30.6
6-1903.00	Gardner River below Lava Creek near Mammoth.	44°57'48" 110°40'29"	4- 4-67	57.6
6-1904.10	Mammoth Hot Springs tributary, near Mammoth	44°58'08" 110°41'10"	4- 4-67	8.20
6-1905.40	Hot River, near Mammoth.	44°59'10" 110°41'15"	4- 4-67	19.0
6-1910.00	Gardner River at gaging station, near Mammoth	44°59'35" 110°41'25"	4- 4-67	85.6
6-2798.50	Middle Creek at East Entrance	44°29'19" 110°00'02"	8-16-68	49.4

** U.S.G.S. Report - Table 4 (3)

TABLE A-4. SELECTED STREAM TURBIDITES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*

6-0368.00 Firehole River above diversion dam, near Old Faithful lat 44°26'33" N.; long 110°48'15" W.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
1967					
May 2	1300	7	34.5	2	0.19
May 24	1430	10	155	25	10
June 21	1130	7	275	5	3.7
June 26	1355	11	177	5	2.4
July 18	0910	9	98.4	6	1.6
Sept. 19	1000	6	60.0	--	---
1968					
May 22	1325	7	---	5	---
June 12	1235	8	207	10	5.6

6-1897.30 Gardner River above diversion dam, near Mammoth lat 44°53'36" N.; long 110°44'56"W.

1966					
Oct. 28	1030	2	12.8	3	0.10
1967					
May 23	0815	--	280	88	66
	1520	1	420	325	370
	1945	1	410	205	230
May 24	0745	1	300	91	74
	1715	3	540	312	450
May 25	1830	5	430	141	160
May 26	1720	7	290	103	81
May 27	1845	8	310	136	110
May 28	1745	8	300	134	110

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* (contd.)

6-1897.30 Gardner River above diversion dam, near Mammoth lat 44°53'36" N., long 110°44'56" W. (contd.)

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
1967 contd.					
May 29	1830	5	320	98	85
May 30	1810	7	280	68	51
May 31	1825	7	280	44	33
June 4	1630	7	270	51	37
June 12	1845	8	220	16	9.5
June 17	1325	7	280	65	49
July 3	1325	8	210	57	32
July 17	1640	9	140	72	27
July 26	1000	8	66.4	---	------
Sept. 20	1600	12	23.7	2	.13
1968					
May 29	1325	6	-----	40	------
June 3	1425	7	-----	201	------
June 5	1120	3	-----	92	------
June 8	1135	4	-----	58	------
June 10	1810	9	-----	46	------
Aug. 13	1535	15	33.5	4	.36

6-1897.50 Panther Creek above diversion dam, near Mammoth lat 44°53'36" N.; long 110°46'00" W.

1966					
Oct. 28	1145	1	3.44	3	0.03

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park* contd.

6-1898.20	Indian Creek diversion, near Mammoth lat 44°53'20" N.; long 110°45'44" W.				
DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
1966					
Oct. 28	1225	3	7.45	2	0.04
6-1898.90	Glen Creek above Rustic Falls; above tributary, near Mammoth lat 44°55'58" N.; long 110°43'36" W.				
1966					
Oct. 28	0920		1.85	2	0.01
1967					
May 2	1435	--	E 2.5	8	.05
May 23	1400	7	33.1	34	3.0
May 24	0730	3	E 25	2	.14
May 24	1910	9	49.7	23	3.0
May 25	1855	11	E 35	2	.19
May 27	1905	12	E 30	3	.24
June 4	1610	12	27.8	9	.68
June 12	1900	10	E 25	3	.20
June 17	0930	8	20.1	3	.16
July 3	0830	7	11.5	4	.12
July 17	1620	9	9.43	E 3	.07
Sept. 20	1425	9	3.10	10	.08
1968					
May 29	1450	11	12.8	6	.21
Aug. 13	1325	9	3.21	36	.31

E Estimated

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.00	Tributary to Glen Creek above Rustic Falls, near Mammoth lat 44°55'58" N.; long 110°43'36" W.				
1967					
May 23	1405	8	46.6	49	6.1
May 24	0730	4	E 40	3	.32
May 24	1935	9	45.9	60	7.4
May 25	1850	11	E 40	23	2.5
May 27	1910	12	E 30	10	.81
June 4	1615	11	21.1	2	.11
June 12	1905	10	E 20	3	.16
June 17	0910	8	16.8	3	.14
July 3	0825	8	10.2	3	.08
July 17	1605	9	14.4	E 3	.12
Sept.20	1355	9	13.0	3	.11
1968					
May 29	1425	16	6.43	1	.02
Aug. 13	1320	10	15.4	4	.17
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W.				
1968					
May 8	1220	2	23	5	0.31
	2035	3	24	6	.39
May 9	1010	2	20	3	.16
	1945	5	28	8	.60
May 10	1010	2	22	5	.30
	1825	6	26	10	.70

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W.-contd.				
May 11	1105	4	22	2	.12
	1940	6	27	8	.58
May 12	1125	5	23	3	.19
	2010	6	27	6	.44
May 13	1055	4	22	4	.24
	1940	7	23	4	.25
May 14	1140	5	22	3	.18
	1940	6	22	3	.18
May 15	1020	3	21	2	.11
May 16	1125	3	19	3	.15
May 17	1110	3	19	2	.10
May 18	1245	7	18	5	.24
May 19	1320	8	18	3	.15
May 20	0955	4	18	2	.10
May 21	1155	6	18	6	.29
May 22	1020	4	20	3	.16
May 23	1030	5	19	2	.10
May 24	1015	4	19	3	.15
May 25	1950	8	20	6	.32
May 27	1045	6	19	4	.21
May 28	1325	10	19	4	.21
May 29	0950	8	19	4	.21
May 30	1125	8	19	4	.21
May 31	1125	4	18	5	.24
June 1	1030	7	18	5	.24
June 2	1130	9	18	5	.24
June 3	1045	8	18	4	.19

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W. -contd.				
1968 contd.					
June 4	1010	7	19	6	.31
	1800	8	21	8	.45
June 5	0745	6	22	9	.53
June 6	1000	7	23	6	.37
	1440	7	29	11	.86
	1840	8	34	53	4.9
June 7	0950	6	30	15	1.2
	1815	11	31	5	.42
June 9	1150	6	31	8	0.67
	2015	9	40	6	.65
June 10	1100	8	36	4	.39
	1830	11	37	5	.50
June 11	0840	6	34	11	1.0
	1905	13	33	5	.45
June 12	1020	8	33	4	.36
	1935	13	31	5	.42
June 13	1455	8	36	3	.29
June 21	1740	14	19	5	.26
Aug. 13	1430	11	19	3	.15
6-1899.10	Glen Creek at Mammoth Diversion, near Mammoth lat 44°56'40"N.; long 110°42'18" W.				
1967					
June 12	1945	9	E 45	3	0.36
1968					
May 7	2025	1	33	13	1.2
May 8	1245	2	23	5	.31
	2100	3	24	5	.32

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.10	Glen Creek at Mammoth Diversion, near Mammoth lat 44°56'40" N.; long 110°42'18" W.-contd.				
1968 contd.					
May 9	1025	2	20	4	.22
	2000	5	28	7	.53
May 10	1025	3	22	3	.18
	1845	9	26	8	.56
May 11	1120	4	22	5	.30
	1955	6	27	4	.29
May 12	1145	5	23	3	.19
	2025	6	27	6	.44
May 13	1110	5	22	3	.18
	2000	7	23	5	.31
May 14	1155	5	22	3	.18
	1955	6	22	3	.18
May 15	1035	3	21	6	.34
May 16	1030	3	19	3	.15
May 17	1125	4	19	3	.15
May 18	1300	7	18	2	.10
May 19	1335	8	18	3	.15
May 20	1020	4	18	2	.10
May 21	1110	6	18	3	.15
May 22	0915	5	20	4	.22
May 23	1050	6	19	4	.21
May 24	0925	4	19	4	.21
May 25	2035	7	20	32	1.7
May 26	1300	6	19	4	.21
May 27	1100	6	19	5	.26

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park. * -contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (Milligrams per liter)	Sediment discharge (tons per day)
6-1899.10 1968 contd.	Glen Creek at Mammoth Diversion, near Mammoth-contd.				
May 28	1345	11	19	5	.26
May 29	1010	8	19	5	.26
May 30	1155	8	19	4	.21
May 31	1155	7	18	5	.24
June 1	1050	7	18	5	.24
June 2	1145	9	18	5	.24
June 3	1105	8	18	5	.24
June 4	1025	7	19	11	.56
	1815	8	21	8	.45
June 5	0805	6	22	10	.59
June 6	1015	7	23	7	.43
	1505	7	29	25	2.0
	1900	8	34	32	2.9
June 7	1010	7	30	8	0.65
	1750	9	31	10	.84
June 8	1355	7	29	11	.86
June 9	1205	6	31	21	1.8
	2030	8	40	16	1.7
June 10	1115	8	36	11	1.1
	1850	10	37	16	1.6
June 11	0855	6	34	11	1.0
	1845	12	33	6	.53
June 12	0955	6	33	5	.45
	1955	13	31	5	.42
June 13	1435	8	36	9	.87
June 21	1705	12	19	2	.10
June 27	1755	12	14	16	.60
July 15	1105	9	22	5	.30

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (Milligrams per liter)	Sediment discharge (tons per day)
6-1899.80	Lava Creek above Lupine Creek, near Mammoth lat 44°56'22" N.; long 110°37'36" W.				
1967					
May 2	1620	4	14.4	3	0.12
May 23	1100	--	95.3	33	8.5
May 25	0625	3	E 105	87	25
May 26	1345	8	112	18	5.4
May 28	0735	3	E 125	19	6.4
June 2	1250	8	147	15	6.0
June 12	1925	7	E 150	11	4.5
June 17	1015	7	E 155	34	14
July 3	1010	8	148	17	6.8
July 17	1450	9	84.9	16	3.7
Aug. 23	1400	13	39.2	---	-----
Sept.20	1035	8	27.3	2	.15
1968					
May 8	1035	3	26	1	.07
	2000	7	27	10	.73
May 9	0845	2	25	4	.27
	1800	7	27	5	.36
May 10	0935	4	29	2	.16
	1800	9	31	6	.50
May 11	1035	4	31	5	.42
	1910	7	36	10	.97
May 12	1055	5	34	4	.37
May 13	1010	4	39	6	.63
	2025	7	45	6	.73

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.80	Lava Creek above Lupine Creek, near Mammoth lat 44°56'22" N.; long 110°37'36" W.-contd.				
1968 contd.					
May 14	1035	6	43	10	1.2
	2030	6	43	14	1.6
May 15	0950	4	40	10	1.1
May 16	1010	3	32	4	.35
May 17	1000	4	31	3	.25
May 18	1210	6	30	4	.32
May 19	1245	7	30	4	.32
May 20	0920	3	32	3	.26
May 21	0945	5	36	4	.39
May 22	0835	5	42	10	1.1
May 23	0950	4	43	7	.81
May 24	0900	4	43	8	.93
May 25	2015	7	43	6	.70
May 26	1215	6	40	4	.43
May 27	0930	4	40	5	.54
May 28	1255	9	43	6	.70
May 29	0915	5	58	46	7.2
	1935	10	67	68	12
May 30	1010	6	87	61	14
	1835	9	87	36	8.5

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.80 Lava Creek above Lupine Creek, near Mammoth -contd.					
1968 contd.					
May 31	0940	4	83	23	5.2
	1915	8	80	17	3.7
June 1	0955	4	73	---	------
June 2	1045	6	83	18	4.0
June 3	1015	6	105	66	19
	1800	9	103	49	14
June 4	0940	6	114	56	17
	1720	3	116	51	16
June 5	0710	5	120	53	17
	1800	8	114	28	8.6
June 6	0905	6	109	23	6.8
	1410	6	129	76	26
June 7	0845	7	129	33	11
	1725	7	131	38	13
June 8	1100	5	125	18	6.1
June 9	1110	7	139	43	16
	1910	7	146	42	17
June 10	1020	6	141	29	11
	1735	8	143	29	11
June 11	0810	5	134	18	6.5
	1820	10	129	16	5.6
June 12	0905	6	129	17	5.9
	1910	8	134	18	6.5
June 13	1400	6	143	29	11
June 21	1410	9	166	30	13
June 27	1720	12	125	13	4.4
July 15	1415	13	63	5	.85
Aug. 13	1125	9	36	2	.19

*USGS Report (3)
E Estimated

TABLE A-4. SELECTED STREAM TURBIDITES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	TIME (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1900.05	Lupine Creek at mouth, near Mammoth lat 49°56'25" N.; long 110°37'38" W.				
1968					
June 3	1810	8	E 20	149	8.0
June 4	1925	4	E 20	73	3.9

* USGS REPORT (3)

E Estimated

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of discharge and color of water in Lava Creek and Glen Creek near Mammoth, Yellowstone National Park.

6-1899.80 Lava Creek above Lupine Creek lat 44°56'22"N.;long 110°37'36" W.				6-1899.10 Glen Creek at Mammoth Diversion lat 44°56'40" N.; long 110°42'18" W.			
Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)	Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)
May				May			
27	0930	40	10	27	1100	19	5
29	0925	58	10	29	1010	19	10
29	1935	67	10				
30	1020	87	15	30	1155	19	15
30	1835	87	10				
31	0940	83	10	31	1155	18	20
31	1915	80	10				
June				June			
1	0955	73	10	1	1050	18	20
2	1105	83	10	2	1145	18	20
3	1015	105	10	3	1105	18	20
3	1800	103	10				
4	0940	114	10	4	1025	19	30
4	1720	116	10	4	1815	21	30
5	0710	120	10	5	0805	22	30
5	1800	114	10				
6	0905	109	10	6	1015	23	30
				6	1505	29	30

TABLE A-4. SECLECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of discharge and color of water in Lava Creek and Glen Creek near Mammoth, Yellowstone National Park-contd.

6-1899.80 Lava Creek above Lupine Creek
lat 44°56'22" N.; long 110°37'36"W.

Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)
June (contd.)			
7	0845	129	10
7	1725	131	10
8	1100	125	10
9	1110	139	10
9	1710	146	20
10	1020	141	10
10	1735	143	10
11	0810	134	10
11	1820	129	10
12	0905	129	10
12	1915	134	10
13	1400	143	10

6-1899.10 Glen Creek at Mammoth Diversion
lat 44°56' 40" N.; long 110°42'18"W.

Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)
June (contd.)			
6	1900	34	30
7	1010	30	30
7	1750	31	30
8	1355	29	20
9	1205	31	25
9	2030	40	30
10	1115	36	20
10	1850	37	25
11	0900	34	20
11	1845	33	20
12	0955	33	20
12	1955	31	20
13	1435	36	20

Table A-5. EXISTING TANK SCHEDULE

COMMUNITY	MAMMOTH HOT SPRINGS	TOWER FALL	TOWER JUNCTION	ROOSE-VELT LODGE	ROOSE-VELT LODGE	CANYON	CANYON	LAKE
TYPE	Underground concrete	None	None	Upright wood	Upright wood	Underground concrete	Underground concrete	Underground concrete
	old	--	--	old	new	new	new	new
CAPACITY	26,000	--	--	10,000	20,000	500,000	250,000	500,000
CONDITION								
Inside	Good	--	--	Dirty leaks some	Dirty	Good	Good	Good
Outside	Good	--	--		Good	--	--	--
INLET SIZE	18"	--	--	4"	4"	6"	6" pump 6"(from 500,000 gal.tank)	8"
OUTLET SIZE	18"	--	--	4" to 20,000 gal.tank	4"	2-6" to 250,000 gal.tank	8"	8"
ROOF TYPE	concrete	--	--	wood	wood	concrete	concrete	concrete
ROOF CONDITION	Good	--	--	Bad	Bad	Good	Good	Good
INSIDE LADDER	No	--	--	No	No	Yes	Yes	Yes
OUTSIDE LADDER	--	--	--	Yes	Yes	--	--	--
ROOF VENT	No	--	--	No	No	Yes	Yes	Yes
M.H. ON TOP	Yes	--	--	Yes	Yes	Yes	Yes	Yes
OVERFLOW	No,not req'd. can't go higher than Lake	--	--	Yes	Yes	Yes	Yes	Yes
FOUNDATION	--	--	--	Good	Good	--	--	--
LOCKS ON M.H.	No	--	--	No	No	No	No	Yes

TABLE A-5. EXISTING TANK SCHEDULE-contd.

COMMUNITY	LAKE	FISHING BRIDGE	BRIDGE BAY	GRANT	GRANT	WEST THUMB	WEST THUMB	MADISON JUNCTION	NORRIS	OLD FAITHFUL
TYPE	Upright steel new	Upright concrete old	Upright steel new	Upright steel new	Underground concrete new	Underground concrete new	Underground concrete old	Upright steel new	Upright steel new	Underground old
CAPACITY	500,000	250,000	100,000	1,500,000	500,000	50,000	50,000	100,000	40,000	35,000
CONDITION										
Inside	good	good	fair, needs painting	good	good	good	fair	fair, needs painting	fair, needs painting	good
Outside	good	fair	fair	good	--	--	--	good	fair, needs painting	--
INLET SIZE	8"	6" 4" from spring area	4"	8"	8"	6"	6"	8"	4"	12"
OUTLET SIZE	8"	6"	6"	10"	10"	4"	4"	8"	6"	12"
ROOF TYPE	steel	concrete	steel	steel	concrete	concrete	concrete	steel	steel	concrete
ROOF CONDITION	good	good	fair	good	good	good	good	good	fair, needs painting	good
INSIDE LADDER	yes	yes	yes	yes	yes	--	--	yes	yes	yes
OUTSIDE LADDER	yes	yes	yes	yes	yes	--	--	yes	yes	--
ROOF VENT	yes	yes	yes	yes	yes	no	no	yes	yes	yes
M.H. on TOP	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
OVERFLOW	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
FOUNDATION	good	good	good	good	--	--	--	good	good	--
LOCKS ON M.H.	yes	no	no	yes	yes	no	no	no	no	yes

APPENDICES

APPENDIX A

SUPPLEMENTARY DATA

TABLE A-1. TEMPERATURE AND PRECIPITATION DATA [1]

Areas and dates	Temperature, degrees Farenheit				Precipitation	
	Max	Ave. max.	Min.	Ave. min.	inches	Days of occurrence
MAMMOTH HOT SPRINGS						
Jan. 1968	45	30	-18	10	3.81	10
Feb. 1968	48	36	- 3	17	0.29	5
Mar. 1968	57	45	5	22	0.75	7
Apr. 1968	66	45	10	22	0.33	9
May 1968	69	57	23	33	1.93	14
June 1968	84	68	24	42	3.82	17
July 1968	89	82	25	47	0.39	4
Aug. 1967	89	83	36	45	0.34(*)	8(*)
Aug. 1968(*)	85	76	24	43	3.87	16
Sep. 1967	90	72	31	41	0.65	6
Oct. 1967	66	54	19	32	2.53	14
Nov. 1967	55	41	- 1	20	1.27	10
Dec. 1967	42	24	-18	7	1.91	13
Total annual					18.02	117
TOWER FALL						
June 1968	81	67	26	34	4.71	15
July 1968	88	79	28	38	1.37	5
Aug. 1968	85	71	25	38	3.98	16
OLD FAITHFUL						
June 1968	79	66	21	36	1.69	12
July 1968	83	78	28	39	0.34	6
Aug. 1-20, 1968	85	69	33	39	4.04	13
LAKE						
June 11-30, 1968	74	63	26	32	1.00	6
July 1968	79	72	27	37	0.78	9
Aug. 1967	79	72	32	37	1.02	8
Sept. 1967	73	61	23	33	1.41	16

(*) A month of abnormal weather; precipitation not included in total.

TABLE A-2. MEASURED UNIT WATER USE(*)

Facility Checked	Unit	Measured unit water use, gpd
Campgrounds		
Grant	Per person	20
Bridge Bay	Per person	20
Lodge or cabins		
Lake Lodge	Per person	45
Old Faithful Lodge	Per person	52(*)
Old Faithful Cabins	Per person	50(*)
Hotels		
Lake Hotel	Per person	76(*)
Mammoth Inn	Per person	78(*)
Old Faithful Inn	Per person	164
Trailer village		
Fishing Bridge	Per person	32
Hospital		
Lake Hospital (25 beds)	Per bed	192
Dormitory or bunkhouse		
Haynes Canyon	Per person	60
Haynes Tower	Per person	64
Haynes Old Faithful	Per person	65
Hamilton's Fishing Bridge	Per person	76
Cafeteria or Dining Room		
Old Faithful Lodge	Per table seat	150(*)
Old Faithful Cabins	Per table seat	150(*)
Lake Hotel	Per table seat	150(*)
Mammoth Inn	Per table seat	150(*)
Mammoth Cafeteria	Per table seat	111-190
Fishing Bridge Cafeteria	Per table seat	300

TABLE A-2. MEASURED UNIT WATER USE (contd.)

Facility Checked	Unit	Measured unit water use, gpd
Coffee shop		
Hamilton's Fishing Bridge Store	Per counter seat	375
Hamilton's Old Faithful Upper Store	Per counter seat	93
Hamilton's Canyon Store	Per counter seat	82
Gas stations		
Old Faithful Upper	Per station	2,000
Old Faithful Lower	Per station	12,000
Canyon	Per station	2,400
Laundromats		
Canyon	Per washing machine	450
Old Faithful	Per washing machine	120
Fish cleaning stations		
Bridge Bay	Per station	8,000
Grant	Per station	5,000-8,000

(*) Estimated.

TABLE A-3. SELECTED STREAM FLOWS

LOCATION		MEAN MONTHLY AND YEARLY DISCHARGE, (*) cfs												
		Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
YELLOWSTONE RIVER at Fishing Bridge (DA = 1,006 sq. mi.)	Max.	607	570	717	801	2,194	6,640	6,238	3,590	1,883	1,231	984	775	1,773
	Ave.	381	375	426	534	1,138	3,764	4,106	2,144	1,184	806	595	460	1,337
	Min.	211	180	217	366	605	2,611	2,423	1,301	848	534	406	277	943
GARDNER RIVER at State Line (DA = 202 sq.mi.)	Max.	105	100	95	160	811	1,158	523	205	169	153	130	114	273
	Ave.	95	91	90	118	474	773	296	157	133	124	108	102	213
	Min.	79	80	79	85	283	436	149	113	96	96	90	85	167
MADISON RIVER at State Line (DA = 420 sq.mi.)	Max.	471	447	460	580	1,212	1,225	673	542	556	513	497	475	585
	Ave.	405	400	393	478	864	812	478	423	420	420	417	412	494
	Min.	332	356	326	396	665	526	361	348	356	354	357	343	411

(*) Based on 15 years of records (1952-1966) from U.S. Geological Survey.
DA = Drainage Area

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK **

STATION NO.	STREAM	LOCATION (N.Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-0368.00	Firehole River above diversion dam, near Old Faithful.	44°26'33" 110°48'15"	5- 2-67	34.5
			5-24-67	155
			6-21-67	275
			6-26-67	177
			7-18-67	98.4
			9-19-67	60.0
			5-22-68	101
			6-12-68	207
			8-14-68	59.1

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES,
YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N. Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-1897.50	Panther Creek above diversion dam, near Mammoth	44°53'36" 110°46'00"	10-28-66	3.44
			8-14-68	9.98
6-1898.10	Indian Creek above diversion dam, near Mammoth.	44°53'20" 110°45'44"	8-14-68	23.2
6-1898.20	Indian Creek diversion, near Mammoth.	44°53'20" 110°45'44"	10-28-66	7.45
6-1898.90	Glen Creek above Rustic Falls above tributary, near Mammoth.	44°55'58" 110°43'36"	10-28-66	1.85
			5-23-67	33.1
			5-24-67	49.7
			6- 4-67	27.8
			6-17-67	20.1
			7- 3-67	11.5
			7-17-67	9.43
			9-20-67	3.10
			5-29-68	12.8
			8-13-68	3.21
6-1899.00	Tributary to Glen Creek above Rustic Falls, near Mammoth	44°55'58" 110°43'36"	5-23-67	46.6
			5-24-67	45.9
			6- 4-67	21.1
			6-17-67	16.8
			7- 3-67	10.2
			7-17-67	14.4
			9-20-67	13.0
			5-29-68	6.43
			8-13-68	15.4

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES,
YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N.Lat.and W. Long.)	Date	DISCHARGE (cubic feet per second
6-0368.50	Old Hotel Spring, near Fountain Paint Pot.	44°33'17" 110°48'03"	10-16-68	.04
6-0369.00	Nez Perce Creek above bridge at picnic area, near Fountain Paint Pot.	44°35'05" 110°46'41"	8-14-68	77.4
6-0369.25	Castle Creek below diversion dam, near Norris Junction	44°42'23" 110°40'23"	9-19-67	1.96
6-0369.27	Castle Creek at turnaround in road, near Norris Junction	44°42'49" 110°40'49"	9-19-67	3.96
6-0369.30	Gibbon River near Norris picnic area, near Norris Junction.	44°43'47" 110°41'20"	8-13-68	30.2
6-1870.35	Tributary to Cascade Creek above diversion dam, near Canyon Village	44°45'37" 110°28'18"	7-25-68	.27
6-1870.50	Cascade Creek above diversion dam, near Canyon Village.	44°44'25" 110°29'59"	7-25-68	4.64
6-1871.00	Tributary to Sulphur Creek above diversion dam, near Canyon Village.	44°45'57" 110°27'52"	7-25-68	.44
6-1890.10	Blacktail Deer Creek above Blacktail pond tributary, near Mammoth	44°57'20" 110°35'28"	9-27-67 8-13-68	3.77 8.11
6-1890.20	Blacktail pond tributary, near Mammoth.	44°57'31" 110°35'40"	9-27-67	.10
6-1890.30	Blacktail Deer Creek below Blacktail pond tributary, near Mammoth	44°57'42" 110°35'26"	9-27-67 8-13-68	4.11 9.12
6-1897.30	Gardner River above diversion dam, near Mammoth	44°53'36" 110°44'56"	10-28-66 7-26-67 9-20-67 8-13-68	12.8 64.4 23.7 33.5

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK**(contd.)

STATION NO.	STREAM	LOCATION (N.Lat. and W. Long.)	Date	DISCHARGE (cubic feet per second)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth.	44°55'59" 110°43'33"	5- 8-68	23.0
			5- 9-68	20.5
			5- 9-68	28.1
			5-14-68	22.2
			5-17-68	18.3
			5-27-68	19.9
			5-29-68	19.2
			6- 6-68	33.2
			6- 7-68	30.7
			6- 9-68	39.2
			8-13-68	17.8
6-1899.80	Lava Creek above Lupine Creek, near Mammoth	44°56'22" 110°37'36"	5- 2-67	14.4
			5-23-67	95.3
			5-26-67	112
			6- 2-67	147
			7- 3-67	148
			7-17-67	84.9
			8-23-67	39.2
			9-20-67	27.3
			5- 8-68	24.6
			5-10-68	30.2
			5-13-68	38.5
			5-14-68	42.4
			5-21-68	34.4
			5-27-68	38.4
			5-29-68	57.0
			5-29-68	69.7
			5-30-68	83.8
			5-31-68	75.2

TABLE A-3. (contd.)

DISCHARGE MEASUREMENTS MADE AT MISCELLANEOUS SITES, YELLOWSTONE NATIONAL PARK ** (contd.)

STATION NO.	STREAM	LOCATION (N. Lat. and W. Long.)	Date	DISCHARGE (cubi feet per second
			6- 1-68	70.1
			6- 3-68	103
			6- 4-68	121
			6- 5-68	119
			6- 5-68	116
			6- 6-68	128
			6-10-68	143
			8-13-68	37.2
			10-10-68	30.6
6-1903.00	Gardner River below Lava Creek near Mammoth.	44°57'48" 110°40'29"	4- 4-67	57.6
6-1904.10	Mammoth Hot Springs tributary, near Mammoth	44°58'08" 110°41'10"	4- 4-67	8.20
6-1905.40	Hot River, near Mammoth.	44°59'10" 110°41'15"	4- 4-67	19.0
6-1910.00	Gardner River at gaging station, near Mammoth	44°59'35" 110°41'25"	4- 4-67	85.6
6-2798.50	Middle Creek at East Entrance	44°29'19" 110°00'02"	8-16-68	49.4

** U.S.G.S. Report - Table 4 (3)

TABLE A-4. SELECTED STREAM TURBIDITES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*

6-0368.00 Firehole River above diversion dam, near Old Faithful lat 44°26'33" N.; long 110°48'15" W.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
1967					
May 2	1300	7	34.5	2	0.19
May 24	1430	10	155	25	10
June 21	1130	7	275	5	3.7
June 26	1355	11	177	5	2.4
July 18	0910	9	98.4	6	1.6
Sept. 19	1000	6	60.0	--	---
1968					
May 22	1325	7	---	5	---
June 12	1235	8	207	10	5.6

6-1897.30 Gardner River above diversion dam, near Mammoth lat 44°53'36" N.; long 110°44'56"W.

1966					
Oct. 28	1030	2	12.8	3	0.10
1967					
May 23	0815	--	280	88	66
	1520	1	420	325	370
	1945	1	410	205	230
May 24	0745	1	300	91	74
	1715	3	540	312	450
May 25	1830	5	430	141	160
May 26	1720	7	290	103	81
May 27	1845	8	310	136	110
May 28	1745	8	300	134	110

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* (contd.)

6-1897.30 Gardner River above diversion dam, near Mammoth lat 44°53'36" N., long 110°44'56" W. (contd.)

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
1967 contd.					
May 29	1830	5	320	98	85
May 30	1810	7	280	68	51
May 31	1825	7	280	44	33
June 4	1630	7	270	51	37
June 12	1845	8	220	16	9.5
June 17	1325	7	280	65	49
July 3	1325	8	210	57	32
July 17	1640	9	140	72	27
July 26	1000	8	66.4	---	------
Sept. 20	1600	12	23.7	2	.13
1968					
May 29	1325	6	-----	40	------
June 3	1425	7	-----	201	------
June 5	1120	3	-----	92	------
June 8	1135	4	-----	58	------
June 10	1810	9	-----	46	------
Aug. 13	1535	15	33.5	4	.36
6-1897.50 Panther Creek above diversion dam, near Mammoth lat 44°53'36" N.; long 110°46'00" W.					
1966					
Oct. 28	1145	1	3.44	3	0.03

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park* contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1898.20	Indian Creek diversion, near Mammoth lat 44°53'20" N.; long 110°45'44" W.				
1966					
Oct. 28	1225	3	7.45	2	0.04
6-1898.90	Glen Creek above Rustic Falls; above tributary, near Mammoth lat 44°55'58" N.; long 110°43'36" W.				
1966					
Oct. 28	0920		1.85	2	0.01
1967					
May 2	1435	--	E 2.5	8	.05
May 23	1400	7	33.1	34	3.0
May 24	0730	3	E 25	2	.14
May 24	1910	9	49.7	23	3.0
May 25	1855	11	E 35	2	.19
May 27	1905	12	E 30	3	.24
June 4	1610	12	27.8	9	.68
June 12	1900	10	E 25	3	.20
June 17	0930	8	20.1	3	.16
July 3	0830	7	11.5	4	.12
July 17	1620	9	9.43	E 3	.07
Sept. 20	1425	9	3.10	10	.08
1968					
May 29	1450	11	12.8	6	.21
Aug. 13	1325	9	3.21	36	.31

E Estimated

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.00	Tributary to Glen Creek above Rustic Falls, near Mammoth lat 44°55'58" N.; long 110°43'36" W.				
1967					
May 23	1405	8	46.6	49	6.1
May 24	0730	4	E 40	3	.32
May 24	1935	9	45.9	60	7.4
May 25	1850	11	E 40	23	2.5
May 27	1910	12	E 30	10	.81
June 4	1615	11	21.1	2	.11
June 12	1905	10	E 20	3	.16
June 17	0910	8	16.8	3	.14
July 3	0825	8	10.2	3	.08
July 17	1605	9	14.4	E 3	.12
Sept.20	1355	9	13.0	3	.11
1968					
May 29	1425	16	6.43	1	.02
Aug. 13	1320	10	15.4	4	.17
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W.				
1968					
May 8	1220	2	23	5	0.31
	2035	3	24	6	.39
May 9	1010	2	20	3	.16
	1945	5	28	8	.60
May 10	1010	2	22	5	.30
	1825	6	26	10	.70

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (°C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W.-contd.				
May 11	1105	4	22	2	.12
	1940	6	27	8	.58
May 12	1125	5	23	3	.19
	2010	6	27	6	.44
May 13	1055	4	22	4	.24
	1940	7	23	4	.25
May 14	1140	5	22	3	.18
	1940	6	22	3	.18
May 15	1020	3	21	2	.11
May 16	1125	3	19	3	.15
May 17	1110	3	19	2	.10
May 18	1245	7	18	5	.24
May 19	1320	8	18	3	.15
May 20	0955	4	18	2	.10
May 21	1155	6	18	6	.29
May 22	1020	4	20	3	.16
May 23	1030	5	19	2	.10
May 24	1015	4	19	3	.15
May 25	1950	8	20	6	.32
May 27	1045	6	19	4	.21
May 28	1325	10	19	4	.21
May 29	0950	8	19	4	.21
May 30	1125	8	19	4	.21
May 31	1125	4	18	5	.24
June 1	1030	7	18	5	.24
June 2	1130	9	18	5	.24
June 3	1045	8	18	4	.19

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.02	Glen Creek above Rustic Falls below tributary, near Mammoth lat 44°55'59" N.; long 110°43'33" W. -contd.				
1968 contd.					
June 4	1010	7	19	6	.31
	1800	8	21	8	.45
June 5	0745	6	22	9	.53
June 6	1000	7	23	6	.37
	1440	7	29	11	.86
	1840	8	34	53	4.9
June 7	0950	6	30	15	1.2
	1815	11	31	5	.42
June 9	1150	6	31	8	0.67
	2015	9	40	6	.65
June 10	1100	8	36	4	.39
	1830	11	37	5	.50
June 11	0840	6	34	11	1.0
	1905	13	33	5	.45
June 12	1020	8	33	4	.36
	1935	13	31	5	.42
June 13	1455	8	36	3	.29
June 21	1740	14	19	5	.26
Aug. 13	1430	11	19	3	.15
6-1899.10	Glen Creek at Mammoth Diversion, near Mammoth lat 44°56'40"N.; long 110°42'18" W.				
1967					
June 12	1945	9	E 45	3	0.36
1968					
May 7	2025	1	33	13	1.2
May 8	1245	2	23	5	.31
	2100	3	24	5	.32

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.10	Glen Creek at Mammoth Diversion, near Mammoth lat 44°56'40" N.; long 110°42'18" W.-contd.				
1968 contd.					
May 9	1025	2	20	4	.22
	2000	5	28	7	.53
May 10	1025	3	22	3	.18
	1845	9	26	8	.56
May 11	1120	4	22	5	.30
	1955	6	27	4	.29
May 12	1145	5	23	3	.19
	2025	6	27	6	.44
May 13	1110	5	22	3	.18
	2000	7	23	5	.31
May 14	1155	5	22	3	.18
	1955	6	22	3	.18
May 15	1035	3	21	6	.34
May 16	1030	3	19	3	.15
May 17	1125	4	19	3	.15
May 18	1300	7	18	2	.10
May 19	1335	8	18	3	.15
May 20	1020	4	18	2	.10
May 21	1110	6	18	3	.15
May 22	0915	5	20	4	.22
May 23	1050	6	19	4	.21
May 24	0925	4	19	4	.21
May 25	2035	7	20	32	1.7
May 26	1300	6	19	4	.21
May 27	1100	6	19	5	.26

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park. * -contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (Milligrams per liter)	Sediment discharge (tons per day)
6-1899.10 1968 contd.	Glen Creek at Mammoth Diversion, near Mammoth-contd.				
May 28	1345	11	19	5	.26
May 29	1010	8	19	5	.26
May 30	1155	8	19	4	.21
May 31	1155	7	18	5	.24
June 1	1050	7	18	5	.24
June 2	1145	9	18	5	.24
June 3	1105	8	18	5	.24
June 4	1025	7	19	11	.56
	1815	8	21	8	.45
June 5	0805	6	22	10	.59
June 6	1015	7	23	7	.43
	1505	7	29	25	2.0
	1900	8	34	32	2.9
June 7	1010	7	30	8	0.65
	1750	9	31	10	.84
June 8	1355	7	29	11	.86
June 9	1205	6	31	21	1.8
	2030	8	40	16	1.7
June 10	1115	8	36	11	1.1
	1850	10	37	16	1.6
June 11	0855	6	34	11	1.0
	1845	12	33	6	.53
June 12	0955	6	33	5	.45
	1955	13	31	5	.42
June 13	1435	8	36	9	.87
June 21	1705	12	19	2	.10
June 27	1755	12	14	16	.60
July 15	1105	9	22	5	.30

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (Milligrams per liter)	Sediment discharge (tons per day)
6-1899.80	Lava Creek above Lupine Creek, near Mammoth lat 44°56'22" N.; long 110°37'36" W.				
1967					
May 2	1620	4	14.4	3	0.12
May 23	1100	--	95.3	33	8.5
May 25	0625	3	E 105	87	25
May 26	1345	8	112	18	5.4
May 28	0735	3	E 125	19	6.4
June 2	1250	8	147	15	6.0
June 12	1925	7	E 150	11	4.5
June 17	1015	7	E 155	34	14
July 3	1010	8	148	17	6.8
July 17	1450	9	84.9	16	3.7
Aug. 23	1400	13	39.2	---	-----
Sept.20	1035	8	27.3	2	.15
1968					
May 8	1035	3	26	1	.07
	2000	7	27	10	.73
May 9	0845	2	25	4	.27
	1800	7	27	5	.36
May 10	0935	4	29	2	.16
	1800	9	31	6	.50
May 11	1035	4	31	5	.42
	1910	7	36	10	.97
May 12	1055	5	34	4	.37
May 13	1010	4	39	6	.63
	2025	7	45	6	.73

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.* -contd.

DATE	Time (24 hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.80	Lava Creek above Lupine Creek, near Mammoth lat 44°56'22" N.; long 110°37'36" W.-contd.				
1968 contd.					
May 14	1035	6	43	10	1.2
	2030	6	43	14	1.6
May 15	0950	4	40	10	1.1
May 16	1010	3	32	4	.35
May 17	1000	4	31	3	.25
May 18	1210	6	30	4	.32
May 19	1245	7	30	4	.32
May 20	0920	3	32	3	.26
May 21	0945	5	36	4	.39
May 22	0835	5	42	10	1.1
May 23	0950	4	43	7	.81
May 24	0900	4	43	8	.93
May 25	2015	7	43	6	.70
May 26	1215	6	40	4	.43
May 27	0930	4	40	5	.54
May 28	1255	9	43	6	.70
May 29	0915	5	58	46	7.2
	1935	10	67	68	12
May 30	1010	6	87	61	14
	1835	9	87	36	8.5

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park*-contd.

DATE	Time (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1899.80 Lava Creek above Lupine Creek, near Mammoth -contd.					
1968 contd.					
May 31	0940	4	83	23	5.2
	1915	8	80	17	3.7
June 1	0955	4	73	---	------
June 2	1045	6	83	18	4.0
June 3	1015	6	105	66	19
	1800	9	103	49	14
June 4	0940	6	114	56	17
	1720	3	116	51	16
June 5	0710	5	120	53	17
	1800	8	114	28	8.6
June 6	0905	6	109	23	6.8
	1410	6	129	76	26
June 7	0845	7	129	33	11
	1725	7	131	38	13
June 8	1100	5	125	18	6.1
June 9	1110	7	139	43	16
	1910	7	146	42	17
June 10	1020	6	141	29	11
	1735	8	143	29	11
June 11	0810	5	134	18	6.5
	1820	10	129	16	5.6
June 12	0905	6	129	17	5.9
	1910	8	134	18	6.5
June 13	1400	6	143	29	11
June 21	1410	9	166	30	13
June 27	1720	12	125	13	4.4
July 15	1415	13	63	5	.85
Aug. 13	1125	9	36	2	.19

*USGS Report (3)
E Estimated

TABLE A-4. SELECTED STREAM TURBIDITES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of temperature, discharge, and suspended sediment in streams, Yellowstone National Park.*-contd.

DATE	TIME (24 Hour)	Temperature (° C)	Discharge (cubic feet per second)	Sediment Concentration (milligrams per liter)	Sediment discharge (tons per day)
6-1900.05	Lupine Creek at mouth, near Mammoth lat 49°56'25" N.; long 110°37'38" W.				
1968					
June 3	1810	8	E 20	149	8.0
June 4	1925	4	E 20	73	3.9

* USGS REPORT (3)

E Estimated

TABLE A-4. SELECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of discharge and color of water in Lava Creek and Glen Creek near Mammoth, Yellowstone National Park.

6-1899.80 Lava Creek above Lupine Creek lat 44°56'22"N.;long 110°37'36" W.				6-1899.10 Glen Creek at Mammoth Diversion lat 44°56'40" N.; long 110°42'18" W.			
Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)	Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)
May				May			
27	0930	40	10	27	1100	19	5
29	0925	58	10	29	1010	19	10
29	1935	67	10				
30	1020	87	15	30	1155	19	15
30	1835	87	10				
31	0940	83	10	31	1155	18	20
31	1915	80	10				
June				June			
1	0955	73	10	1	1050	18	20
2	1105	83	10	2	1145	18	20
3	1015	105	10	3	1105	18	20
3	1800	103	10				
4	0940	114	10	4	1025	19	30
4	1720	116	10	4	1815	21	30
5	0710	120	10	5	0805	22	30
5	1800	114	10				
6	0905	109	10	6	1015	23	30
				6	1505	29	30

TABLE A-4. SECLECTED STREAM TURBIDITIES, TEMPERATURE, DISCHARGE, AND COLOR

Periodic determinations of discharge and color of water in Lava Creek and Glen Creek near Mammoth, Yellowstone National Park-contd.

6-1899.80 Lava Creek above Lupine Creek lat 44°56'22" N.; long 110°37'36"W.				6-1899.10 Glen Creek at Mammoth Diversion lat 44°56' 40" N.; long 110°42'18"W.			
Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)	Date 1968	Time (24 hour)	Discharge (cubic feet per second)	Color (standard units)
June (contd.)				June (contd.)			
				6	1900	34	30
7	0845	129	10	7	1010	30	30
7	1725	131	10	7	1750	31	30
8	1100	125	10	8	1355	29	20
9	1110	139	10	9	1205	31	25
9	1710	146	20	9	2030	40	30
10	1020	141	10	10	1115	36	20
10	1735	143	10	10	1850	37	25
11	0810	134	10	11	0900	34	20
11	1820	129	10	11	1845	33	20
12	0905	129	10	12	0955	33	20
12	1915	134	10	12	1955	31	20
13	1400	143	10	13	1435	36	20

Table A-5. EXISTING TANK SCHEDULE

COMMUNITY	MAMMOTH HOT SPRINGS	TOWER FALL	TOWER JUNCTION	ROOSE-VELT LODGE	ROOSE-VELT LODGE	CANYON	CANYON	LAKE
TYPE	Underground concrete	None	None	Upright wood	Upright wood	Underground concrete	Underground concrete	Underground concrete
	old	--	--	old	new	new	new	new
CAPACITY	26,000	--	--	10,000	20,000	500,000	250,000	500,000
CONDITION								
Inside	Good	--	--	Dirty	Dirty	Good	Good	Good
Outside	Good	--	--	leaks some	Good	--	--	--
INLET SIZE	18"	--	--	4"	4"	6"	6" pump 6"(from 500,000 gal.tank)	8"
OUTLET SIZE	18"	--	--	4" to 20,000 gal.tank	4"	2-6" to 250,000 gal.tank	8"	8"
ROOF TYPE	concrete	--	--	wood	wood	concrete	concrete	concrete
ROOF CONDITION	Good	--	--	Bad	Bad	Good	Good	Good
INSIDE LADDER	No	--	--	No	No	Yes	Yes	Yes
OUTSIDE LADDER	--	--	--	Yes	Yes	--	--	--
ROOF VENT	No	--	--	No	No	Yes	Yes	Yes
M.H.								
ON TOP	Yes	--	--	Yes	Yes	Yes	Yes	Yes
OVERFLOW	No,not req'd. can't go higher than Lake	--	--	Yes	Yes	Yes	Yes	Yes
FOUNDATION	--	--	--	Good	Good	--	--	--
LOCKS ON M.H.	No	--	--	No	No	No	No	Yes

TABLE A-5. EXISTING TANK SCHEDULE-contd.

COMMUNITY	LAKE	FISHING BRIDGE	BRIDGE BAY	GRANT	GRANT	WEST THUMB	WEST THUMB	MADISON JUNCTION	NORRIS	OLD FAITHFUL
TYPE	Upright steel new	Upright concrete old	Upright steel new	Upright steel new	Underground concrete new	Underground concrete new	Underground concrete old	Upright steel new	Upright steel new	Underground old
CAPACITY	500,000	250,000	100,000	1,500,000	500,000	50,000	50,000	100,000	40,000	35,000
CONDITION										
Inside	good	good	fair, needs painting	good	good	good	fair	fair, needs painting	fair, needs painting	good
Outside	good	fair	fair	good	--	--	--	good	fair, needs painting	--
INLET SIZE	8"	6" 4" from spring area	4"	8"	8"	6"	6"	8"	4"	12"
OUTLET SIZE	8"	6"	6"	10"	10"	4"	4"	8"	6"	12"
ROOF TYPE	steel	concrete	steel	steel	concrete	concrete	concrete	steel	steel	concrete
ROOF CONDITION	good	good	fair	good	good	good	good	good	fair, needs painting	good
INSIDE LADDER	yes	yes	yes	yes	yes	--	--	yes	yes	yes
OUTSIDE LADDER	yes	yes	yes	yes	yes	--	--	yes	yes	--
ROOF VENT	yes	yes	yes	yes	yes	no	no	yes	yes	yes
M.H. on TOP	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
OVERFLOW	yes	yes	yes	yes	yes	yes	yes	yes	yes	yes
FOUNDATION	good	good	good	good	--	--	--	good	good	--
LOCKS ON M.H.	yes	no	no	yes	yes	no	no	no	no	yes

APPENDIX B

HARDY CROSS NETWORK ANALYSIS

ALL AREAS

Appendix B. HARDY CROSS NETWORK ANALYSIS ALL AREAS

Figures B-1 through B-17 represent the water systems used for the network analysis. Though drawn schematically each system does accurately represent the proposed distribution system of the respective area covered. Flow in and flow out were assumed as shown on the drawings. A supplement to each Figure follows immediately after the Figure and gives all of the hydraulic data pertinent for each pipe. The supplement represents our final output for each system after all necessary proposed mains are included. Design was based on having a maximum of 20 p.s.i. available at the worst possible fire location in the system. All networks were run using a teletype terminal which accessed a General Electric Time Sharing computer service. Software for the program was the Aug. 1967 manual "Hydraulic Network Analysis - Users Guide." (8) To present the 17 Figures shown, at least three times that many networks were run.

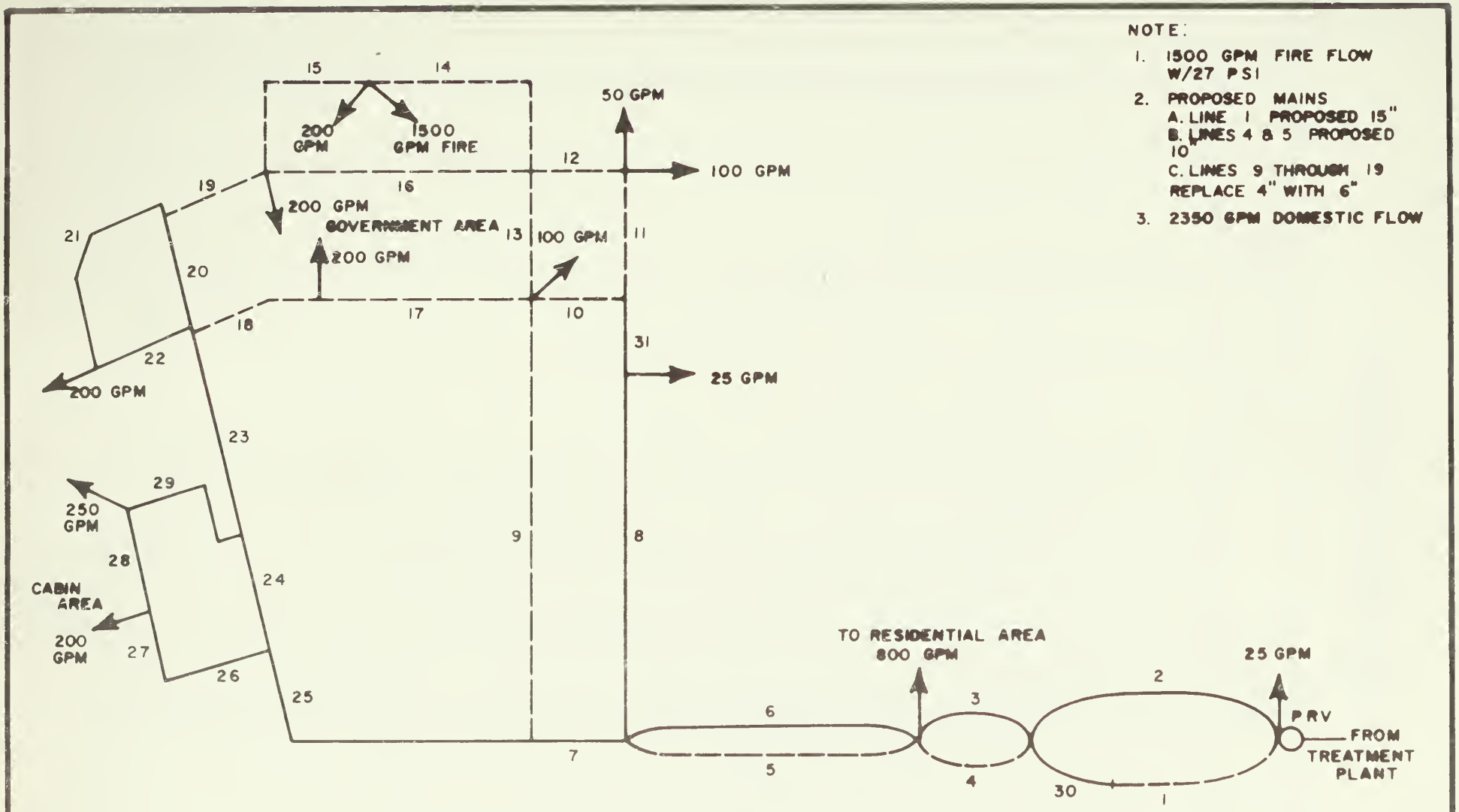


FIG. B-1 MAMMOTH HOT SPRINGS AREA
SKETCH OF NETWORK ANALYSIS
COMMERCIAL FIRE FLOW

MAMMOTH HOT SPRINGS AREA
SUPPLEMENT TO FIG. B-1

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	900	15	140	2984.4	2.2
2	1350	10	100	840.6	4.2
3	275	10	100	1593.8	2.8
4	275	10	140	2231.3	2.8
5	1550	10	140	1764.6	10.3
6	1550	10	100	1260.4	10.3
7	225	10	100	2453.4	5.1
8	925	6	100	571.7	17.1
9	1300	6	140	694.0	18.4
10	275	6	140	27.0	0.0
11	375	6	140	573.6	3.7
12	290	6	140	423.6	1.7
13	400	6	140	478.2	5.4
14	500	6	140	910.1	11.7
15	600	6	140	789.9	10.8
16	700	6	140	191.7	0.9
17	400	6	140	111.1	0.2
18	400	6	140	311.1	1.3
19	350	6	140	798.2	6.4
20	440	10	100	856.8	1.4
21	675	4	100	58.7	1.3
22	275	4	100	141.4	2.8
23	550	10	100	1309.3	3.9
24	300	10	100	1639.2	3.2
25	800	10	100	1759.3	9.8
26	375	6	100	120.1	0.4
27	200	$2\frac{1}{2}$	100	120.1	14.6
28	250	$2\frac{1}{2}$	100	79.9	8.6
29	475	6	100	329.9	3.2
30	450	15	100	2984.4	2.0
31	375	6	100	546.7	6.4

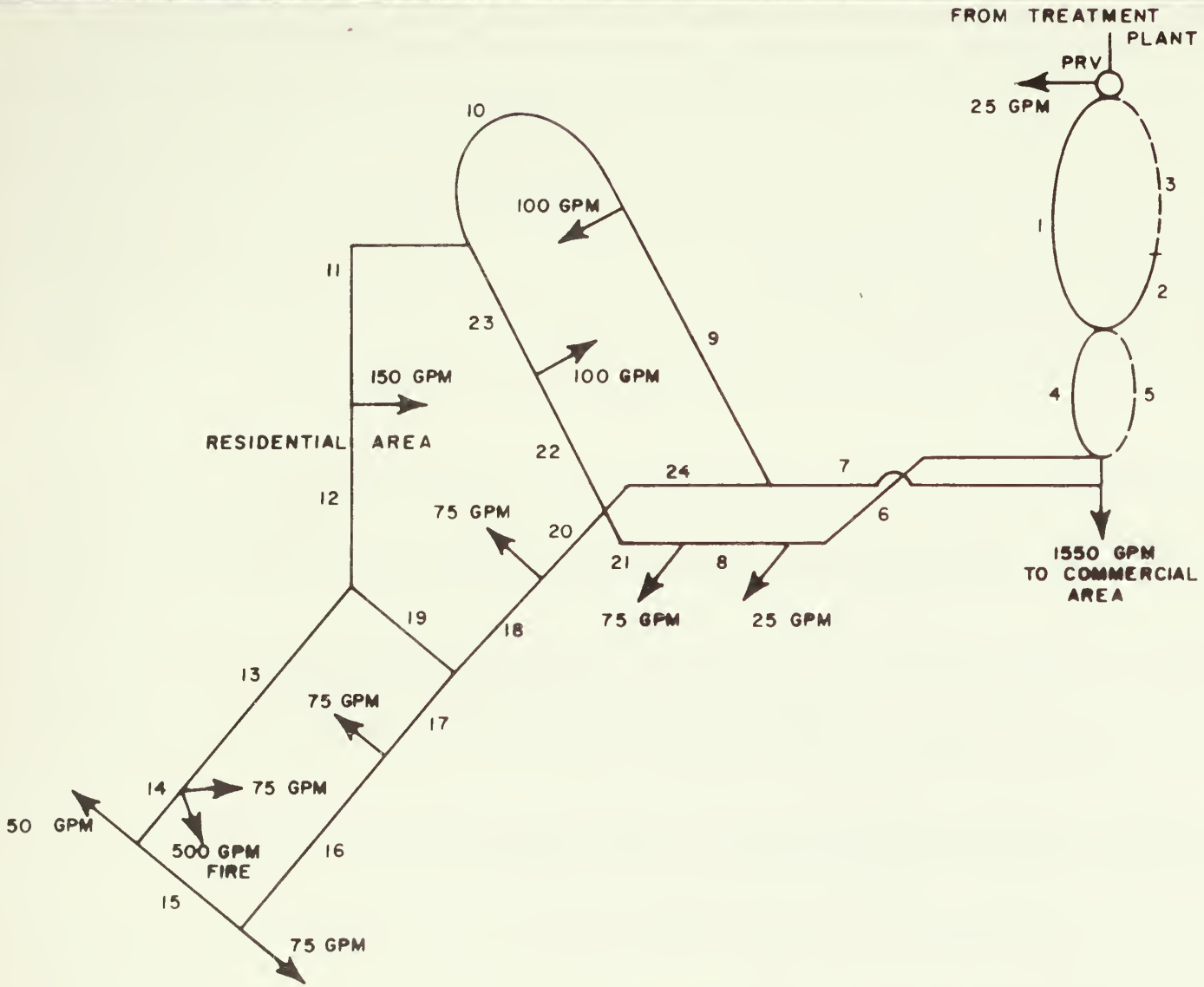


FIG.B-2 MAMMOTH HOT SPRINGS AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

MAMMOTH HOT SPRINGS AREA

SUPPLEMENT TO FIG. B-2

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	1350	10	100	620.8	2.4
2	450	15	100	2204.2	1.2
3	900	15	140	2204.2	1.2
4	275	10	100	1177.1	1.6
5	275	10	140	1647.9	1.6
6	2150	8	100	1099.9	32.8
7	1600	4	100	175.1	23.8
8	850	4	100	150.1	9.5
9	675	6	130	378.0	3.6
10	600	6	130	278.0	1.8
11	600	6	130	360.1	2.9
12	200	6	130	210.1	0.4
13	550	6	130	391.2	3.1
14	250	6	130	158.9	0.3
15	275	6	130	208.9	0.5
16	400	6	130	283.9	1.2
17	300	6	130	358.9	1.4
18	300	6	130	539.9	3.1
19	250	6	130	181.1	0.3
20	325	6	130	614.9	4.2
21	150	4	130	75.1	0.3
22	375	4	130	182.1	3.7
23	300	4	130	82.1	0.7
24	200	8	130	721.9	0.9

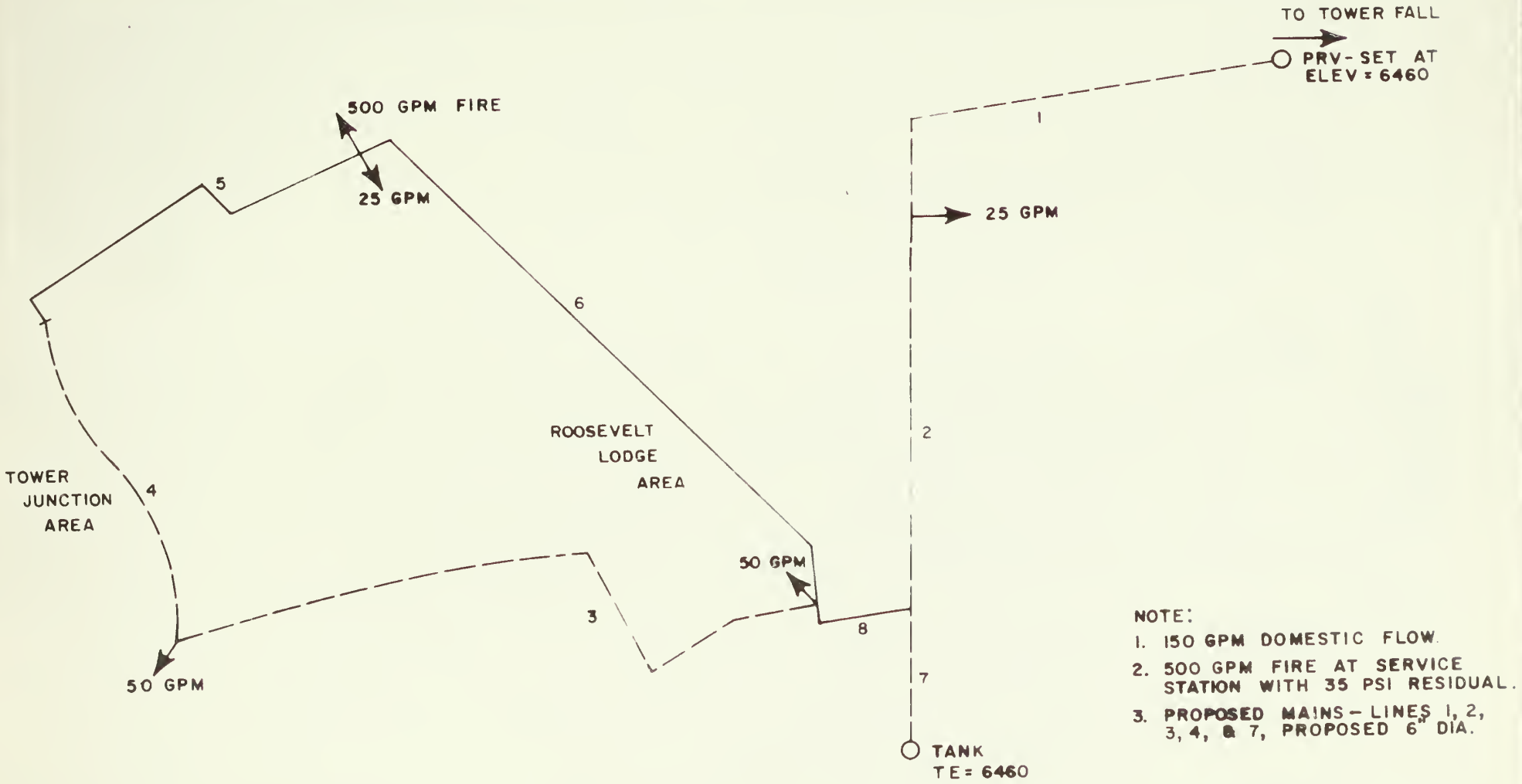


FIG. B-3 TOWER AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW
TOWER JUNCTION - ROOSEVELT LODGE

TOWER AREA

SUPPLEMENT TO FIG. B-3

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	5500	6	140	122.9	3.2
2	1200	6	140	97.9	0.5
3	1475	6	140	327.3	5.2
4	780	6	140	277.3	2.0
5	800	4	130	277.2	17.2
6	1400	4	130	247.8	24.4
7	425	6	140	527.1	3.6
8	175	6	130	625.0	2.3

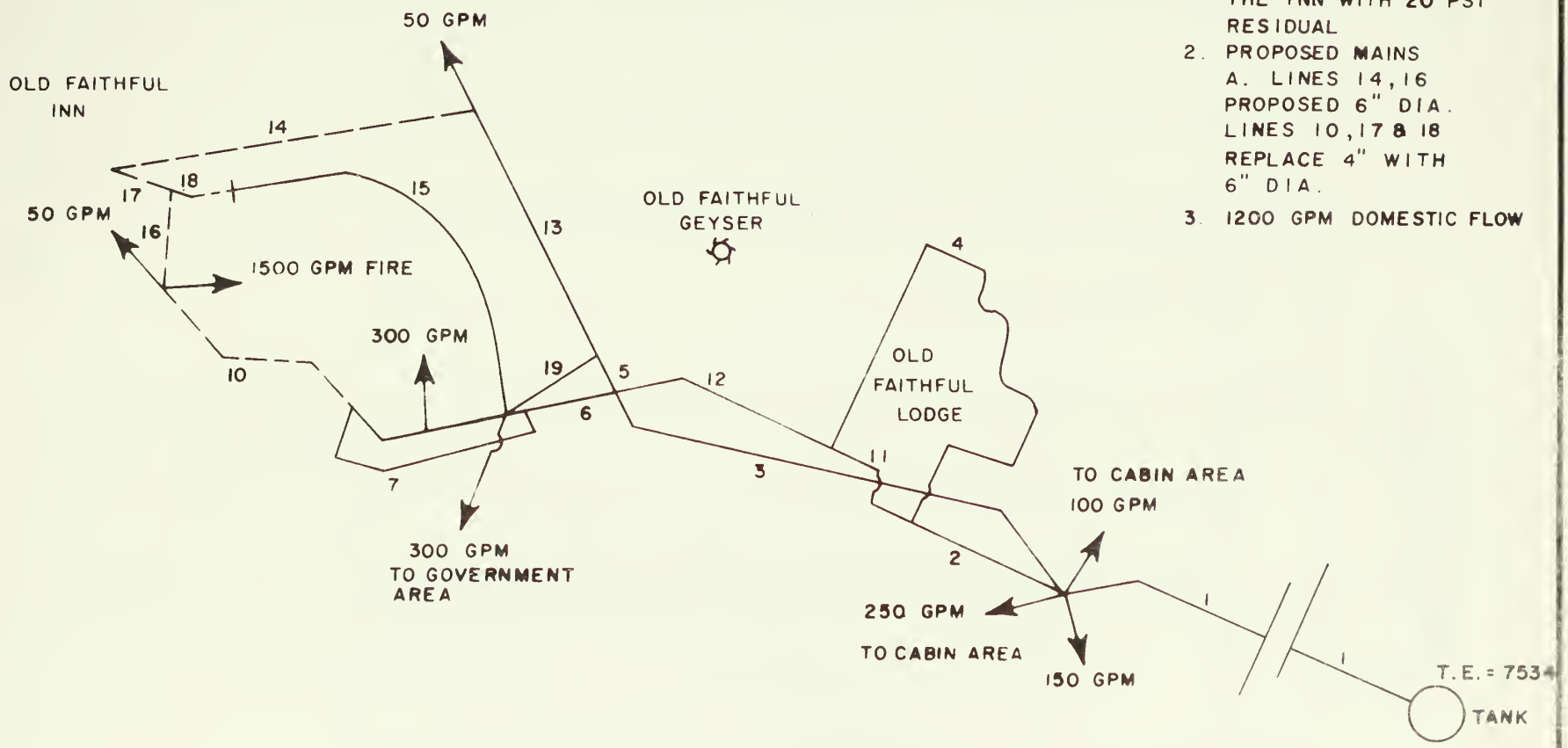


FIG. B-4 OLD FAITHFUL AREA
SKETCH OF NETWORK ANALYSIS
COMMERCIAL FIRE FLOW

OLD FAITHFUL AREA

SUPPLEMENT TO FIG. B-4

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	4000	12	140	2700.0	23.9
2	400	6	100	481.2	5.4
3	1200	10	100	1718.8	14.1
4	1650	6	140	148.8	1.3
5	100	10	100	1591.9	1.0
6	200	6	100	608.1	4.1
7	625	6	100	399.3	5.9
8	250	6	100	585.9	4.8
9	225	6	100	285.9	1.2
10	550	6	140	685.2	7.6
11	200	6	100	332.5	1.4
12	550	6	100	481.2	7.4
13	650	6	100	479.1	8.7
14	87[illegible]	6	140	429.1	5.1
15	950	6	100	435.7	10.6
16	100	6	140	864.8	2.1
17	150	6	140	429.1	0.9
18	150	6	140	435.7	0.9
19	200	8	100	1112.8	3.1

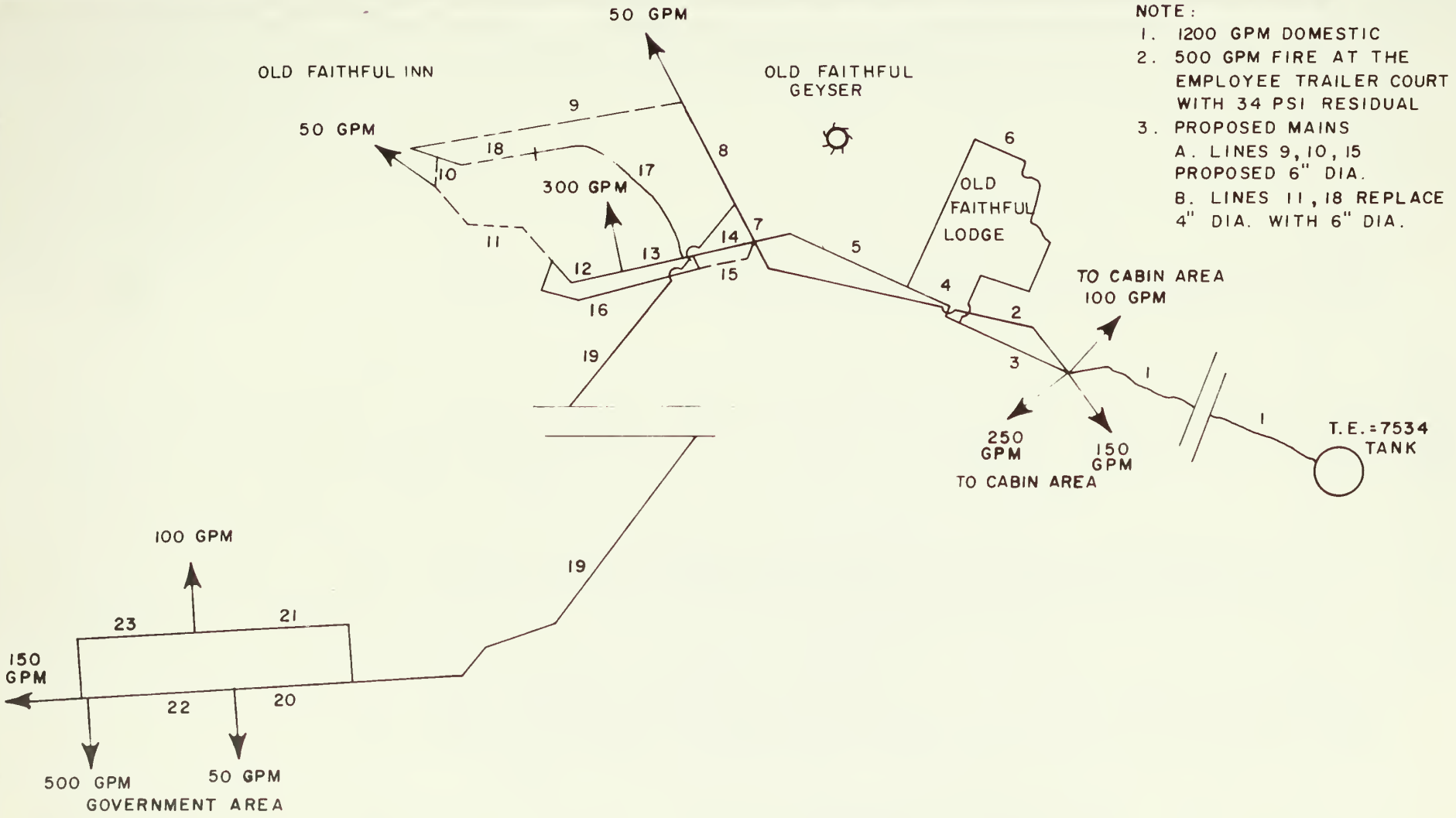


FIG. B-5 OLD FAITHFUL AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

OLD FAITHFUL AREA
SUPPLEMENT TO FIG. B-5

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	4000	12	140	1700.0	10.2
2	1200	10	100	937.5	4.6
3	400	6	100	262.5	1.7
4	200	6	100	181.4	0.4
5	550	6	100	262.5	2.4
6	1650	6	140	81.1	0.4
7	100	10	100	865.7	0.3
8	650	6	100	65.7	0.2
9	1025	6	140	15.6	0.0
10	100	6	140	75.8	0.0
11	550	6	140	25.8	0.0
12	225	6	100	115.9	0.2
13	250	6	100	184.1	0.6
14	200	6	100	138.4	0.3
15	200	6	140	196.0	0.3
16	625	6	100	90.1	0.4
17	950	6	100	60.1	0.3
18	150	6	140	60.1	0.0
19	3025	8	120	800.0	18.3
20	400	8	120	560.2	1.2
21	700	6	120	239.9	1.8
22	450	8	120	510.2	1.2
23	600	6	120	139.9	0.5

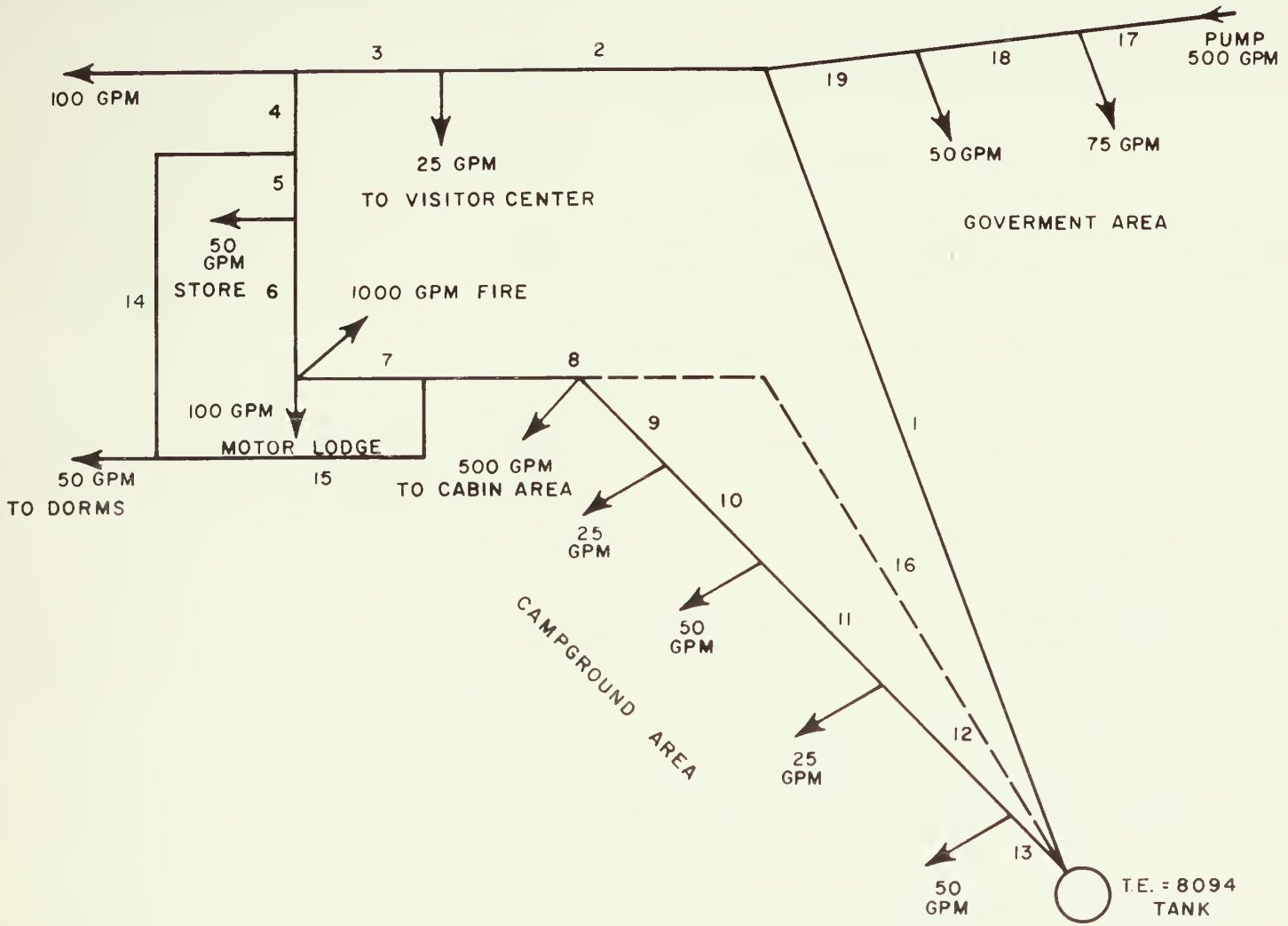


FIG. B-6 **CANYON AREA**

SKETCH OF NETWORK ANALYSIS

COMMERCIAL FIRE FLOW

CANYON AREA

SUPPLEMENT TO FIG. B-6

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	4875	6	140	136.3	3.4
2	875	6	100	511.3	13.1
3	325	6	100	486.3	4.4
4	225	6	100	386.3	2.0
5	120	8	100	505.0	0.4
6	375	8	100	455.0	1.1
7	375	8	100	645.0	2.1
8	50	8	100	813.8	0.4
9	525	8	100	521.1	2.0
10	550	8	100	546.1	2.3
11	800	8	100	596.1	3.9
12	1400	8	100	621.1	7.4
13	1000	8	100	671.1	6.1
14	950	8	100	118.7	0.2
15	725	8	100	168.7	0.3
16	4875	8	140	792.7	21.8
17	810	6	140	500.0	6.3
18	550	6	140	425.0	3.1
19	1000	6	140	375.0	4.5

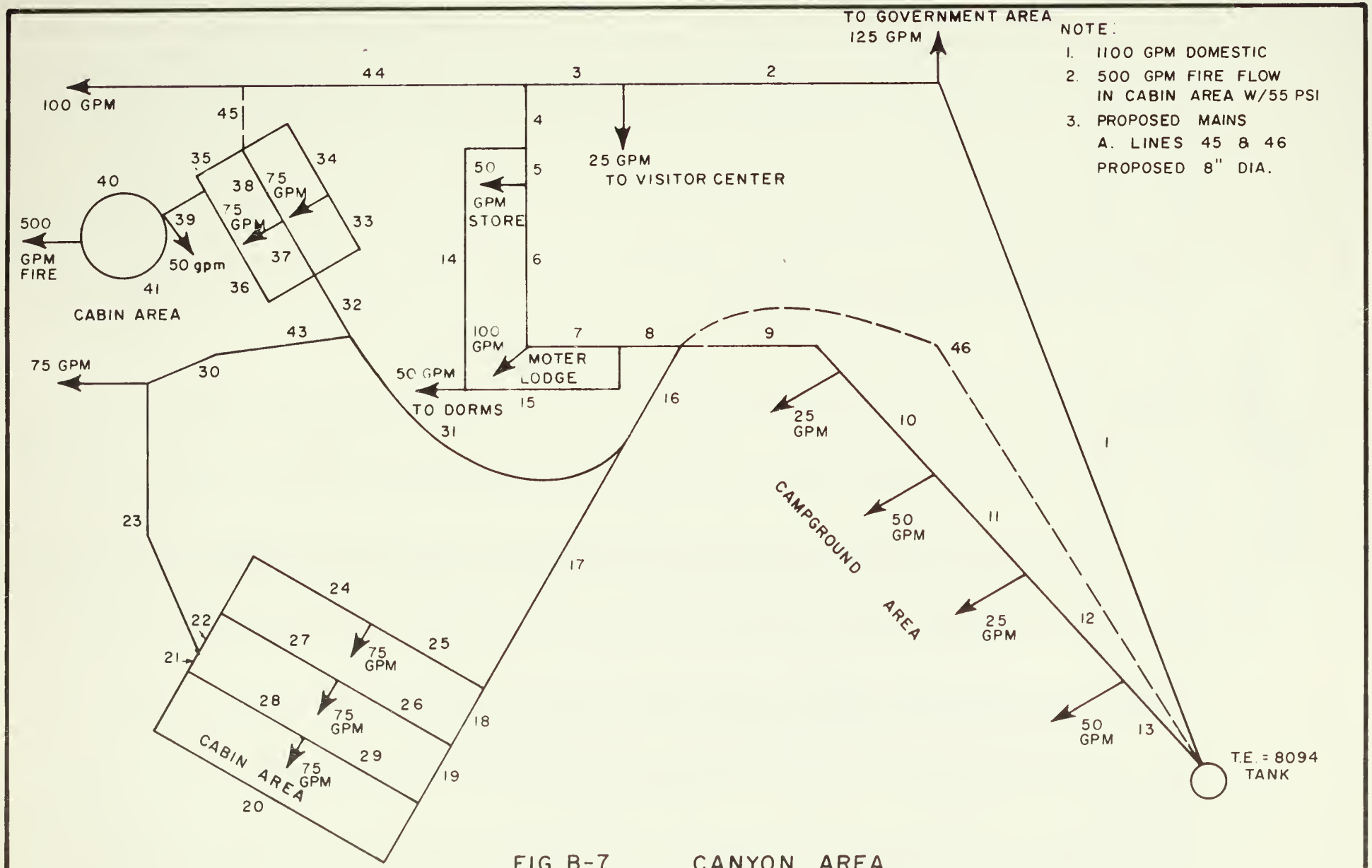


FIG. B-7 CANYON AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

CANYON AREA

SUPPLEMENT TO FIG. B-7

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	4875	6	140	321.9	16.7
2	875	6	100	196.9	2.2
3	325	6	100	171.9	0.6
4	225	6	100	430.4	2.5
5	120	8	100	228.5	0.1
6	375	8	100	278.5	0.5
7	375	8	100	378.5	0.8
8	50	8	100	630.4	0.3
9	525	8	100	419.2	1.3
10	550	8	100	444.2	1.6
11	800	8	100	494.2	2.8
12	1400	8	100	519.2	5.3
13	1000	8	100	569.2	4.5
14	950	8	100	201.8	0.6
15	725	8	100	251.8	0.7
16	450	6	100	497.8	6.4
17	500	6	100	271.3	2.3
18	260	6	100	154.4	0.4
19	190	6	100	84.3	0.1
20	1450	6	100	29.4	0.1
21	60	6	100	9.3	0
22	65	6	100	37.0	0
23	320	6	100	46.3	0.1
24	500	6	100	41.9	0.1
25	550	6	100	116.9	0.5
26	525	6	100	70.1	0.2
27	425	6	100	4.9	0
28	450	6	100	20.1	0
29	525	6	100	54.9	0.1

CANYON AREA

SUPPLEMENT TO FIG. B-7-contd.

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
30	325	6	100	28.7	0.2
31	875	6	100	226.5	2.9
32	350	6	100	197.7	0.9
33	475	6	100	22.2	0
34	500	6	100	97.2	0.3
35	575	6	100	298.6	3.2
36	700	6	100	251.4	2.8
37	400	6	100	31.5	0
38	400	6	100	106.5	0.3
39	275	6	100	550.0	4.7
40	275	6	100	255.9	1.1
41	300	6	100	244.1	1.1
43	300	6	100	28.7	0
44	1100	8	100	602.3	5.5
45	150	8	140	502.3	0.3
46	4275	8	140	708.9	15.5

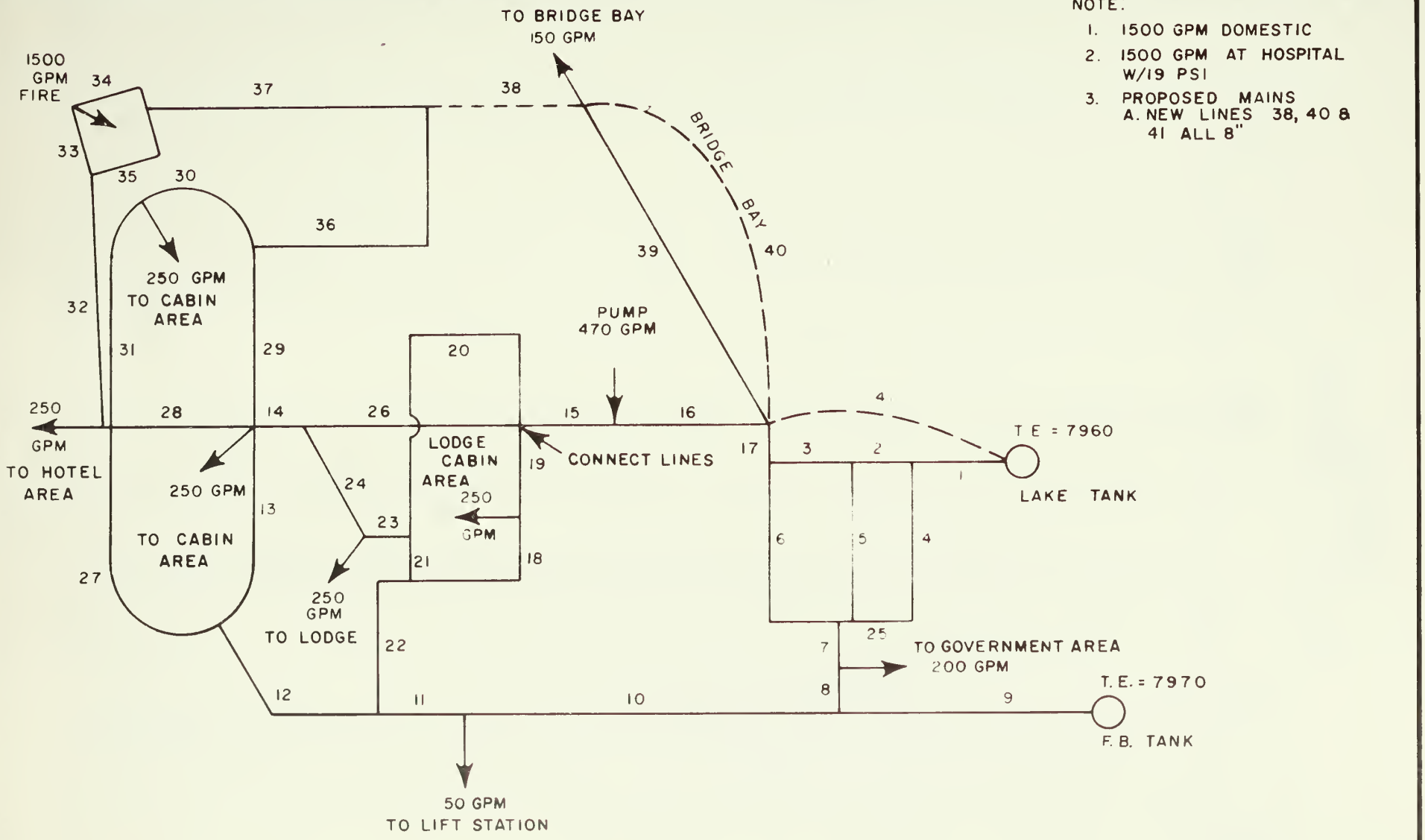


FIG. B-8 LAKE AREA

SKETCH OF NETWORK ANALYSIS

COMMERCIAL FIRE FLOW

LAKE AREA

SUPPLEMENT TO FIG. B-8

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	1150	8	100	869.2	11.3
2	100	8	100	799.6	0.8
3	300	8	100	751.3	2.3
4	575	4	100	69.6	1.6
5	450	4	100	48.4	0.6
6	600	6	100	52.3	0.1
7	670	6	100	170.2	1.3
8	650	6	100	29.8	0.1
9	3200	8	100	690.1	20.6
10	2950	8	100	660.3	17.5
11	100	6	140	610.3	1.1
12	1300	6	140	397.9	6.6
13	575	6	100	163.9	1.0
14	700	10	100	893.2	2.5
15	1200	8	140	1180.8	11.2
16	675	8	100	710.8	4.6
17	700	8	100	699.0	4.6
18	1075	6	140	95.7	0.4
19	825	6	140	154.3	0.7
20	1825	6	140	69.9	0.4
21	100	6	140	116.7	0.1
22	500	6	140	212.4	0.8
23	350	4	100	186.6	5.9
24	675	4	100	63.4	1.5
25	250	4	100	117.9	1.8
26	725	8	140	956.6	4.6
27	1300	6	100	234.0	4.6
28	450	8	100	768.9	3.5
29	750	6	100	38.2	0.1
30	400	6	100	354.1	3.0
31	500	6	100	104.1	0.4

LAKE AREA

SUPPLEMENT TO FIG. B-8-contd.

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
32	400	6	140	857.0	8.4
33	625	6	100	586.3	12.1
34	225	6	100	913.7	9.9
35	475	6	100	270.7	2.2
36	1350	6	140	315.9	4.5
37	1500	6	140	643.0	18.5
38	720	8	140	958.9	4.6
39	2850	6	100	278.2	13.9
40	2850	8	140	830.7	13.9
41	2250	8	140	1120.8	19.1

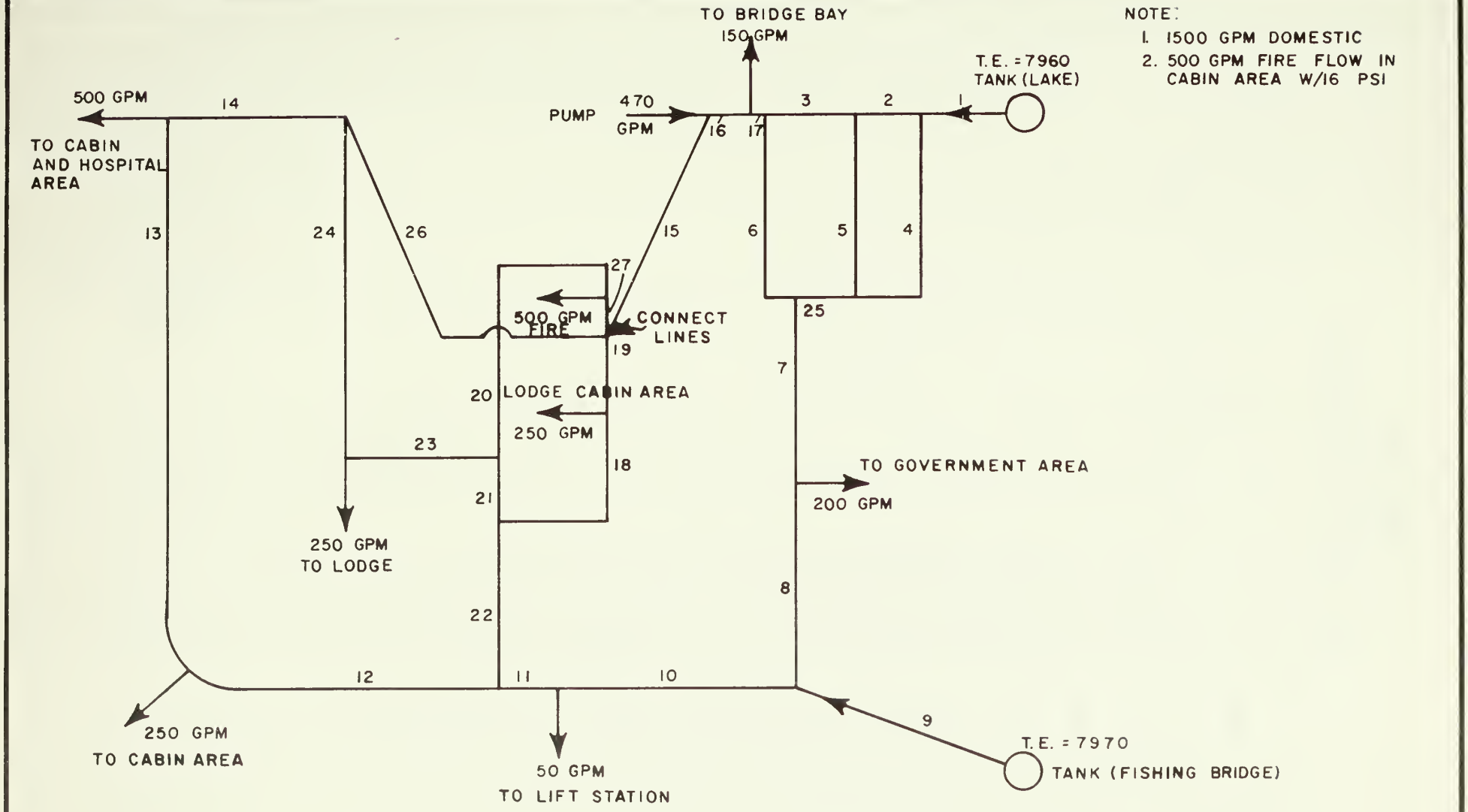


FIG. B-9 LAKE AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

LAKE AREA

SUPPLEMENT TO FIG. B-9

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	1150	8	100	950.4	13.4
2	100	8	100	876.6	1.0
3	300	8	100	823.4	2.7
4	575	4	100	73.8	1.7
5	450	4	100	53.2	0.7
6	600	6	100	50.2	0.1
7	670	6	100	177.3	1.4
8	650	6	100	22.8	0
9	3200	8	100	729.6	22.9
10	2950	8	100	706.9	19.9
11	100	6	140	656.9	1.2
12	1300	6	140	287.8	3.6
13	575	6	100	37.8	0.1
14	700	10	100	462.2	0.7
15	1900	8	140	1093.2	15.4
16	675	8	100	623.2	3.6
17	700	8	100	773.2	5.6
18	1075	6	140	90.8	0.4
19	825	6	140	159.2	0.8
20	1825	6	140	123.3	1.1
21	100	6	140	278.2	0.3
22	500	6	140	369.0	2.2
23	350	4	100	155.0	4.1
24	675	4	100	95.1	3.2
25	250	4	100	127.0	[illegible]
26	725	8	140	557.2	[illegible]
27	400	6	140	376.7	[illegible]

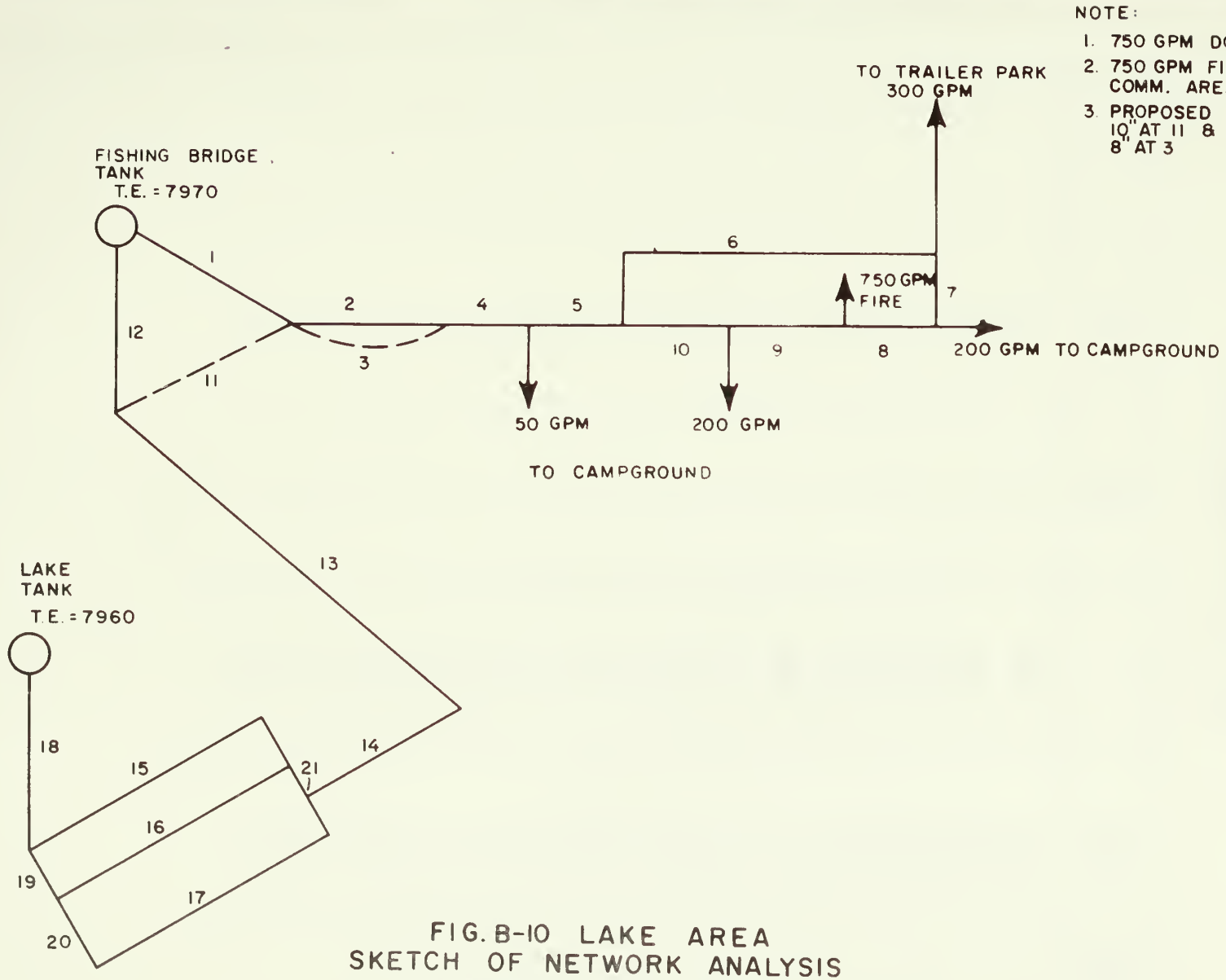


FIG. B-10 LAKE AREA
SKETCH OF NETWORK ANALYSIS
COMMERCIAL FIRE FLOW
FISHING BRIDGE

LAKE AREA

SUPPLEMENT TO FIG. B-10

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	2000	6	100	398.6	18.9
2	1300	8	100	625.0	7.0
3	1300	8	140	875.0	7.0
4	1100	10	100	1500.0	10.0
5	175	10	100	1450.0	1.5
6	1970	8	100	813.5	17.2
7	350	6	100	513.5	5.3
8	275	6	100	313.5	1.7
9	550	6	100	436.5	6.2
10	800	6	100	636.5	18.0
11	1270	10	140	1101.4	3.5
12	1725	8	100	824.0	15.4
13	1520	8	100	277.4	1.8
14	1320	6	100	277.4	6.4
15	575	4	100	42.1	0.6
16	450	4	100	46.0	0.6
17	600	6	100	189.3	1.4
18	1150	8	100	277.4	1.4
19	100	8	100	235.3	0.1
20	300	8	100	189.3	0.2
21	250	4	100	88.1	1.0

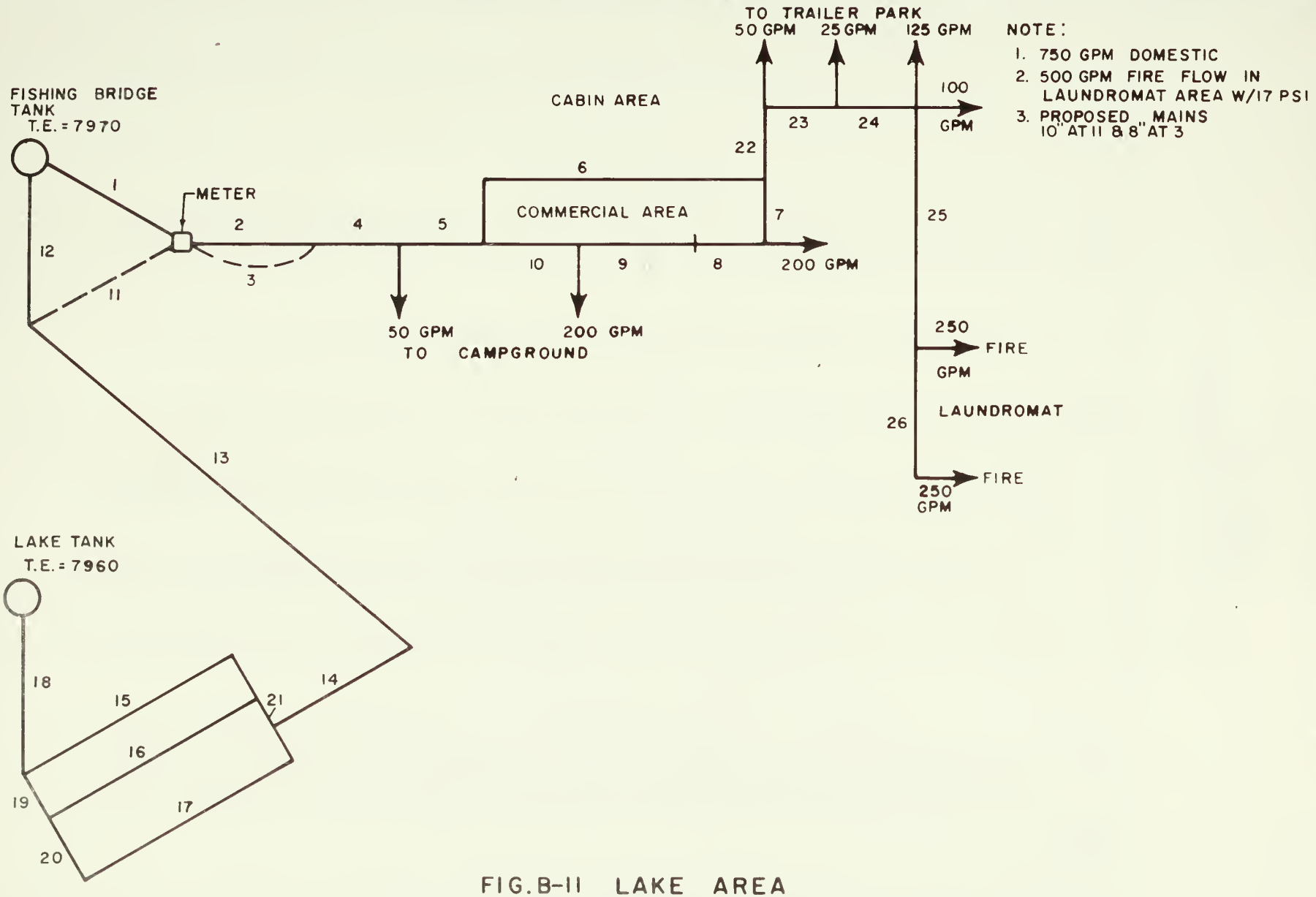


FIG. B-11 LAKE AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW
FISHING BRIDGE

LAKE AREA

SUPPLEMENT TO FIG. B-11

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	2000	6	100	335.9	13.8
2	1300	8	100	520.8	5.0
3	1300	8	140	729.2	5.0
4	1100	10	100	1250.0	7.2
5	175	10	100	1200.0	1.1
6	1970	8	100	731.3	14.1
7	350	6	100	68.8	0.1
8	275	6	100	268.8	1.3
9	550	6	100	268.8	2.5
10	800	6	100	468.8	10.2
11	1270	10	140	914.2	2.5
12	1725	8	100	696.7	11.3
13	1520	8	100	217.5	1.2
14	1320	6	100	217.5	4.1
15	575	4	100	32.4	0.4
16	450	4	100	36.5	0.4
17	600	6	100	148.6	0.9
18	1150	8	100	217.5	0.9
19	100	8	100	185.1	0.1
20	300	8	100	148.6	0.1
21	250	4	100	68.9	0.7
22	575	6	130	800.0	12.2
23	325	6	130	750.0	6.1
24	300	6	130	725.0	5.3
25	400	6	130	500.0	3.5
26	175	6	130	250.0	0.4

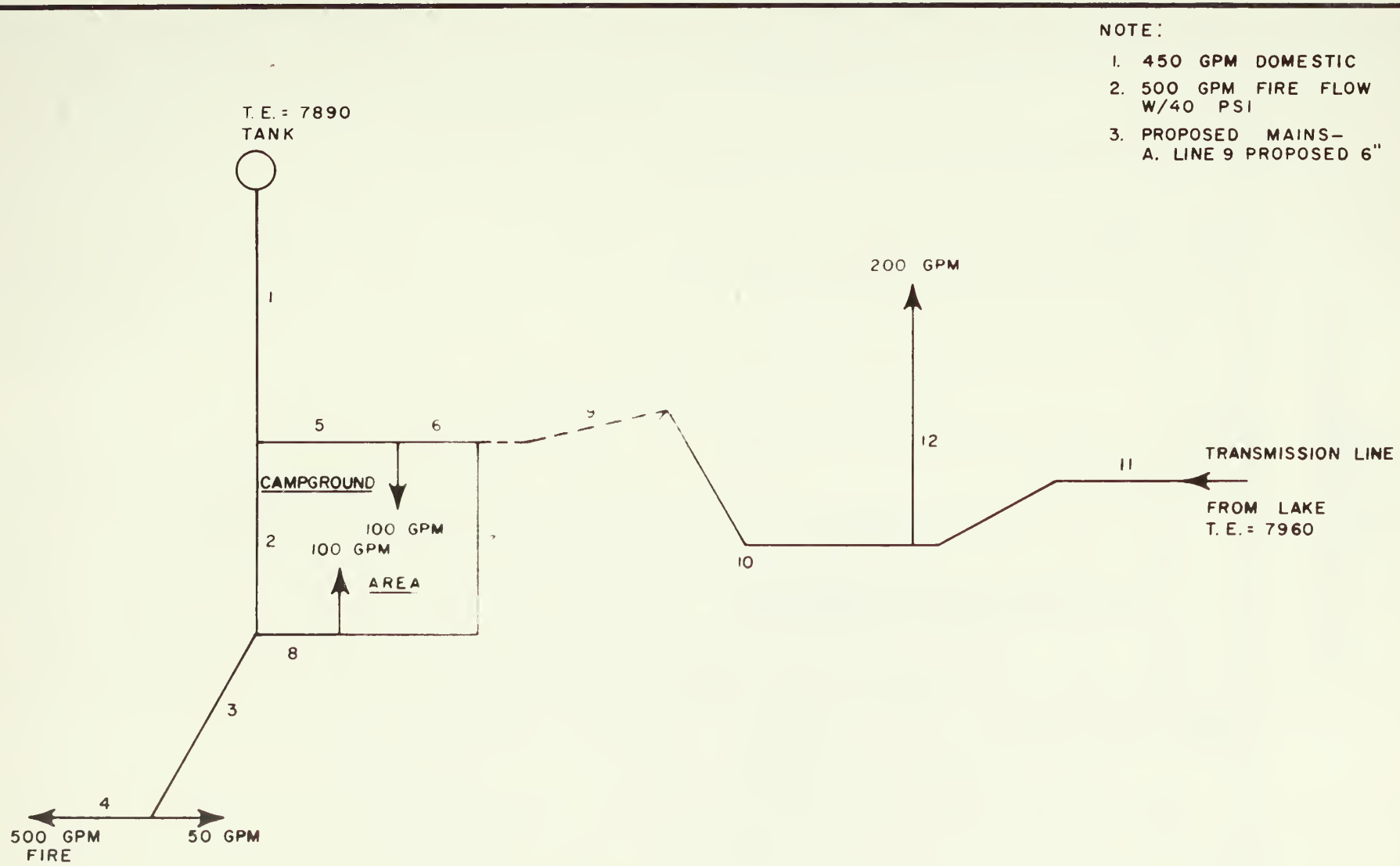


FIG. B-12 LAKE AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW
BRIDGE BAY

LAKE AREA

SUPPLEMENT TO FIG. B-12

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	1425	6	140	607.7	15.8
2	650	6	140	524.6	5.5
3	920	6	140	550.0	8.5
4	200	6	140	500.0	1.5
5	750	6	140	83.1	0.2
6	700	6	140	16.9	0
7	1200	4	140	125.4	5.2
8	550	4	140	25.4	0.1
9	800	6	140	142.3	0.6
10	1200	4	140	292.3	24.8
11	950	6	140	342.3	3.6

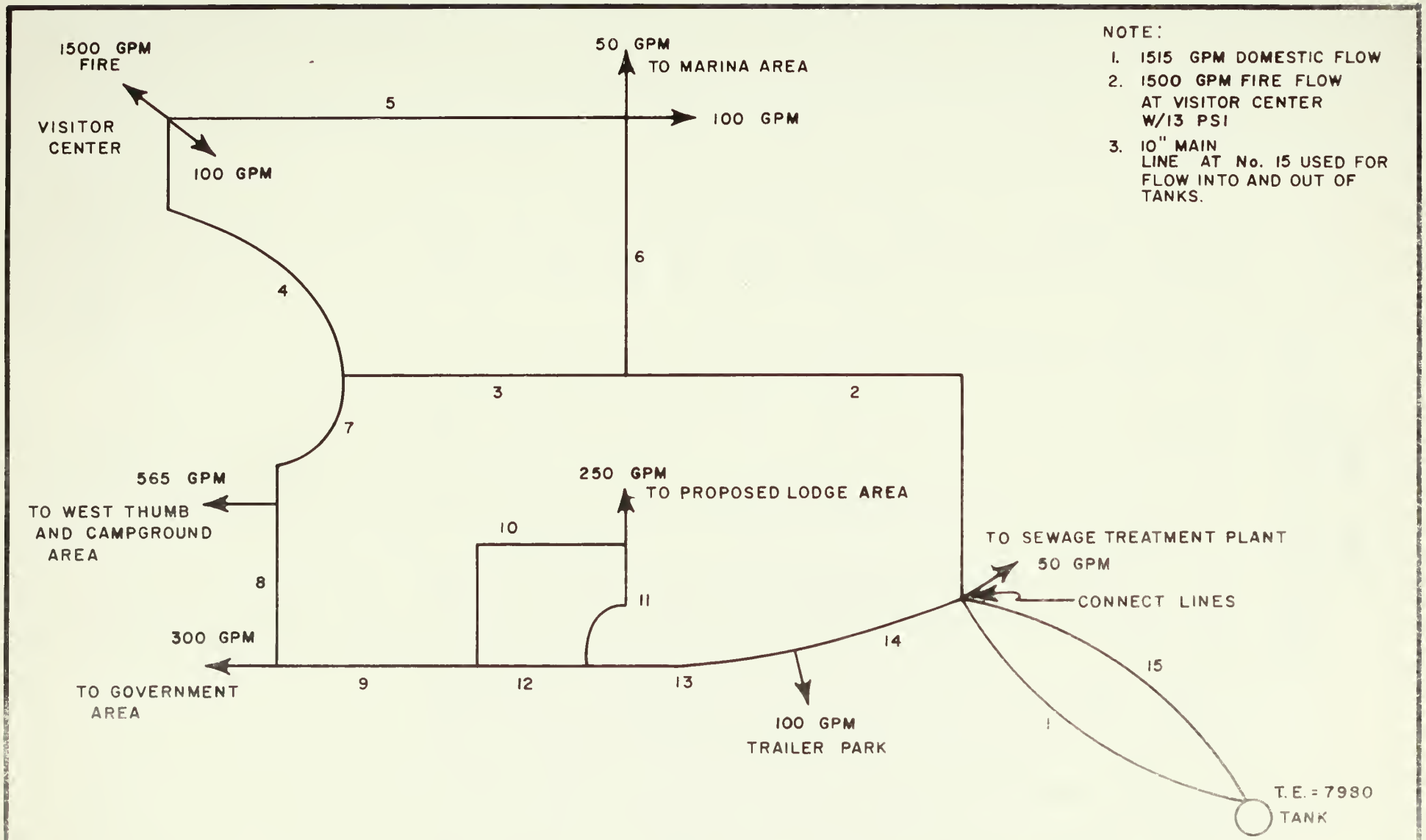


FIG. B-13 GRANT AREA
SKETCH OF NETWORK ANALYSIS
COMMERCIAL FIRE FLOW

GRANT AREA

SUPPLEMENT TO FIG. B-13

PIPE No.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	3300	8	140	1077.0	26.0
2	2325	8	140	1557.9	36.3
3	575	8	140	918.2	3.4
4	950	8	140	1110.3	7.9
5	1025	6	140	489.8	7.6
6	300	6	140	639.8	3.6
7	875	8	140	192.1	0.3
8	575	8	140	757.1	2.4
9	300	8	140	1057.1	2.3
10	1000	8	140	268.9	0.6
11	625	8	140	518.9	1.3
12	425	8	140	788.3	1.9
13	1650	8	140	1307.1	18.6
14	1100	8	140	1407.1	14.2
15	3300	10	140	1938.0	26.0

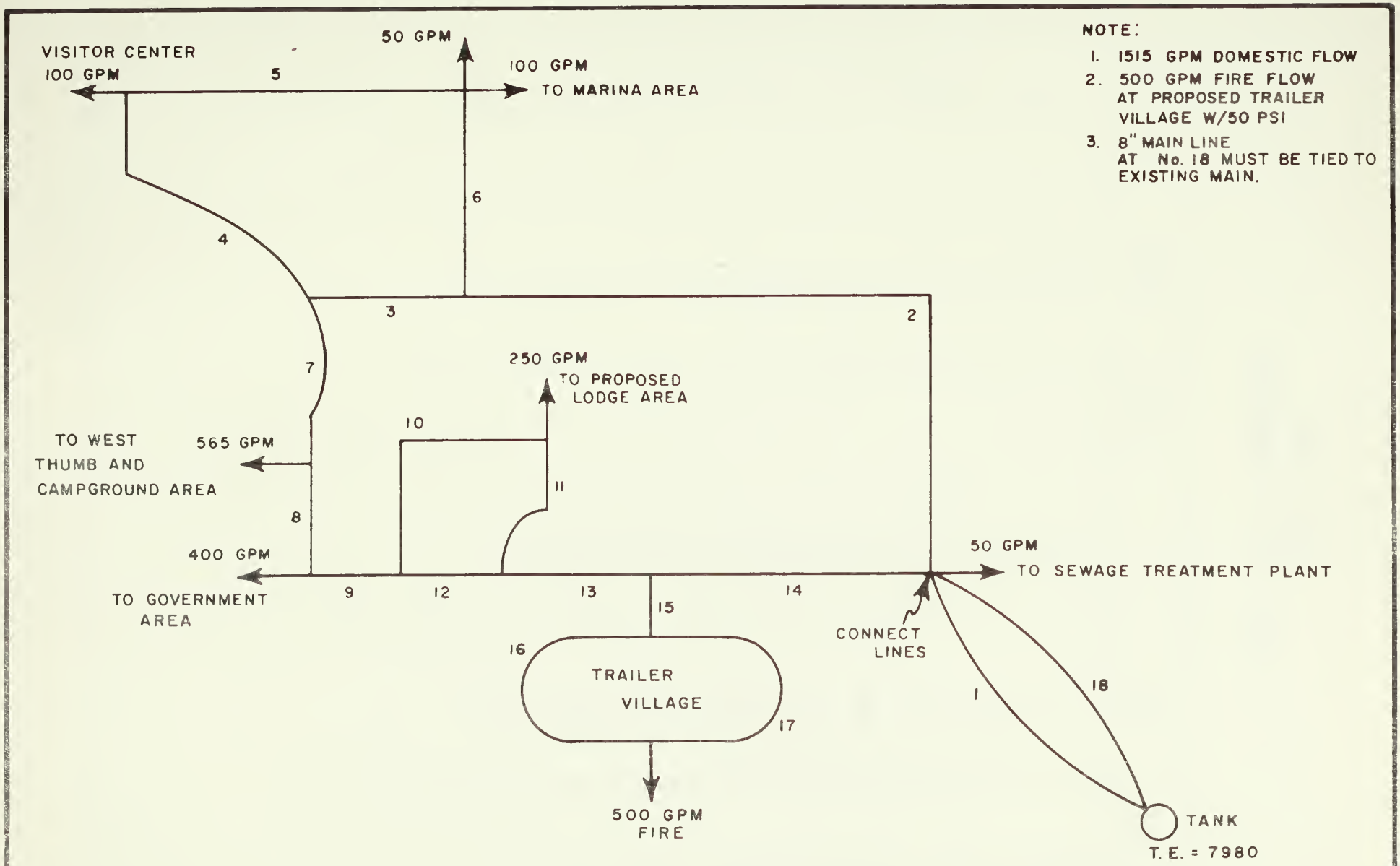


FIG. B-14 GRANT AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

GRANT AREA

SUPPLEMENT TO FIG. B-14

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	3300	8	140	1007.5	23.0
2	2325	8	140	835.5	11.4
3	575	8	140	562.2	1.4
4	950	8	140	23.4	0
5	1025	6	140	123.4	0.6
6	300	6	140	273.4	0.8
7	875	8	140	585.5	2.2
8	575	8	140	20.5	0
9	300	8	140	379.5	0.3
10	1000	8	140	29.9	0
11	625	8	140	279.9	0.4
12	425	8	140	349.5	0.4
13	1650	8	140	629.5	4.8
14	1100	8	140	1129.5	9.5
15	650	6	140	500.0	5.0
16	925	6	140	176.2	1.0
17	300	6	140	323.8	1.0
18	3300	8	140	1007.5	23.0

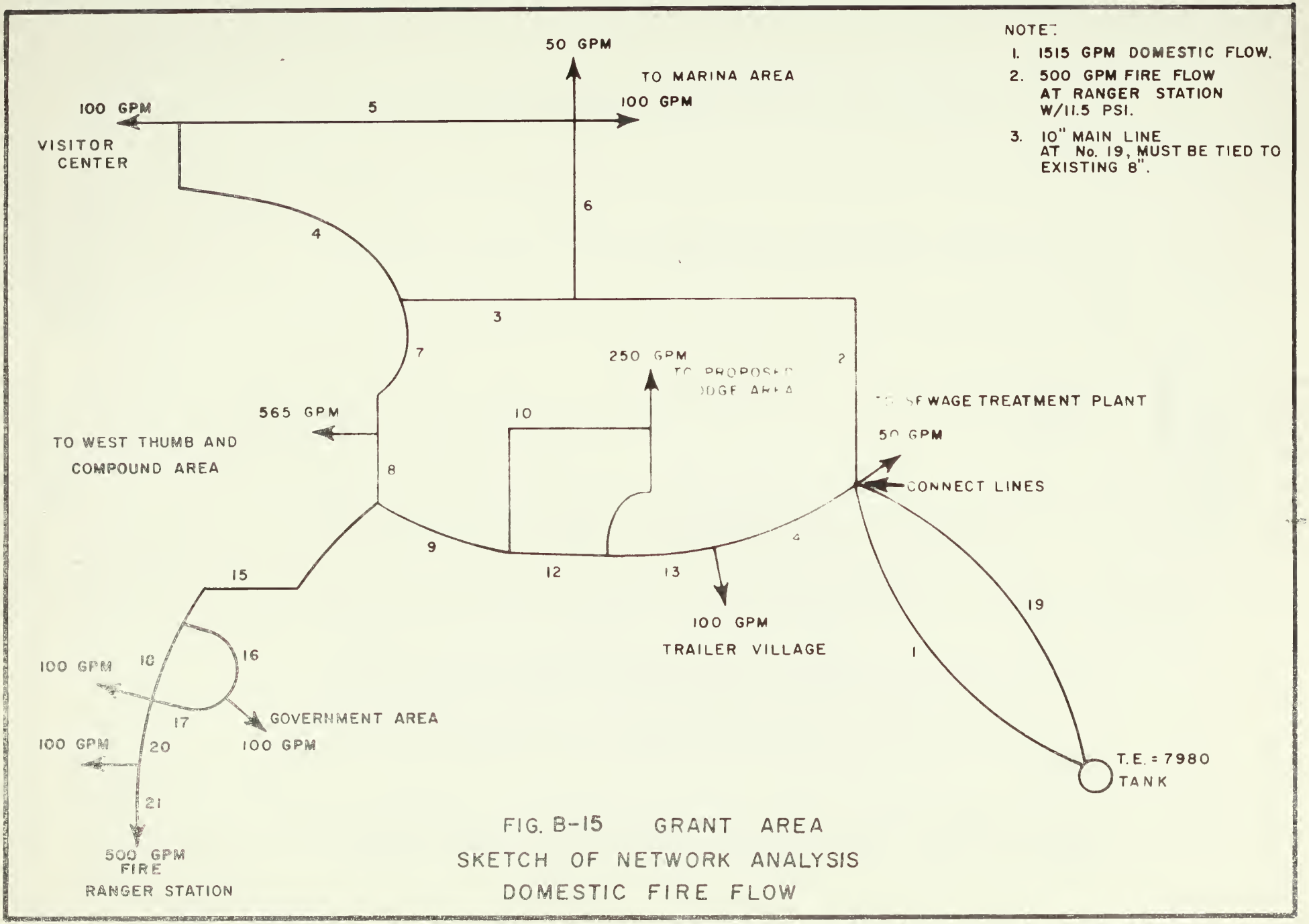


FIG. B-15 GRANT AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

GRANT AREA

SUPPLEMENT TO FIG. B-15

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	3300	8	140	719.8	12.3
2	2325	8	140	945.3	14.4
3	575	8	140	646.5	1.8
4	950	8	140	48.8	0
5	1025	8	140	148.8	0.8
6	300	6	140	298.8	0.9
7	875	6	140	695.3	3.1
8	575	8	140	130.3	0.1
9	300	8	140	619.7	0.8
10	1000	8	140	136.5	0.2
11	625	8	140	386.5	0.7
12	425	8	140	533.2	0.9
13	1650	8	140	919.7	9.7
14	1100	8	140	1019.7	7.8
15	1200	8	140	800.0	5.5
16	225	6	140	234.4	0.4
17	250	6	140	134.4	0.2
18	250	8	140	565.6	0.6
19	3300	10	140	1295.2	12.3
20	550	8	140	600.0	1.5
21	500	6	140	500.0	3.9

NOTE:

1. 150 GPM DOMESTIC
2. 500 GPM FIRE FLOW AT STORE W/30 PSI FROM WEST THUMB TANK
3. PROPOSED MAINS, A. LINES No. 18 TO 20, 22, 24 TO 26 PROPOSED NEW 6"
4. LINES 1 to 18 IN GRANT VILLAGE

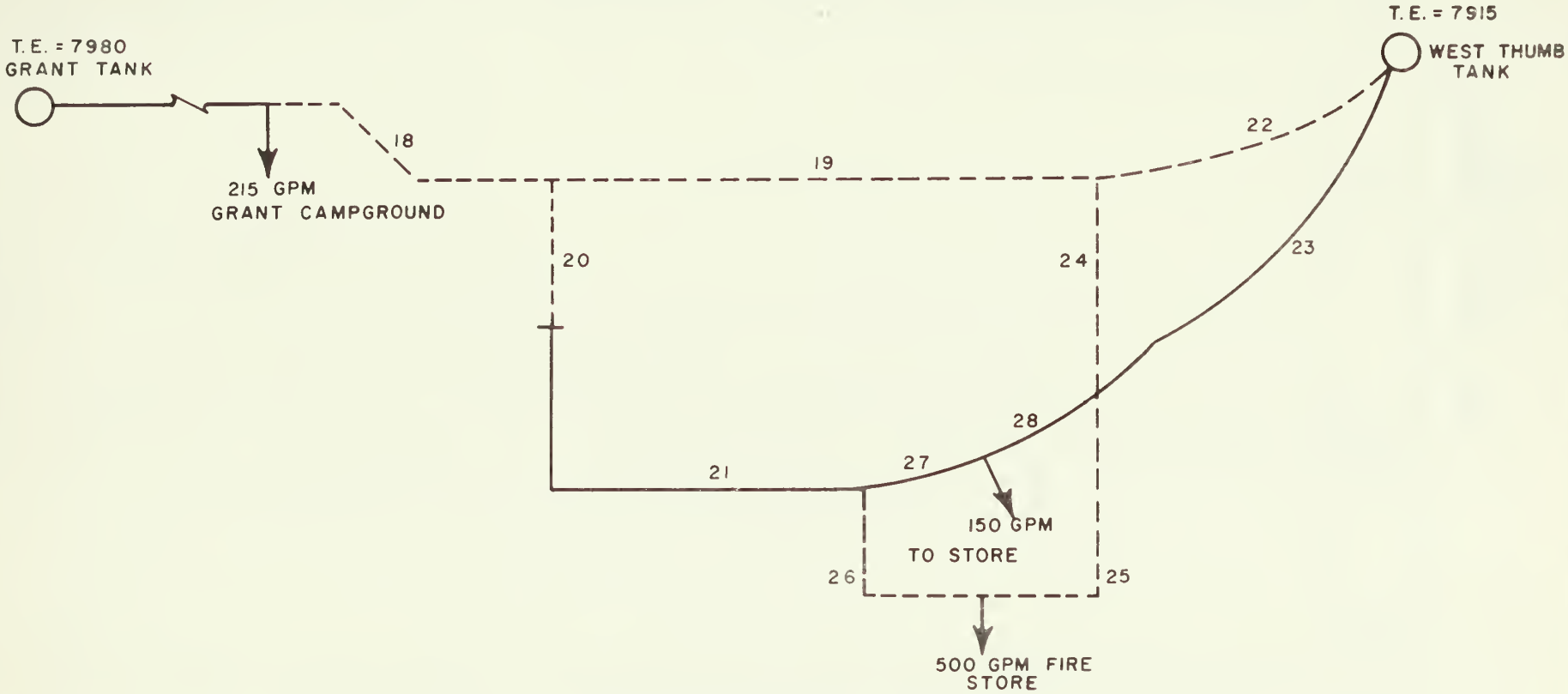
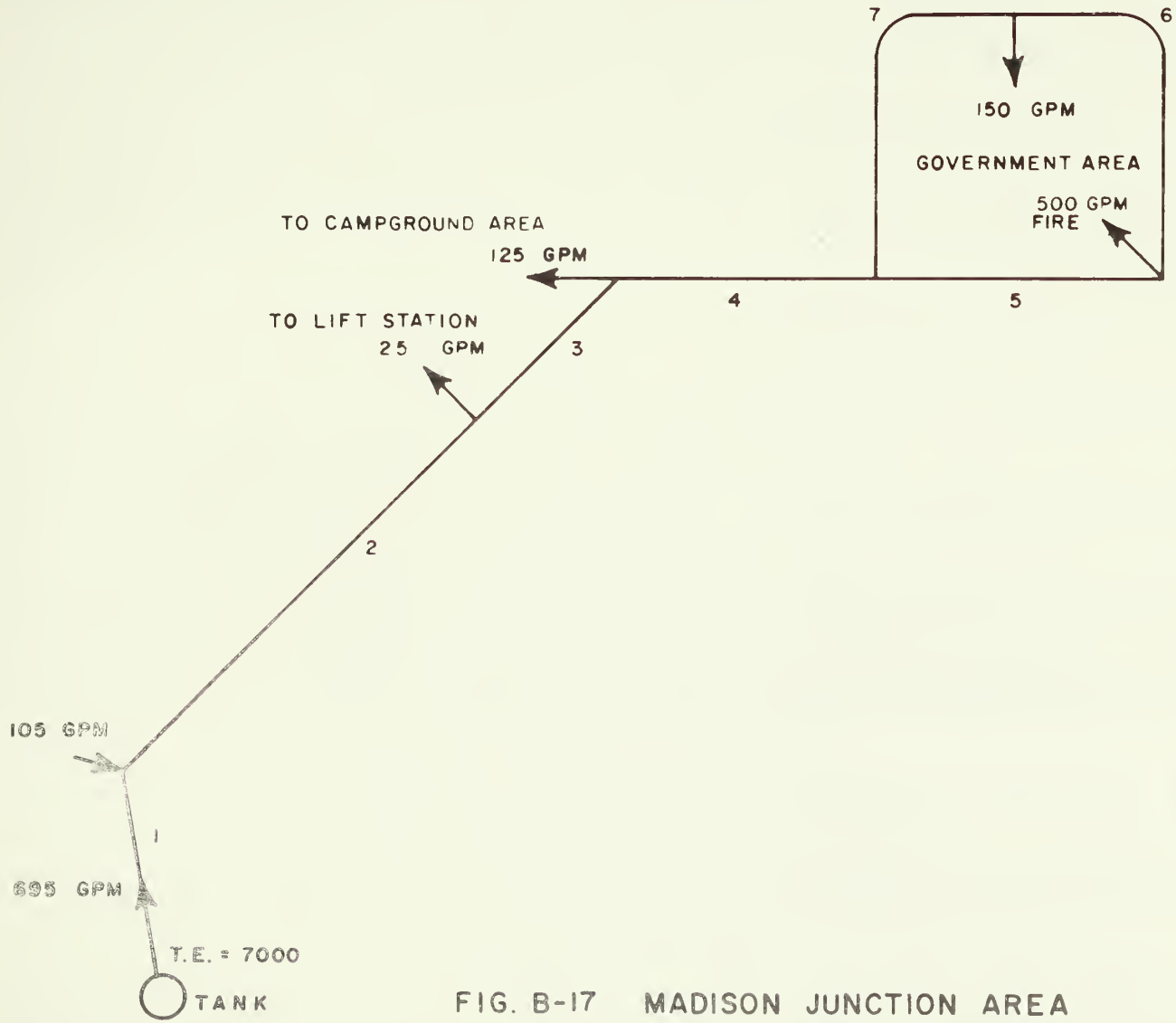


FIG. B-16 GRANT AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW
WEST THUMB

GRANT AREA

SUPPLEMENT TO FIG. B-16

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	3300	8	140	514.8	6.6
2	3300	10	140	926.1	6.6
3	1100	8	140	664.2	3.5
4	1650	8	140	564.2	3.9
5	425	8	140	311.6	0.3
6	300	8	140	314.2	0.2
7	1000	8	140	2.6	0
8	625	8	140	252.6	0.3
9	575	8	140	14.2	0
10	875	8	140	476.6	1.5
11	950	8	140	2.9	0
12	1025	6	140	97.2	0.4
13	300	6	140	247.2	0.6
14	575	8	140	479.4	1.0
15	1450	8	140	726.6	5.5
16	2600	6	140	490.8	19.4
17	2100	6	140	290.8	6.0
18	2450	6	140	75.8	0.6
19	3050	6	140	11.8	0
20	775	4	140	64.0	1.0
21	3975	4	100	64.0	9.2
22	200	6	140	445.7	12.5
23	2075	4	100	128.5	17.4
24	750	6	140	457.5	4.9
25	815	6	140	454.2	5.3
26	460	6	140	45.8	0
27	225	4	100	18.3	0.1
28	600	4	100	131.8	5.3



NOTE:

1. 300 GPM DOMESTIC FLOW
2. 500 GPM FIRE FLOW IN GOVERNMENT AREA W/20 PSI.
3. NO PROPOSED MAINS.

FIG. B-17 MADISON JUNCTION AREA
SKETCH OF NETWORK ANALYSIS
DOMESTIC FIRE FLOW

MADISON JUNCTION AREA

SUPPLEMENT TO FIG. B-17

PIPE NO.	LENGTH (ft.)	SIZE (in.)	C	FLOW (gpm)	HEAD LOSS (p.s.i.)
1	575	8	140	695.0	2.0
2	2300	8	140	800.0	10.5
3	675	8	140	775.0	2.9
4	1050	8	140	650.0	3.2
5	280	8	140	474.4	0.5
6	300	6	140	25.7	0
7	425	6	140	175.7	0.5

A P P E N D I X C

L A B O R A T O R Y R E S U L T S

Summaries of Laboratory Results by

W.E.A., Inc. field tests

Park Service tests and other tests

Certificates of Analyses by Chemical & Geological Laboratories

Table C-1. FIELD CHEMICAL TESTS BY W.E.A.,INC.

	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	pH OBSERVED	FLUORIDES	TURBIDITY	NITRATE NITRITE	CHLORINE	TOTAL HARDNESS	PHOSPHATE	TEMP. °C @ SOURCE
MAMMOTH														
Panther Creek Intake	0	0	5.0	0	140	0	7.0	0.17	5	0	--	115	0.2	10
Gardner River Intake	0	7	7.5	0	100	0	7.0	0.09	13	0		100	0.3	11
Glen Creek Intake	0	TR	5.0	0	140	0	7.2	0.10		0		114	0.3	10
Tap Water	0	TR	5.0	0	130	0	8.2	0.10		0	0.27	105	0.2	12
Lava Creek	0	TR	5.0	0	40	0	6.6	0.70		0		20	0.2	10
Gardner River Intake*		70		0	150	0		0.50	0			165		13
Panther Creek Intake*		0		0	130	0		0				110		13
Tap Water*		5		0	90	0		0				120		14
TOWER AREA														
Roosevelt Lodge Intake	0	5	5.0	0	50	0	7.6	0.21		0		30	0.1	10
Tower Junction Intake	0	16	10.0	0	160	0	7.9	0.49		0		120	0	11
Tower Fall Intake	0	4	2.5	0	50	0	8.2	0.39		0		40	TR	6
Tower Fall Tap Water	0	0	5.0	0	110	0	8.0	0.8		4	0	40	0	13
Roosevelt Lodge Tap Water	0	TR	10.0	0	60	0	7.9	0		0	0.15	32	0.18	12

Table C-1. FIELD CHEMICAL TESTS BY W.E.A., INC.-contd.

	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	pH OBSERVED	FLUORIDES	TURBIDITY	NITRATE NITRITE	CHLORINE	TOTAL HARDNESS	PHOSPHATE	TEMP. °C @ SOURCE
TOWER AREA-contd.														
Tower Junction Tap Water	0	20	7.5	0	170	0	8.1	0.65		5	0	120		16
Roosevelt Lodge Tap Water		TR		0	60	0		0.56				40		16
Tower Junction Intake*		18		0	155	0		0.29				120		14
Tower Fall Tap Water		TR		0	90	0		0.34				35		15
OLD FAITHFUL														
Firehole Intake	0	0	10	0	35	0	7.1	1.2		0		5	0	14
Tap Water	0	5	12.5	0	30	0	7.1	1.17		0	1.65	10	0	12
Firehole Tap Water*		4		0	25	0		1.5				20		13
CANYON														
Tap Water	0	5	5.0	0	50	0	7.6	0.17		0	0.03	32	0.1	15
Soda Creek Upper Intake	0	2	5.0	0	45	0	6.6	0.05		0		25	0.25	5
Soda Creek Upper Intake*		2		0	60	0			20			40		10
Cascade Creek Intake	0	0	5.0	0	45	0	7.5	0.43	6	30		21	TR	12
LAKE AREA														
Fishing Bridge Intake	0	4	5.0	0	40	0	7.1	2.9		0		30	0	9
Fishing Bridge Tap Water		5		0	40	0		3.0			0.28	20		15
Lake Tap Water	0	0	5.0	0	40	0	7.2	10.0		7.0	0.20	35	0	8

Table C-1. FIELD CHEMICAL TESTS BY W.E.A., INC.-contd.

	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	pH OBSERVED	FLUORIDES	TURBIDITY	NITRATE NITRITE	CHLORINE	TOTAL HARDNESS	PHOSPHATE	TEMP. °C @ SOURCE
LAKE AREA-contd.														
Lake Intake	0	0	7.5		30	0	7.0	2.9		6.5		25	0.25	
Bridge Bay Tap Water	0	0	5.0	0	30	0	7.45	3.9		10.0	0.08	20	TR	9
Fishing Bridge Intake*		0		0	25	0		2.92				35		11
Lake-Yellowstone Lake	0	TR	12.5	0	40	0	7.4	0.28		4.5		25	TR	16
Lake -Winter Spring	0	TR	5.0	0	30	0	7.2	3.0		5.5		25	0	9
Bridge Bay Tap Water*		0		0	25	0		3.7				25		11
GRANT AREA														
Grant Tap Water		5		0	50	0		0.43			0	25		14
Grant - Yellowstone Lake Intake	0	0	20	0	60	0	7.3	0.38		16		20	TR	13
West Thumb Tap Water*		0		0	20	0		0			0.21	20		20
West Thumb-Duck Lake Intake	0	TR	5.0	0	30	0	6.9	0.05		9		25	0	21
MADISON														
Tap Water		0	5.3	0	60	0	7.9	6.0			0	30	0	19
Spring Intake*		0		0	75	0	7.7	6.0				30		17
NORRIS														
Tap Water		0	5.0	0	50	0	7.4	3.3		4	0.01	25	0	22
Castle Creek Intake		TR	5.0	0	50	0	7.0	3.0		5		20	0.07	20

Table C-1. FIELD CHEMICAL TESTS BY W.E.A.,INC.-contd.

	IRON	SULFATE	CHLORIDE	CARBONATE	BICARBONATE	HYDROXIDE	pH OBSERVED	FLUORIDES	TURBIDITY	NITRATE NITRITE	CHLORINE	TOTAL HARDNESS	PHOSPHATE	TEMP.°C ● SOURCE
NORRIS-contd.														
Gibbon River	0.13	5	7.5	0	30	0	6.9	2.64		5.5		20	0	14
Solfatara Creek	0.1	TR	5.0	0	40	0	6.9	1.57		5.5		25	0	14
Castle Creek Below Intake	0	15	15	0	80	0	8.3	7.35		9.0		25	0	23

* MONITER TEST

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-6
WELL NO. Mammoth Gardner River Intake — LOCATION
FIELD — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM September 1, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 174
Fluoride, mg/l ---------- 0.14
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	13	0.55	Sulfate	64	1.33
Potassium	1	0.03	Chloride	4	0.11
Lithium	-	-	Carbonate	trace	-
Calcium	43	2.15	Bicarbonate	159	2.61
Magnesium	16	1.32	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		4.05	Total Anions		4.05

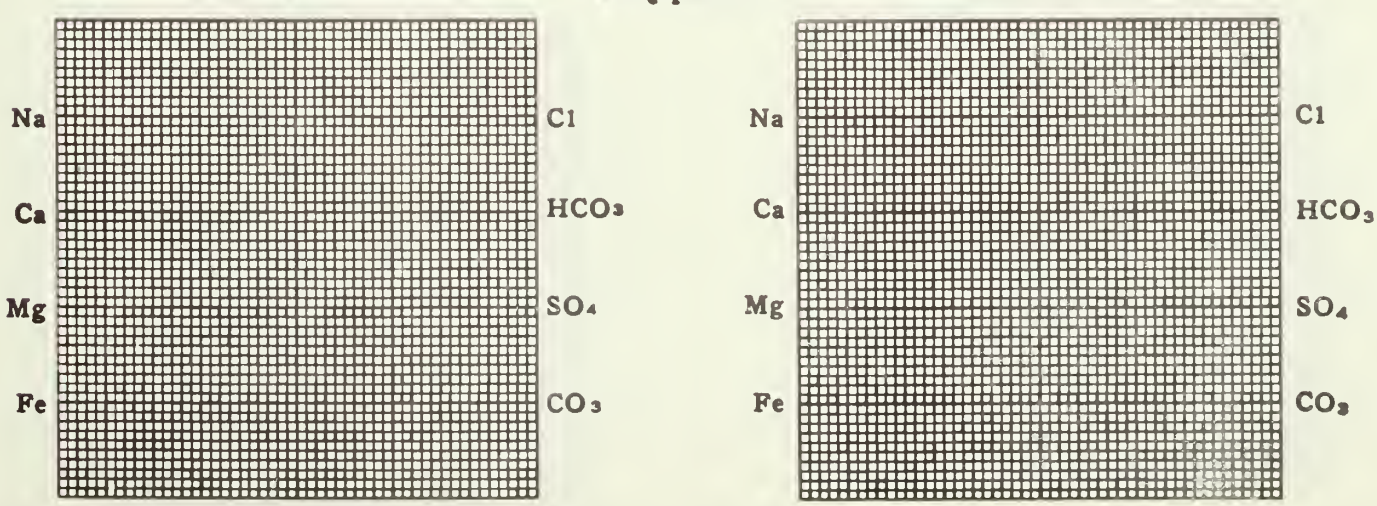
Total dissolved solids, mg/l — 219
NaCl equivalent, mg/l — 166
Observed pH — 8.3

Specific resistance @ 68°F.:
Observed — 32.00 ohm-meters
Calculated — 35.00 ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-5
WELL NO. Mammoth Panther Indian Creek — LOCATION
FIELD Intake — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM September 1, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 104
Fluoride, mg/l ---------- 0.03
Sample submitted in glass container and fluoride content is probably low.

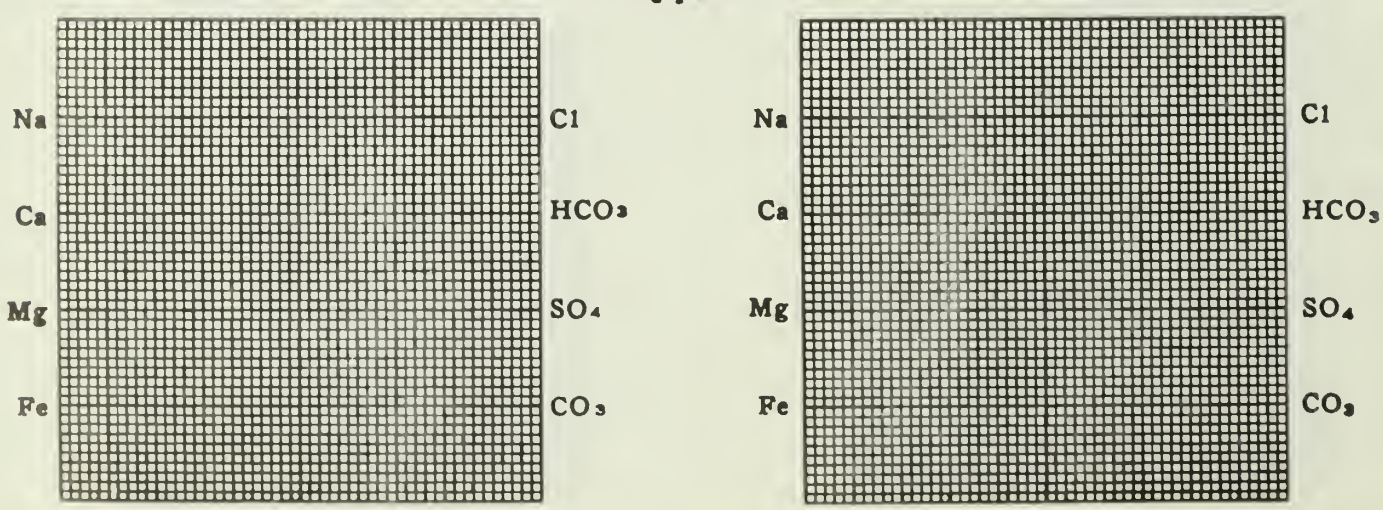
Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	12	0.54	Sulfate	4	0.08
Potassium	1	0.03	Chloride	6	0.17
Lithium	-	-	Carbonate	0	-
Calcium	25	1.25	Bicarbonate	146	2.39
Magnesium	10	0.82	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		2.64	Total Anions		2.64

Total dissolved solids, mg/l	130	Specific resistance @ 68°F.:	
NaCl equivalent, mg/l	104	Observed	52.00 ohm-meters
Observed pH	8.1	Calculated	56.00 ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

TABLE C-2

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects
WELL NO. Tower Fall Intake -- Inside
FIELD M. H.
COUNTY
STATE

DATE March 9, 1972 LAB NO. 7291-4
LOCATION
FORMATION
INTERVAL
SAMPLE FROM July 1, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l -------- 39
Fluoride, mg/l ---------- 0.40
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	24	1.03	Sulfate	6	0.12
Potassium	1	0.03	Chloride	4	0.11
Lithium	-	-	Carbonate	0	-
Calcium	9	0.45	Bicarbonate	98	1.61
Magnesium	4	0.33	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.84	Total Anions		1.84

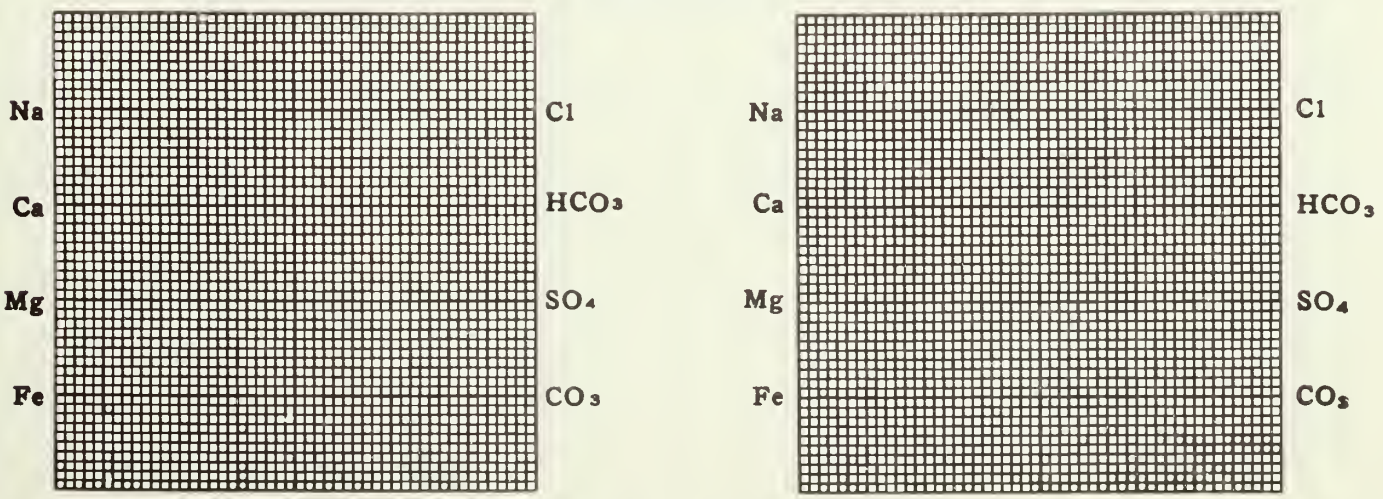
Total dissolved solids, mg/l 96
NaCl equivalent, mg/l 75
Observed pH 7.8

Specific resistance @ 68°F.:
Observed 75.00 ohm-meters
Calculated ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects DATE March 9, 1972 LAB NO. 7291-13
WELL NO. Old Faithful Intake LOCATION
FIELD (Firehole) FORMATION
COUNTY INTERVAL
STATE SAMPLE FROM July 13, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l -------- trace
Fluoride, mg/l ---------- 0.78
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	25	1.10	Sulfate	19	0.40
Potassium	3	0.08	Chloride	6	0.17
Lithium	-	-	Carbonate	0	-
Calcium	trace	-	Bicarbonate	37	0.61
Magnesium	trace	-	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.18	Total Anions		1.18

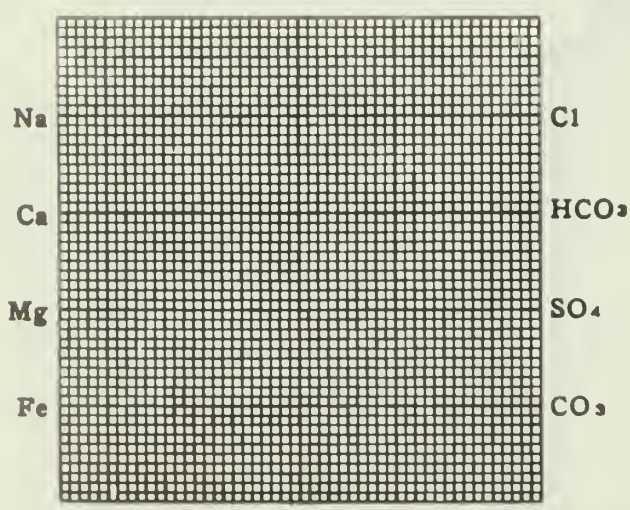
Total dissolved solids, mg/l 71
NaCl equivalent, mg/l 54
Observed pH 7.0

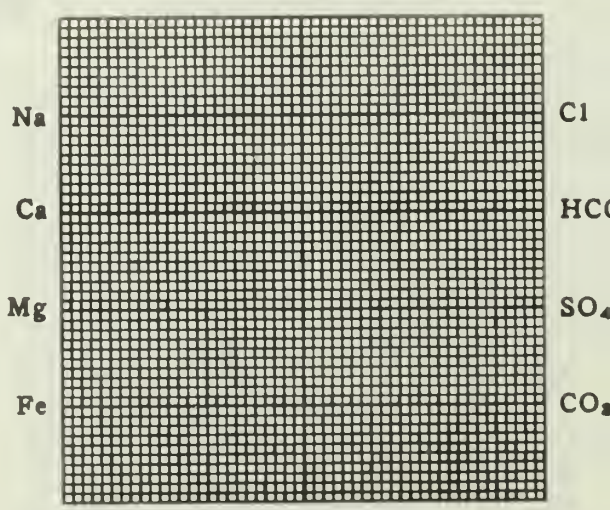
Specific resistance @ 68°F.:
Observed 180.00 ohm-meter
Calculated ohm-meter

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit





(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects DATE March 9, 1972 LAB NO. 7291-2
WELL NO. Canyon - Cascade Creek LOCATION
FIELD FORMATION
COUNTY INTERVAL
STATE SAMPLE FROM August 30, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l -------- 21
Fluoride, mg/l ---------- 0.23
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	13	0.55	Sulfate	4	0.08
Potassium	1	0.03	Chloride	4	0.11
Lithium	-	-	Carbonate	-	-
Calcium	5	0.25	Bicarbonate	49	0.80
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		0.99	Total Anions		0.99

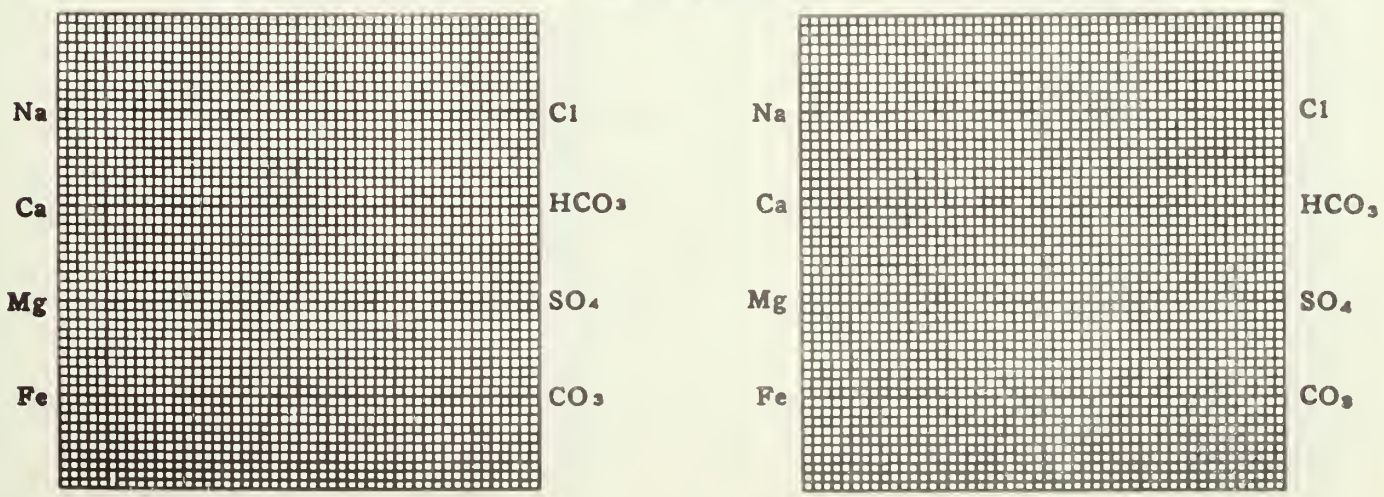
Total dissolved solids, mg/l 53
NaCl equivalent, mg/l 42
Observed pH 7.5

Specific resistance @ 68°F.:
Observed 150.00 ohm-meters
Calculated ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects DATE March 9, 1972 LAB NO. 7291-3
WELL NO. Upper Canyon Intake LOCATION
FIELD FORMATION
COUNTY INTERVAL
STATE SAMPLE FROM July 1, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 16
Fluoride, mg/l ---------- ND(0.02)
ND(0.02) = not detected--if present, less than 0.02 mg/l
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	14	0.59	Sulfate	7	0.15
Potassium	1	0.03	Chloride	6	0.17
Lithium	-	-	Carbonate	0	-
Calcium	3	0.15	Bicarbonate	37	0.61
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		0.93	Total Anions		0.93

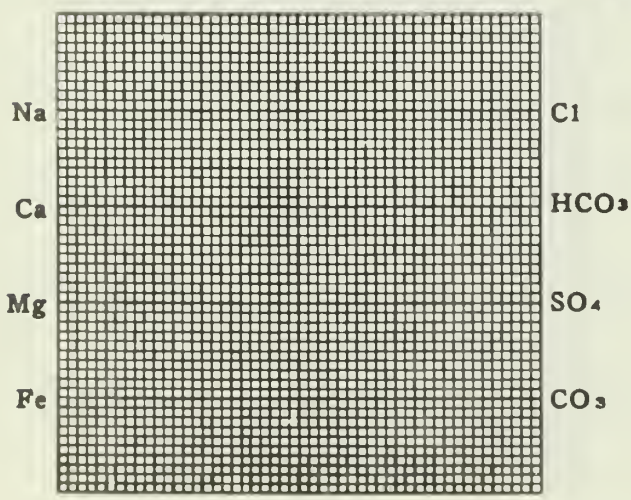
Total dissolved solids, mg/l 51
NaCl equivalent, mg/l 41
Observed pH 7.3

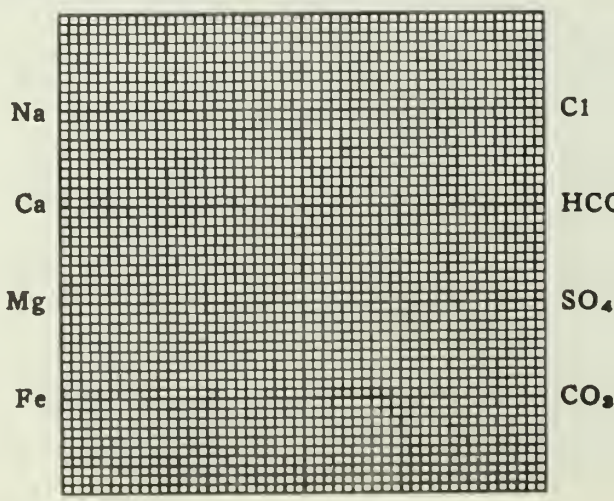
Specific resistance @ 68°F.:
Observed 185.00 ohm-meter
Calculated ohm-meter

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit





(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-12
WELL NO. Lake Winter Spring — LOCATION
FIELD — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM September 3,1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 18
Fluoride, mg/l ---------- 2.38
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	9	0.39	Sulfate	4	0.08
Potassium	2	0.05	Chloride	4	0.11
Lithium	-	-	Carbonate	0	-
Calcium	4	0.20	Bicarbonate	37	0.61
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		0.80	Total Anions		0.80

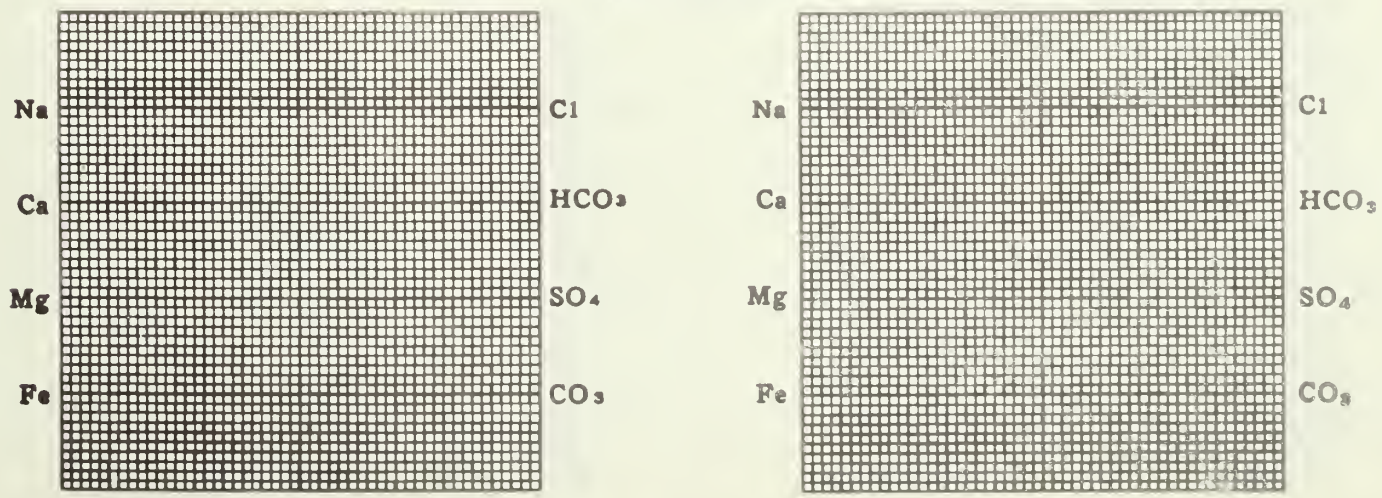
Total dissolved solids, mg/l ---- 43
NaCl equivalent, mg/l ---- 35
Observed pH ---- 7.3

Specific resistance @ 68°F.:
Observed ---- 170.00 ohm-meters
Calculated ---- ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-1
WELL NO. Fishing Bridge-Overflow at — LOCATION
FIELD Collection Box — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM August 29, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ------- 21
Fluoride, mg/l ------------------- 2.29
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	5	0.22	Sulfate	18	0.37
Potassium	2	0.05	Chloride	4	0.11
Lithium	-	-	Carbonate	-	-
Calcium	5	0.25	Bicarbonate	12	0.20
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		0.68	Total Anions		0.68

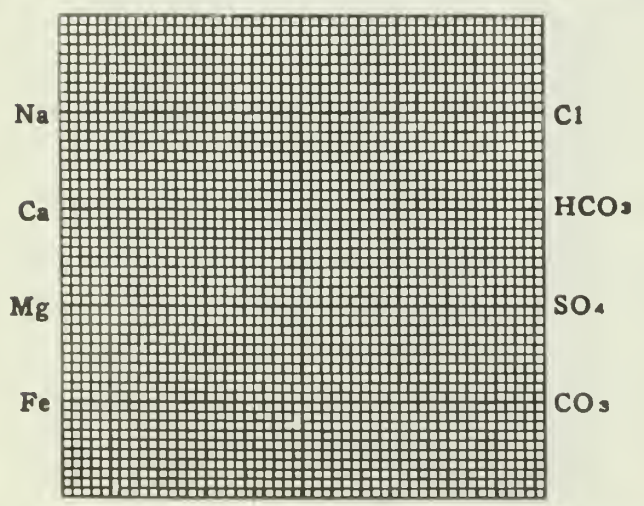
Total dissolved solids, mg/l ---- 42
NaCl equivalent, mg/l ---- 32
Observed pH ---- 7.2

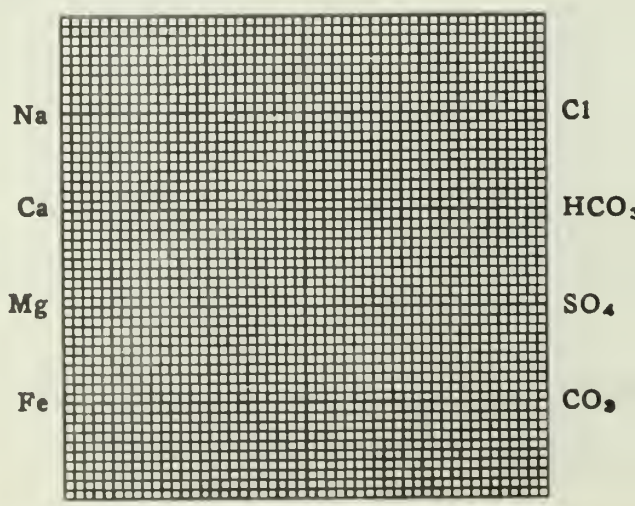
Specific resistance @ 68°F.:
Observed ---- 175.00 ohm-meters
Calculated ---- ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit





(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-11
WELL NO. Collection Box for Springs-- — LOCATION
FIELD Lake Area — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM

REMARKS & CONCLUSIONS: Clear water.
Total hardness as $CaCO_3$, mg/l-----21
Fluoride, mg/l----------2.21
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	13	0.56	Sulfate	16	0.33
Potassium	3	0.08	Chloride	4	0.11
Lithium	-	-	Carbonate	0	-
Calcium	5	0.25	Bicarbonate	37	0.61
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.05	Total Anions		1.05

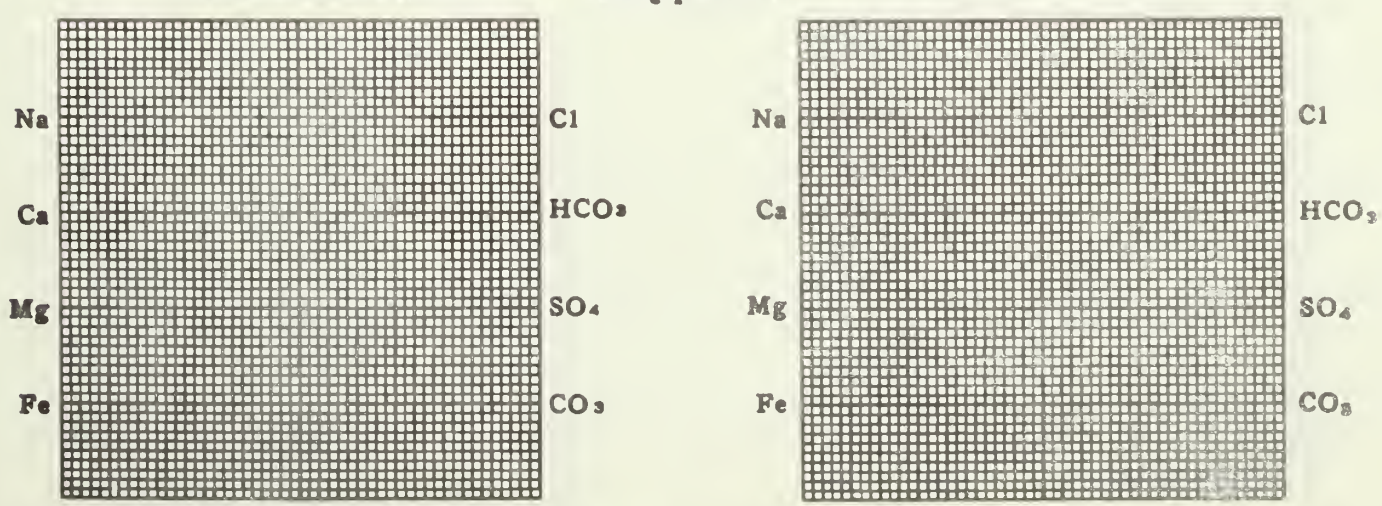
Total dissolved solids, mg/l ---- 61
NaCl equivalent, mg/l ---- 47
Observed pH ---- 7.5

Specific resistance @ 68°F.:
Observed ---- 146.00 ohm-meters
Calculated ---- ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent=by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-10
WELL NO. Yellowstone Lake Shore - Grant — LOCATION
FIELD — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM August 12, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 23
Fluoride, mg/l ---------- 0.34
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	19	0.83	Sulfate	9	0.25
Potassium	2	0.05	Chloride	10	0.28
Lithium	-	-	Carbonate	0	-
Calcium	4	0.20	Bicarbonate	49	0.80
Magnesium	3	0.25	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.33	Total Anions		1.33

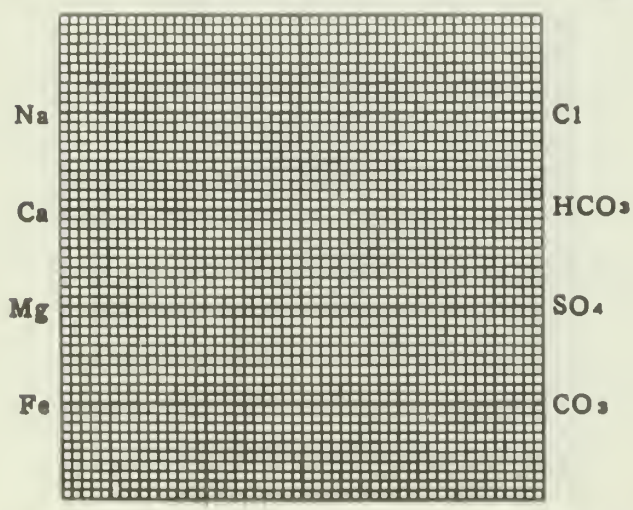
Total dissolved solids, mg/l ---- 71
NaCl equivalent, mg/l ---- 59
Observed pH ---- 7.5

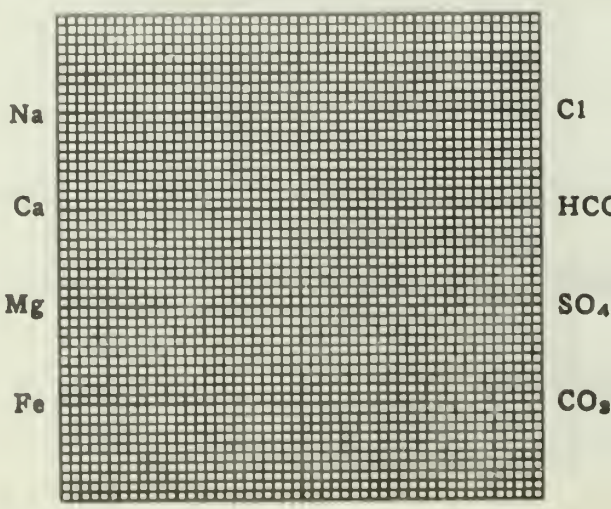
Specific resistance @ 68°F.:
Observed ---- 108.00 ohm-meter
Calculated ---- ohm-meter

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit





(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

TABLE C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-7
WELL NO. Madison Jct. Intake — LOCATION
FIELD — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM August 10, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ---------- 25
Fluoride, mg/l ---------- 3.80
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	30	1.31	Sulfate	7	0.15
Potassium	4	0.10	Chloride	20	0.56
Lithium	-	-	Carbonate	0	-
Calcium	5	0.25	Bicarbonate	73	1.20
Magnesium	3	0.25	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.91	Total Anions		1.91

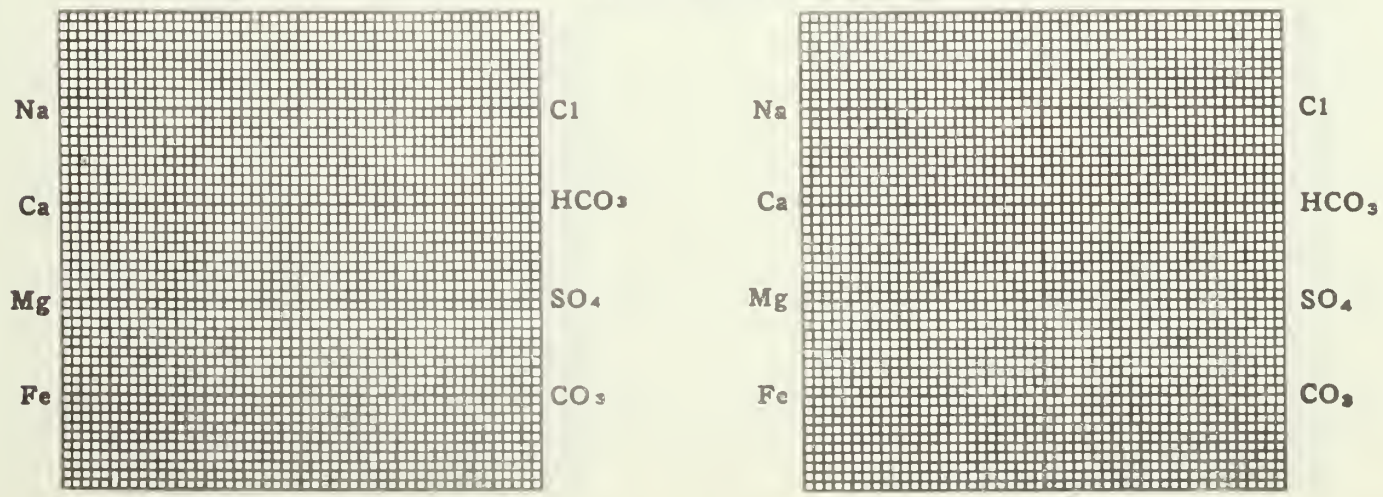
Total dissolved solids, mg/l ---------- 105
NaCl equivalent, mg/l ---------- 88
Observed pH ---------- 7.7

Specific resistance @ 68°F.:
Observed ---------- 56.00 ohm-meters
Calculated ---------- ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

CL1-12A (REV. 1964)

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects — DATE March 9, 1972 — LAB NO. 7291-8
WELL NO. Norris Jct. Solfatara Creek — LOCATION
FIELD — FORMATION
COUNTY — INTERVAL
STATE — SAMPLE FROM August 31, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l ------- 12
Fluoride, mg/l ------------------- 1.13
Sample submitted in glass container and fluoride content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	12	0.53	Sulfate	6	0.12
Potassium	3	0.08	Chloride	4	0.11
Lithium	-	-	Carbonate	0	-
Calcium	3	0.15	Bicarbonate	37	0.61
Magnesium	1	0.08	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		0.84	Total Anions		0.84

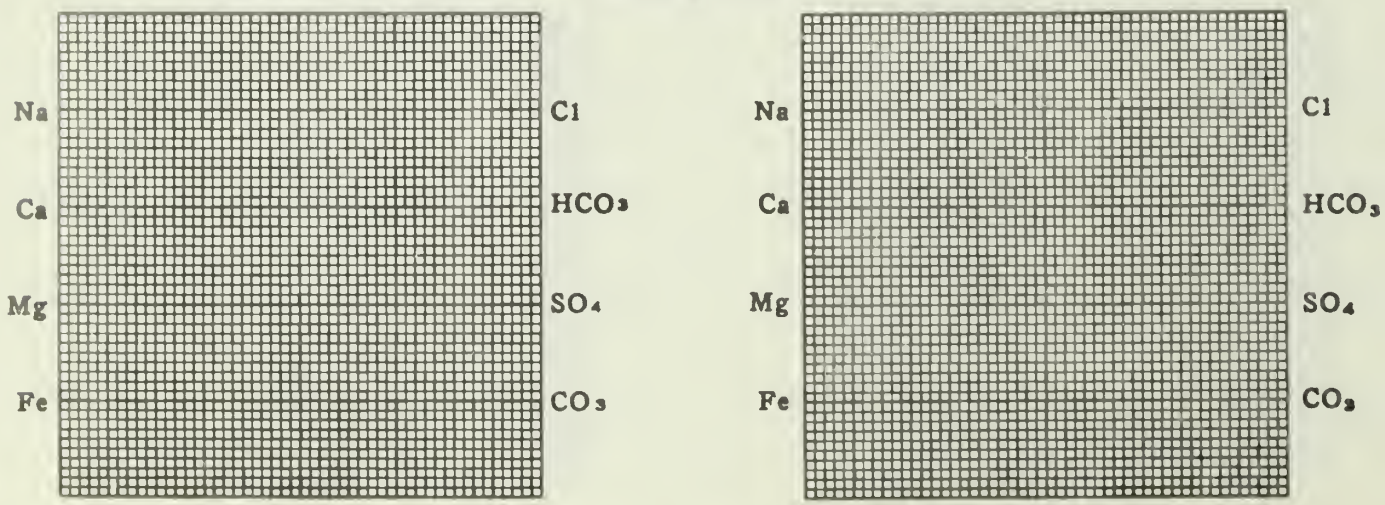
Total dissolved solids, mg/l ----- 47
NaCl equivalent, mg/l ----- 37
Observed pH ----- 7.4

Specific resistance @ 68°F.:
Observed ---- 132.00 ohm-meters
Calculated ---- ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming

WATER ANALYSIS REPORT

OPERATOR Western Engineers & Architects
WELL NO. Norris Jct. Castle Creek Intake
FIELD
COUNTY
STATE

DATE March 9, 1972 LAB NO. 7291-9
LOCATION
FORMATION
INTERVAL
SAMPLE FROM August 11, 1971

REMARKS & CONCLUSIONS: Total hardness as $CaCO_3$, mg/l -------- 15
Fluoride, mg/l ---------- 2.21
Sample submitted in glass container and fluroide content is probably low.

Cations	mg/l	meq/l	Anions	mg/l	meq/l
Sodium	26	1.12	Sulfate	24	0.50
Potassium	7	0.18	Chloride	4	0.11
Lithium	-	-	Carbonate	0	-
Calcium	3	0.15	Bicarbonate	61	1.00
Magnesium	2	0.16	Hydroxide	-	-
Iron	-	-	Hydrogen sulfide	-	-
Total Cations		1.61	Total Anions		1.61

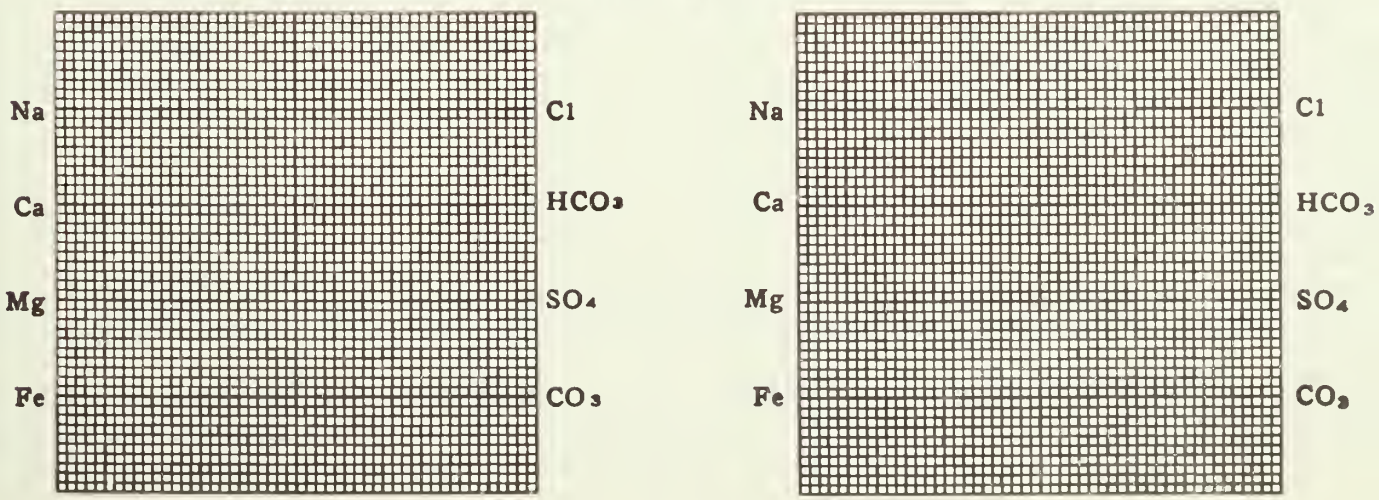
Total dissolved solids, mg/l - - - - - 96
NaCl equivalent, mg/l - - - - - - - - 72
Observed pH - - - - - - - - - - - 7.5

Specific resistance @ 68°F.:
Observed - - - - 98.00 ohm-meters
Calculated - - - - ohm-meters

WATER ANALYSIS PATTERN

Sample above described

Scale
MEQ per Unit



(Na value in above graphs includes Na, K, and Li)
NOTE: Mg/l = Milligrams per liter Meq/l = Milligram equivalents per liter
Sodium chloride equivalent = by Dunlap & Hawthorne calculation from components

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming 82601

ANALYTICAL REPORT

Company Western Engineers-Architects, Inc. Type of sample Water
Address Casper, Wyoming Date Oct. 30, 1972 Lab. No. 8945
Other Pertinent Data

Analytical method Analytical classification Quantitative

Milligrams per liter

Sample		Mammoth Panther Crk.	Gardner R.	Tower Fall Spr.	Old Faithful Firehole R.	Canyon Cascade Crk.	Soda Cr
1 Arsenic	(As)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
2 Barium	(Ba)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1
3 Cadmium	(Cd)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
4 Chromium	(Cr) (total)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
5 Copper	(Cu)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
6 Cyanide	(CN)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
7 Fluoride	(F)	0.09	0.16	1.20	0.34	0.14	4.8
8 Lead	(Pb)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.0
9 Manganese	(Mn)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
10 Nitrate	(NO_3)	0.3	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1
11 Selenium	(Se)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.0
12 Silver	(Ag)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
13 Zinc	(Zn)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
14 Phenols		ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.0
*15 Conductivity		300	300	106	80	85	62
16							
17							
18							
19							
20							
21							
22							
23							
24							
25							
26							
27							
28							
29							
30							
Threshold							

ND - Not detected; if present, less than value given in parentheses

*Remarks Conductivity at 77°F, micromhos

Table C-2.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming 82601

ANALYTICAL REPORT

Company Western Engineers-Architects — Type of sample Water
Address Casper, Wyoming — Date Oct. 30, 1972 — Lab. No. 8945
Other Pertinent Data

Analytical method — Analytical classification Quantitative

Milligrams per liter

Sample		Lake Fish Br. Spr.	Lake Spr.	Grant Yellowstone Lake	Madison Springs	Norris Castle Crk.	Solfatara C
Arsenic	(As)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Barium	(Ba)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)	ND (0.1)
Cadmium	(Cd)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Chromium	(Cr)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Copper	(Cu)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Cyanide	(CN)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Fluoride	(F)	5.00	1.15	1.17	6.90	3.90	2.90
Lead	(Pb)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
Manganese	(Mn)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	0.04	0.03
Nitrate	(NO_3)	0.1	ND (0.1)	ND (0.1)	0.2	ND (0.1)	ND (0.1)
Selenium	(Se)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.02)	ND (0.02)
Silver	(Ag)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Zinc	(Zn)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Phenols		ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)	ND (0.01)
Conductivity		62	97	150	195	118	98

reshold
) - Not detected; If present, less than value given in parentheses.

emarks Conductivity at 77°F, micromhos

Table C-3. RESULTS OF COLIFORM TESTS ON TREATED WATER

LOCATION	DATE	RESIDUAL CHLORINE (mg/l)	COLIFORM #/ 100 ml
Mammoth	5-17-70	0.1	**
	7-21-70	0.2	**
	7-28-70	0.2	20
Tower Fall	6-14-70	0	**
	6-21-70	0	**
	7-12-70	0	**
	7-20-70	0	1
	7-26-70	0	1
	8- 3-70	0	**
	8-11-70	0	1
	8-17-70	0	**
Tower Junction	5-21-70	0	**
	6-14-70	0	32
	6-16-70	0	45
	7- 6-70	0	1
	7-12-70	0	89
	7-26-70	0	43
	8- 4-70	0	**
	8-11-70	0	**
	8-17-70	0	**
Roosevelt Lodge	6-16-70	0	40
	6-29-70	0	**
	7- 6-70	0	**
	7-12-70	0.5	**
	7-19-70	0.5	**
	7-26-70	0.5	**
	8- 3-70	0.5	1
	8-11-70	0.5	4
	8-17-70	0.2	**

Table C-3. RESULTS OF COLIFORM TESTS ON TREATED WATER-contd.

LOCATION	DATE	RESIDUAL CHLORINE (mg/l)	COLIFORM #/100ml
Old Faithful	5-19-70	0	**
	6-10-70	0	**
	7- 1-70	0	**
	7- 7-70	0	5
	7-21-70	0	**
	7-28-70	0.15	**
	8- 4-70	0	**
	8-11-70	0	**
	8-17-70	0	**
Canyon	6- 9-71	0.15	**
	6-24-71	0.05	**
	7- 8-71	0	**
	7-21-71	0.05	**
	8-4-71	0.05	**
	8-11-71	0	**
	8-20-71	0.1	**
Lake	6- 8-71	0.1	**
	6-21-71	0.5	**
	7-20-71	0.08	**
	7-21-71	0.05	**
	8- 5-71	0.13	**
	8-20-71	0.28	**
Fishing Bridge	6- 8-71	0	**
	6-21-71	0.2	**
	7- 6-71	0.05	**
	7- 8-71	0.05	**
	7-21-71	0.75	**
	8- 3-71	0.3	**
	8- 4-71	0.1	**
	8-20-71	0.15	**

Table C-3. RESULTS OF COLIFORM TESTS ON TREATED WATER - contd.

LOCATION	DATE	RESIDUAL CHLORINE (mg/l)	COLIFORM #/100 ml
Bridge Bay	6- 8-71	0	**
	6-21-71	0.2	**
	7-22-71	0.3	**
	7-27-71	0.05	**
	8- 3-71	0.1	**
	8-19-71	0.3	**
Grant	6- 9-71	0.1	**
	6-22-71	0.05	**
	7-22-71	0.3	**
	7-27-71	0.05	**
	8- 3-71	0.1	**
	8-19-71	0.3	**
West Thumb	6- 9-71	0	**
	6-22-71	0.05	**
	7- 7-71	0.05	**
	7-12-71	0	**
	7-13-71	0.1	**
	7-19-71	0.02	**
	8- 2-71	0.3	**
	8-18-71	0.05	**
Madison Junction	5-19-70	0	**
	6-10-70	0	**
	7- 1-70	0	**
	7- 7-70	0	**
	7-14-70	0.1	**
	7-21-70	0.35	**
	7-28-70	0.35	**

Table C-3. RESULTS OF COLIFORM TESTS ON TREATED WATER - contd.

LOCATION	DATE	RESIDUAL CHLORINE (mg/l)	COLIFORM #/100 ml
Madison Junction-contd.			
	8- 4-70	0.2	**
	8-11-70	0.15	**
	8-17-70	0	**
Norris	6-10-70	0	**
	7- 1-70	0	**
	7- 7-70	0	5
	7-14-70	0	**
	7-21-70	0	**
	7-28-70	0	**
	8- 4-70	0.5	**
	8-11-70	0	5
	8-16-70	0.5	**
East Entrance	6- 9-71	-	4
	6-16-71	-	**
	7- 6-71	-	**
	7-20-71	-	**
	8- 3-71	-	**
	8-16-71	-	**
Lewis Lake	7-17-71	0.05	**
	7-19-71	-	**
	8- 2-71	0	**
	8-18-71	0.05	**
Otter Creek	8- 4-71	0	**
	8-11-71	0	**
South Entrance	6- 9-71	-	**
	6-22-71	-	**

Table C-3. RESULTS OF COLIFORM TESTS ON TREATED WATER - contd.

LOCATION	DATE	RESIDUAL CHLORINE (mg/l)	COLIFORM # 100 ml
South Entrance-contd.	7- 7-71	-	**
	7-19-71	-	**
	8- 2-71	-	**
	8-18-71	-	**

** Indicates less than 1 colony /100/ml

— Indicates no test taken

Table C-4. COLOR REMOVAL-YELLOWSTONE PARK WATERS

Tested 6/15/72-6/16/72
Sampled 6/1/72-6/ 2/72
Cl-as mg/l.color as APHA Platinum-Cobalt Standard Units

TEST#1 OLD FAITHFUL - 5 liter samples
CHLORINE FEED ONLY

SAMPLE #	Initial Cl^- Dosage	Detention Time-Min.	Hach Colors	Detention Time-Min.	Hach. Color	Cl^- Residual	Detention Time-Min.	Hach Color	Stir Vigorously Cl^- residual after 55 min.	Detention Time-Min.	Hach Color	Chem Lab Color
1	0	15	30	25	32	0	40	30	0	1 hr. 20 min.	35	35
2	1	15	20	25	25	.15	45	25	.01	" "	20	20
3	2	15	25	25	20	0.9	45	20	0.8	" "	20	15
4	3	15	15	25	18	1.5	45	18	1.4	" "	20	15
5	5	15	20	27	20	3.5	50	18	3.0	" "	15	10
6	10	15	15-20	27	15	8	50	15	7.5	" "	10	less than 5

CHLORINE FOLLOW WITH ACT.CARBON FILTER-6 gpm/ft^2

				Chem Lab. Color	Cl^- Residual
7	0	90	≤10	less than 5	0
8	1	90	≤10	less than 5	0
9	2	90	≤10	less than 5	0
10	3	90	≤ 5	7	0
11	5	90	≤ 5	7	0
12	10	90	≤ 5	8	0

COLOR SAMPLE - NO TREATMENT - KEPT CONSTANTLY COVERED

19	30 units of color

CANYON-CASCADE CREEK-SAMPLES
CHLORINE FEED ONLY

				Cl^-	Detention Time-Min.	Hach Color	Cl^-	Detention Time-Min.	Hach Color	Cl^-
20	0	30	35	0	60	30	0	1 hr. 30 min.	35	0
21	5	30	20	2.8	60	15	2.7	" "	15	2.5
22	10	30	20	7.5	50	20	7.5	" "	10	7.2

CHLORINATION + ACTIVATED CARBON FILTRATION

23	0	75	≤5	0
24	5	75	≤5	0
25	10	75	≤5	0

Table C-4. COLOR REMOVAL-YELLOWSTONE PARK WATERS-contd.

Tested 6/15/72-6/16/72
Sampled 6/1/72-6/ 2/72
Cl^- as mg/l. color as APHA Platinum-Cobalt Standard Units

@ 4°C FIREHOLE RIVER - OLD FAITHFUL

CHLORINE FEED ONLY

SAMPLE #	Initial Cl^- Dosage	Detention Time-Min.	Hach Color	Cl^- Residual	Detention Time-Min.	Hach Color	Cl^- Residual	Detention Time-Min.	Hach Color	Cl^- Residual
26	0	30	30	0	1 hr. 5 min.	30	0	5 hrs.	30	0
27	5	30	15	3.3	" "	15	3.0	5 "	15	2.7

CHLORINATION AND ACTIVATED CARBON FILTRATION @ 4°C

28	0	5 hrs.	5	0
29	5	5 "	5	0

OTHER DATA

1. Cascade Creek at Canyon does not carry large amounts of turbidity in the spring runoff as was originally expected. It does carry a moderate amount of color.
2. The color in Cascade Creek and the Firehole River at Old Faithful are appreciably reduced with chlorination and practically eliminated when the chlorination is followed by activated carbon filtration. The carbon filtration removes all of the chlorine.
3. The chlorination-carbon filtration process works well at 4°C as well as at higher temperatures and should prove to be an economical treatment method for color removal at Canyon, Old Faithful and if desired at Norris.
4. The color in the Mammoth supply is coming entirely from Glen Creek which will be by-passed by the new system. Panther Creek had almost no color.

Table C-4.

CHEMICAL & GEOLOGICAL LABORATORIES

P. O. Box 2794
Casper, Wyoming 82601

ANALYTICAL REPORT

Company Western Engineers & Architects, Inc. Type of sample Water
Address Casper, Wyoming Date June 16, 1972 Lab. No. 7974
Other Pertinent Data

Analytical method Analytical classification Quantitative

	Sample No.		Platinum-Cobalt Color Units
1	1		35
2	2		20
3	3		15
4	4		15
5	5		10
6	6		less than 5
7	7		less than 5
8	8		less than 5
9	9		less than 5
10	10		7
11	11		7
12	12		8
13	19		30
14	Firehole No. 1	6/12/72	30
15	Firehole No. 2	6/12/72	35
16	Firehole No. 3	6/12/72	30
17	Cascade Creek No. 1	6/ 8/72	35
18	Cascade Creek No. 2	6/15/72	40
19			
20			
21			
22			
23			
24			
25			
26			
27			
28			
29			
30			
	Threshold		

ND - Not detected

Remarks Reference: Standard Methods for the Examination of Water and Wastewater, 13th Edition, p. 160

A P P E N D I X D

C O N S T R U C T I O N C O S T S

Appendix D. CONSTRUCTION COSTS

Construction cost estimates were made using 1972 equipment prices, 1971 installation costs in Colorado and Wyoming with particular proportionate increases being made based upon "Abstract of Bids" furnished by the Park Service for estimating purposes. These prices were compared with the Engineering News Record construction cost index which in June 1971 was:

(year 1913 base = 100)	
U.S. average	1575
Denver	1309
San Francisco	1709
Minneapolis	1727
Kansas City	1770

June 1971 costs in Yellowstone would approximate an ENR index of 1700. From June, 1967 to June, 1971 the cost indexes increased an average of 10 percent per year. With wage-price controls or changes in the economy this factor may vary. Therefor, to adjust costs to a future year the ENR index percentage increase from June 1971 should be applied.

In preparing estimates for this report, equipment details and costs were obtained from the following:

Control Data Corporation - Autocon
Culligan
Golden-Anderson Valves
Infilco Division
Johnston Pump Co.
L * A Water Treatment Division
Roberts Filter Manufacturing Co.
Wallace and Tiernman
Western Filter Co.

Contingency and engineering costs have been added on a basis of 30 percent of the construction cost.

Table D-1. CONSTRUCTION COST ESTIMATES

MAMMOTH HOT SPRINGS AREA

COLLECTION			$ 151,550
Backwashable Infiltration Gallery - 4 filters			
Includes:	Panther Creek Diversion	$ 10,000	
	Lined Channel	8,500	
	Filters Installed	18,500	
	Indian Creek Diversion	5,000	
	Backwash Pumps	6,000	
	Filter and Plant Piping	33,500	
	Auto & Manual Valves	31,050	
	Gardner River Intake Remodel	2,000	
	Controls, Meters, & Generator	15,000	
	Housing, Controls, etc.	12,000	
	Landscape and Fence	10,000	
TRANSMISSION			$ 784,800
Pressure Main -	Intake to Filter Plant	$650,000	
	Appurtenances for line	8,000	
	Gate Valves	5,600	
	Tie Main to Bridge	9,000	
16" and 10" Trans. into Mammoth		67,500	
	PRV - 8" & 3"	4,400	
	Plug lines and tie in new lines	11,500	
	Gate Valves	5,300	
Control Circuits in new Transmission Trenches		23,500	

Table D-1. CONSTRUCTION COST ESTIMATES
MAMMOTH HOT SPRINGS AREA-contd.

TREATMENT		$ 254,500
Auto Valves, PRV, before Filter Plant	- $ 4,500	
D.E. filtration plant - 4 filters Complete, automated, chlorination, fluoridation, backwash, valves, piping, house	- 225,000	
Metering - flow in and out - TIR	- 10,000	
Controls - all systems	- 15,000	
DISTRIBUTION		$ 148,000
Main (includes pavement & lawn repair)	- $110,000	
Gate Valves	- 4,500	
Fire Hydrants (includes valves)	- 7,000	
Fittings	- 4,000	
Tie to existing system	- 2,500	
Replace services and tie to existing services	- 10,000	
Metering Changes	- 10,000	
STORAGE		$ 270,000
Clearwell at Infiltration gallery	- $ 30,000	
Clearwell at Filter Plant	- 240,000	
Sub Total Construction		$ 1,608,850
Contingency & Engineering		482,650
GRAND TOTAL		$ 2,091,500

Table D-2. CONSTRUCTION COST ESTIMATES
TOWER AREA

COLLECTION			$ 14,000
Fence and Drain Tower Fall Spring	- $	2,000	
Submersible Turbine Pump and Well-winter	-	7,000	
Obliterate Roosevelt Lodge and Tower Junction Sources	-	5,000	
TRANSMISSION			$ 175,700
Main - Tower Fall Spring to Tank	-	63,000	
Main - Tank to Roosevelt Lodge	-	108,000	
Altitude Valve and PRV's	-	4,700	
TREATMENT			$ 66,400
Upper-Tower Fall			
Pressure Actuated (Diff.Alt. Valve) T.F. Tank	- $	1,400	
With by-pass valves and piping	-	3,000	
TIR Meter	-	2,000	
Chloridation, Fluoridation	-	4,000	
Housing	-	10,000	
Controls	-	3,000	
Road and Power, Tower Fall	-	25,000	
Lower-Tower Junction-Roosevelt Lodge			
Road to Tank	- $	5,000	
TIR Meter-winter	-	2,000	
Chlorination	-	1,500	
Housing	-	5,000	
Controls	-	4,500	
DISTRIBUTION			$ 29,300
Main-Lower Area	- $	15,400	
Gate Valves	-	1,400	
Fittings	-	1,600	
Fire Hydrants with Gates	-	4,200	
Connections to Existing Systems	-	3,800	
Highway boring & New Main-winter well-		2,900	

Table D-2. CONSTRUCTION COST ESTIMATES

TOWER AREA-contd.

STORAGE			$ 44,000
Background tank - Tower Fall	-	$ 36,000	
Underground tank - Roosevelt	-	8,000	
		Sub Total Construction	$ 329,400
		Contingency and Engineering	98,820
		GRAND TOTAL	$428,220

Table D-3. CONSTRUCTION COST ESTIMATES

OLD FAITHFUL AREA

COLLECTION			$ 110,000
Backwashable Infiltration gallery-2 filters	-	$ 75,000	
Remodel Firehole Intake	-	5,000	
Power to Intake	-	30,000	
TRANSMISSION			-0-
TREATMENT			207,000
Auto-Valve into Plant	-	$ 4,000	
Activated Carbon Filters, pre and post chlorination, semi-auto consoles, backwash pump, auto-valves and housing	-	195,000	
Controls and Meters -TIR	-	8,000	
DISTRIBUTION			41,400
Main	-	$ 25,000	
Valves		800	
Ties to Existing System and services	-	5,600	
Metering		10,000	
STORAGE			109,500
Clearwell at Treatment Plant	-	$ 109,500	
OTHER			
Obliterate Existing Intakes	-	$ 5,000	
Sub Total Construction			$ 472,900
Contingency and Engineering			141,700
GRAND TOTAL			$ 614,600

Table D-4. CONSTRUCTION COST ESTIMATES

COLLECTION		$ 77,000
Remodel Cascade Creek Intake	- $ 2,000	
Backwashable Infiltration Gallery	- $ 75,000	
TREATMENT		$164,000
Clean and place Permutit Filter in service	- $ 1,000	
Activated Charcoal Filters - Complete, automate, backwash pump, housing, generator	- 125,000	
Complete System Control Center	- 20,000	
T.I.R. meters	- 6,000	
High Service Pumps	- 6,000	
Auto-Valve - T.I.R. meter - Soda Creek	- 6,000	
TRANSMISSION		$ 47,700
Main Cascade Creek to Tank	$ 45,000	
Valves	1,500	
Ties to Existing Mains	1,200	
DISTRIBUTION		$ 22,300
Main	$ 10,000	
Valves	400	
Ties to Existing Mains	400	
Repair fire hydrants	500	
Fittings	1,000	
Metering	10,000	
STORAGE		$ 36,000
Clearwells at Treatment Plant	$ 36,000	
Sub Total Construction		$347,000
Contingency and Engineering		104,100
GRAND TOTAL		$451,100

Table D-5. CONSTRUCTION COST ESTIMATES

LAKE AREA

COLLECTION			$ 31,000
Lake			
Develop Gallery Spring, Fence, etc.	-	$ 25,000	
Obliterate existing pumphouse on Lake Shore	-	1,000	
Fishing Bridge			
Raze existing pumphouse and wood tank	-	4,000	
Bridge Bay			
Obliterate wells	-	1,000	
TREATMENT			$ 78,300
Lake			
Auto-valve for clearwell inflow	-	2,800	
High Service Pump, standby generator	-	10,000	
T.I.R. Meter	-	3,000	
Chlorine house addition	-	2,500	
Plant piping	-	5,000	
Controls	-	10,000	
Fishing Bridge			
High Service Pump	-	3,000	
Meter - T.I.R.	-	3,000	
Control - at Pump	-	1,000	
Pumphouse and small clearwell	-	4,000	
Telemetering to Lake	-	10,000	
Bridge Bay			
Telemetering to Lake	-	14,000	
Other - Defluoridation Units	-	10,000	
TRANSMISSION			$ 99,700
Fishing Bridge			
10" by-pass line	-	22,400	
8" by-pass line	-	15,600	
Valves	-	1,200	
Tie to existing lines	-	1,500	
Main-Pumphouse to tank	-	3,500	
Control valves to fill tank	-	5,500	

TABLE D-5. CONSTRUCTION COST ESTIMATES

LAKE AREA-contd.

TRANSMISSION-contd.			
Lake			
8" Main tank to distribution	-	$ 38,000	
Valves	-	1,200	
Ties	-	2,000	
Altitude valve	-	4,500	
Bridge Bay			
Altitude valve	-	4,300	
DISTRIBUTION			$ 44,100
Fishing Bridge			
Install valves in existing lines	-	2,400	
Repair fire hydrants	-	600	
Lake			
Install valves in existing lines	-	6,500	
8" Main	-	8,800	
Valves	-	300	
Bridge Bay			
Mains	-	12,600	
Valves	-	400	
Connect to existing lines	-	2,000	
Install valve in existing line	-	500	
Metering		10,000	
STORAGE			$ 20,000
Clearwell at Lake Springs	-	20,000	
Sub Total Construction			273,100
Contingency and Engineering			81,900
GRAND TOTAL			$ 355,000

Table D-6. CONSTRUCTION COST ESTIMATES

GRANT AREA

COLLECTION		$ 2,500
Destroy Duck Lake Pumphouse & Facilities	$ 2,500	
TREATMENT		149,500
Submersible pumps - Caisson intake	6,000	
Plant piping	2,500	
D.E. filtration plant complete Automated, fluoridation, backwash, standby generator, housing	100,000	
Install existing high service pumps	3,000	
T.I.R. meter to tanks	5,000	
Controls and complete telemetry	18,000	
West Thumb tanks - telemetry	11,000	
Surge relief - Grant	4,000	
TRANSMISSION		72,700
Connect lines together - Grant	4,000	
Altitude valve - West Thumb	4,300	
Main - Grant to West Thumb	15,400	
Main - West Thumb to West Thumb tanks	49,000	
DISTRIBUTION		14,200
Grant - Future hydrants and repair	2,100	
Main - 4"	5,600	
Valves	1,600	
Valves - cut into existing	1,000	
Connect mains to existing	2,500	
Fire hydrants with valves	1,400	
STORAGE		52,500
Grant clearwell	52,500	
Sub Total Construction		291,400
Contingency and Engineering		87,420
GRAND TOTAL		$378,820

Table D-7. CONSTRUCTION COST ESTIMATES

MADISON JUNCTION AREA

COLLECTION			$ 27,500
Develop more supply	-	$ 7,500	
Fence and drainage-Spring area	-	20,000	
TREATMENT	-		23,000
Defluoridate residences (max.)	-	10,000	
T.I.R. meter	-	3,000	
Control system & bury power	-	10,000	
TRANSMISSION and DISTRIBUTION			0
STORAGE			10,000
Clearwell at pump		10,000	
Sub Total Construction			60,500
Contingency and Engineering			18,150
GRAND TOTAL			$78,650

Table D-8. CONSTRUCTION COST ESTIMATES

NORRIS AREA

COLLECTION			$ 5,500
Backwashable infiltration gallery Piping, auto valves and filter material	-	$ 5,500	
TREATMENT & CONTROL			$ 58,400
D.E. filtration plant - complete Automation backwash, chlorination, standby generator, housing	-	$ 35,000	
Power to Intake -Treatment	-	15,400	
Control Center	-	5,000	
T.I.R. meter	-	2,000	
Altitude valve	-	1,000	
TRANSMISSION			$ 25,900
Main - filtration to tank	-	$ 25,200	
Valves	-	200	
Tie to existing line	-	500	
DISTRIBUTION	-		-0-
STORAGE			$ 5,000
Clearwell at filtration Plant	-	$ 5,000	
Sub Total Construction			$ 94,800
Contingency and Engineering			28,400
GRAND TOTAL			$ 123,200

LIST OF KEY PROJECT PERSONNEL

WESTERN ENGINEERS-ARCHITECTS, INC.

RUSSELL L. DONLEY, III	PROJECT ENGINEER
DUANE FEHRINGER	FIELD ENGINEER
EVELYN L. LYNCH	TYPIST
NORA BEST	DRAFTING

LIST OF REFERENCES

(1) Metcalf & Eddy, Engineers, Report "Master Sewerage Study, Yellowstone National Park, Wyoming, Nov.,1968, "xxii, 1-1, 1-7, 1-9, 1-11, 1-13, 1-15, 2-1, 2-15, A-1, 8-17, 12-15, 3-3

(2) Steel, Ernest W., Water Supply and Sewerage, 4th edition 1960, 20, 128, 303

(3) Cox, Edward R., U.S.G.S. Report, "Results of Water Resources Investigations Through 1968 in Yellowstone National Park, Wyoming," Sept.,1969, 70, 66, 76-87

(4) Environmental Protection Agency "Final Preliminary" of the Yellowstone National Park Survey, May-Aug.,1970 includes Soda Butte Survey May-Oct.,1969."

(5) Public Health Service Drinking Water Standards 1962, 6, 7, 8, 15, 16

(6) Cox, Edward R., U.S.G.S. Report, "Results of Water Resources Investigations During Fiscal Year 1969 in Yellowstone National Park, Wyoming," June, 1970.

(7) Vennard, John K., Elementary Fluid Mechanics, 3rd edition, 1959, 316, 318

(8) "Hydraulic Network Analysis-Users Guide," General Electric, Information Service Department, Aug., 1967 manual.

(9) "Manual for Evaluating Public Drinking Water Supplies," Public Health Service, 1969,iii, 5, 19, 36, 38

(10) "Fluoridation of Public Water Supplies-Statement of Recommended Policy," American Water Works Association, V.55, No. 6, June, 1963, 677

(11) Savinelli, E. A. and Black, A.P, "Defluoridation of Water with Activated Alumina, J. A.W.W.A., V50 , No. 1, Jan., 1958,33

(12) "Design and Use of Radial Collector Wells," Ranney Water Systems, Inc., 1963

(13) AWWA, Water Quality and Treatment 3rd edition, 1971, 70, 90-95, 161, 158-224

(14) Black, A. P., "The Chemistry of Water Treatment," Water and Sewage Works bound booklet, 1947, 1,2,14

(15) Nordell, E., Water Treatment for Industrial and Other Uses, 2nd edition, 1961, 136, 137

LIST OF REFERENCES-contd.

(16) "Recreational Use of Domestic Water Supply Reservoirs," AWWA Statement of Policy.J.AWWA (Ref. edition).

(17) Standard Methods for the Examination of Water and Wastewater, APHA, AWWA, and WPCF, New York 11th edition, 1960

(18) The Chlorine Institute, Inc., 342 Madison Ave., N.Y., N.Y., 10017

(19) Berg, G. "Virus Transmission by the Water Vehicle III. Removal of Viruses by Water Treatment Procedures," Health Laboratory Science, V.3, No. 3, July, 1966, 180

(20) Clark, N. A. and Chang, S.L., "Enteric Viruses in Water," J.AWWA,V 51, No. 10, Oct., 1959, 1310-1311

(21) Kelly, S. and Sanderson, W. W., "The Effect of Chlorine in Water on Enteric Viruses," Am. J. Public Health 48: 1323-1334, Oct., 1958

(22) Donley, R.L., unpublished Master's Thesis, "Electrophoretic Studies of Turbidity Removal by Coagulation with a New Synthetic Cationic Polyelectrotyte," Univ. of Florida, June, 1962.

(23) Black, A.P., "Basic Mechanisms of Coagulation," J.AWWA,52, 492, 1960

(24) Black, A.P. and Hamnah,S.A., "Electrophoretic Studies of Turbidity Removal by Coagulation with Aluminum Sulfate," J.A.W.W.A., V. 53, 438, 1961.

(25) Black, A. P. and Willem , D.G., "Electrophoretic Studies of Coagulation for Removal of Organic Color," J.AWWA, V 53, 589, 1961.

(26) AWWA Task Group 225 M on Water Quality Criteria for High Quality Finished Water

(27) Packham, R. F., Proc. Soc. Water Treat. Exam., 12:15, 1963

(28) Moffett, J.W. "The Chemistry of High Rate Water Treatment," J.AWWA , V 60, No.11, Nov., 1968, 1255

(29) Moffett, J.W., "High Rate Filtration-Plant Operating Experiences," paper presented to TAPPI 4th Water Conference, Phil., Pa., April, 1967

(30) Fair, G.M. and Geyer, J.C. Water Supply and Waste Water Disposal 7th printing, 1966, 700-701

(31) U.S. Public Health Service Bulletins - 172 (1927) and 193 (1929); also U.S. Public Health Report, 1933, 396

(32) Hunter, J.V.; Bell, G.R. and Henderson, C.N.; "Coliform Organism Removals by Diatomite Filtration", J.AWWA, V 58, Sept. 1966, 1160-1169

(33) Brown, T. S.; "Virus Removal by Diatomaceous Earth Filtration", Paper presented to AWWA annual convention, Chicago, June 1972.

(34) Hassler, J.W., "Activated Carbon", Chemical Publishing Co., Inc. New York, 1963, 1-2

(35) Woodard, R.L.; Dostal, K.A.; Roberck, C.G., "Granular-Activated-Carbon Beds for Odor Removal", J.AWWA, V 56, Mar. 1964, 287

(36) Flentje, M.E. Hager, D.G., "Reevaluation of Granular-Carbon Filters for Taste and Odor Control", J.AWWA, V 56, Feb.,1964, 191