LARAMIE WATER MANAGEMENT PLAN, LEVEL II

VOLUME I OF II

August 25, 2006

Submitted to:

Wyoming Water Development Commission
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Cheyenne, WY 82001

Prepared for:

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TABLE OF CONTENTS
LARAMIE WATER MANAGEMENT PLAN, LEVEL II

VOLUME I OF II

Page

ES EXECUTIVE SUMMARY E-1

CHAPTER 1.0 INTRODUCTION

1.1 Introduction 1-1
1.2 Objectives 1-2
1.3 Report Summary 1-2

CHAPTER 2.0 EXISTING WATER SUPPLIES

2.1 Introduction 2-1
2.2 Water Supply Development History 2-1
2.3 Surface Water 2-3
2.3.1 Availability and Reliability 2-3
2.3.2 Low-Flow Frequency Analysis 2-4
2.3.3 Water Quality 2-5
2.4 Groundwater 2-6
2.4.1 General Description of City Wellfields 2-6
2.5 Water Rights 2-8
2.5.1 Surface Water Rights 2-8
2.5.1.1 Dowlin Ditch 2-8
2.5.1.2 Pioneer Canal 2-9
2.5.1.3 Fivemile Creek 2-9
2.5.1.4 Simpson Springs Creek 2-10
2.5.1.5 Harney Creek 2-10
2.5.2 Ground Water Rights 2-10
2.6 Institutional Constraints 2-11
2.6.1 Court Decrees 2-12
2.6.2 Platte River Recovery Implementation Program (PRRIP) 2-13

LIST OF TABLES

Table 2-1 Laramie River at Pioneer Canal One Day Low Flows 2-18
Table 2-2 Well Completion Data 2-19
Table 2-3 Laramie Wells Groundwater Quality Casper Aquifer 2-20
Table 2-4 City of Laramie Surface Water Rights 2-21
Table 2-5 City of Laramie Groundwater Rights 2-22
Table 2-6 City Wellfield Production Compared to SEO Wellfield Production Caps 2-23

LIST OF FIGURES

Figure 2-1 Existing Water Sources 2-24
Figure 2-2 Upper Laramie River Basin 2-25
Figure 2-3a Monthly Mean Streamflow, Laramie River 2-26
Figure 2-3b Monthly Mean Streamflow, Little Laramie River 2-26
Figure 2-4a Laramie R. & Pioneer Canal, N-Day Low Flow Frequency 2-27
Figure 2-4b Laramie R. & Pioneer Canal, 1-Day Low Flow Frequency 2-27
Figure 2-4c Laramie R. & Pioneer Canal, 7-Day Low Flow Frequency 2-27
Figure 2-5 Laramie River Water Quality 2-28
Figure 2-6 Wellfield Details 2-29
Figure 2-7 Wellfield Details 2-30
Figure 2-8 Wellfield Details 2-31
Figure 2-9 Wellfield Details 2-32

CHAPTER 3.0 EXISTING WATER USE

3.1 Introduction 3-1
3.2 Historic Use of Water Supplies to Meet Demand 3-1
3.3 Service Area 3-2
3.4 Population 3-2
3.5 Existing Water Demand – Per Capita Basis 3-2
3.5.1 General 3-2
3.5.2 Average Day Per Capita Water Demand 3-3
3.5.3 Peak Day Per Capita Water Demand 3-3
3.6 Existing Water Demand – Meter Data 3-3
3.7 Unaccounted For Water 3-5

LIST OF TABLES

Table 3-1 Service Area Population Data, Estimates and Projections 3-6
Table 3-2 Water Demand by Season in Gallons Per Capita Per Day 3-7
Table 3-3 July 2005 Water Consumption by Zoning Type 3-8
Table 3-4 Unaccounted for Water Production 3-9
Table 3-5 Distribution of Water Use by Meter Size, July 2005 3-10

LIST OF FIGURES

Figure 3-1 City of Laramie Water Production 1992-2005 3-11
Figure 3-2 Monthly Average Production from Surface Water Treatment Plant 1995-2005 3-12
Figure 3-3 July 2005 Consumption (MGal) by Zoning Type 3-8

CHAPTER 4.0 FUTURE WATER DEMAND

4.1 Introduction 4-1
4.2 Service Area 4-1
4.3 Population Forecast 4-1
4.4 Water Demand Projections for Supply Planning 4-2
4.5 Water Demand Projections for Distribution System Planning 4-2

LIST OF TABLES

Table 4-1 City of Laramie Service Area Projected Water Demand 4-3

LIST OF FIGURES

Figure 4-1 Population Data and Projections 4-4
Figure 4-2 Projected Average Day Demand 4-5
Figure 4-3 Projected Peak Day Demand 4-5

CHAPTER 5.0 SOURCE OF SUPPLY ALTERNATIVES

5.1 Introduction 5-1
5.2 Background 5-1
5.3 Long List of Water Supply Opportunities 5-1
5.4 Feasibility Criteria and Preferred Strategies 5-2
5.4.1 Considerations and Criteria 5-2
5.4.2 Strategies 5-3
5.4.2.1 Strategy 1 Ownership and management control over water supply resources 5-3
5.4.2.2 Strategy 2 Maximize existing water supply assets and resources 5-4
5.4.2.3 Strategy 3 Preserve, protect and build on existing water supply investments 5-5
5.4.2.4 Strategy 4 - New reservoir development options 5-5
5.5 Preferred Water Supply Alternatives 5-6

LIST OF TABLES

Table 5-1 Long List of Water Supply Opportunities (Fassett, 2004) 5-8
Table 5-2 Short List of Water Supply Alternatives (Fassett, 2004) 5-9

LIST OF FIGURES

Figure 5-1 Long List of Potential Water Development Options as Presented by: Fassett, 2004 5-10

CHAPTER 6.0 WATER TREATMENT EVALUATION

6.1 Objective 6-1
6.2 Raw Water Quality 6-1
6.3 Existing WTP Facilities 6-1
6.3.1 Surface Water Treatment Plant 6-1
6.3.2 Groundwater Treatment Facilities 6-3
6.4 Compliance with the SDWA Regulations 6-3
6.4.1 General Discussion 6-3
6.4.2 Surface Water Treatment 6-4
6.4.3 Groundwater Treatment 6-4
6.5 Long-Term Water Treatment Alternative 6-4
6.5.1 General Considerations 6-5
6.5.2 Option A Conventional Treatment with Enhanced Coagulation 6-6
6.5.3 Option B Low Pressure Membrane Treatment with Enhanced Coagulation 6-8
6.5.4 Option C and D Nanofiltration or Reverse Osmosis Membrane Treatment 6-9
6.5.5 Option E, F, and G Low Pressure Membrane Treatment for Groundwater 6-10
6.5.6 General Comparison of Costs for Process Alternatives 6-11
6.6 Costs of Probable Alternatives 6-12
6.6.1 Capital Costs for New WTP Facilities 6-12
6.6.2 Capital Costs for Upgrade of Existing WTP Facilities 6-12
6.7 Conclusions and Recommendations 6-12
6.7.1 Surface Water Treatment Alternatives 6-12
6.7.2 Ground Water Treatment Alternatives 6-13

LIST OF TABLES

Table 6-1 Laramie River Raw Water Quality 6-14
Table 6-2 Laramie Wells Groundwater Quality Casper Aquifer 6-15
Table 6-3 SDWA Regulatory Summary 6-16
Table 6-4 Future Water Treatment Goals for the Laramie Water Treatment Facilities 6-17
Table 6-5 Capital and Operation/Maintenance Cost Comparison 6-18
Table 6-6 Preliminary Estimation of Probably Capital Costs For Possible Future Water Treatment Facilities, Conventional Filtration with Enhanced Coagulation 6-19
Table 6-7 Short Term Improvements for the Existing WTP Facility 6-19

LIST OF FIGURES

Figure 6-1 Laramie Existing WTP Process 6-20
Figure 6-2 Option A – Laramie Water System master Plan Conventional Treatment With Enhanced Coagulation 6-21

Figure 6-3 Option B – Laramie Water System Master Plan Low Pressure Membranes Enhanced Coagulation 6-22
Figure 6-4 Option C – Laramie Water System Master Plan Conventional With Nano/Ro Treatment 6-23
Figure 6-5 Option D – Laramie Water System Master Plan – Membrane W/Nano Or Ro Treatment 6-24
Figure 6-6 Option E, F, & G – Laramie Water System Master Plan Typical Groundwater Treatment System 6-25

CHAPTER 7.0 TRANSMISSION, DISTRIBUTION AND STORAGE SYSTEM

7.1 Introduction 7-1
7.2 Background 7-1
7.3 Exiting System Configuration 7-2
7.4 Existing System Physical Condition 7-3
7.4.1 Transmission Pipelines 7-3
7.4.1.1 36” Raw Water Pipeline 7-3
7.4.1.2 24” Treated Water Pipeline WTP to Hwy 230 Valve Vault 7-6
7.4.1.3 24” Treated Water Hwy 230 Valve Vault to 3oth St. 7-7
7.4.1.4 20” Treated Water WTP to Riverside Drive 7-7
7.4.1.5 20” Treated Water Riverside Drive to Pine Street 7-8
7.4.1.6 16” Pope-Soldier Springs / Pope Springs to Spring Creek 7-8
7.4.1.7 18” Spur Wells to Reynolds St. 7-8
7.4.1.8 10” Airport Hwy 230 to Airport 7-9
7.4.1.9 18” West Laramie Airport Tank to West Laramie 7-10
7.4.1.10 14” Grand Ave. Pipeline 7-10
7.4.1.11 16” Grand Ave. Pipeline 7-11
7.4.2 Distribution System Piping 7-11
7.4.3 Storage Reservoirs 7-12
7.4.3.1 8 MG Reservoir 7-13
7.4.3.2 Zone 2 Tanks (High Level Tanks) 7-14
7.4.3.3 Airport Tank 7-15
7.4.3.4 East Side Tank 7-16
7.4.3.5 South of Laramie Water Tank 7-16
7.4.4 Water Meter Calibration 7-16
7.5 Existing System Hydraulic Performance 7-17
7.5.1 Modeling Summary 7-17
7.5.2 Peak Hour Conditions 7-18
7.5.3 Fire Flow Analysis 7-19
7.5.4 Water Quality Evaluation 7-20
7.5.4.1 Stage 2 Disinfection Byproducts Rule 7-20
7.5.4.2 Water Quality Simulation 7-21
7.6 Future T, D & S System Evaluation 7-22
7.6.1 Planning Discussion 7-22
7.6.2 Future Water Demand 7-23
7.6.3 Future Infrastructure Solutions 7-23

7.6.3.1 Solution to Address Future Peak Hour Demand _____7-24
7.6.3.2 Solution No. 1 to Address Future Fire Flow on Maximum Day Demand _____7-24
7.6.3.4 Solution No. 2 to Address Future Fire Flow on Maximum Day Demand _____7-25
7.6.3.5 Solution No. 3 to Address Future Fire Flow on Maximum Day Demand _____7-26

LIST OF TABLES

Table 7-1 Laramie Transmission Pipelines_____7-28
Table 7-2 Laramie Storage Capacity_____7-29
Table 7-3 Fire Flow Scenario Summary – Existing Condition_____7-30
Table 7-4 Requested Fire Flow Results_____7-31
Table 7-5 City of Laramie AVWater Model Characteristics 2006_____7-32
Table 7-6 Water Demand Allocation for Future Growth Scenario_____7-33

LIST OF FIGURES

Figure 7-1 System Facilities and Pressure Zones_____7-34
Figure 7-2 Laramie Hydraulic Profile Static Condition_____7-35
Figure 7-3 Water Main Break Data_____7-36
Figure 7-4 Curb Pressure, Peak Hour Demand, Existing Conditions_____7-37
Figure 7-5a Fire Flow Analysis, Fire on Maximum Day, Existing Conditions_____7-38
Figure 7-5b Fire Flow Analysis, Fire on Maximum Day, Existing Conditions_____7-39
Figure 7-6 Water Residence Time, Existing Conditions_____7-40
Figure 7-7 Assumed Location of New Future Water Demands_____7-41
Figure 7-8 Basic Improvements, Peak Hour Demand, and Future Conditions_____7-42
Figure 7-9 Solution No. 1, Fire on Maximum Day, Future Conditions_____7-43
Figure 7-10 Solution No. 2, Fire on Maximum Day, Future Conditions_____7-44

CHAPTER 8.0 LARAMIE RIVER PIPELINE

8.1 Introduction _____8-1
8.1.1 Objective _____8-1
8.1.2 Background _____8-1
8.1.3 Previous Studies _____8-2
8.2 Pipeline Design Capacity _____8-3
8.3 Conceptual Design _____8-5
8.3.1 Horizontal Alignment _____8-5
8.3.2 Vertical Alignment _____8-6
8.3.3 Material _____8-6
8.3.4 Existing Utilities _____8-6
8.3.5 Design Survey _____8-6
8.4 Hydraulic Design _____8-7
8.5 Cost Estimate _____8-7

8.6 Easements 8-7
8.7 Permits 8-8
8.8 Project Schedule 8-9
8.9 Additional Conceptual Design 8-9
8.9.1 Move Point of Diversion 8-9
8.9.2 Hydraulic Evaluation 8-10
8.9.3 Cost Estimate 8-10
8.9.4 Feasibility Evaluation 8-11

LIST OF FIGURES

Figure 8-1 Location Map, Laramie River Pipeline 8-12
Figure 8-2a Laramie River Pipeline 8-13
Figure 8-2b Laramie River Pipeline 8-14

CHAPTER 9.0 IRRIGATION WATER

9.1 Introduction 9-1
9.2 Approach 9-1
9.3 Irrigation Water Requirements 9-2
9.4 Irrigation Water Quality 9-2
9.4.1 Surface Water 9-2
9.4.2 Groundwater 9-3
9.5 Surface Water Irrigation Alternatives 9-3
9.5.1 On-Site Storage Options 9-4
9.6 Groundwater Irrigation Alternative 9-5
9.6.1 Hydrogeology of the Forelle Limestone 9-6
9.6.2 Water Development from the Forelle 9-7
9.7 Alternative Evaluation 9-8
9.7.1 Cost Evaluation 9-9
9.7.2 Qualitative Evaluation 9-10
9.7.3 Summary 9-12
9.8 Dual Systems 9-12
9.9 Demand Management 9-13
9.10 Reuse Water 9-13
9.10.1 Quantity 9-13
9.10.2 Quality 9-14

LIST OF TABLES

Table 9-1 Consumptive Irrigation Requirement and Assumed Design Flows 9-15
Table 9-2 Surface Water Irrigation Water Quality 9-16
Table 9-3 Forelle Limestone Water Quality 9-17
Table 9-4 Data from Wells Completed in Forelle Limestone, Vicinity of Laramie 9-18
Table 9-5 Financial Comparison of Irrigation Alternatives 9-19

Table 9-6 Water and Wastewater Production and Groundwater Return Flow Estimates 9-20

LIST OF FIGURES

Figure 9-1 Raw Water Irrigation Surface Water Facilities 9-21
Figure 9-2 Groundwater Irrigation Forelle Limestone 9-22
Figure 9-3 Water and Wastewater Production, and GW Return Flow Estimates 9-23

CHAPTER 10.0 DEVELOPMENT AND MANAGEMENT OF THE CASPER AQUIFER

10.1 Objective 10-1
10.2 Hydrogeology of the Casper Aquifer 10-1
10.2.1 Casper Aquifer Recharge 10-4
10.2.1.1 Field Observations 10-5
10.2.1.2 Well Hydrographs 10-5
10.2.1.3 Pump Test at the Brow #2 Well 10-6
10.2.1.4 Precipitation 10-7
10.2.1.5 Aquifer Recharge Dynamics 10-8
10.2.2 Hydraulic Role of Geologic Structures 10-8
10.3 Present Day Hydrologic Conditions in the Casper Aquifer 10-9
10.4 Turner Wellfield (City Springs) 10-11
10.4.1 Capture of City Springs Discharge by the Turner Wells 10-12
10.4.2 Performance Testing of the Turner Wells 10-15
10.4.3 Potential Conflicts with Proposed Groundwater Development(s) 10-17
10.5 Spur Wellfield 10-20
10.6 Pope Wellfield and Soldier Springs 10-24
10.7 Casper Aquifer Storage and Recovery 10-25
10.8 Groundwater Development of the Casper Aquifer 10-29
10.8.1 Safe Yield Concept 10-30
10.8.2 Groundwater Development Prospects 10-31
10.8.2.1 Turner Wellfield and Spur Wellfield 10-32
10.8.2.2 Simpson Springs 10-32
10.8.2.3 Laramie Fault 10-34
10.9 Casper Aquifer Protection Plan 10-35
10.10 Casper Aquifer Monitoring Program 10-37
10.11 Groundwater Under the Direct Influence of Surface Water 10-39
10.11.1 GWUDISW Evaluation Process 10-40
10.11.2 GWUDISW Study at Soldier Springs 10-41
10.11.3 Future Assessment of GWUDISW at City Wellfields 10-41
10.12 Summary of Casper Aquifer Development and Management 10-43

LIST OF TABLES

Table 10-1 Production and Drawdown Characteristics of Municipal Production wells 10-45
Table 10-2 Depth to Water and Head Elevations at Wells Completed in Casper Aquifer; Lundy 1976-77 and Taboga 2005 10-46
Table 10-3 Completion Data for the Turner Wells 10-47
Table 10-4 Spur Wellfield Agreement Drawdown/Production Specifications And Water Level Monitoring 10-48
Table 10-5 Water Levels at Soldier Springs Monitoring Wells Completed in Casper Aquifer 10-49
Table 10-6 Water Quality of Injection Water (IW) and Receiving Aquifer (RA) 10-50
Table 10-7 Casper Aquifer Monitoring Program Wells and Water Quality Parameters 10-51
Table 10-8 Monitoring Wells Owned by City of Laramie 10-52
Table 10-9 Results of Microscopic Particulate Analysis (MPA) at City Wellfields 10-53

LIST OF FIGURES

Figure 10-1 Huntoon #1 Monitoring Well Hydrograph, 1977-2005 10-54
Figure 10-2 Huntoon #1 Monitoring Well Hydrograph, 1997-2005 10-55
Figure 10-3 Difference from Mean March + April Precipitation, Laramie FAA Airport (485415) Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-56
Figure 10-4 Location of Proposed Shallow Wells at City Springs 10-57
Figure 10-5 Annual Production Rate from the Turner Wellfield-1983 to 2005 Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-58
Figure 10-6 Cross-Section A-A 10-59
Figure 10-7 Design of Proposed Wells at City Springs 10-60
Figure 10-8 Comparison of Drawdown Curves at Turner No.1 and Turner No.2 Wells 1995 Turner No.1/No.2 Test and 2005 Turner No.1/No. 2 Test 10-61
Figure 10-9 Time-Drawdown at Observation Well 41T3, September 27 to October 4, 2005, Pump Test Turner No.1 and Turner No.2, Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-62
Figure 10-10 Proposed Red Jacoby Golf Course Expansion 10-63
Figure 10-11 Total Monthly Production From Spur Wellfield-2001 to 2005. Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-64
Figure 10-12 Hydrograph of Spur MW-7,9/1999 to 6/2006 Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-65
Figure 10-13 Combined Annual Production From Pope and Soldier Wellfields-1983-2005. Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-66
Figure 10-14 ASR Conceptual Design 10-67

Figure 10-15 ASR Conceptual Design 10-68
Figure 10-16 Annual Wellfield Production-1983-2005. Laramie Water Management Study, Level II, Wyoming Water Development Commission 10-69

CHAPTER 11.0 WATER SUPPLY ELEMENT

11.1 Introduction 11-1
11.2 Water Supply Capabilities 11-1
11.3 Water Supply Development Plan 11-1
11.4 Water Supply Element 11-3
11.5 Environmental Report 11-3

LIST OF TABLES

Table 11-1 Summary of Water Supply Capability 11-4
Table 11-2 Water Supply Development and Protection Plan Summary 11-5
Table 11-3 Summary of Capital Improvements for the Water Supply Element of the Water System Master Plan 11-6

CHAPTER 12.0 TRANSMISSION, DISTRIBUTION AND STORAGE ELEMENT

12.1 Introduction 12-1
12.2 TD&S Element Plan 12-1

LIST OF TABLES

Table 12-1 Summary of Capital Improvements for the Transmission, Distribution and Storage Element of the Water System Master Plan 12-2

CHAPTER 13.0 OPERATIONS ELEMENT

13.1 Introduction 13-1
13.2 Definition 13-1
13.3 QualServe Introduction 13-1
13.4 QualServe Factors 13-3
13.4.1 Risk Management Planning 13-3
13.4.2 Training Hours per Employee 13-3
13.4.3 Customer Accounts per Employee 13-4
13.4.4 Disruption of Water Service Rate per 1,000 Customers 13-4
13.4.5 Debt Ratio 13-4
13.4.6 System Renewal / Replacement Ratio (%) 13-5
13.4.7 Return on Assets 13-6
13.4.8 Water Distribution System Integrity 13-7
13.4.9 Operation & Maintenance Cost Ratios 13-7
13.5 Summary 13-8

LIST OF TABLES

Table 13-1 Summary of Annual Costs for the Operations Element of the Water System Master Plan 13-9

CHAPTER 14.0 WATER SYSTEM MASTER PLAN

14.1 Introduction 14-1
14.2 Water System Master Plan Tool 14-2
14.3 Scenarios and Strategies 14-3
14.3.1 Scenario A: All Improvements and Full Growth 14-3
14.3.2 Scenario B: All Improvements, No Growth, No Supply Development 14-3
14.3.3 Scenario C: Exclude Lower Priority Projects 14-3
14.3.4 Scenario D: Conservation – No Supply Development 14-4
14.3.5 Scenario E: Addition of Groundwater Treatment, if required 14-4
14.4 Summary 14-4

LIST OF TABLES

Table 14-1 Summary of Rate Structure and Master Water System Plan Scenarios (Dollars) 14-5
Table 14-2 Ranking of Water Rates in Various Locations in Wyoming 14-6

LIST OF FIGURES

Figure 14-1 Water System Master Plan Schematic 14-7

CHAPTER 15.0 RECOMMENDATIONS

15.1 Recommendations 15-1

REFERENCES CITED R-1

LIST OF PLATES

Plate 10-1 Geologic Map with Well Locations
Plate 10-2 Potentiometer Surface Map of Casper Aquifer, Nov. 2005

LIST OF APPENDICES – SEE VOLUME II OF II

3A Water Production Data
5A Cost Estimates
6A Summary of SDWA Regulations
6B Cost Estimates

7A Cathodic Protection 20/24 Inch Transmission
7B Water Main Failure Information
7C Cost Estimates
7D Meter Replacement Designs and Costs
7E Distribution System Hydraulic Evaluation
8A Cost Estimates1
9A Irrigation Audits
9B Cost Estimates and Conceptual Design Information
9C Demand Management
10A Misc. Documents
10B Karl Taboga Research Summary
10C Monitoring Well Hydrographs
10D Cost Estimates
11A Environmental Report
14A City Budget Sheets
14B Water System Master Plan Worksheets

ES
EXECUTIVE SUMMARY

EXECUTIVE SUMMARY
LARAMIE WATER MANAGEMENT PLAN, LEVEL II

August 25, 2006

Submitted to:

Wyoming Water Development Commission
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I, Murray T. Schroeder, a Wyoming registered Professional Engineer, certify that this Laramie Water Management Plan, Level II report was prepared by me or under my direct supervision.

Professional Engineer (Civil)
MURRAY T. SCHROEDER
6820
Date 8-25-06
WYOMING

Murray T. Schroeder

I, Christopher Moody, a Wyoming registered Professional Geologist, certify that this Laramie Water Management Plan, Level II report was prepared by me or under my direct supervision.

PROFESSIONAL GEOLOGIST
CHRISTOPHER G. MOODY
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Christopher Moody

EXECUTIVE SUMMARY

ES.1 Introduction

The City of Laramie has completed the Laramie Water Management Plan, Level II funded by the Wyoming Water Development Commission. The general objectives of the project included:

- Prepare a preliminary design and cost estimate for the Laramie River Pipeline. This pipeline would bring water from the Laramie River to the existing water treatment plant southeast of the City. The justification for this project had been documented in previous planning studies, but the concept was lacking a design and cost estimate suitable for WWDC Level III funding.
- Investigate the feasibility of controlling spring discharges in the City Springs (Turner Wells) area to provide additional water supply to the City and to protect water quality. This concept had been presented in previous planning studies, but had not been developed.
- Investigate the feasibility of constructing a non-potable irrigation water system to water large green spaces in the City. This concept had also been examined in previous planning studies, but the cost of irrigating with non-potable water had never been directly compared to the cost of continuing to irrigate with potable water.
- Prepare a Water System Master Plan that addresses the comprehensive water system needs of the City including water supply development to meet increased demands, to correct internal distribution system deficiencies, and to improve operational performance.

ES.2 Laramie River Pipeline

The City diverts water into the Pioneer Canal for delivery to Sodergreen Reservoir, about 18 miles southwest of the City. The canal is about 2.5 miles long. Next, an existing pipeline transmits water from Sodergreen Reservoir to the City water treatment plant. Canal seepage loss does not allow the City to use their entire permitted water right. During periods

of drought and despite having the Number 1 priority water right in the river, diverted water does not make it to the water treatment plant. This was experienced in 2002.

The Laramie River Pipeline would eliminate seepage losses and provide supply reliability during drought like conditions. A conceptual design of the pipeline is presented on Figure ES1. A total project cost estimate for this pipeline project is $7,700,000. This project is recommended for final design and construction as a priority capital project.

ES.3 Turner Wellfield Modifications

The exiting Turner wells do not capture and control all of the natural discharge from City Springs. Having the capability to capture and control all of the natural discharge from City Springs would provide assurance of safe water quality and make full use of the City's water rights.

A conceptual design was developed to install three shallow wells close to City Springs to enhance the collection of spring discharge. Figure ES-3 shows the location of proposed wells. Each well would have a design capacity of approximately 500 gpm. The shallow wells would be operated continuously at rates needed to maintain the head in the Casper Aquifer below the existing Springbox collection system. Pumped water would be treated and piped into the City Zone 1 Reservoir. When municipal demand is low, the water may be re-injected into the Casper Aquifer at the Spur Wellfield via a Casper Aquifer Storage and Retrieval system. The Turner Wellfield improvements and Aquifer Storage and Retrieval projects have a total project cost estimate of $3,630,000. The City should pursue a WWDC Level II study that includes test well work in the Turner area and a pilot test of the aquifer storage project.

ES.4 Irrigation Water Alternatives

Large green space irrigation of parks and athletic fields, as shown in Figure ES-3, could be achieved with several water resources. The objective of the evaluation of irrigation alternatives was to determine which of the following practices is best:

- Alternative No. 1 - Potable Water. Continue, as past and current practice, to irrigate large green spaces using treated municipal water.

- Alternative No. 2 – River Water. Transfer a portion of the irrigation water rights off the Monolith Ranch to points of use within the City. Water from the Monolith Ranch would flow downstream in the Laramie River and would then be pumped from the river and distributed in a piping and storage system separate from the treated water distribution system.
- Alternative No. 3 – Groundwater. Make use of groundwater supplies from the Forelle Limestone Aquifer. Wells would be located at individual green spaces and supply water to those areas.
- Reuse water. Use of wastewater effluent was evaluated, but not in depth. Estimates of the available water reuse water supply were prepared.

The evaluation considered the capital and operational costs of each alternative and intangible factors. Irrigation with groundwater was found to be about $752/acre/year and irrigation with potable water was found to be about $800/acre/year. Based on 280 acres of parks that could potentially be irrigated with groundwater, this difference translates to about $13,500/year. On the other hand, the water quality benefits of using potable water in the distribution system are critically important. The additional irrigation water circulating through the distribution system (Alternative 1) promotes better drinking water quality by providing a lower water age. The City water distribution system presently has borderline water quality concerns with respect to disinfection by products (not in violation of standards), and the additional "circulation" is beneficial. The City should continue to irrigate with potable water.

ES.5 Transmission Distribution and Storage System

The study included an evaluation of the City's water transmission, distribution, and storage (TD&S) system. In addition, projects were described that would correct system deficiencies. Figure ES-4 is a system schematic. The findings of this evaluation include:

Transmission Pipeline Condition. All transmission pipelines are in good condition. Recent cathodic protection projects and transmission line replacement projects have extended the life of these lines many years.

Water Storage Tanks. All of Laramie's water storage tanks are of adequate size and physical condition to meet the needs of the City for several years.

Large Water Meters. New large water meters are required at five of the City's water production facilities. A project cost estimate to provide these meters is $134,000.

Distribution System Piping - Condition

The condition of the existing distribution system piping is poor, especially in the older pressure Zones 1 and 2. Cast iron pipelines in these zones are damaged from the effects of soil corrosion. The water main failure rate is about three times the rate of similar municipalities. Water main replacement costs were estimated at:

Priority No. 1 Mains (35,000 lf) - $ 5,060,000
Priority No. 2 Mains (72,200 lf) - $10,900,000
Priority No. 3 Mains (94,500 lf) - $13,800,000

Distribution System Piping - Capacity

The hydraulic performance of the water distribution system is projected to be adequate in the eastern and western portions of the city (Pressure zone 3,4,6 and 7) even with modest City growth. This positive finding is because the City has invested in several water systems infrastructure projects since the mid 1990's, including the West Laramie Tank and the East Side Tank Projects.

The hydraulic performance of the water distribution system in Zones 1 and 2 has several deficiencies under current conditions and is projected to have further problems under conditions of modest City growth. Planning level conceptual designs and cost estimates were prepared for projects that would correct these deficiencies and they include the following:

Peak Hour Service Pressure Upgrades	$15,200,000
Fire Suppression Upgrades	$9,000,000

The fire suppression upgrades require that the peak hour service pressure upgrades have been made. Both of these projects include water storage tank construction, transmission, line construction, and the replacement of small water mains.

ES.6 Water Supply Master Plan

A Water System Master Plan was prepared to help guide decisions regarding capital, operational and financing needs. Figure ES-5 presents the organization of the Water System Master Plan. The Plan addresses four basic elements of the water supply system, including Water Supply; the Transmission, Distribution, and Storage System; Operations and Revenues. The Elements of the Water System Master plan were evaluated with a simple financial accounting model to estimate the approximate revenue structure that must be in place to recover the costs for operating the water utility for a 20-year planning period. The evaluation considered the cost to fund the projects presented earlier in this summary as well as other projects and operational costs. Rate structures were estimated for several different planning scenarios including ones that assumed:

- municipal growth as projected by the Comprehensive Plan,
- no municipal growth,
- Conservation induced decreased water sales,
- and the effect of treating the groundwater supplies due to groundwater contamination,

The planning work provided the following important findings:

- Future water rate increases should track inflationary increases.
- Even with inflationary increases in the water rate structure, the planning work estimated that about $3,000,000 per year of additional income would be needed to correct system deficiencies regardless of the planning scenario. This required revenue stream was based on favorable grant funding assumptions.
- Laramie water rates are high relative to other Wyoming municipalities. Therefore, the City should pursue revenue sources such as a capital facilities tax.

ES.7 Recommendations

1. Obtain a resolution from the City Council that supports a comprehensive water system master plan and financing structure to correct existing water infrastructure deficiencies, to provide supplies for growing demand, and to support economic development. Key to that plan is a commitment to water rate increases that follow inflation.

2. Apply for a WWDC Level II Study grant from the WWDC to perform field investigations and additional analysis for the objective of controlling spring discharge at the City Springs and to field test the feasibility of an aquifer storage and recovery program in the Spur Wellfield.

3. Apply for a WWDC Level II Study grant from the WWDC to check all GIS data in the City water main database. The study program should include the collection of sufficient system monitoring data such that hydraulic model calibration can be performed.

4. Apply for a WWDC Level III grant to begin the final design and construction of the Laramie River Pipeline.

5. Implement the Casper Aquifer Protection Plan and enforce aquifer protection ordinance. Continue participation with the Environmental Advisory Committee, the WDEQ, the County, and University of Wyoming to facilitate CAPP support and enforcement.

6. Continue to implement and develop monitoring programs in the Casper Aquifer. Either hire a staff person or a local consultant to perform annual data collection and reporting for this program.

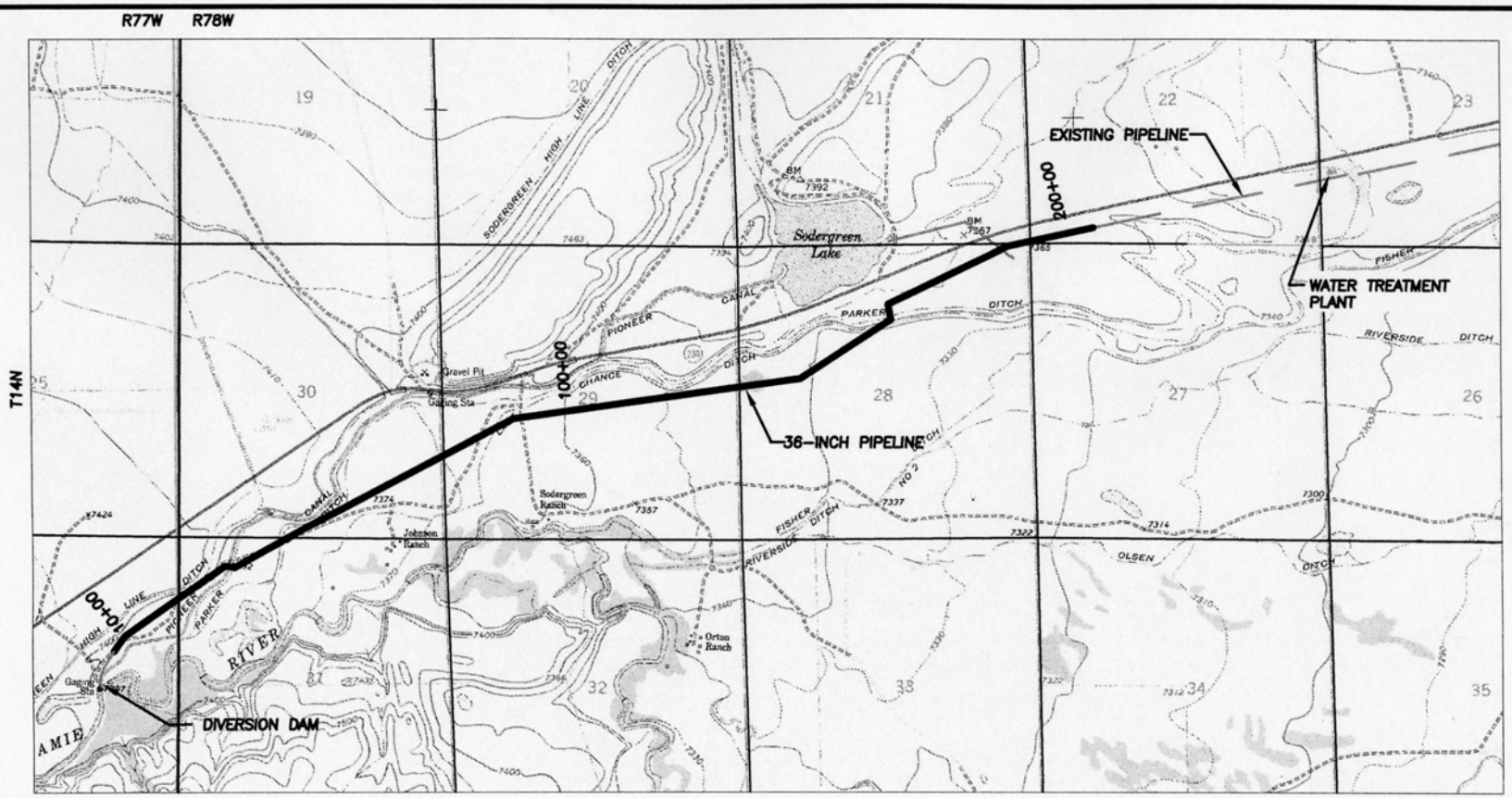
7. The City should request that the Laramie Economic Development Corporation market the fact that the City of Laramie has the potential water supply capacity to

support businesses that need large amounts of water. The City has water to sell and needs revenue to support the water enterprise fund. A specific volume or rate of water and the value of that water remains to be determined. A water marketing study should be performed.

8. The City should define a water treatment contingency plan that will provide immediate supply relief if the Casper Aquifer supplies do not meet federal drinking water standards, from either contamination or changing regulations.

9. The City should approach the senior water right holder west of the present Laramie River point of diversion to see if they are willing to sell the water right and or the land at a fair market value.

10. At this time the City should continue to irrigate large green spaces with treated potable water.



LOCATION MAP

ES–1

LOCATION MAP
LARAMIE RIVER PIPELINE

LARAMIE WATER MANAGEMENT PROJECT, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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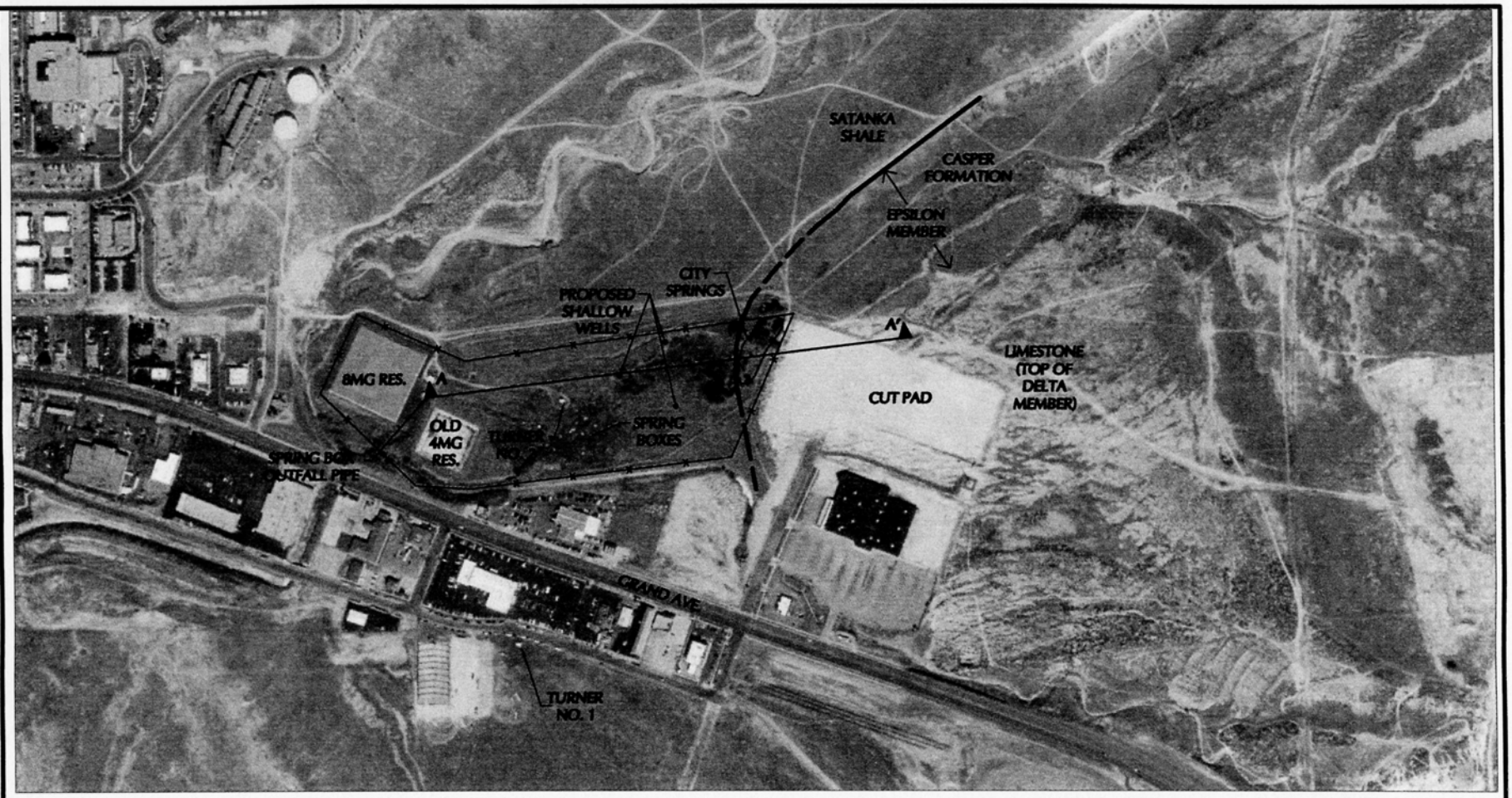

0 600'
SCALE

ES-2
Location of Proposed Shallow Wells at City Springs

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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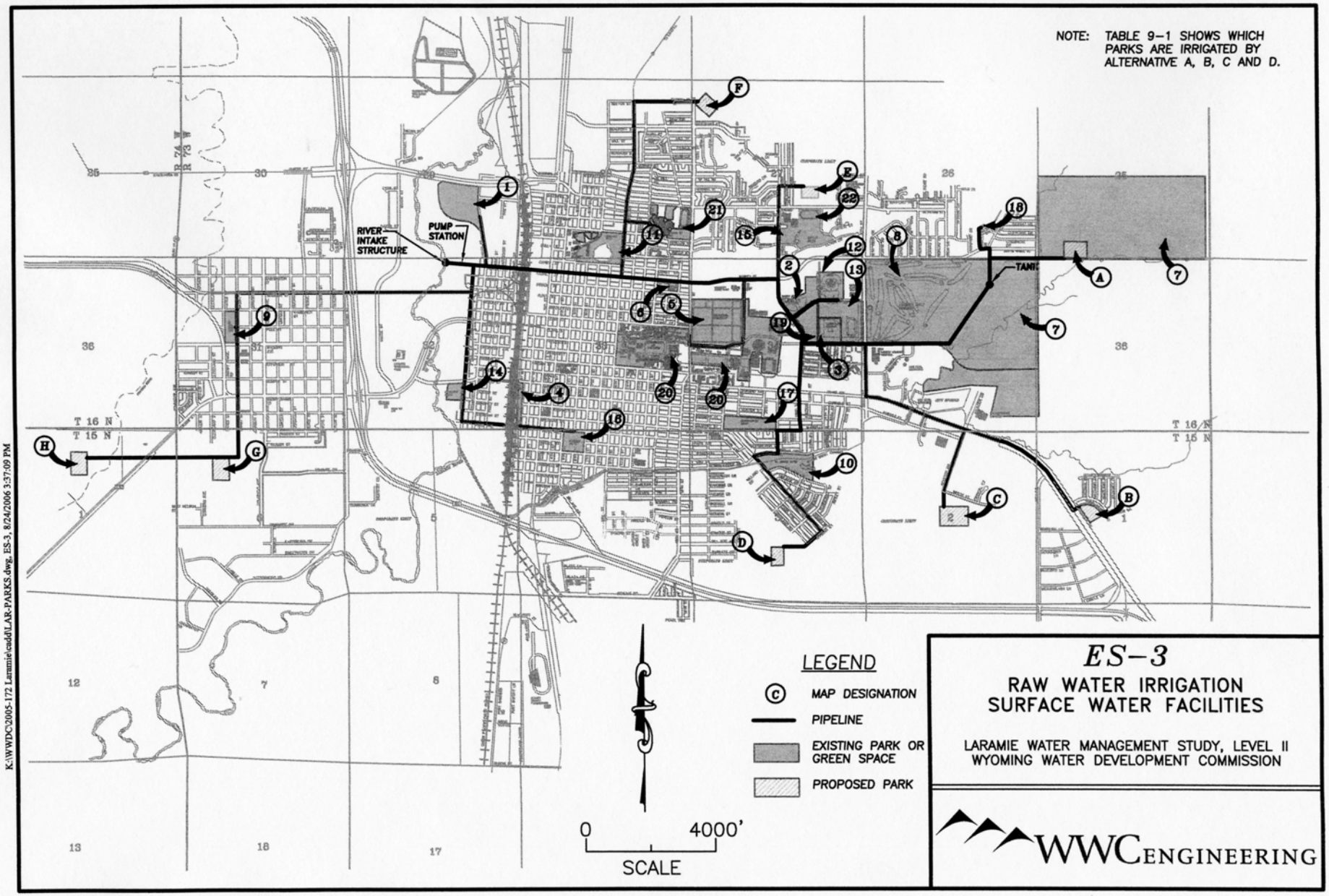

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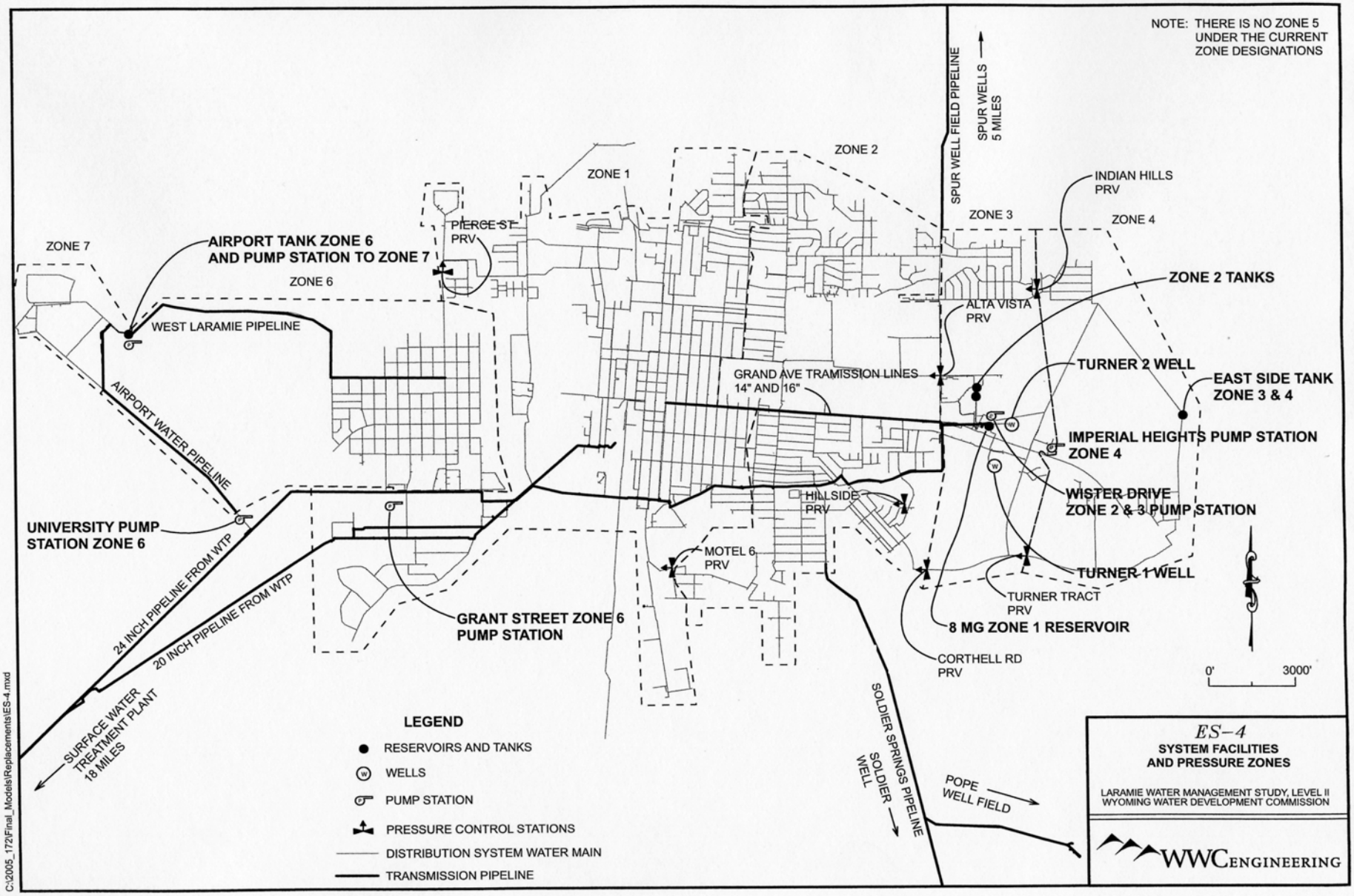
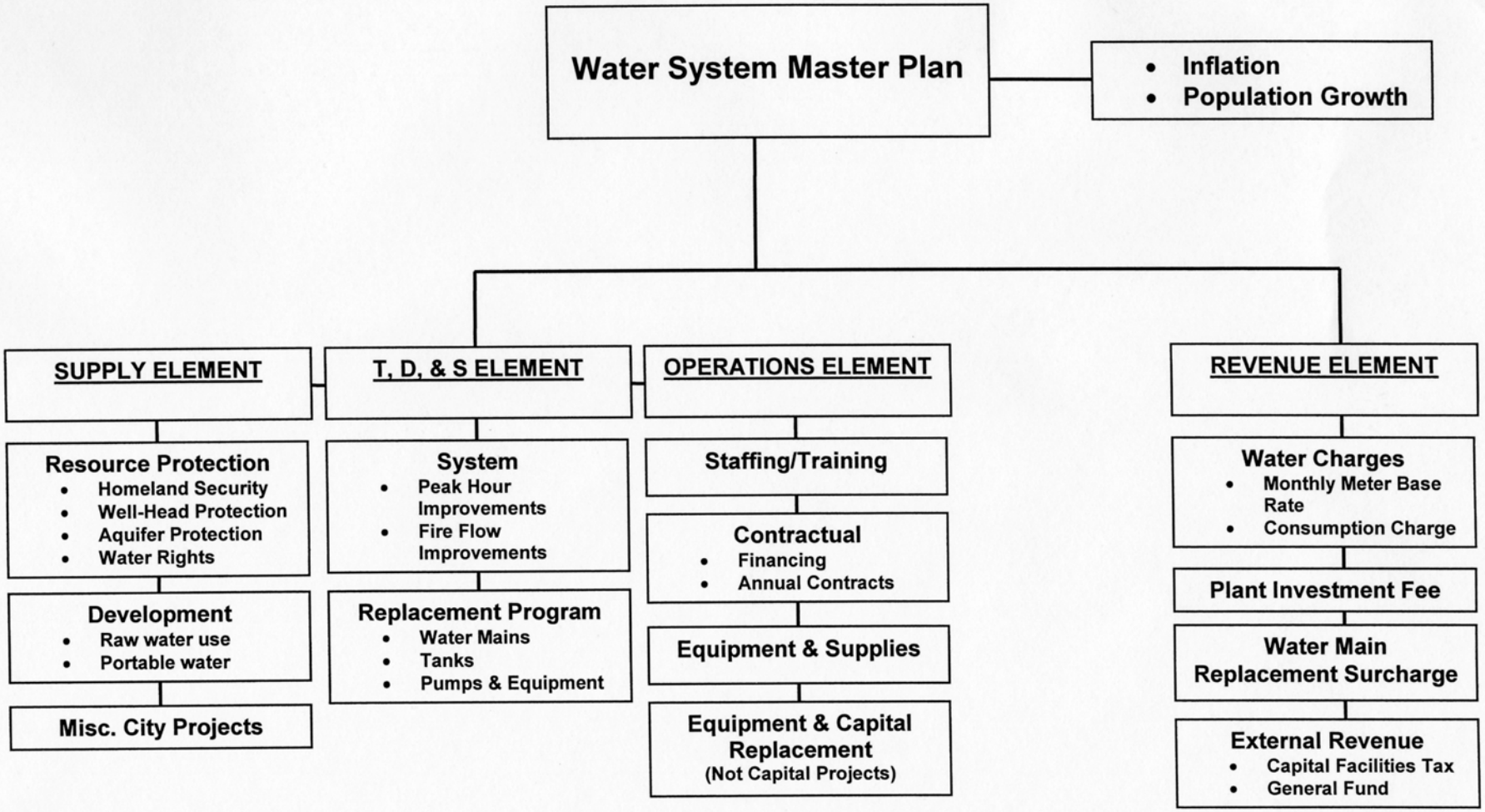

NOTE: THERE IS NO ZONE 5 UNDER THE CURRENT ZONE DESIGNATIONS
ZONE 7
ZONE 6
ZONE 1
ZONE 2
ZONE 3
ZONE 4
AIRPORT TANK ZONE 6 AND PUMP STATION TO ZONE 7
PIERCE ST PRV
WEST LARAMIE PIPELINE
AIRPORT WATER PIPELINE
UNIVERSITY PUMP STATION ZONE 6
24 INCH PIPELINE FROM WTP
20 INCH PIPELINE FROM WTP
SURFACE WATER TREATMENT PLANT 18 MILES
GRANT STREET ZONE 6 PUMP STATION
MOTEL 6 PRV
HILLSIDE PRV
GRAND AVE TRAMISSION LINES 14" AND 16"
SPUR WELL FIELD PIPELINE
SPUR WELLS 5 MILES
INDIAN HILLS PRV
ALTA VISTA PRV
ZONE 2 TANKS
TURNER 2 WELL
EAST SIDE TANK ZONE 3 & 4
IMPERIAL HEIGHTS PUMP STATION ZONE 4
WISTER DRIVE ZONE 2 & 3 PUMP STATION
TURNER 1 WELL
TURNER TRACT PRV
8 MG ZONE 1 RESERVOIR
CORTHELL RD PRV
SOLDIER SPRINGS PIPELINE
SOLDIER WELL
POPE WELL FIELD
0'
3000'
LEGEND
RESERVOIRS AND TANKS
WELLS
PUMP STATION
PRESSURE CONTROL STATIONS
DISTRIBUTION SYSTEM WATER MAIN
TRANSMISSION PIPELINE
ES-4
SYSTEM FACILITIES AND PRESSURE ZONES
LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION
WWC ENGINEERING
C:\2005_172\Final_Models\Replacements\ES-4.mxd

ES-5 Water System Master Plan Schematic



CHAPTER 1.0
INTRODUCTION

1.0 INTRODUCTION

1.1 Introduction

In 2004, the City of Laramie completed the "Monolith Ranch Water Rights Management Plan" (MRWRMP) (Fassett, 2004). The focus of that project was to prepare specific recommendations for managing the water rights of the City, especially for the Monolith Ranch water assets. A prerequisite exercise in the development of those recommendations was to review historic municipal water demands, to project future use, and to evaluate water supply alternatives that could be implemented to meet future demands. Naturally, the recommendations for ranch water rights management were contingent on which of the water resources the City would likely turn to as demand increased in the future.

As an important work product, the MRWRMP presented a Water Supply Development and Protection Plan. This Plan presented a 30 year time line for the development of water supplies to meet planning horizon water demands and to protect related water rights. Each water development project also included a list of action items and costs that were required in addition to the capital cost of the project.

In the fall of 2004 the City applied to the Wyoming Water Development Commission to complete a more detailed set of investigations and evaluate the feasibility of three water supply projects identified in the Water Supply Development and Protection Plan. Additional study was necessary for two reasons. One, the cost estimate for the Laramie River Pipeline presented by Fassett was originally estimated in a previous planning study (WWC, 1995). This estimate had been updated to 2004 using a cost inflation index. Given recent construction cost escalation factors, the WWDC program was not willing to use that cost estimate as a basis for Level III funding. The second reason to re-examine these projects was that two of the water development alternatives were only at a Level I feasibility level. The alternatives for irrigating parks with raw water and the ideas of developing more water at the Turner wells were in their infancy.

1.2 Objectives

The objectives of this Laramie Water Management Plan, Level II, include:

- Prepare a preliminary design for a Pipeline from the Laramie River to the water treatment plant, complete with a modern cost estimate.
- Investigate the feasibility of controlling spring discharges in the City Springs (Turner Wells) area to provide additional water supply to the City and to protect water quality.
- Investigate the feasibility of constructing a non-potable irrigation water system to water large green spaces in the City.
- Prepare a Water System Master Plan that addresses the comprehensive water system needs of the City including water supply development to meet increased demands, to correct internal distribution system deficiencies, and to improve operational performance.

1.3 Report Summary

The following report is organized similarly to previous water system investigations of the City. The initial chapters (2, 3, and 4) focus on the water supplies: their availability, current use, and future need. Chapter 5 addresses the water supply opportunities that are under consideration for meeting future needs. Chapter 6 and 7 present the results of an investigation into the water treatment operation and the existing water transmission, storage, and distribution system. Chapters 8, 9, and 10 present detailed analyses of the water supply alternatives that were identified for further study, as explained in the Introduction (River Pipeline, Irrigation Water, and Turner Wells). And finally, Chapters 11, 12, 13, and 14 present a comprehensive Water System Master Plan. This Plan is a recommended approach and schedule for constructing needed improvements and financing those improvements for a 20-year planning horizon.

CHAPTER 2.0
EXISTING WATER SUPPLIES

2.0 EXISTING WATER SUPPLIES

2.1 Introduction

The purpose of this chapter is two-fold. First, the chapter presents a brief historical perspective of water supply development for the City. Second, the remainder of the chapter provides the following information regarding both the surface and groundwater resources:

- Physical availability and reliability
- Quality
- Water Rights
- Institutional Constraints

2.2 Water Supply Development History

The City of Laramie obtains water from two sources: the Casper Aquifer and the Laramie River. Figure 2-1 is a map showing the location of the City's existing water sources. The conjunctive use of these two sources has allowed the City great flexibility to meet its municipal water demands.

Water development for the City of Laramie has evolved through three distinct phases. The first phase, from 1868 to about 1940, relied on the natural discharge from three springs, City Springs, Pope Springs, and Soldier Springs, that discharged water from the Casper Aquifer. This spring collection system could provide only what the aquifer offered by way of natural discharge from the springs. With the installation of the Pope Wells in 1937-39, the City began to use the storage capacity of the Casper Aquifer to meet its water requirements.

The second phase began in 1940 with the acquisition and use of water rights on the Laramie River. The City purchased water rights from three holders of the Dowlin Ditch, the first priority on the Laramie River. In 1945, the City proceeded with a water right transfer of 10 cubic fee per second (cfs) from the Dowlin Ditch to the Pioneer Canal for municipal use and the Board of Control approved this change of use of water rights. In 1947, the City constructed a 20-inch diameter pipeline from Sodergreen Reservoir to carry the water to the City. At that time, Laramie River water was to be used for railroad purposes, lawn irrigation at the Cemetery, and on part of the University campus. Because the City made Laramie River water available to the Union Pacific Railroad, the UPRR exchanged their surface water

right at City Springs for municipal purposes. In 1953, municipal demands had grown to the extent that the City chose to treat some of the Laramie River water for use in the municipal system. A water treatment plant was constructed at the intersection of Garfield and Pine streets for this purpose.

In 1963, the City again petitioned the Board of Control to change an additional 4.3713 cfs of Dowlin Ditch water rights to municipal purposes. The Board allowed the transfer of only 4.3113 cfs when it was discovered that the City had not acquired 0.06 cfs attached to 9.62 acres owned by the Laramie Valley Railroad Company. With the 1964 transfer, the City has the right to divert from the Laramie River at the Pioneer Canal headgate 14.3113 cfs (9.25 mgd). The City then constructed a water treatment plant near Sodergreen Reservoir with a rated capacity of 6.0 million gallons per day (mgd) and added a 24-inch pipeline to bring treated water to the City.

In 1981, the City purchased the Monolith Ranch and its associated water rights, including an additional portion of the Dowlin Ditch right amounting to 20.1 cfs. No portion of the water rights associated with the 1981 purchase has been transferred to municipal purposes. With the acquisition of Laramie River water rights and the construction of surface water transmission and treatment facilities, the City had developed conjunctive surface water and groundwater supply systems and also continued to aggressively pursue the development of groundwater.

The third phase, from 1981 to the present, involved development of groundwater resources. In 1982, the City drilled a fourth well at the Pope Wellfield (Pope No. 4) and installed two wells (Turner No. 1 and No. 2) near City Springs to allow capture of the natural discharge from better control the flow of the springs. Other studies and investigations continued through the decade and in 1991, the surface water right for City Springs was transferred to the Turner No. 2 well. In 1998, a well was drilled at Soldier Springs and the City's Soldier Spring surface water rights were transferred to the Soldier No. 1 well later that year. In 2000, the Spur Wellfield area was developed with the installation and drilling of two wells (Spur No. 1 and No. 2) 6 miles north of Laramie. The development of wellfields at the major springs at the base of the Laramie Range provides the City the opportunity to take advantage of the storage characteristics of the Casper Aquifer.

2.3 Surface Water

This section presents a discussion of the City's surface water resources, including a presentation of general stream flow hydrology in the Upper Laramie basin, and a discussion of a low flow frequency analysis on Laramie River.

The City of Laramie obtains a significant portion of its water supply from the Laramie River, the primary stream in the Upper Laramie River Basin. The City diverts water at the Pioneer Canal Enlargement headwork's about 24 miles west of the City. Water is metered in a City metering facility before being conveyed to Sodergreen Reservoir in the Pioneer Canal Enlargement. Water from this re-regulating reservoir is then transmitted to the City's water treatment plant, treated, and conveyed to the City in two gravity flow pipelines. These facilities are generally shown in Figure 2-1 and in more detail on Figure 8-1. Detailed discussion of these facilities can be obtained in Banner (1983) and WWC (1995).

2.3.1 Availability and Reliability

Figure 2-2 depicts the boundary of the Upper Laramie River Basin. The hydrology and water use in the basin has been examined in several previous studies, including States West Water Resources (1991) and WWC (1993). The following discussion of stream flow hydrology is presented as general background information on basin water resources. This discussion should provide the reader an appreciation for the City's relatively strong priority position for the use of surface water within the basin.

Figure 2-2 also presents summary information on the primary surface water streamflow measuring stations within the basin. The data from these USGS stations are often used in evaluations regarding basin water resources. The Wyoming State Engineer's Office also collects hydrologic data in the basin, primarily canal diversion and reservoir storage records.

Mountain snowpack melt is the principal contributor to streamflows in the Upper Laramie River Basin, while the plains areas contribute limited runoff. Hydrographs of mean monthly stream flow for key locations along the Laramie and Little Laramie Rivers are shown in Figures 2-3A and 2-3B.

2.3.2 Low-Flow Frequency Analysis

As part of the Monolith Ranch Water Rights Management Plan (MRWRMP) (Fassett, 2004), a low flow frequency analysis was performed on the available Laramie River streamflow records. The reader is referred to that report for a detailed presentation of the data and methods. The results of that work, as presented below, offer insight into the reliability of this surface water supply.

The analysis was performed on data from 1912 through 2002 for the USGS gaging station at the Laramie River and Pioneer Canal. This flow gaging location is directly reflective of the water supply source for the current municipal diversion to the City's water treatment plant.

Figure 2-4a is a plot of the low flow frequency relationships estimated for the May 5 to September 30 data set. This figure shows that Laramie River flows are infrequently below 10 cfs, with statistically about a 100-year return interval. The following is a list of flow rates to consider when examining this figure:

<u>14.31 cfs.</u> This is the current municipal diversion water right. This equates to 12.16 cfs, at Sodergreen Reservoir after the Pioneer Canal Lake Hattie Irrigation District (PCLHID) has assessed a 15% canal conveyance loss (The agreed loss rate is 20% when there is less than 40 cfs in the canal). The City has indicated that this conveyance loss is physically much higher during periods when only the City is diverting water and trying to deliver it down the Pioneer Canal Enlargement. Figure 2-4a indicates that the Laramie River 1-day low flow drops below 14.31 cfs with a recurrence interval of 20 years.

<u>24.31 cfs.</u> The probable maximum future river utilization by the City can be estimated as the sum of the 14.31 cfs existing diversion and assuming another 10 cfs resulting from a future transfer of Dowlin Ditch water rights. This value is based on the assumption that there is no 15% conveyance loss assessment by the PCLHID. This loss assumption is realistic if the City constructs a pipeline from the diversion location to the water treatment plant. Figure 2-4a indicates that the 1-day low flow drops below 24.31 cfs with a recurrence interval of about 5 years.

10 cfs. Previous planning efforts (WWC, 1998) have mentioned 10 cfs as a "good neighbor" instream flow amount for river and fishery maintenance. The diversion dam for the Pioneer Canal and City of Laramie headgates was constructed to pass approximately 10 cfs downstream through a low flow notch in the crest. Although this by-pass flow is not legally required, when water supply and municipal demands allow for flexibility, the City should consider providing this voluntary maintenance by-pass flow amount.

Figures 2-4b and 2-4c present low flow frequency relationships estimated for each month. Figure 2-4b is for the 1-day low flow and Figure 2-4c is for the 7-day low flow. Both figures demonstrate that extreme low streamflows become progressively worse as the summer advances from June through September. However, even though September low streamflows are the lowest, peak City demands are waning in September. This data also shows the reliability of the surface water supply system for the City of Laramie under very extreme conditions. As indicated on Figure 2-4c the probability of a 7-day low flow in August of 14.31 cfs is about a one in fifty year event. This level of reliability is excellent. If the event were to happen, a combination of aggressive groundwater use and water conservation should be sufficient.

The low-flow frequency analysis suggests that the drought of 2002 was extreme when compared to other dry years. Table 2-1 presents the 10 lowest one-day low flows for the period of record.

2.3.3 Water Quality

The Laramie River was sampled at five different locations by the Laramie Rivers Conservation District on November 2, 2004, and June 6, 2005. Figure 2-5 shows the sampling points and presents a table of the water quality along the river. This table demonstrates that in general the water quality decreases as the water travels downstream along the Laramie River.

2.4 Groundwater

The Casper Aquifer is the primary groundwater resource in the vicinity of Laramie capable of providing adequate potable water quality and quantity for municipal purposes. The Casper Aquifer is comprised of the saturated portion of the Casper Formation which consists of sandstone and limestone exposed on the west flank of the Laramie Range. A detailed description of the hydrogeology of the Casper Aquifer is provided in Chapter 10 and Appendix 10.

2.4.1 General Description of City Wellfields

Since 1992, the City has derived approximately 58% of its municipal supply from four wellfields completed in the Casper Aquifer. Figure 2-6 shows the layout of production wells relative to pertinent features at each wellfield. All production wells are completed in the Casper Aquifer. Wells at the Turner, Pope, and Spur wellfields obtain water by pumping, whereas water from Soldier Springs is obtained by pumping or artesian flow from the Soldier No.1 Well. Table 2-2 summarizes the current design and production capabilities of each well.

Table 2-3 summarizes water quality from the Casper Aquifer at representative wells from each wellfield. Groundwater from the Casper Aquifer is classified as a calcium-bicarbonate type with total dissolved solid concentrations ranging from 213 to 224 mg/L. The water is very hard due to calcium and magnesium. Groundwater quality satisfies all of the EPA's primary and secondary standards for a public water supply.

Turner Wellfield (City Springs)

Prior to 1982, the City obtained groundwater directly from the natural discharge at City Springs. The Turner wells were installed in 1982 to enhance groundwater production capabilities and to intercept groundwater in the subsurface before water discharges to the surface at City Springs. The Turner Wellfield consists of the Turner No. 1 and the Turner No. 2 wells located on the eastern end of Laramie in the vicinity of City Springs. Turner No. 2 is located in the City Springs fenced enclosure a short distance west of the original discharge point of City Springs. Turner No. 1 is located on City property south of the City Springs enclosure. When the Turner wells are operating, City Springs cease to flow; whereas

when the Turner wells are off, discharge from City Springs flows into Spring Creek. The Turner wells can be operated separately or concurrently depending on demand.

Spur Wellfield

The Spur Wellfield is located 5.7 miles north of City Springs and consists of two wells, the Spur No. 1 and Spur No. 2. The Spur wells were installed in 1997 and completed in the Casper Aquifer along the western extension of the Spur Anticline. There is no spring in the vicinity of the Spur Wellfield. Both wells are very productive as illustrated by less than 8 feet of drawdown occurring in each well after being pumped continuously for 30 days at a rate of 1,400 gpm (i.e., 2,800 gpm combined). The Spur wells can be operated separately or concurrently depending on demand.

As shown on Figure 2-6, a monitoring well network, MW-1 to MW-13, was installed in the vicinity of the wellfield to evaluate the hydrogeology and monitor water level and water quality.

Pope Wellfield (Pope Springs)

The Pope Wellfield consists of four (4) wells located 2.8 miles south of City Springs and a short distance west of the now dry Pope Springs. The wells are grouped closely together within a 6.4 acre parcel. Pope No. 1, No. 2, and No. 3 were installed in 1937-39 after Pope Springs ceased to flow in 1934 due to a prolonged drought and the lowering discharge works at Soldier Springs. Pope No. 4 was installed in 1982 as a high capacity well to be used during period of peak demand.

Soldier Wellfield (Soldier Springs)

In about 1915 the City began to convey water from Soldier Springs. In 1937, the City dug a 21 feet deep cistern (Forney Shaft) that penetrated the lowermost 8 feet of the Satanka Shale and 10 feet of the uppermost sandstone of the Casper Formation, and installed a pump to allow more production. Average annual production from the cistern from 1989 to 1998 was 504 million gallons (1.4 million gallons per day, mgd). Due to water quality concerns and limited operational flexibility associated with the cistern, the City plugged the cistern in 1998 and replaced it with a production well, Soldier No. 1, located 450 feet west of the

cistern. Soldier No. 1 went on-line in late 1998 and is designed to provide water by artesian flow or by pumping depending on demand.

Prior to installing Soldier No. 1 well, five (5) monitoring wells were completed in the Casper Aquifer on the City owned property at Soldier Springs. The wells monitoring are operational and can be used for water quality and water level monitoring.

2.5 Water Rights

The City of Laramie owns water rights for the use of both surface and groundwater supplies. A brief description of those water rights follows and Table 2-4 summarizing these surface and groundwater rights is also included in this section of the report.

2.5.1 Surface Water Rights

2.5.1.1 Dowlin Ditch

In 1944, the City purchased from the Bath, Titus, Hohnholz, and Monolith Ranches a portion of the first priority water right on the Laramie River, the Dowlin Ditch irrigation right. The Dowlin Ditch right was given priority number 1 on the Laramie River for a total diversion of 46.79 cfs with a date of 1868 as adjudicated by a District Court decree entered December 27, 1912. Under Wyoming water law, the first priority must be satisfied before any other appropriator on the river receives water. The City, by stipulation with the owners of the remaining rights under the Dowlin Ditch, obtained the right to use its water prior to those rights. Thus, the City has the first right on the Laramie River.

In 1945, the City petitioned the State Board of Control (BOC) to change 10 cfs of rights it had purchased in the Dowlin Ditch from irrigation to municipal and other preferred uses and to change the point of diversion from the Dowlin Ditch headgate upstream to the diversion for the Pioneer Canal with the means of conveyance through the Enlarged Pioneer Canal, Pioneer Reservoir (Sodergreen Lake), and City of Laramie Pipeline. The BOC approved the transfer and the change in point of diversion and means of conveyance on November 14, 1945.

In 1963, the City again petitioned the BOC to change 4.3713 cfs of Dowlin Ditch right, which it had purchased that year from the Bath and Monolith Ranches, to

preferred uses and to change the point of diversion and means of conveyance to the Enlarged Pioneer Canal, Pioneer Reservoir, and City of Laramie Pipeline. On November 21, 1964 the BOC approved the transfer of 4.3113 cfs when they discovered that the City had not acquired 0.06 cfs attached to 9.62 acres owned by the Laramie Valley Railroad Company. With the 1945 and 1964 transfers, the City of Laramie now has the first right on the Laramie River for 14.3113 cfs (9.25 mgd) for preferred purposes for diversion at the Pioneer Canal headgate.

In 1981, the City purchased most of the Monolith Ranch and its associated irrigation water rights including an additional portion of the Dowlin Ditch water right amounting to 20.10 cfs (13.0 mgd). No portion of the water rights associated with the 1981 acquisition has been transferred from its original irrigation use.

2.5.1.2 Pioneer Canal

The City of Laramie is a member of the Pioneer Canal-Lake Hattie Irrigation District and has 100 acres of Class A shares and 127 acres of Class B shares within the district. These lands are north of the Laramie River and south of Highway 230. Class A shares participate in the earliest priority Pioneer Canal appropriation, April 19, 1879 while Class B shares participate in their second priority October 1, 1884.

2.5.1.3 Fivemile Creek

Associated with the 1981 purchase of the Monolith Ranch, the City acquired 450 acres of water rights diverting from Fivemile (Willow) Creek. These lands have Priority Number 5 (April 1881) and 7 (September 1883) on the source creek as determined by the 1912 Court Decree. The Flag Ranch, upstream on the creek, has about 11 cfs of water rights senior to the City's. Only infrequently does water flow in Fivemile Creek reach or flow through the City's property.

2.5.1.4 Simpson Springs Creek

Also associated with the 1981 Monolith Ranch purchase, the City acquired 270 acres of water rights on Simpson Springs Creek. These are the first priority on Simpson Springs Creek. Water is being diverted under these water rights for irrigation of lands along the creek.

2.5.1.5 Harney Creek

The Monolith Ranch lands also have several water rights appropriated from Harney Creek. The Goode Ditches (city owned) have the first priority on the creek for the irrigation of 180 acres. The Johnson Ditch has priority number 2 for 75 acres, and the Peter Ditch has priority number 3 for 80 acres. Another important right on Harney Creek is the storage water right for the Columbus (Goforth) Reservoir. This reservoir has a priority of October 13, 1917 and is unadjudicated. The spillway washed out in 1983 and needs to be rehabilitated. Because the City has the first irrigation rights on the creek, it might be possible to petition the State Engineer to approve the storage of the direct flow rights in the reservoir to better assure the availability of storage water. The reservoir is permitted for 168 acre-feet of storage capacity.

2.5.2 Groundwater Rights

The City has several groundwater rights used to provide water to the municipal system. The rights are listed in Table 2-5. There are also several groundwater rights, which were acquired in the purchase of the Monolith Ranch. These are primarily shallow stock wells and an irrigation well water right.

As shown on Table 2-5, the City has groundwater rights for each production well at the Turner, Pope, Soldier, and Spur wellfields, and wells on the Monolith Ranch. The original surface water rights at City Springs and Soldier Spring have been transferred to the Turner No. 2 and Soldier No. 1 wells, respectively. As a result of transferring the point of diversion of the Soldier Spring surface water right to the Soldier No. 1 well, the instantaneous groundwater right at Soldier No. 1 was adjusted to 0 gpm. The groundwater

rights at the City production wells have a permitted allowable instantaneous production and an annual volumetric limit.

In the early 1990s, the State Engineer's Office (SEO) established caps on the maximum annual and 10-year average annual combined production from the Turner and Pope wellfields. As shown on Table 2-9, from 1996 to 2005, the combined production from the Turner and Pope wellfields has been substantially less than the specified cap of no more than 5,000 acre-feet in any one year and no more than 4,500 acre-ft average annual production over a 10 year period.

When the production caps were established by the SEO, the Turner and Pope wellfields were the only wellfields in existence. Since then, the City has developed the Spur and Soldier wellfields. A question arises whether the production caps apply to all of the City wellfields or just the Turner/Pope wellfields. At present, the SEO requests that the City report annual production from the Turner and Pope wellfields with respect to the established production caps.

However, for the purpose of groundwater development planning, if in the future the SEO takes a position that the production caps apply to all the wellfields, then the City should know how the combined groundwater production from all the wellfields stand relative to the production caps. During 1996 to 2005, total wellfield production was slightly less than the 10 year average annual production cap (Table 2-9). If groundwater production during the extreme drought year of 2002 is adjusted to a more typical average production value, the estimated total City wellfield production of 3,568 acre-feet is substantially less than 4,500 acre-feet. These calculations demonstrate that even under a conservative interpretation of the SEO wellfield production caps the City can extract more groundwater from the existing wellfields within the caps established by the SEO. If needed, the annual production caps could be increased in consideration of Casper Aquifer head data indicating that the Casper Aquifer has not been adversely impacted by historical wellfield production as discussed in Chapter 10.

2.6 Institutional Constraints

This section presents detailed discussions on two important institutional constraints that affect water supply and related activities in the entire North Platte River basin, including

the Laramie River basin; Court Decrees and the Platte River Recovery Implementation Program. These are two of the larger set of primarily federal and state laws, rules, and regulations and policies that affect the business of water supply development and management in the basin that are mentioned in Chapter 5, and contained in Appendix G of the 2004 MRWRMP project report.

2.6.1 Court Decrees

After years of interstate litigation, in 1922 the U.S. Supreme Court issued the Laramie River Decree, which allowed Colorado to divert 39,750 acre feet per year from the Laramie River basin. By stipulation between the States of Colorado and Wyoming in 1957, the U.S. Supreme Court decreed that Colorado could only divert 19,875 acre feet per year from the Laramie River Basin and that only 29,750 acre feet per year could be diverted to irrigate certain specified lands within the Laramie River basin in the State of Colorado.

In 1945, the U. S. Supreme Court issued a decree apportioning the waters of the North Platte River (and some tributaries) among the States of Wyoming, Colorado, and Nebraska. This Decree was modified by the Court in 1953 to accommodate the construction of Glendo Reservoir and to address other matters. On October 6, 1986, Nebraska petitioned the Court to reopen the North Platte Decree. Among her allegations, Nebraska contended that Wyoming's use of water from the Laramie River exceeded the use envisioned in the 1945 apportionment and therefore impacted her entitlements to 75% of the natural flow that arrived at North Platte River between the Whalen Diversion Dam and the Wyoming/Nebraska state line.

Ultimately, the 1986 Nebraska v. Wyoming law suit was settled and the U.S. Supreme Court approved a Final Settlement Stipulation presented by the parties on November 13, 2001. During the settlement process, Wyoming successfully argued that the Laramie River Decree essentially apportioned all of the water in the Upper Laramie River basin to Colorado and Wyoming, including lands within the boundaries of Wheatland Irrigation District that are irrigated by natural flows and storage water from Wheatland Reservoir Nos. 2 and 3, and that any Modified North Platte Decree should not impact that already long-settled interstate equitable apportionment. Therefore, the Upper Laramie River basin, defined as the entire drainage upstream and including the Wheatland Tunnel is not affected by the Modified North Platte Decree.

2.6.2 Platte River Recovery Implementation Program (PRRIP)

The Endangered Species Act of 1973 (ESA) constrains all federal agencies from taking any action that may jeopardize the continued existence of an endangered species. If a federal agency is considering an action that may jeopardize a listed threatened or endangered species, Section 7 of the ESA requires that agency to consult with the U.S. Fish and Wildlife Service (USFWS). Federal actions that require consultation include, for example, issuing Section 404 Permits under the Clean Water Act, disbursing federal loans and grants, approving federal right-of-ways, leasing or acquisition of federal lands or minerals, contracting for water from U.S. Bureau of Reclamation (USBR) water projects, and many others. Actions requiring such consultations are said to fall under the "federal nexus".

The "federal nexus" has been affecting water development and management in the Platte River basin in Wyoming and elsewhere since the late 1970's with the designation of the whooping crane, least tern, and pallid sturgeon as endangered species, the piping plover as a threatened species, and the designation of the Central Platte River in Nebraska as critical habitat. Initially, consultations were only required for new water uses and projects. In the late 1980's, the USFWS began requiring consultations on a wider set of actions and projects that improved or rehabilitated existing water supply facilities or systems. In essence, the USFWS was requiring that all depletions, whether existing or new, resulting from a federal action, be replaced until such time as it was deemed that there was enough water in the system to recover the endangered species and restore their designated critical habitat in the Central Platte River basin in Nebraska.

In the 1990's, representatives from the Department of the Interior (representing both USFWS and USBR) and the States of Wyoming, Colorado, and Nebraska began meetings to discuss the feasibility of developing a recovery program that would: 1) benefit the listed species and their habitat, and 2) provide ESA compliance for the water users in the three states. On July 1, 1997, the parties executed the North Platte Cooperative Agreement (NPCA). Under this agreement, the parties agreed to cooperatively develop a Platte River Recovery Implementation Program (PRRIP). The negotiations relating to the PRRIP are nearing completion. The goal is to have the PRRIP operational on October 1, 2006.

During the term of the NPCA, the USFWS was completing interim consultations on new water related activities in the three states. The City of Laramie underwent such an

interim consultation to receive federal approvals for improvements at the Laramie River Intake Facility in 1998. The interim consultations completed since July of 1997 allowed projects to obtain the necessary approvals in accordance with federal law and precede with the payment of annual depletion fees by the project proponents. However, the approvals of the federal actions covered by these interim consultations were predicated on the completion of the PRRIP. Once the PRRIP is operational, the projects that obtained approval through these interim procedures, including the City of Laramie, will undergo an abbreviated re-consultation that will eliminate the need for the payment of annual depletions fees and will document that the PRRIP is serving as the "reasonable and prudent" alternative under the ESA for the projects. If the PRRIP is not completed and implemented, the project receiving an interim approval will be subjected to an intensive re-consultation which could result in the requirement for the project proponents to pay higher depletion fees and provide an off-setting amount of replacement water for the depletions resulting from the project previously covered by the interim consultations.

One of the overall goals of the PRRIP is to provide an average of 130,000-150,000 acre feet per year to reduce shortages to USFWS target flows along the Platte River in Central Nebraska. The State of Wyoming's water contribution under the recovery program on behalf of all water users in the basin is the Environmental Account in the Pathfinder Modification Project. Funding to be provided by the parties will be used to acquire additional water, provide and maintain 10,000 acres of habitat in the Central Platte River valley, and implement a scientific adaptive management approach to determine the water and habitat needs of the species. The term of the PRRIP is 13 years. The term may be extended if approved by the parties.

In addition, the three states recognized that it did not make sense to provide water to the PRRIP and, at the same time, increase its water use thereby undermining the water goals of the PRRIP. Therefore, the states agreed to curtail their water use to 1997 levels with the understanding that the PRRIP would provide the regulatory certainty for that use under the ESA. Each state developed a depletions plan that quantified its pre-1997 water use and thereby determined the water use to be covered by the PRRIP.

The State of Wyoming developed the "Depletions Plan, Platte River Basin, Wyoming" (Wyoming's Depletions Plan). The plan establishes three (3) existing water related baselines.

Each particular water use has a benchmark under the baseline. The City of Laramie's water use is included as a benchmark under existing water related baseline no. 2, which also includes the irrigation water use in the entire North Platte River Basin (which includes the Laramie River), with the exception of the irrigation uses between the Colorado/Wyoming state line and Guernsey Reservoir. The information contained in this baseline was developed on the basis that the threshold for pre-1997 water use is the maximum annual water use of each particular use between 1992 and 1996. In the future under the PRRIP, if all of the water use in the basin during a particular year when added together is less than the total water use under existing water related baseline no. 2, the baseline will not be exceeded. This provides flexibility under the baseline. For example, if a particular municipality exceeds its benchmark under the baseline, but the irrigated water use is less than its benchmark by an amount greater than the excess water use of the municipality, the baseline is not exceeded and no mitigation is required. However, if the baseline is exceeded when all the water uses in a particular year are considered, the State of Wyoming will be responsible for mitigating the excess use at the Wyoming/Nebraska state line.

The benchmarks of historic use contained within the baselines for municipalities are based on depletions (diversion less return flow). The City of Laramie's benchmark was based on information provided by the City. That information indicated that the city's maximum depletions between 1992 and 1996 occurred in 1994. The benchmark for the City of Laramie's water use under existing water related baseline no. 2 is shown below. The benchmark is broken down into depletions that occurred during the irrigation season and non-irrigation season. This is due to the fact that overruns in the irrigation season have different effects on the streamflows at the Wyoming/Nebraska state line than overruns in the non-irrigation season.

Season	Depletions (acre-feet/year)
Irrigation season (May 1-September 30)	2,990
Non-irrigation season (October 1-April 30)	670
Total	3,660

The following discussion reviews the assumptions made in the development of the City of Laramie's benchmark and some actions the City may take to provide opportunity for additional water use under their benchmark.

1. The City's surface water diversions from the Laramie River were based on the measured production from the water treatment plant and do not consider the losses suffered from the delivery of water from the Laramie River through the Pioneer Canal and Sodergreen Lake to the water treatment plant. If this delivery system is improved, as proposed in this study through the construction of a pipeline, in such a manner that depletions caused by evaporation are reduced, the reduced depletions could be used to offset increased municipal depletions in the future.

2. When the return flow measurements from the wastewater treatment plant were used to determine depletions, it was apparent that the wastewater system was subject to infiltration during the non-irrigation season. Therefore, standard return flow factors for municipalities the size of Laramie were used to calculate depletions. The City may wish to develop means to more accurately measure diversions and the resulting return flows to the wastewater treatment system.

3. It was assumed that Laramie's groundwater wells were hydrologically connected and therefore depletions resulting from use of the wells are included under the City's benchmark. A hydrologically connected groundwater well is defined for this program; as a well so located and constructed that if water were withdrawn by the well continuously for 40 years, the cumulative stream depletion would be greater than or equal to 28% of the total volume of groundwater withdrawn. Depletion of water from non-hydrologically connect wells do not count against water use benchmarks. The City may want to evaluate the groundwater wells to determine if any or all of them can be considered non-hydrologically connected wells. Previous analyses suggest that a portion of the well withdrawals would be considered non-hydrologically. If the water from the wells, or a portion thereof, are determined to be non-hydrologically connected, the depletions resulting from the operation of the wells in 1994 would be subtracted from the above benchmark. However, the City would get credit for the return flow to the Laramie River provided from the operation of the wells.

If the City decides to undertake improvements that could improve the opportunity for new uses under the benchmark, the City should contact the State Coordinator of Wyoming's Depletions Plan in the Interstate Streams Division of the Wyoming State Engineer's Office. The State Coordinator will evaluate the improvements to determine the amount of additional water usage that could be permitted under a revised benchmark and covered by Wyoming's Depletions Plan.

If the City of Laramie exceeds its benchmark with water use through its existing water rights and water supply system, that excess may be offset by under-runs to other benchmarks. If the existing water related baseline no. 2 is exceeded, the State of Wyoming, through the Wyoming Water Development Commission, will provide the mitigation to offset the effects of the excess at the Wyoming/Nebraska state line. However, if the City is proposing to expand its water use and water system and the effects of that expansion is that the City's benchmark will be exceeded, the expansion will be considered a new water related activity that cannot be covered by Wyoming's Depletions Plan. The City will need to contact the State Coordinator of Wyoming's Depletions Plan. The State Coordinator will assist the City in developing a mitigation plan that will be acceptable to the U.S. Fish and Wildlife Service and will meet Wyoming's obligations under the PRRIP.

TABLES AND FIGURES

Table 2-1 Laramie River at Pioneer Canal One Day Low Flows

Rank	Year	One-Day Low Flow	Estimated Recurrence Interval*
		cfs	years
1	1934	9	100+
2	2002	9	100
3	1954	10	85
4	1932	16	20
5	1958	17	18
6	1935	18	15
7	1948	18	15
8	1959	18	15
9	1953	19	10
10	1943	20	7

*Recurrence interval estimated graphically from Figure 2-4.

*The table is from the Monolith Ranch Water Rights Management Plan, (Fassett, 2004).

Table 2-2 Well Completion Data

Well Name	UW Permit #	Year Drilled	Ground Elevation	Total Depth	Cased Interval	Casing OD	Open Hole Interval	Open Hole Dia.	Pump Type/Make	Motor Rating	Pump Intake Setting	Production Capacity
			ft, amsl	ft	ft	in	ft	in		hp	ft	gpm
Spur Wellfield												
Spur No. 1	106547	1997	7290.65	305	0 - 91	16	255 - 323	14.75	LST/Floway	100	76	1,400
Spur No. 2	107279	1997	7269.59	323	0 - 255	16	91 - 305	14.75	LST/Floway	100	86	1,400
Turner Wellfield												
Turner No. 1	55507	1982	7272.7	240	0 - 100	16	100 - 350	12.25	LST/Aurora	40	81	2,500
Turner No. 2	55508	1982	7259.8	350	0 - 100	16	100 - 350	12.25	LST/Aurora	40	96	1,600
Pope Wellfield												
Pope No. 1	153	1937	7335.5	156	0 - 64	8	64 - 156	7.25	LST/Aurora	7.5	55	475
Pope No. 2	154	1938	7338.8	162	0 - 64	8	64 - 154	7.25	LST/Peerless	15	42	650
Pope No. 3	155	1939	7338.8	158	0 - 66	15	66 - 158	14	LST/Aurora	40	62	994
Pope No. 4	55506	1982	7351	350	0 - 100	16	100 - 350	12.25	LST/Aurora	75	80	1,935
Soldier Springs												
Soldier No. 1	105576	1997	7322.07	289	0 - 79.5	16	79.5 - 289	13.75	LST/Floway	75	46	2,300
					Screen				VFD			
					44.1 - 64.4							

Table 2-3
Laramie Wells Groundwater Quality Casper Aquifer

Location		Major Cations				Major Anions				Other Key Parameters				
Well/Spring	pH	Ca	Mg	Na	K	Cl	SO_4	HCO_3	NO_3	F	Fe	TDS	Hardness mg/L	RSI
	su	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L as $CaCO_3$	
MCL	6.5-8.5	---	---	---	---	250	250	---	10.0	4.0	0.3	500	---	
Spur No. 1	8.0	52	16	2.6	<1.0	1.1	6.0	215	1.58	0.18	<0.05	213	196	---
Turner No. 2	7.4	55	18	3.1	0.8	<1.0	9.7	230	1.7	0.1	---	224	200	7.5
Pope Wells	8.2	54	13	2.1	0.7	1.8	5.8	222	1.66	0.2	0.04	218	191	6.7
Soldier No. 1	8.1	58	17	1.9	<1.0	3.5	12.0	218	1.98	0.21	<0.05	208	217	---

Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; Cl = Chloride; SO_4 = Sulfate; HCO_3 = Bicarbonate; NO_3 – Nitrate; F = Fluoride; Fe – Iron
TDS = Total Dissolved Solids
RSI = Ryznar Stability Index (incrusting <7 <corrosive)
MCL – Maximum Contaminant Level
--- - Not Analyzed for this Compound

Table 2-4 City of Laramie Surface Water Rights

Surface Water Rights	Permit No.	Priority	Status	Acres	Amount	Unit	Use
LARAMIE RIVER							
Dowlin Ditch					46.79[1]	CFS	MUN, IRR
1945 Water Right Transfer					10.00	CFS	
Bath water right deed					7.00	CFS	MUN
Titus water right deed					1.50	CFS	
Hohnholz water right deed	CR48/001A	12/31/1868	ADJ	3,374.62	1.50	CFS	
1964 Water Right Transfer					4.31	CFS	
Bath water right deed					3.00	CFS	MUN
Monolith Ranch water right deed					1.31	CFS	
1981 Monolith Ranch Deed					20.10	CFS	IRR
Pioneer Canal							
Class A	C48/006A	4/19/1879	ADJ	100			IRR
Class B	C48/006A	10/1/1884	ADJ	127			IRR
FIVEMILE CREEK							
VanBuskirk No. 3 Ditch	CR48/108A	4/30/1881	ADJ	50	0.71	CFS	IRR
VanBuskirk No.1 Ditch	CR48/111A	9/30/1883	ADJ	219	3.13	CFS	IRR
VanBuskirk No. 2 Ditch	CR48/110A	9/30/1883	ADJ	181	2.59	CFS	IRR
SIMPSON SPRINGS							
Simpson No.1 Ditch	CR48/165A	10/31/1879	ADJ	40	0.57	CFS	IRR
Simpson No.3 Ditch	CR48/166A	10/31/1879	ADJ	120	1.71	CFS	IRR
Simpson No. 2 Ditch	CR48/167A	10/1/1879	ADJ	110	1.57	CFS	IRR
HARNEY CREEK							
Goode No. 5 Ditch	CR48/195A	6/20/1878	ADJ	35	0.5	CFS	IRR
Goode No. 3 Ditch	CR48/196A	6/20/1878	ADJ	45	0.64	CFS	IRR
Goode No. 4 Ditch	CR48/197A	6/20/1878	ADJ	100	1.43	CFS	IRR
Peter Ditch	CR48/199A	6/1/1884	ADJ	80	1.14	CFS	IRR, STO
Columbus Reservoir	P3442R	10/13/1917	PU	N/A	168	AC-FT	IRR
Johnson Ditch	CR48/198A	6/1/1883	ADJ	75	1.07	CFS	IRR, STO
Enl.Johnson Ditch	P3235E	7/3/1914	ADJ	18.5	0.26	CFS	IRR

(1) This is the original Dowlin Ditch water right which has only been partially aquired by the City of Laramie.

Table 2-5: City of Laramie Groundwater Rights

Groundwater Rights	Permit No.	Date of Priority	Status	Permitted Instant. Rate	Use	Comments
				gpm		
Turner Wellfield						
Turner No. 1	UW 55507	1/30/1981	Adj.	1,400	Mun	2,500 gpm total
1st Enl. Turner No. 1	UW 61724	6/23/1982	Adj.	800	Mun	
2nd Enl. Turner No. 1	UW 72689	6/5/1986	Adj.	300	Mun	
Turner No.2	UW 55508	1/30/1981	Adj.	1,400	Mun	2,815 gpm total (1,600 grdwtr + 1,215 surf. wtr)
1st Enl. Turner No. 2	UW 59131	10/28/1981	Adj.	200	Mun	
City Springs	OR 7/261	1868	Adj.	1,215	Mun	Surface water right (1,215 gpm) with change of point of diversion to Turner No. 2
		Turner Wellfield Total Water Right =		5,315		
Pope Wellfield						
Pope No. 1	SC 153	6/10/1937	Adj.	600	Mun	600 gpm total
Pope No. 2	SC 154	6/17/1938	Adj.	600	Mun	675 gpm total
1st Enl. Pope No. 2	UW 72690	6/5/1986	Adj.	75	Mun	
Pope No. 3	SC 155	6/30/1939	Adj.	600	Mun	900 gpm total
1st Enl. Pope No. 3	UW 55505	1/30/1981	Adj.	250	Mun	
2nd Enl. Pope No. 3	UW 72691	6/5/1986	Adj.	50	Mun	
Pope No. 4	UW 55506	1/30/1981	Adj.	1,750	Mun	1,800 gpm total
1st Enl. Pope No. 4	UW 72692	6/5/1986	Adj.	50	Mun	
		Pope Wellfield Total Water Right =		3,975		
Soldier Springs Wellfield						
Soldier No. 1	UW 105576	2/27/1997	-	0	Mun	
Soldier Springs	OR 53/5		Adj.		Mun	Surface water right (6.56 cfs) with change
	OR 1/176	5/1870		808		of point of diversion to Soldier No. 1 well
	OR 1/176	4/21/1885		512		
	OR 5/764	11/10/1909		1,625		
		Soldier Wellfield Total Water Right =		2,945		2,945 gpm total (0 grwtr + 2945 surf. wtr)
Spur Wellfield						
Spur No. 1	UW 106547	12/1/1994	Adj.	2,500	Mun	2,500 gpm total
Spur No. 2	UW 115181	3/10/1999	Adj.	2,500	Mun	2,500 gpm total
		Spur Wellfield Total Water Right =		5,000		
Monolith Ranch						
Stock Well #5	P216G	10/1/1953		2	Stock	
Stock Well #6	P217G	10/1/1953		2	Stock	
Stock Well #7	P218G	10/1/1953		2	Stock	
Stock Well #8	P219G	10/1/1953		7	Stock	
Stock Well #9	P220G	10/1/1953		NI	Stock	
Stock Well #1	P475C	12/31/1927		2	Stock	
Stock Well #2	P476C	12/31/1942		2	Stock	
Stock Well #3	P477C	12/31/1945		2	Stock	
Stock Well #10	P478C	12/31/1945		NI	Stock	
Nunn #83-1-City	P65344W	9/7/1983		10	Sto. & Dom.	
K.F. Knudsen #1	P51C	5/31/1941		1,000	Sto. & Irr.	aka Hunziker Well
Hunziker #1	U.W. 628	2/16/1961		1,100	Sto. & Irr.	aka K.F. Knudsen #1
Simpson MW-1	P105082W	2/27/1997		0	Mon.	
Mono Well #5-2	P140436W	11/5/2001		NI	Stock	
University 1	P14076	11/2/2001		0	Mon.	
Miscellanous Monitoring Wells						
See Table 10-7 for list of City-owned monitoring wells						

Note: By stipulation on the above Turner and Pope Wellfield permits (except City Springs diversion) the State Engineer has limited the combined production from the Turner and Pope wellfields to no more than 5,000 acre-feet in any one year and an average annual production of 4,500 acre-feet computed for 10 consecutive year periods.

Note: By stipulation dated 3/26/1998, the City of Laramie agreed to limit withdrawal from both Spur wells according to measured water level drawdown in monitoring wells located east of the Spur Wellfield. See Table 10-4 and stipulated agreement in Appendix 10-A.

Table 2-6: City Wellfield Production Compared to SEO Wellfield Production Caps

Year	Turner + Pope Wellfield Prod.	Turner + Pope Wellfield Prod.	Total City GW Prod.	Adjusted Total City GW Prod.
	mg	**ac-ft**	**mg**	**ac-ft**
1996	778.7	2,390	1,275.3	3,914
1997	610.0	1,872	1,073.5	3,295
1998	801.6	2,460	1,298.2	3,984
1999	564.3	1,732	1,250.0	3,836
2000	476.8	1,463	1,266.2	3,886
2001	447.9	1,375	1,325.6	4,068
2002	652.2	2,002	3,717.3	11,409
2002*	N/A	N/A	**1,162.7**	**3,568**
2003	302.5	928	998.8	3,065
2004	292.2	897	970.2	2,978
2005	300.7	923	1,006.6	3,089
	mg/yr	**ac-ft/yr**	**mg/yr**	**ac-ft/yr**
1 yr max cap	1,629.1	5,000	1,629.1	5,000
10 yr avg. cap	1,466.2	4,500	1,466.2	4,500
10 yr avg. prod.	522.7	1,604	1,394.9	4,281
10 yr avg. prod. (adjusted)	N/A	N/A	**1,162.7**	**3,568**

* 2002 value was adjusted by using the average groundwater production calculated from 1996-2001 and 2003-2005 data.

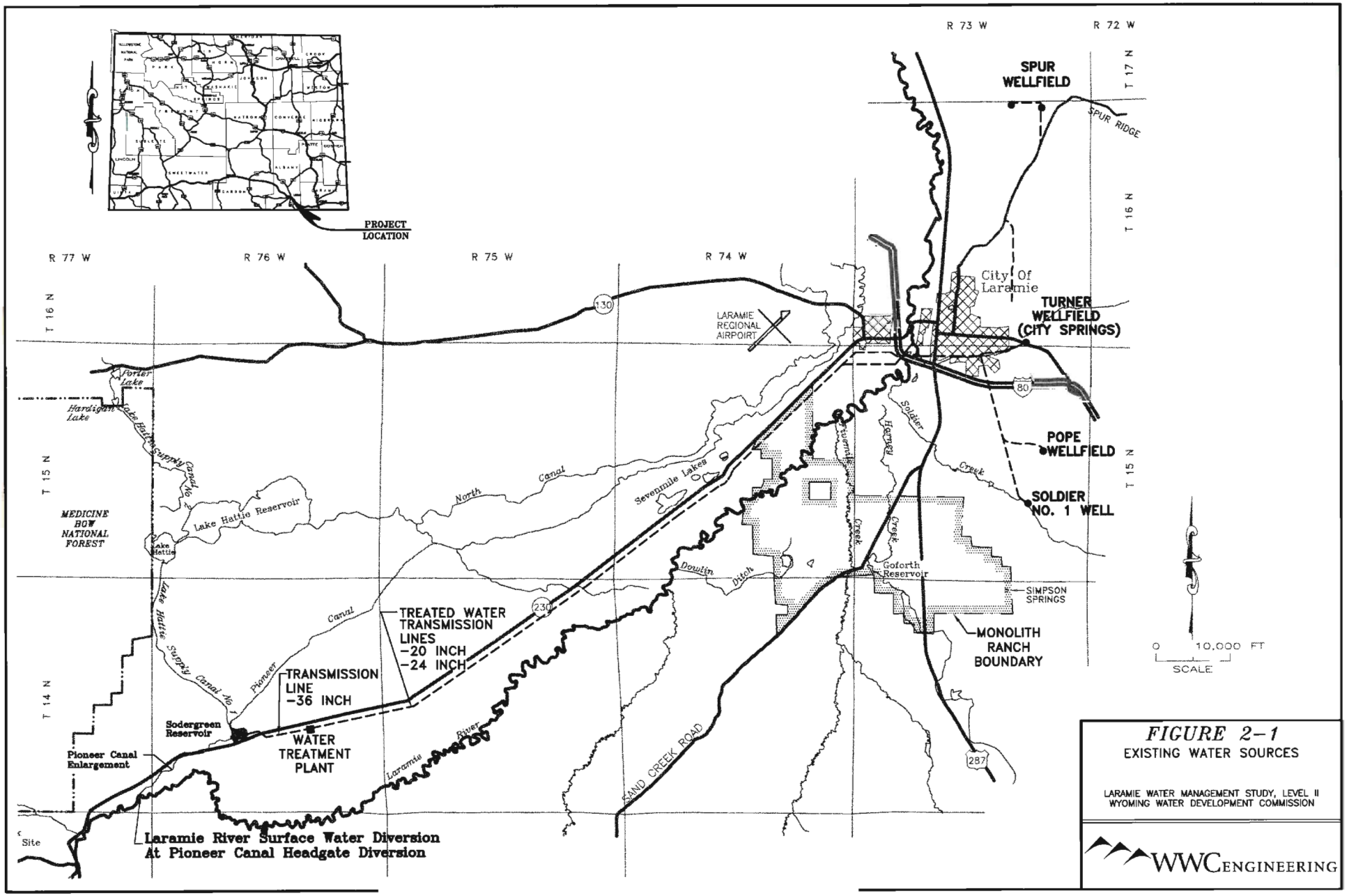
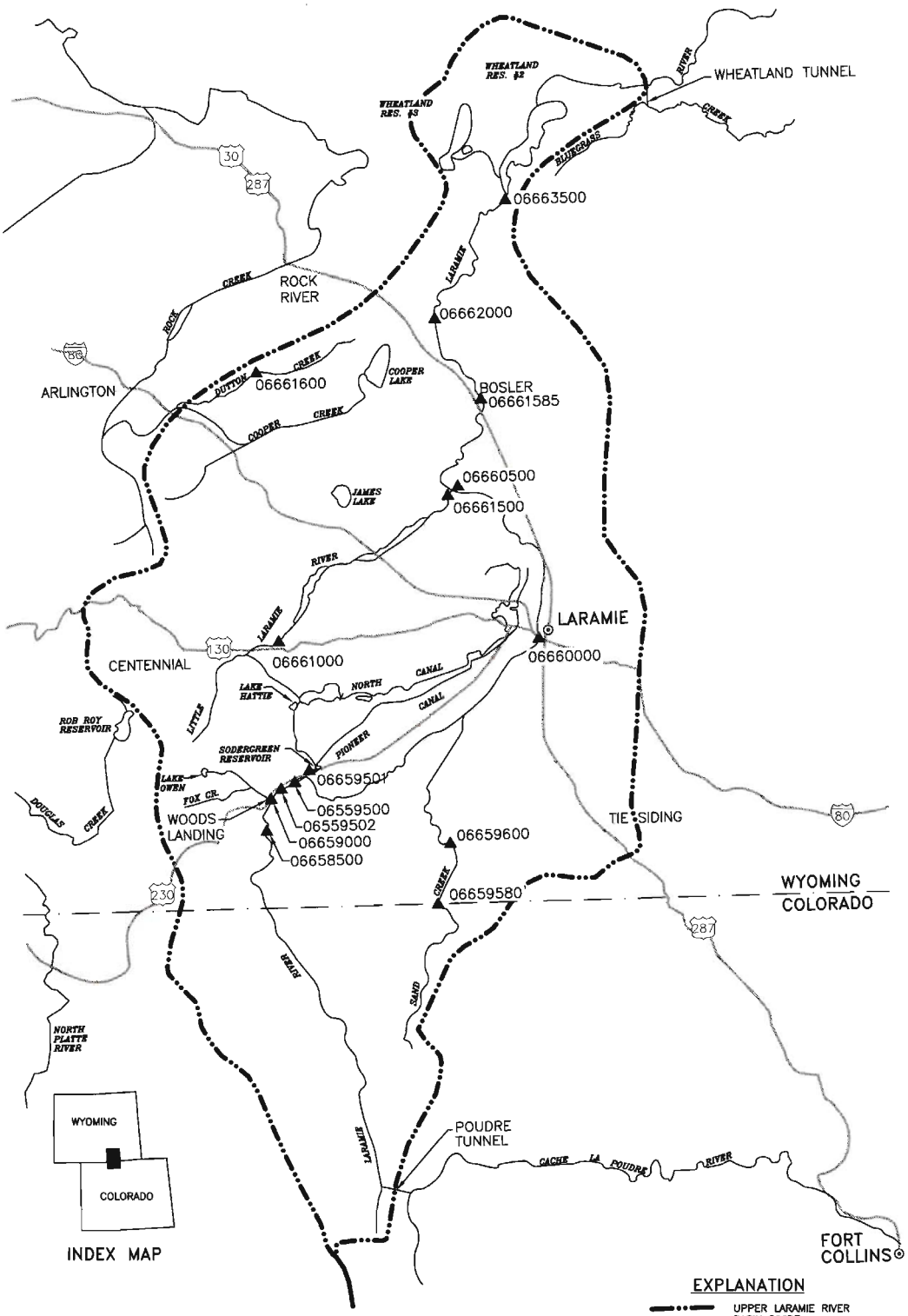


FIGURE 2-1
EXISTING WATER SOURCES

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

K:\WWC\C2005-172 Laramie\cadd\LARAMIE-WATER-SX.DWG, FIGURE 2-1, 8/18/2006 9:52:52 AM



STREAMFLOW GAGING STATIONS

SITE NUMBER	SITE NAME	FROM	TO	COUNT
06658500	LARAMIE RIVER NEAR JELM, WYO	7/1/1904	4/8/1963	19548
06659000	LARAMIE RIVER AT WOODS LANDING WYO	1/1/1897	9/30/1911	1338
06659500	LARAMIE R AND PIONEER CANAL NR WOODS LANDING, WY	5/1/1912	9/30/2005	16419
06659501	PIONEER CANAL NEAR WOODS, WY	4/1/1975	9/30/2005	6559
06659502	LARAMIE R BL PIONEER CANAL NR WOODS LANDING, WY	4/1/1975	9/30/2005	5673
06659580	SAND CREEK AT COLORADO-WYOMING STATE LINE	10/1/1968	10/6/2006	7348
06659600	SAND CREEK NEAR TIE SIDING, WY	4/1/1957	9/30/1968	4201
06660000	LARAMIE RIVER AT LARAMIE, WYO.	4/1/1933	9/30/1972	10997
06660500	LARAMIE RIVER AT TWO RIVERS, WYO.	1/1/1910	9/30/1972	20574
06661000	LITTLE LARAMIE RIVER NEAR FILMORE, WYO.	8/1/1902	9/30/2005	26524
06661500	LITTLE LARAMIE RIVER AT TWO RIVERS, WYO.	1/1/1911	9/30/1972	19939
06661585	LARAMIE RIVER NEAR BOSLER, WY	10/1/1972	9/30/2005	12053
06661600	DUTTON CREEK NEAR MCFADDEN, WY	4/1/1958	12/31/1963	2101
06662000	LARAMIE RIVER NEAR LOOKOUT, WYO.	6/1/1912	9/30/1996	20136
06663500	LARAMIE RIVER BEL WHEATLAND RESERVOIR NO 2, WY	10/1/1951	9/30/1963	4383

FIGURE 2–2

UPPER LARAMIE RIVER BASIN

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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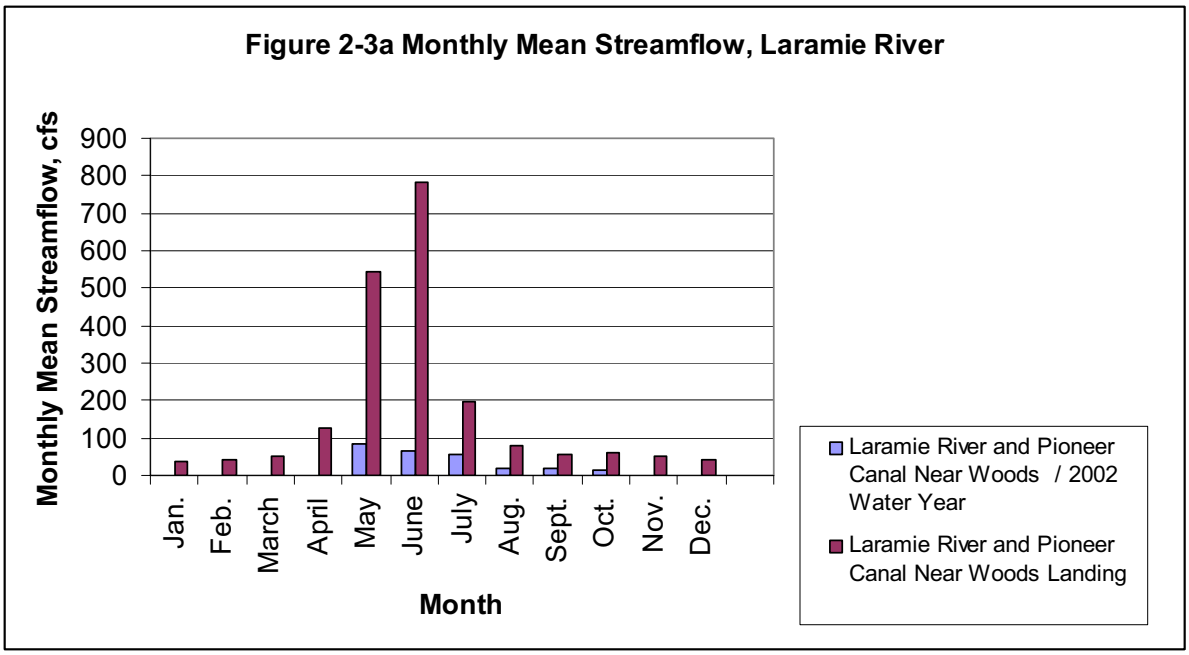
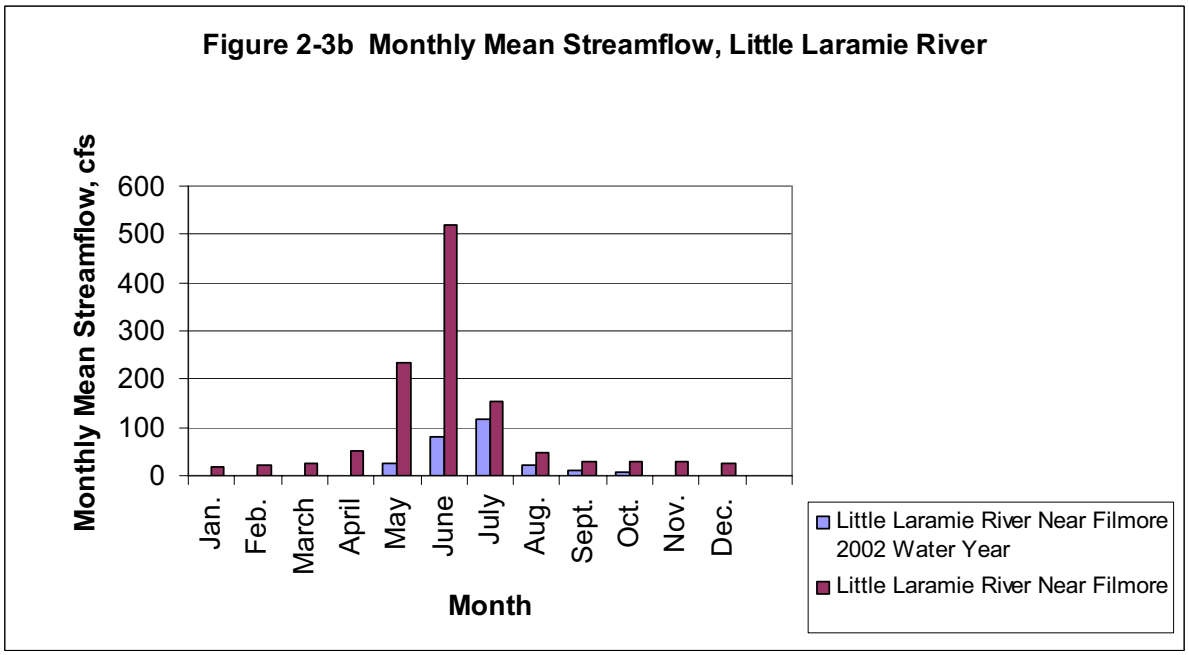




Notes for both figures:
1. Period of record, Laramie River and Pioneer Canal – 1912 through 1916, 1933, 1934, and 1950 through 2005. No winter records after 1972.

2. Period of record, Little Laramie – 1902, 1903, 1911 through 1926, 1932 through 2005. No winter records after 1971.

3. Year 2002 is provided as a comparison of the lowest year on record to the mean.

Figure 2-4a Laramie R. & Pioneer Canal
N-Day Low Flow Frequency
May 5 - Sept 30 Season

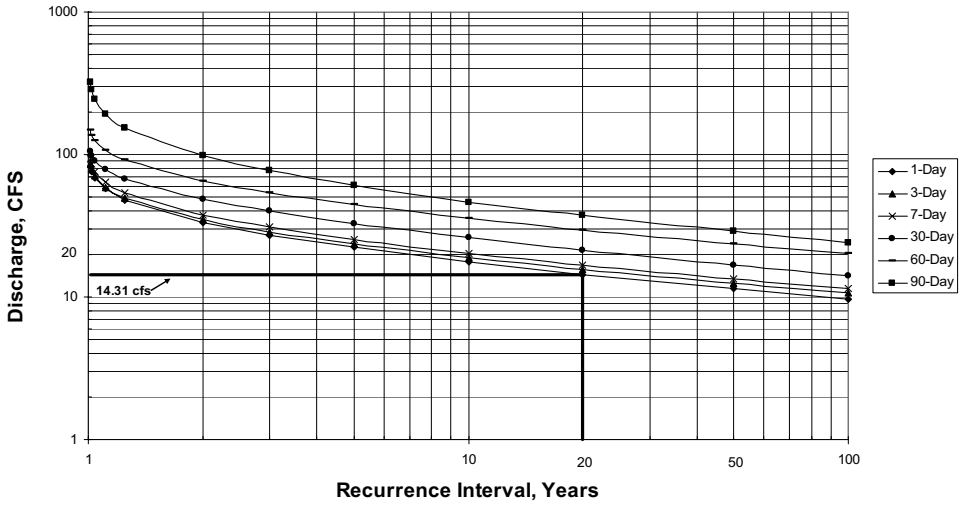


Figure 2-4b Laramie R. & Pioneer Canal
1-Day Low Flow Frequency

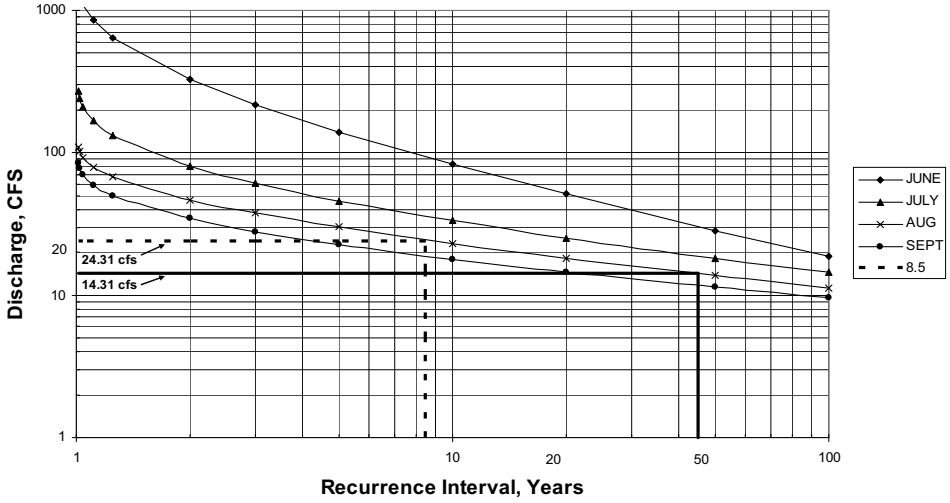
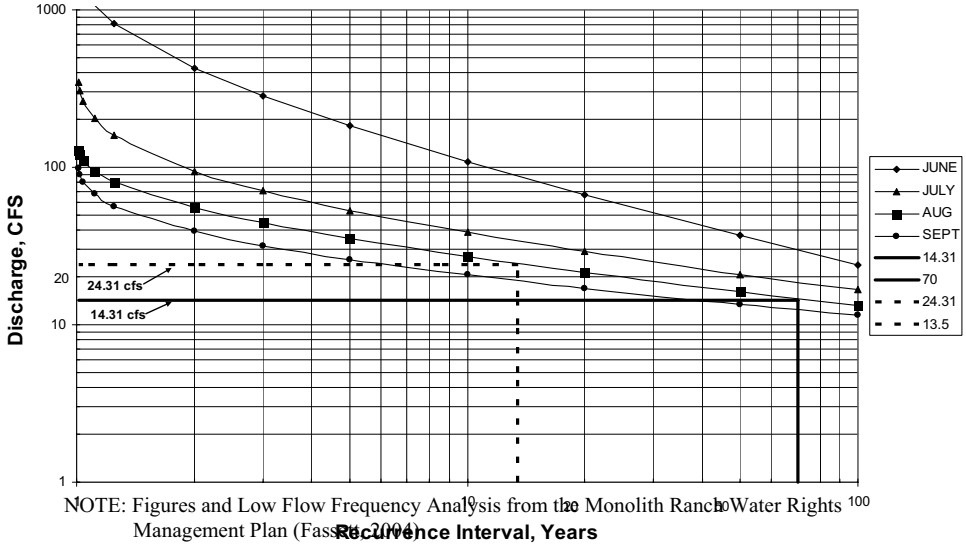


Figure 2-4c Laramie R. & Pioneer Canal
7-Day Low Flow Frequency



NOTE: Figures and Low Flow Frequency Analysis from the Monolith Ranch Water Rights Management Plan (Fassett, 2004).

Date Sampled	Sample Location	Parameter											
		Flow (cfs)	Turbidity (NTU)	Aluminum (mg/L)	Copper (mg/L)	Iron (mg/L)	Manganese (mg/L)	TDS (mg/L)	Zinc (mg/L)	Hardness (mg/L)	Sulfate (mg/L)	Nitrate (mg/L)	pH (s.u)
6/6/2005	Woods Landing, Sample ID 1.1	flood	23.2	0.211	0.002	0.71	0.066	120	0.055	53	21	0.05	7.7
6/6/2005	Brubaker Lane, Sample ID 1.2	flood	8.63	0.088	0.002	0.34	0.014	220	0.070	110	61	<0.05	7.8
6/6/2005	Monolith Fishing Access, Sample ID 1.3	flood	7.85	0.064	0.002	0.29	0.023	500	0.051	250	230	<0.05	7.9
6/6/2005	Snowy Range Road, Sample ID 1.4	flood	9.85	0.071	0.002	0.31	0.032	460	0.060	220	190	<0.05	7.9
6/6/2005	Below WWTP, Sample ID 1.5	flood	13.2	0.088	0.002	0.38	0.048	470	0.063	230	190	<0.05	7.9
11/2/2004	Woods Landing, Sample ID 1.1	52	5.75	0.107	0.003	0.645	0.023	100	0.186	72	26	<0.05	8.0
11/2/2004	Brubaker Lane, Sample ID 1.2	69	6.81	0.102	0.002	0.704	0.074	140	0.170	95	36	<0.05	8.0
11/2/2004	Monolith Fishing Access, Sample ID 1.3	60	6.87	0.102	0.002	0.570	0.056	210	0.214	130	76	<0.05	8.1
11/2/2004	Snowy Range Road, Sample ID 1.4	54	6.42	0.091	0.002	0.487	0.069	280	0.175	190	120	0.19	8.1
11/2/2004	Below WWTP, Sample ID 1.5	64	11.5	0.113	0.003	0.524	0.075	350	0.201	210	140	0.81	8.1

REFERENCE: LARAMIE RIVERS CONSERVATION DISTRICT DATA, 2004–2005.

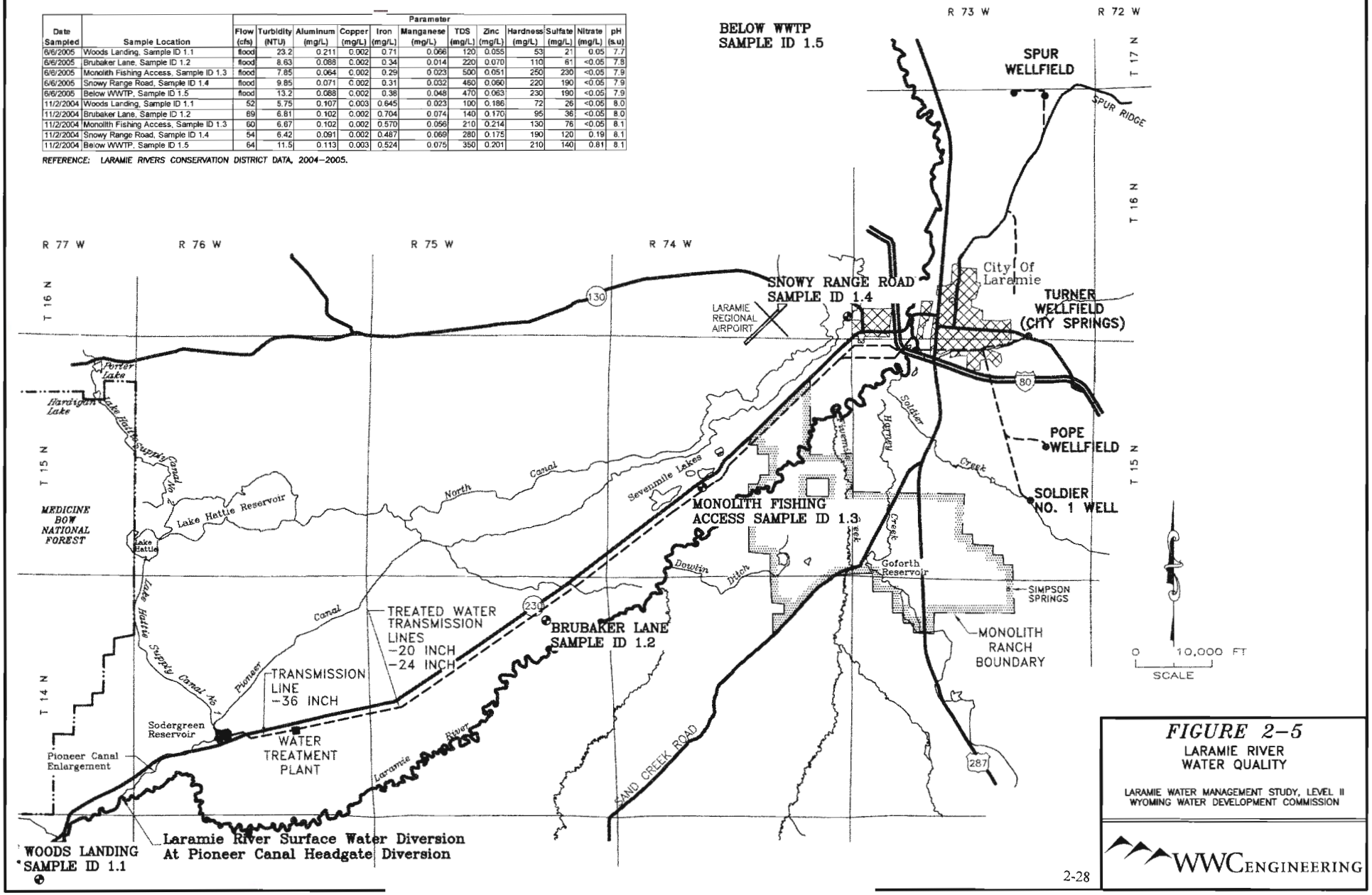


FIGURE 2–5
LARAMIE RIVER WATER QUALITY

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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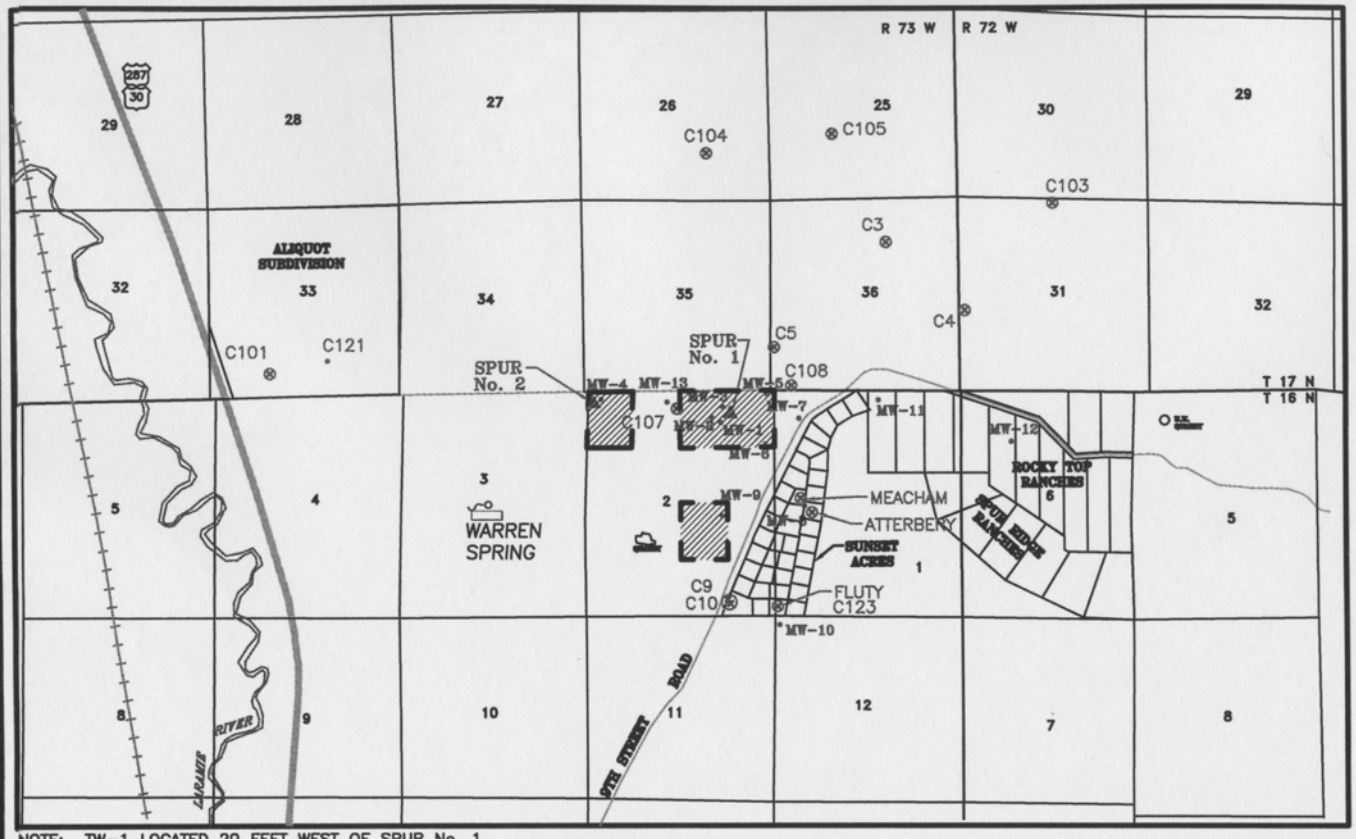


NOTE: TW-1 LOCATED 20 FEET WEST OF SPUR No. 1.

EXPLANATION

▲ PRODUCTION TEST WELL INSTALLED FOR THE SPUR WELLFIELD PROJECT

MW-5 • MONITORING WELL INSTALLED DURING THE MASTER PLAN STUDY AND FOR THE SPUR WELLFIELD PROJECT

⊗ PRIVATE WELL MONITORED DURING TESTING

STATE LAND

0 3000 FT.
SCALE

FIGURE 2-1
MONITORING WELL NETWORK

SPUR WELLFIELD PROJECT – PHASE I
CITY OF LARAMIE
LARAMIE, WYOMING

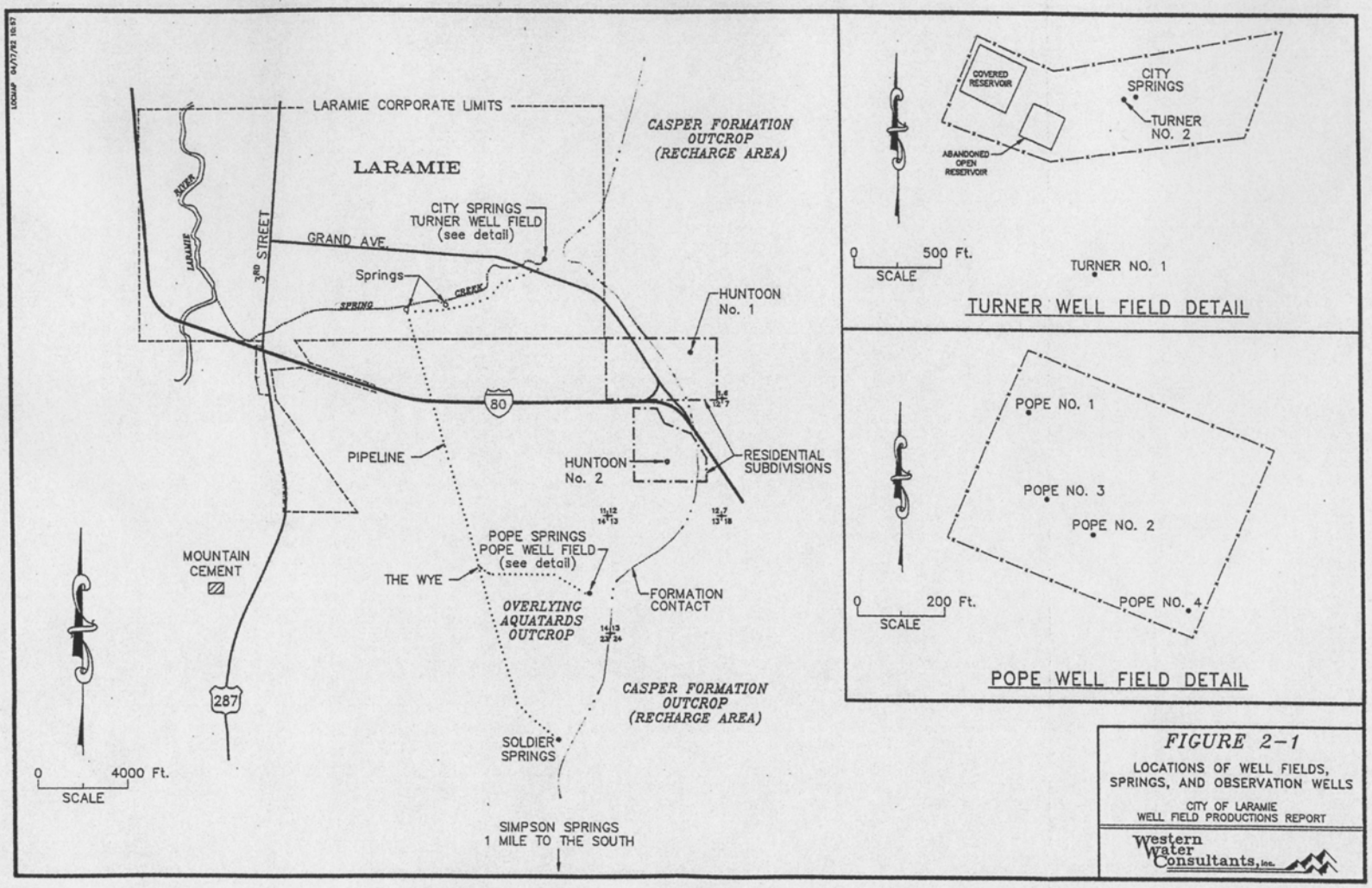
Western Water Consultants, Inc. WWC Engineering
Engineering Environmental Mining Water Resources

SPUR WELLFIELD

FIGURE 2-6
WELLFIELD Details

WYOMING GROUNDWATER, LLC

K:\WY Ground Water\2006-047_Laramie water management plan\CADD\wellfields.dwg, FIGURE 2-6, 8/18/2006 9:31:54 AM

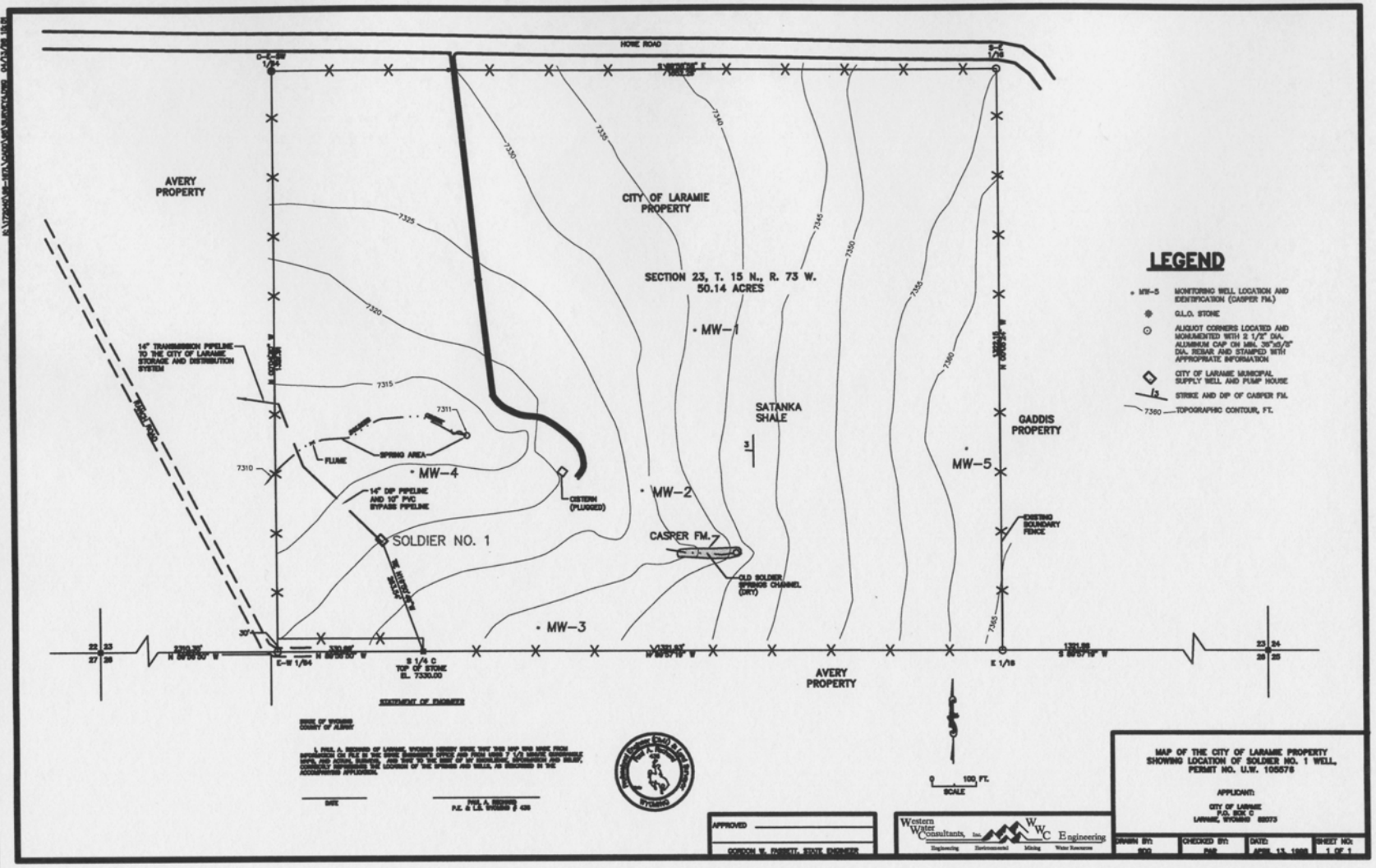


POPE WELLFIELD

FIGURE 2–7
WELLFIELD Details

WYOMING GROUNDWATER, LLC

K:\WY Ground Water\2006-047_Laramie water management plan\CADD\wellfields.dwg, FIGURE 2-7, 8/18/2006 9:32:25 AM

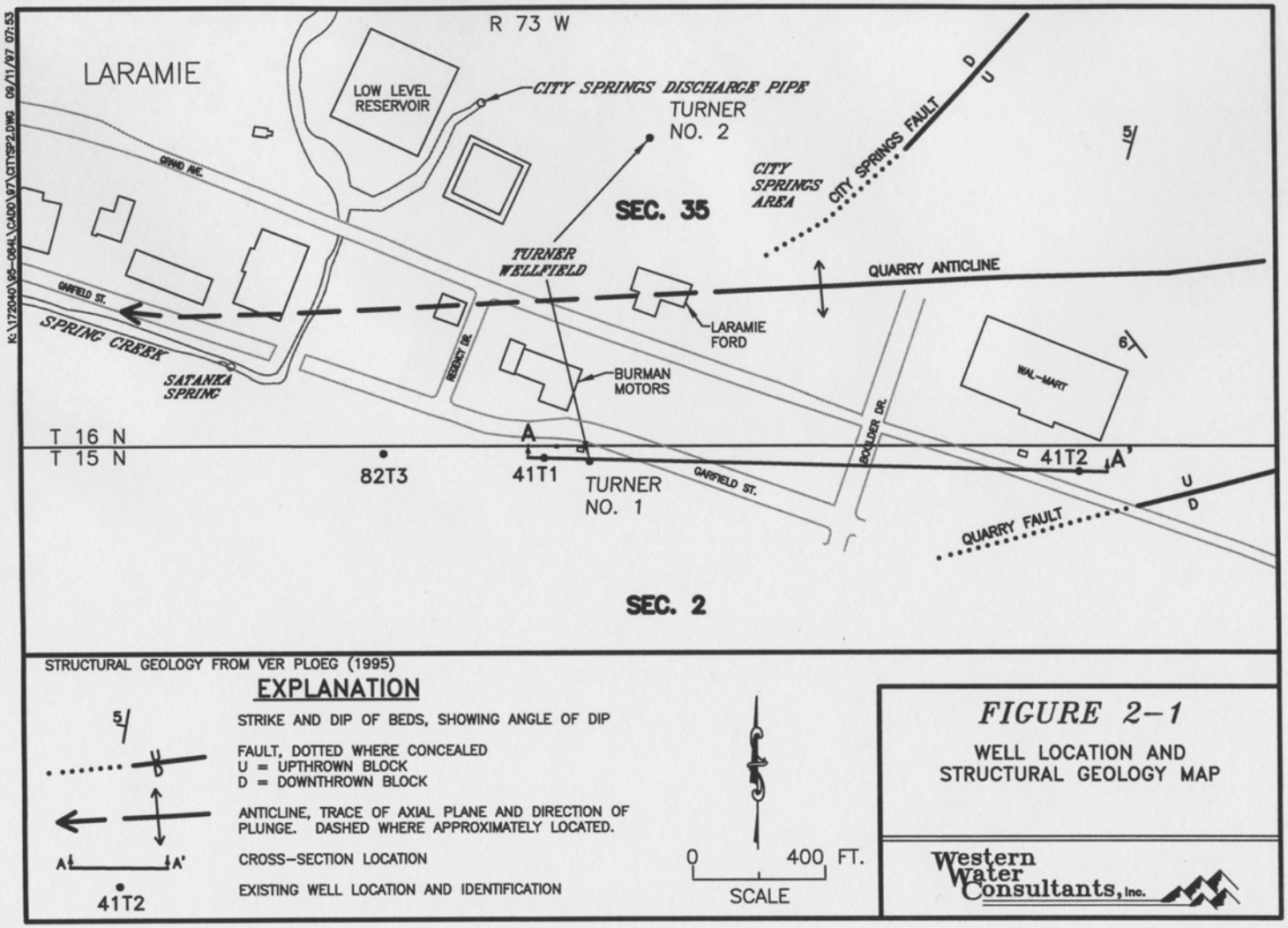


SOLDIER WELLFIELD

FIGURE 2-8
WELLFIELD Details

WYOMING GROUNDWATER, LLC

K:\WY Ground Water\2006-047_Laramie water management plan\CADD\wellfields.dwg, FIGURE 2-8, 8/18/2006 9:54:20 AM



K:\172040\95-0641\CADD\97\CITYSP2.DWG 06/11/97 07:53

K:\WY Ground Water\2006-047_Laramie water management plan\CADD\wellfields.dwg, FIGURE 2-9, 8/18/2006 9:54:10 AM

TURNER WELLFIELD

FIGURE 2-9
WELLFIELD Details

WYOMING GROUNDWATER, LLC

CHAPTER 3.0
EXISTING WATER USE

3.0 EXISTING WATER USE

3.1 Introduction

This chapter presents information about the City's existing municipal water demand. As with previous water planning efforts (Banner, 1983, WWC Engineering, 1995, Fassett, 2004), existing water use will be characterized using population and water production estimates. In addition, this 2006 project will characterize existing water use based on actual individual meter data.

3.2 Historic Use of Water Supplies to Meet Demand

As a general introduction to historical City water demand, Figure 3-1 presents water production from surface water and groundwater sources for the period 1992 through 2005. Data used for this figure is included in Appendix 3A. From 1992 to 2005, the surface water treatment plant (SWTP) has provided 42% of the City supply and the wellfields the remaining 58%.

Prior to 1995, the SWTP was operated from May to October and served as a peaking supply for the high demand summer months and the wellfields were used as the base winter supply and summer time peaking as needed. In 1995, the use of surface water and groundwater was modified to the present day operational strategy: the SWTP is now operated year round and provides a base winter (November – April) supply of approximately 1.5 mgd, as shown on Figure 3-2, supplemented by the 1.8 mgd artesian flow from Soldier No. 1. During the winter months, the Turner and Pope wellfields are allowed to recover and are used as needed to satisfy demand. As demands and surface water supplies increase during May – October, the surface water treatment plant production increases to about 6 mgd. During the summer months, the Turner, Pope, and Soldier wells are pumped as needed to meet peak demands. The Spur Wellfield is used exclusively to provide water for peak periods during the summer.

As shown on Figure 3-1, since 1992 there have also been some noticeable shifts in the relative annual production from the City wellfields:

- Increase in production from Soldier Springs following incorporation of the Soldier No. 1 well in 1998;

- Decrease in production from the Pope Wellfield; and a
- Noticeable decrease in production from the Turner and Pope Wellfields from 2003 – 2005 due primarily to a decline in summer time demand.

3.3 Service Area

A basic consideration in understanding present water use and projecting future needs is to define the service area of the water system. The present service area of the City water distribution system includes:

- The corporate limits of the City.
- Seven Mile Water District, west of the City. This District has about 37 active domestic water taps and it was brought into the service area in June 1985.
- South of Laramie Water District. This District has about 185 active taps and was brought into the service area in February 1996.
- 20 and 24 inch Transmission Lines. There are about 20 domestic water taps on the transmission pipelines between the water treatment plant and the City. These taps are believed to have been connected to the service area for at least the period of water demand data studied in this report.
- The Nine Mile Water District. This district includes 100 domestic water taps. The District began using water in May 2003. The existing water demand data used in this study does not reflect much use by the Nine Mile Water District.

3.4 Population

Table 3-1 presents historic service area population estimates. The estimates are a combination of census data from the U.S. Census Bureau, the Wyoming Department of Administration, and population estimates for the special service areas identified above and in Table 3-1.

3.5 Existing Water Demand – Per Capita Basis

3.5.1 General

In the arid climate of the Laramie River Basin, water demand varies greatly depending on the season. Irrigation demands by Laramie residents, City green space, and

UW landscaping greatly increase the total water use during the summer season. As with previous planning studies, this 2006 study divides the year into 4 periods:

- November through March; no irrigation demand
- October and April; small irrigation demand
- May and September; moderate irrigation demand
- June through August; high irrigation demand

3.5.2 Average Day Per Capita Water Demand

Average daily demands by season from 1970 through 2005 are presented in Table 3-2. These per capita demands were generated by dividing the water production values by the service area population estimates presented previously. Appendix 3A includes a detailed justification for the information presented in Table 3-2. The average values reported in Table 3-2 are used in the following chapter as one method for projecting future water demands.

3.5.3 Peak Day Per Capita Water Demand

The annual peak day demand statistic is usually evaluated during system operation and planning work. The annual peak day demand is the maximum demand (production) for any given day within the year. The 1983 Master Plan (Banner, 1983) presented 7-day maximum water demands and the peak day water demands. The 1995 Master Plan (WWC, 1995) presented only the 7-day maximum water demand. The 1995 plan clearly assumed that internal distribution system treated water storage is adequate to meet peak day and peak hour demands. The Management Plan for Water Right on the Monolith Ranch (Fassett, 2004) used the peak day statistic for water planning.

Table 3-2 presents peak day water production statistics from the 1983 Master Plan and those obtained from the 1992-2005 water records. Appendix 3A includes a detailed justification for the information presented in Table 3-2. The peak day values reported in Table 3-2 are used in the following chapter to project future peak day water demands.

3.6 Existing Water Demand – Meter Data

Water consumption data was received from the City of Laramie Utility Department. The database included water consumption for each system meter by month since the

upgraded RF-read meters were completely installed in July of 2004. Because averages of each month in 2004 and 2005 could not be calculated, our study examined only the 2005 data.

The water use database did not include spatial data, so it was joined to another City furnished database which related meter number to spatial location. In the process of joining these meter and location records, we could not locate approximately 5% of the records in the original water consumption database, so those records were discarded. The joined consumption data records were then mapped and a spatial analysis was performed to develop consumption statistics.

Because the objective of examining this data was to load the hydraulic model (Chapter 7) with peak day demands, only the July 2005 records were used to develop the information in the following sections.

The consumption data for July 2005 was selected by spatial location in reference to the City of Laramie zoning, and Table 3-3 and Figure 3-3 present the results of that analysis.

Water demand was also separated into two general demand types, residential and commercial. Business and Industrial demands were considered commercial and only the generalized residential numbers were used for its further generalization. U.S. Census Bureau demographic and population data were used to estimate population in the areas with residential zoning designations. The estimates are approximate, because census block delineations (polygons) do not precisely overlap residential zoning area delineations (polygons). Thus, GIS methods were used to assign census block population estimates to residential zoning areas that were in close proximity. The actual consumption numbers from the meter data were then used to determine a gpcd (gallons per capita per day) water demand for the residential zoning types. This demand was calculated as 230 gpcd, which compares well with literature values.

In contrast, commercial-type consumption statistics are less useful in a gpcd format. Commercial zoning types have relatively smaller populations in proportion to the consumption demands they produce. In this case a gallons per acre per day (gpad) form of consumption is generally used. For this portion of the analysis, total area of each zoning type block was determined using the GIS and related to consumption from the actual metered

data. This demand was calculated to be about 350 gpad. This number appears to be very low compared to literature values of 1,300 gpad.

3.7 Unaccounted For Water

The monthly production data in Appendix 3A was compared to the July 2005 metered data that was summed using the GIS meter data. Table 3-4 presents that comparison. The estimated unaccounted for water production is about 15% of the total production. Note that this estimate may be or is influenced by:

- The truncated GIS data set described in Section 3.6.
- The fact that park and cemetery use estimates are not metered. They are estimated by the Parks and Recreation Department.
- Production data is for the month of July, more or less, while meter read data is for standard meter read period.

Unaccounted for water use estimates provide some information regarding distribution system leakage. City staff suspect some leakage is present, primarily due to the aging and deteriorating distribution system piping. The recently completed water meter replacement project has reduced staff concerns that unaccounted for water use was due in part to meters in good condition (i.e. allowing water use, but not functioning). The City should regularly estimate unaccounted for water use and track trends in this quantity. The automated meter read program should help in this regard.

Purely for interest, the GIS database was queried to estimate the distribution of water use by meter size. The results of that work are shown in Table 3-5. Although the data is specific for July 2005, it provides additional information about the distribution of water use in town.

TABLES AND FIGURES

Table 3-1: Service Area Population Data, Estimates and Projections

	Census Data and Population Estimates							Target Population Projections
	Laramie Corporate Limits		Seven Mile W.D.	South Laramie W.D.	20/24 Inch Transmission Lines	Nine Mile W.D.	Total Estimated Service Area Population	From the 2006 Comp Plan
Year	U.S. Census Bureau Data	Wyoming Dept. of Administration and Information Data	Estimated See Note 1	Estimated See Note 2	Estimated See Note 3	Estimated See Note 4	Sum of Estimates Left of this Column	
1940	10,627						10,627	
1950	15,581						15,581	
1960	17,520				46		17,566	
1970	23,143				46		23,189	
1980	24,410				46		24,456	
1990	26,687		85		46		26,818	
1991		27,057	85		46		27,188	
1992		27,247	85		46		27,378	
1993		27,764	85		46		27,895	
1994		27,967	85		46		28,098	
1995		28,098	85		46		28,229	
1996		28,160	85	426	46		28,716	
1997		27,579	85	426	46		28,136	
1998		27,452	85	426	46		28,009	
1999		27,409	85	426	46		27,966	
2000	27,204		85	426	46		27,761	27,204
2001		26,859	85	426	46		27,416	
2002		26,622	85	426	46		27,179	
2003		26,515	85	426	46	230	27,302	
2004		26,441	85	426	46	230	27,228	
2005		27,140	85	426	46	230	27,927	29,245
2006		26,427						
2010		26,511						30,561
2015		26,716						31,717
2020		26,909						32,834
2030								33,830
2035								
2040								

Notes

1 Special Service Area Population based on 2.3 persons per household and 37 taps

2 Special Service Area Population based on 2.3 persons per household and 185 taps

3 Special Service Area Population based on 2.3 persons per household and 20 taps

4 Special Service Area Population based on 2.3 persons per household and 100 taps

Table 3-2 Water Demand by Season in Gallons Per Capita Per Day (gpcd)

	Average Day				Average Peak Day Demand		
	1971-1980[1]	1981-1990[2]	1992-2005[3]	2000-2005[3]	1971-1980[1]	1992-2005[3]	Peak[3,4]
	gpcd						
Winter (N, D, J, F, M)	150	180	155	144	240	247	295
Summer (J, J, A)	390	410	331	332	550	504	624
Oct/Apr	175	195	171	164	385	263	342
Sept/May	248	320	239	233	480	372	443
Annual	230	264	210	198	550	-----	623

Notes:

1. Source: Water Supply Master Plan, Banner 1983, Table 2.12 Recommended for planning.
2. Source: Level 1 Water Supply Master Plan, WWC 1995.
3. Source: City of Laramie as part of this study. The 1991 data is incomplete. More detail provided in Appendix 2-1.
4. Source: Peak is the peak day for each season from the 1992-2005 data.

Table 3-3 July 2005 Water Consumption by Zoning Type

Original Zoning		Generalized Zoning Type	Area	Population[1]	Total Consumption July 2005		
			ac		gpm	Mgal	total, by zoning type, Mgal
Undefined	--	Undefined	5	300	<1	0.0	<1
Not Zoned	--	Unzoned	-	368	197	8.8	8.8
Limited Business	B1					10.4	
General Business	B2					23.6	
B1R	B1R					0.0	
Commercial Wholesale	C2	Business	1,540	3,143	785	1.1	35.1
Light Industrial	I1					0.0	
Industrial	I2					3.3	
Industrial Park	IP	Industrial	569	573	75	0.0	3.4
Light Manufacturing	LM					0.1	
Low Density Residential	LR					11.3	
Open Zone	O					1.7	
Planned Unit Development	PUD					0.1	
Rural Residence	RR	Miscellaneous	2,359	5,809	361	3.0	16.1
Low Density Residential	R1					33.5	
Medium Density Residential	R2					32.7	
Medium Density Residential W/ Independent Mobile-Homes	R2M					7.6	
Multifamily	R3	Residential	2,660	17,989	3219	69.9	143.7
		TOTAL	**7,133**	**28,182**	**4,638**	**207.1**	**207.1**

(1) Estimated using census block data.

Figure 3-3 July 2005 Water Consumption (MGal) by Zoning Type

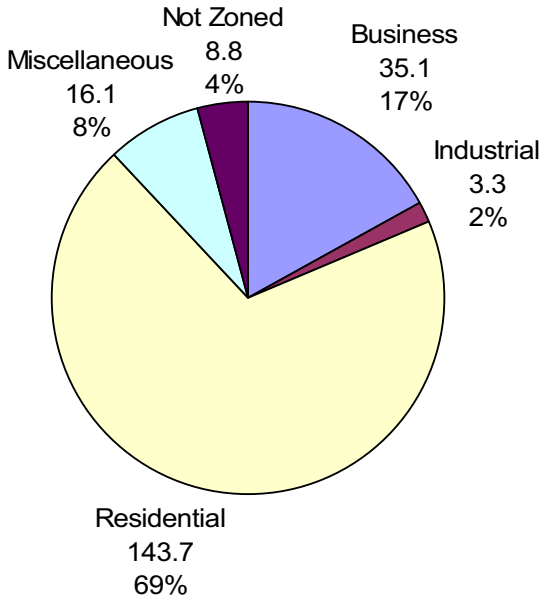


Table 3-4 Unaccounted for Water Production

		MGal
July 2005 Production	**Total Production**	**283.31**
July 2005 Consumption	Metered	207.024
	Unmetered Cemetary	6.007
	Unmetered Parks, Buildings, UW Golf Course, and UW Recreation Fields	26.998
	Total Consumption	**240.029**
Unaccounted for Production		43.281
% Loss		15.28

Table 3-5 Distribution of Water Use by Meter Size, July 2005

Meters		Total Consumption July 2005	
Size (in)	**Count**	**Mgal**	**Approximate Gal/Tap**
0.75	7190	98.77	14,000
1	710	18.04	25,000
1.5	129	16.64	129,000
2	138	21.70	157,000
3	31	9.69	313,000
4	18	13.88	771,000
6	21	19.57	932,000
8	9	9.73	1,081,000
Unknown	-	75.30	-
Total	**8246**	**283.31**	**-**

Figure 3-1 City of Laramie Water Production 1992-2005

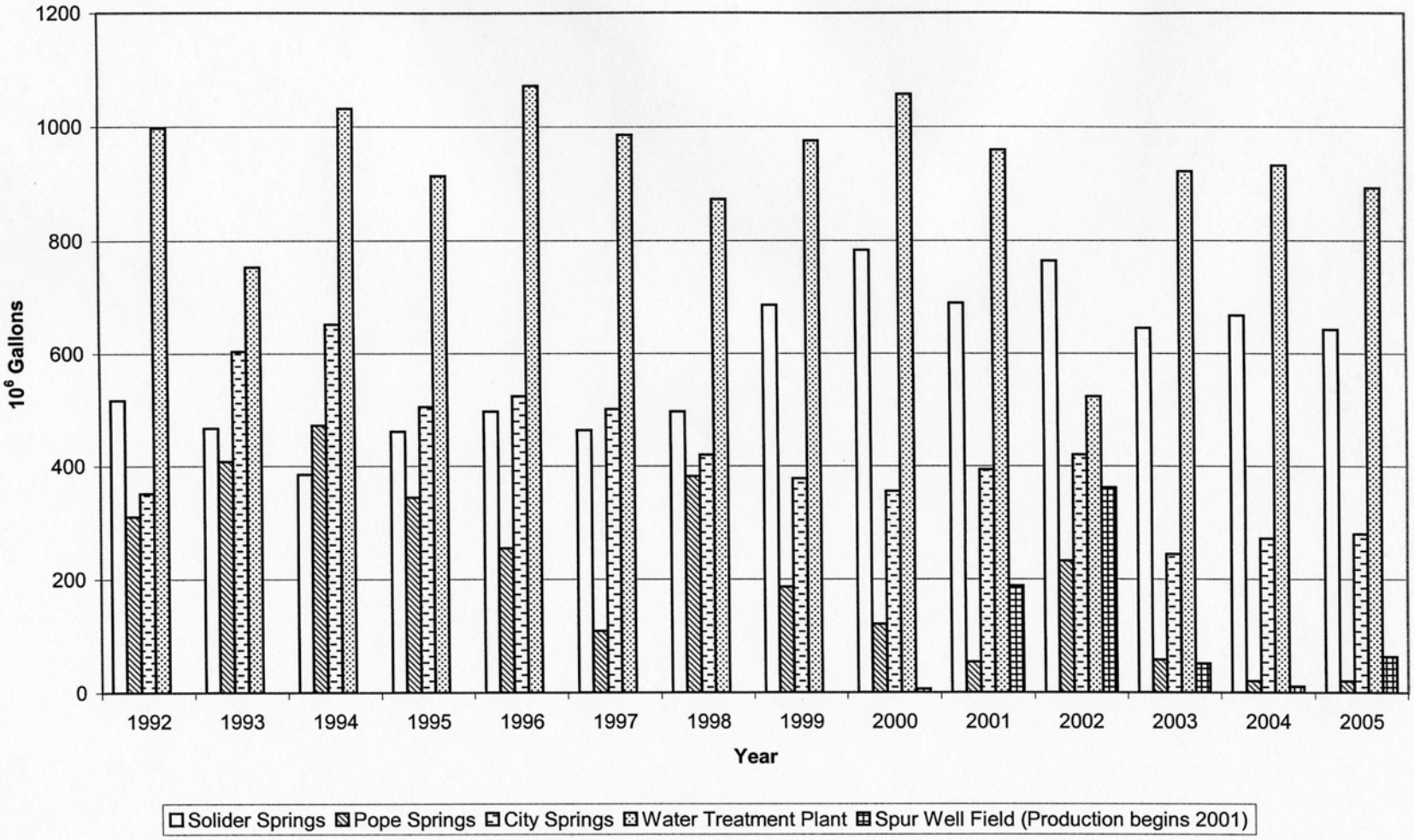
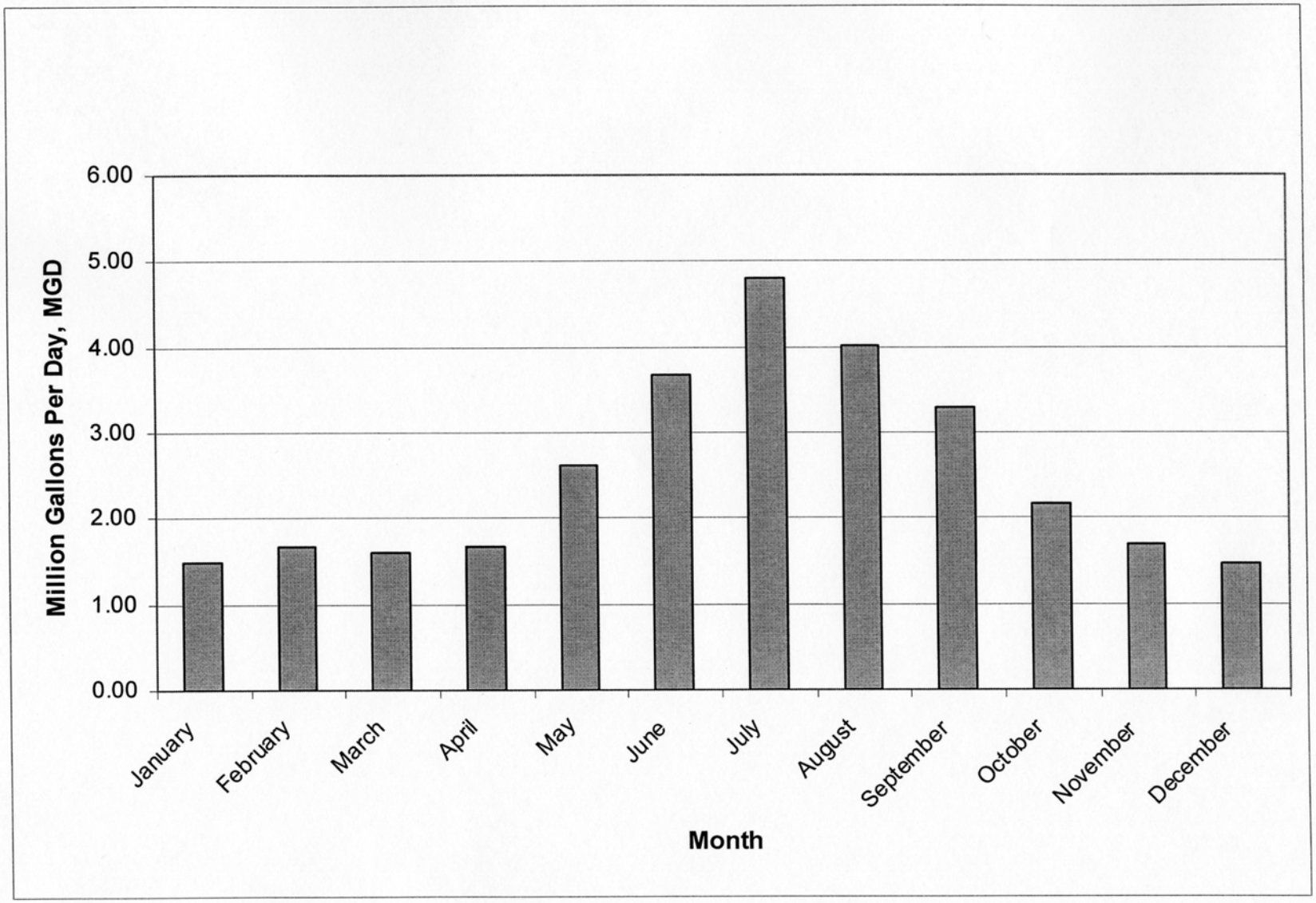


Figure 3-2 Monthly Average Production from Surface Water Treatment Plant-1995-2005



CHAPTER 4.0
FUTURE WATER DEMAND

4.0 FUTURE WATER DEMAND

4.1 Introduction

This chapter presents a forecast of the City's future water needs. This work updates the most recent population and water demand projections included in the Management Plan for Water Rights on the Monolith Ranch (Fassett, 2004).

4.2 Service Area

For the purposes of forecasting water demand, the future service area of the City water distribution system was assumed to be the same as the existing service area presented in Chapter 3.

During the course of this study, WWC staff met with several local developers regarding their plans for residential, commercial, and industrial development. WWC met (or tried to meet) with everyone that had an active development proposal in the City Planning Office and with developers who otherwise had been identified by the City as actively pursuing on developments. The general consensus of the developer group was that Laramie continued to be in a steady growth mode as it has for several years. However, from discussions WWC also learned that the developers are not confident that all developments will proceed nor will they "build out." Also, developers acknowledge that economies and politics will encourage other developments that were not reviewed during this study.

During the developer discussions presented above, WWC was made aware of several developments adjacent to but not within current city limits, including ones south of the City, on North 3rd Street, and along Highway 230 as examples. Our future conditions planning, presented in Chapter 7, took these types of developments into account.

4.3 Population Forecast

In late 2005, the City of Laramie resumed work on a community wide comprehensive plan. The plan was to address 12 standard planning elements, including water system infrastructure. That plan was to be prepared using a 20-year planning horizon, and one comprehensive plan task was to forecast the City population at the planning horizon. At the time of this report writing, the comprehensive plan was not complete, but draft target

population data was available. This target population was developed as a result of forecasting several future populations using different methodologies.

At the request of the City, this current Water Management Study has adopted the same planning horizon and population target used in the ongoing comprehensive plan.

Figure 4-1 presents the historical population data presented in Chapter 3, and the targeted City population presented by the Comprehensive Plan, which is through the year 2025. It should be noted that Figure 4-1 does not show the projected population for the water supply service area. Table 4-1 includes the water supply system service area population, which is the comprehensive plan target plus the estimated population of the special service areas (787 people as shown in Table 3-1).

For reference, the statewide population projections prepared by the Wyoming Department of Administration & Information actually suggests and presents a decrease in Laramie's population to 26,590 in 2020.

4.4 Water Demand Projections for Supply Planning

The per capita demand method was used to estimate future water demands. Water demand is estimated by multiplication of estimated population by per capita unit demands. Table 4-1 and Figures 4-2 and 4-3 present the projected water demands for the 20-year planning horizon.

4.5 Water Demand Projections for Distribution System Planning

The demand forecasts for new growth in the distribution system model (Chapter 7) were arrived at using an approach based on water use for both residential and commercial land use types. The method is different than the per capita approach, but it provides an alternative technical forecasting method of loading individual demand nodes with types of water use estimates. There is a table in Chapter 7 that presents those projected demands using the water use by land use type statistics developed in Chapter 3.

TABLES AND FIGURES

Table 4-1 - City of Laramie Service Area Projected Water Demand

			Average Day Demand					Annual Total	Peak Day Demand			
			M&S[2]	A & O[2]	Summer J,J,A[2]	Winter N,D,J,F,M[2]	Annual		M&S	A & O	Summer J,J,A	Winter N,D,J,F,M
Year	Projected Service Area Population[1]		mgd					ac-ft	mgd			
		gpcpd	239	171	331	155	210		372	263	504	247
		days	61	61	92	151	365		61	61	92	151
2006	30,295		7.2	5.2	10.0	4.7	6.4	7,127	11.3	8.0	15.3	7.5
2011	31,579		7.5	5.4	10.5	4.9	6.6	7,429	11.7	8.3	15.9	7.8
2016	32,727		7.8	5.6	10.8	5.1	6.9	7,699	12.2	8.6	16.5	8.1
2021	33,820		8.1	5.8	11.2	5.2	7.1	7,956	12.6	8.9	17.0	8.4
2026	34,816		8.3	6.0	11.5	5.4	7.3	8,190	13.0	9.2	17.5	8.6
2031	35,812		8.6	6.1	11.9	5.6	7.5	8,425	13.3	9.4	18.0	8.8
2036	36,808		8.8	6.3	12.2	5.7	7.7	8,659	13.7	9.7	18.6	9.1
2046	38,800		9.3	6.6	12.8	6.0	8.1	9,128	14.4	10.2	19.6	9.6
2055	40,593		9.7	6.9	13.4	6.3	8.5	9,549	15.1	10.7	20.5	10.0

(1) The Projected Service Area Population is the Comprehensive Plan Target Population plus the population estimate (787 people) for the special service areas identified in Table 3-1. The values in this column are the same as those presented in Table 11-2.

(2) M&S = March and September
A&O = August and October
J,J,A = June, July, and August
NDJFM = November, December, January, February, and March

Figure 4-1 - Population Data and Projections

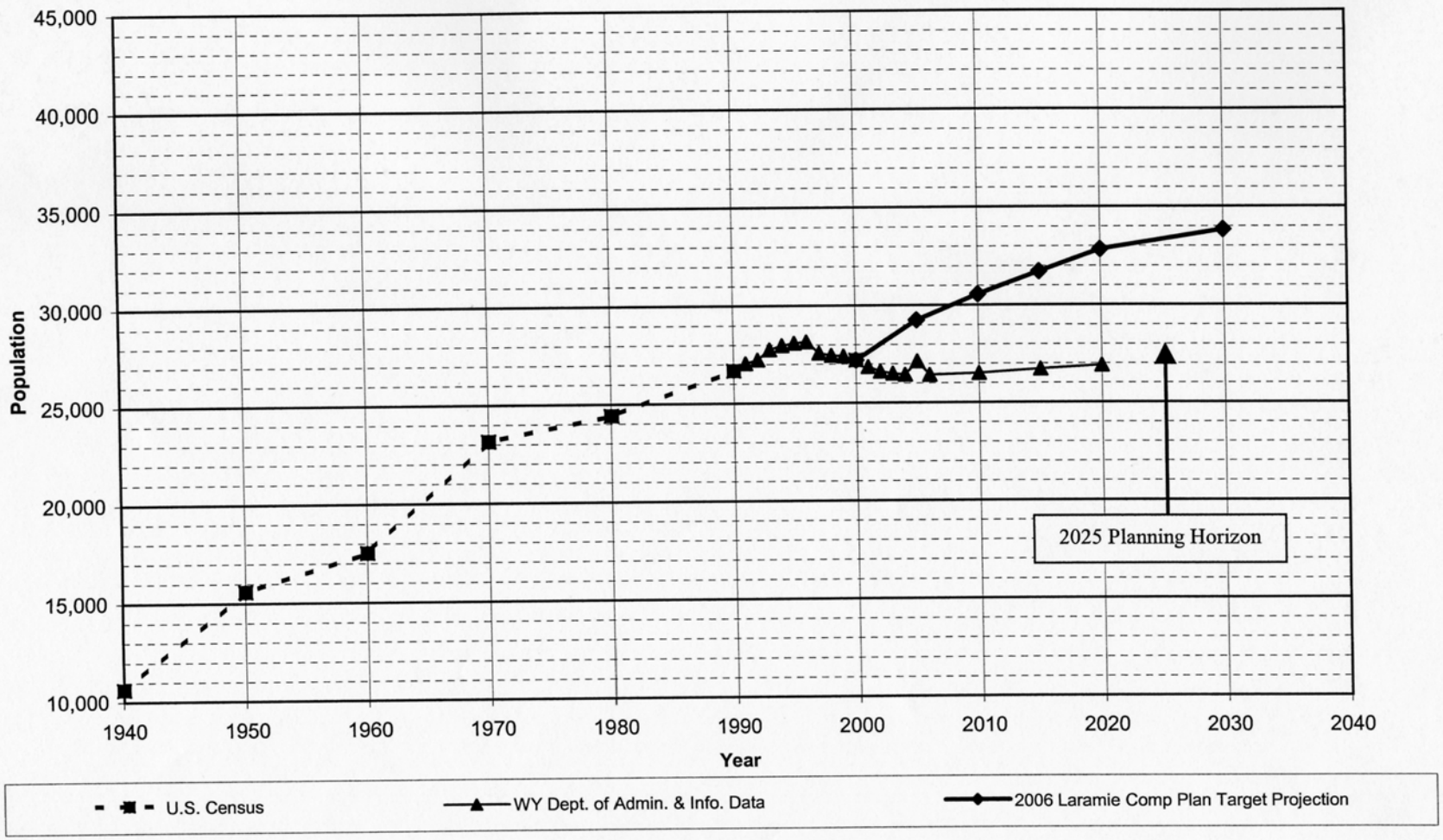


Figure 4-2 Projected Average Day Demand

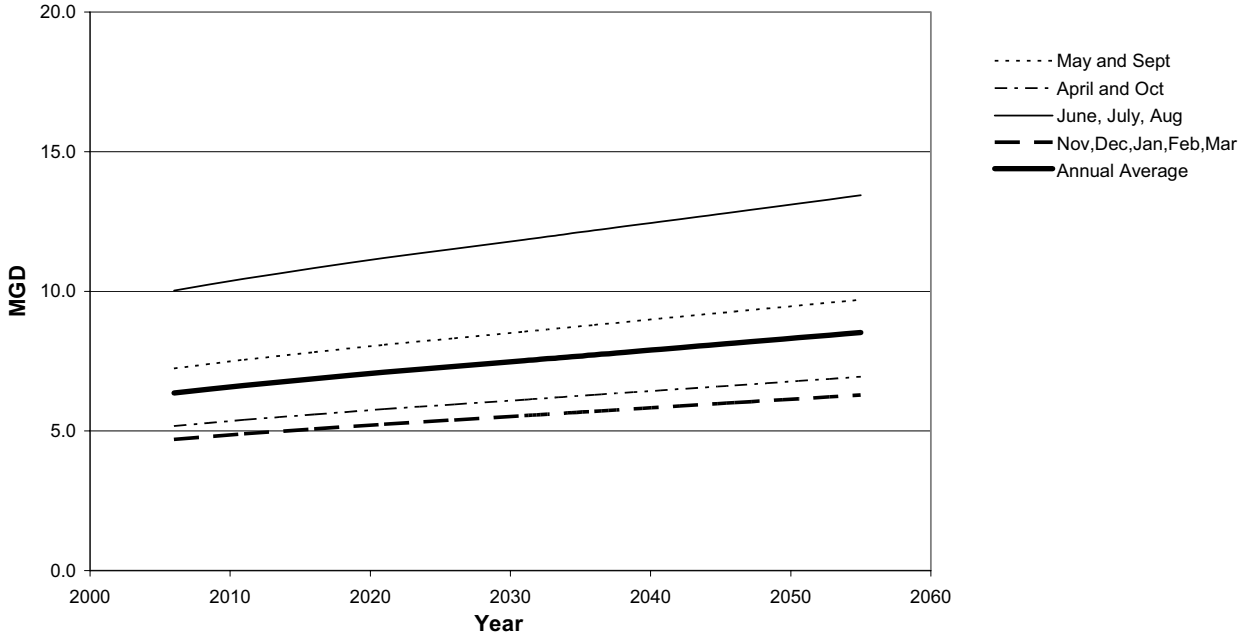
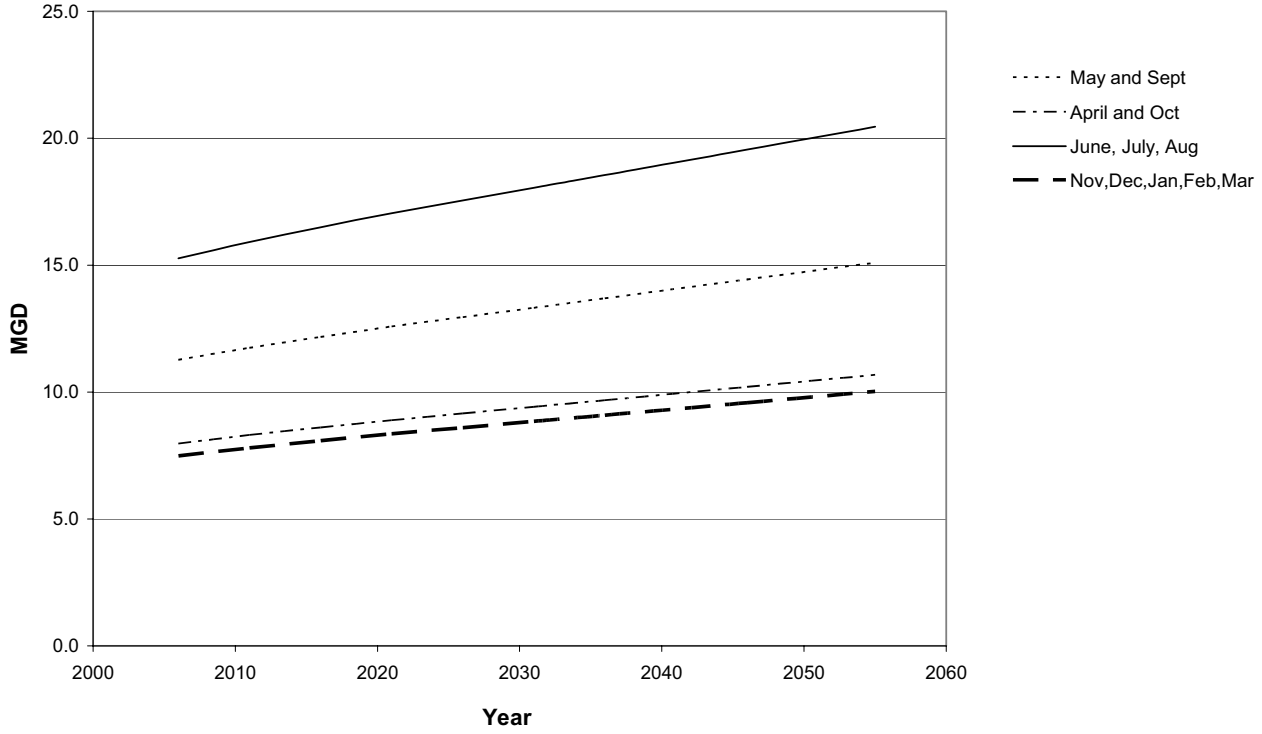


Figure 4-3 Projected Peak Day Demand



CHAPTER 5.0
SOURCE OF SUPPLY ALTERNATIVES

5.0 SOURCE OF SUPPLY ALTERNATIVES

5.1 Introduction

Chapters 2, 3, and 4 of this report presented an evaluation of the existing water resources, their current use and Laramie's forecasted water needs. This chapter presents information regarding the variety of water supplies available to the City and presents recommendations on which sources should be considered when municipal needs dictate. It is not the objective of this chapter to present a specific water supply development plan. That specific plan is reviewed, rationalized, and presented in Chapter 11.

5.2 Background

In 2004, the City completed the Monolith Ranch Water Rights Management Plan (MRWRMP) (Fassett, 2004). During that project the City and its consultants expended considerable effort discussing, evaluating, and presenting three items related to water supply alternatives, including:

- A long list of water supply opportunities;
- Criteria and strategies for developing new water supplies, allowing preferred projects to be identified in the long list of opportunities; and
- A list of preferred water supply development alternatives that would meet the needs of the City at and beyond the planning horizon.

The next three sections of this chapter (5.3, 5.4, and 5.5) include a summary presentation of the items outlined above as they were presented in the MRWRMP. The reader should review the actual MRWRMP report for in-depth information on these subjects.

5.3 Long List of Water Supply Opportunities

A wide variety and large number of alternative water supply projects have been previously studied, evaluated, and implemented over the years. The MRWRMP (Fassett, 2004) presents a modern discussion on the long list of past, present, and future water supply opportunities for Laramie. As a summary of the information presented in the MRWRMP, the long list opportunities are summarized in Figure 5-1 and Table 5-1.

5.4 Feasibility Criteria and Preferred Strategies

For the MRWRMP project, City officials and the consultants completed a review of the substantial body of technical work related to the long list of water supply opportunities and presented recommended water supply options and strategies for the City's consideration. In developing these recommendations they relied on engineering, hydrologic principals, and their professional experiences with similar projects. The following two report sections include the key considerations, criteria, and strategies that were identified and considered during the reduction of long list opportunities into a practical short list of opportunities:

5.4.1 Considerations and Criteria

- Cost. Project cost is an important criterion in evaluating water supply options and alternatives. However, the least expensive options may not have always been the top recommendation or selection because of other important criteria.
- Location. The physical location of the various water projects is an important feasibility consideration because of the cost of the right-of-way and infrastructure to develop and convey new sources of municipal water to the City. The alternatives that can take advantage of the existing water supply facilities or expand upon the City's prior investments are often a part of the recommended mix of options and alternatives.
- Firm yield. In virtually all water development investigations, decisions regarding what water supply options to pursue are all largely based on water yield expectations and cost comparisons.
- Institutional procedures and constraints. A wide variety of primarily federal and state laws, rules, regulations, and policies affect the business of water supply development and management. For the purposes of this report, the institutional constraints, primarily in terms of the federal or state permitting that would likely be required for each of the recommended water supply options, alternatives, and strategies were considered and updated. Two important changes and clarifications in several procedures were updated included in Chapter 2 related to the Modified North Platte Decree and the

Platte River Endangered Species Recovery Program. In addition, summarized in Appendix 5A of the MRWRMP are a broader set of key institutional constraints that have been identified and considered in this study and arriving at the recommended water supply alternatives. Detailed examination of the applicability of specific laws and regulations would be required as a part of any particular project or strategy advancing to implementation.

5.4.2 Strategies

5.4.2.1 Strategy 1 - Ownership and management control over water supply resources

The water supply options where the City maintains the primary ownership, control and management of the facilities and rights are a priority. Many municipal entities have developed water systems and established relationships with other entities for the use and operation of those facilities that have had mixed results and benefits to the city. While many of these types of projects can be workable, often they are not the preferred options for a city because of: 1) the potential exposure to liability resulting from an accident or an unsafe condition at certain shared infrastructure, 2) costs, often resulting from a perception that the partnering City is a "deep pocket" for repairs, rehabilitation, and operating expenses, 3) and control over decision-making, where the priority for decisions for meeting municipal water supply needs takes precedence over the other shared uses, verses situations where conflicting missions or goals result in a disadvantage to the municipal uses.

In this light, some of the long-list of water supply alternatives was discounted in the final list of recommended project alternatives and management strategies due to any circumstances where the City is not in control of its water supply system. These include:

- For future transfers of water rights, relying upon the Pioneer Canal for conveyance to the City WTP,
- For re-regulating or managing purchased direct flow water rights from either the Big or Little Laramie River systems, into and through Lake Hattie, currently owned and operated by the Lake Hattie Irrigation District, and

- Relying upon potential groundwater well supplies that are shared or jointly owned by entities or individuals with perhaps a different mission or goal for the use and management for the groundwater, such as the University of Wyoming or a homeowners association.

5.4.2.2 Strategy 2 - Maximize existing water supply assets and resources

A long-list of water supply options were considered in the MRWRMP (Fassett, 2004). These options included those raised by City officials and the public or those studied previously, including a variety of options and water management strategies that were preferred, because they relied upon or maximized the efficient use of the City's existing water supply facilities and resources. These options make excellent use of the City's existing infrastructure, which greatly reduces the costs by: 1) minimizing the up-front project construction investments, 2) shortening the implementation schedule, and importantly 3)reducing the institutional constraints outlined in the feasibility criteria above. The details of options are discussed below but include:

- Reducing municipal treated water demands by instituting water conservation guidelines and developing raw water supply options for meeting those demands where treated water is not necessary, such as, for City parks, recreation areas, golf courses and similar uses. This could include the use of Laramie River surface water or the development of groundwater wells not completed in the Casper Aquifer to meet these needs and reducing the demands upon the municipal water treatment plant, Casper Aquifer wells, and the treated water distribution system.
- Making full use of existing municipal water rights and infrastructure, such as those associated with the Monolith Ranch and current springs and groundwater well developments.
- Reduction in the amount of historic and on-going municipal system water losses, which reduce the water delivered to meet the needs of the citizens and businesses, such as: 1) the leakage from older water distribution water mains, 2) seepage along the Pioneer Canal deliveries to the Laramie Water Treatment

Plant, 3) operational changes at City Springs and the Turner Wellfield to reduce the lost water yield from the springs, 4) minimizing the losses of the City's water rights as a result of the transfer or change of use from irrigation to municipal use, and 5) recapture, exchange or reuse of non-tributary groundwater return flows currently discharged to the Laramie River through the wastewater treatment plant. While reuse of a portion of the City's surface water rights previously transferred from irrigation use is restricted under the terms of the State Board of Control Order approving those transactions, the reuse, recapture or exchange of the City's return flows derived from the non-tributary portion of the City's groundwater supplies should be considered.

5.4.2.3 Strategy 3 - Preserve, protect, and build on existing water supply investments

Water supply options, that build or expand upon the City of Laramie's existing water resource investments and foresight is another category of preferred alternatives that will be discussed in detail below. Beginning many years ago, City officials made decisions and investments for the long-term security of a reliable water supply, most notably, the purchase of the land and water rights associated with the Monolith Ranch. Investments in the Laramie River Water Treatment Plant and the Casper Aquifer groundwater developments associated with City Springs, and the Turner, Pope, Soldier and Spur wellfields have served the City reliably and projects that expand upon, complement, and use the existing facilities will be given full review and consideration in this study. The drought-like conditions in 2002 have pointedly defined the importance of the City's having a mix of surface and groundwater resources to complement each other during times of stress. The recommendations below will build on this base to meet the future municipal demands.

5.4.2.4 Strategy 4 - New reservoir development options

As noted and described previously, a wide variety of surface water reservoir sites have been evaluated over the years as a water supply option to meet the City's

demands for the future. The MRWRMP did not recommend development of any new water supply reservoirs for the City of Laramie. The reasons for these conclusions are several:

- The projected municipal water demands for the 30-year study period do not identify nor support the need for a new storage reservoir. The wide variety of recommended water projects and management strategies are more than satisfactory to meet all identified future municipal demands even during the rarest of drought conditions recently experienced.
- Every identified new dam and reservoir site is a very expensive undertaking and when compared to the other alternatives, such investments are not warranted.
- The institutional constraints criteria for the construction of a new reservoir place prohibitive up-front costs on a time consuming and uncertain outcome. At best, the rehabilitation or uses of some existing reservoirs are the only alternatives worthy of further consideration, such as Sodergreen Reservoir.
- The best possible reservoir development is conjunctively managing and using the Casper Aquifer and other groundwater supply options in concert with the available surface water supplies. The City has facilities, access, and rights to use a significant portion of a carryover storage reservoir that is so important during period of drought. It is simply located underground. The current study continues to promote this philosophy by advancing a conceptual design for an aquifer storage retrieval project (Chapter 10).

5.5 Preferred Water Supply Alternatives

The MRWRMP presented an in-depth discussion on preferred (short list) water supply alternatives, and the reader should consult that document for in-depth discussion. Table 5-2 is provided as a summary of those short listed alternatives.

During the execution of this current Laramie Water Management Level II Study, the City and the consulting Team reviewed the short list presented in the MRWRMP. Our recommendation is that the City continues to view this short list as the most practical and

feasible set of alternative water supply opportunities. There have been no findings in the current study that would support a change to the short list.

In future years, as new information is obtained and the water resource needs change, the City should periodically revisit this short list to refine understanding regarding individual opportunities and to ensure that the short list remains reasonable. In fact, a stated objective of this current study is to refine understanding regarding several of these water supply alternatives and to further evaluate their feasibility. Table 5-2 identifies which of the short list alternatives is being reviewed during this present study.

TABLES AND FIGURES

Table 5-1 Long List of Water Supply Opportunities (Fassett, 2004)

	Opportunity [Fassett, 2004]	Transbasin Diversion Opportunities	Reservoir Storage Opportunities	Water Efficiency Improvement Opportunities	Groundwater Development Opportunities
1.a.	Diversion from the North Platte River Basin	x			
1.b.	Purchase of surplus water from Cheyenne Stage II	x			
1.c.	Purchase of water from the Laramie-Poudre Tunnel	x			
2.a.	Roberton-McConnell Reservoir		x		
2.b.	Lake Hattie		x		
2.c.	Enlarge Sodergreen Reservoir		x		
2.d.	Fox Creek Reservoir		x		
2.e.	Boswell Creek Reservoir		x		
2.f.	Laramie River Reservoir Site No. 1		x		
2.g.	Laramie River Reservoir Site No. 2		x		
2.h.	Monolith Ranch Reservoir		x		
2.i.	An Off-steam Reservoir located north of Laramie		x		
2.j.	GoForth Reservoir		x		
2.k.	Spring Creek Reservoir		x		
3.a.	Line Pioneer Canal to Sodergreen Reservoir			x	
3.b.	Pipeline from Laramie River to Water Treatment Plant			x	
3.c.	Use of Laramie River Water for Non-potable Purposes			x	
3.d.	Reduce Waste of City Springs Water			x	
3.e.	Non-Potable Use of Wastewater Treatment Plant Effluent			x	
3.f.	System Integration and Conjunctive Use Management			x	
3.g.	Storage of Direct Flow			x	
3.h.	Conservation			x	
4.b.	Wellfield Prospects in the Casper Aquifer				x
	(1) McGuire Well				x
	(2) Ranch, Windmill, and Red Hill Prospects				x
	(3) Alcoa Well				x
	(4) Spur Anticline				x
	(5) Jack Rabbit Fault and Anticline				x
	(6) Expansion of Turner Wellfield Using the 1941 Turner No. 2 Well				x
	(7) LePrele Park (aka Spring Creek)				x
	(8) Laramie Fault				x
	(9) Hunziker Well				x
	(10) West Simpson Anticline and Laramie Fault				x
	(11) Simpson Springs Area				x
	(12) Boulder Ridge and Associated Anticlines				x
4.c.	Modifications to Existing Wellfields				x
4.d	Redbed Groundwater Development for Irrigation Purposes				x

Table 5-2 Short List of Water Supply Alternatives (Fassett, 2004)

Alternative Number (Fassett, 2004)	Alternative	Comments
1	Monolith Ranch	
1a.	Dowlin Ditch	
i.	Change point of diversion for municipal use	
ii.	Change in place of use for parks and other City Irrigation needs	See Chapter 9
1b.	Goforth Reservoir	
1c.	Fivemile / Harney Creek	
2	Pioneer Canal	
2a.	Diversion / Conveyance Improvements from River to WTP	
i.	Canal lining	
ii.	Piping	See Chapter 6
3	Conservation	
3a.	Distribution System Leakage	See Chapter 3
b.	Water Restrictions	
c.	Water Reuse	
4	Groundwater Supply	
4a.	City Springs / Turner Wells	See Chapter 10
b.	Spur Well	
c.	Simpson Springs	
d.	Satanka Shale and Forelle Limestone Aquifer Development	

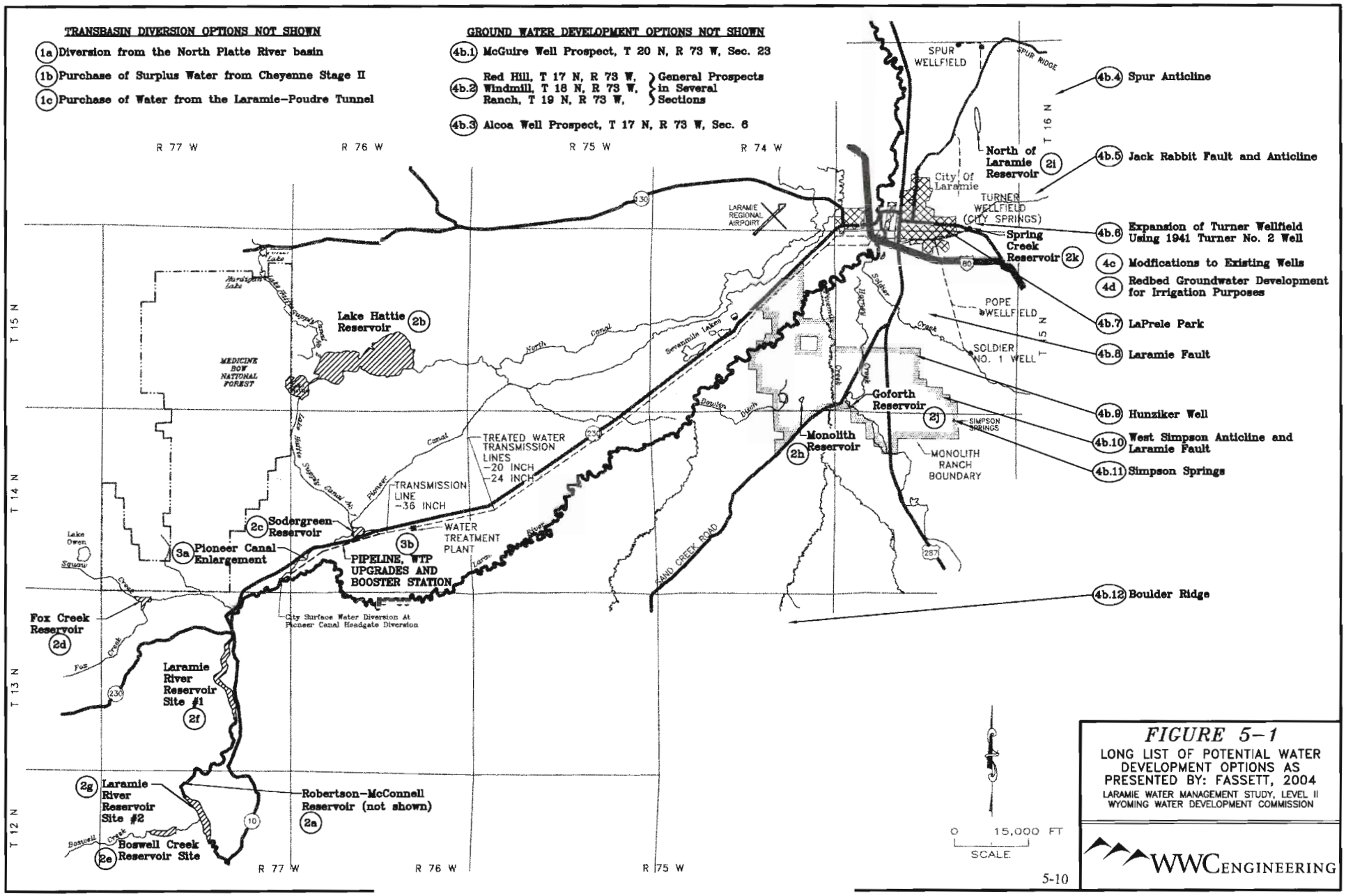


FIGURE 5–1
LONG LIST OF POTENTIAL WATER DEVELOPMENT OPTIONS AS PRESENTED BY: FASSETT, 2004
LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

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CHAPTER 6.0
WATER TREATMENT EVALUATION

6.0 WATER TREATMENT EVALUATION

6.1 Objective

The purpose of this chapter is to present the current and future water treatment regulations and discuss the best approach or treatment process to meet these requirements

6.2 Raw Water Quality

Typical values for the key water quality parameters affecting treatment for the Laramie surface water and the groundwater supplies are listed in Tables 6-1, titled "Laramie River Raw Water Quality" and Table 6-2, titled "Laramie Wells Groundwater Quality". A more extensive review of the water quality of each source was presented previously in Chapters 2 and 3. In Table 6-1, the water quality for both the existing Water Treatment Plant (WTP) intake and the Monolith Ranch intake are shown. It should be noted that the water quality degrades from the existing WTP intake to Monolith Ranch intake. Specifically, there is a substantial increase in the Total Dissolves Solids (TDS), hardness and sulfates. As a result, any future treatment facilities using surface water at the Monolith will require treatment processes to reduce hardness and other minerals. This will be discussed in greater detail in a subsequent section.

6.3 Existing WTP Facilities

6.3.1 Surface Water Treatment Plant (WTP)

The City of Laramie's existing WTP is a conventional surface water treatment plant. The plant currently serves approximately 30,000 people and operates year-round. The plant operates 24 hours per day and includes rapid mix (coagulation), flocculation, sedimentation, ozonation, filtration, and chlorine disinfection. The plant was constructed in 1962 and is about 44 years old. The original design capacity of the WTP was 6.0 mgd. According to the plant operator, Mike Lytle, the WTP is operated from 6.5 to 7.0 mgd. Each unit process is discussed in further detail below. Figure 6-1, titled "Laramie Existing WTP Process", shows the basic flow of the treatment plant processes and chemical addition points.

The raw water entering the plant is conveyed by the 36-inch gravity pipeline from Sodergreen Reservoir. The raw water flows through a rapid mix chamber with a mechanical mixer. Powdered Activated Carbon (PAC) and alum (used for alkalinity purposes) are added

upstream of the mixer. Downstream of the mixer, the treated water enters coagulation and flocculation facilities. Here a coagulant polymer and fluoride are added to the water. One of these treatment trains has been converted to a solids contact clarifier. The other is a conventional flocculation and sedimentation basin. These clarifiers provide flocculation, clarification, and positive sludge collection in each basin. These facilities have a combined treatment capacity of about 8.0 mgd.

The water flows from the coagulation and flocculation basins to six (6) dual media gravity filters. Each filter has a surface area of 360 square feet. The dual media consists of 27-inches of anthracite and 9-inches of silica sand. WYDEQ standards allow for filtration rates up to 5 gpm/sf for dual media filters. Using this rate and assuming one filter out of service for backwashing, the filters have a firm capacity of 13 mgd (5 filters x 2.6 gpd). The filters also have a surface wash system and air scour system installed. The water backwash system is limited to supplying 10 to 12 gpm/sf of backwash water. The system should be able to provide up to 20 gpm/sf to meet regulatory requirements.

The filtered water is conveyed to a clearwell that has an approximate capacity of 500,000 gallons. Chlorine and caustic soda are added at the head of the clearwell for disinfection and pH control. From the clearwell, the filtered water flows by gravity about 20 miles to the City through two pipelines that are 24-inches and 20-inches in diameter. The WTP provides gravity service to the main pressure zone in the distribution system and a portion of water is pumped to City's higher pressure zones and storage tanks. More discussion on the distribution system is contained in Chapter 7.0.

The Disinfection Contact Time (CT) requirements are met in the existing WTP clearwell and pipeline to the City. Disinfection CT is defined as the product of the disinfectant residual 'C', in mg/L, and disinfectant contact time 't_{10}', in minutes. The Surface Water Treatment Rule (SWTR) currently requires 3-log removal/inactivation of *Giardia* cysts and 4-log removal/inactivation of viruses. The City of Laramie WTP can assume a 2.5-log removal for *Giardia* and 2.0-log removal for viruses. Therefore, disinfection at the City of Laramie WTP must provide an additional 0.5-log removal/inactivation for *Giardia* and 2.0-log removal/inactivation of viruses. The City is currently meeting this CT requirement through the existing clearwell. It should be noted that ozone is not considered in the CT calculation since the water is blended.

6.3.2 Groundwater Treatment Facilities

There are three groundwater treatment facilities for the well sources summarized previously. One facility treats the water from both the Soldier Springs and Pope Wells at the "Wye" (where the two discharge pipelines meet). The second facility is at Turner Wells (City Springs). The third facility treats the groundwater from the Spur Wells. Treatment is limited to chlorination and fluoridation.

6.4 Compliance with the SDWA Regulations

6.4.1 General Discussion

A careful review of the raw and finished water quality was conducted to determine if existing or future regulations are a concern at the facility. The City is currently meeting the regulatory requirements of all existing rules. A detailed discussion of the future regulations is presented in Appendix 6A. The key regulations from the Safe Drinking Water Act (SDWA) and their impact to the City are listed in Table 6-3, titled "SDWA Regulatory Summary".

The remainder of this section will discuss the various methods available to the City of Laramie for meeting both current and future SDWA regulations. The regulation with the biggest impact for the surface WTP is the Long-Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR), which regulates the inactivation of *Cryptosporidium*. This regulation could also impact the groundwater sources in the event that one or more of the well sites were determined to be "Groundwater Under the Direct Influence of Surface Water" (GWUDI). If the wells were reclassified as GWUDI, the existing treatment would not be sufficient for compliance with the SDWA regulations. GWUDI means the source must be considered and treated as surface water in terms of complying with regulations. Since the well water is low in turbidity and Total Organic Carbon (TOC), the most likely treatment options would be the addition of filtration and providing adequate CT to meet the log removal requirements for surface water. Filtration could be provided by pressure filters, gravity filters, or membrane treatment, which has become cost competitive in recent years. We recommend the implementation of low pressure membranes (microfiltration or ultrafiltration) as the preferred treatment method should the wells be reclassified as GWUDI.

This recommendation is based on the fact that the membranes provide a positive barrier and present many advantages over conventional filtration.

6.4.2 Surface Water Treatment

The surface water treatment is discussed in terms of two potential long term locations for the WTP. The first site being the current location of the existing WTP. Based on the review of historical water quality data and the current and future regulations affecting the City of Laramie, the primary concern at the City's existing WTP is compliance with LT2ESWTR. The second site is located at Monolith Ranch; and this would take advantage of the water rights available in the Laramie River. As discussed in an earlier section, the water quality at the Monolith Ranch site has poorer water quality characteristics than the present WTP site. In addition to compliance with LT2ESWTR at the Monolith Ranch site, compliance with some of the secondary limits such as TDS, hardness, and sulfate will be a challenge.

6.4.3 Groundwater Treatment

The existing groundwater wells pump water from the Casper Aquifer. There are three disinfection facilities: one is used for the Turner Wells (City Springs), the second is used at the "Wye," the junction point for the pipelines from Soldier Springs and Pope Wells, and the third is at the Spur Wellfield. Previous reports have described the risk for the groundwater wells being reclassified as GWUDI because of the fractured formation of the Casper Aquifer. Some field testing and Microscopic Particulate Analysis (MPA) testing has been done, but none of the sources have been reclassified to date.

6.5 Long-Term Water Treatment Alternative

Based on the SDWA regulation requirements, the City was asked what their treatment goals would be for the future Laramie WTP facilities. Table 6-4, titled "Future Water Treatment Goals" is a summary of these goals for some of the key parameters affected by future regulations. All the future treatment process options will be based on achieving these goals.

6.5.1 General Considerations

Based on the above finished water treatment goals and future SDWA regulatory requirements, four (4) treatment process options were identified which could meet the surface water quality goals. Three (3) options are discussed for groundwater treatment if GWUDI reclassification occurs. The four surface water treatment options are shown in Figures 6-2 through 6-5:

- Figure 6-2, titled "Option A – Conventional Treatment Enhanced Coagulation"
- Figure 6-3, titled, "Option B – Low Pressure Membrane Treatment with Enhanced Coagulation"
- Figure 6-4, titled "Option C – Nano Membrane Treatment with Enhanced Coagulation"
- Figure 6-5, titled "Option D – Low Pressure Membrane Treatment and Disinfection"

Options A and B are for treatment of the surface water supply from the existing WTP. Option C is for treatment of the surface water from the Laramie River at the Monolith Ranch location. Option D is for the treatment of the groundwater from the existing and future groundwater sources should they be determined to be GWUDI.

A summary of the key considerations used for generating the future treatment alternatives is given below:

- TOC removal to meet the D/DBP rule (see Table 6A.4).
- Either low pressure or nanofiltration membranes will provide a positive barrier to microbials.
- TDS, hardness, and sulfate removal at the Monolith Ranch Site could be achieved using sidestream treatment such as nanofiltration or reverse osmosis (RO).
- The LT2ESWTR may require up to 5.5-log removal of microbials. For the purposes of this report, it is assumed that the plants will need to provide the additional 2.5-log removal associated with Bin 4 of the rule (see Table 6A.1).

- Low pressure membranes would meet the requirements for GWUDI without the need for flocculation/clarification.

We have chosen the most likely water treatment technology options for both surface water and groundwater that are available for compliance with the relevant regulations. The technologies and treatment processes for the surface water and groundwater sources are presented below based on a preliminary review and the limited data available. These were selected due to their widespread use in water treatment, packaging, ease of operation, flexibility, site considerations, expandability, and capital cost. The following is a summary of the treatment options and their advantages and disadvantages.

6.5.2 Option A – Conventional Treatment with Enhanced Coagulation

This option would use an identical conventional treatment process train (rapid mix, flocculation/clarification, filtration) as is currently used at the existing WTP. This option would employ enhanced coagulation (increased coagulant dosage) to achieve the TOC removal required by the D/DBP rule. Some of the advantages and disadvantages associated with this option are as follows:

<u>Advantages</u>

1. Low cost alternative
2. Would require minimum modifications to the existing facility
3. Conventional treatment process is the same as the existing WTP
4. Operators are familiar with this process
5. Existing plant may be modified or upgraded for this process

<u>Disadvantages</u>:

1. Does not provide a complete barrier to pathogens
2. The lower pH associated with additional coagulant chemical may change the sedimentation kinetics

Conventional treatment in compliance with the Interim Enhanced Surface Water Treatment Rule (IESWTR) will provide a 3-log removal of pathogens. As discussed in Chapter 8 of this report, an alluvial intake could also be utilized to improve water quality to

the plant. The effect of this intake on *Cryptosporidium* levels is site specific, but it is not likely that the EPA would grant log removal credit. In order to receive the additional 2.5-log credit needed to meet Bin 4 of the LT2ESWTR, one of the following disinfection processes and/or credit for existing processes could be used:

Strategies to meet Bin 4 (additional 2.5-log removal):

- Ultraviolet (UV) disinfection (> 2.5-log removal credit)
- Lower turbidity (0.5-log) + Ozone (2-log)

If the City can use the existing ozone system and maintain the lower turbidity standard, this strategy will meet the LT2ESWTR requirements. For conservative costing of the Alternatives we have assumed that UV would be used for LT2ESWTR and that ozone would continue to be used for TOC removal.

UV light achieves the inactivation of pathogens using a specific wavelength of UV light. The degree of microorganism inactivation is based on the applied UV dose, which is a function of UV intensity and exposure time. UV units are a self-contained process requiring only piping, valving, and electrical/instrumentation equipment. There are three different types of UV lamps available, summarized below:

- Low pressure, low intensity
- Low pressure, high intensity
- Medium pressure, high intensity

Each of these has advantages and disadvantages, but they will not be addressed here. Advantages and disadvantages for UV disinfection in general are discussed below.

Advantages:

1. Effective against *Cryptosporidium* and *Giardia*
2. Does not form disinfection by-products
3. Cost effective
4. Simple operation and maintenance
5. No hazardous chemical handling

Disadvantages:

1. No disinfectant residual
2. Requires lamp replacement on an approximately annual basis (low pressure) and semi-annual basis (medium pressure)
3. Some concern on disposal of spent mercury lamps (lamp manufacturers will typically take the spent lamps).
4. Ongoing controversy over patent infringement and the payment of royalty fees for the use of the UV technology.

Based on the technology table contained in the LT2ESWTR, UV disinfection will likely receive a 2.5-log removal credit for *Cryptosporidium*. Third-party validation will be required to verify the actual credit once the EPA UV Disinfection Guidance Manual is finalized. Because of the high level of log removal credit and the reasonable cost of installing UV at both plants, it is recommended that the City consider implementation of UV disinfection.

6.5.3 Option B – Low Pressure Membrane Treatment with Enhanced Coagulation

This option uses low pressure membranes (microfiltration or ultrafiltration) in place of conventional gravity filters, but would retain a similar enhanced coagulation process. In addition to constructing a new WTP with this technology it may be possible to retrofit the existing filters' cells with submerged-type membranes. Below are some of the advantages/disadvantages of this option:

Advantages:

1. Membranes provide a positive barrier for microbials
2. Existing filters could be converted to membranes
3. Easy to expand
4. Finished water quality is independent of feed water quality

Disadvantages:

1. Membranes require replacement every 7-10 years
2. Membrane filters generate more backwash waste
3. Requires chemical cleaning waste handling
4. Proprietary equipment

Low pressure membranes would likely be granted a > 2.5-log additional removal credit from the EPA and WYDEQ based on the treatment credit outlined in the LT2ESWTR. Given this, no additional treatment would be required downstream of the membranes other than chlorine disinfection for the distribution system.

The existing plant could be retrofitted to accommodate the immersion type membranes. However, this would require extensive renovation of the existing WTP and replacement of all the internal conveyance piping. Based on this and that the City has adequate property at the existing WTP site, we are recommending the next capacity expansion consist of an entirely new facility and the existing WTP be decommissioned.

6.5.4 Option C and D – Nanofiltration or Reverse Osmosis Membrane Treatment

Option C and D would utilize nanofiltration (NF) or reverse osmosis (RO) membranes as the heart of the treatment train to remove TDS, hardness, and other minerals. This option is required at the Monolith Ranch site because of the higher levels of hardness and minerals in the Laramie River at this location. To maximize the efficiency of the process and meet water quality goals, a sidestream of the flow could be treated and reblended as shown in Figure 6-4. To minimize fouling of the membranes, adequate pretreatment is required to remove suspended solids. Most membrane manufacturers require a turbidity of 0.5 to 1.0 NTU and a 15-minute silt density index (SDI) between 3.0 and 5.0. This requirement can generally be met with rapid mix and gravity filtration (Option C) or low pressure membrane filtration (Option D). In addition to the pretreatment, moderate to high pressure pumping (~100 to 200 psi) for feed to the NF/RO is generally required. Some of the implementation advantages and disadvantages of this option are given below:

Advantages:

1. May be a positive barrier to microbials
2. Effective TOC and inorganic material removal
3. Expansion is relatively simple
4. Equipment is standardized
5. Effective taste and odor control
6. Lower hardness levels could be achieved

Disadvantages:

1. Higher energy costs (especially if RO is used)
2. May have to add alkalinity after membrane treatment to prevent distribution pipe corrosion
3. High capital costs
4. Sensitive to feed water quality

Combined with low pressure membranes, NF or RO is likely to be given a > 2.5-log removal credit by the EPA and WYDEQ. If NF or RO are used in combination with gravity filters as a sidestream treatment, UV would be needed to meet the LT2ESWTR requirements. Chlorine disinfection would need to be added to the distribution system.

6.5.5 Option E, F, and G – Low Pressure Membrane Treatment for Groundwater

These options would utilize low pressure membranes (microfiltration or ultrafiltration) for treatment of the groundwater sources if the wells are reclassified as GWUDI. Ultimately there would need to be three (3) groundwater treatment facilities: one for the 4.0 mgd from Spur Wells, a second for the 5.6 mgd from Turner Wells and a third for the 7.5 mgd from the Pope and Soldier Springs Wells. The last set of wells would have treatment at the "Wye" where both the discharge pipelines come together. Below are some of the advantages/disadvantages of this option if GWUDI is determined applicable for some or all of the wells:

Advantages:

1. Membranes provide a positive barrier for microbials
2. With the high groundwater quality, pretreatment with coagulation/flocculation may not be required.
3. Easily expandable
4. Finished water quality is independent of feed water quality
5. Highly automated - the facility could operate unattended if desired.

Disadvantages:

1. Membranes require replacement every 7-10 years
2. The membrane filters at these locations would generate backwash waste needing disposal.
3. Requires chemical cleaning waste handling or neutralization
4. Proprietary equipment would be required for the membranes

Low pressure membranes would likely be granted a > 2.5-log additional removal credit from the EPA and WYDEQ based on the treatment credit outlined in the LT2ESWTR. No additional treatment would be required downstream of the membranes other than chlorine disinfection for the distribution system. Fluoride would still be added upstream to continue the existing practice. If the membrane treatment is not required; the existing treatment facilities (disinfection and fluoridation) would need to be upgraded. It is likely that the existing buildings would be retained and new chemical feed equipment would be installed to meet the future flow requirements.

6.5.6 General Comparison of Costs for Process Alternatives

For a general comparison of the alternatives, EPA cost curves and past water treatment plant projects were used to generate a cost range for each process option. Both capital and operation/maintenance costs were estimated to give the City a general idea of the cost to construct and maintain the various options. Operation and maintenance costs assume the plant is a base load plant running all year. Table 6-5, titled "Capital and Operation/Maintenance Cost Comparison", summarizes these costs.

6.6 Costs of Probable Alternatives

6.6.1 Capital Costs for New WTP Facilities

Based on the previous discussions regarding the expected size of treatment facilities and the raw water quality and SDWA requirements, we have prepared cost opinions for the following treatment facilities:

- Option A - 10 mgd Conventional WTP at Existing WTP Site
- Option B - 10 mgd Low Pressure Membrane WTP at Existing WTP Site
- Option C - 10 mgd WTP at the Monolith Ranch Site
- Option D - 13 mgd WTP at the Monolith Ranch Site
- Option E - 7.5 mgd Groundwater WTP at the "Wye"
- Option F - 5.6 mgd Groundwater WTP at the Turner Well Site
- Option G - 4 mgd Groundwater WTP at the Spur Well Site

The following Table 6-6, titled "Conceptual Opinion of Probable Cost for Possible Future Water Treatment Facilities" shows a summary of the costs for these facilities. A detailed breakdown estimate for each facility is included in Appendix 6B.

6.6.2 Capital Costs for Upgrade of Existing WTP Facilities

As mentioned earlier, the existing WTP has reached its useful life. Based on the conclusions to be described later in this Chapter, the existing plant should only be upgraded to operate for the next 5 to 10 years.

A summary of the recommended short term improvements are listed in Table 6- 7, titled "Short Term Improvements for the Existing WTP Facility".

6.7 Conclusions and Recommendations

6.7.1 Surface Water Treatment Alternatives

Based on the discussion in this Chapter, the following conclusions are reached regarding surface water treatment for the future:

- The surface water quality degrades from the existing WTP intake to the Monolith Ranch intake location.

- A 10 mgd surface WTP plant would meet the projected demand for the next 50 years
- The existing WTP has reached it's useful life without significant maintenance and upgrades

Based on these conclusions, a new WTP should be constructed for Laramie within the next 5 to 10 years. This long term plan would meet the surface water needs for the next 50 years. In the interim, only essential improvements should be made to the existing WTP to provide continued compliance with the SDWA regulations.

6.7.2 Groundwater Treatment Alternatives

Based on the discussion in this Chapter, the following conclusions are reached regarding treatment of the groundwater sources for the future:

- The existing wells have a potential for testing as GWUDI in the future based on the characteristics of the Casper Aquifer
- If the wells are determined to be GWUDI, treatment facilities will need to meet the requirements for a surface water source
- The current disinfection system is meeting the requirements for the Ground Water Rule (GWR) for the existing wells

The process used for determination of GWUDI is discussed further in Appendix 6A and in Chapter 10. In the event that any of the groundwater sources are reclassified as GWUDI in the future, facilities will need to be provided with a new low pressure membrane system followed by disinfection. These processes were discussed in the previous sections in this Chapter.

TABLES AND FIGURES

Table 6-1
Laramie River Raw Water Quality

Parameter	Units	EPA Primary Standard	EPA Secondary Standard	At Existing WTP Site			At Monolith Ranch Site		
				Low	High	Avg	Low	High	Avg
Temp	Deg C	n/a		1	20	14	1	19	17
pH	Standard Units	n/a		7.4	8.6	8.0	7.6	8.3	8.0
Hardness	mg/L as $CaCO_3$	n/a		53	72	63	130	250	190
Alkalinity	mg/L as $CaCO_3$	n/a		39	54	47	79	94	87
TDS	mg/L		500	100	120	110	210	500	355
Turbidity	NTU	0.3 – 95% of Time		4	23	9	7	8	7
TOC	mg/L	2		3	11	7	3	14	9
Iron	mg/L		0.3	0.6	0.7	0.7	0.3	0.6	0.4
Manganese	mg/L		0.05	0.02	0.07	0.05	0.01	0.06	0.04
Sulfate	mg/L		250	21	26	24	76	230	153

Notes:
1. These numbers are based on data from the Wyoming Department of Agriculture and limited use of data from the Laramie Rivers Conservation District.

Table 6-2
Laramie Wells Groundwater Quality Casper Aquifer

Location		Major Cations				Major Anions				Other Key Parameters				
Well/Spring	**pH**	**Ca**	**Mg**	**Na**	**K**	**Cl**	**SO_4**	**HCO_3**	**NO_3**	**F**	**Fe**	**TDS**	**Hardness mg/L**	**RSI**
		mg/L	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L**	**mg/L as $CaCO_3$**	
MCL	6.5-8.5	---	---	---	---	250	250	---	10.0	4.0	0.3	500	---	
Spur No. 1	8.0	52	16	2.6	<1.0	1.1	6.0	215	1.58	0.18	<0.05	213	196	---
Turner No. 2	7.4	55	18	3.1	0.8	<1.0	9.7	230	1.7	0.1	---	224	200	7.5
Pope Wells	8.2	54	13	2.1	0.7	1.8	5.8	222	1.66	0.2	0.04	218	191	6.7
Soldier No. 1	8.1	58	17	1.9	<1.0	3.5	12.0	218	1.98	0.21	<0.05	208	217	---

Ca = Calcium; Mg = Magnesium; Na = Sodium; K = Potassium; Cl = Chloride; SO_4 = Sulfate; HCO_3 = Bicarbonate; NO_3 = Nitrate; F = Fluoride; Fe = Iron
TDS = Total Dissolved Solids
RSI = Ryznar Stability Index (incrusting <7 <corrosive)
MCL = Maximum Contaminant Level
--- - Not Analyzed for this Compound

Table 6-3
SDWA Regulatory Summary

Regulation	Regulatory Intent	City in Compliance?	Relative Impact
Primary Standards	Primary standards are set for specific compounds such as metals, volatile organics, synthetic organics, etc., with known health effects. The primary standards are referred to as Maximum Contaminant Levels (MCLs). These standards are set to protect the public health	Yes	Low
Secondary Standards	Secondary standards are non-enforceable standards that are set to ensure aesthetic quality and customer acceptance of the water supply. For example: Color, Dissolved solids, taste and odor.	Yes	Low
Disinfectant/Disinfection Byproduct Rule (D/DBPR)	The D/DBPR sets MCLs and treatment requirements to reduce DBPs with known health effects. MCLs have been set for a number of DBPRs and three disinfectants, as well as specifying treatment techniques to reduce total organic carbon (TOC) (ie. enhanced coagulation).	Yes	Medium to High
Lead and Copper Rule (LCR)	The LCR was established to reduce adverse health effects caused by lead and copper contamination. The rule specifies MCLs for lead and copper as well as specifying treatment techniques to reduce corrosion; the leading cause of lead and copper in drinking water.	Yes	Low to Medium
Coliform Rule (CR)	The CR was established to provide an indication of possible contamination of a potable water supply or indicate inadequate treatment. An MCL was established for coliforms in the distribution system with corresponding actions necessary if coliforms are detected.	Yes	Low
Surface Water Treatment Rule (SWTR)	SWTR was established to reduce the risk from water borne pathogens by setting a turbidity MCL and requiring treatment techniques (ie. filtration and specific disinfection requirements).	Yes	Low
Enhanced Surface Water Treatment Rule (ESWTR)	ESWTR was proposed to further reduce risks from water borne pathogens. Standards were established for additional removal and disinfection requirements.	Yes	Medium to High
Interim Enhanced Surface Water Treatment Rule (IESWTR)	The IESWTR applies to large systems and set the maximum contaminant level goal (MCLG) for *Cryptosporidium* at zero. The turbidity level of a system's combined filtered water must be less than or equal to 0.3 NTU (previously 0.5 NTU) in at least 95% of the time. Turbidity level of combined filtered water must at no time exceed 1 NTU (previously 5 NTU).	Yes	Medium to High
Long Term 1 Enhanced Surface Water Treatment Rule (LT1ESWTR)	LT1ESWTR applies to small systems including the City of Laramie. The City will be required to meet 0.3 NTU 95% of the time, with a maximum turbidity of 1 NTU. In addition, the system will be required to remove 99% (2-log) of *Cryptosporidium*.	NA	NA
Long Term 2 Enhanced Surface Water Treatment Rule (LT2ESWTR)	The LT2ESWTR requires additional *Cryptosporidium* inactivation. Each utility must test for and establish the concentration of *Cryptosporidium* in the source water and then provide the appropriate level of treatment based on a "bin" classification (see Table 6A.1).	Yes	Medium to High

Notes:

1. There are additional regulations and rules. These are most important to Laramie's surface water supply and treatment.

Table 6-4
Future Water Treatment Goals for the Laramie Water Treatment Facilities

Parameter	Regulatory Requirements	Laramie Finished Water Goals
Turbidity	≤ 0.3 (95% of time)	≤ 0.15 (95% of time)
TOC	15-50% [1]	≤ 2 mg/L
Particle Counts	n/a	≤ 40 @ 3 microns
TTHM	80 ug/L	≤ 40 ug/L
HAA5	60 ug/L	≤ 30 ug/L
Microbials	-	-
Giardia	3-log	0
Cryptosporidium	2-log (4.5-log) [2]	0
Log Removal	-	4
Manganese	0.05 mg/L	< 0.05 mg/L
Nitrate	10 mg/L	≤ 2 mg/L
Taste & Odor	n/a	≤ 1 TON[3]

Notes:
1. Requirement if raw water TOC is > 2.0; actual removal dependent on raw water alkalinity
2. The IESWTR requires 2.0-log. The LT2ESWTR will require up to an additional 2.5-log depending on raw water *Cryptosporidium* concentration. The City has selected to design for Bin 4, which will require 4.5-log removal.
3. TON = Threshold Odor Number

Table 6-5 Capital and Operation/Maintenance Cost Comparison

Process Option	Capital Cost Range ($/gal)	O&M Cost Range ($/1000 gallons)
Conventional Treatment w/ Enhanced Coagulation	$1.00-$1.30	$0.15-$0.25
Low Pressure Membranes w/ Enhanced Coagulation	$1.30-$1.60	$0.15-$0.25
Reverse Osmosis Membranes	$1.50-$2.50	$0.60-$0.75
Low Pressure Membrane for Groundwater	$0.80-$1.00	$0.10-$0.20

Note: Costs ranges include only the processes shown. Pretreatment, disinfection or additional treatment, such as sedimentation or ozonation are not included.

Table 6-6 Preliminary Estimation of Probable Capital Costs For Possible Future Water Treatment Facilities Conventional Filtration with Enhanced Coagulation

Possible Treatment Facility Options	Opinion of Capital Cost
A - 10 mgd Conventional WTP at Existing WTP Site	$18,000,000
B - 10 mgd Low Pressure Membrane WTP at Existing WTP Site	$25,000,000
C - 10 mgd Low Pressure and Nano/RO WTP at the Monolith Ranch Site	$28,000,000
D - 13 mgd Low Pressure and Nano/RO WTP at the Monolith Ranch Site	$45,000,000
E - 7.5 mgd Low Pressure Membrane Groundwater WTP at the "Wye"	$11,000,000
F - 5.6 mgd Low Pressure Membrane Groundwater WTP at the Turner Well Site	$9,900,000
G - 4 mgd Low Pressure Membrane Groundwater WTP at the Spur Well Site	$7,600,000

Notes:

1. These costs include construction, engineering and contingencies.
2. Costs are based on a June 2006 ENR Construction Cost Index of 7,700.

Table 6-7 Short Term Improvements for the Existing WTP Facility

Possible Improvement	Opinion of Capital Cost
Rapid Mix Equipment Improvements	$85,000
Second Solids Contact Clarifier	$750,000
On-Site Chlorine Generation	$480,000
General Chemical System Improvements	$400,000
SCADA Improvements	$650,000
Other General Improvements	$200,000
Total	$2,565,000

Notes:

1. These improvements are suggested to be made to extend the life of the facility another 5 to 10 years.
2. These costs include construction, engineering, and contingencies.
3. Costs are based on a June 2006 ENR Construction Cost Index of 7,700.

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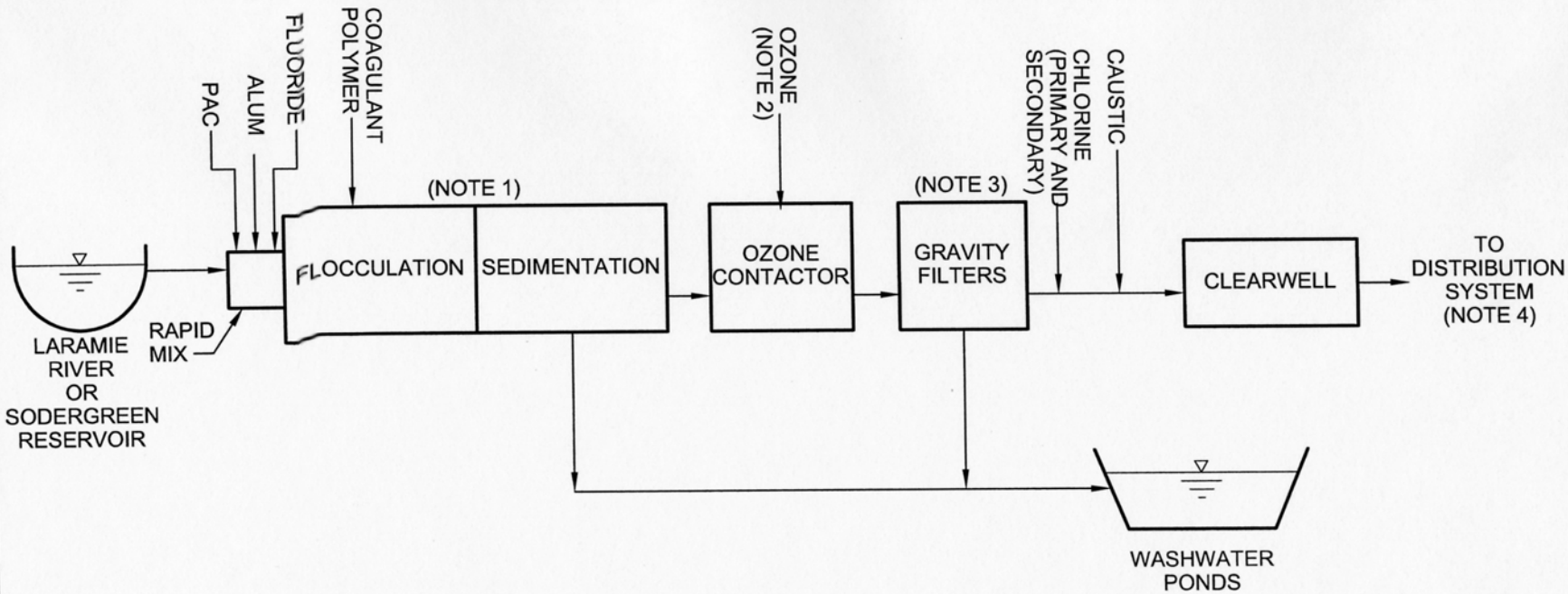

NOTES:

1. THERE ARE TWO TREATMENT TRAINS. ONE TRAIN CONTAINS A SOLIDS CONTACT CLARIFIER. THE OTHER IS CONVENTIONAL FLOCCULATION/SEDIMENTATION.
2. OZONE IS USED TO LOWER TOC NOT REMOVED DURING FLOCCULATION/SEDIMENTATION.
3. THERE ARE A TOTAL OF SIX GRAVITY FILTERS.
4. WATER FLOWS BY GRAVITY APPROXIMATELY 20 MILES TO CITY DISTRIBUTION SYSTEM.

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Figure 6-1

LARAMIE EXISTING WTP PROCESS

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-1.DWG 08-14-2006 8:09 R_FULK

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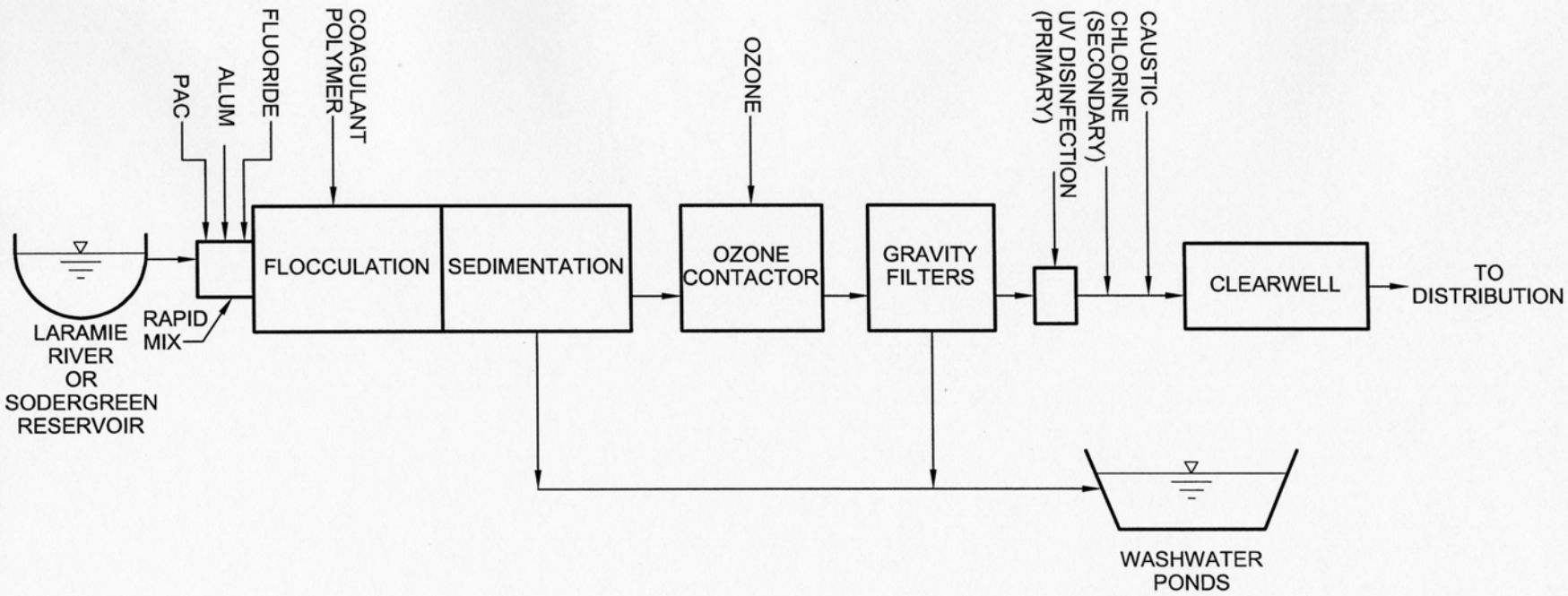

NOTES:

1. THIS PROCESS COULD BE USED FOR THE EXISTING WATER SUPPLY FROM THE LARAMIE RIVER.
2. THE EXISTING OZONE TREATMENT SCHEME MAY ALLOW FOR COMPLIANCE WITH LT2ESWTR AND UV WOULD NOT BE NEEDED.

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Figure 6-2
OPTION A - LARAMIE WATER SYSTEM MASTER PLAN CONVENTIONAL TREATMENT WITH ENHANCED COAGULATION

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-2.DWG 08-14-2006 8:13 R_FULK

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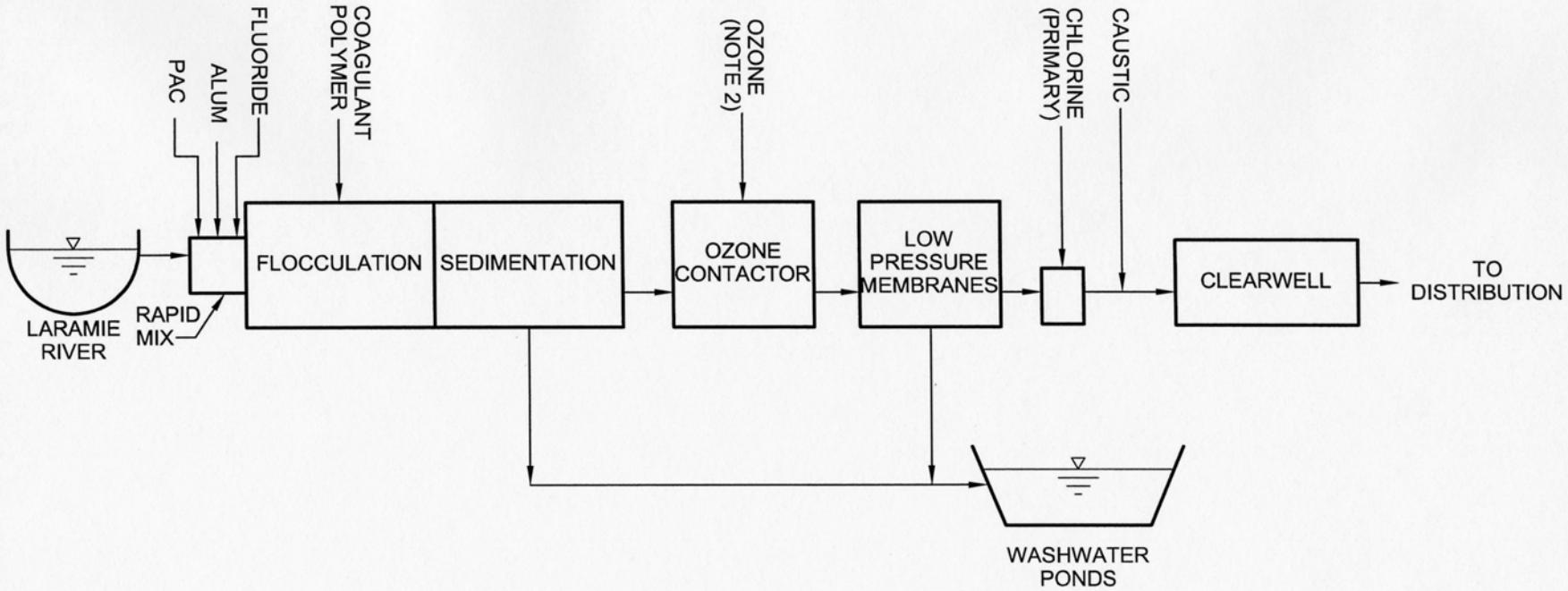

NOTES:

1. THIS PROCESS COULD BE USED FOR THE EXISTING WATER SUPPLY FROM THE LARAMIE RIVER.
2. OZONE IS USED TO LOWER TOC NOT REMOVED DURING FLOCCULATION/CLARIFICATION.
3. LOW PRESSURE MEMBRANES WOULD MEET THE REQUIREMENTS FOR LT2ESWTR.

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Figure 6-3
OPTION B - LARAMIE WATER SYSTEM MASTER PLAN LOW PRESSURE MEMBRANES WITH ENHANCED COAGULATION

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-3.DWG 08-14-2006 8:17 R_FULK

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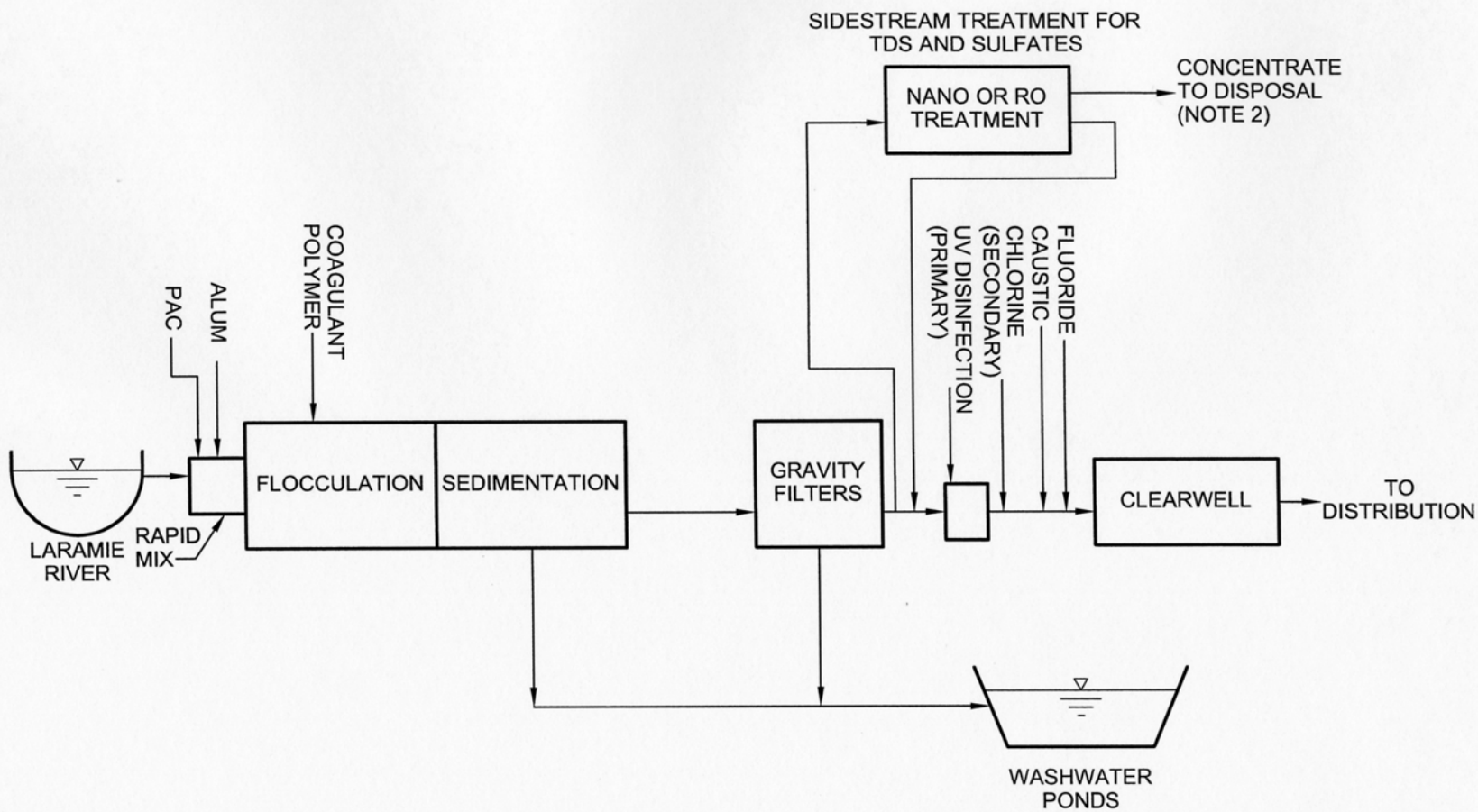

NOTES:

1. THIS PROCESS WOULD BE USED FOR THE WATER QUALITY AT THE MONOLITH RANCH.
2. APPROPRIATE DISPOSAL FOR THIS WASTE WOULD HAVE TO BE DETERMINED.

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Figure 6-4
OPTION C
LARAMIE WATER SYSTEM MASTER PLAN CONVENTIONAL WITH NANO/RO TREATMENT

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-4.DWG 08-14-2006 8:32 R_FULK

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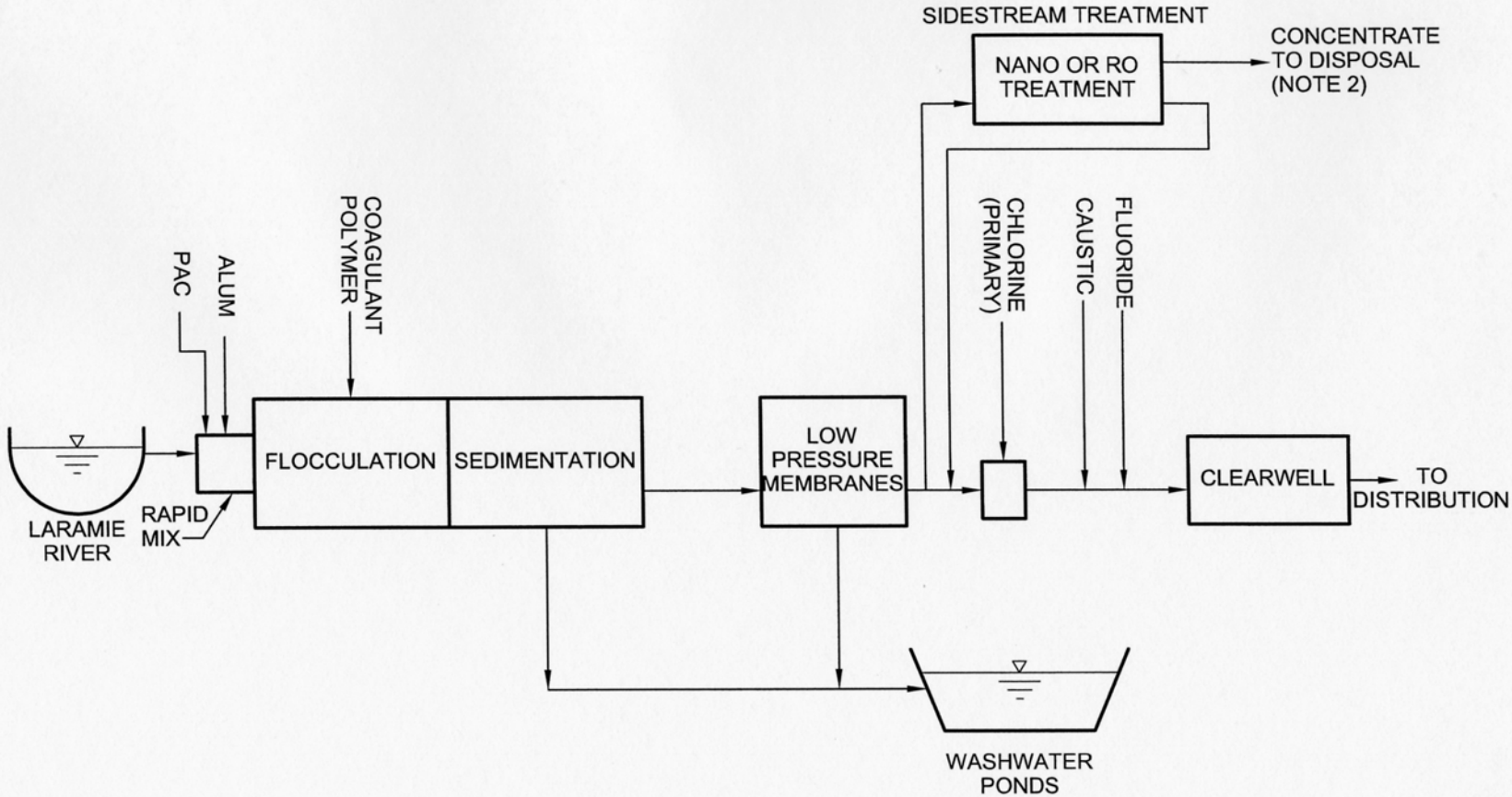

NOTES:

1. THIS PROCESS WOULD BE USED FOR THE WATER QUALITY AT THE MONOLITH RANCH.
2. APPROPRIATE DISPOSAL FOR THIS WASTE WOULD HAVE TO BE DETERMINED.

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Figure 6-5
OPTION D
LARAMIE WATER SYSTEM
MASTER PLAN-MEMBRANE
W/NANO OR RO TREATMENT

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-5.DWG 08-14-2006 8:33 R_FULK

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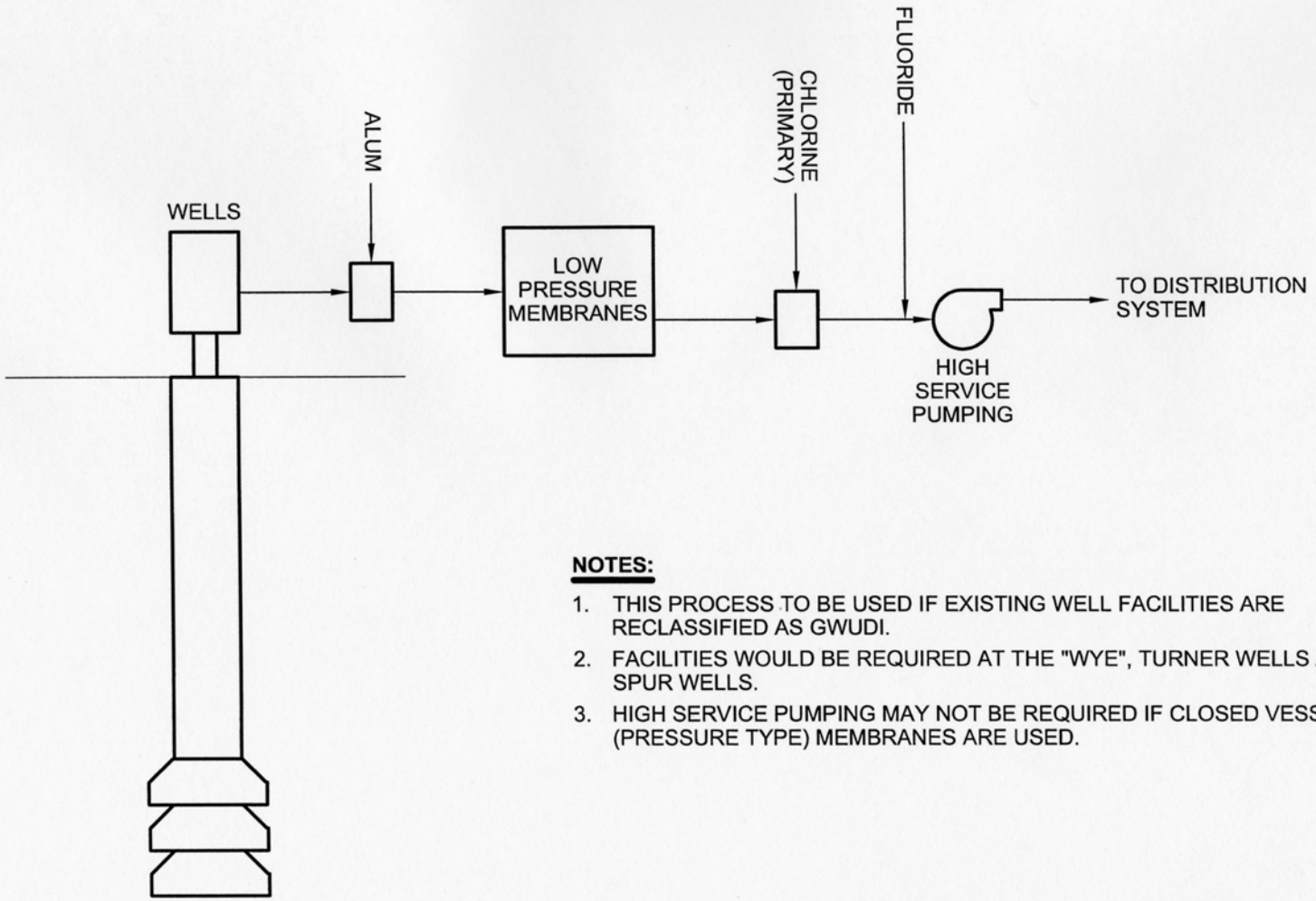

NOTES:

1. THIS PROCESS TO BE USED IF EXISTING WELL FACILITIES ARE RECLASSIFIED AS GWUDI.
2. FACILITIES WOULD BE REQUIRED AT THE "WYE", TURNER WELLS AND SPUR WELLS.
3. HIGH SERVICE PUMPING MAY NOT BE REQUIRED IF CLOSED VESSEL (PRESSURE TYPE) MEMBRANES ARE USED.

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Figure 6-6
OPTION E,F&G - LARAMIE WATER SYSTEM MASTER PLAN TYPICAL GROUNDWATER TREATMENT SYSTEM

J:\LARAMIE\40916-W MASTER PLAN\CADD\PROCESS\FIGURES\FIGURE6-6.DWG 08-14-2006 8:36 R_FULK

CHAPTER 7.0
TRANSMISSION, DISTRIBUTION, AND STORAGE SYSTEM

7.0 TRANSMISSION, DISTRIBUTION AND STORAGE SYSTEM

7.1 Introduction

This chapter presents an evaluation of the existing condition of the City's water transmission, distribution, and storage (TD&S) system. The evaluation includes both an assessment of the system's current physical condition and an evaluation of its current hydraulic performance. Our Team's opinions on the physical condition of the TDSS are based on interviews with City staff, knowledge of past improvement projects, and limited actual inspection work. Our Team's opinions on the hydraulic performance of the system are based on the assembly, limited calibration, and execution of a comprehensive hydraulic pipe network model.

In addition, the hydraulic model was used to evaluate projects that would correct current system deficiencies and projects that would address deficiencies caused by an expansion of municipal water demand.

7.2 Background

The condition and capability of the transmission, storage and distribution system was last characterized in the Laramie Master Plan Level I (WWC, 1995) and the Laramie Master Plan Level II (RBD, 1996). These studies examined the physical and hydraulic conditions of the system, and both studies noted several deficiencies. Since the completion of these studies, there has been significant upgrades and modifications to the water supply and distribution system, including:

- Corrosion control programs have been performed on the transmission pipelines between Sodergreen Reservoir, the WTP, and the City.
- The 24-inch transmission line through the City has been replaced.
- The Spur Wellfield water supply and transmission system has been installed.
- The West Laramie Transmission Line to the Airport has been installed, including a 1.0 million gallon water tank. A fire pumping station serves the Airport.

- The East Side Tank project was recently completed and its associated transmission lines. This project brings 1.0 MG of storage into Zone 4. Pumping stations for this project will be complete soon.
- The exiting 8 MG tank was rehabilitated, the Zone II tanks painted, and modifications have been made to the water treatment plant clear well.

Even with the notable and costly improvements of the last decade, there remain several challenges to maintaining and improving the functionality and reliability of the transmission, distribution, and storage system. Some of the challenges we were aware of at the beginning of this study included:

- A water main replacement strategy to upgrade failing mains.
- Fire flow capacity improvements within several areas of the oldest pressure zones (I and II).
- Extension of adequate service to new developments on the fringes of the current distribution system.

7.3 Existing System Configuration

The City's existing transmission, storage and distribution system infrastructure is depicted in Figure 7-1. The system includes 6 water pressure zones. Zones 1,2,4, and 6 are fed directly from gravity water storage reservoirs or tanks. Zone 3 service will be fed under normal conditions via the new Wister Drive pump station , and under peak demands (such as fire) by water transfer from Zone 4 via three pressure control stations. Zone 7, at the Laramie Airport, is normally served water by a small pump taking suction from Zone 6 storage. Zone 7 would be served by a large fire pump station during a peak fire demand. There are several other pressure control stations that allow water to pass from a higher zone to a lower zone during periods of peak demand in the lower zone. These PRV stations address very localized low pressure problems.

Figure 7-2 presents a generalized hydraulic grade lines for the water service area. The approximate water pressure served to customers in each zone is also shown on the exhibit. It is important for the reader to note that the original construction of the Laramie water system was based in part on the simple fact (author's opinion) that the City Springs area was the first water source put to use in 1869, and that it just so happened to provide

reasonable water pressure when served to the Zone 1 area of the young city. However, if the town were to be retrofit with a completely new distribution system, it is certain that the Zone 1 water storage tank would be located several feet higher than it was in the early years of the system when storage was conveniently located next to the water supply of City Springs.

7.4 Existing System Physical Condition

7.4.1 Transmission Pipelines

The transmission systems were evaluated to identify their condition. The evaluation consisted of discussions with water systems operators, review of previous reports and updates on construction work that had been done since the last master plan. The evaluation did not include excavations of components.

7.4.1.1 36" Raw Water Pipeline

The 36" Raw Water Pipeline is located between Sodergreen Lake and the Laramie Water Treatment Plant (WTP). It is a steel pipe constructed in 1946 with coal tar lining and coating. Pipe joints are welded with the exception of sleeve-type couplings every 500 feet. The location of these couplings is recorded in the record drawings for the 36" Pipeline Rehabilitation project, 1997.

The 1996 Master Plan Level II Report (RBD, 1996) identified three deficiencies with the 36" pipeline:

- Exterior corrosion that was causing leaks
- High hydraulic headloss created by the fish screen structure at the WTP
- Potential air binding due to the lack of air release valves at high points

Exterior Corrosion

The 36" pipe was recommended for replacement because of external corrosion identified in the 1996 Master Plan. Further evaluation of the pipe performed by RUSTNOT Corrosion Control Services, Inc. in 1997 determined the pipe was in relatively good condition and could be preserved with a cathodic protection system. The City decided to rehabilitate the pipe instead of replacing it.

An impressed current cathodic protection system was designed to protect the entire length of 36" pipe from the intake structure to the WTP. For the cathodic protection to function properly, the pipe must have electrical continuity through all pipe joints. To accomplish this No. 2 AWG insulated copper jumper wires were cadwelded to the pipe across all sleeve-type couplings. The couplings were also bonded to the adjacent pipe with No. 12 insulated copper wire to provide cathodic protection to the coupling. After the joint bonding program was completed, electrical continuity was confirmed for the entire length of 36" pipeline.

A vertical impressed current anode bed was installed approximately 1,000 feet south of the 36" pipe approximately 3,000 feet west of the WTP. There have not been any leaks in the 36" pipeline since the cathodic protection was put into operation in 1998. The anode bed will need to be replaced every 20 to 25 years. RUSTNOT estimated there is 15 to 20 years remaining life in the existing anode bed.

The remaining life of the 36" Raw Water Pipeline is indefinite as long as the cathodic protection system is maintained. The rectifier should be checked once per month and an outside consultant should perform an annual survey of the system at an estimated cost of $10,000 per year.

Air valves

The interior of the 36" pipe was videotaped during the 1996 Level II study. This identified high points in the pipe that did not have provisions for air and vacuum release. The high points were located near Sodergreen Lake. Excavations for joint bonding revealed the pipe was installed in bedrock in this area which may explain why the pipe was not installed at constant grade. High groundwater near Sodergreen Lake could have also contributed to grade problems during the construction of the 36" pipe.

The 36" pipe was potholed in 1998 to confirm the actual location of the high points identified by the 1996 Level II study. Four air/vacuum valve vaults were installed, three on the north side of Hwy 230 and one on the south side.

Fish Trap

The 1996 Level II study identified high headloss in the fish trap structure located near the end of the 36" pipe at the water treatment plant. The study recommended the structure be by-passed. Approximately 260 feet of 36" pipe were constructed around the fish trap in 1998 and the fish trap was abandoned.

Future Raw Water Booster Pump

Maximum flow in the 36" pipeline is 7 to 8 mgd. This is only possible when Sodergreen Lake is full. 4 mgd is available during winter months when the water level in the lake is lower. Minimal water levels have produced as little as 1-2 mgd. If the capacity of the WTP is to be increased to 12 to 15 mgd, then the capacity of the 36" Raw Water Pipeline will need to be increased. During the design of the 36" bypass around the Fish Trap it was decided to include provisions for a future raw water booster pump. Two 36" x 36" tees were installed with a 36" butterfly in between to divert flow to a low lift booster pump installed at the WTP. This pump would be used seasonally and, therefore, would not be housed in a building.

Evaluation of a raw water pipeline from the Pioneer Canal Diversion Dam to the WTP has shed new light on the capacity of the existing 36" Raw Water Pipeline. Approximately thirty feet of head would be available from the Pioneer Canal Diversion Dam to the WTP. This would approximately double the slope of the hydraulic grade line, increasing the capacity of the 36" pipe to 14 to 15 mgd by gravity flow. This would eliminate the need for a raw water booster pump. This issue needs to be incorporated into the design of the new raw water pipeline.

Cathodic Protection Interference from Walden Gas line

A gas line was built from Laramie to Walden in the mid-1990s. It is constructed of coated aluminum pipe and it is cathodically protected. The cathodic protection system for the gas line has caused interference with the cathodic protection for the Laramie's 36" Raw Water pipeline and the City of Cheyenne's raw water pipelines which is located approximately three miles west of Sodergreen Lake as identified by RUSTNOT. RUSTNOT has had varying degrees of success attempting

to work with the corrosion specialist employed by Walden. Laramie and Cheyenne required that their pipelines were not to be negatively impacted by the Walden Gas line. Therefore, it is the responsibility of the Town of Walden that their cathodic protection system be configured in such a manner that it does not impact the existing water pipelines. The agreement between the City of Laramie and the Town of Walden is in Appendix 7A. The status of potential interference from the Walden gas line needs to be monitored during monthly O&M of the rectifier for the 36" raw water pipeline.

7.4.1.2 24" Treated Water Pipeline WTP to Hwy 230 Valve Vault

A corrosion inspection and testing program was conducted on the 20" and 24" pipelines for the 1995 Laramie Water Supply Master Plan (WWC, 1995). The program consisted of three major components; soil resistivity measurements, pipeline excavation and testing, and analysis of the existing cathodic protection system. The purpose of the field testing program was to gather information about the corrosivity of the soil along the pipeline route, the condition of the existing pipe, and the effectiveness of the existing cathodic protection system. The corrosion program evaluated the condition of the pipelines at locations excavated by the City to determine the general areas where damage may have occurred and the extent of that damage. The field information was used to estimate remaining useful life of the transmission pipelines, and develop recommendations for corrosion control improvements.

Except for a short reach east of the Laramie Country Club wastewater lagoons (scheduled for completion in 2006), the recommendations of the 1995 report have been implemented over the past eleven years. Approximately 18 miles of pipe have been excavated at each joint and bonded to provide electrical continuity. Impressed current anode beds have been replaced and rectifiers set to provide protection. The remaining life of the pipeline is now indefinite as long as the cathodic protection system is properly operated and maintained. The Utilities Division budget includes costs for a maintenance contract with RUSTNOT Corrosion Control Services for annual evaluation and adjustment of the corrosion protection systems. The City

appears committed to maintain the system as evidenced by a recent allocation to fund maintenance in the FY 2006-2007 budget.

7.4.1.3 24" Treated Water Hwy 230 Valve Vault to 30th St.

The 24" pipeline from the Hwy 230 Valve Vault (near west edge of West Laramie) to a point approximately 650 feet east of 30th Street was replaced in 1999. PVC pipe was used with the exception of the reach from I-80 to 5th Street. Steel pipe was used in this reach because of soil contamination near the Laramie River from the UPRR Tie Plant and leaking underground storage tanks in the vicinity of 3rd Street. Sacrificial anodes with test stations were used to protect the steel pipe and metallic pipe fittings and valves. The status of the anodes should be check yearly to determine their remaining life. This pipe has an expected life span of 75 to 100 years.

7.4.1.4 20" Treated Water WTP to Riverside Drive

A corrosion inspection and testing program was conducted on the 20" and 24" pipelines for the 1995 Laramie Water Supply Master Plan. Except for a short reach east of the Laramie Country Club wastewater lagoons (scheduled for completion in 2006); the recommendations of the 1995 report have been implemented over the past eleven years. Approximately 18 miles of pipe have been excavated at each joint and bonded to provide electrical continuity. Impressed current anode beds have been replaced and rectifiers set to provide protection. The remaining life of the pipeline is now indefinite as long as the cathodic protection system is properly operated and maintained.

The 20" pipe under the sewage lagoons on the south side of Hwy 230, across from the Laramie Country Club, was replaced in 1999 with a 20" steel pipe routed around the north side of the lagoons. The pipe is tape wrap coated and cement mortar lined. The pipe joints are welded. The reach around the lagoons has electrical continuity and is protected by the impressed current cathodic protection system for the adjacent 20" pipe.

7.4.1.5 20” Treated Water Riverside Drive to Pine Street

Portions of the 20” pipeline from the west end of Riverside Drive to Pine Street were replaced in 2002. The 20” pipe line was replaced from the west end of Riverside Drive to Adams Street and approximately 200’ west of the Laramie River to Pine Street. The section starting at Adams Street and ending approximately 200’ west of the Laramie River was not replaced but was joint bonded. A new pipe alignment was selected north of the homes on Riverside Drive to avoid street replacement. Pipe under the Laramie River was replaced with HDPE pipe to provide protection from damage during a flood. HDPE pipe is flexible and has no joints and therefore, it could survive being undermined and struck by debris and continue to remain in service. The remainder of the pipe replaced was PVC pipe. Sacrificial anodes were used to protect metallic pipe fittings and valves. This pipe has an expected life span of 75 to 100 years.

7.4.1.6 16” Pope-Soldier Soldier Springs/ Pope Springs to Spring Creek

A corrosion inspection and testing program was conducted on the 12”, 14” and 16” pipelines for the 1995 Laramie Water Supply Master Plan. The results of the study concluded the cast iron pipes appear to be in good condition at the locations excavated and are not anticipated to require any additional corrosion protection to meet project design life over the next 25 to 50 years.

7.4.1.7 18” Spur Spur Wells to Reynolds St.

The 18” Spur Pipeline extends approximately five miles north of Laramie from the intersection of 30th and Reynolds St to the Spur Wells. It is constructed in the year 2000 with PVC pipe. Sacrificial anodes were used to protect the metallic pipe fittings and valves. This pipe has an expected life span of 75 to 100 years.

The Spur Wells are the only source of water that is piped into Zone 2. All other sources of water are piped into Zone 1.

The hydraulic grade line of the Spur pipeline is close to the ground line. This requires that important stop / start procedures be followed to prevent the pressure in

the pipeline from being negative during shut down of the Spur Wells. Power failure can cause this problem as well; however, power failures cannot be controlled.

The Spur water supply system was designed to be able to be converted from Zone 2 to Zone 3 or 4. Pipe pressure capacity and electrical system capacity are sized for this future conversion. The hydraulic grade lines for the conversions are identified in the construction plans for the Spur Pipeline. This conversion could allow pumping directly to higher pressure zones, thereby eliminating the need for Spur well water to travel to the Wister Drive Pumping Station and then back to Zone 3 and 4 customers on the north side of Laramie. It would also provide more uniform pressure in the northern extremities of Zones 3 and 4. Conversion of the Spur pipeline to a higher operating head would also eliminate the possibility of creating a negative pressure in the pipeline during shut down of the Spur wells.

7.4.1.8 10" Airport Hwy 230 to Airport

The 10" Airport Pipeline extends approximately 1.5 miles northwest from Hwy 230 to a connection vault. The vault was built in 2000 as part of the Laramie West Water Project. Water in the Airport Pipeline is diverted at the connection vault to the Airport Tank through a PVC pipeline. A normally closed valve in the connection vault serves as a zone break between Zone 6 and Zone 7. The Laramie Regional Airport intends to use the 10" cast iron pipe west of the vault for their distribution system. The Airport Pipeline was constructed in the year 1969 with cast iron pipe.

A corrosion inspection and testing program was conducted on the 10" Airport Pipeline in 1997 (RUSTNOT, 1998). Corrosion was identified and attributed to corrosive soils. Corrosion depths at two of the four locations excavated was approximately 1/2 the pipe wall thickness. The remaining life of the pipeline was estimated at 15 to 20 years. There have been a small number of water main breaks since the study, indicating the conclusions of the study were conservative. Pressure in the Airport Pipeline was reduced by approximately 30 psi when it was converted to Zone 6 in the year 2000. This, coupled with the fact that it is no longer required to provide fire flow to the airport, should extend the useful life of the pipeline.

If the number of water main breaks increases, then consideration could be given to slip lining the pipe with 8” HDPE. The pipeline has three connections and therefore the number of intermediate excavations would be minimal. The original selection of pipeline diameter was based on the ability to provide fire flow to the airport. This capacity is no longer required of the 10” pipe since it is now provided by the 16” pipeline from the Airport Pumping Station. The purpose of the 10” Airport Pipeline is to fill the Airport Tank, which can be done with an 8” pipe.

7.4.1.9 18” West Laramie Airport Tank to West Laramie

The 18” West Laramie Pipeline extends approximately 1.5 miles west of West Laramie. It was constructed in the year 2000 with PVC pipe. Sacrificial anodes were used to protect the metallic pipe fittings and valves. This pipe has an expected life span of 75 to 100 years.

7.4.1.10 14" Grand Ave. Pipeline

Mr. Foster White, former distribution system superintendent, was consulted for historical information about the 14" Grand Ave. pipeline. The 14" Grand Ave. pipeline was constructed by the Union Pacific Railroad in the early 1900's. It replaced the original UPRR pipeline that was constructed when the railroad arrived at Laramie in the 1800's. The original pipeline from City Springs to the UPRR yard was constructed of riveted steel with a cement mortar lining and coating. The riveted steel pipeline was abandoned in place and can still be encountered when excavating across Grand Ave. The 14" Grand Ave. pipeline is Class 200 cast iron (sand cast) with lead joints. It is not cement mortar lined. It has a minimal number of valves. Two 14" valves were installed as part of the East Campus Drainage Project in the 1980's; one west of the Hi-Lo Pumping Station (in the Village Inn parking lot) and another on the east side of 15th Street. There is an original valve at 6th St. The 14" Grand Ave. Pipeline does not have a history of leaks. This could be due to many reasons including less corrosive soils and because the pipe is sand cast. Cast iron pipe cast in a sand mold melted some of the sand on its outer surface. This small amount of liquefied sand coating acts as protective coating. This may be one of the reasons

some cast iron pipes from the 1700's and 1800's are still in service. Unfortunately, this advantage was lost when the pipe manufacturing process was changed to centrifugally cast in a metal mold around 1927. The original purpose of the 14" Grand Ave. Pipeline was to deliver City Springs groundwater to the UPRR roundhouse. Its function was converted to supplying the City with potable water when the City took over ownership of the pipeline in the 1940's. In exchange, the City delivered raw water to the UPRR roundhouse from the 20" pipeline that was constructed from Lake Sodergreen in 1945.

7.4.1.11 16" Grand Ave. Pipeline

The 16" Grand Ave. Pipeline was constructed with cast iron pipe in the 1950's. It has lead joints. There is a history of a few joints leaking but there have not been pipe breaks. The joints have been repaired with joint repair kits that compress a rubber gasket against the spigot of one pipe and the bell of the next pipe. The 16" pipeline has valves about every 3 or 4 city blocks. Some of the pipe is shallow, as indicated by street construction at 26th and Grand Ave. that broke a 2" operating nut off of a valve.

7.4.2 Distribution System Piping

The City of Laramie has a documented serious issue with the condition of the distribution system piping (See Appendix 7B). One problem is that soils in the area tend to be highly corrosive and that fact has contributed to rapid deterioration of the distribution piping, which is composed largely of metallic pipes. A second issue that has contributed to deterioration is the unstable nature of soils. Area soils have gypsum pockets, which are vulnerable to dissolution if exposed to moisture. This condition may contribute to unstable pipe foundations, with the result being beam break pipe failures.

As part of this study, we obtained pipe break history data from the City in a GIS format, and that data is presented in Figure 7-3. As shown on the figure, the data is grouped into three priorities, based on the number of breaks per 100 feet length per year. In addition, this data is further divided into the total length of pipe in each diameter. Replacement cost

estimates (See Appendix 7C) were prepared for each of these priority grouping, and those estimates are presented in Table 7C-5, 7C-6, and 7C-7.

This grouping will be used in the planning section of this report to schedule improvements to the distribution system.

7.4.3 Storage Reservoirs

The Laramie water storage system consists of four ground level steel tanks and two below ground concrete tanks. Table 7-2 is a summary of the storage capacity in the Laramie water system. The required capacity (shown in Table 7-2) was calculated according to the requirements of Chapter XII of the Wyoming DEQ Water Quality Rules and Regulations. The zone population plus the required fire flow for each zone was used to calculate the required capacity. Required capacity for the year 2025 is based on the projected population increases as determined in Section 3.2 of this report.

The storage capacity of higher zones could be considered tributary to lower zones since water from the higher zones could travel by gravity through pressure reducing valves to a lower zone. Storage capacity of lower zones could be considered tributary to higher zones, however, the actual capacity to deliver water to a higher zone is limited to the capacity of the booster pumps. For simplicity purposes, the capacities stated in Table 7-2 do not take into account contribution from other zones.

Note that required fire flow is more than half of the storage required for the zones with small population (Zones 3, 4, 6). Therefore, future population increases in these zones do not require significant increases in required storage.

The 8 MG Reservoir is significantly oversized and, therefore, its capacity could be reduced when it is eventually replaced. Operating experience of the supply requirements to the new Wister Drive Pumping Station will need to be included a re-sizing evaluation of the 8 MG Reservoir. The remaining reservoirs are slightly greater than required capacity based on existing population. Required capacity for the year 2025 is approximately equal to present capacity; therefore, additional capacity will not be required until after 2025.

7.4.3.1 8 MG Reservoir

The 8 Mg Reservoir is located at City Springs. It is a concrete structure covered with a galvanized steel roof. The reservoir has a history of leaking. In 1996 (WWC, 1996) performed a structural evaluation and made repairs to the reservoir concrete slabs. Unfortunately, the rehabilitation project has not corrected the leakage problem entirely, as evidenced by observation wells that respond to changes in reservoir level. A new overflow standpipe was installed in 1995 to assist operations during reservoir shut down.

Because of leakage, the reservoir is not normally operated at maximum level (18 feet). Instead, it is typically operated between 13 and 15 feet. The 8 MG Reservoir is filled by the Turner Wells, Pope Springs Wells, Soldier Springs Well and flow from the Water Treatment Plant.

The elevation of the reservoir was established by construction of the original UPRR water system constructed in the 1800s. Present day expectations of adequate water pressure are greater than during the 1800s and, therefore, Zone 1 water pressure is considered to be minimal (40 to 50 psi). This limits available fire flow to the downtown business district. Consideration should be given to replacing the 8 MG Reservoir with a taller structure when its useful life has ended. Replacement with a standard height 32 foot steel tank at City Springs ground elevation of 7270 could add 15 psi to Zone 1. This would help provide fire flow in deficient areas of Zone 1.

The effect of increased pressure on the existing water mains would need to be evaluated before increasing the tank height. A system wide pressure test could be conducted. If it is determined the effect of increased pressure would have a significant impact, then the height of the tanks could not be increased until the majority of the cast iron and ductile iron water mains are replaced with PVC.

Seal and Sand Trap Tank

Turner Wells No. 1 and No. 2 have a history of producing sand. Most of this sand settles out in the 8 MG Reservoir but some passes through to the distribution system. The sand is difficult to remove from either location. In response to this, Laramie has contracted

for the design of the Seal and Sand Trap for the City Springs Chemical Feed Station. The Seal and Sand Trap will be located between the 8 MG Reservoir and the City Springs Chemical Feed Station. Construction is anticipated to be completed in 2007. The Seal and Sand Trap has five functions as follows:

1. Improve accuracy of the flow meter in the City Springs chemical feed building by maintaining a full pipe.
2. Eliminate loss of prime of chemical feed pumps in the City Springs chemical feed building when the Turner Wells are not operated for extend periods.
3. Eliminate changing reservoir levels which cause variation in the chemical feeds rates due to varying backpressure on the feed pumps.
4. Eliminate stagnant water in the 8 MG Reservoir by moving the inlet pipe to the northeast corner of reservoir.
5. Trap sand before it enters the 8 MG Reservoir and provide for easy means to periodically flush the sand from the sand trap.

7.4.3.2 Zone 2 Tanks (High Level Tanks)

The Zone 2 tanks are located immediately north of City Springs near the hospital. They are constructed of welded steel. They are filled by the Wister Drive Pumping Station and the Spur Wells. The south tank is 90 feet diameter, 32 feet tall and the north tank is 145 feet diameter, 29 feet tall. The bottom of the south tank is at a lower elevation making the tops approximately equal.

The interiors of both Zone 2 Tanks were sandblasted to bare metal and painted in 2001. The exteriors appear to need painting in the next ten years. The south tank has an exterior surface area of approximately 16,000 square feet and the north tank has approximately 30,000 square feet. Using a unit cost of $5.00/ square foot for re-painting results in estimated costs of $80,000 for the south tank and $150,000 for the north tank.

The high water elevation of the Zone 2 tanks is 7353 (1988 USGS Datum) resulting in approximately 45 psi static pressure at the upper boundary. This elevation was established in the 1950s when the tanks were built. Present day water

system customers have greater expectations than those of the 1950s and hence, there have been complaints of low pressure along the upper boundary of Zone 2. This includes Corthell Hill, UW student housing, Richards Park and W Hill. Pressures between 35 and 40 psi have been experienced during high demand periods because of the addition of conveyance losses.

A possible solution to this problem would be to increase the elevation of the Zone 2 Tanks by 20 to 25 feet to add approximately 10 psi to all locations in Zone 2. This could be done by raising the tanks and adding to the bottom. Additional height must be added at the bottom to preserve the original design. Welded steel tanks are typically constructed in 8 foot high rings. The thickness of the steel plate of the bottom rings is thickest, varying from 0.25" to 0.75" depending on the height of the tank. Thickness decreases towards the top of the tank to a minimum of 0.25".

The effect of increased pressure on the existing water mains would need to be evaluated before increasing the tank height. A system wide pressure test could be conducted. If it is determined the affect of increased pressure would have a significant impact, then the height of the tanks could not be increased until the majority of the cast iron and ductile iron water mains are replaced with PVC.

Note the Zone 2 pumps in the Wister Drive Pumping Station were designed to pump to the current high water line. If the tanks are raised, then the existing 75 HP motors would need to be replaced with 100 HP motors and one stage would need to be added to the vertical turbine pumps. The electrical service to each Zone 2 pump was designed with extra capacity to allow for this future possibility.

7.4.3.3 Airport Tank

The Airport Tank is located east of the Laramie Regional Airport. It is a welded steel tank with 1.0 million gallon capacity constructed in 2001. The tank has a separate inlet and outlet to enhance turnover in the tank. The tank was designed in accordance with AWWA Standard D100 and is in good condition. The Airport Tank is filled by the University Pumping Station and the Grant Street Pumping Station. During low demand season (October – May), the Airport Tank can be filled by gravity flow from the Water Treatment Plant.

The Airport Tank serves West Laramie (Zone 6) by gravity and the Laramie Regional Airport (Zone 7) by pumped flow through the Airport Pumping Station.

7.4.3.4 East Side Tank

The East Side Tank is located north of Imperial Heights subdivision. It is a glass lined bolted tank of 1.0 million gallon capacity constructed in 2005. The tank has a separate inlet and outlet to enhance turnover in the tank. The tank was designed in accordance with AWWA Standard D103 and is in good condition. The East Side Tank is filled by the Imperial Heights Pumping Station. The tank serves Zone 4 by gravity. The Indian Hills and Turner Tract and Pressure Control Stations allow the Zone 4 Tank to provide flow to the northern and southern areas of Zone 3 during brief high demand periods such as a fire in Zone 3.

7.4.3.5 South of Laramie Water Tank

The South of Laramie Water and Sewer District is a consecutive water system receiving water from the City of Laramie through a pumping station located at 2461 County Shop Road. The connection to the Laramie system is at Zone 1 pressure. Water is boosted to fill the South of Laramie Water Tank located on Howe Road. This is an elevated tank with capacity of 300,000 gallons, high water line elevation 7376 (1988 USGS datum). It was built in 1995 and is owned and operated by the South of Laramie Water and Sewer District.

7.4.4 Water Meter Calibration

The study scope of work for this Level II Study required the calibration of five meters contained in the Laramie Water System transmission pipelines. These five meters are propeller and ultrasonic types. All other meters in the system are magnetic meters, which is the preferred because of better accuracy and ability to send information via the City's telemetry system. The City desired to have all magnetic meters in the system. At the scoping meeting on July 6, 2005, the City directed WWC Engineering to evaluate the replacement of these five meters. This will improve water production accounting and will provide more

accurate chemical feed where the meters are used to pace chlorine and fluoride feed equipment. The five meters that will be replaced are as follows:

City Springs	16”
Wye	16”
Pope Springs	12”
Soldier Springs	14”
Water Treatment Plant	24”

The City indicated they would like to apply to the WWDC for funding for the meter replacement. With this information, direction of the study was shifted to developing the items required for the WWDC application. Each site was visited and preliminary plans were drafted for the meter replacements. Cost estimates were generated in WWDC format. The City used the cost estimate information to apply for WWDC funding in the fall of 2005. The funding was approved in 2006. A copy of the meter replacement designs and cost estimates are included in Appendix 7D.

7. 5 Existing System Hydraulic Performance

7.5.1 Modeling Summary

The AVwater software is used by the City water utility to manage the inventory of pipe, valves, and other items. The software can also be used to perform pipe network hydraulic calculations. As part of this project, WWC used a copy of this software provided by the City. As stated in AVwater software literature : *AVwater provides the functionality to define the geometric configuration, establish the materials inventory, introduce supply and demand loads, perform analyses and display pertinent results in graphic and/or tabular format. Storage tanks, pressure regulating, sustaining and open/close valves, pumps, meters, etc. can be included in the water distribution model. Extended period simulations which adjust liquid levels in tanks over a user-specified simulation period may be modeled. AVwater provides a semi-automated approach for fire flow analyses with node and pipe summary tables being created facilitating the system adequacy determination, as well as, Dynamic Water Quality modeling which tracks the fate of a dissolved substance flowing*

through the network over time. AVwater uses an ArcView GIS and ArcGIS interface to (a) KYPIPE modeler and (b) EPANET Version 1 and Version 2 modelers, thereby integrating modeling and GIS technology.

An unstated objective at the beginning of this project was to make the database of water utility information complete enough and accurate enough for use. This required the assignment of pipe friction factors, the assignment of elevations to pipe nodes, the specification of pumping and tank systems, and the general correction of pipe data that was not accurately specified.

Appendix 7E contains a technical memorandum that presents the detailed approach and assumptions for the hydraulic evaluation work, and the interested reader will find it necessary to consult the memorandum for a complete presentation.

7.5.2 Peak Hour Conditions

A peak hour evaluation of the existing distribution system was performed. The model included the following conditions:

- The analysis was a 24-hour extended period simulation.
- Water consumption data was allocated to each service connection in the system using actual July 2005 meter data. The average day demand in July was used. This provided a spacial distribution of water demand that could be inflated using a peaking factor to simulate a peak day demand.
- A peak day to average day peaking factor of 1.81 was used. This approximation was obtained from the peak day ratio information included in the Appendix 7A evaluation of actual data.
- A diurnal demand curve was used to estimate the daily distribution of water use in the summer. The curve was constructed from meter data (the Grand Avenue, Lewis Street, and Reynolds Street meters) and that procedure is outlined in Appendix 7E.
- Irrigation demands were applied to City green spaces during evening hours. These demands were based on estimated water use.

The results of the peak hour evaluation are presented in Figure 7-4. The evaluation shows that there are three areas in the system that have low (less than 42 psi at the curb)

residual pressure. These areas include the North end of Zone 1 North and East of 3rd Street, the area of Zone 1 between 6th and 13th Street South of the University, and the southern end of the service area on U.S. Highway 287. The other areas with low pressure indicated on the figure are for transmission pipelines and areas adjacent to water storage tanks.

Although the mapping was presented in terms of a 42 psi residual, the reader may be able to imagine that the deficient areas would tend to grow around these three locations if the low pressure criteria were increased to say 50 psi.

7.5.3 Fire Flow Analysis

A fire flow evaluation of the existing system was performed. The model included the following conditions:

- The analysis was a steady state simulation.
- Water storage reservoirs were assumed to be depleted to the level below the combined volume of the maximum diurnal tank fluctuation from the peak hour simulation and the fire flow volume of a two-hour 4,000 gpm fire.
- The legislated fire flow was applied to the model node at the distribution side of the fire hydrant lead, not at the node at the hydrant end of the lead.
- A maximum day demand was applied to the system as was the peak day demand described in the peak hour evaluation, except that no diurnal demand curve was used. This is the normal practice for evaluating fire flow.

Results of the evaluation are presented on Figure 7-5. As seen on this figure, there are several areas of the distribution system that can not provide the legislated fire flow through a single hydrant, primarily in the areas zoned for a 4,000 gpm fire. Tables 7-3 and 7-4 are provided to supplement the understanding of the fire flow capability of the system.

Table 7-3 presents judgment as to why the results of the fire flow evaluation indicate non-performance. As shown in the table, most of the problems are related to parts of the distribution system that have a combination of insufficient pressure and long or small water mains. The table also indicates that there are some areas of town where the model results were not anticipated and we attribute the issue to one with poor pipe connectivity or some

other issue related to the software (or perhaps solution convergence). These specific areas may require further study if they are issues for the City.

Table 7-4 presents the results of the fire flow evaluation at the 18 locations identified by the Water Department during a meeting. Some of the locations are incapable of delivering fire flow with even 2 or 3 hydrants. Some locations, however, can deliver the legislated fire flow if more than one hydrant is used.

7.5.4 Water Quality Evaluation

7.5.4.1 Stage 2 Disinfection Byproducts Rule

The Stage 2 DBP rule requires systems to evaluate their distribution systems to identify locations of high disinfection by-product concentrations. These locations will then be used for Stage 2 DBP rule compliance monitoring of TTHM (total trihalo methanes) and HAA5 (haloacetic acids).

Under Stage 2 DBP, the City has to conduct an evaluation of their water distribution system. This evaluation is known as the Initial Distribution System Evaluation. The IDSE is a one-time study that is to identify locations in the distribution system that have high concentrations of TTHM and HAA5. The identification of these locations can be made based on testing or based on the use of a hydraulic model that meets certain criteria. There is a 40/30 Certification process that allows water systems to avoid the IDSE requirements. To comply with the requirements of this certification process requires that test results from the Stage 1 DBP are less than threshold amounts. Laramie may meet the 40/30 Certification, based on conversation with Staff, but a final determination is pending as of this report writing. The water quality evaluation was performed assuming that the City would not qualify for the 40/30 Certification.

The following Table 7-5 is a checklist of the modeling requirements from EPA and it has been annotated to show how this current modeling effort complies with those requirements. As noted the model constructed for this project does not comply with EPA requirements because it has not been adequately calibrated. The hydraulic model can not be calibrated until the East Side Tank Project is complete and operational data is collected against which the model can be calibrated.

Operational data (tank levels, system pressures) and water demands data need to be collected during low demand periods. The City Staff expressed an interest in continuing to advance the water quality model work, even if it could not occur under this project due to a lack of calibration data. In addition to using the model for the purposes of demonstrating regulatory compliance, the City would like to use the water quality simulation to help evaluate and design a distribution systems flushing program.

7.5.4.2 Water Quality Simulation

An extended period simulation of the water system was performed to estimate the age of water in the distribution system during the low demand period of the year. The model included the following conditions:

- Water consumption data was allocated to each service connection in the system using actual November 2005 meter data. The average day demand in November was used. This provided a special distribution of water demand that could be deflated using a reducing peaking factor to simulate a low day demand.`
- The average day November demand was applied without a diurnal curve.
- A reducing factor of 0.77 was applied to reduce the demands across the system to levels observed in the year 2005.
- Winter time operation of the water treatment plant was simulated by limiting WTP production to about 0.9 mgd.

The results of the simulation, presented on Figure 7-6, indicate that the water residence time is less than 3 days (57 hour maximum). Figure 7-6 shows that water in the western portion of the City is typically older than that in the Eastern portion of the City. This is the expected result, since most of the water supply is introduced into the Zone 1 at the 8 MG tank on the east side. One exception is the 20-inch transmission line from the water treatment plant, which terminates in west Laramie (see Figure 7-1).

Although this evaluation and the model do not meet the requirement of the Stage II DBP rule IDSE requirements, the results generally indicate that water quality issues in the distribution system should not be a concern.

7.6 Future T,D&S System Evaluation

7.6.1 Planning Discussion

The true impact of an individual water using development, such as a subdivision, on the performance of an entire water system can not be reasonably estimated unless a system wide evaluation is performed. Traditionally, evaluations prepared by proponents of subdivisions, or other developments, assess the local impact that their project has on the water utility. These assessments are performed using system data, typically fire hydrant test data. If the developer can demonstrate that water can be provided to the development within requirements for flow and residual pressure, then the development will likely be deemed to be acceptable from the water supply standpoint. This approach to assessing the impact of individual developments has been a practical necessity for at least a couple of reasons:

- The cost to perform a system wide evaluation is relatively large. Even with modern water models which make the calculations relatively straight forward, the investment in a model and adequately trained staff is a difficult proposition to fund for small and modest sized water systems, most of which have more pressing water system issues.
- The incremental effect of a single development project on an existing system is often small, or modest, and does not result in what appears to be a significant reduction in the water system performance.

The impact of a new development on an existing system has far more reaching effects than simply requiring the water utility to produce more water. An additional water using development will in fact change water storage requirements, alter treatment needs, and generally reduce the performance of water service to those using the present system. If the cumulative effects of small or modest additions to the water system are not evaluated and mitigated, then the providing water system will be unable to deliver water further and further from the core storage and pumping facilities. There will eventually be a failure of the system to meet performance criteria, which will first be noted on an expanding service area perimeter.

The proper way to plan for an expansion of the water distribution system is straight forward and includes three steps:

- Visualize and estimate the size and location of future water demands at a given planning horizon.
- Identify the cumulative system changes that would need to be made to accommodate the above identified demand increases without sacrificing system performance for the existing users.
- Assess a "plant investment fee" charge that will pay for the construction of all the facilities. The charge should be levied on the newcomers to the system and the existing users in a proportion that agrees with local political opinion.

7.6.2 Future Water Demand

During this project, our Team met with private developers in the City that had development submittals at the City of Laramie Planning office, including final plat and preliminary plats. In addition, we met with other developers that had conceptual plans that were not public information at the time. This provided an excellent sample in time of the current developer pressures that were being exerted on the community (also see Section 4.2).

Figure 7-7 presents the assumed new future water demand locations that were modeled as part of the future system evaluation. Table 7-6 presents the water demand estimates for future developments, including City Parks. City Parks and Recreation provided information on the future sites and locations of City Parks.

Although these figures and tables are very specific with regard to which development is going to happen in a specific location, the modeling effort is not intended to provide a design basis for the actual incorporation of any one individual development into the water system. Instead, the modeling effort approximates the cumulative impact of all the future developments and allows for the conceptualization of global solutions to address the impact.

7.6.3 Future Infrastructure Solutions

The hydraulic model was used to estimate the type and location of future infrastructure that would be needed to correct the present day deficiencies identified in Section 7.5 and the additional deficiencies caused by future demand expansion. The process for identifying the solutions was trial and error. First, an addition was made to the system model, such as a water storage tank or a PRV station, then the model was run and the results

for residual pressure were mapped. If the addition to the system reduced the number of locations with less than the required pressure (42 psi), then that improvement was retained in the model. This process of incrementally adding improvements was continued to eliminate substandard residual pressures. An acceptable solution was one where residual pressure met requirements at all locations.

For the case of fire flow solutions, a modeling approximation was made. This is because to access the entire system would have required time and effort beyond the scope of this study. The AVwater model is not efficient at solving the fire flow solution on a global basis. The approximation entailed the monitoring of 80 fire hydrants in the downtown core area of the city, many of which were shown to be deficient in the evaluation of the existing system.

7.6.3.1 Solution to Address Future Peak Hour Demand

Figure 7-8 presents a solution to the current/future peak hour deficiency. That solution included the following improvements:

- Replace all pipe in Zone1 and Zone 2 that are smaller than 6-inch diameter with 6-inch diameter PVC.
- Construct an elevated water storage tank south of I-80 near the location shown on Figure 7-8. This tank would be filled by a pipeline and booster station connected to the Soldier Springs Pipeline.
- Install large diameter water mains to connect this tank to the U.S. Highway 287 area, the end of 18th Street, and the Corthell Hill area.
- Rezone the northern and southern areas of Zone 1 to be serviced by Zone 2.

A cost estimate to do this project is $15,200,000 with a detailed itemization is in Appendix 7C.

7.6.3.2 Solution No. 1 to Address Future Fire Flow on Maximum Day Demand

One solution for addressing the fire flow capacity problem is to build on the peak day infrastructure by improving the conveyance of Zone 1 water from storage at

the 8MG tank to the needed areas using large diameter feeder mains. The solution, for this scenario presented in Figure 7-9 includes:

- Replace all pipe in Zone1 and Zone 2 that are smaller than 6-inch diameter with 6-inch diameter PVC.
- Construct an elevated water storage tank south of I-80 near the location shown on Figure 7-8. This tank would be filled by a pipeline and booster station connected to the Soldier Springs Pipeline.
- Install large diameter water mains to connect this tank to the U.S. Highway 287 area, the end of 18th Street, and the Corthell Hill area.
- Rezone the northern and southern areas of Zone 1 to be serviced by Zone 2.
- Replace selected reaches of water main in West Laramie.
- The replacement of the Zone 1 line in Grand Avenue with a 24-inch main. At the present time WYDOT's tentative plans for reconstructing Grand Ave. are scheduled for 2012. Consideration should be given to extending this 24-inch line westward across the rail yard to connect with the 20-inch transmission main. The potential benefits include more effective replenishment of the 8 MG reservoir and move effective fire flow supply to the central part of Zone 1.
- The replacement of the 9th Street water main with a large diameter feeder main.
- Installing two PRV stations to serve a fire demand in Zone 1 with water from Zone 1 and Zone 2.

A cost estimate to do this project is $24,200,000, with a detailed itemization in Appendix 7C.

7.6.3.4 Solution No. 2 to Address Future Fire Flow on Maximum Day Demand

A second solution for addressing fire flow capacity problem is to build on the peak day infrastructure by improving conveyance of Zone 1 water from storage at the 8MG tank to the needed areas by essentially replacing the network of distribution

system piping with larger mains. The solution presented in Figure 7-10 for this scenario includes:

- Construct an elevated water storage tank south of I-80 near the location shown on Figure 7-8. This tank would be filled by a pipeline and booster station connected to the Soldier Springs Pipeline.
- Install large diameter water mains to connect this tank to the U.S. Highway 287 area, the end of 18th Street, and the Corthell Hill area.
- Rezone the northern and southern areas of Zone 1 to be serviced by Zone 2.
- Replace selected reaches of water main in West Laramie.
- Replacing all of the pipe in Zone 1 and 2 that is 8-inch or less with 12-inch piping.

A cost estimate to do this project is $52,600,000 and a detailed itemization is presented in Appendix 7C.

7.6.3.5 Solution No. 3 to Address Future Fire Flow on Maximum Day Demand

This solution was not actually modeled, nor is it developed as extensively as the previous solutions. This third solution would involve reconfiguring Zone 1 water storage to a higher elevation, thus providing more system operating pressure throughout Zone 1. The actual elevation is not critical to determine for the purposes of the conceptual design.

To provide adequate system pressure to overcome peak hour and fire flow deficiencies could probably be accomplished (would need to be verified by modeling) with a 30 to 50 foot (13 to 22 psi) raise in the Zone 1 system pressure. This additional Zone 1 pressure would undoubtedly increase the pipe break issue identified by City Staff (Van Zee, pers. comm. 2006) and presented earlier in this chapter. Therefore a necessary part of this conceptual solution would be to include an aggressive pipe replacement program. One attraction of this scheme is that it will be eventually necessary to replace the 8 MG reservoir when it reaches its service life. The following is a list of the elements in this conceptual idea:

- Replace 8 MG reservoir with a bolted steel reservoir or perhaps elevated reservoir on the City Springs property. Reservoir size will be approximately that presented in a previous section of this chapter.
- Replace all Zone 1 pipe that can not take the additional pressure.

  A reconnaissance level cost estimate for this project is $50,000,000 and an itemization is presented in Appendix 7C. The quantity and diameter of pipe in Zone 1 that requires replacement was estimated using the GIS functionality of AVwater and includes the lengths and diameters of all Zone 1 piping that is not PVC pipe. This total length of pipe is 251,537 lf, which compares to the Zone 1 piping identified by the City as having a break history (61,526 lf).
- Evaluate the need to add additional pump bowls or upgrade motors on the well pumps at Turner, Pope and Soldier Wells. Although upgrades may not be needed at all sites they may be needed to overcome the higher hydraulic grade line of the modified pressure zone.
- Construct a water booster station at the WTP.

TABLES AND FIGURES

Table 7-1 Laramie Transmission Pipelines

Pipeline	Reach	Material	Year Built
36" Raw Water	Sodergreen Lake to WTP	Steel	1946
24" Treated Water	WTP to Hwy 230 Valve Vault	Steel	1964
24" Treated Water	Hwy 230 Valve Vault to 30th St.	PVC/Steel	1999
20" Treated Water	WTP to Riverside Dr.	Steel	1946
20" Treated Water	Riverside Dr. to Spruce St.	PVC/HDPE	200_
18" Spur	Spur Wells to Reynolds St.	PVC	2000
18" West Laramie	Airport Tank to West Laramie	PVC	2000
16" Pope-Soldier	Soldier Springs to Spring Creek Dr.	Cast Iron	1920
10" Airport	Hwy 230 to Airport	Cast Iron	1969
14" Grand Ave.	8 MG Reservoir to Downtown	Cast Iron	Early 1900's
16" Grand Ave.	8 MG Reservoir to Downtown	Cast Iron	1950s

Table 7-2 Laramie Storage Capacity

Tank	Zone	Year Built	Capacity	High Water Line Elevation	Wyoming DEQ Req. Capacity, 2006	Wyoming DEQ Req. Capacity, 2025
			gal	ft, 1988 USGS Datum	gal	gal
8 MG Reservoir	1	1964	8,000,000	7,267	2,300,000[A]	2,500,000[A]
Zone 2 (South)	2	1950s	1,500,000	7,353	1,300,000	1,400,000[A]
Zone 2 (North)	2	1963	2,000,000	7,353	1,700,000[A]	1,900,000[A]
Zone 3 (Future)	3	Future	Future	7,465	1,200,000[B]	1,600,000[B]
East Side Tank	4	2005	1,000,000	7,553	700,000[B]	900,000[B]
Airport Tank	6 & 7	2001	1,000,000	7,325	900,000[B]	1,000,000[B]
WTP Clear Well	1 & 6	1964	500,000	7,342	Not Applicable	Not Applicable

[A] Water systems serving in excess of 500,000 gallons on the design average daily demand shall provide storage equal to 25% of the design maximum daily demand, plus added fire storage based on recommendations established by the State Fire Marshall or local fire agency.

[B] Water systems serving from 50,000 to 500,000 gallons on the design average daily demand shall provide storage equal to the average daily demand plus added fire storage based on recommendations established by the State Fire Marshall or local fire agency.

[C] Water systems serving less than 50,000 gallons on the design average daily demand shall provide storage equal to the average daily demand.

Table 7-3 Fire Flow Scenario Summary - Existing Condition

Pressure Zone	Area	Demand	Number of hydrants	Classification of Results				
				Insufficient Pressure	Small Mains	Long dead end runs	Model specifics unknown or connectivity issue	Works in EPANET not Avwater
		gpm						
Zone #1								
	Cottonwood Dr.	1,500	3		X	X		
	3rd St. and surrounding areas	4,000	80	X	X			
	North 9th St.	1,500/3,000/4,000	16	X				
	12th and Sheridan	1,500/3,000	20	X	X			
	Petro	4,000	4	X	X			
	Trailer Park on Mc Cue St.	3,000	5	X	X	X		
	Banner Rd. and Carrol Ave	3,000	5	X				
Zone #2								
	North Quarter of Zone	1,500/4,000	6			X		
	Remaining Hydrants in Zone			X	X			
Zone #3								
	Alta Vista	1,500	4				X	X
	Laramie Rec Center	3,000	4				X	X
Zone #4								
	Sherman Hills	1,500	1				X	X
	Indian Hills	1,500/3,000	2				X	X
Zone #6								
	West Laramie - Snowy Range Road	4,000	8		X			
	Wyo Tech	4,000	27	X	X			

Note: This table describes areas in the City that appear to have serious fire flow deficiencies when viewing the results shown on Figure 7-5A and 7-5B. Under Classification of Results, we identified what we believed to be the cause for this condition. The Wyo Tech Zone 6 issue may be a non issue, because there is apparently a water main in the system that the current model does not have.

Table 7-4 Requested Fire Flow Results

		No. of Hydrants Sufficiently Removed from Each Other		
Location ID	**NFF**	**1**	**2**	**3**
	gpm			
1	1,500	No	No	No
2	4,000	No	No	No
3	3,000	No	No	No
4	1,500	No	No	No
5	4,000	Yes	Yes	Yes
6	4,000	No	No	Yes
7	1,500	No	Yes	Yes
8	3,000	Yes	Yes	Yes
9	3,000	Yes	Yes	Yes
10	1,500	Yes	Yes	Yes
11	3,000	No	No	No
12	1,500	No	Yes	Yes
13	1,500	Yes	Yes	Yes
14	1,500	Yes	Yes	Yes
15	1,500	Yes	Yes	Yes
16	1,500	Yes	Yes	Yes
17	4,000	Yes	Yes	Yes
18	1,500	Yes	Yes	Yes

1. Location ID is in reference to Figure 7-7.
2. These locations for evaluating fire flow capacity were specifically requested by City Staff.

3. NO = Fire flow cannot be delivered
   YES = Fire flow can be delivered

Table 7-5 City of Laramie AVWater Model Characteristics 2006

Checklist 2.1 Minimum Requirements Checklist for an SSS Using a Distribution System Hydraulic Model

Yes	No	
☒	☐	Does your model run in extended period simulation?
☐	☒	Does it simulate 24-hr variation in demand and show a consistently repeating 24-hr pattern of 24-hr residence time? Needs a diurnal curve.
☒	☐	Does your model include 75% of pipe volume?
☒	☐	Does it include 50% of pipe length?
☒	☐	Does it represent all pressure zones?
☒	☐	Does your model include all 12" diameter and larger pipes?
☒	☐	Does your model include all 8" diameter and larger pipes that connect pressure zones, influence zones from different sources, storage facilities, major demand areas, pumps, and control valves or are known or expected to be significant conveyors of water?
☒	☐	Does it include all 6" diameter and larger pipes that connect remote areas of the distribution system to the main portion of the system?
☒	☐	Are all storage facilities with standard operations represented in your model?
☒	☐	Are all active pump stations with controls represented in your model?
☒	☐	Does your model include all active control valves?
☐	☒	Has your model been calibrated (or do you have plans to complete calibration in the next 12 months) for the current configuration of the distribution system during periods of high TTHM formation potential? Does not reflect zone 4 tank.
☐	☒	Were all storage facilities evaluated as part of the calibration process?

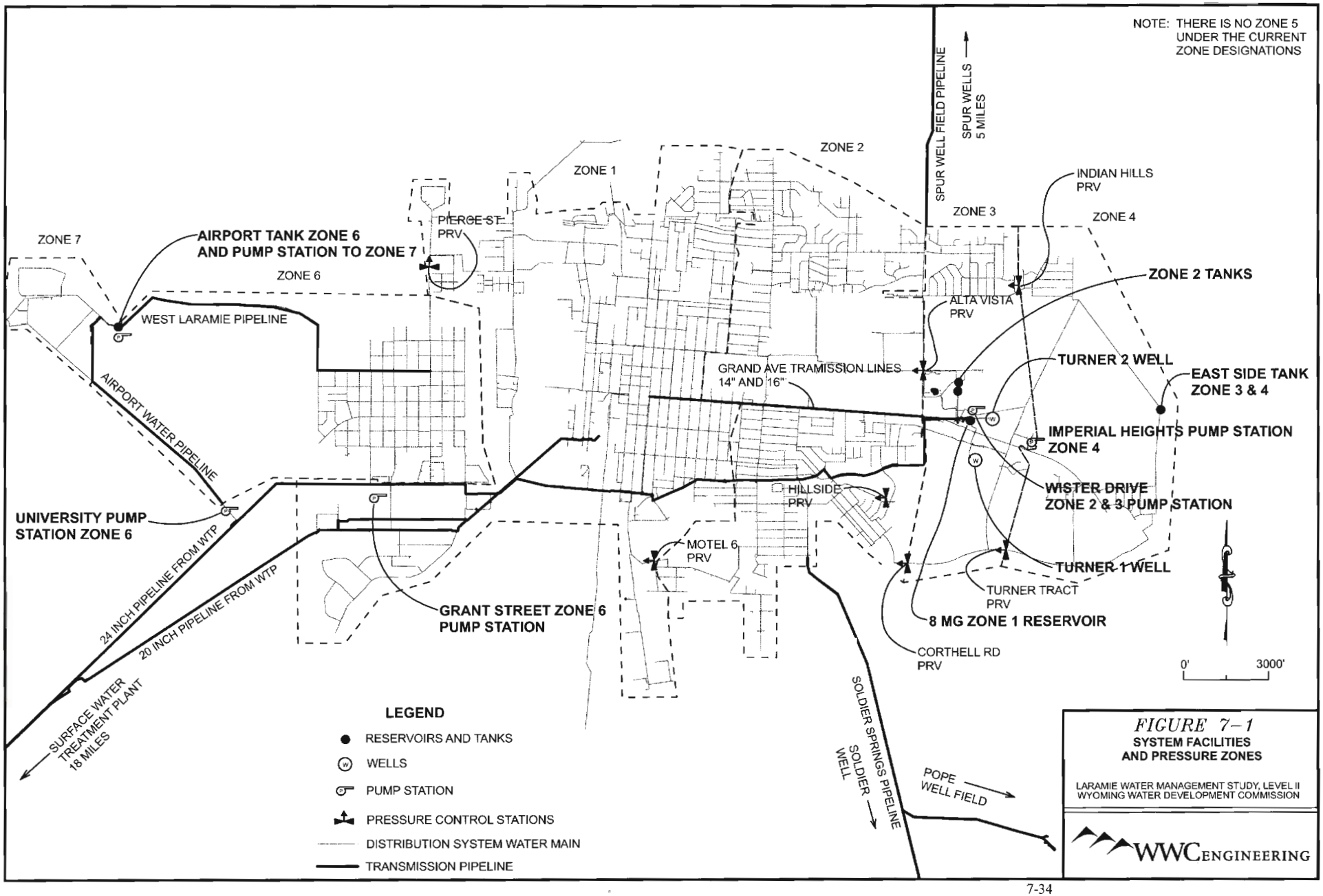
*If you answered yes to **all** of the above questions, you meet EPA's minimum requirements for a model SSS. Remember, though, that EPA or the state can still require you to conduct standard monitoring, even if you meet the minimum requirements, or you can choose to conduct standard monitoring.*

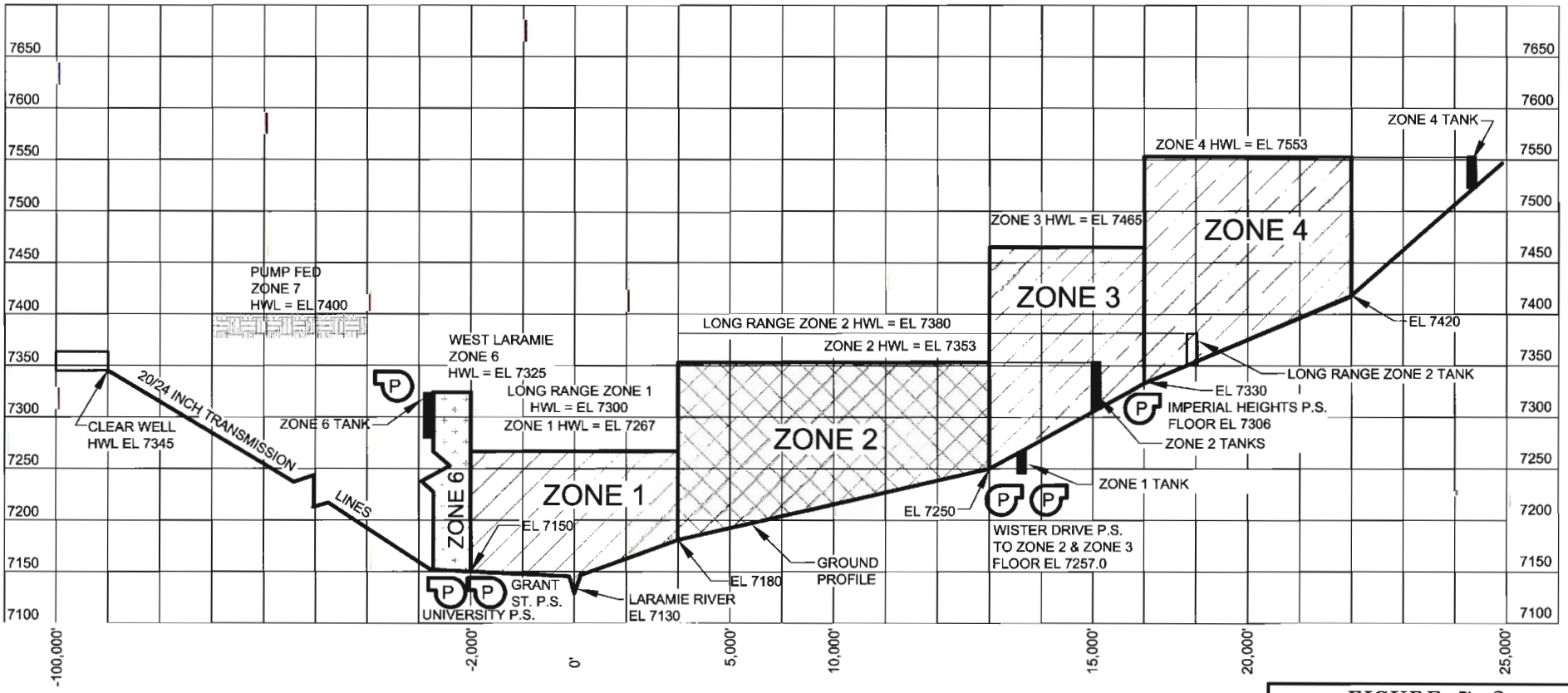
Refer to Section 6.1 for additional guidance on minimum requirements.

Table 7-6 Water Demand Allocation for Future Growth Scenario[1]

			Assumed Use and Size					Commercial Business (Acres)		Average July Day (gpm)		Average July Day Adjusted For 2025 Projection (gpm)
			Single Family	Twin Home	Multi-Family	Total Est. Occupants						
		Assumed People per Unit	3	6	9							
	Development		No. of Units	No. of Units	No. of Units							
1	Coughlin-Pole Mountain 3rd Addition		253			759				121		85
2	UW Conference Center/Plaza							15.5		14		10
3	Montevue Estates		13			39				6		4
4	Grand View Heights		88	178	5	1,377				220		154
5	CPL Addition		190			570				91		64
6	Snowy Range Addition		56			168				27		19
7	Westfield Village		24			72				12		8
8	Wyoming 12th Addition		18			54				9		6
9	Laramie Ridge Estates		19			57				9		6
10	Wyoming Person				12	108				17		12
11	Turner Tract							24		22		15
12	Coughlin-Pole Mountain 2nd Addition		60			180				29		20
13	Fall Creek		145			435				69		49
14	Bob Blake Trailer Court		101			303				48		34
15	Prairie's Edge		249			747				119		83
16	Jacoby Golf Course		750			2,250				359		252
17	Laramie Country Club		300			900				144		101
18	WyoTech Dorms				71	639				102		71
19	Skyline Plaza							18		16		11
20	Greasers - 60 Unit Condo			60		360				58		40
21	UW Housing				50	450				72		50
22	Boysen North 3rd							60		54		38
23	South Gate (WYDOT also, but not estimated)							80		72		51
	Park A									100		100
	Park B									50		50
	Park C									100		100
	Park D									50		50
	Park E									50		50
	Park F									50		50
	Park G									100		100
	Park H									100		100
	Total											
						9,468				2,291		1,783
	Per Capita Water Consumption, Ave July Day	230	gpcd									
	Commercial/Business Water Consumption	1300	gpac									
	2006 Comp Plan 2025 Projected Pop Increase	6626										

(1) Refer to Figure 7-7 for map of assumed locations of new future water demands


NOTE: THERE IS NO ZONE 5 UNDER THE CURRENT ZONE DESIGNATIONS
ZONE 7
ZONE 6
ZONE 1
ZONE 2
ZONE 3
ZONE 4
AIRPORT TANK ZONE 6 AND PUMP STATION TO ZONE 7
PIERCE ST. PRV
WEST LARAMIE PIPELINE
AIRPORT WATER PIPELINE
UNIVERSITY PUMP STATION ZONE 6
24 INCH PIPELINE FROM WTP
20 INCH PIPELINE FROM WTP
SURFACE WATER TREATMENT PLANT 18 MILES
GRANT STREET ZONE 6 PUMP STATION
MOTEL 6 PRV
HILLSIDE PRV
GRAND AVE TRAMISSION LINES 14" AND 16"
SPUR WELL FIELD PIPELINE
SPUR WELLS 5 MILES
INDIAN HILLS PRV
ALTA VISTA PRV
ZONE 2 TANKS
TURNER 2 WELL
EAST SIDE TANK ZONE 3 & 4
IMPERIAL HEIGHTS PUMP STATION ZONE 4
WISTER DRIVE ZONE 2 & 3 PUMP STATION
TURNER 1 WELL
TURNER TRACT PRV
8 MG ZONE 1 RESERVOIR
CORTHELL RD PRV
SOLDIER SPRINGS PIPELINE
SOLDIER WELL
POPE WELL FIELD
0'
3000'
LEGEND
RESERVOIRS AND TANKS
WELLS
PUMP STATION
PRESSURE CONTROL STATIONS
DISTRIBUTION SYSTEM WATER MAIN
TRANSMISSION PIPELINE
FIGURE 7-1
SYSTEM FACILITIES AND PRESSURE ZONES
LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION
WWC ENGINEERING
C:\2005_172\Final_Models\Replacements\figure 7-1.mxd



HORIZONTAL SCALE = NOT TO SCALE

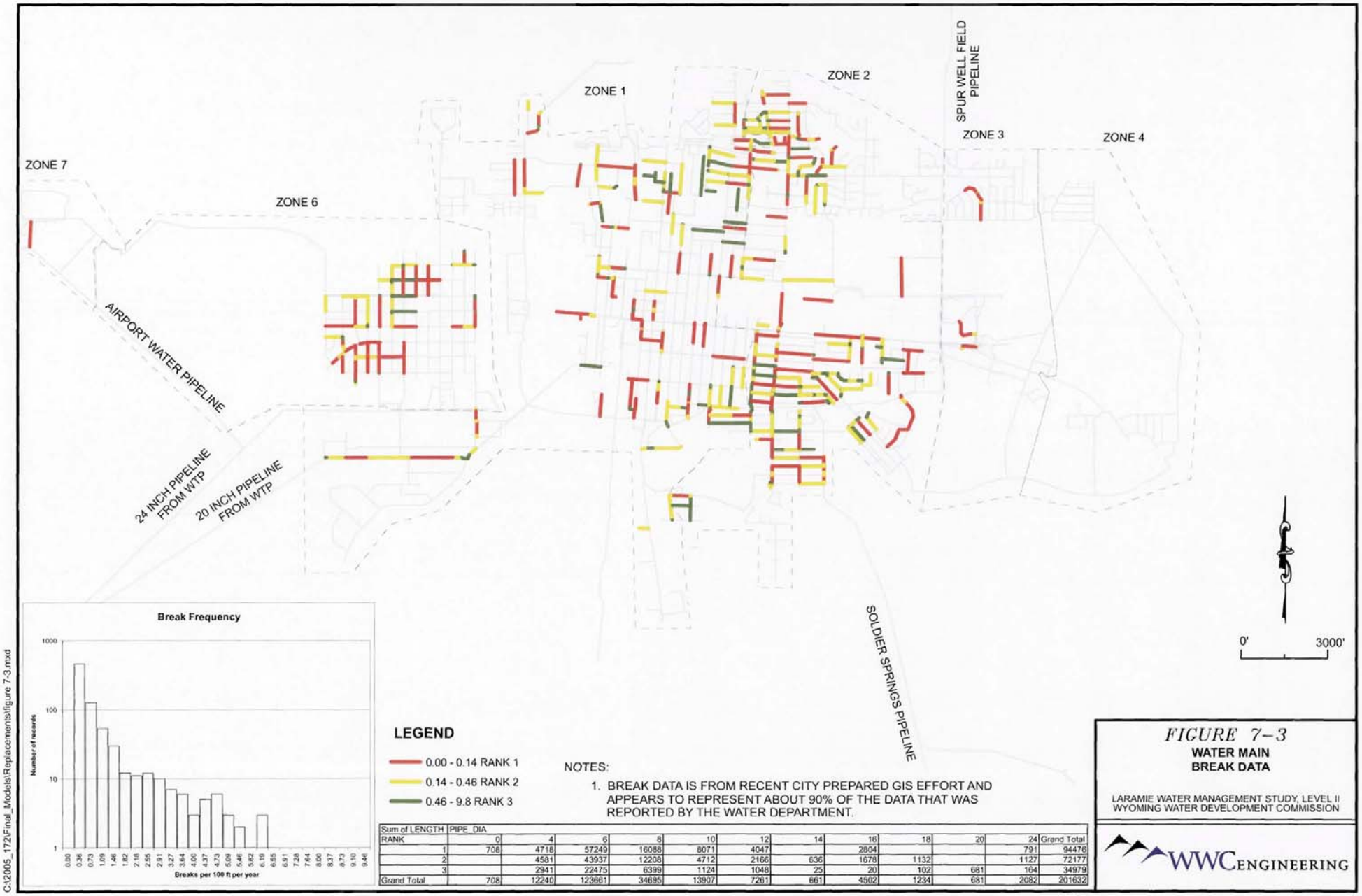
FIGURE 7–2

LARAMIE HYDRAULIC PROFILE
STATIC CONDITION

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

K:\WWDC\2005-172 Laramie\cad\hydraulic schematics\FIGURE_6-2.DWG, PHASE 1 - G-2, 8/17/2006 12:32:27 PM



NOTES:

1. BREAK DATA IS FROM RECENT CITY PREPARED GIS EFFORT AND APPEARS TO REPRESENT ABOUT 90% OF THE DATA THAT WAS REPORTED BY THE WATER DEPARTMENT.

Sum of LENGTH	PIPE_DIA											
RANK	0	4	6	8	10	12	14	16	18	20	24	Grand Total
1	708	4718	57249	16088	8071	4047		2804			791	94476
2		4581	43937	12208	4712	2166	636	1678	1132		1127	72177
3		2941	22475	6399	1124	1048	25	20	102	681	164	34979
Grand Total	708	12240	123661	34695	13907	7261	661	4502	1234	681	2082	201632

FIGURE 7-3
WATER MAIN BREAK DATA

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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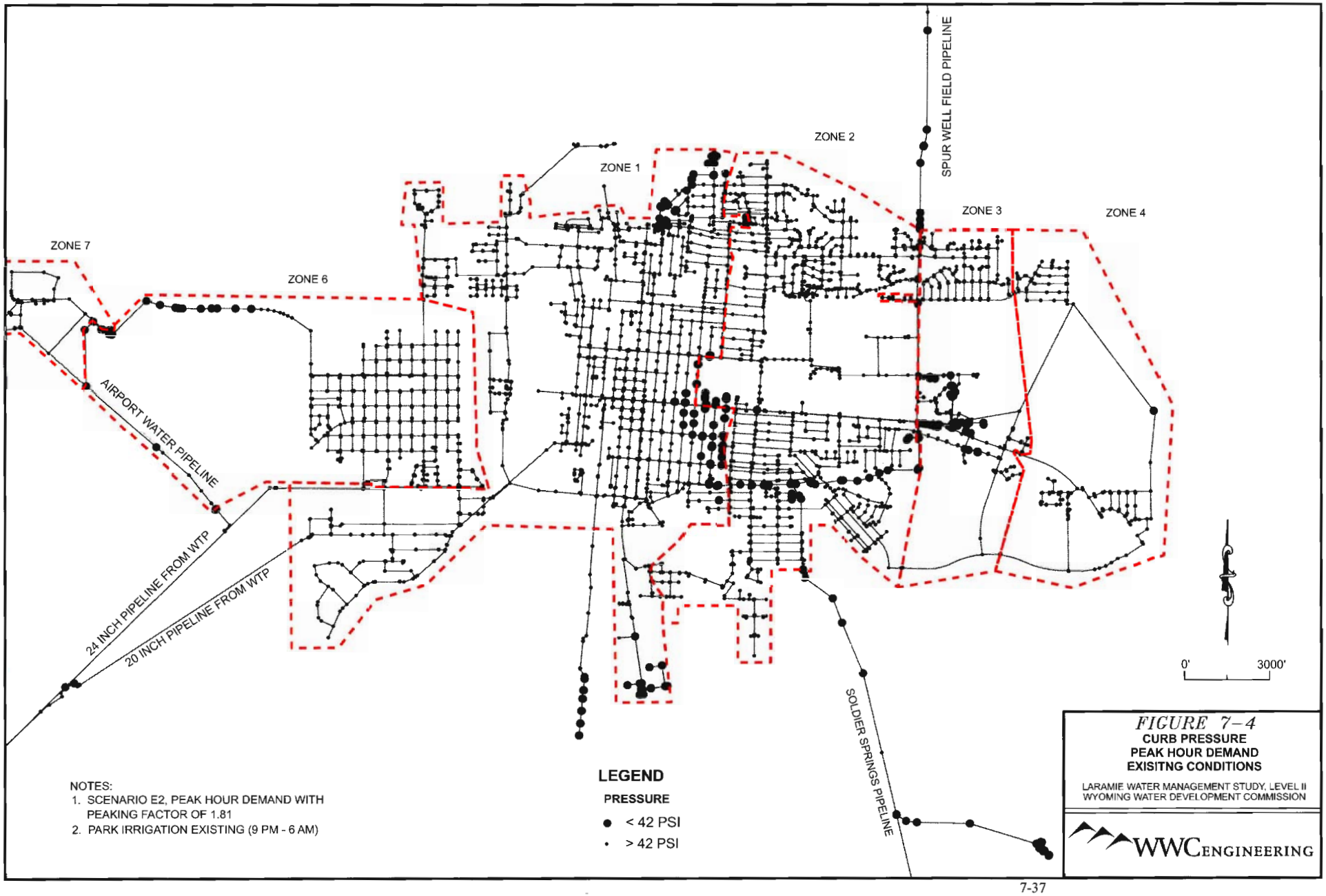

FIGURE 7–4
CURB PRESSURE
PEAK HOUR DEMAND
EXISITNG CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

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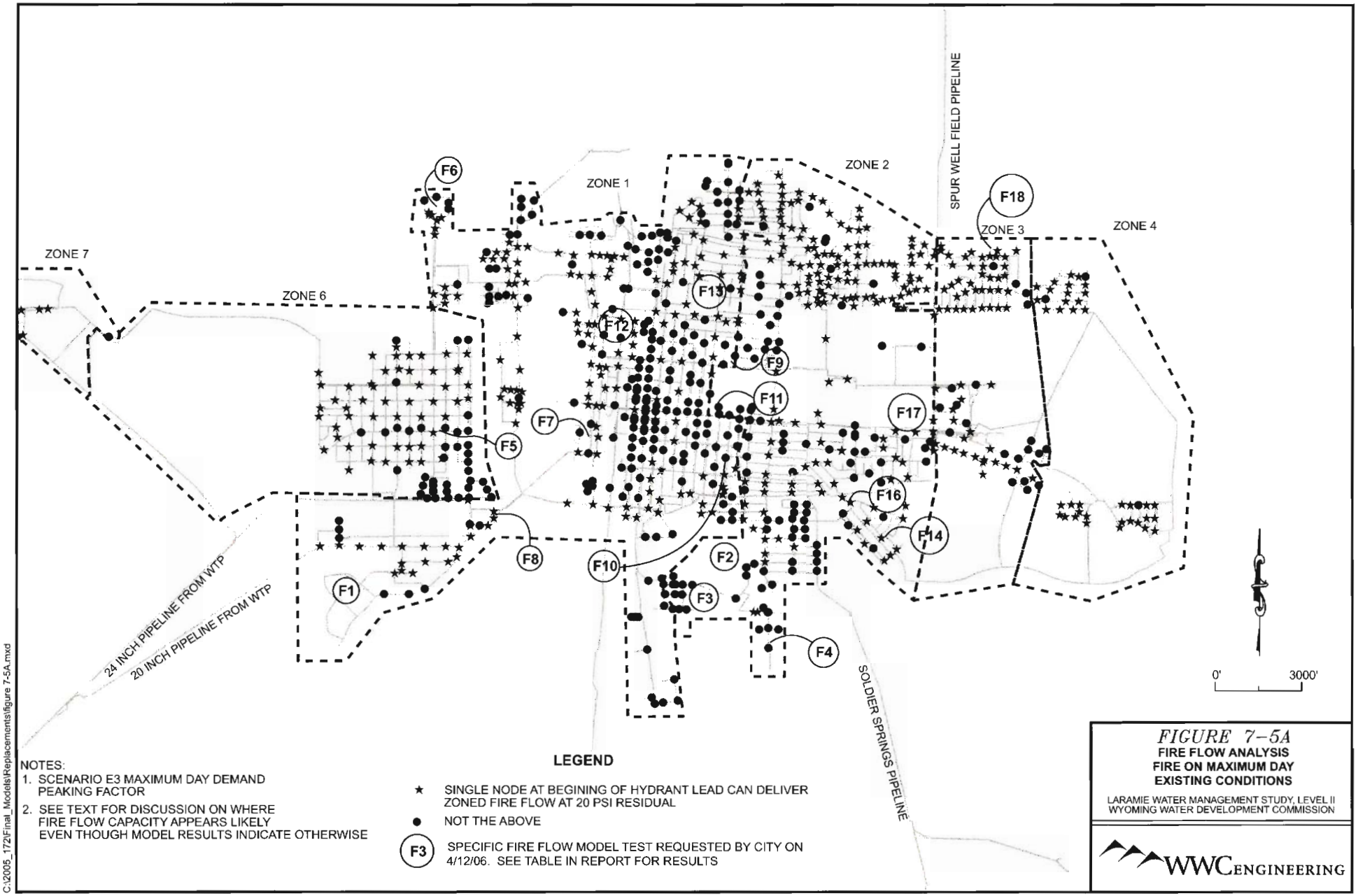


FIGURE 7-5A
FIRE FLOW ANALYSIS
FIRE ON MAXIMUM DAY
EXISTING CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

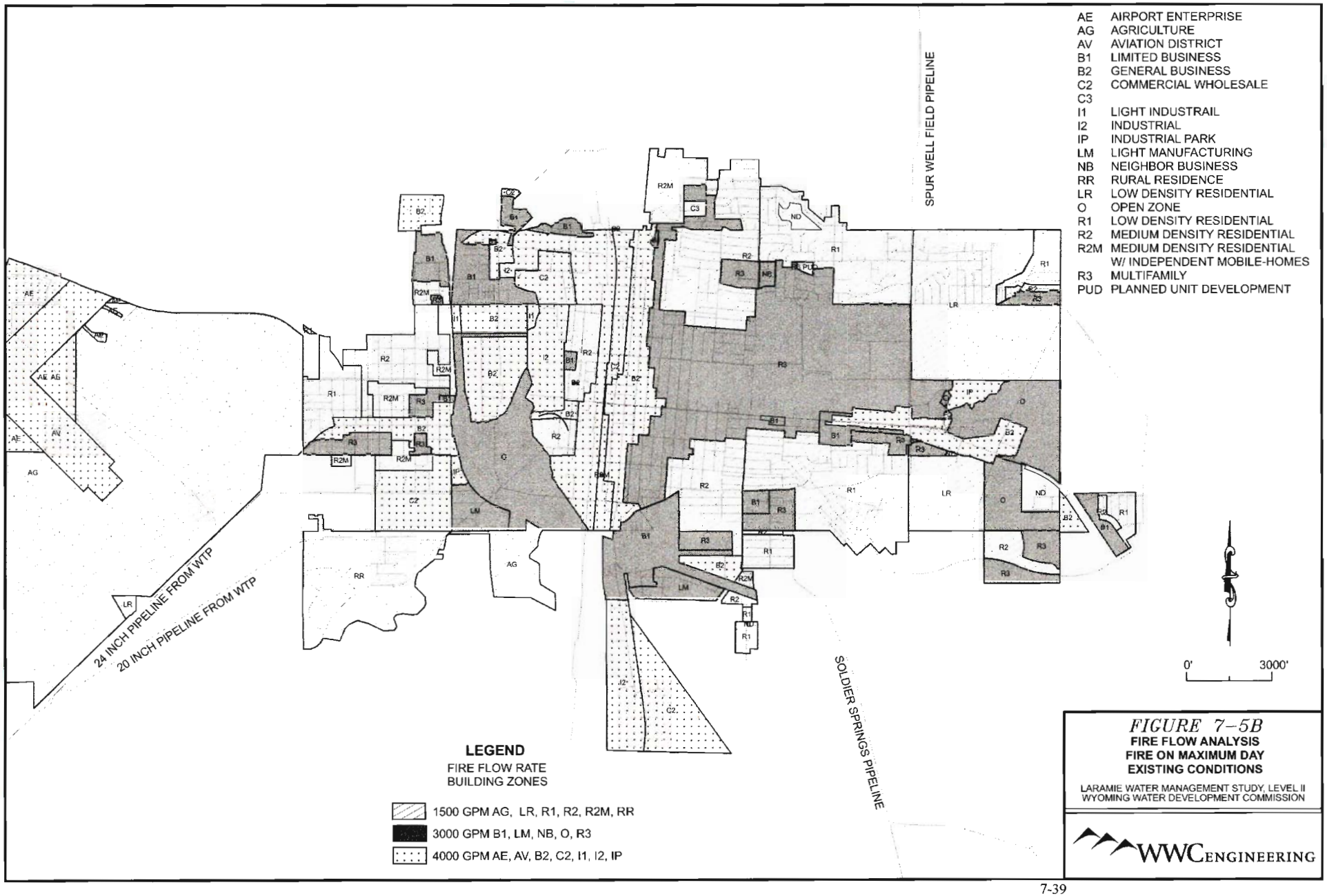


FIGURE 7-5B
FIRE FLOW ANALYSIS
FIRE ON MAXIMUM DAY
EXISTING CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

C:\2005_172\Final_Models\Replacements\figure 7-5B.mxd

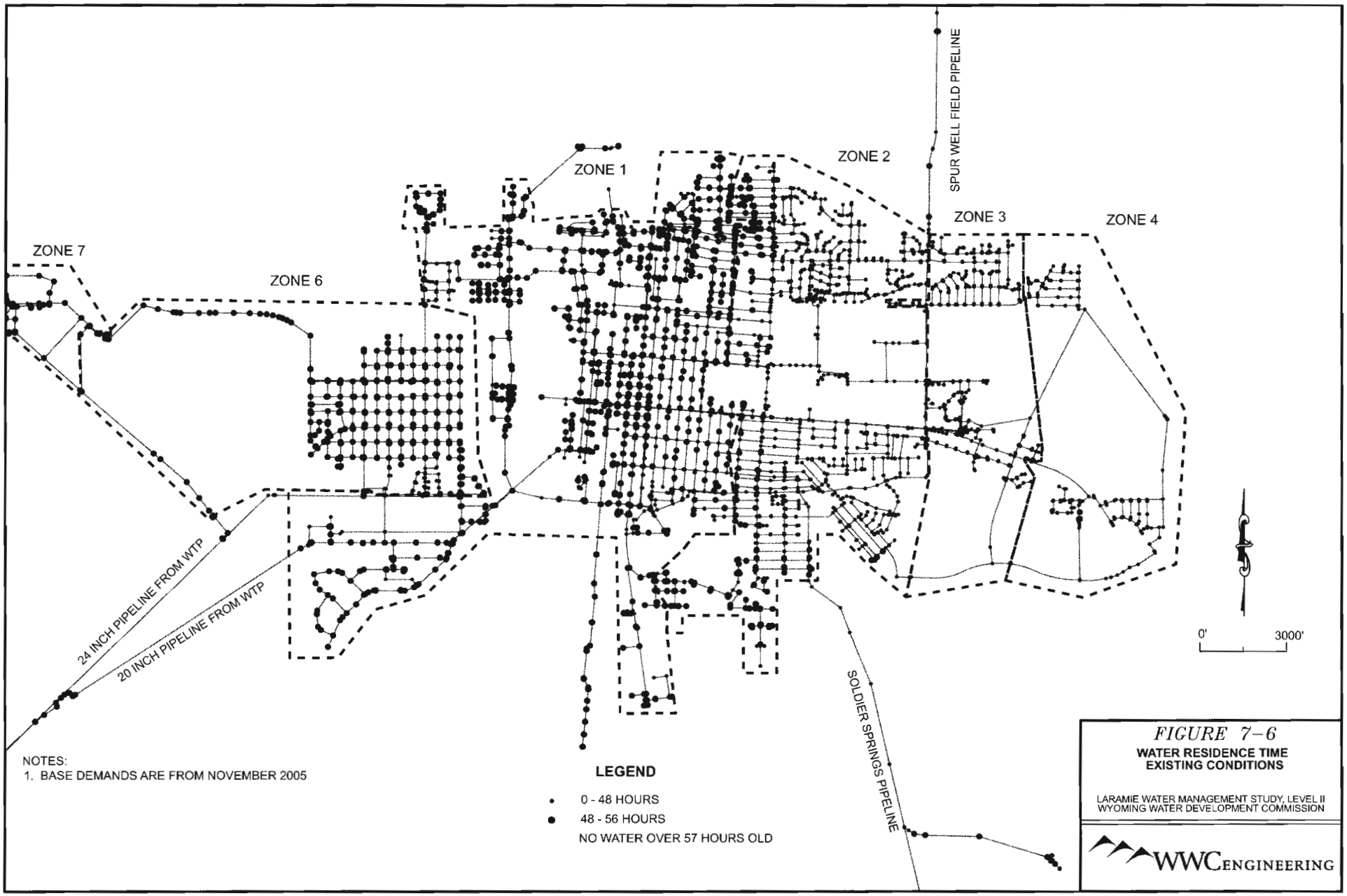
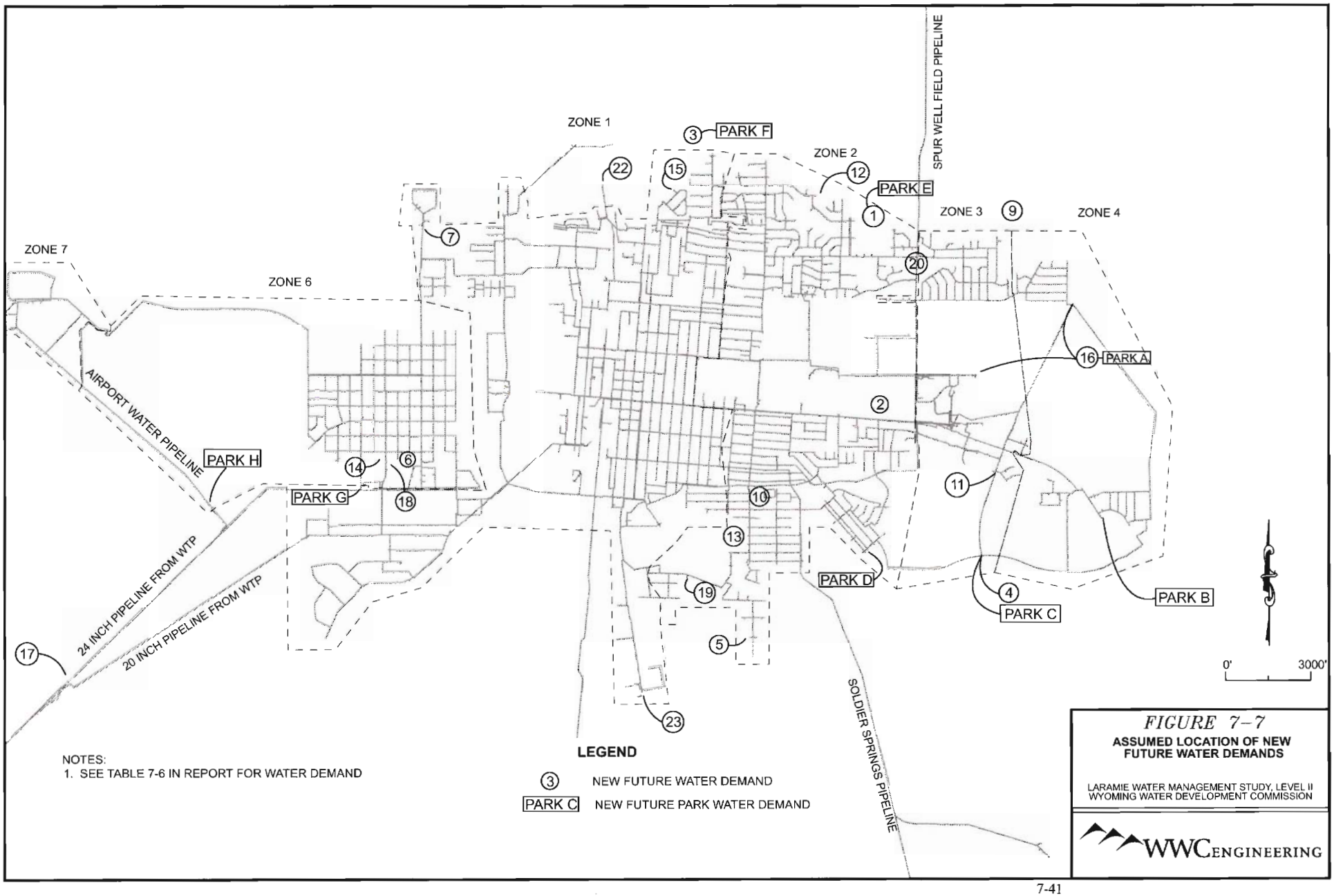


FIGURE 7–6

WATER RESIDENCE TIME
EXISTING CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING


ZONE 1
ZONE 2
ZONE 3
ZONE 4
ZONE 6
ZONE 7
SPUR WELL FIELD PIPELINE
AIRPORT WATER PIPELINE
24 INCH PIPELINE FROM WTP
20 INCH PIPELINE FROM WTP
SOLDIER SPRINGS PIPELINE
PARK A
PARK B
PARK C
PARK D
PARK E
PARK F
PARK G
PARK H
0'
3000'
NOTES:
1. SEE TABLE 7-6 IN REPORT FOR WATER DEMAND
LEGEND
NEW FUTURE WATER DEMAND
NEW FUTURE PARK WATER DEMAND
FIGURE 7-7
ASSUMED LOCATION OF NEW FUTURE WATER DEMANDS
LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION
WWC ENGINEERING
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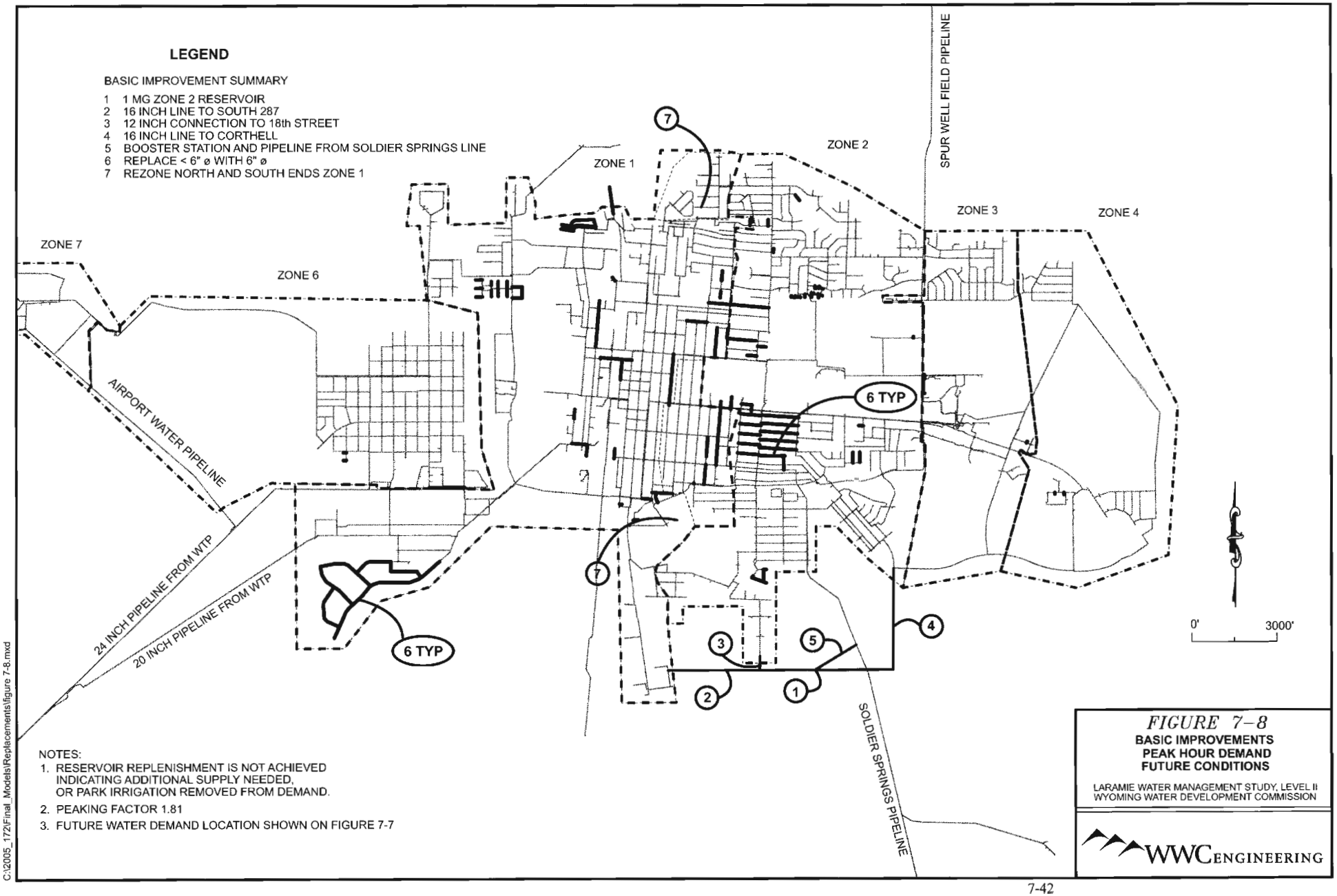
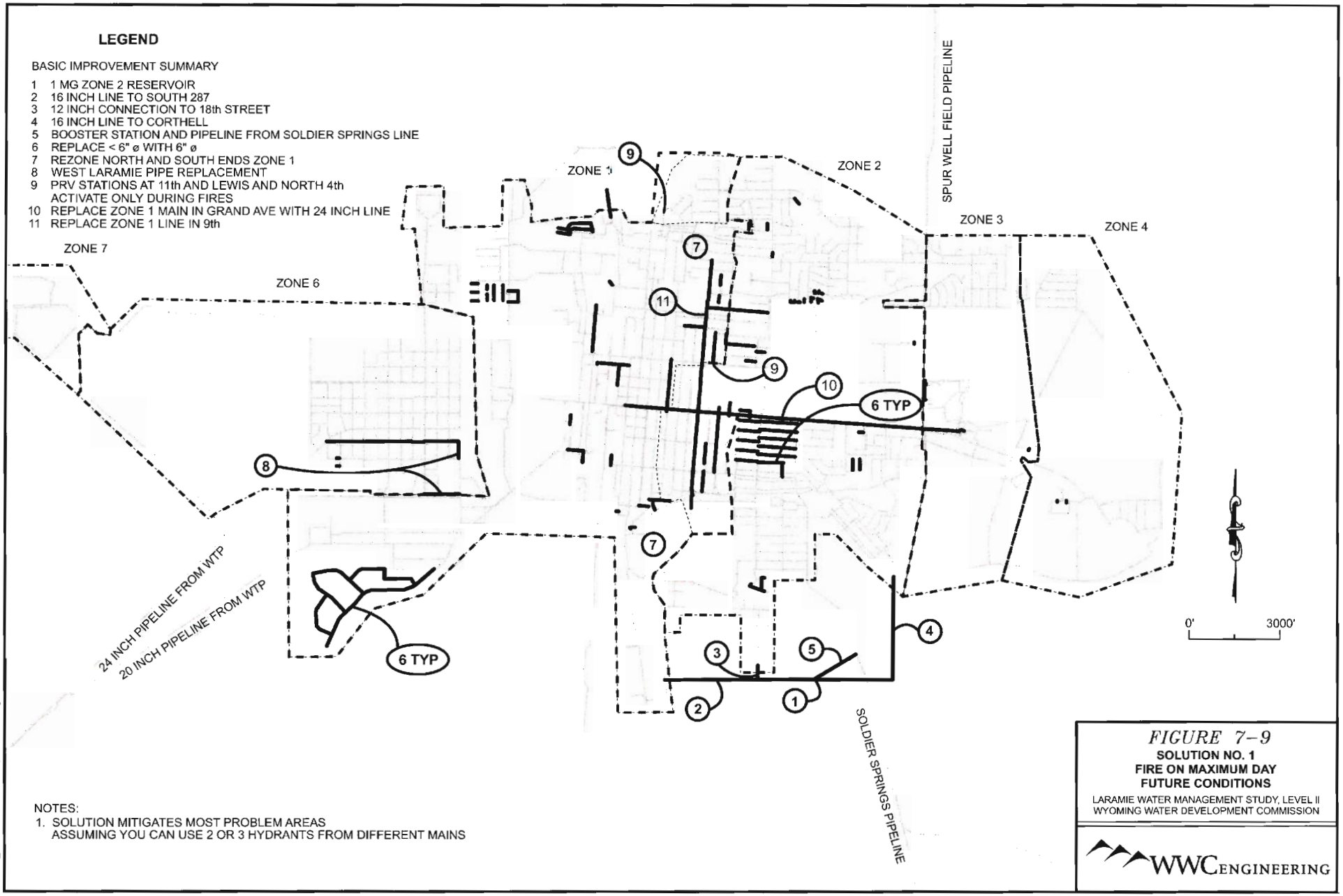


FIGURE 7–8
BASIC IMPROVEMENTS PEAK HOUR DEMAND FUTURE CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION



NOTES:
1. SOLUTION MITIGATES MOST PROBLEM AREAS ASSUMING YOU CAN USE 2 OR 3 HYDRANTS FROM DIFFERENT MAINS

FIGURE 7–9
SOLUTION NO. 1
FIRE ON MAXIMUM DAY
FUTURE CONDITIONS
LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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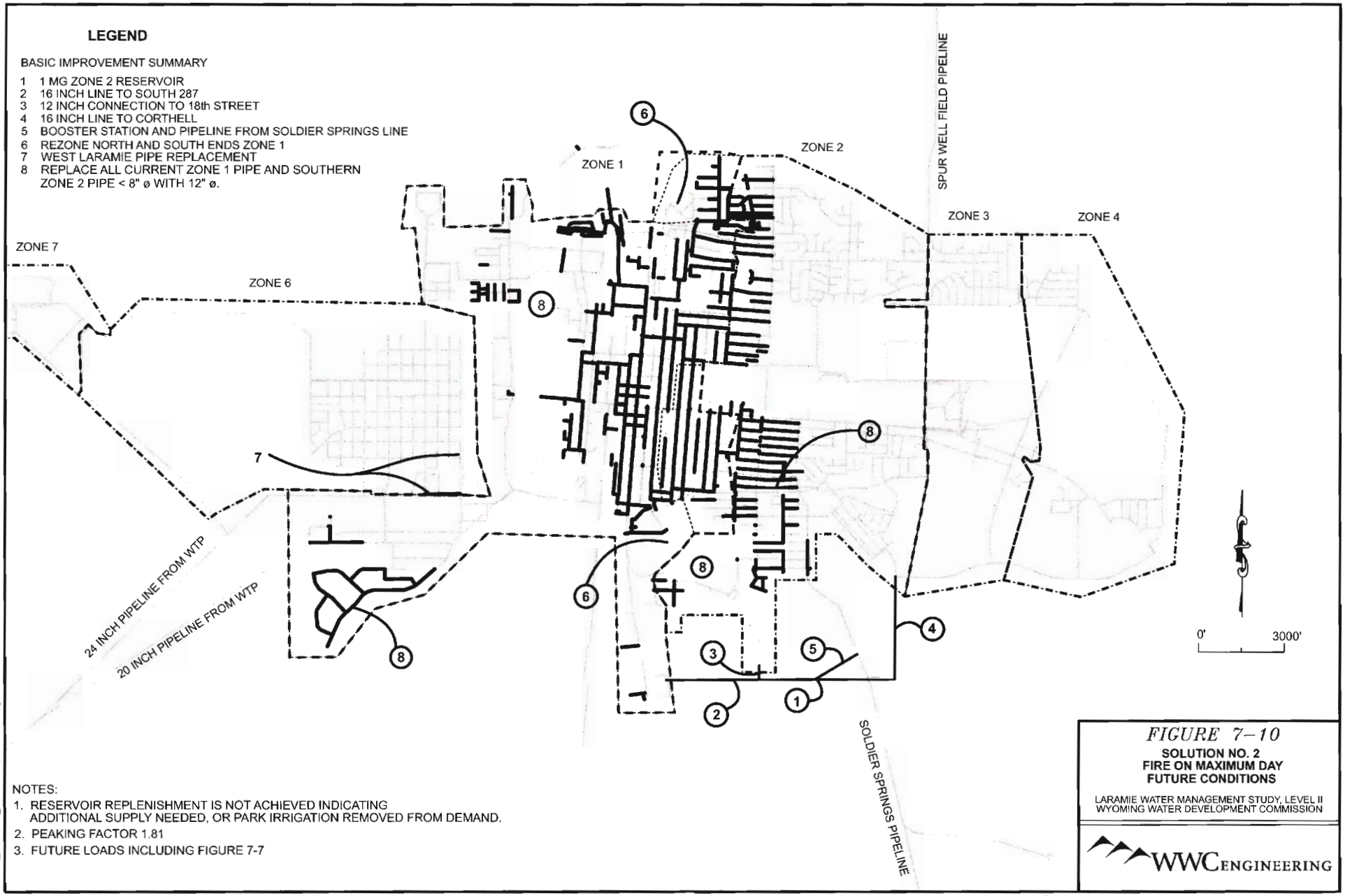

NOTES:
1. RESERVOIR REPLENISHMENT IS NOT ACHIEVED INDICATING ADDITIONAL SUPPLY NEEDED, OR PARK IRRIGATION REMOVED FROM DEMAND.
2. PEAKING FACTOR 1.81
3. FUTURE LOADS INCLUDING FIGURE 7-7

FIGURE 7–10
SOLUTION NO. 2
FIRE ON MAXIMUM DAY
FUTURE CONDITIONS

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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CHAPTER 8.0
LARAMIE RIVER PIPELINE

8.0 LARAMIE RIVER PIPELINE

8.1 Introduction

8.1.1 Objective

As identified in Chapter 1-Introduction, and reiterated at the conclusion of Chapter 5, Alternative Sources of Supply, an objective of this Laramie Water Management Plan Level II Study was to prepare a preliminary design for a water pipeline that would replace the City's use of the Pioneer Canal. This water supply alternative is one of the supply short list alternatives presented in Table 5-2.

8.1.2 Background

The City of Laramie is permitted to divert 14.31 cfs of Laramie River Water at the Pioneer Canal diversion for municipal use as shown in Figure 8-1. The present means of conveyance to the water treatment plant is as follows: Water is first diverted through a bank intake structure adjacent to the Pioneer Canal Diversion Dam. Next, water flows in a 24-inch pipeline through a metering building before it is discharged into the Pioneer Canal about 800 feet from the intake. This arrangement allows the City to measure water independently of the Pioneer Canal diversion, which is measured by a 20-foot Parshall flume. Next, diverted water flows to Sodergreen Reservoir via the Pioneer Canal. At the southeast corner of Sodergreen Reservoir water enters an intake and is piped to the Water Treatment Plant (WTP) in a 36-inch steel pipeline.

The above described conveyance is problematic for the City for at least three reasons:

- One. There are high conveyance losses due to infiltration and evapotranspiration in the physically large Pioneer Canal. This is especially the case during drought condition, such as those experienced during 2002. Although water was available in the Laramie River in the late summer of 2002, the City was unable to treat and deliver this water, because the conveyance losses exceeded the amount of water available at the point of diversion.

- Two. In addition to the above conveyance losses, the Pioneer Canal Lake Hattie District assesses the City a "conveyance loss" for the use of the Pioneer Canal and Sodergreen Reservoir during periods when both City and District water is being diverted. This assessment leaves at most 12.16 cfs (7.86 mgd) available to the City from Sodergreen Reservoir. The City can avoid both the actual and assessed conveyance losses by transporting the water in a pipeline from the river to the water treatment plant.
- Three. The reliable maximum hydraulic capacity of the existing 36-inch pipeline from Sodergreen Reservoir to the WTP is only about 7.5 mgd during the summer (Mike Lytle, pers. comm., 2006). This capacity declines further in late summer as the Sodergreen reservoir storage is depleted by the Pioneer Canal Irrigation District. This deficiency means that conveyance improvements would have to be made between Sodergreen and the WTP if the City is to maximize the use of their water right. An alternative solution is to construct a pressure pipeline from the river to the WTP, which would make better use of the available hydraulic energy.

8.1.3 Previous Studies

Previous studies (Banner, 1983, WWC, 1995) investigated various pipeline alignments, diversion rates, and configurations, including:

- Single gravity pipelines from the Pioneer Canal Diversion Dam to the WTP capable of delivering the current water right and future water right transfer from the Monolith Ranch.
- Parallel pipelines with staged construction to coincide with expanded diversion requirements.
- Pipelines terminating in Sodergreen Reservoir or going directly to the WTP.
- Pipelines diverting from locations downstream of the present Pioneer Land Diversion Dam to shorten the pipeline length. These concepts required a pump station.

8.2 Pipeline Design Capacity

During this project, the Project Team met with City staff to discuss an important long range strategy. That strategy pertained to the City's conversion of agricultural water rights on the Monolith Ranch to municipal water rights and the location where that water should be treated to the best long term advantage to the City. In other words, the appropriate design flow capacity for the Laramie River Pipeline is, or may be, related to the present and future location and capacity of surface water treatment.

The current WTP capacity is about 6.7 mgd, limited in part by the capacity of the transmission lines to the City. If the future water treatment capacity is to be expanded at this location, then a Laramie River Pipeline with a capacity in excess of the present treatment plant capacity may be needed.

Presently, all surface water is treated at the WTP southwest of the City, as it has since 1964. Prior to 1964, the City treated surface water at a water treatment plant at the intersection of Pine street and Garfield streets. Currently this is the City Wells and Pumps shop, and City staff often refers to this facility as the old "filter plant". The 20-inch steel transmission line down U.S. Highway 230 was a raw water delivery line to the plant

The long range strategy for where to treat surface water has been casually evaluated for several years. The lack of a rigorous evaluation is understandable, because the projected need for increasing surface water treatment has been a long range concern. However, the present day initiative to perform final planning and construction of the Laramie River Pipeline requires that a more complete evaluation be made. To that end, this study performed two activities which are described below:

Brainstorming. A brainstorming effort was performed in which several qualitative and quantitative factors were discussed with City Staff in a meeting (see Project Notebook for memos documenting this subject). That effort concluded that future water treatment would remain at the present WTP location with a capacity up to the current permitted diversion rate of 14.31 cfs. Future surface water treatment needs would be met by constructing a second water treatment plant closer to the City, probably on the City owned Monolith Ranch property. A key consideration in this decision was that with a plant at the Monolith, use of Ranch water rights would be maximized. Moving these Ranch water rights

upstream to the present day point of diversion was viewed as a move that would not result in the largest return on the City's water right investment.

Life Cycle Cost Evaluation. As presented in Chapter 6, the Water Treatment Plant will likely require replacement in the coming years, as it has nearly reached the end of its useful life. For that reason, a reconnaissance life cycle cost evaluation was performed that compared the following alternatives:

Alternative No.1

- Replacing the current plant with a new plant, either of the conventional variety like the current plant or a membrane plant
- Building a water booster station to transmit the full water right of 14.31 cfs to the City in the existing 20 and 24 inch transmission lines
- Constructing the Laramie river Pipeline

Alternative No. 2

- Constructing a new water treatment plant on the Monolith Ranch with the ability to treat poor water quality, as the lower reach of the river experiences in late summer.
- Constructing a river intake and pumping station to deliver water to the plant
- Constructing a booster station to lift water into Zone 1 (the 20/24 inch lines north of the plant).
- Inserting a small diameter treated water line into one of the 20 or 24 inch mains to bring water back to the west to serve users along those lines.

Annualized costs for the construction of the facilities were estimated assuming WWDC grants at 67% on the booster stations and transmission lines, WSLIB grants of 50% on the plant work, and SRF loans at 2.5% for 20 years on the non grant balance. Next, annual power costs for pumping were estimated on a monthly basis, assuming that during the summer the plant was treating at the full capacity of 14.31 cfs. The sum of the annualized capital and power costs were compared. Alternative No.1 was found be about 25% less

expensive than Alternative No.2. The detailed calculation is included in the project notebook.

In addition to the brainstorming effort described above, the life cycle evaluating supports our recommendation that water treatment continue at the present location, and that a Laramie River Pipeline is an integral part of that treatment system.

8.3 Conceptual Design

This study examined several pipeline alignments and configurations. The alignments were based on different factors including the shortest alignment from the intake pipeline to the WTP, avoiding heavily wooded and agricultural areas, avoiding possible wetlands, paralleling existing fence lines and roads, and providing for pressurized flow. In addition, the landowners provided significant input with respect to the alignment. The remainder of this section presents the recommended alignment alternative. Material related to alternative alignments and configurations can be found in the Project Notebook.

8.3.1 Horizontal Alignment

With reference to Figures 8-2A and 8-2B the Laramie River Pipeline (LRP) project begins at the City's existing bank intake adjacent to the Pioneer Canal Diversion Dam. The LRP would include making use of the first 650 feet of existing 24-inch PVC pipe. At about Station 6+50, the existing 24-inch pipeline would be reconfigured and new pipeline installation would begin. Next, the alignment follows a cross country route to connect to the existing 36-inch steel pipe, at Station 203+00, located in the WYDOT Highway 230 right-of-way between Sodergreen Lake and the WTP. From this connection, the LRP would make use of about 4,760 feet of existing 36-inch pipeline (and 24-inch at the plant) to deliver water to the water treatment plant.

The conceptual design includes a valve arrangement at the connection with the existing 36-inch steel line (203+00). This configuration would allow the City to use Sodergreen Lake under emergency situations (or for line flushing discharge), provided that an agreement for temporary use is made with the Pioneer Canal Lake Hattie Irrigation District.

At the WTP (247+00), the design includes control valves that will be used to regulate diversion amounts. During this study, the City stated that valves are already in place and will require very little modification to perform the control function. As such, the conceptual design does not include a cost for valves or controls at the WTP. However, some modification of the process feed pumps may be required. An evaluation of this impact was not performed during this study.

8.3.2 Vertical Alignment

The LRP vertical alignment was selected to avoid open channel flow conditions in the pipeline at the design flow. To do this requires that the pipeline vertical profile be located below the hydraulic grade line, which is shown on Figures 8-2 and 8-3. Near Station 166+00 the alignment is steep where the pipe climbs out of the valley bottom and onto higher ground. It is at the crest of this climb that the hydraulic grade line and the ground line are closest to each other.

8.3.3 Material

The gravity pipeline will be a low pressure pipeline. As shown on Figure 8-3 the maximum pressure in the line will be 28 psi at zero flow, at Station 162+05. Although several pipe materials could be used (PVC, steel, ductile iron, or HDPE), WWC recommends the use of AWWA C905 PVC, with a 100 psi pressure rating. PVC pipe use will avoid the corrosion concerns and costs associated with metallic pipe.

8.3.4 Existing Utilities

There are very few utilities located along the pipeline alignment. Wyoming-One Call was not contacted during this study. Some of the utilities were located from deed easements and are shown on Figures 8-2A and 8-2B.

8.3.5 Design Survey

A design survey was performed on a local datum that connects the intake structure and the Pioneer Canal diversion to the WTP. A topographical survey was performed from the intake structure along the proposed route to the WTP. This design survey was performed with a vertical accuracy of +/- 4 cm and +/- 2 cm horizontally. Because an insufficient

number of reliable existing monuments were located in the field, the final design survey will require a static survey to bring the local datum survey into the City's preferred datum (NAVD 1988).

8.4 Hydraulic Design

Hydraulic grade lines were calculated for the selected horizontal and vertical alignment using the EPANET 2.0 pressure pipe hydraulic modeling software. For all of these grade lines, minor losses were ignored for pipe fittings, line valves, entrances and tees. These hydraulic losses would generally be small relative to frictional losses of the pipeline. A conservatively low Hazen Williams coefficient of C=135 was used for PVC pipe and a C = 100 was used for the existing 36-inch steel pipeline. Most all of the models assumed the continued use of the short reaches of 24-inch pipe at the diversion and at the WTP. Figures 8-2 and 8-3 present hydraulic grade line a 36-inch diameter pipeline.

One concept that was discussed during meetings with the City (and in previous reports) is to stage the construction of two smaller pipelines so that line velocity can be maintained during low demand. However, this concept is not recommended, because the City would not be able to divert their full water right of 14.31 cfs for the purposes of water rights maintenance. In addition, although not demonstrated under this project, the cost to stage the construction of two smaller pipelines has a higher present value than the construction of one large pipeline. This is probably true even with a large number of years between staged projects.

8.5 Cost Estimate

The total project cost estimate for a 36-inch diameter pipeline project is $7,700,000. Appendix 8A presents the detailed project cost estimate. The unit price data was obtained from discussion with suppliers, bid tabulations from recent projects, and the Means Cost estimating publication.

8.6 Easements

Three easements will be required for the recommended alignment. Everett Johnson, James Simon and the State of Wyoming, are the surface owners. During the course of this

project, these three parties were aware of the City's intent of building a pipeline through their property, and they were cooperative during this study. The following are easement stipulations that came up in conversation with Mr. Johnson and Mr. Simon:

- 50-foot wide permanent easement. Construction easements of 100 foot width should be adequate.
- Use existing permanent roads for pipeline maintenance wherever possible.
- Reclamation of all disturbances.
- Weed control-5 years after construction.

A utility license from WYDOT will be needed for construction in the Highway 230 right of way. If WYDOT does not allow the proposed pipeline to be built in the Highway 230 right of way, easements will need to be obtained from Dean Shaw (Tract 1, Jelm Mountain Ranchetes) and Joseph Ball (Tracts 2-4, Jelm Mountain Ranchettes). Both of these surface owners were contacted during the project for the purposes of survey access; however, WWC did not discuss easement needs for the project. Discussion with WYDOT personnel (Tim McGary, pers comm. May 2006) indicates that the City will not be granted a utility license for installing a parallel line in the state owned right of way unless the private owners adjacent to the highway have unreasonable demands.

8.7 Permits

The City will have to obtain the following permits:

- WDEQ Permit to Construct.
- Change in means of conveyance from the Board of Control through a petition process.
- A U.S. Army Corps of Engineers Nationwide Permit No. 12 for Utility Line Activities. This requirement is under Section 404 of the Clean Water Act.
- A Large Construction Permit from WDEQ will need to be obtained by the contractor. The contractor will need to develop and implement a Stormwater Pollution Prevention Plan (SWPPP).

8.8 Project Schedule

Although this project can be constructed in one typical construction season, additional schedule is needed to obtain easements and permits, to perform final design surveys and other investigations (geotechnical borings, wetlands surveys, T&E surveys, cultural response survey) and to design the project. In addition, time should be allowed to provide for the City to obtain financial assistance through the WWDC and or other programs. We recommend allowing 2 to 4 years time to complete the above activities.

8.9 Additional Conceptual Design

During the course of this study, an additional concept was evaluated. This concept was not envisioned at the beginning of the study and was outside the scope of the original work; therefore the evaluation is reconnaissance in depth.

8.9.1 Move Point of Diversion

There are several possible advantages to the City to discontinue diverting water at the present location and to move the point of diversion to an upstream location. The basic question to be answered is whether or not the benefits outweigh the added expense associated with constructing additional pipeline to that more distant point of diversion. The following advantages were identified:

- *Additional Hydraulic Energy*. The further west the point of diversion is moved, the more potential hydraulic energy is available. This energy could be put to use powering treatment functions in the water treatment plant or possibly reducing the water booster station requirements that is envisioned to be needed when the plant capacity is expanded.
- *Avoid fee for diversion use*. Presently, the City pays the Pioneer Canal Lake Hattie Irrigation District a monthly fee for their use of the diversion dam, the Pioneer Canal Enlargement and Sodergreen Reservoir.
- *Alluvial Intake*. It may be possible to improve water treatment by installing an alluvial intake at the point of diversion. Depending on site specific

information, an alluvial intake may provide additional treatment as providing an additional degree of treatment for cryptosporidium. This issue is more completely addressed in Chapter 6.

- *Water Rights Enhancement.* During the study we were approached by the owner of a small senior irrigation water right (1.14 cfs for the irrigation of 80 acres) diverting from the Laramie River a short distance upstream from the present Pioneer Canal diversion. This very senior priority date water right (1877 – No. 4 on the Laramie River system) could, if purchased, and after being changed in use for municipal purposes, result in a slight increase in the amount of water supply for the WTP. While detailed change of use and change in point of diversion analyses have not been completed for this Level II study, you could reasonable expect between 0.40 and 0.80 cfs of additional diversion for municipal purposes, during periods when such additional streamflows are physically available.
- *Source Water Protection.* The current point of diversion is accessible by the public, because it is located on state lands. There would be reduced risk to source water contamination, either deliberate or inadvertent, if the lands around the diversion were under City control.

8.9.2 Hydraulic Evaluation

Hydraulic calculations were performed for the alternative pipeline project described above that would divert water from the approximate location of the Murphy Ditch (which was moved in 1966 to the river diversion headgate of the Sodergreen – Highline Ditch) and deliver it to the WTP. This pipeline project would be about 4,000 feet longer than the alternative originating at the Diversion dam. The hydraulic grade lines for these alternative projects will be higher than those originating at the diversion, but not so significantly different so as to result in a different pipe material or diameter selection recommendation.

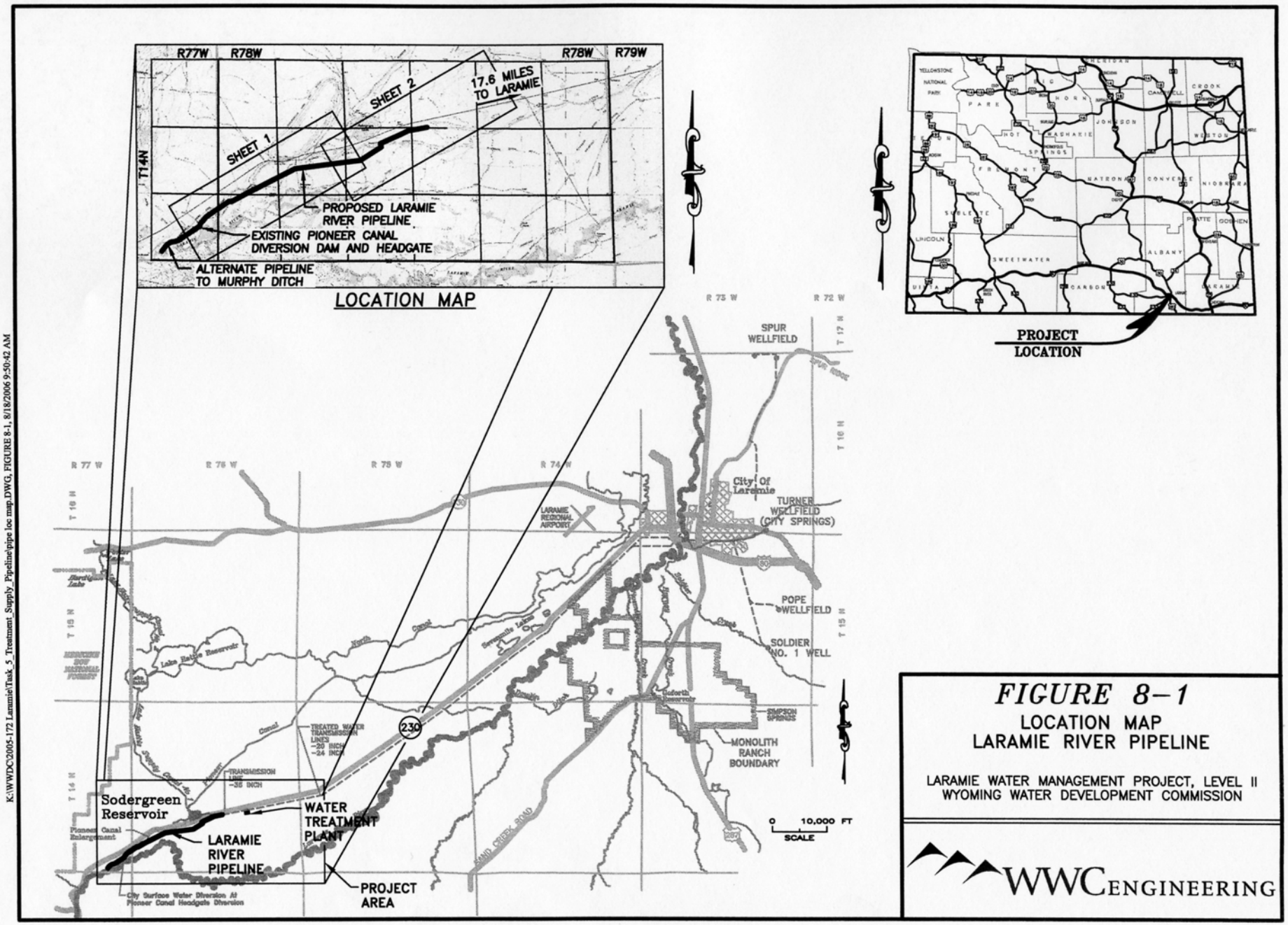
8.9.3 Cost Estimate

A project cost estimate for this alternative project is $9,820,000. A detailed estimate is provided in Appendix 8A.

8.9.4 Feasibility Evaluation

If 0.8 CFS were transferred to municipal use, this would equal about 240 ac-ft of additional water supply (assuming limited to 5 month historic period of use). The value of the water supply would be about $9,000/ac-ft based only on the added construction cost. Based on this simple analysis, which does not account for other potential benefits, we do not recommend pursuing the acquisition of this water right at its present point of diversion.

TABLES AND FIGURES



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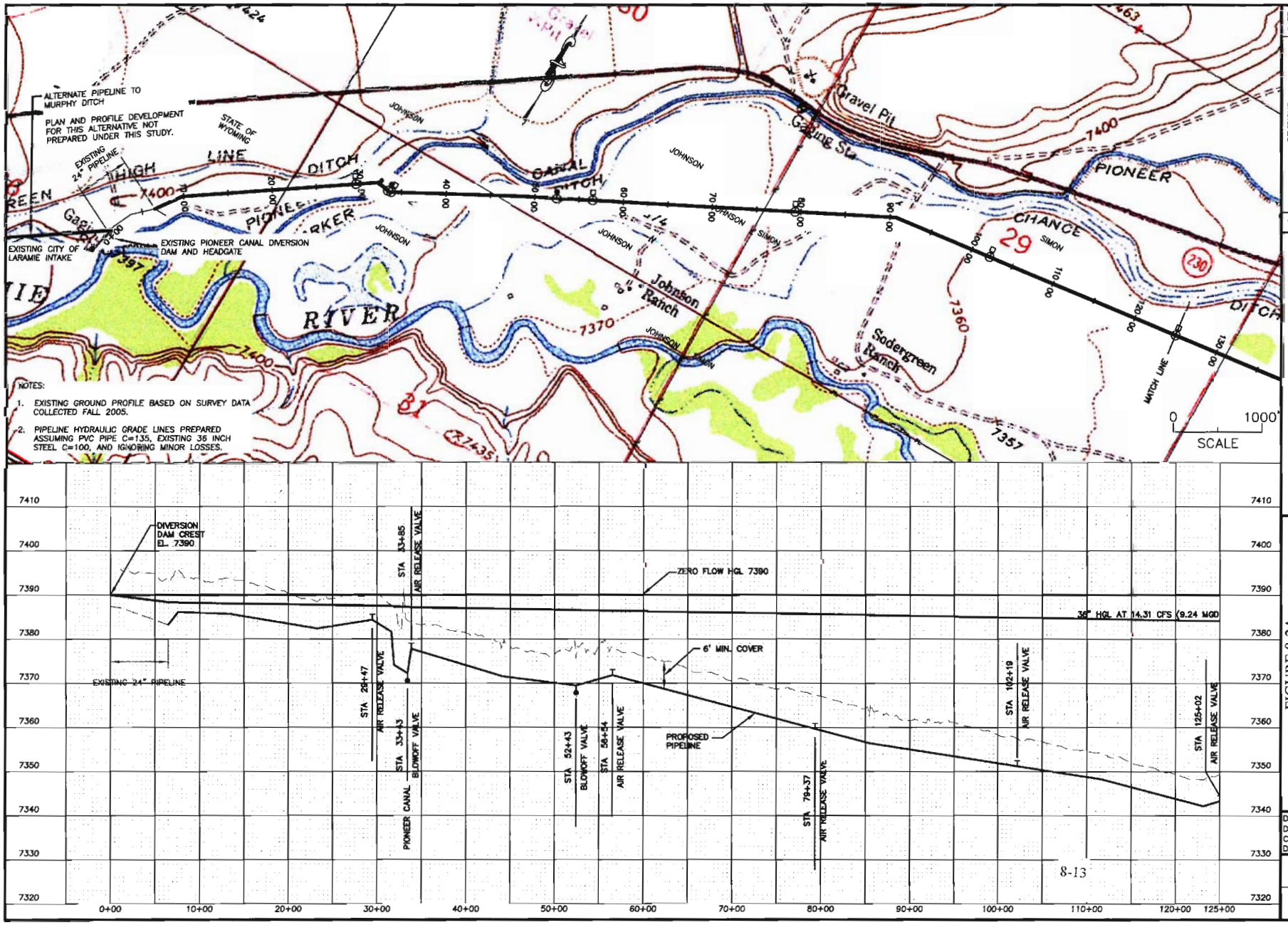

NO. | REVISIONS | DATE

WWC ENGINEERING

FIGURE 8-2A
LARAMIE RIVER PIPELINE

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

DESIGNED BY: RRA
DRAWN BY: RRA, SDC
CHECKED BY: MTS
DATE: 02/02/06

DRAWING

SHEET
1 OF 2

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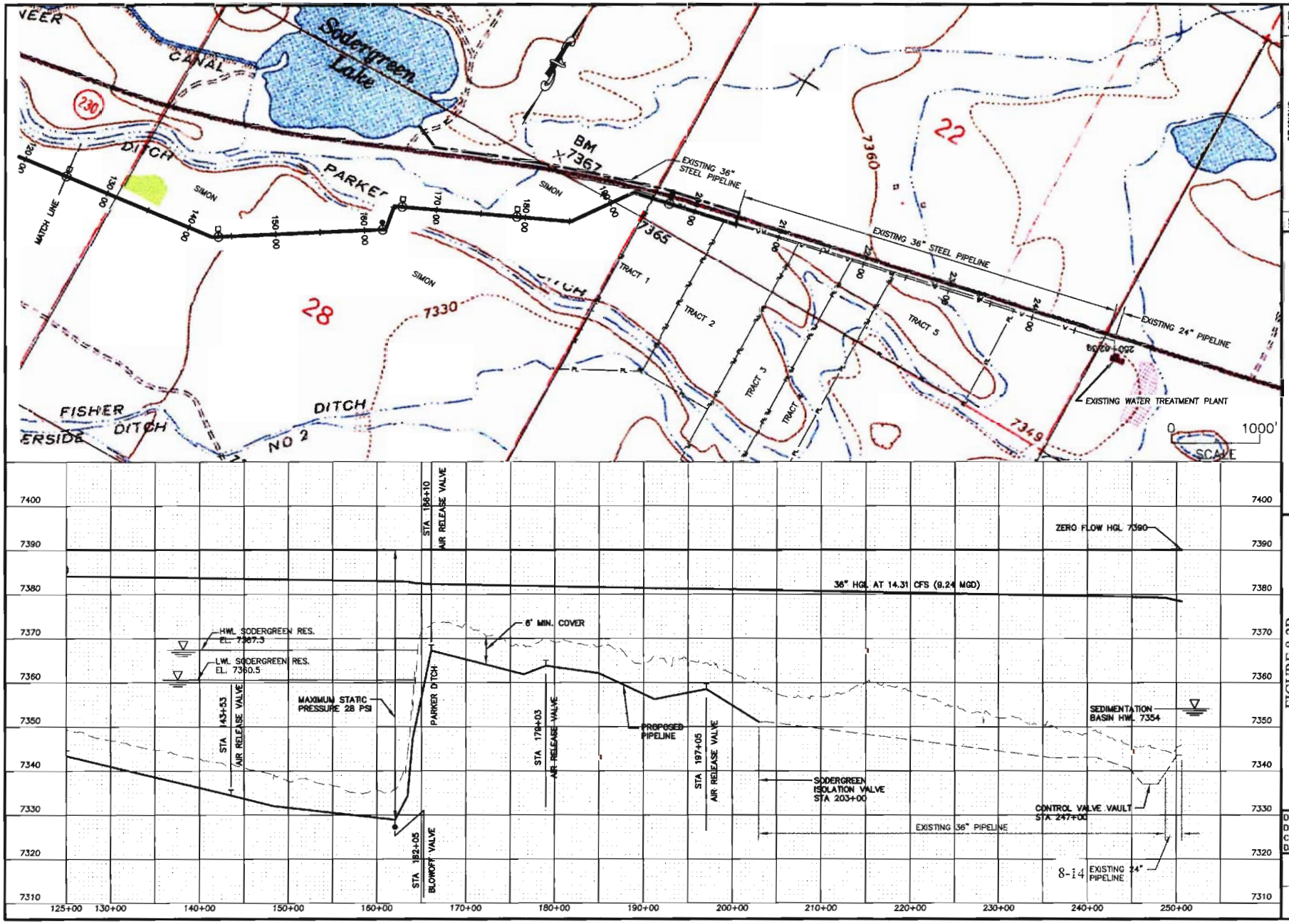

NO. | REVISIONS | DATE

WWC ENGINEERING

FIGURE 8-2B
LARAMIE RIVER PIPELINE

LARAMIE WATER MANAGEMENT PROJECT, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

DESIGNED BY: RRA
DRAWN BY: RRA, SDC
CHECKED BY: MTS
DATE: 02/02/06

DRAWING

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2 OF 2

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CHAPTER 9.0
IRRIGATION WATER

9.0 IRRIGATION WATER

9.1 Introduction

This chapter presents the results of an evaluation of irrigating large green space in the City. The objective is to determine which of the following three alternatives makes the most sense for the City, should be planned on, and supported with capital and operational investment.

- Alternative No. 1 - Potable Water. Continue, as past and current practice, to irrigate large green spaces using treated municipal water. Under this alternative, irrigation water is mixed with and indistinguishable from other water in the distribution system.
- Alternative No. 2 – River Water. This alternative would include transferring a portion of the irrigation water rights off the Monolith Ranch to points of diversion and places of use within the City. Water from the Monolith Ranch would flow downstream in the Laramie River and would then be pumped from the river and distributed in a piping and storage system separate from the treated water distribution system. This concept was recommended for further study in the Management Plan for Water Rights on the Monolith Ranch (Fassett, 2004).
- Alternative No. 3 – Groundwater. This alternative would make use of groundwater supplies from the Forelle Limestone Aquifer. Wells would be located at individual parks and other green spaces, and supply water to those areas. This practice has demonstrated success on University of Wyoming green space. This concept was also identified in the MRWRMP as deserving further study.

9.2 Approach

The evaluation of alternatives and selection of a recommended course of action was primarily performed by comparing the total annualized cost (capital and operating) of each alternative. However, as in most alternative comparisons, there are

attributes that can not be quantified in terms of cost. For this reason, the evaluation of alternatives included an identification and discussion of some qualitative advantages and disadvantages of each alternative. A recommendation is presented that reflects both the quantitative and qualitative attributes of each alternative.

9.3 Irrigation Water Requirements

Figure 9-1 presents a map showing all of the large green spaces that were considered as part of this evaluation. Irrigation water requirements for the green spaces were calculated by two different methods. The first method was to use the consumptive irrigation requirement (CIR) and estimate a volume of water needed to be applied to each park for each month. From that volume, a flow rate was determined based on a nine hour irrigation application, which is the typical night time application period per City staff. The second method of estimating the irrigation requirement was based on the City reported peak water demand for an irrigation sprinkler zone. The method yielding the larger of the two estimates was chosen as the flowrate for each park. This information is presented in Table 9-1. The areas of the green spaces and the demands at each park were provided by the Parks and Recreation Department. This information is in Appendix 3A.

Irrigation audits were performed to determine what techniques could be employed to reduce the water requirements for the parks, and that information is provided in Appendix 9A. Although irrigation water savings are possible, those potential savings are applicable regardless of alternatives. Therefore, the savings do not need to be considered in the evaluation of alternatives presented later in this chapter.

9.4 Irrigation Water Quality

There are two possible water resources that could be used, surface water or groundwater. The following section provides an overview of resource water quality.

9.4.1 Surface Water

An irrigation water quality evaluation was performed using a methodology used by the Wyoming Department of Agriculture Analytical Services. The evaluation estimates the hazard associated with each of the following four water quality parameters: Sodium

Adsorption Ratio (SAR), conductivity, boron, and Residual Sodium Carbonate (RSC). Based on the values for each of these parameters, a class is assigned to determine the hazard level. As shown in Table 9-2, even in the worst month, all of the hazards were Class 1 (highest), except for the salt hazard, which was Class 3.

9.4.2 Groundwater

Water quality data from the University of Wyoming (UW) Forelle wells and a Forelle monitoring well at LaPrele Park and a spring north of the City that discharges from the Forelle Limestone are listed in Table 9-3. Total dissolved solids (TDS) in the Forelle range from 1,130 to 1,270 mg/L. For irrigation purposes, water from the Forelle is rated as having low alkalinity (sodium) hazard (Class 1), high salinity (salt) hazard (Class 3), low residual sodium carbonate hazard (Class 1), low sodium absorption ratio of 0.13, and an overall irrigation water classification of C3/S1. Based on TDS concentrations, water quality from the UW irrigation wells is likely to be similar to the Forelle samples listed in Table 9-3.

The suitability of Forelle water for irrigation is demonstrated by the fact that the University of Wyoming has been using Forelle water to irrigate campus green areas since 1939. Forelle water is, however, suitable for irrigation with limitations; the high salinity requires an application rate of approximately 2.0 inches per week (i.e., 33% overwatering) to leach the salts (Frosty Selmer, UW per. com.). Clay soils or soils with poor drainage should be avoided and sprinkler application will leave residue on nearby cars, etc.

9.5 Surface Water Irrigation Alternatives

Conceptual designs were prepared for four alternative surface water irrigation configurations, and each of these is described below. Figure 9-1 shows the location of the parks and conceptual infrastructure. Pressure pipe network software (EPANET 2.0) was used to size the distribution system piping for each of the alternatives. All of the concepts provide water to the green spaces using one pressure zone. All concepts include a diversion structure in the Laramie River, a bank intake with a traveling water screen, a pumping station, distribution system piping and a water storage tank. The static pressures served by the single storage tank vary from 77 on the eastern side of the service area to 131 psi on the western side of the service area (for Alternative D).

For Alternative D, the recommended City facilities, WWC estimated a total project cost of $14,000,000. A detailed project cost estimate is included in Appendix 9B. A model schematic and results are presented in Appendix 9B, and model schematics and results for the other three alternatives are included in the project notebook.

Alternative A

In this alternative, all possible areas of green space identified in Table 9-1 were included in the design, including the newer parks in remote parts of the City. For several of the parks on the eastern side of the service area (high ground), booster stations are needed to meet a design criteria of 60 psi minimum service pressure.

Alternative B

This alternative included only the facilities currently irrigated by the City, or proposed parks that will be on the City's system when they are built. As with Alternative A, the same parks that were not economically feasible are still not economically feasible. Four of the parks in this scenario would also require booster stations to achieve the minimum service pressure criteria.

Alternative C

This alternative considers all of the recommended facilities, regardless of whether they are irrigated by the City or by UW. The recommended facilities were selected based upon cost per acre of irrigated land. The parks that were a significant distance from the main line and were small are not recommended due to the fact that the cost per acre irrigated was high. Only one of the parks in this scenario would require a booster station.

Alternative D

This alternative includes only the City facilities that were included in Alternative C. Alternative D includes green space that the City irrigates that is fairly close to the main line, making the cost per acre irrigated more reasonable. Also, none of the parks in this scenario require booster stations, which makes this alternative even more economically feasible compared to the other three surface water alternatives.

9.5.1 On-Site Storage Options

For comparison, a cost analysis was performed for a system that would have a storage tanks at each park. This would allow the pipelines to be smaller, and it would also save the

energy costs of pumping to a single storage tank at the east edge of town, only to backfeed to the parks. WWC determined that this alternative was much more expensive than the configuration which used a central water storage tank. A cost estimate for this option is presented in Appendix 9B.

9.6 Groundwater Irrigation Alternative

This section presents information related to developing a presently under used groundwater resource for the irrigation of recreational green areas in the City of Laramie. The installation of a well(s) at selected recreational facilities may be a cost effective alternative to using surface water to supply the irrigation system.

The groundwater evaluation will focus on a continuous 100 foot thick section of rock, in descending order, consisting of the lower-most 60 feet of the Chugwater Formation, the entire 16 foot thickness of the Forelle Limestone, and the upper-most 25 feet of the Satanka Shale (see Plate 10-1). The Forelle Limestone is the primary target, but the overlying 60 feet of the Chugwater Formation has limestone layers and the underlying 25 feet of the Satanka Shale has fractured shaley sandstone that may supplement production from the Forelle Limestone (WWC, 1997). For ease of discussion, the term "Forelle" will be used to refer collectively to this sequence of rock.

The Forelle is considered a potential water supply for the irrigation of City green areas for the following reasons:

- **Hydraulic separation from the Casper Aquifer**: The Forelle is separated from the Casper Aquifer by the Satanka Shale which is approximately 300 feet thick. The Satanka Shale forms the regional confining layer for the Casper Aquifer. It is suspected that locally some of the water in the Forelle may be derived from upward vertical leakage from the Casper Aquifer; groundwater withdrawals from the Forelle, however, are unlikely to noticeably affect the Casper Aquifer.

- **Unused groundwater resource**: At present, there are only two wells within the Laramie city limits that extract water from the Forelle. Both wells are located on the University of Wyoming campus and are used to irrigate campus green areas.

One well, University Well #1 (S.C. 494), has been used since 1939 and the other well, West Campus Well #1 (U.W 144293), was installed in 2003 (Table 9-4).

- **Well yield potential**: The two UW wells completed in the Forelle have permitted pumping capacities of 200 and 400 gpm. At LaPrele Park, the Forelle Limestone and limestones in the lower Chugwater Formation together had an estimated potential production of 100 to 200 gpm (WWC, 1996b). At a domestic well south of Corthell Street, similar yields were observed in the Forelle Limestone (Robb Watson, local driller, pers. com.). These wells illustrate the *potential* for adequate production for green area irrigation; however, the Forelle is oftentimes not as productive as the wells on the UW campus and at LaPrele Park.

9.6.1 Hydrogeology of the Forelle Limestone

The hydrogeology of the Forelle Limestone has not been studied in detail, primarily because of the preference to develop groundwater from the Casper Aquifer. Regardless, data from the LaPrele Park study (WWC, 1996b) and a review of local geologic maps provide reasonable inferences on the groundwater flow system of the Forelle Limestone. The geologic maps of the Laramie, Howell, and Red Buttes Quadrangles (Ver Ploeg, 1998; Ver Ploeg, 1996; and Ver Ploeg, 1995) provide basic information on the Forelle Limestone.

The Forelle Limestone is a thinly bedded grey-purple-tan yellow limestone with local interbeds of thin red siltstone and gypsum laminations. In the vicinity of Laramie, the Forelle Limestone is approximately 16 feet thick. The Forelle Limestone forms a prominent north-south trending dip-slope ridge with the red siltstones/shales of the Chugwater Formation and Satanka Shale on the west and east sides of the ridge, respectively. The Forelle Limestone dips to the west approximately 4 degrees.

The source of groundwater to the Forelle Limestone is from precipitation that infiltrates into the unit at outcrops and from vertical leakage from underlying formations such as the Casper Formation and Satanka Shale with higher hydraulic heads. The relative contribution of vertical leakage from underlying aquifers is not known and has the greatest potential of occurring where geologic structures provide vertical conduits through the Satanka Shale.

The primary discharge point for the Forelle Limestone occurs in the area between the south end of 30th Street and Huck Finn Pond (T15N, R73W, Sections 2 and 3). This area represents the lowest elevation of Forelle Limestone outcrops (i.e., 7,225 feet amsl) for over 13 miles to the south and 5 miles to the north. Groundwater from the Forelle Limestone discharges into Spring Creek and at springs that supply Huck Finn Pond (WWC, 1996b). Flow measurements in Spring Creek indicate that Spring Creek gains approximately 0.5 cfs (220 gpm) along this reach. The elevation of Huck Finn Pond and the springs that feed the pond are approximately 7,215 feet amsl.

Groundwater in the Forelle Limestone from the south is probably diverted to Spring Creek and the Huck Finn Pond springs by the east-west trending Sherman Hills Fault and its western splays (Figure 9-3). Offset on the Sherman Hills Fault probably disrupts the hydraulic continuity of the Forelle Limestone. Groundwater in the Forelle Limestone north of the Sherman Hills Faults discharges to Spring Creek at the nose of the Quarry Anticline at the south end of 30th Street.

A secondary discharge point for the Forelle Limestone occurs at a small spring (Warren Spring) located 5.5 miles north of City Springs (T16N, R73N, Sec. 3). At this location, the elevations of the Forelle Limestone and the spring are 7,190 and 7,175 feet amsl, respectively.

There are not enough data to generate a potentiometric surface for the Forelle Limestone; however, the calculated head elevation of 7,226 feet amsl at the West Campus #1 (UW irrigation well) is higher than the spring elevation at Huck Finn Pond which suggests that groundwater in the Forelle Limestone in the area of the irrigation study area flows towards Spring Creek between 30th Street and Huck Finn Pond.

9.6.2 Water Development from the Forelle

As demonstrated by wells completed in the Forelle at the UW campus and LaPrele Park, the Forelle has the potential to provide adequate quantity and quality for the irrigation of City green areas. No attempt has been made in this study to determine the long term "sustainable yield" of the Forelle. It is reasonable to say that the groundwater resource of the Forelle has not been fully developed. However, as with the development of any groundwater resource, impacts will occur and development of the Forelle will cause some head declines at

existing UW wells and may reduce natural discharge to Spring Creek. The scarcity of existing wells and lack of aquifer test data prevents evaluation of the magnitude of potential impacts in response to various levels of development. If deemed feasible, a pump test should be conducted at the UW wells to calculate aquifer parameters. Any future development of the Forelle aquifer should be performed with proper aquifer monitoring and testing to allow an assessment of aquifer properties and the response of the aquifer to withdrawals.

Figure 9-2 shows the location of existing and proposed City green areas, structure contours of the top of the Forelle Limestone, and the approximate boundary of saturated conditions in the Forelle Limestone. The inset table in Figure 9-2 provides estimated drilling depths required to penetrate the Forelle at individual green areas which is then used to generate cost estimates for the installation of a production well and infrastructure. Based on the estimated cost/acre of irrigated land, reasonable drilling depths (< 300 feet), and the required production at a green area (< 200 gpm), green areas were selected that may be candidates for future well drilling and testing efforts.

Given the scarcity of existing wells completed in the Forelle Limestone, future drilling and groundwater development efforts are exploratory. The Forelle may not be everywhere as productive as observed at LaPrele Park and at the UW wells, and a drilling program involving multiple pilot holes at each location may be required to locate a well or wells with adequate production.

As mentioned earlier, the target zone is comprised of the lower-most 60 feet of the Chugwater Formation, the Forelle Limestone, and the upper-most 25 feet of the Satanka Shale in order to maximize production potential without significantly compromising water quality. This approach, however, is in potential conflict with the State Engineer's Office prohibition of well completions in multiple aquifers. However, in many parts of the state, the Satanka Shale, Forelle Limestone, and lower part of the Chugwater Formation are referred collectively to as the Goose Egg Formation. Discussions with the SEO should be conducted to allow an exception based on hydrogeologic and stratigraphic information.

9.7 Alternative Evaluation

The City irrigates parks with treated potable water, and the overall municipal water supply is currently large enough that this does not cause a shortage of potable water. If raw

water irrigation is implemented, the potable water supply infrastructure does not have to be expanded as quickly to meet an increase in potable water demand. As presented in the introduction, the focus of work in the chapter was to evaluate which of three possible directions make the most sense for the City: continuing to irrigate with potable water, irrigating with surface water, or irrigating with groundwater. As previously identified, this evaluation includes a quantitative assessment of costs and a qualitative assessment of intangible factors, both of which are addressed in the following sections.

9.7.1 Cost Evaluation

The capital and operational costs for the three irrigation alternatives were tabulated, and the costs that were considered are presented in the following sections:

Alternative No. 1 Potable Water

- The evaluation assumes that the City has grown into the maximum use of the supplies and that to irrigate green space will require a supply and treatment expansion. This assumption is academic, but convenient for the purpose of the evaluation.
- The capital investment associated with increasing the capacity of the water treatment plant so that it can handle the extra flowrate during the irrigation season. A booster station will also be needed to pump the extra water that is required to irrigate the parks. At the present time, the supply and treatment system provides adequate potable water.
- The electrical power to run the water booster station.

Alternative No. 2 River Water

- The capital cost to install river diversion, pumping, distribution, and storage infrastructure.
- The power required to operate a pumping station at the river.
- The labor associated with extra manpower during the irrigation season to operate and maintain a diversion and pumping facility at the river.

- The savings associated with using the Monolith Ranch water right to irrigate the parks instead of irrigating on the Ranch were assumed to be negligible.

Alternative No. 3 Groundwater

- The installation of wells, pumps, electrical and telemetry systems at individual parks.
- The power required to operate the well pumps.
- The labor associated with extra manpower during the irrigation season to maintain the dual systems.

Finally, the evaluation considered grants and loans that would be available to the City. For the raw water system, we assumed that 67% of the capital cost would be funded by a WWDC grant. This leaves 33% of the capital investment to be covered by an SRF loan, which offers 2.5% for 20 years. We assumed for the potable water system that 50% of the capital investment would be funded by a WSLIB grant. Again, the City would receive an SRF loan for the other 50%. An annual cost for both of these options was also calculated.

The results of the evaluation are presented in Table 9-5.

9.7.2 Qualitative Evaluation

Overall, these water supply options are presented to identify options for supplying the irrigation needs for the public parks and other green areas within the City, and thus reducing the long term demands on the use of the more expensive and limited treated water suppliers and allow such higher quality water to meet the domestic, commercial and related demands with the municipal water distribution system. These options, in some respects, as discussed below, allows for a more efficient use of the available surface or groundwater resources near the City, and saves and extends the reliable municipal water supplies for the higher public health and safety priority needs of the City.

Alternative 1 Potable Water

As discussed previously in this study, at the current levels of total municipal demand, the irrigation of the green areas located throughout the City has not caused water supply

shortages to the domestic and commercial users. As such, continuing the current irrigation practices using treated water can continue, and at times such practices has provided some additional water quality benefits to the municipal distribution system with additional demands for treated water moving through and circulating through the water system to the green areas. To meet fire flow demand requirements, the distribution system piping is a larger diameter than what is needed to meet peak hour demands. The additional diameter means additional storage and a longer residence time for water in the distribution system. The water demand at parks tends to reduce the residence time and provides a water quality benefit.

Alternative 2 River Water

The 2004 MRWRMP report briefly highlighted the potential efficient transfer and use of a portion of the irrigation water rights located on the Monolith Ranch that can be achieved through a change in point of diversion and place of use of those rights to the City parks and other green areas. One added benefit of this strategy would be the addition of water flowing down the Laramie River, along the pathway and the through the City to the new point of diversion. This additional water in the River, some 1 to 2 cfs, would enhance the flows for fish, aesthetics and recreational benefits of the City's citizens. Although only a modest amount, the additional river flows could also provide some increased water quality benefits through dilution.

This alternative, a result of moving the point of diversion of a portion of the Monolith Ranch water rights downstream would result in a better return on the use of these valuable water rights, than seeking an upstream change in point of diversion and change of use for municipal purposes at the WTP, as discussed in the 2004 report.

Alternative 3 Groundwater

This option has many of the same benefits mentioned above, except for the river flows and efficient use of the Monolith Ranch water rights. Using the available non-Casper Aquifer groundwater resources is an excellent use of this underutilized source of water which is not available for other high quality municipal water supply purposes. The use of groundwater also "frees up" the treated water for the higher priority municipal uses at a

lower investment cost. This option can also be implemented incrementally, by drilling new wells at each park or green area as the treated water demands increase and financial resources are available. The City should consider a limited pilot study at Scout Park. The City should entertain a Level II Study and groundwater exploration grant when they feel they have adequate resources to devote to administering a study.

9.7.3 Summary

The preceding two sections presented a quantitative and qualitative evaluation of alternative irrigation water supplies for large City green space.

The quantitative cost evaluation showed that the cost to water large green acreage is essentially the same for irrigation with groundwater and irrigation with potable water. Although irrigation with groundwater was found to be slightly less expensive than irrigation with potable water, WWC's opinion is that the water quality benefits to the distribution system (explained above) are critically important and outweigh any potential cost savings. The concept of irrigation with local groundwater resources should be revisited periodically (5-10 years) to see if feasibility has improved. At some point in time, if municipal water demands continue to increase, it will be wise to irrigate with non-potable sources, but not at this time.

9.8 Dual Systems

The number of cities that are turning to the use of dual systems is increasing in areas of the country where water is in short supply. The only dual system currently operating in Wyoming is located in Cody, WY. The City of Cody is very pleased with their dual system. The residents have separate pipes for potable and non-potable water. The potable water supply feeds the domestic and commercial demand while the non-potable supply feeds the yard faucets. This type of system is different than the irrigation system evaluated for the City since the raw water would only be fed to the green spaces and not to individual residences. There are several cities in Colorado including Windsor, Commerce City, and Eaton that are also turning to complete dual systems.

9.9 Demand Management

Research was performed to determine how the City of Laramie's Drought Strategy (Ord. 1415 § 2, 2003) compared to neighboring cities. The cities that were investigated were Cheyenne, Rawlins, and Ft. Collins, CO. The water shortage plans for each of these cities and the City of Laramie are included in Appendix 9C. When comparing these plans, it was determined that the City of Laramie's Drought Strategy is very similar to Rawlins' strategy, but more lenient than the plans for Cheyenne and Ft. Collins. Both Cheyenne and Ft. Collins have watering restrictions in place before a concern arises. These restrictions consist of a watering schedule for individual homes, and they prohibit watering between the hours of 10:00 am and 6:00 pm. The plans for Laramie and Rawlins do not have any restrictions until a water shortage is suspected.

9.10 Reuse Water

As a mater of completeness, the following information is provided so that opportunities for reuse water are at least considered in future water planning decisions. Reuse water is municipal wastewater that has been treated to required standards for reusing, typically as irrigation water. This information is being provided in the irrigation chapter, because irrigation use is one of the most likely candidates for reuse water.

The requirements for irrigation with reuse water would include a higher degree of effluent treatment at the wastewater treatment plant, and a longer transmission main to bring the water into the City. Therefore, the cost of a reuse project would be more than the cost of concepts using raw water presented earlier in this Chapter. Also, based on observations of the program in Cheyenne, reuse would require pubic education, more involved permitting, additional signs informing people of the reuse water applications. These facts will likely make reuse a more expensive alternative than irrigating with surface or groundwater.

9.10.1 Quantity

Due to the fact that some of the water that enters into the wastewater treatment plant initially came from non-tributary groundwater sources, that water belongs to the City of Laramie and is not subject to priority regulation from the water rights on the Laramie River.

Table 9-6 and Figure 9-3 present actual water and wastewater production data for a few recent years. Also shown is the groundwater portion of the water production total. Table 9-6 presents an estimate of the groundwater contribution to the wastewater plant effluent. This number assumes that the infiltration into the collection system is about 53 gallons per day per capita.

Based on average plant effluent data, there is approximately 1.84 million gallons per day (mgd) of wastewater effluent that originates from groundwater sources and is therefore able to be used by the City. Based on the irrigation requirements for Alternative D, the amount of water needed is 1.38 mgd. Therefore, the effluent quantity from the wastewater treatment plant would be adequate to irrigate the recommended city parks.

9.10.2 Quality

Wyoming Department of Environmental Quality (WDEQ) Chapter 21 provides standards for water reuse. The feasibility of irrigating with reuse water is highly dependent on the water quality.

In the case of irrigating parks, wastewater would have to be treated to Class A standards, requiring a very low fecal coliform limit. Pathogen removal is generally not as difficult a problem as treating what is typically water with high TDS concentrations. Treatment for high TDS is needed for turf management reasons.

The Burns and McDonnell Engineering Company completed an extensive evaluation of the reuse opportunities in Casper in 2002. That effort demonstrated that reuse was not a viable option. The authors of this current study are aware of the current reuse project in Cheyenne. The City of Laramie should investigate both of these projects as time allows.

TABLES AND FIGURES

Table 9-1 Consumptive Irrigation Requirement and Assumed Design Flows

	April	May	June	July	Aug	Sept
CIR	0.1	3.07	4.76	5.13	4.47	2.75
Days	30	31	30	31	31	30

Existing Green Areas	Map Designation	Alternative A All Parks	Alternative B All City Parks	Alternative C Recommended Parks	Alternative D Recommended City Parks	Alternative Groundwater Irrigation	Park Acreage	Estimated Average Irrigation Requirement						Annual Total	Uniform July Rate Based on 9 hr Application	Average Q from Parks and Rec	Round Q for Design
							ac	gpd	gpd	gpd	gpd	gpd	gpd	mg	gpm	gpm	gpm
AMOCO FIELD	1	X	X	X	X	X	30	2,715	80,669	129,245	134,799	117,456	74,669	17	250	no data	250
ARAGON SOCCER/SOFTBALL	2	X	X	X	X	X	12	1,086	32,268	51,698	53,919	46,982	29,868	7	100	115.30	115
COWBOY FIELD	3	X	X	X	X	X	11.4	1,032	30,654	49,113	51,223	44,633	28,374	6	95	158.40	158
DEPOT	4	X	X	X	X	X	2.68	243	7,206	11,546	12,042	10,493	6,670	1	22	88.40	88
GREENHILL CEMETARY	5	X	X	X	X	X	52	4,706	139,826	224,025	233,651	203,590	129,426	29	433	505.60	506
HARBON	6	X	X	X	X	X	2	181	5,378	8,618	8,987	7,830	4,978	1	17	92.00	92
JACOBY GOLF COURSE - EAST ADDITION	7	X		X			50	4,525	134,448	215,409	224,664	195,760	124,449	28	416	no data	416
JACOBY GOLF COURSE - EXISTING	8	X		X			100	9,051	268,896	430,818	449,328	391,520	248,897	55	832	516	832
KIWANIS PARK	9	X	X				8.4	760	22,587	36,189	37,744	32,888	20,907	5	70	111.30	111
LA PELE PARK	10	X	X	X	X	X	29.1	2,634	78,249	125,368	130,755	113,932	72,429	16	242	123.30	242
LABONTE PARK	11	X	X	X	X	X	34.5	3,123	92,769	148,632	155,018	135,074	85,869	19	287	406.00	406
LITTLE LEAGUE EAST AND WEST	12	X	X	X	X	X	13.72	1,242	36,893	59,108	61,648	53,717	34,149	8	114	95.40	114
NORTH 40 AREA	13	X	X	X	X	X	28.5	2,579	76,635	122,783	128,059	111,583	70,936	16	237	no data	237
OPTIMIST PARK	14	X	X	X	X	X	4.8	434	12,907	20,679	21,568	18,793	11,947	3	40	80.90	81
SCOUT PARK	15	X	X	X	X	X	12	1,086	32,268	51,698	53,919	46,982	29,868	7	100	104.50	105
UNDINE PARK	16	X	X	X	X	X	8.93	808	24,012	38,472	40,125	34,963	22,227	5	74	117.70	118
WASHINGTON PARK	17	X	X	X	X	X	13.44	1,216	36,140	57,902	60,390	52,620	33,452	7	112	244.70	245
KIOWA PARK	18	X	X				1.5	136	4,033	6,462	6,740	5,873	3,733	1	12	29.30	29
INTRAMURAL FIELDS	19	X		X			11.2	1,014	30,116	48,252	50,325	43,850	27,876	6	93	no data	93
UNIVERSITY OF WYOMING CAMPUS	20	X		X			90	8,146	242,007	387,736	404,396	352,368	224,007	50	749	no data	749
HIGH SCHOOL	21	X	X	X	X	X	16	1,448	43,023	68,931	71,893	62,643	39,824	9	133	no data	133
JUNIOR HIGH	22	X	X	X	X	X	11	996	29,579	47,390	49,426	43,067	27,379	6	92	no data	92
Proposed Green Areas																	
PARK A	A	X	X	X			8	724	21,512	34,465	35,946	31,322	19,912	4	67	no data	67
PARK B	B	X	X				5	453	13,445	21,541	22,466	19,576	12,445	3	42	no data	42
PARK C	C	X	X				12	1,086	32,268	51,698	53,919	46,982	29,868	7	100	no data	100
PARK D	D	X	X			X	5	453	13,445	21,541	22,466	19,576	12,445	3	42	no data	42
PARK E	E	X	X			X	4	362	10,756	17,233	17,973	15,661	9,956	2	33	no data	33
PARK F	F	X	X			X	6	543	16,134	25,849	26,959	23,491	14,934	3	50	no data	50
PARK G	G	X	X				8	724	21,512	34,465	35,946	31,322	19,912	4	67	no data	67
PARK H	H	X	X				8	724	21,512	34,465	35,946	31,322	19,912	4	67	no data	67
Q for each alternative (GPM)		5,679	3,589	5,139	2,982	3,107											

Table 9-2 Surface Water Irrigation Water Quality

	Sodium Hazard		Salt Hazard		Boron Hazard		Residual Sodium Carbonate Hazard					
Date Sampled	SAR	Class	Conductivity	Class	Boron	Class	Carbonate	Bicarbonate	Calcium	Magnesium	Residual Na_2CO_3*	Class
			µmhos/cm		mg/L		meq/L	meq/L	meq/L	meq/L	meq/L	
7-May-1968	0.5	1	298	2	0.01	1	0.00	1.39	1.55	0.72	-0.87	1
12-Jun-1968	0.6	1	345	2	0.02	1	0.00	1.66	2.00	0.73	-1.08	1
10-Jul-1968	1.3	1	944	3	0.11	1	0.00	2.92	3.60	4.25	-4.93	1
8-Aug-1968	1.5	1	974	3	0.11	1	0.00	2.61	4.20	3.25	-4.84	1
13-Sep-1968	1.3	1	823	3	0.06	1	0.00	2.18	3.30	2.92	-4.04	1
25-Aug-1969	1.1	1	730	2	0.08	1	0.00	2.56	3.60	2.42	-3.46	1
22-Sep-1969	---	---	1,540	3	---	---	0.00	3.13	---	---	---	---
26-Oct-1969	---	---	414	2	---	---	0.00	2.30	---	---	---	---
17-Nov-1969	---	---	423	2	---	---	0.00	1.87	2.30	1.25	-1.68	1
1-Dec-1969	0.6	1	447	2	0.05	1	0.00	2.30	---	---	---	---
5-Feb-1970	0.5	1	405	2	0.03	1	0.00	2.05	2.40	1.08	-1.43	1
27-Feb-1970	0.9	1	602	2	---	---	0.00	2.43	3.20	1.92	-2.69	1
26-Mar-1970	---	---	495	2	---	---	0.00	2.10	2.50	1.50	-1.90	1
23-Apr-1970	0.7	1	478	2	0.03	1	0.00	2.02	2.55	1.50	-2.03	1
28-May-1970	0.6	1	260	2	0.04	1	0.00	1.43	1.45	0.59	-0.62	1
26-Jun-1970	---	---	476	2	---	---	0.00	1.84	2.10	1.50	-1.76	1

--- Data not available

*Residual Na_2CO_3 = (Carbonate + Bicarbonate) - (Calcium + Magnesium)

Sodium Hazard

Class 1: Low Sodium - Good water, that can be used safely on most soils in Wyoming.

Salt Hazard

Class 2: Medium Salinity - Can be used if moderate amount of excess water is applied to provide some leaching. Plants with moderate salt tolerance can be grown without serious yield reduction when normal cropping practices are followed.

Class 3: High Salinity - Can not be used on clay soils or soils with poor drainage. With adequate drainage, considerable excess water should be applied to provide leaching. Irrigations must be more frequent than normal and soil should be maintained relatively wet. Crops with medium or high salt tolerance should be grown to maintain normal yields. This water is not recommended for use under sprinkler application methods unless leaching is practiced.

Boron Hazard

Class 1: Very low, no effect on crops.

Residual Sodium Carbonate Hazard

Class 1: Safe, no augmented alkali over those listed under alkali rating.

For a full explanation of all water classes and the methods used, see the Wyoming Department of Agriculture's "Explanation of Classification System for Irrigation Waters"

Table 9-3: Forelle Limestone Water Quality

Parameter, mg/L	LAPFOR-1 (LaPrele Park)	Warren Spring (T16N, R73W, Sec. 3)	University Wells (2) in Forelle Ls.
Calcium	231	258	
Magnesium	65	53	
Sodium	8.9	9	
Potassium	2.2	2	
Bicarbonate	180	184	
Carbonate	0	0	
Sulfate	660	747	
Chloride	10	15	
Nitrate, as N	1.1	5.0	
Total Dissolved Solids	1130	1270	1200*
Conductivity, umhos/cm	1340	1500	
pH	7.8	7.94	
Sodium Adsorption Ratio	0.13 (low)	0.13 (low)	
Residual Sodium Carbonate	0	0	
Alkalinity Hazard	low (Class 1)	low (Class 1)	
Salinity Hazard	high (Class 3)	high (Class 3)	
Irrigation Water Classification	C3/S1	C3/S1	

*: per. com., Frosty Selmer, UW Facilities Manager

Table 9-4: Data from Wells Completed in Forelle Limestone, Vicinity of Laramie

Well Name	Well Owner	Well Permit #	T, R, Sec., 1/4	Completion Date	Permitted Yield, gpm	Total Depth	Ground Elev.	Head Elev.
					gpm	ft.	ft amsl	ft amsl
University Well #1	Univ. Wyoming	U.W. 494	16, 73, 34, SW	1939	400	360	7207	---
West Campus #1	Univ. Wyoming	U.W. 144293	16, 73, 33, SE	2003	200	400	7203	7226
LAPFOR - 1	City of Laramie	U.W. 99777	15, 73, 3, NE	1995	0	75	7216	7218

Table 9-5 Financial Comparison of Irrigation Alternatives

	Alternative #1 Potable Water	Alternative #2 River Water	Alternative #3 Groundwater
Total Capital Cost	**$4,050,000**	**$14,000,000**	**$7,600,000**
Cost Covered by Grants	$2,025,000	$9,380,000	$5,092,000
Capital Investment (per year)	$129,000	$293,500	$159,400
Power to Pump (per year)	$61,900	$45,500	$41,800
O&M for Pumps (per year)	$0	$6,650	$6,650
Labor (per year)	$0	$15,600	$15,600
Treatment Costs (power and chemicals) (per year)	$34,600	$0	$0
With Grants and Loans	**$225,500**	**$361,300**	**$223,500**
Cost per Acre of Irrigated Green Space	**$800**	**$1,281**	**$752**

Notes:

- It was assumed for both the River Water and the Groundwater alternatives that the City would receive a WWDC Grant which would cover 67% of the capital investment.
- For the Potable Water alternative, it was assumed that the City would receive a WSLIB Grant which would cover 50% of the capital investment.
- For all three scenarios, we assumed that the remainder of the capital investment would be covered by an SRF Loan, which offers a 2.5% interest rate for 20 years. Ignored loan origination fee.

Table 9-6 Water and Wastewater Production and Groundwater Return Flow Estimates

Infiltration /Total Eff = 0.33

Data From City

Day	Month	Ave. WWTP Effluent mgd	Water Production, MG SS Soldier	PS Pope	CS City	WP Wplant	SW Spur	Total Water Prod. MG	Total Water Prod. AC-FT	Groundwater Use MG	Groundwater Use AC-FT	WWTP Effluent MG	WWTP Effluent AC-FT	EFF/TOT Ratio	GW/TOT Ratio	GW Return Flow Est MG	GW Return Flow Est AC-ft
31	Mar-03	4.94	54.64	0.51	6.70	50.01	0.99	113	346	63	193	153	470	1.36	0.41	42	129
30	Apr-03	5.38	55.42	0.53	6.77	44.70	0.94	108	333	64	195	161	495	1.49	0.39	43	131
31	May-03	5.13	56.00	0.55	24.01	58.82	1.99	141	434	83	253	159	488	1.12	0.52	55	170
30	Jun-03	5.39	55.34	0.57	22.00	111.38	0.17	189	581	78	240	162	496	0.85	0.48	52	161
31	Jul-03	3.9	54.52	1.21	77.45	169.63	19.22	322	988	152	468	121	371	0.38	1.26	102	313
31	Aug-03	3.71	48.62	48.58	38.07	137.51	16.50	289	888	152	466	115	353	0.40	1.32	102	312
30	Sep-03	4.05	50.15	4.05	27.45	96.41	0.96	179	549	83	254	122	373	0.68	0.68	55	170
31	Oct-03	4.12	53.39	0.00	20.12	62.17	5.34	141	433	79	242	128	392	0.91	0.62	53	162
30	Nov-03	3.98	55.08	0.01	5.46	52.29	0.14	113	347	61	186	119	366	1.06	0.51	41	125
31	Dec-03	3.76	55.75	1.41	4.55	39.12	1.40	102	314	63	194	117	358	1.14	0.54	42	130
31	Jan-04	4.11	56.74	0.00	11.85	37.71	2.15	108	333	71	217	127	391	1.17	0.56	47	145
28	Feb-04	4.45	56.81	0.00	20.48	40.45	1.36	119	366	79	241	125	382	1.05	0.63	53	162
31	Mar-04	4.89	57.24	0.00	23.33	41.11	0.11	122	374	81	248	152	465	1.24	0.53	54	166
30	Apr-04	5.13	57.80	0.00	18.38	54.98	0.94	132	405	77	237	154	472	1.17	0.50	52	159
31	May-04	5.11	56.89	0.00	30.91	116.97	0.60	205	630	88	271	158	486	0.77	0.56	59	182
30	Jun-04	4.56	54.88	0.00	36.99	138.85	0.18	231	709	92	282	137	420	0.59	0.67	62	189
31	Jul-04	4.52	55.07	0.00	31.65	141.80	2.27	231	708	89	273	140	430	0.61	0.64	60	183
31	Aug-04	4.46	53.28	5.31	35.20	130.83	0.97	226	692	95	291	138	424	0.61	0.69	63	195
30	Sep-04	5.18	54.12	0.00	24.96	90.57	1.20	171	524	80	246	155	477	0.91	0.52	54	165
31	Oct-04	5.33	54.39	15.05	15.31	52.06	0.61	137	422	85	262	165	507	1.20	0.52	57	176
30	Nov-04	4.19	54.81	0.00	11.67	43.02	0.16	110	337	67	205	126	386	1.15	0.53	45	137
31	Dec-04	4.11	55.00	0.00	11.07	43.74	0.50	110	339	67	204	127	391	1.16	0.52	45	137
31	Jan-05	4.75	54.99	0.00	22.76	43.05	0.45	121	372	78	240	147	452	1.21	0.53	52	161
28	Feb-05	4.37	54.98	0.00	14.41	41.89	3.28	115	352	73	223	122	376	1.07	0.59	49	149
31	Mar-05	4.65	54.61	0.00	7.85	43.76	0.13	106	326	63	192	144	442	1.36	0.43	42	129
30	Apr-05	5.6	54.73	0.00	24.78	46.84	0.14	126	388	80	244	168	516	1.33	0.47	53	164
31	May-05	6.41	54.49	0.00	31.54	79.02	1.55	167	511	88	269	199	610	1.19	0.44	59	180
30	Jun-05	5.43	53.88	0.69	26.08	113.22	4.43	198	609	85	261	163	500	0.82	0.52	57	175
31	Jul-05	4.45	48.67	19.73	37.14	149.72	28.06	283	870	134	410	138	423	0.49	0.97	90	275
31	Aug-05	4.4	52.65	0.01	35.33	122.94	11.43	222	682	99	305	136	419	0.61	0.73	67	204
30	Sep-05	4.48	50.38	0.00	43.75	113.12	13.88	221	679	108	331	134	412	0.61	0.80	72	222
31	Oct-05	4.47	54.09	0.02	16.83	55.00	0.20	126	387	71	218	139	425	1.10	0.51	48	146
30	Nov-05	4	53.37	0.00	15.33	38.82	0.19	108	331	69	211	120	368	1.11	0.57	46	142
31	Dec-05	3.95	55.20	0.00	4.48	45.32	0.14	105	323	60	184	122	376	1.16	0.49	40	123
	TOTALS		1848	98	785	2647	123	5500	16881	2853	8757	4794	14714			1912	
	Average	4.63														56	173
																1.84	Average MGD/month

Note: Per 86 HDR Study, infiltration estimate is 53 gpcd. At 27,000 people this is about 1.51 million gallons/day, which is about 1/3 of the average effluent

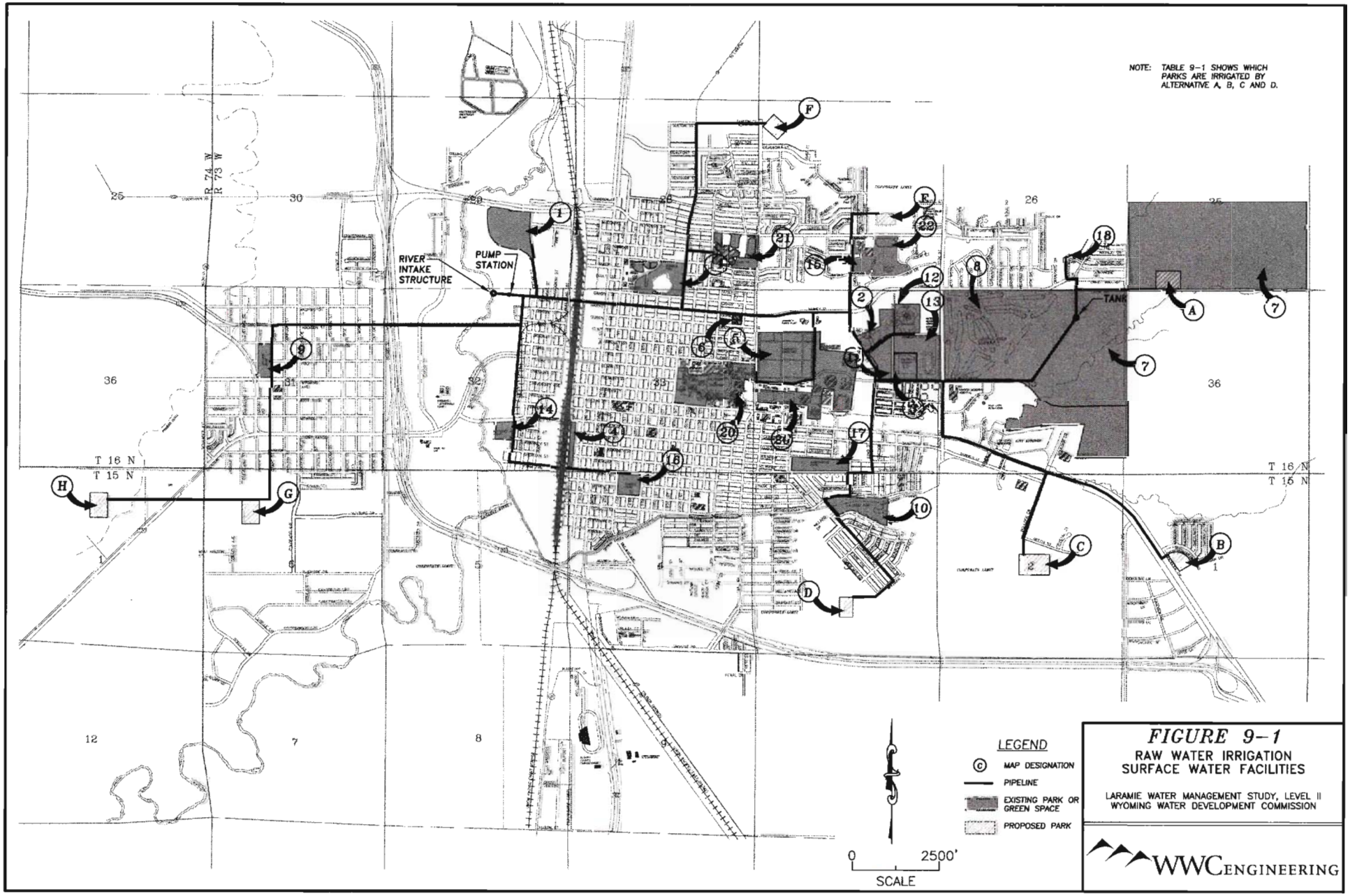

FIGURE 9-1
RAW WATER IRRIGATION SURFACE WATER FACILITIES

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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Estimated Drilling Depths for Wells Completed in the Forelle Limestone at City Green Spaces.

Existing Green Area	Map ID	Approximate Ground Elevation, ft.	Estimated Elevation Top of Forelle Ls., ft.	Estimated Drilling Depth* ft.	Comments
Amoco Field	1	7133	6320	854	
Aragon Soccer/Softball	2	7240	7050	231	
Cowboy Field	3	7245	7170	116	
Depot Park	4	7154	6490	705	
Greenhill Cemetery	5	7210	6930	321	
Harbon Park	6	7180	6770	451	
Jacoby Golf Course - East Add.	7				No Forelle Ls.
Jacoby Golf Course - Existing	8	7274	7130	185	
Kiwanis Park	9	7160			Too far west; too deep
La Preie Park	10	7216	7152	105	Forelle Ls. well at east end of park
LaBonte Park	11	7147	6650	538	
Little League East and West	12	7250	7100	191	
North 40 Area	13	7250	7170	121	
Optimist Park	14	7137	6360	818	
Scout Park	15	7200	7020	221	
Undine Park	16	7160	6630	571	
Washington Park	17	7195	7050	186	
Kiowa Park	18	7330			On Forelle Ls. outcrop, unsaturated
Intramural Fields	19	7240	7080	201	
University of Wyoming Campus	20				Univ. campus has Forelle Ls. wells
High School	21	7190	6770	461	
Junior High School	22	7210	7000	251	
Proposed Green Areas					
Park A	A	7370			No Forelle Ls.
Park B	B	7385			No Forelle Ls.
Park C	C	7320			On Forelle Ls. outcrop, unsaturated
Park D	D	7220	7000	261	
Park E	E	7210	6950	301	
Park F	F	7210	6670	581	
Park G	G				Too far west; too deep
Park H	H				Too far west; too deep

* Drilling depths based on a well located at the east edge of a green area, Forelle Limestone thickness of 16 feet, and penetration of 25 feet of underlying Satanka Shale.

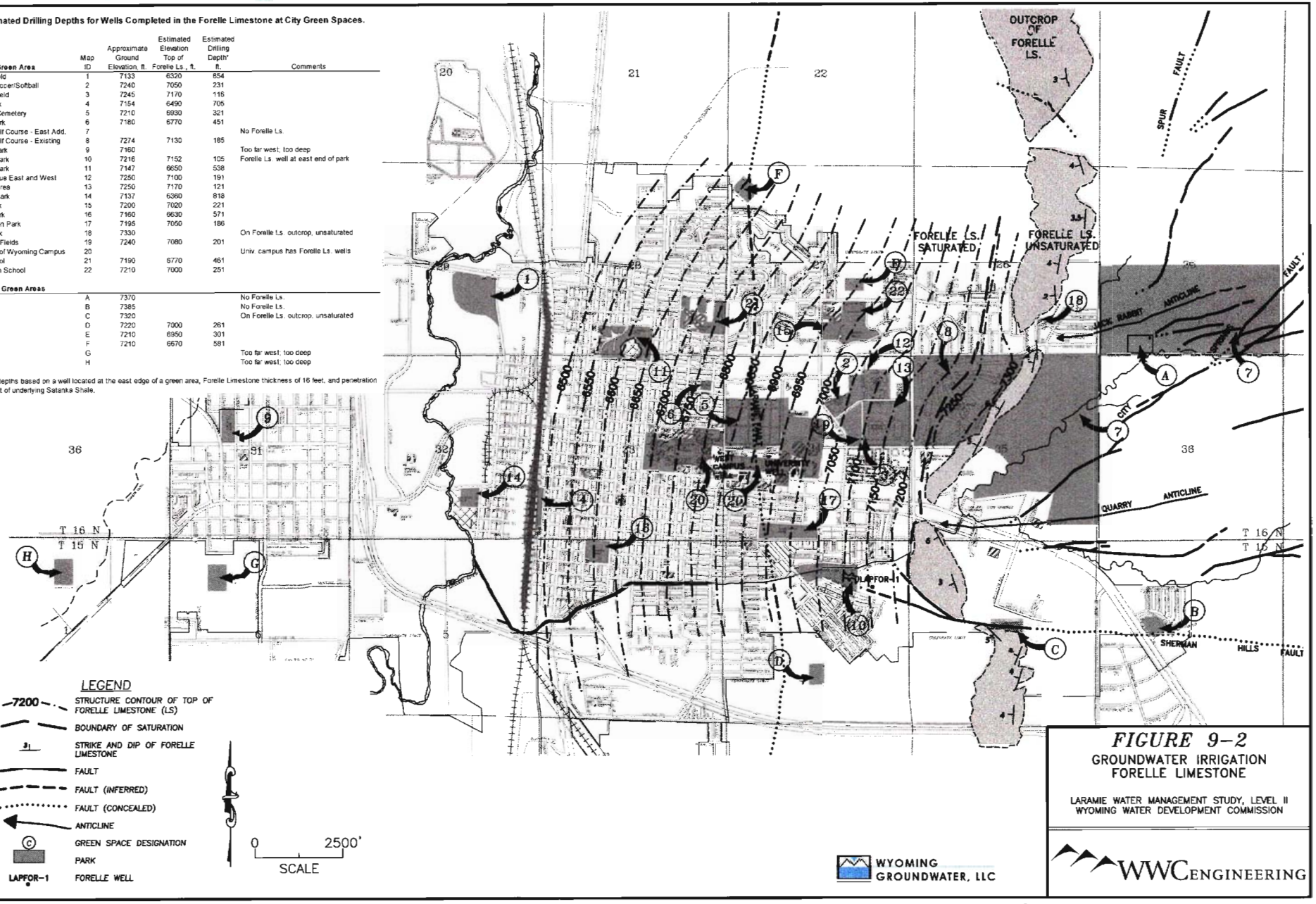

FIGURE 9-2

GROUNDWATER IRRIGATION FORELLE LIMESTONE

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

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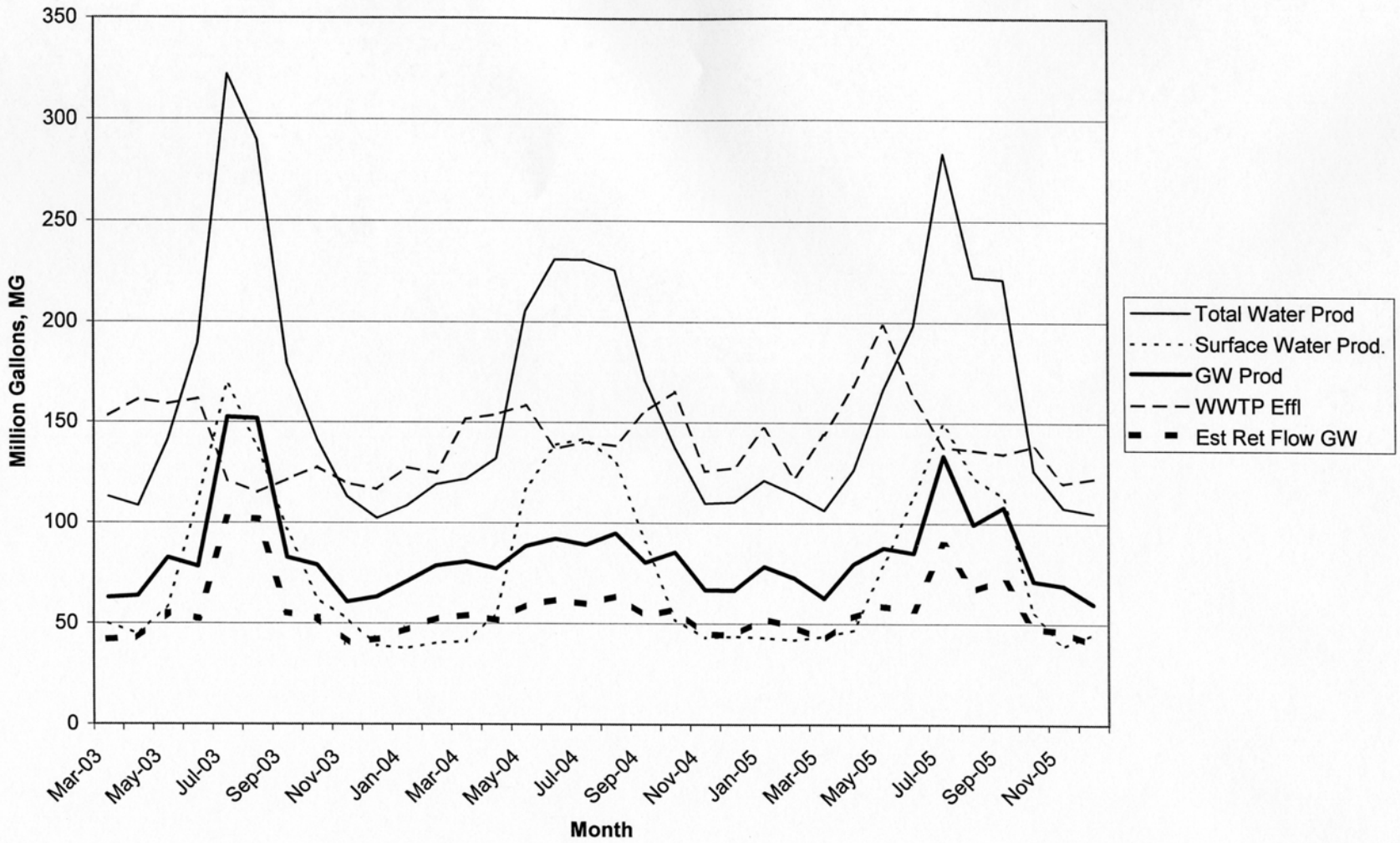
Figure 9-3 Water and WastewaterProduction, and GW Return Flow Estimates



CHAPTER 10.0
DEVELOPMENT AND MANAGEMENT OF THE CASPER AQUIFER

10.0 DEVELOPMENT AND MANAGEMENT OF THE CASPER AQUIFER

10.1 Objective

The Casper Aquifer is the keystone to the City's water supply by virtue of its reservoir capacity and ability to contribute to both peak and base demands. Since 1983, the City wellfields have extracted an annual average of 3.8 million gallons per day (mgd) while local county users (e.g, domestic, stock, and industrial) presently extract an estimated 1.8 mgd. Judicious future development of the Casper Aquifer will require an understanding of resource characteristics and the aquifers' response to use. The City must take full advantage of existing water rights at each wellfield while pursuing further development of the Casper Aquifer as dictated by supply/demand economics and the aquifers' response to use.

This chapter is divided into five topics that provide a comprehensive description of the Casper Aquifer, potential for future aquifer development, and recent efforts in aquifer monitoring and protection.

- Overview of the hydrogeology and condition of the Casper Aquifer
- Hydrologic conditions and issues at the Turner, Spur, and Pope-Soldier wellfields
- Casper Aquifer storage and recovery opportunities
- Casper Aquifer development potential and prospects
- Casper Aquifer monitoring and protection

10.2 Hydrogeology of the Casper Aquifer

There is an enormous body of work dating back to 1937 regarding the hydrogeology of the Casper Aquifer. A bibliography of Casper Aquifer studies is provided in Appendix 10-A. The Casper Aquifer Protection Plan (2002) provides a comprehensive description of the aquifer. Recent City/WWDC funded studies from 1993 to 1997 dealing with groundwater development at City Springs, Soldier Springs, and the Spur have enhanced our understanding of the aquifer. On-going field research on the Casper Aquifer from 2003 to 2007 by University of Wyoming PhD candidate Mr. Karl Taboga will provide insight into aquifer recharge and hydrodynamics, and will form an

extensive database for future aquifer monitoring and analysis. Appendix 10-B provides a summary of preliminary results and future aquifer evaluation efforts associated with Mr. Taboga's research. The following discussion summarizes basic hydrogeology and results from recent studies related to the development, management, and protection of the Casper Aquifer.

Plate 10-1 consists of a geologic map, hydrostratigraphic column, and schematic cross-section that allow the reader to visualize the spatial geometry and hydrologic relationships between the various rock units. The location of City wellfields, municipal production wells, monitoring wells, faults/folds, springs, and groundwater development features are also shown.

The Casper Aquifer is comprised of water saturated portions of the Casper Formation that consists of approximately 700 feet of interbedded sandstone, limestone, and minor siltstone and shale. In the vicinity of Laramie, sandstones comprise approximately 85% of the total thickness of the Casper Formation with limestones comprising most of the remainder. From Laramie, sandstone percentages increase to the south and decrease to the north and west. Sandstone layers bounded above by a regionally continuous limestone was informally subdivided by Lundy (1978) into five members; designated from top to bottom of the Casper Formation as the epsilon, delta, gamma, beta, and alpha (Plate 10-1). Water is stored and transmitted primarily in the sandstones whereas the relatively impermeable limestones serve as aquitards between the sandstones. In many places, however, vertical fractures associated with faults and folds have cut through the limestones and have hydraulically integrated the sandstones in each member.

East of Laramie, the Casper Formation is exposed on the entire west slope of the Laramie Range. The Casper Formation strikes north-south and dips 3-5 degrees to the west. As the Casper Formation dips westward into the Laramie Basin, the formation is overlain by younger rock consisting of, in ascending order from the top of the Casper Formation, the Satanka Shale, Forelle Limestone, and Chugwater Formation (Plate 10-1) that are collectively referred to as the Redbed formations. On the west slope of the Laramie Range, only the lower portion of the Casper Formation is saturated and the aquifer is characterized by a combination of confined, semi-confined, and unconfined

conditions. West of the Casper-Satanka contact, the entire thickness of the Casper Formation is saturated and the aquifer is confined above by the Satanka Shale. A short distance west of the Casper-Satanka contact, wells completed in the Casper Aquifer are flowing.

Groundwater in the Casper Aquifer flows from east to west with primary points of aquifer discharge at range-front springs (e.g., from north to south: City Springs, Soldier Springs, and Simpson Springs) located at or a short distance west of the Casper-Satanka formation contact. The head in the Casper Aquifer is greater than the head in overlying Redbed formations, and consequently, water from the Casper Aquifer will flow vertically upward into the Redbed formations. Vertical flow from the Casper Aquifer into overlying Redbed formations is likely to occur primarily where the confining ability of the Satanka Shale, Forelle Limestone, and Chugwater Formation is compromised by vertical faults and fractures.

The Casper Aquifer has complex water storage and transmission characteristics because of the presence of both intergranular and fractured permeability/porosity (i.e., a dual porosity media). The intrinsic permeability of limestone matrix is very poor while the intrinsic intergranular permeability of sandstone matrix is variable, with the epsilon sandstone having the largest intrinsic permeability and the alpha sandstone having the smallest. Production from water wells that rely only on the intrinsic permeability of sandstone and limestone is generally 5 to 50 gpm with substantial drawdown during pumping. The average porosity for the epsilon sandstone is approximately 24% (Davis, 1976). The lower-most alpha member sandstone probably has a lower porosity value. The intergranular porosity of Casper Formation sandstones serve to store enormous quantities of water.

Superimposed on the intrinsic permeability of sandstone and limestone is fracture permeability associated with faults and folds created by compressional and extensional forces that occurred during the Laramide Orogeny that uplifted the Laramie Range. Fractures can transmit tremendous quantities of water as demonstrated by municipal well production in fracture zones on the order of 1,000 to 2,000 gpm with 4 to 40 feet of drawdown (Table 10-1). Observations during drilling and downhole camera surveys at the Spur No. 1, Spur No. 2, Turner No. 2, and Soldier No. 1 wells indicate the importance

of horizontal bedding plane fractures in the sandstone immediately above/below the sandstone/ limestone contacts in the epsilon, delta, and gamma members. Slippage along the interface of contrasting lithology during deformation events may have created discrete horizontal zones of fractured sandstone. Vertical fractures play an important role in the hydraulic integration of the members and create local zones of high permeability.

As shown on Plate 10-1, the surface exposure of the Casper Formation is populated by numerous faults, folds, and monoclines. Additional detail on mapped faults and folds is available on the geologic maps of the Red Buttes, Howell, and Laramie Quadrangles (Ver Ploeg, 1995, 1996, and 1998). Many of these structural features originate from high angle Laramide-age faults in the Precambrian basement (e.g., Sherman Granite). As basement faults propagate upward into the Casper Formation, the brittle carbonates fracture whereas the thicker clastic sandstones will tend to fracture and deform. Anticlines and monoclines with large structural offsets, such as the Spur and Pilot Hill, are usually cored by reverse faults in the brittle crystalline basement rocks (Huntoon and Lundy, 1979a). Reverse faults are usually offset and terminated by major normal faults that extend laterally from Precambrian outcrops into the Casper Formation where the faults are exposed on the surface. The Jackrabbit, Red Buttes, and Telephone Canyon faults originate as normal faults in the Sherman Granite. Ver Ploeg (1995) has documented right-lateral strike-slip motion on the north-south trending Red Buttes and Red Hills faults.

The occurrence of the major range front springs and the large production characteristics at the municipal wellfields are likely related to a particular fault, fold, or fault/fold system.

10.2.1 Casper Aquifer Recharge

Recharge is the process by which water is added to the subsurface zone of saturation. The Casper Aquifer is recharged primarily by the infiltration of precipitation (rainfall and snow melt) through the porous sandstones exposed on the west slope of the Laramie Range. Isotopic research indicates that the Casper Aquifer may also be recharged from below by fractures in the Sherman Granite (Toner, 2000). The dynamics

and timing of Casper Aquifer recharge will be illustrated by a discussion of the following topics.

- Field observations
- Well hydrographs
- Recent pump test near Simpson Springs
- Precipitation

10.2.1.1 Field Observations

The infiltration of surface water from rainfall and snow melt into Casper Formation sandstones is quite remarkable as observed by Beckwith (1937) and Lundy (1978). For example, following a spring snow storm, Beckwith observed 3 to 4 cubic feet per second of stream flow infiltrate into sandstones over the course of a few hundred feet. Lundy also observed the rapid infiltration of overland flow into sandstone exposures during a rain storm. During recent field work, Karl Taboga has observed the rapid infiltration of overland flow from snow melt into sandstones exposed in upland drainages. The ability of exposed sandstones to absorb surface water is illustrated by the fact that surface water rarely flows out of the drainages that dissect the west slope of the range. The exposed limestones shed and/or pond water unless highly fractured.

10.2.1.2 Well Hydrographs

The most direct evidence of the occurrence and timing of aquifer recharge is the rise of water levels in wells. From September 2003 through 2006 on a monthly basis, Karl Taboga has monitored approximately 50 water wells on the west slope of the Laramie Range (Plate 10-1). Hydrographs for these monitoring wells are presented in Appendix 10-C. Upland wells located at the higher elevation of the Laramie Range – Frenchy, Government, Klein, Powerline, and Nichols - experienced a pronounced water level rise of 5 to 17 feet following the melt-off of a snow storm in April 2005. The upland wells are located in areas where snowpack is greatest and persistent, and during snowmelt periods the water level in these wells rise. Consequently, head increases (water level rise in wells)

most likely represents an increase in saturated thickness rather than a downgradient pressure pulse. Head increases in the upland wells occur on the order of days to weeks following the precipitation event which illustrates that water can flow rapidly through the unsaturated zone. A rainfall event in September 2004 produced a water level rise of approximately 1 foot in these upland wells. The hydrograph of the Government Well, documents measurable head increases caused by snow melt events in March 2004, late September 2004, April 2005, and April 2006 (Appendix 10-C)

Recharge of the Casper Aquifer from major late-winter/early spring precipitation events is clearly documented in the Huntoon No. 1 and Huntoon No. 2 monitoring wells located in the Sherman Hill Estates and Valley View residential subdivisions, respectively (Plate 10-1). These wells have been used exclusively for water level monitoring since 1977-78 and are part of a statewide groundwater monitoring well network administered by the State Engineers Office and the USGS. Hydrographs for the Huntoon No. 1 and Huntoon No. 2 wells are shown on Figure 10-1 and Figure 10-2, respectively. In 1983, the head in the Casper Aquifer at these wells increased 22 to 25 feet in response to above-average precipitation (snow) in March and April (Figure 10-3). Water levels in the Huntoon monitoring wells peaked in late-1984, and from 1984 to 1994 water levels declined gradually to pre-1983 levels. The 1983 recharge event caused noticeable head increases throughout the Casper Aquifer along the west slope of the Laramie Range as evidenced by above-average discharge at City Springs, Soldier Springs, upland springs, and high water levels in the Pope wells from 1983 to 1990 (WWC, 1996a).

10.2.1.3 Pump Test at the Brow #2 Well

In October-November 2005, a 30-day pump test was conducted at the Brow #2 well located 0.6 miles southeast of Simpson Springs (CBMA, 2006). The test provided a unique opportunity to observe the rapid infiltration of surface water through the unsaturated zone and into saturated sandstone of the Casper Aquifer. The Brow #2 well is spudded on the delta member and has a depth to

water of 68 feet. Water from Brow #2 was discharged to the ground surface approximately 600 feet west of the well which corresponds to the west edge of the delta member exposure. Approximately 1,200 minutes (0.83 days) into the pump test, the rate of drawdown in Brow #2 declined and was followed by a brief rise in water level. Apparently, in less than a day, pump test water discharged to the ground surface had infiltrated through approximately 50 feet of unsaturated material and was recycling through the aquifer to the Brow #2 well.

10.2.1.4 Precipitation

As first introduced by Huntoon and Lundy (1979b), described in detail by WWC (1996a), and supported by Karl Taboga's on-going research, aquifer recharge responds to the timing of a precipitation event more than the amount of annual precipitation. Snowfall is the most important form of precipitation for recharging the Casper Aquifer. As stated by Huntoon and Lundy (1979b), "*Most recharge to the Casper Aquifer occurs in March and April when monthly precipitation is above average and the ground has thawed. Recharge rates are negligible in the fall and winter due to frozen ground conditions.*" Rainfall in the summer does not appear to provide an appreciable amount of recharge to the Casper Aquifer. Summer rainfall flows quickly down the drainages and evapotranspiration by vegetation is at maximum. Precipitation stored and applied to the ground surface as a slowly melting snowpack during the diurnal freeze-thaw period of March-April appears to be the most effective mechanism for aquifer recharge.

This concept of recharge timing should be the basis for evaluating annual aquifer recharge potential. As shown on Figure 10-3, below-average combined March and April precipitation has occurred from 1991 to 2005. The identification of an "aquifer drought" should be defined and considered in different terms than a drought defined by annual precipitation and surface water.

10.2.1.5 Aquifer Recharge Dynamics

The Casper Aquifer is a responsive hydrogeologic system due to the mountain flank exposure of porous sandstones with superimposed fracture permeability from bedding planes, faults, folds, and monoclines. In the upland recharge area, water infiltrates through the unsaturated zone days to weeks after the occurrence of snow melt in March and April. Above-average snowfall in March and April can cause rapid and long-term head increases as demonstrated in the Huntoon monitoring wells after the 1983 recharge event. Recharge events can quickly reverse gradual head declines that occur during extended periods of average or below-average recharge. Research and water chemistry analysis by Karl Taboga over the next 2 years will further refine the amount, distribution, and mechanics of recharge to the Casper Aquifer (Appendix 10-B).

10.2.2 Hydraulic Role of Geologic Structures

Faults in fractured aquifers can function as hydraulic conduits (Huntoon and Lundy, 1979a), barriers, or both (Caine et al., 1996). Pump tests conducted at the Spur, Turner, Pope, and Soldier municipal wells, and a salt tracer test at Turner No. 1 (WWC, 1997a; WWC, 1996a; WWC, 1995; and WWC, 1993) confirm the highly permeable and conduit-like character of the Casper Aquifer at locations near mapped faults and folds. In the vicinity of Laramie, faults are likely to redirect the general east to west flow of groundwater to a flow direction along the strike of the fault (Huntoon and Lundy, 1979a). Faults can also provide pathways for vertical circulation within and between formations that possess significant matrix permeabilities (Huntoon and Lundy, 1979a; Younus, 1992).

As discussed in Appendix 10-B, preliminary data indicate that well hydrograph behavior is strongly dependent on the spatial position of a well to mapped geologic structure. At fault associated wells, head increases caused by recharge events tend to be of lower magnitude (e.g., < 1.5 feet) relative to upland wells. Fault associated wells tend to exhibit low slope declines during dry periods; and corresponding gradual head increases during recharge periods. For example, Peanut, a fault associated well located on the Red Hills Fault, shows a steady linear head decline during 2004 when snow pack

was low, then increases moderately in response to snowmelt in the spring of 2005 and to a late spring snowstorm in June 2005. In addition, head elevations are depressed in fault associated wells.

Preliminary analyses of the data strongly suggest that faults intercept and redirect groundwater flow. The potentiometric surface along strike of the City Spring Fault shows a markedly lower rate of decrease in head elevation relative to the change in the topographical surface. This relationship suggests that City Springs Fault is highly transmissive throughout its length and not just at its southwest end in the vicinity of the Turner Wellfield. The conduit structure associated with the highly productive municipal wells appears to be extensive. Taboga's on-going examination of fault system hydraulics will be useful to explain the observed temporal and spatial variations in the well hydrographs and to define how faults distribute groundwater in the Casper Aquifer.

10.3 Present-Day Hydrologic Conditions in the Casper Aquifer

Hydrologic conditions in the Casper Aquifer are evaluated by potentiometric surface maps that provide a "snapshot" of aquifer head over a large area, and by time-series head data at an individual well (i.e., well hydrograph). Extensive water level data collected by Taboga and the long history of data collection at the Huntoon monitoring wells provides an opportunity to evaluate the hydraulic health of the Casper Aquifer.

As shown on Figures 10-1 and 10-2, the recovered (i.e., winter-time) water levels in the Huntoon monitoring wells in 2005 are similar to water levels recorded in these wells during 1977 to 1982 which is prior to the 1983 recharge event and prior to the development of the Turner Wellfield. At the Huntoon monitoring wells, the head in the Casper Aquifer appears to be typical of long-term, pre-wellfield development values.

The well hydrographs presented in Appendix 10-C document head fluctuations in the Casper Aquifer from September 2003 to July 2006. As discussed previously, hydrograph behavior is a function of location relative to geologic structures and stratigraphic/topographic position. Some wells show very little to no cumulative head decline during this time period (e.g., Harris #1, Working, Unreg. Piper, Frenchy, Government, Peanut, and Colter) while a few wells (e.g., MacLean and Swiatek) experienced 6 to 9 feet of head decline. In general, it appears that during September 2003

to March 2006 the head in the Casper Aquifer has declined approximately 2 feet (e.g., Pruner, Kassahn, Klein, Peter, Spur 9, Spur 10, West, and Powerline) and is similar to the head decline observed at the Huntoon wells during the same period. These relatively minor head declines may be related to the below-average March-April precipitation since 1991 (Figure 10-3).

Plate 10-2 is a potentiometric surface map of the Casper Aquifer for November 2005. Data collection efforts focused on the west flank of the Laramie Range and do not include head distributions further to the west. The potentiometric surface illustrates the following characteristics of groundwater flow in the Casper Aquifer:

- east to west groundwater flow;
- complex head distribution in area of Spur Ridge and the Spur Anticline; and
- flattening of the hydraulic gradient west of the range front and in the area east and north of City Springs.

The 2005 potentiometric surface map includes 25 monitoring wells used by Lundy (1978) to generate the 1976 potentiometric surface map. Table 10-2 lists head values from these two comprehensive water level surveys in 1976 and 2005. Head differences at these common wells from 1976 and 2005 range from +6.0 to -8.6 feet, and the average difference is -1.5 feet. Hydraulic conditions in 1976 are presumed to be representative of typical conditions in the Casper Aquifer because the Pope Wellfield was the only wellfield in existence at that time and the March-April precipitation prior to 1976 appears to be normal. Regional head values in the Casper Aquifer in 2005 are not substantially different than head values measured in 1976 which is also in agreement with head values at the Huntoon monitoring wells.

In summary, hydrographs and 1976/2005 head differences indicate that recent head values in the Casper Aquifer in the vicinity of Laramie are within the range of typical values and there is no apparent evidence that the Casper Aquifer is being depleted by over-pumping.

10.4 Turner Wellfield (City Springs)

There are four issues at the Turner Wellfield that will be discussed in this section:

- Beneficial development of the water right and discharge at City Springs;
- Evaluation of wellfield performance;
- Potential for wellfield interference as a result of proposed groundwater development; and
- Water quality and aquifer protection.

A brief overview of the history and hydrogeology of City Springs and the development of the Turner Wellfield will facilitate a discussion of these issues. Figure 10-4 shows the historic discharge location of City Springs, water storage facilities, and the Turner wells. From 1868 to 1982, the artesian discharge from City Springs was collected and treated for municipal use. In the early 1900's, discharge from the spring was conveyed directly to the old 4 MG reservoir. A shallow collection pipe and springbox system was installed that intercepts discharge in the subsurface prior to surface discharge. In 1982, the Turner wells were installed to intercept groundwater before it seeped into the springbox collection system and to allow groundwater extraction during both low and high demand periods. Detailed completion data for the Turner wells are listed in Table 10-3.

The Turner No. 1 well is located approximately 1,500 feet southwest of City Springs and has a permitted groundwater right of 2,500 gpm for instantaneous production. The Turner No. 2 well is located approximately 850 feet west of City Springs and has a permitted groundwater right of 1,600 gpm instantaneous production. In 1991, the City's surface water right from City Springs of 1.75 mgd (1,215 gpm) was transferred to the Turner No. 2 well (i.e. change in the point of diversion). Table 2-5 provides a summary of these water rights.

From 1915 to 1944, documented discharge from City Springs varied from 1.6 to 1.8 mgd (Banner, 1976). For the 15 year period prior to installation of the Turner wells (1967 – 1981), City production records indicate that the mean artesian discharge rate from City Springs was 1.64 mgd (WWC, 1996a). Since full-time operation of the Turner Wellfield began in 1983, the annual production rate from the Turner wells has varied

from 0.64 to 1.97 mgd with an average annual production rate of 1.17 mgd (Figure 10-5). In only 4 of the last 23 years have the Turner wells produced groundwater at a rate that equaled or exceeded the natural historic discharge of City Springs of 1.64 mgd.

Groundwater flow in the Casper Aquifer converges at City Springs primarily because this location is the lowest elevation (7,270 feet) of the surface exposure of the top of the Casper Formation (i.e., epsilon member). West of City Springs, the Casper Formation is fully saturated and confined by the overlying Satanka Shale. City Springs is an area of enhanced aquifer permeability due to vertical and horizontal fractures associated with deformation of the Casper Formation along the City Springs Fault, Spur Fault, Quarry Fault, and Quarry Anticline all of which converge upon the City Springs area.

In March 2004, the City pulled the pump out of Turner No. 2 to facilitate pump repair and allow a downhole camera inspection of the well. Turner No. 2 has 16-inch diameter steel casing from 0 to 100 feet and 12-inch diameter open hole from 100 to 350 feet. The downhole camera inspection showed that the casing was in good condition and the open hole had maintained excellent integrity after 22 years of service. There were no observable "skin effects" (e.g., mineral precipitation or bio-fouling) that can reduce well performance. Based on these observations, rehabilitation of Turner No. 2 was not deemed necessary. To maximize well operation, the pump intake was lowered 4 feet to a set depth of 96 feet. The downhole camera also revealed large horizontal openings and fractures in Casper Formation sandstones that lie immediately above and below limestone interbeds. It is reasonable to believe that groundwater production from Turner No. 2 is derived primarily from the cracks, fractures, and bedding plane openings in sandstones, especially from the zone at 146 to 150 feet.

10.4.1 Capture of City Springs Discharge by the Turner Wells

Natural discharge from City Springs is captured by a clay pipe and springbox system buried approximately 4-5 feet into the Satanka Shale throughout the City Springs area. Groundwater captured by the springbox system is discharged from an outlet pipe directly into Spring Creek on the east side of the 8 MG covered reservoir (Figure 10-4). The springbox system keeps the City Springs area dry, and has been an effective means

of capturing groundwater before discharging to the surface. When the hydraulics of the springbox system is altered, as occurred in December 2005 when a flowmeter was installed on the outlet pipe, groundwater will discharge to the surface at the original location of City Spring.

When operating, the Turner wells are capable of capturing all of the natural discharge at City Springs such that the head in the Casper Aquifer is lowered below the level of the buried pipe in the springbox system. Turner No. 2 is located west of the spring and is capable of eliminating flow from the springbox outlet pipe after 3 to 4 days of pumping at a rate of 1,400 gpm. When both the Turner No. 1 and No. 2 wells are operating at a total withdrawal rate of 3,300 to 4,100 gpm, flow from the springbox outlet pipe will cease in 1 to 2 days following the commencement of simultaneous pumping. When the Turner wells are shut-off, the head in the Casper Aquifer will begin to recover, and flow from the springbox outlet pipe will gradually resume and increase with time. When the Turner wells are off for an extended period, the discharge rate from the springbox outlet pipe will return to the natural discharge rate of the spring.

In this manner, the head in the Casper Aquifer at City Springs fluctuates up and down, above and below the level of the springbox system, and water periodically discharges from the springbox outlet pipe and into Spring Creek. Turner No. 2, due to its proximity to the spring and a pump rate (1,400 gpm) greater than the average natural discharge of the spring (1,140 gpm), is capable of eliminating discharge from the springbox system. However, after approximately 7 days of pumping, the water level in Turner No. 2 approaches the pump bowls and the well must be shut-off; consequently, the aquifer head recovers and discharge from the springbox outlet pipe resumes.

The present design of the Turner wells does not provide an effective way to capture and control all of the natural discharge from City Springs. The cone of depression at Turner No. 2 is too steep and the magnitude of drawdown at the well is too large to allow continuous pump operation. Having the capability to control/capture all of the natural discharge from City Springs over an extended time period ensures that water is not "wasted" to Spring Creek, that the City exercises its water rights, provides assurance of safe water quality, and eliminates potentially contentious issues related to EPA sanitary surveys.

A critical practicality associated with the continuous capture of discharge from City Springs is the ability of the City to store and use the water. At present, the City does not have the demand in the winter for all of the water from City Springs. The surface water treatment plant and Soldier Springs provide most all of the water needed during the winter months. Later in this chapter, Section 10.7 provides a potential solution to this problem of water storage and use in the winter.

Three approaches to the capture and control of natural discharge from City Springs are presented.

Shallow Pumping Wells. Install three (3) shallow wells close to City Springs to enhance the effectiveness of lowering the head in the main area of discharge. Figure 10-4 shows the location of proposed wells and Figure 10-6 is a west-east cross section through City Springs. A cumulative pumping capacity of approximately 1,400 gpm, as demonstrated by Turner No. 2, should be capable of lowering the head sufficiently below the springbox system. Each well would have a design capacity of approximately 500 gpm. A proposed well design is shown on Figure 10-7. As demonstrated in the downhole video of Turner No. 2 and nearby water wells, prominent horizontal fractures occur immediately above and below the first limestone in the Casper Formation. Drilling deep into the Casper Formation is unnecessary and total depths for the proposed shallow wells would range from 120 to 150 feet.

The shallow wells would be operated continuously at rates needed to maintain the head in the Casper Aquifer below the springbox system. Pumped water would be treated and piped into the City storage/distribution system. If municipal demand is low, the water can be reinjected into the Casper Aquifer at the Spur Wellfield (see Section 10.7). The Turner No. 1 and No. 2 wells would be used primarily for peaking during high demand periods in the summer.

The proposed shallow wells at City Springs can also provide important additional wellfield capacity during peak day(s) conditions. Meeting peak day demands in the summer is the condition that the City will first encounter future water supply shortages. It is assumed that the three proposed shallow wells will

be capable of producing an additional 1,100 gpm (1.6 mgd) from the Turner Wellfield during occasional high demand 24-hour periods.

Modifications to the Turner No. 2 Well Pump. Install a variable frequency drive (VFD) motor control in Turner No. 2 that allows pump rates to vary according to the presence/absence of discharge from the springbox outlet pipe. A monitoring well should be installed between Turner No. 2 and City Springs such that water levels in the monitoring well would be correlated with spring discharge and used to control the VFD. For example, when flow from the springbox system ceases, the pump rate at Turner No. 2 could be reduced slightly such that the rate of drawdown in Turner No. 2 will decline or stabilize and allow a longer duration of continuous pumping. The pump rate could be "fine tuned" to achieve the balance between capturing most or all of the natural discharge from City Springs while allowing Turner No. 2 to operate continuously.

As discussed in Section 10.7, water from this steady-state pumping could be reinjected into the Casper Aquifer at the Spur Wellfield. This base flow capture system would run during the winter months from November to March. Artesian discharge from City Springs into Spring Creek would be reduced or eliminated in the winter. This modification will not enhance the peak day production capabilities of the Turner Wellfield.

Do Nothing. Continue the present day operation strategy of the Turner Wellfield as an as-needed and peaking supply. Allowing water from the springbox system to discharge to Spring Creek is not necessarily a bad thing; the community enjoys the esthetics and recreational opportunities of a live stream. Keep the springbox system well maintained to ensure that water does not back-up to the spring. Implement the previous two options when the need arises.

10.4.2 Performance Testing of the Turner Wells

The Turner wells were pumped simultaneously for 7 days on September 27 – October 4, 2005. The purpose of the pump test was to:

- Establish a baseline of Turner Wellfield performance for any future evaluation of hydraulic interference with the Turner wells;
- Determine if there has been any observable decline in wellfield performance since 1995 when a controlled pump test was last performed; and
- Document the timing and magnitude of head responses in the Casper Aquifer (i.e., drawdown) north of City Springs.

Figure 10-8 shows time-drawdown curves for pumping wells Turner No. 1 and Turner No. 2 wells. During the 2005 pump test, both wells were pumped at an average combined production of 3,650 gpm during the 7 day test. Pump test data are provided in the project notebook. These data can be used to document wellfield performance under conditions of maximum production. A similar test should be performed in July when the Turner wells are being used continuously (i.e., under high demand conditions).

Figure 10-8 also shows the time-drawdown curves for the Turner No. 1 and Turner No. 2 wells when both wells were pumped simultaneously at an average combined production of 3,435 gpm for 2.9 days in 1995. The 1995 and 2005 time-drawdown curves indicate that there has not been an observable decline in Turner Wellfield performance since 1995. A direct comparison of wellfield performance from one year to another, however, is qualitative because pre-test conditions are always different (i.e., pre-test wellfield pumping history, hydraulic conditions in the aquifer). Recovery data were not analyzed.

During the September-October 2005 pump test, water levels were monitored at wells in the vicinity of City Springs. Figure 10-9 shows the time-drawdown curve for observation well 41T3 that is located 1.05 miles north of the Turner wells in the area of the proposed expansion of the Red Jacoby Golf Course (RJGC) and approximately 0.22 miles southwest of proposed irrigation wells (JRC-1 and JRA-1) for the golf course (Figure 10-10). Drawdown at 41T3 began approximately 1 hour after the start of pumping, and after 7 days of pumping the Turner wells, 41T3 experienced 4.93 feet of drawdown. Recovery at 41T3 began immediately after the termination of pumping. The response of drawdown and recovery at 41T3 was noticeably more rapid than at

observation wells SHMWW and SHMWE located south of and 0.47 to 0.61 miles, respectively, from the Turner wells (Plate 10-1). A plot of drawdown and recovery at observation wells SHMWW and SHMWE is provided in Appendix 10-A. A comparison of the head responses at observation wells monitored during the pump test indicates that the Casper Aquifer in the area of 41T3 is in excellent hydraulic connection with the Turner wells, and that the cone of depression created by the Turner wells is elongated to the north (i.e., the aquifer is anisotropic with greater transmissivity to the north).

10.4.3 Potential Conflicts with Proposed Groundwater Development(s)

City Springs and the Turner Wellfield are particularly vulnerable to production and water quality impacts due to proximity to existing and future residential, commercial, and recreational development. A recent proposal by the University of Wyoming (UW) to expand the Red Jacoby Golf Course from 18 holes to 27 holes with approximately 700 to 1000 residences will be used here to illustrate future water development pressures on City Springs and the Turner Wellfield. The proposed golf course expansion and residential development are located immediately north and northeast of City Springs and have potential water supply and water quality implications to the Turner Wellfield.

Water for golf course (existing or expanded) irrigation can be obtained from the City, as is done presently, or from water wells that UW would drill, own, and operate. UW has filed for and received permits from the State Engineer's Office (SEO) for two wells that are proposed to be completed in the Casper Aquifer (U.W. 165500 and U.W. 165501). Figure 10-10 shows the location of the proposed wells, area of golf course expansion, Casper Aquifer protection zone, and geologic features. Each proposed well, JRC-1 and JRA-1, has a permitted instantaneous pump rate of 1,200 gpm and an annual maximum volumetric withdrawal of 280 acre-feet.

As of August 2006, the City and UW entered into a new 10-year agreement whereby the City will provide water to the RJGC, and UW agrees to not drill wells into the Casper Aquifer. At the end of the 10 year agreement or if the agreement is amended or nullified by future City Councils, UW may choose to develop groundwater from the Casper Aquifer for RJGC irrigation. A potential problem associated with the proposed use of the permitted wells to irrigate the RJGC is the likelihood for hydraulic interference

with the Turner wells. Specifically, well pumping for golf course irrigation will occur during the high demand summer months when the Turner wells are also being pumped. A concern is that the golf course wells will reduce the simultaneous run times of the Turner wells, and thereby reduce the ability of the Turner Wellfield to provide water during peak demand. As shown in Figure 10-10, the area between the proposed wells and City Springs has three prominent geologic features - Spur Fault, City Springs Fault, and the epsilon member of the Casper Formation - that provide excellent hydraulic connection to City Springs. Excellent hydraulic connection in this area was demonstrated during a Turner pump test conducted in September-October 2005 by the magnitude and timing of drawdown/recovery at monitoring well 41T3.

The owners of senior groundwater rights, such as the City of Laramie water rights at the Turner wells relative to the proposed RJGC wells, are often under the mistaken belief that a junior water right will be shut-down if hydraulic interference to a senior right can be demonstrated. A groundwater right does not include a guarantee of a specific water level (or head), and more importantly, an interference claim will be reviewed by the SEO only if the well is "adequate" which requires, in part, that the well fully penetrate the aquifer. Because the Turner wells do not fully penetrate the Casper Aquifer, the SEO may not require that UW cease or curtail production from the proposed wells based on an interference claim by the City. Interestingly, there are no wells in the Laramie area that fully penetrate the entire 700 feet of the Casper Aquifer, which causes considerable uncertainty regarding the prioritization of groundwater use by the SEO during water shortages via the senior/junior water rights concept. Interference claims between groundwater users in the Casper Aquifer may not be resolved by the SEO on the basis of water right priority dates, but rather by the 1) deepening of wells, 2) creation of a groundwater control area, or 3) water use agreements between the affected parties. In essence, the City must take an active role in the defense of their water rights and wellfield production capabilities.

Attached to the JRA-1 and JRC-1 well permits are Additional Conditions and Limitations that include a pump test and water level monitoring program designed to allow the SEO to identify and evaluate any unreasonable interference to water wells with a senior water right. As stated in a February 18, 2005, letter from the SEO regarding the

issuance of permits for the proposed UW wells, "*if the proposed UW wells interfere unreasonably with any adequate well with a senior water right, the State Engineer's Office will take steps to stop, rectify, or ameliorate the interference or damage caused.*" As defined by the SEO, an adequate well must penetrate the entire thickness of the aquifer.

Another issue related to the proposed expansion of the RJGC, is the protection of water quality in the Casper Aquifer. As shown in Figure 10-10, the eastern part of the proposed golf course expansion area is within Zone 2 (Primary Aquifer Protection Area) of the Casper Aquifer protection area as identified in the Casper Aquifer Protection Plan. Zone 2 includes areas that are particularly vulnerable to contamination (i.e., epsilon and delta members, shallow depth to groundwater). Golf course turf management will involve the storage and application of fertilizers, herbicides, and pesticides. In addition, the proposed residential development and stormwater runoff have the potential for water quality impacts to the Casper Aquifer. The proposed golf course expansion and residential development must be evaluated within the context of the Casper Aquifer Protection Plan (see Section 10.9). The presence of faults/folds and exposures of epsilon and delta member sandstones within the proposed golf course expansion area, and the proximity of the proposed development to City Springs, warrant a close and careful evaluation of the UW proposal with respect to the risk of water quality degradation at the Turner Wellfield.

In general, the City must be vigilant regarding land use to the east and north of City Springs. For example, there is a cut pad in the top of the delta member sandstone immediately east of City Springs (Figure 10-4). The cut pad exposes one of the most permeable layers in the Casper Aquifer in the vicinity of City Springs. The introduction of contaminants (e.g., chemical spill) at this location will quickly impact the quality of water extracted from the Turner wells.

In summary, the City of Laramie is not the only user of the Casper Aquifer and does not have exclusive rights for its use. This is demonstrated by the issuance of well permits to UW with large yield capability for the proposed golf course expansion, and by the agreement between the City of Laramie and domestic well owners in the vicinity of the Spur Wellfield. The City must be diligent in the fair and thoughtful administration of

the Casper Aquifer Protection Plan and the Casper Aquifer Monitoring Program to ensure a continued safe water supply. Water right conflicts arising from hydraulic interference will probably have to be resolved between water users as opposed to resolution from state agencies.

10.5 Spur Wellfield

The Spur Wellfield has been in operation since December 2000 and has been used exclusively for peaking during the summer months (Figure 10-11). Figure 2-6 shows the location of twelve (12) Casper Aquifer monitoring wells installed in the Spur area as part of the Spur Wellfield project. Five of the monitoring wells (MW-7, MW-8, MW-10, MW-11, and MW-12) are used to record head changes in the Casper Aquifer in the area of local water wells. From 2003 to 2005, the City has been very cautious regarding production from the Spur Wellfield in consideration of head (i.e., water levels in wells) declines and the wellfield production agreement with local residents. This section will discuss the behavior and probable cause(s) for head declines in the Spur area and present a wellfield operation strategy within the context of the agreement and groundwater resource.

A head decline in the Casper Aquifer has been documented in the Spur area since 1994. From June 1994 to August 1997, prior to Spur Wellfield testing and operation, the head in well TW-1 gradually declined at a rate of 0.85 ft/year (WWC, 1997a). The head decline observed during this period is assumed to be "natural" in that the decline was not caused by the pumping of domestic wells or the Spur wellfield. In 1997, there were approximately 35 domestic water wells in Spur area subdivisions (e.g., Sunset Acres, Spur Ridge, Rocky Top, and Aliquot) completed in the Casper Aquifer (WWC, 1997a). Assuming 2.2 people per residence and 200 gals/day/capita, the total withdrawal of groundwater from local domestic wells is approximately 5.6 million gallons per year. This relatively small quantity of water can not be responsible for a gradual head decline of 0.85 feet/year in the Spur area.

Subsequent analyses will demonstrate that a natural head decline has been documented at the Spur Wellfield monitoring wells from 1997 to 2006 at rates varying from 0.8 to 1.5 ft/year. For example, although the City produced only 13.1 million

gallons during March 2004 to June 2005 from the Spur wells, the Spur monitoring wells recorded head declines ranging from 1.0 to 1.5 ft/year during this period. On a regional scale, domestic and stock wells further to the east and southeast of the Spur Wellfield (e.g., Swiatek, S. Canyon, Spur Mill, and Mathis #1; Appendix 10-C) have experienced head declines of 0.8 to 3.6 feet from September 2003 to March 2006.

Superimposed upon the natural head decline are the temporary and residual head declines caused by Spur Wellfield production. A hydrograph of MW-7 (Figure 10-12), illustrates that summertime pumping of the Spur Wellfield causes immediate head declines and that head does not fully recover during the winter months when the wellfield is not operating. Based on 2001 and 2002 wellfield production volumes and the residual drawdown calculated from the extrapolation of the natural head decline (i.e., 0.8 ft/year) through the pumping and recovery periods of 2001 and 2002, the extraction of approximately 141 million gallons from the Spur wells cause a residual head decline of about 1 foot at MW-7 over the course of an annual wellfield production cycle. The residual decline dictates probable drawdown magnitudes at the monitoring wells for the upcoming summer season.

Temporary head declines occur at the monitoring wells over the course of the three month summer production period and represent the drawdown that occurs during pumping. As documented by wellfield production volumes and drawdown at MW-7 in June – July of 2001 and 2002, approximately 23 million gallons from the Spur wells cause a temporary head decline of about 1 foot. The temporary head declines at monitoring wells will, in large part, dictate Spur Wellfield production volumes and rates during the summer months.

From August 1997 to January 2006, MW-7 has experienced a total head decline of approximately 10.2 feet. During that period, pump testing and production from the Spur wells has extracted a total of 765 million gallons. Using the estimate of 141 million gallons per foot of residual head decline, an estimated 5.4 feet of residual head decline has been caused by Spur Wellfield production in the immediate vicinity of the wellfield. At MW-7, the remaining 4.8 feet of head decline has been caused by a natural head decline.

In March 1998, the City entered into a 20-year agreement with local water well owners that define maximum annual and maximum daily withdrawal rates from the Spur Wellfield based on the magnitude of drawdown at the five monitoring wells mentioned previously. Table 10-4 summarizes the terms of the agreement and drawdown values at monitoring wells as of January 2006. A copy of the agreement and the January 1, 2006 aquifer monitoring report are provided in Appendix 10-A. As of January 1, 2006, the City has not exceeded the greater than 20 feet of drawdown criterion that would initiate restrictive wellfield production limits. The City, however, voluntarily reduced wellfield production during 2003 – 2005 to allow the aquifer to recover. Despite these efforts, water levels in the Spur area continued to decline. Given the combined effects of the natural head decline, post-pumping residual drawdown, and the temporary head decline that occurs during wellfield pumping, the City will soon be subject to the restrictive annual and daily withdrawal rates specified in the agreement.

After 6 years of wellfield operation and monitoring, it is apparent that the Casper Aquifer in the vicinity of the Spur Wellfield is particularly sensitive to natural and man-made hydraulic stress. The poor recovery following summer-time production and natural head decline suggest that recharge to the Casper Aquifer in this area may not be as efficient as the City, Pope, and Soldier area to the south. The scarcity of vegetated slopes to hold snow east of Spur Ridge may be a contributing factor to poor recharge (Karl Taboga, per. com.). In addition, the last 11 years appear to have been particularly low recharge years as indicated by below-average precipitation for the critical months of March and April (Figure 10-3). One observation to consider is that in 1997 (i.e., the starting point for drawdown calculations in the agreement) the water levels in the Spur area were 8-9 feet higher than water levels measured by Lundy in 1976. The on-going natural head decline in the Spur area may be a manifestation of a very slow adjustment of head to the large head increases caused by the 1983 recharge event.

In contrast to wellfields developed at City Springs, Pope Springs, and Soldier Springs, the Spur Wellfield was developed in an area without an active spring. Perhaps, the sensitivity to pumping is, in part, a result of not being able to capture spring discharge. The stabilization of drawdown must, instead, rely on the capture of water

from other types of discharge such as leakage to overlying formations, downgradient flow, or far distant springs.

Structural elements (faults and folds) in the Spur area may have created "aquifer compartments" with low permeability boundaries. Tritium data collected and analyzed by Dr. Carol Frost and Rachel Toner in 1996 provide insight into the groundwater flow system at the Spur. Tritium values at the MW-7 and MW-2 wells indicate a mixture of pre- and post-1953 water such the average age of these waters is less than 43 years. Water from the Hayward well (located near MW-12) has a high tritium value indicative of primarily post-1953 water. In contrast, the Flesher-McCraken well (670 Rogers Canyon Road) has a low tritium value indicative of very little bomb-era water. In the Spur area, there are pockets of old water that suggests limited recharge to some areas. In general, the Spur area groundwater appears to have lower tritium values and may be slightly older compared to groundwater from the City Spring and Soldier Springs area. These data indicate that the Spur area may have a less active groundwater flow system compared to further south in the immediate vicinity of Laramie. The Spur Anticline is the most deformed geologic structure in the Laramie area; the effect of this structure on the groundwater flow system is still not well understood.

To summarize, the residual drawdown after a summer season of pumping is a concern; the City should be cautious, but opportunistic. A good recharge year could quickly reverse decline trends and allow more reliable use of the Spur Wellfield. To minimize drawdown at MW-7, the City should use Spur No. 2 as often as possible when both wells do not need to be operated simultaneously. The City should investigate approaches to modify the wellfield production agreement to accommodate brief periods of high pump rate (4 mgd) under non-compliance drawdown conditions (> 20 feet of drawdown). The Spur Wellfield should continue to be used as a peaking supply during the summer.

The long-term reliability of the Spur Wellfield as a peak supply will evolve with time as aquifer behavior is better defined with respect to recharge events, drought cycles, and wellfield pumping. In the meantime, the City must continue to monitor water levels and operate the wellfield within the terms of the agreement.

As discussed in Section 10.7 of this chapter, an Aquifer Storage and Recovery concept involving the winter-time injection of water from City Springs into the Casper Aquifer near the Spur No. 1 well (i.e., TW-1) may mitigate declining water levels at the Spur monitoring wells and provide enhanced flexibility in the operation of the Spur Wellfield.

10.6 Pope Wellfield and Soldier Springs

The operation and production capabilities of the Pope and Soldier wellfields must be considered together. The Pope and Soldier wells are located only 1.2 miles from each other and appear to be intimately connected by aquifer structure and a common transmission pipeline. Morgan (1947) first identified that discharge at Soldier Springs was affected by withdrawals at the Pope Wellfield. This hydraulic relationship was confirmed by a pump test conducted in 1993 (WWC, 1995) and by the decline of artesian flow from Soldier No. 1 when the Pope wells are operating.

At the Wye, water from the Pope and Soldier No. 1 wells are commingled into a common pipeline that conveys water to the City storage and distribution system. Consequently, pipeline hydraulics dictate well operation and the quantity of water that can be produced instantaneously from the Pope-Soldier wellfields. During high demand, maximum production of 5.0 mgd is achieved when the Soldier No. 1 and Pope No. 4 wells are pumped simultaneously. Low demands are met using the artesian production from Soldier No. 1 (gravity flow to Wye) and moderate demands are met using artesian production from Soldier No. 1 and pumping the Pope No. 1-3 wells.

Figure 10-13 illustrates annual production from the Pope-Soldier system since the Soldier No. 1 well replaced the cistern in late 1998. Prior to 1998, discharge from the Soldier Springs cistern was approximately 1.3 mgd and the Pope wells were pumped as needed on the order of 0.70 to 1.4 mgd. Since 1999, artesian flow from Soldier No. 1 has varied from 1.7 to 2.2 mgd which is a noticeable increase from the historical discharge of 1.4 mgd from Soldier Springs and the old cistern. The increased discharge could be easily explained if the discharge elevation at Soldier No. 1 was lower than the discharge elevation at the cistern; however, the water level elevation in the Soldier No. 1 well is approximately 7,315 feet which is nearly identical to the water level elevation measured

in the cistern prior to plugging and abandonment. Consequently, the higher artesian flow at Soldier No. 1 is probably a result of highly permeable fractures encountered by the well (i.e., larger transmissivity, improved well hydraulics) and reduced pumping from the Pope wells. It is anticipated that the artesian flow from Soldier No. 1 will gradually decline, but over the last 3 years the artesian flow has held fairly steady at 1.78 mgd.

With the increased artesian flow from Soldier No. 1, production from the Pope wells since 1999 has been significantly reduced (Figure 3-1). Average production from the Pope-Soldier system since 1992 has been approximately 2.18 mgd, with recent production in 2003 – 2005 being slightly lower at 1.87 mgd due to low demands.

Prior to installing Soldier No. 1, five (5) monitoring wells were completed in the Casper Aquifer on the City-owned property around Soldier Springs. The monitoring wells can be used for water quality and water level monitoring. As listed in Table 10-5, water levels in Soldier monitoring wells have declined approximately 1.5 feet since 2003 and approximately 6.7 feet since the Soldier No. 1 well was put in service in 1998. Water level monitoring in the area of Soldier Springs indicates a head decline of approximately 0.5 feet from 2003 to 2006 in wells within a mile radius of Soldier Springs (Taboga, pers. com.). The City should periodically measure water levels at the Soldier Springs monitoring wells to identify head trends in the Casper Aquifer in the vicinity of Soldier Springs. These data may help explain any future changes in artesian flow from the Soldier No. 1 well.

The Pope-Soldier wellfield system consists of low and high production capacity wells that provide adequate operational flexibility for low to high demands. No additional wells are needed under the present limitations of pipeline hydraulics. The City should operate the Pope-Soldier wellfields as needed to meet demands and in the most economical manner. The extraction of additional water from the Pope-Soldier system would require a new pipeline.

10.7 Casper Aquifer Storage and Recovery

The basic concept of aquifer storage and recovery (ASR) involves the injection of water into an aquifer and the subsequent removal (recovery) of the injected water at a later date. ASR requires a suitable source of water for injection, a means of conveyance

from the source to the injection well, an adequate injection well, favorable aquifer conditions for injection, and a pumping system for recovery. A unique opportunity to apply ASR is available at the Spur Wellfield using groundwater from the Turner Wellfield.

ASR in the Casper Aquifer at the Spur Wellfield may mitigate three water supply issues as listed below:

1. Provide storage for City water that is not being used during low demand winter months;
2. Reduce natural and pumping induced head declines in the vicinity of the Spur Wellfield; and
3. Ensure reliable use of the Spur Wellfield as a peaking supply.

As discussed earlier in this chapter, during the last 10 years the average production from the Turner Wellfield has been approximately 1.1 mgd which is less than the natural historic discharge of 1.6 mgd from City Springs and significantly less than the City's water rights at the Turner wells (Table 2-5). The difficulty in consistently using, at least, all the natural discharge from City Springs is a combination of low demand, insufficient storage, and design limitations of the Turner wells. Options were presented for the redesign of well and pumping systems at the Turner Wellfield that would allow the City to more effectively capture the natural discharge from City Springs. The problem to be solved is how to use and/or store water during the low demand winter months. Since a major user of water during the winter months has not been identified, the storage of water in the Casper Aquifer at the Spur Wellfield is a potential solution.

Pipelines from the Turner Wellfield into the Zone 2 tank, Zone 2 distribution system, and on to the Spur wells can provide conveyance of water from the Turner wells to the Casper Aquifer at the Spur. Because water from the Turner wells would be stored in the Zone 2 tank, the water gravity fed to the Spur would be a blend of treated surface water and groundwater. A review of the hydraulic gradeline indicates that approximately 1,280 gpm could be conveyed to the Spur by gravity flow with at least 10 feet of positive pressure at pipeline summits (Figure 10-14).

The Spur No. 1 and Spur No. 2 wells could be used as injection wells; however, the City owns an 8-inch diameter well (TW-1) located adjacent to the Spur No. 1 well that would be better suited as a dedicated injection well in the Casper Aquifer. TW-1 was completed in 1994 and was the original exploration and test well for the development of the Spur Wellfield. In 1994, TW-1 was pumped at a rate of 620 gpm for 3.8 days with 1.9 feet of drawdown (WWC, 1995). Given the exceptional aquifer permeability and suitable well construction, TW-1 could be used as the injection well, and Spur No. 1 and Spur No. 2 used as recovery wells. The groundwater mound in TW-1 at injection rates of 1,000 gpm would be on the order of 3 to 5 feet. Figure 10-15 illustrates TW-1 well construction, approximate depth to water, and proximity to proposed recovery well Spur No. 1.

From a regional aquifer perspective, the Spur area is an excellent candidate for ASR. The potentiometric surface map for the Casper Aquifer at the Spur wells (WWC, 1997a) indicates a very low hydraulic gradient with groundwater flowing from east to west. Water injected into the Casper Aquifer would likely remain in the vicinity of the Spur wells such that all or most of the injected water could be recovered at a later date. In addition, any water from the injection well TW-1 that flows to the west could be captured by Spur No. 2.

As discussed earlier in this chapter, in the Spur area, the head in the Casper Aquifer has been declining as a result of natural and wellfield induced factors. Due to the agreement between local well owner and the City, the magnitude of head decline places future limitations on production from the Spur Wellfield. The potential for ASR to halt or slow future head declines will provide the City more flexibility to use the Spur Wellfield at full capacity during the peak summer months. If ASR was applied only to the quantity of water that bypasses City Springs (i.e., 1.6 mgd – 1.1 mgd = 0.5 mgd), the injection volume at the Spur wellfield would be 183 million gallons per year, which represents approximately 47% of the maximum allowable annual production of 391 million gallons from the Spur Wellfield.

With respect to water quality, the injection source water as described above would be a blend of treated surface water and groundwater with associated residual chlorine, fluoride, treatment by-products, and possible bacterial contaminants derived from the

storage and distribution system. The WDEQ requires that the injection water have as good or better water quality as the receiving aquifer. Table 10-6 lists the basic inorganic water quality of the receiving aquifer at TW-1 and the source (i.e., water from the Zone 2 system). The basic inorganic water quality of blended water in Zone 2 is slightly better (e.g., lower TDS concentration) than groundwater in the Casper Aquifer at Spur No. 1.

The discussion to this point provides a basic conceptual framework for ASR; however, there are significant regulatory issues to consider and/or resolve before the ASR concept at Turner/Spur can be deemed feasible. As of 2006, a municipal ASR project has not yet been permitted in the State of Wyoming. Consequently, permitting issues from state agencies such as the WDEQ/WQD and SEO are not presently well-defined.

Preliminary discussions with the underground injection control (UIC) division of the WDEQ/WQD and the SEO identified the following issues associated with the ASR concept at Turner/Spur:

- Demonstrate that the aquifer will not be damaged;
- Demonstrate that water quality will not be degraded;
- Address concerns of local groundwater users (i.e., injection of fluoridated and chlorinated water); and
- Water rights issues such as a partial change of point of diversion, demonstration of historic beneficial use (5-year annual well production volume), meter-in/meter-out, and conformance with established City groundwater production limits.

Preliminary discussions with the EPA have identified an issue that may significantly affect the feasibility of ASR at Turner/Spur using a blend of surface water and groundwater from the Zone 2 storage/distribution system. Apparently, because surface water treatment does not provide 100% removal of surface water pathogens, if the injection water contains a component of treated surface water, then the groundwater recovered at the Spur wells would be classified as groundwater under the direct influence of surface water (GWUDISW). Groundwater sources that are classified as GWUDISW would require treatment in conformance with the Surface Water Treatment Rule. The

expense of treating groundwater from the Spur Wellfield to surface water standards would probably negate the advantages of water management by ASR.

A potential solution to the GWUDISW issue is to install a dedicated pipeline from the Turner Wellfield to the Spur pipeline at 30th and Reynolds as shown in Figure 10-14. The 1.6 mile pipeline would provide untreated groundwater from the Turner Wellfield directly to the Spur pipeline, and consequently, would eliminate ASR issues associated with GWUDISW, fluoride and chlorine treatment, and disinfection by-products.

A cost estimate for the development of the ASR concept is $3,630,000 (Appendix 10-D). The projects include the installation of shallow production wells at the Turner Wellfield, VFD motor control at Turner No. 2, and a dedicated pipeline from the Turner Wellfield to the existing Spur pipeline at 30th and Reynolds.

10.8 Groundwater Development of the Casper Aquifer

Based on the observation that the Casper Aquifer has not experienced significant head declines as a result of wellfield production, the City has the opportunity to extract more groundwater or, at least, to more fully exercise the water right and production potential of the existing wellfields. Figure 10-16 illustrates that on an average annual basis, wellfield withdrawals are only slightly above (7.8%) the historical annual natural discharge of 3.5 mgd (Morgan, 1947; Huntoon and Lundy, 1979b; and Banner, 1983) from the original spring collection systems at City, Pope, and Soldier Springs.

In the vicinity of Laramie, the other significant users of the Casper Aquifer include private domestic wells, the Mountain Cement (MC) plant south of Laramie, and institution facilities (Cathedral Home, WyoTech, and Western Research Institute - WRI) at the north end of 3rd Street. An estimated 550 county residences obtain water from the Casper Aquifer in the area between the Spur and Simpson Springs. Assuming 2.2 people/residence and a per capita demand of 200 gallons/day, domestic systems extract approximately 0.24 mgd. Well production records from MC were not available from the SEO, but the permitted instantaneous water right of the five MC wells completed in the Casper Aquifer total 620 gpm which equates to 0.89 mgd. The combined total permitted instantaneous water rights from the Cathedral Home, WyoTech, and WRI wells is 449 gpm which equates to 0.65 mgd. Based on the municipal and primary non-municipal

water users, approximately 5.6 mgd is withdrawn from the Casper Aquifer with no apparent hydraulic impact. It should be recognized, however, that head data to the west, in vicinity of the Mountain Cement/Cathedral Home/WyoTech/WRI wells was not investigated in this study, and that the instantaneous permitted water right probably overestimates actual production. A more accurate groundwater use inventory will require obtaining water production records from these the non-municipal facilities.

10.8.1 Safe Yield Concept

Decisions regarding what water supply options to pursue are based primarily on well yield expectations and cost comparisons. When groundwater prospects are identified and ranked in a relative sense, two common criteria are the size of the recharge area and proximity to obvious forms of aquifer discharge such as springs. As the decision making process continues, and more detailed evaluations of prospects are required, the next question is, "What is the safe yield and/or sustainable production of a prospect?"

Typically, safe yield has been equated to the amount of recharge to the groundwater aquifer system. Bredehoeft (2002) emphasizes that using recharge to estimate safe yield is incorrect, and states, "*The size of a sustainable groundwater development usually depends on how much of the discharge from the system can be captured by the development. Capture is independent of recharge; it depends on the dynamic response of the aquifer system to the development.*" When a well is pumped, the cone of depression expands and captures groundwater that would otherwise discharge to a spring or stream, leak into adjacent formations, flow into an intermountain basin, or be lost to evapotranspiration. The cone of depression may capture water directly from a stream/lake or other hydraulic boundary. In the case of the Casper Aquifer, estimating the sustainable yield of a prospect solely on the assumed ability of a well to capture the discharge from a local spring may significantly underestimate the potential yield. It is often impossible to accurately quantify all the discharges that a well may be able to capture. This is the case with groundwater development prospects identified in this report; the sustainable yield of a groundwater prospect cannot be determined precisely

because the discharges from the Casper Aquifer, especially leakage into overlying formations, and the dynamic response of the aquifer to pumping are not known precisely.

Head decline (drawdown) in an aquifer occurs when a well is pumped and substantial drawdown may be needed to capture the various types of discharge. The issue becomes, how much drawdown is acceptable? For example, at the Spur Wellfield, safe yield has been defined by drawdown in local water wells and has little to do with the capture of flow in the basin, leakage into overlying formations, or a demonstrated ability of the aquifer to supply water to the wellfield.

Sustainable annual yield estimates for potential groundwater projects provided by Banner (1983) and WWC (1995) were based on the assumed capture of water discharged at a nearby spring, an unknown amount of aquifer leakage into the Satanka Shale, and flow into the basin.

Some general comments, however, can be made regarding the overall use of the Casper Aquifer in the Laramie area. If the safe yield criterion is no decline on the regional head and no decline in the discharge at local springs, then the City is currently operating their well fields within these safe yield parameters. As discussed in Huntoon and Lundy (1979b), this safe yield criterion is very conservative and does not account for the capture of groundwater that is leaking into overlying formations and flowing westward into the Laramie Basin. Huntoon and Lundy's estimate that an additional 1 mgd may be available from combined development in the area of City Springs, Pope Springs, and Soldier Springs is probably still applicable. While the initial estimates of the reliable yield from the Spur Wellfield are lower than originally estimated, the wells at City, Pope and Soldier Springs show remarkable strength.

10.8.2 Groundwater Development Prospects

Numerous groundwater development prospects were identified in the Management Plan for Water Rights on the Monolith Ranch (Fassett, 2004). To enhance groundwater supplies for municipal use, the City can improve the production characteristics of existing wellfields or develop new wellfields in the Casper Aquifer. Three of the top prospects are discussed.

10.8.2.1 Turner Wellfield and Spur Wellfield

As discussed in previous sections of this chapter, the Turner Wellfield should be designed to reliably capture the natural discharge of water from City Springs. Installation of a VFD in Turner No. 2 and/or installation of shallow extraction wells will improve the ability to capture artesian flow and the installation of shallow extraction wells will enhance peak day production capabilities. An ASR concept was developed whereby, during the winter (low demand), discharge from City Springs is piped to and injected into the Casper Aquifer at the Spur Wellfield. The ASR concept provides a place (Casper Aquifer) to store unused water from City Springs and will mitigate to some degree the declining water levels at Spur which will allow more flexibility to operate the Spur Wellfield during the summer.

10.8.2.2 Simpson Springs

When supply/demand economics require that the City develop new groundwater supplies, Simpson Springs is the highest priority prospect for development. Located on the eastern edge of the Monolith Ranch in T14N, R73W, Section 2, Simpson Springs is the next range front spring 2 miles south of Soldier Springs. Simpson Springs has been a highly ranked groundwater development prospect in previous studies (WWC, 1982; Banner, 1983; WWC, 1995) due to the presence of springs and favorable geologic structure. At Simpson Springs, the springs are small and spread over a large area. The average surface spring discharge at Simpson Springs is 0.28 mgd. Geologically, Simpson Springs is located near the Simpson Springs Anticline, a gentle west-east trending fold. Limestones in the Casper Formation thin to the south such that at Simpson Springs the Casper Aquifer is composed of a greater percentage of sandstone compared to sandstone percentages in the Casper Formation north of the Spur Wellfield. These hydrogeologic conditions are favorable for productive wells in the Casper Aquifer.

The Simpson Springs area is a viable groundwater prospect based on the abundance of springs that discharge from the Casper Formation and from the

lower portion of the Satanka Shale south of Simpson Springs. For example, springs at Red Buttes, Leazenby Lake boggy area, Colores Springs, and Willow Springs, located 3 to 5 miles south of Simpson Springs, have a combined discharge estimated at 0.5 mgd (Davis, 1976). WWC recently performed hydrologic studies of the Satanka Shale in the Red Buttes area and there appears to be abundant groundwater in the Satanka Shale. Although not quantified, water from the underlying Casper Aquifer that flows upward through the overlying Satanka Shale could be captured with wellfield development.

In many respects, the hydrogeologic conditions at Simpson Springs are identical to conditions at Soldier Springs, Pope Springs, and City Springs. It is highly likely that the City will be able to locate and install high yield production wells in the Casper Aquifer at Simpson Springs.

To summarize, Simpson Springs is the best prospect for the expansion of new groundwater supplies for the following reasons:

- Proximity to the City;
- Location on the City-owned Monolith Ranch;
- Scarcity of competing water users;
- Presence of active springs on the Monolith Ranch;
- Proximity to a high yield well (i.e., the Brow #2 well: 19 feet of drawdown after 48 hours of pumping at 900 gpm; CBMA, 2006);
- Greater relative percentage of sandstone in the Casper Formation; and
- Abundant springs located further south of Simpson Springs.

The Casper Aquifer is a laterally continuous and hydraulically connected aquifer from the Spur to Simpson Springs and further south. As such, there is likely to be some hydraulic interference between the municipal well at Soldier Springs and a wellfield at Simpson Springs. In addition, wellfield development at Simpson Springs may cause some water level declines at local domestic wells. Water level fluctuations in response to wellfield pumping are an unavoidable consequence of groundwater development. The magnitude of interference will

depend on wellfield pumping rates and the hydraulic characteristics of the Casper aquifer to the north, south, east, and west of Simpson Springs.

10.8.2.3 Laramie Fault

If water quality or water use conflicts evolve at the wellfields located at range front springs, the development of wellfield further west toward the basin may be attractive. Of the westward groundwater development prospects, the Laramie Fault is the most promising. The Laramie Fault trends north-south through the area east of Highway 287 and south of Laramie (Plate 10-1). The fault displaces the Casper Formation and the overlying Satanka Shale, Forelle Limestone, and Chugwater formations, and groundwater seeps occur along its trace.

Groundwater development prospects along the Laramie Fault were first identified by Banner (1981 and 1983) as the "Monolith Well" site located in the northeast quarter of Section 28 on the Monolith Ranch property, and by WWC (1982) as the "Laramie" site which includes a large portion of the Laramie Fault trace south of Laramie. There have been no detailed hydrogeologic investigations on the production characteristics of the Casper aquifer along the Laramie Fault. Wellfield development along the Laramie Fault would seek to capture groundwater that flows westward into the Laramie Basin and that is leaking into overlying formations. Municipal development of groundwater along the Laramie Fault would be part of an exploration program that follows the development of more viable water supply options such as Simpson Springs.

Three prospects located on the trace of the Laramie Fault are discussed:

- North (South Laramie)
- Central (Hunziker Well area)
- South (Simpson Springs area)

North: WWC (1995) identified the northern extension of the Laramie Fault into the City limits as an option for groundwater development. No additional data on the existence or groundwater production potential of the Laramie Fault in this area are available. As such, potential groundwater

development at the northern extension of the Laramie Fault is considered highly speculative, but it attractive due to proximity to City infrastructure.

Central: The Hunziker well was drilled in 1940 and is located on the surface trace of the Laramie Fault in the northeast quarter of Section 28 on the Monolith Ranch property. The well provides water for flood irrigation at the Monolith Ranch and was evaluated in detail by WWC (1995). The Hunziker well has a pump rated for 800 gpm. The Hunziker well was drilled to a total depth of 336 feet but caving of the open hole has reduced the well depth to 145 feet. Well depth and water quality data indicate that the well is completed in and obtains water from the Chugwater Formation.

The excellent production from the Chugwater Formation at this well is unusual and is attributed to fractures that may be related to the wells' proximity to the Laramie Fault. This was probably why Banner (1983) located the Monolith Well Site near the Hunziker well. Although groundwater from this well is not suitable as a potable municipal supply (i.e., total dissolved solids concentration of 2,300 mg/L), the vicinity of the Hunziker well is a viable prospect for future groundwater exploration and testing efforts in the Casper Aquifer.

South: WWC (1995) identified a prospect located at the intersection of the Simpson Anticline and the Laramie Fault on the Monolith Ranch property (Sec. 33, T15N, R73W). The intersection of two geologic structures enhances the potential for fracture permeability in the Casper Aquifer. Like the other Laramie Fault prospects, the West Simpson Anticline/Laramie Fault prospect would seek to capture groundwater flowing westward into the Laramie Basin and leaking into overlying formations. This prospect is speculative because there are no wells in the area to indicate municipal well production potential.

10.9 Casper Aquifer Protection Plan

Since 1993, the City has pursued the development of wellhead and aquifer protection plans designed to protect the Casper Aquifer for future use by City and County groundwater users. The City of Laramie, in conjunction with Albany County, decided to pursue an aquifer protection plan that provides a more comprehensive and regional

protection strategy compared to wellhead protection that tends to deal primarily with protection of City wellfields. Aquifer protection involves establishing community awareness, education, land use management, emergency response, and contingency planning that focuses on the reducing the opportunity for the degradation of water quality in the Casper Aquifer in the vicinity of Laramie.

In 2002, a Casper Aquifer Protection Plan (CAPP) was developed that delineated aquifer protection areas and identified contaminant sources, contaminant management strategies, and a water supply contingency plan. The CAPP document is probably the most extensive and detailed aquifer protection effort in Wyoming to date. City Council members, County Commissioners, and land use planners/developers are encouraged to become familiar with the CAPP as an aid to making future land use and aquifer development decisions. The CAPP document will be revised every 2 years in consideration of new water supply information and aquifer management objectives.

In addition to local City and County support of the CAPP, the Wyoming Department of Environmental Quality (WDEQ) has a review and approval process for wellhead (aquifer) protection plans. WDEQ has a Wellhead Protection Program Guidance Document (1998) that is used by the state to evaluate wellhead (and aquifer) protection plans. As of August 2006, the WDEQ has assured the City that the CAPP will be approved based on WDEQ's review of the CAPP and comments provided on June 28, 2006. The City is presently revising the CAPP to included WDEQ comments and will resubmit the CAPP to WDEQ for final approval. Approval by WDEQ demonstrates that the CAPP has met the requirements of the states' wellhead/aquifer protection plan guidelines and provides the authority for WDEQ to issue construction and subdivision permits that are in compliance with local regulations.

To safeguard the Casper Aquifer wells and springs that provide a large portion of the municipal water supply, the City of Laramie approved an Ordinance No. 1404 in October 2002 that does the following:

- Creates an aquifer protection overlay (APO) zone within the City corporate limits;
- Identifies prohibited land use within the APO zone;
- Establishes construction setbacks from vulnerable features; and

- Design standards for on-site wastewater treatment systems.

In June 2002 the Albany County Board of County Commissioners approved the CAPP and resolved to establish an aquifer protection overlay zone with the same components identified in the City Ordinance. A copy of the city ordinance and county resolution are provided in Appendix 10-A.

In the future, the CAPP will likely be a primary source of information pertaining to proposed land use development(s) and the protection of water quality in the Casper Aquifer on the west flank of the Laramie Range in the vicinity of Laramie.

10.10 Casper Aquifer Monitoring Program

In 2004, the City initiated a Casper Aquifer Monitoring Program (CAMP) designed to monitor head and water quality conditions in the Casper Aquifer. These data can be used to assess aquifer conditions and water quality, and to better manage City use of the Casper Aquifer. This section will describe the City's present definition of the CAMP with recommendations for program implementation and expansion.

Plate 10-1 shows the location of 14 wells that are presently designated as monitoring wells for the CAMP and Table 10-7 lists basic monitoring well information. From north to south, these wells cover the area from the Spur to Simpson Springs and provide continuity of data collection from Karl Tabogas' regional monitoring of head in the Casper Aquifer since September 2003. Water levels at these wells will be measured quarterly. Water quality samples are collected semi-annually from three wells. The City has contracted with a local consulting firm to perform data collection, reduction, and reporting.

In addition to the CAMP wells, the City collects continuous water level data at five (5) monitoring wells in the vicinity of the Spur in compliance with the Spur Wellfield production agreement. Another source of continuous water level data are the Huntoon No. 1 and Huntoon No. 2 wells collected by the State Engineer's Office and US Geological Survey. The location of the Spur and Huntoon monitoring wells are shown on Plate 10-1.

As a result of previous studies, the City owns numerous wells in the vicinity of Laramie that can be used as head and water quality monitoring wells as listed in Table 10-6.

From late-2003 through 2006, Mr. Karl Taboga has been monitoring water levels at approximately 50 wells completed in the Casper Aquifer. An excellent foundation for monitoring of the Casper Aquifer has been established that should be continued. As mentioned previously, 14 of these wells have been selected for long-term monitoring as part of the CAMP. Future adjustments and expansion of the CAMP should consider the wells used by Mr. Taboga during his research studies.

The CAMP is an important component to the on-going management of the Casper Aquifer. The existing CAMP represents a good initial effort that should be modified and expanded as listed below.

1. Include the collection of quarterly water level data at the following City-owned wells: 41T2, 41T3, Soldier MW-1, Soldier MW-3, and Soldier MW-5, and Simpson MW-1.
2. Include annual review and evaluation of the Huntoon No. 1 and Huntoon No. 2 monitoring well hydrographs as provided by the SEO and USGS.
3. Include quarterly monitoring of "highland springs" (e.g., Laycock, Buck-Sullivan, Telephone Canyon, and Klein) located at the upper elevations of the Laramie Range (Plate 10-1). The flow of highland springs in May-June will indicate aquifer recharge conditions (poor, moderate, or good) for the coming year.
4. Include the collection of quarterly water level (or wellhead pressure) data at approximately 4 wells located west of the municipal wellfields, in a south to north transect from the Mountain Cement Plant to the Aliquot Subdivision. Potential monitoring wells have not been identified.
5. Expand the number of water quality sampling locations to include the semi-annual collection and analysis of nitrate and coliform bacteria from wells downgradient of the Sherman Hill Estates, Laramie Plains, and Valley View subdivisions located east of Laramie city limits. These subdivisions are located on the Casper Formation (Zone 2 of the CAPP) and represent the area

of greatest density of private septic systems. Water quality data from this area will allow an evaluation of the impact of septic systems on water quality in the Casper Aquifer. A minimum of 4 existing domestic (or dedicated monitoring) wells should be identified in these subdivisions.

6. Annual compilation, review, and evaluation of head and water quality data obtained by the City (i.e, CAMP and Spur Wellfield monitoring) and other state monitoring programs during the previous year. Data reduction should include time-series plots of head (hydrographs) and water quality. A brief annual report will document results, observations, and trends that the City should be aware of in the coming year.
7. Every two years, a comprehensive water level survey should be performed to update the potentiometric surface of the Casper Aquifer. The survey should include the wells used in this study.
8. Every four years, the City should modify the CAMP (i.e., monitoring frequency, parameters, and wells) as deemed necessary.
9. Integrate hydrogeologic and geochemistry information obtained from on-going UW graduate studies on the Casper Aquifer into the CAMP and modify the monitoring program as necessary. In the future, the Casper Aquifer may be an important subject for academic research and applied science.
10. If the City decides to develop Simpson Springs on the Monolith Ranch, water level monitoring of the east-west transect of wells east of Simpson Springs should be initiated to establish baseline data prior to development.

10.11 Groundwater Under the Direct Influence of Surface Water

Every 5 years the EPA performs a sanitary survey that includes a field evaluation of whether the City's groundwater collection facilities (Spur, Turner, Pope, and Soldier wellfields) are influenced by surface water. This evaluation is referred to as Groundwater Under the Influence of Surface Water (GWUDISW) and has important water treatment consequences. If a groundwater source is designated as GWUDISW, then the source is considered a "surface water" in terms of complying with Safe Drinking Water Act

(SDWA) regulations. Groundwater would have to be filtered and disinfected to surface water standards, per the Surface Water Treatment Rule, at considerable cost to the City.

The discussion on GWUDISW will include the following:

- GWUDISW evaluation and designation process used by the EPA;
- GWUDISW study at Soldier Springs; and
- Future status of City wellfields with respect to GWUDISW.

10.11.1 GWUDISW Evaluation Process

During EPA's periodic sanitary surveys of the City water system, EPA personnel will inspect each wellfield and use a field evaluation form to assign a numerical score to each wellfield. The evaluation form used in the past is provided in Appendix 10-A and consists of the following 4 basic elements that have point values that are combined for a total score.

- Type of Subsurface Water Source (i.e., well, spring, or infiltration gallery);
- Historical Microbiological Contamination (i.e., any documented historical outbreaks or violations);
- Hydrological Features; and
- Structural Features (i.e., well/spring construction and conditions).

A total score of greater than or equal to 40 indicates that the groundwater source may be GWUDISW and that additional assessment is needed. Additional assessment involves, primarily, a water sampling program using Microscopic Particulate Analysis (MPA) to document the presence or absence of bio-indicators of surface water influence. Each MPA sample receives a score based on the Consensus Method (EPA, 1992) and a relative risk (i.e., low, moderate, or high) of surface water contamination is assigned to the sample. In general, if MPA samples indicate a high risk, the groundwater source will be designated GWUDISW; a moderate risk may require the sampling and analysis of additional samples and water quality parameters; and low risk samples will allow the source to considered not GWUDISW.

10.11.2 GWUDISW Study at Soldier Springs

In February 1995, based on the results of a sanitary survey, the EPA notified the City that the Soldier Springs source was GWUDISW. In 1995, water from Soldier Springs was obtained from a shallow cistern that had construction inadequacies with the potential to compromise water quality. The City and EPA designed a groundwater sampling program to assess whether Soldier Springs was GWUDISW. As part of the approved sampling program, five (5) monitoring wells were installed in the Casper Aquifer at Soldier Springs. Water quality data were collected from November 1995 to June 1996, that included MPA, total coliform, temperature, conductivity, and particle counts. Based on the results of the study, the City concluded that Solder Springs was not GWUDISW (July 26, 1996, report from City to EPA).

The City, however, recognized the problems associated with the cistern, and in 1998 the cistern was plugged/abandoned and replaced with a production well, Soldier No. 1, located 450 feet west of the cistern. Since the installation of the well, Soldier Springs has not been designated as GWUDISW by the EPA.

10.11.3 Future Assessment of GWUDISW at City Wellfields

Due to the uncertain evolution of EPA's implementation of the GWUDISW concept, the City has no guarantee regarding how the wellfields will be evaluated and designated. The following discussion, however, attempts to provide a reasonable future assessment of GWUDISW using existing methods and data.

From a hydrogeologic perspective, it is difficult to conceptualize a wellfield completed in the Casper Aquifer as GWUDISW. One of the unique aspects of the exposure of the Casper Formation on the west flank of the Laramie Range is the absence of perennial streams or standing water in the form of ponds or lakes. The wellfields are completed in confined bedrock formations and are not part of shallow alluvial aquifer systems. Livestock grazing, a potential source of cryptosporidium, on the recharge area is low density. As discussed previously in this chapter, the Casper Aquifer appears to have excellent recharge characteristics; however, this should not be an absolute criterion for the designation of a source as GWUDISW.

The primary evaluation tool of GWUDISW is the assessment form used during the sanitary survey. Using information provided by the City, well construction, and local surface/subsurface conditions, each wellfield received an estimated score of 15 points by project consultant, Wyoming Groundwater. The points were derived solely from the fact that the Casper Aquifer is fractured. The point total is well below the 40 points needed to initiate further assessment of GWUDISW. Unless the EPA makes a future ruling that all fractured aquifers will be considered GWUDISW, it is unlikely that City wellfields will require a detailed assessment of GWUDISW.

Regardless of EPA's GWUDISW designation process, the City must ensure that the groundwater source is a safe municipal supply. Existing MPA data from City monitoring and production wells are listed in Table 10-9. A total of 43 MPA samples have been collected from monitoring wells at Soldier Springs (33 samples) and production wells at the Pope and Turner wellfields (10 samples). All MPA samples, with the exception of one sample from Pope No. 3, have scores ranked as low risk. A sample collected from Pope No. 3 in 1994 was ranked as a moderate risk with a subsequent sample collected in 1996 ranked as low risk.

City water system operators, however, have observed occasional turbidity and chlorine demand spikes at Soldier No. 1. The cause of these spikes is not known. As an aid to better understanding groundwater characteristics, it is recommended that the City perform MPA sampling and analysis on a sample collected from Soldier No. 1 when these turbidity/chlorine demand spikes occur. As an added precaution, water from Soldier No. 1 should be diverted to Soldier Creek while the turbidity/chlorine demand spikes are occurring until a better understanding of the character and ultimate cause is determined.

In recognition of the value and vulnerability of the Casper Aquifer, the City has developed a Casper Aquifer Protection Plan and a Casper Aquifer Monitoring Program as described previously in this chapter. These programs are designed to ensure continued adequate water quality and quantity from the Casper Aquifer for use by the City of Laramie.

Based on the present day GWUDISW evaluation process used by EPA, existing water quality data, and established Casper Aquifer management programs it is unlikely

that the EPA will designate groundwater from the Spur, Turner, Pope, and Soldier wellfields as GWUDISW. The regular collection and analysis of MPA samples does not appear to be necessary; except as noted during turbidity/chlorine demand spikes at Soldier No. 1.

10.12 Summary of Casper Aquifer Development and Management

1. Casper Aquifer has excellent recharge, storage, and transmission characteristics. The aquifers' value to the City and resiliency to pumping was demonstrated in 2002 during extreme low flow conditions in the Laramie River.
2. Monthly water level monitoring at 50 wells since 2004 by Karl Taboga will provide information needed to evaluate, in real time, hydraulic conditions in the Casper Aquifer. Aquifer research and monitoring efforts must continue and will provide a valuable tool for the protection and development of the Casper Aquifer in the vicinity of Laramie.
3. The 2005 potentiometric surface indicates that the Casper Aquifer is in good hydraulic health despite the below-average March-April precipitation from 1991 to 2005. There is no apparent evidence that the Casper Aquifer is being depleted by over-pumping.
4. Additional groundwater from the Casper Aquifer can be extracted by exercising the City's existing water rights at wells and, when needed, developing wellfields at other locations.
5. With respect to the operation of the Spur Wellfield: when possible, use Spur No. 2 exclusively to reduce drawdown at MW-7 which is the most critical monitoring well for administration of the Spur Wellfield production agreement.
6. The ASR concept of injecting groundwater from the Turner Wellfield into the Spur Wellfield, with associated Turner No. 2 well modifications and/or shallow wells installed near City Springs, should be investigated further.
7. The Turner Wellfield is highly vulnerable to contamination and hydraulic impacts due to proximity to existing and proposed development. The City

(and County) must be diligent and thoughtful regarding the implementation of the Casper Aquifer Protection Plan and associated land use ordinances.

8. The Casper Aquifer Monitoring Program is an important component to the on-going management of the Casper Aquifer. The existing CAMP represents a good initial effort that should be modified and expanded as specified in Section 10.10.

TABLES AND FIGURES

Table 10-1: Production and Drawdown Characteristics of Municipal Production Wells

Well Name	Test Duration	Test Pump Rate	Drawdown End of Test	Specific Capacity
	days	gpm	ft	gpm/ft drawdown
Fractured Casper Aquifer				
Spur No. 1	6.0	2,000	3.4	580
Spur No. 2	5.0	2,000	4.5	440
Turner No. 1	6.9	2,030	30.5	66
Turner No. 2	2.0	1,250	20	62
Pope No. 1	1.0	475	12	40
Pope No. 3	1.0	994	16	62
Pope No. 4	2.0	1,500	12	125
Soldier No. 1	5.8	1,800	9.4	191
Unfractured Casper Aquifer				
LaPrele No. 1*	2.8	200	308	0.6

* Not a municipal production well

Table 10-2: Depth to Water and Head Elevations at Wells Completed in Casper Aquifer; Lundy 1976-77 and Taboga 2005.

Permit #	Well Name	Measuring Point Elevation	Standup	Taboga: Nov - Dec 2005			Lundy: 1976-1977			Head Difference 2005-1976
				Measurement Date	Depth to Water	Head Elevation	Measurement Date	Depth to Water	Head Elevation	
		ft	ft		ft	ft		ft	ft	ft
25335P	Cash 2	7323.2	1.17	11/07/05	72.65	7250.6	11/20/76	72.	7251.2	-0.6
8764P	#1 Berner Mill	7528.0	1.97	11/07/05	157.84	7370.1	11/24/76	153.5	7374.5	-4.3
1483P	Constantinides	7438.0	-5.90	11/22/05	108.6	7329.4	11/24/76	100.5	7337.5	-8.1
30940W	Yramiris #1	7383.9	1.85	11/22/05	61.11	7322.7	12/09/77	52.5	7331.4	-8.6
Unregistered	Unregistered Piper	7487.8	0.75	11/22/05	158.27	7329.5	11/23/76	150.8	7337.0	-7.5
8767P	Government	8366.7	1.69	11/26/05	41.11	8325.6	11/23/76	45.5	8321.2	4.4
8766P	Frenchy	8436.9	0.92	11/13/05	72.52	8364.4	11/23/76	71.7	8365.2	-0.8
8772P	Peanut	7778.2	2.17	11/10/05	30.88	7747.3	11/23/76	31.2	7747.0	0.3
8769P	Kassahn	7540.4	1.38	11/10/05	46.71	7493.7	11/23/76	45.5	7494.9	-1.2
8770P	Klein	8111.4	1.42	11/10/05	89.	8022.4	11/23/76	95.	8016.4	6.0
8768P	Jackrabbit	7849.0	0.00	11/21/05	272.	7577.	11/22/76	274.8	7574.2	2.8
8765P	Dummy	7963.1	0.08	11/20/05	76.73	7886.4	11/24/76	82.2	7880.9	5.5
8777P	West	7914.5	1.45	11/20/05	429.1	7485.4	01/30/77	423.6	7490.9	-5.5
80874P	Powerline	8149.4	2.38	11/20/05	167.2	7982.2	11/22/76	169.3	7980.1	2.1
15315P	Peter	7601.7	1.67	11/03/05	276.05	7325.6	11/22/76	273.	7328.7	-3.1
8778P	Working	7331.3	3.33	11/20/05	86.06	7245.3	11/24/76	88.6	7242.7	2.5
8773P	Pruner	7478.3	1.33	11/21/05	224.75	7253.6	11/22/76	223.8	7254.5	-0.9
8776P	Spur Mill	7799.0	1.00	11/20/05	194.97	7604.	11/22/76	189.6	7609.4	-5.4
8775P	Sawmill	7873.5	0.50	11/20/05	211.26	7662.2	11/22/76	208.8	7664.7	-2.5
8774P	S Canyon	7673.9	3.92	11/20/05	178.39	7495.5	11/18/76	174.4	7499.5	-4.0
5767W	Brow #1	7390.0	-1.50	12/29/05	51.48	7338.5	12/04/76	47.5	7342.5	-4.0
5768W	Brow #2	7420.0	0.50	12/29/05	68.21	7351.8	12/04/76	67.3	7352.7	-0.9
158C	41T3	7354.0	1.30	11/03/05	70.22	7283.8	11/24/76	68.5	7285.5	-1.7
156C	41T1	7273.2	1.30	11/03/05	.34	7272.9	11/29/76	.9	7272.3	0.6
157C	41T2	7305.0	1.00	11/03/05	30.23	7274.8	11/24/76	28.7	7276.3	-1.5

Max	6.0
Min	-8.6
Avg	-1.5

Note: Negative standup values due to measuring point in below-ground vault.

Table 10-3: Completion Data for the Turner Wells

Well	Completion Date	Total Depth	Ground Elevation	Production Capacity	Cased Interval	Casing OD/ID	Pump Intake Set Depth	Pump Bowl Dia.	Annular Cement Seal	Annular Gravel Pack	Open Hole Diameter	Open Hole Interval	Depth to Top of Casper Fm.	Casper Fm. Exposed in Open Hole	Casper Fm. Members Penetrated
		ft	ft amsl	gpm	ft	in	ft	in	ft	ft	in	ft	ft	ft	
Turner No. 1	Oct-81	240	7272.7	2,000	0 - 100	16/15.25	81	13.38	0 - 50	50 - 100	12.25	100 - 240	102	138	epsilon delta
Turner No. 2	Oct-81	350	7259.8	1,400	0 - 100	16/15.25	96	13.25	0 - 50	50 - 100	12.25	100 - 350	76	250	epsilon delta gamma beta

Table 10-4: Spur Wellfield Agreement Drawdown/Production Specifications and Water Level Monitoring

Drawdown at Monitoring Wells per Agreement	Max. Annual Wellfield Production Rate		Max. Daily Wellfield Production Rate	Monitoring Well	Drawdown Jan. 2006	Max. Observed Drawdown 1/01 to 1/06
ft	acre-ft	mg	mgd		ft.	ft.
< 20	1,200	391	4.0	MW-7	10.2	14.0
20 - 25	900	293	3.0	MW-8	10.1	10.6
25 - 30	600	195	2.0	MW-10	9.5	9.5
30 - 35	300	98	1.0	MW-11	10.5	14.1
> 35	0	0	0	MW-12	5.1	5.3

Table 10-5: Water Levels at Soldier Springs Monitoring Wells Completed in Casper Aquifer

Well	Measurement Date	Depth to Water	Head (Water Level)	Comments
		ft	ft amsl	
	5/30/2006	21.09	7318.37	Soldier No. 1 artesian
	6/3/2003	19.65	7319.81	Soldier No. 1 artesian
Soldier MW-1	10/6/1993	17.47	7321.99	
	5/30/2006	11.30	7318.20	Soldier No. 1 artesian
	6/3/2003	9.79	7319.71	Soldier No. 1 artesian
	5/5/1997	4.23	7325.27	
Soldier MW-2	8/21/1995	11.90	7317.60	cistern pump on
	5/30/2006	14.72	7318.18	Soldier No. 1 artesian
	6/3/2003	13.27	7319.63	Soldier No. 1 artesian
	5/5/1997	7.78	7325.12	
	4/21/1997	7.31	7325.59	
	12/31/1996	8.44	7324.46	
Soldier MW-3	8/21/1995	15.43	7317.47	cistern pump on
	5/30/2006	3.06	7317.93	Soldier No. 1 artesian
	6/3/2003	1.55	7319.44	Soldier No. 1 artesian
	5/5/1997	3.90	7324.89	water level above top of casing
	12/31/1996	2.86	7318.13	
Soldier MW-4	8/21/1995	3.86	7317.13	cistern pump on
	5/30/2006	43.00	7321.65	Soldier No. 1 artesian
	6/3/2003	41.32	7323.33	Soldier No. 1 artesian
	4/21/1997	37.12	7327.53	
	12/31/1996	38.34	7326.31	
Soldier MW-5	8/21/1995	46.58	7318.07	cistern pump on

Table 10-6: Water Quality of Injection Water (IW) and Receiving Aquifer (RA)

Parameter	IW - Option 1 Laramie High School* Zone 2	IW - Option 2 Turner No. 2 Casper Aquifer	RA TW-1 Well Casper Aquifer	RA Spur No. 1 Well Casper Aquifer
	mg/L	mg/L	mg/L	mg/L
Calcium	39	55	50	52
Magnesium	11	18	13	16
Sodium	8.2	3.1	2	2.6
Potassium	0.9	0.8	<1	<1.0
Bicarbonate	140	230	213	215
Carbonate	0	0	0	0
Chloride	3.3	<1.0	3	1.1
Sulfate	37	9.7	<1	6.0
Nitrate, as N	0.82	1.7	1	1.6
Fluoride	0.7	0.1	N.D.	0.18
Iron	0.026	N.D.	N.D.	<0.05
TDS	180	224	190	213
pH	7.8	7.4	7.4	8.0

* Proposed injection water is a blend of treated surface water and groundwater

Table 10-7: Casper Aquifer Monitoring Program Wells and Water Quality Parameters

Well Name	Permit #	Location* T, R, Sec, 1/4 1/4	Well Owner	Data Collection	Monitoring Frequency
MacLean	104799	15, 72, 6, NWNE	Wm. MacLean	Water Level	Quarterly
Peanut	8772	15, 72, 29, SESW	Warren Livestock	Water Level	Quarterly
Government	8767	15, 72, 28, NESE	Warren Livestock	Water Level	Quarterly
Frenchy	8766	15, 72, 33, SWNE	Warren Livestock	Water Level	Quarterly
Klein	8770	15, 72, 20, NENE	Warren Livestock	Water Level	Quarterly
S. Canyon	8774	16, 72, 5, SESE	Warren Livestock	Water Level	Quarterly
Spur Mill	8776	16, 72, 8, SESE	Warren Livestock	Water Level	Quarterly
Pruner	8773	16, 73, 13, NWNE	Warren Livestock	Water Level	Quarterly
Nichols	8771	16, 72, 15, SESW	Warren Livestock	Water Level	Quarterly
West	8777	16, 72, 19, NWSE	Warren Livestock	Water Level	Quarterly
Yramiris	30940	15, 73, 14, SESE	Warren Livestock	Water Level	Quarterly
Dummy	8765	15, 72, 8, NESE	Warren Livestock	Water Quality and Level	Semi-Annual
Jackrabbit	8768	16, 72, 29, NWSE	Warren Livestock	Water Quality and Level	Semi-Annual
Peter	15315	16, 72, 30, NWSW	Warren Livestock	Water Quality and Level	Semi-Annual

* See Plate 10-1 for well locations

Water Quality Parameters (Development Series)

Calcium
Magnesium
Sodium
Potassium
Carbonate
Bicarbonate
Chloride
Fluoride
Nitrate as N
Nitrite as N
Sulfate
Copper
Iron
Lead
Manganese
Zinc
pH
Conductivity
TDS, sum

Table 10-8: Monitoring Wells Owned by City of Laramie

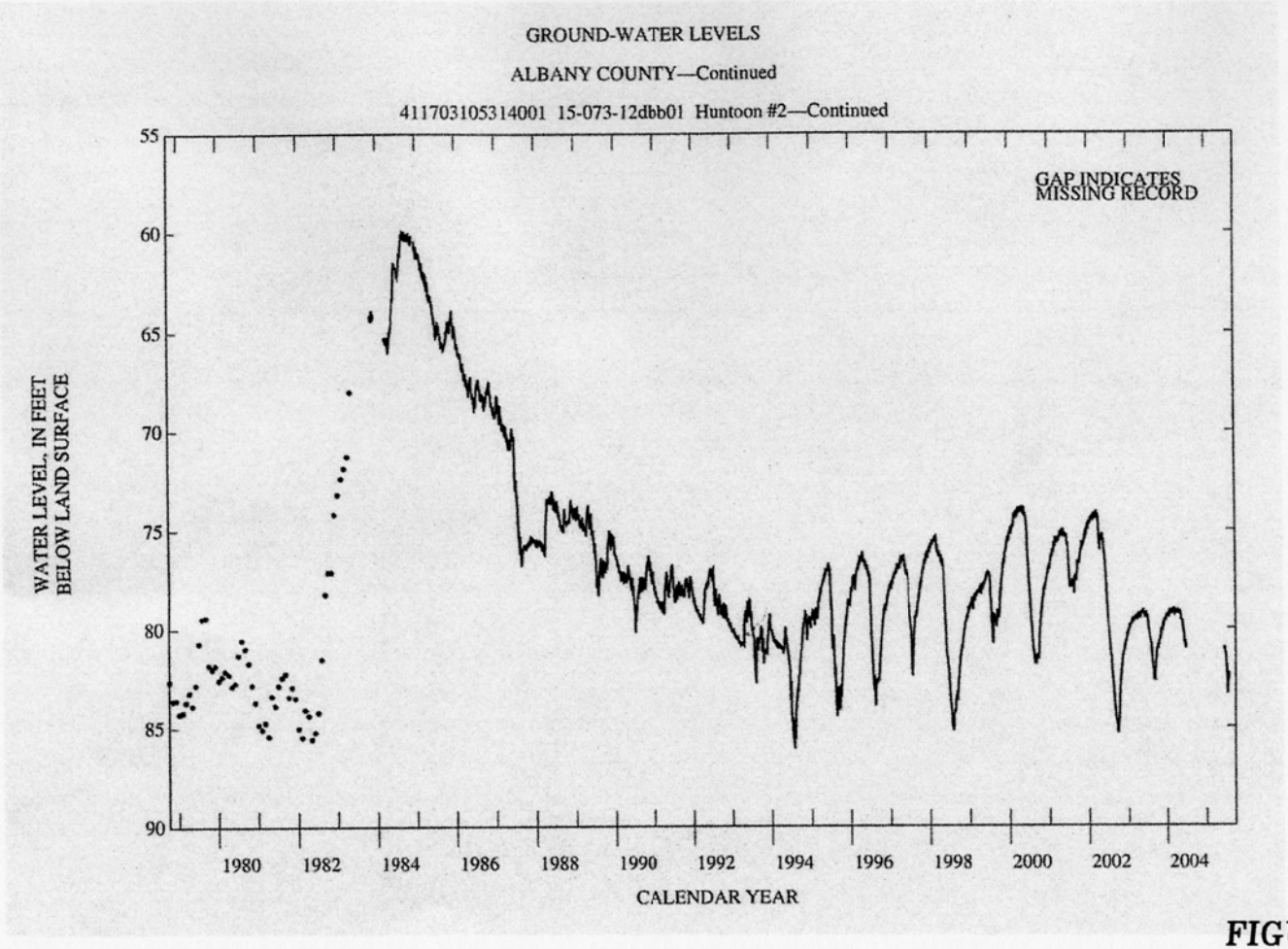
Well Name	Permit #	Location* T, R, Sec, 1/4 1/4	Formation of Well Completion	Comments
Turner No. 1 (41T1)	S.C. 156	15, 73, 2, NENW	Casper	Completed in 1941
Turner No. 2 (41T2)	S.C. 157	15, 73, 2, NWNE	Casper	Completed in 1941
Turner No. 3 (41T3)	S.C. 158	16, 73, 35, NENE	Casper	Completed in 1941
LAPCA-1	99776	15, 73, 3, NWNE	Casper	East end of LaPrele Park
LAPFOR-1	99777	15, 73, 3, NENE	Forelle Limestone	East end of LaPrele Park
SHFCA-1	99778	15, 73, 2, SENW	Casper	SHMWE on Plate 10-1
SHFCA-2	99779	15, 73, 2, SWNE	Casper	SHMWW on Plate 10-1
LaPrele No. 1	99780	15, 73, 3, SENE	Casper	
TW-1	95556	16, 73, 2, NENE	Casper	Next to Spur No. 1
Spur MW-1	95553	16, 73, 2, NWNE	Casper	
Spur MW-2	95554	16, 73, 2, NWNE	Casper	
Spur MW-3	95555	16, 73, 2, NENE	Casper	
Spur MW-4	105336	16, 73, 2, NWNW	Casper	
Spur MW-5	105337	16, 73, 2, NENE	Casper	
Spur MW-6	105338	16, 73, 2, NENE	Casper	
Spur MW-7	106525	16, 73, 1, NWNW	Casper	Spur agreement mon. well
Spur MW-8	106528	16, 73, 1, SWNW	Casper	Spur agreement mon. well
Spur MW-9	106527	16, 73, 2, NWSE	Casper	
Spur MW-10	106528	16, 73, 12, NWNW	Casper	Spur agreement mon. well
Spur MW-11	106529	16, 73, 1, NWNE	Casper	Spur agreement mon. well
Spur MW-12	106530	16, 72, 6, NENW	Casper	Spur agreement mon. well
Spur MW-13	107120	16, 73, 2, NENW	Satanka Shale	
Soldier MW-1	92936	15, 73, 23, SWSE	Casper	Sampling pump in well
Soldier MW-2	99770	15, 73, 23, SWSE	Casper	Sampling pump in well
Soldier MW-3	99771	15, 73, 23, SWSE	Casper	Sampling pump in well
Soldier MW-4	99772	15, 73, 23, SESW	Casper	Sampling pump in well
Soldier MW-5	99773	15, 73, 23, SWSE	Casper	Sampling pump in well
Simpson MW-1	105082	15, 73, 34, SESE	Casper	
Laramie East Quarry #1	106852	15, 72, 18, NENW	Casper	Laramie East #1 on Plate 10-1
Laramie East Quarry #2	106853	15, 72, 7, SESW	Casper	Laramie East #2 on Plate 10-1

* Location of most wells shown on Plate 10-1

Table 10-9 : Results of Microscopic Particulate Analysis (MPA) at City Wellfields

Well ID	Sample Date	MPA Score	Risk*	Bioindicators Detected
Soldier Wellfield				
Soldier MW-1	11/5/1995	0	Low	ciliates
	1/7/1996	0	Low	pollen, ciliates
	3/27/1996	0	Low	pollen, ciliates, flagellates
	4/10/1996	0	Low	pollen, ciliates
	4/11/1996	0	Low	pollen, ciliates
	4/12/1996	0	Low	pollen
	4/14/1996	0	Low	pollen, ciliates
	4/16/1996	0	Low	ciliates
	5/19/1996	0	Low	pollen, ciliates
Solder MW-2	11/5/1995	0	Low	N.D.
	1/7/1996	0	Low	N.D.
	3/27/1996	0	Low	N.D.
	4/10/1996	0	Low	N.D.
	4/11/1996	0	Low	N.D.
	4/12/1996	0	Low	N.D.
	4/14/1996	0	Low	N.D.
	4/16/1996	0	Low	pollen
	5/19/1996	0	Low	N.D.
Soldier MW-3	11/12/1995	0	Low	N.D.
	1/15/1996	0	Low	N.D.
	5/26/1996	0	Low	ciliates
Soldier MW-4	11/12/1995	0	Low	N.D.
	1/15/1996	0	Low	N.D.
	3/27/1996	0	Low	N.D.
	4/10/1996	0	Low	N.D.
	4/11/1996	0	Low	N.D.
	4/12/1996	0	Low	N.D.
	4/14/1996	0	Low	N.D.
	4/16/1996	0	Low	N.D.
	5/19/1996	0	Low	N.D.
Soldier MW-5	11/12/1995	0	Low	pollen, ciliates
	1/15/1996	0	Low	flagellates
	5/26/1996	0	Low	pollen
Pope Wellfield				
Pope No. 1	7/6/1994	6	Low	diatoms, pollen, ciliates
	2/4/1996	1	Low	rotifers, pollen, flagellates
Pope No. 2	7/6/1994	6	Low	diatoms, pollen, ciliates
	2/5/1996	1	Low	rotifers, pollen
	5/26/1996	6	Low	diatoms, pollen
Pope No. 3	6/15/1994	15	Moderate	algae, diatoms, pollen
	2/4/1996	1	Low	rotifers, pollen
Pope No. 4	6/21/1994	0	Low	pollen
Turner Wellfield				
Turner No. 1	6/7/1994	0	Low	pollen
Turner No. 2	6/27/1994	0	Low	pollen

* Risk of Surface Water Contamination: Score ≥ 20 = high risk, 10 - 19 = moderate risk, ≤ 9 = low risk
N.D. = Not Detected



Source: USGS, 2005, Water Resource Data, Wyoming Water Year 2005, Vol. 2. Ground Water, Water–Data Report WY–05–2.

FIGURE 10–1
Huntoon #1 Monitoring Well Hydrograph, 1977–2005

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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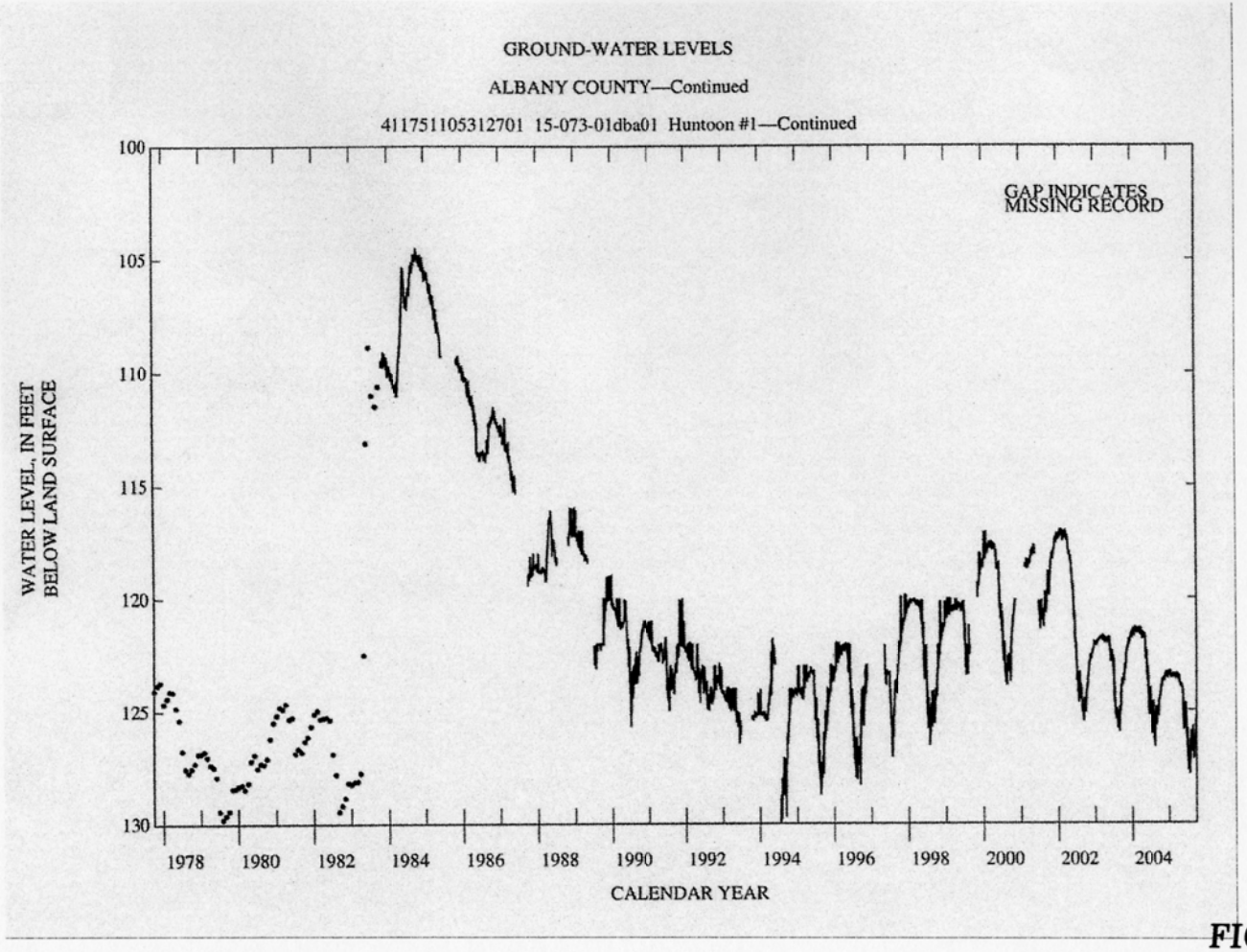

Source: USGS, 2005, Water Resource Data, Wyoming Water Year 2005, Vol. 2. Ground Water, Water–Data Report WY–05–2.

FIGURE 10–2
Huntoon #1 Monitoring Well Hydrograph, 1997–2005

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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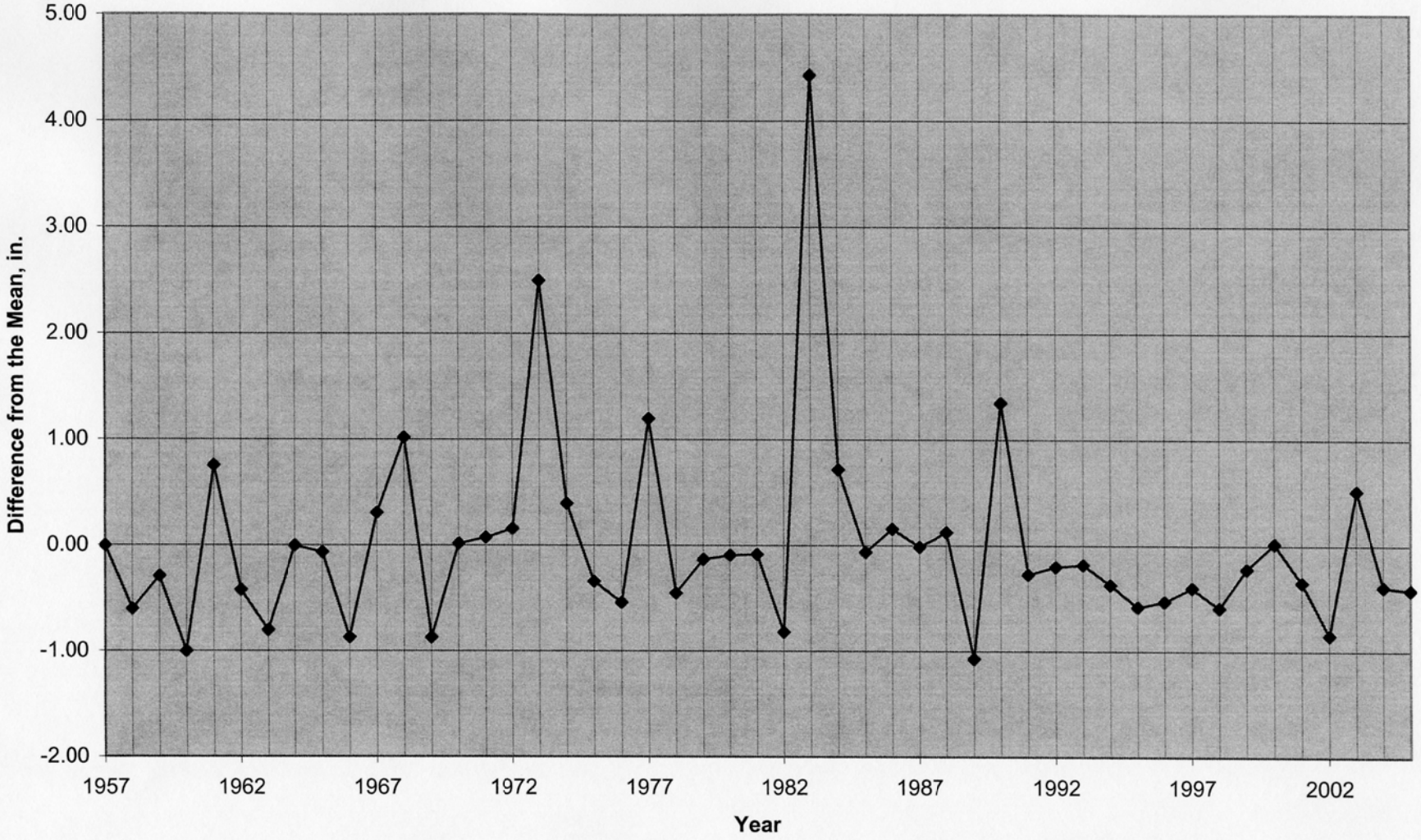
Figure 10- 3: Difference from Mean March + April Precipitation, Laramie FAA Airport (485415)
Laramie Water Management Study, Level II, Wyoming Water Development Commission



0 400'
SCALE

FIGURE 10-4
Location of Proposed Shallow Wells at City Springs

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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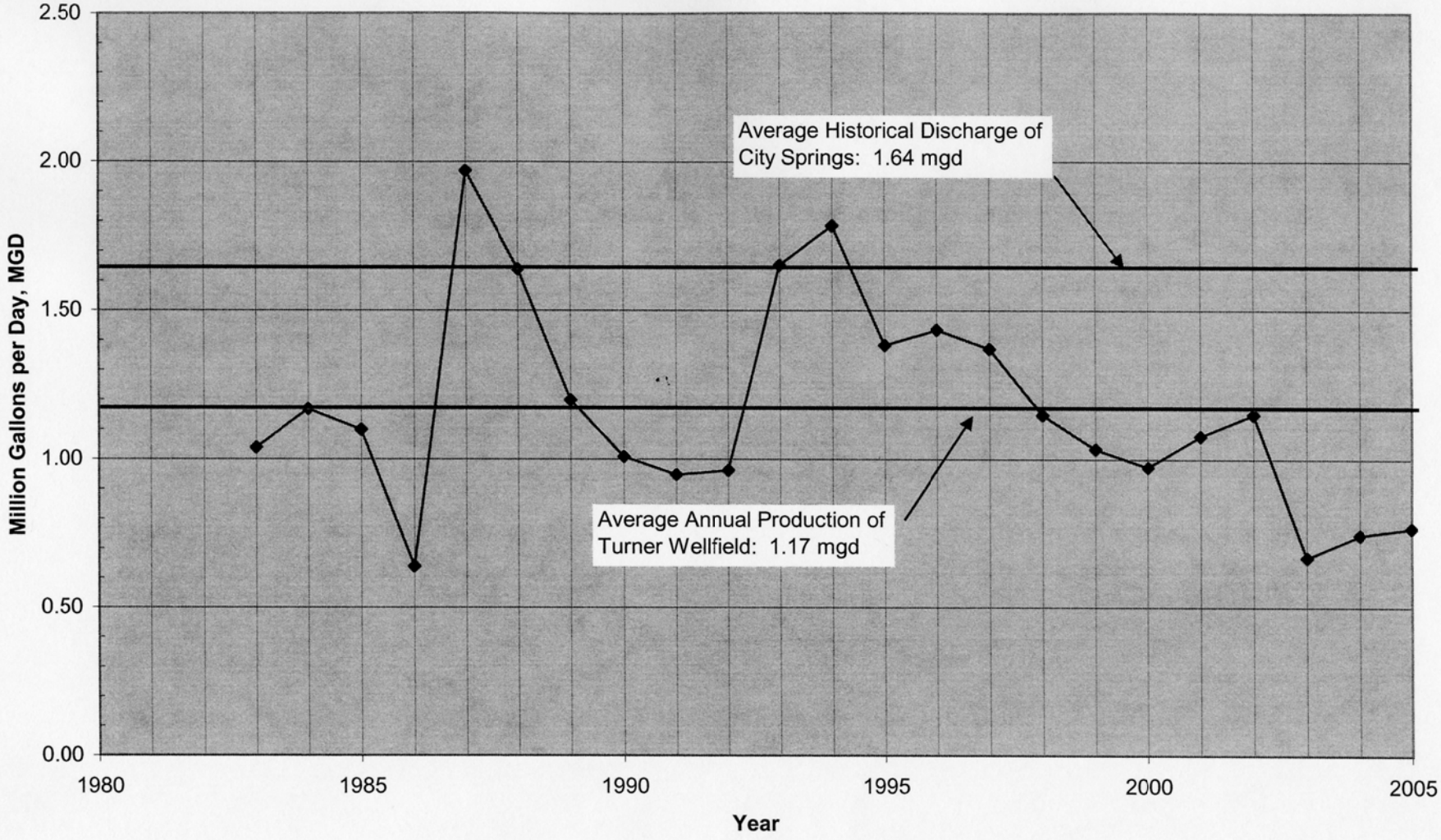
Figure 10-5: Annual Production Rate from the Turner Wellfield - 1983 to 2005.
Laramie Water Management Study, Level II, Wyoming Water Development Commission



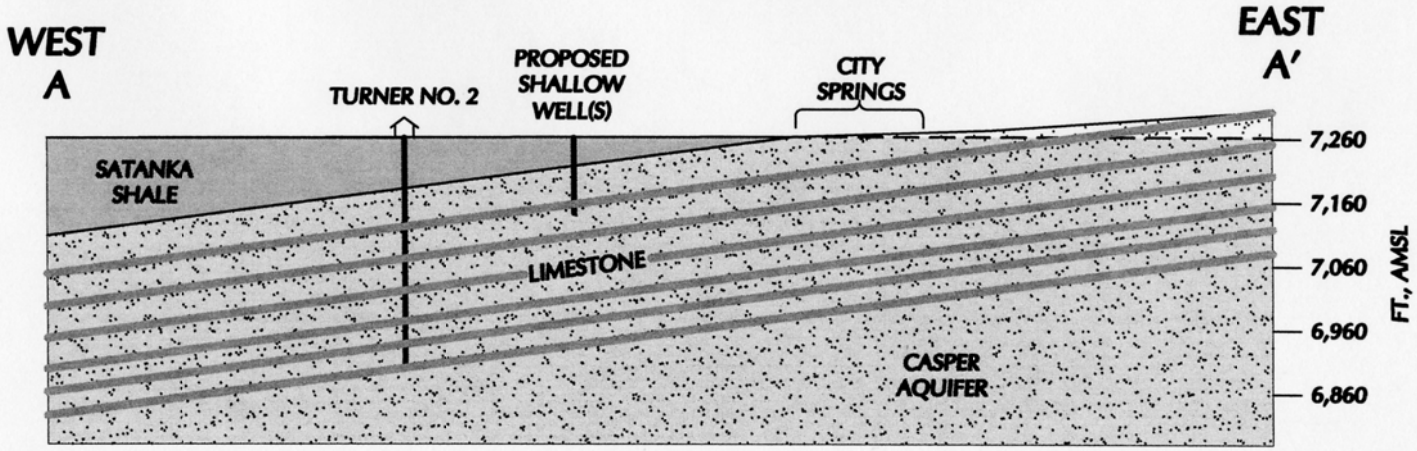


FIGURE 10–6
CROSS–SECTION A–A'

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

0 300'
SCALE

WYOMING
GROUNDWATER, LLC

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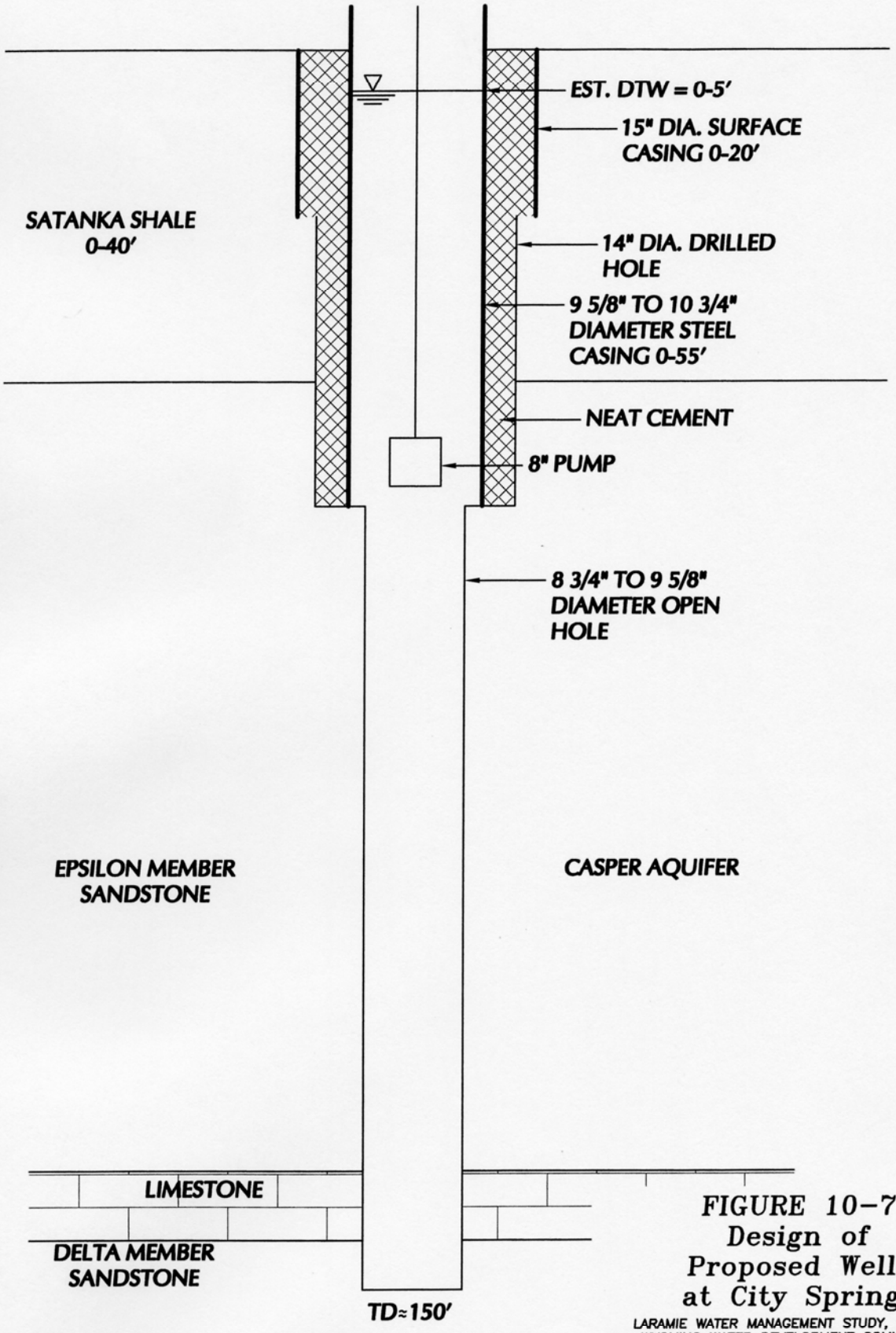

FIGURE 10-7
Design of Proposed Wells at City Springs

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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Figure 10 - 8: Comparison of Drawdown Curves at Turner No. 1 and Turner No. 2 Wells
1995 Turner No. 1/No. 2 Test and 2005 Turner No. 1/No. 2 Test

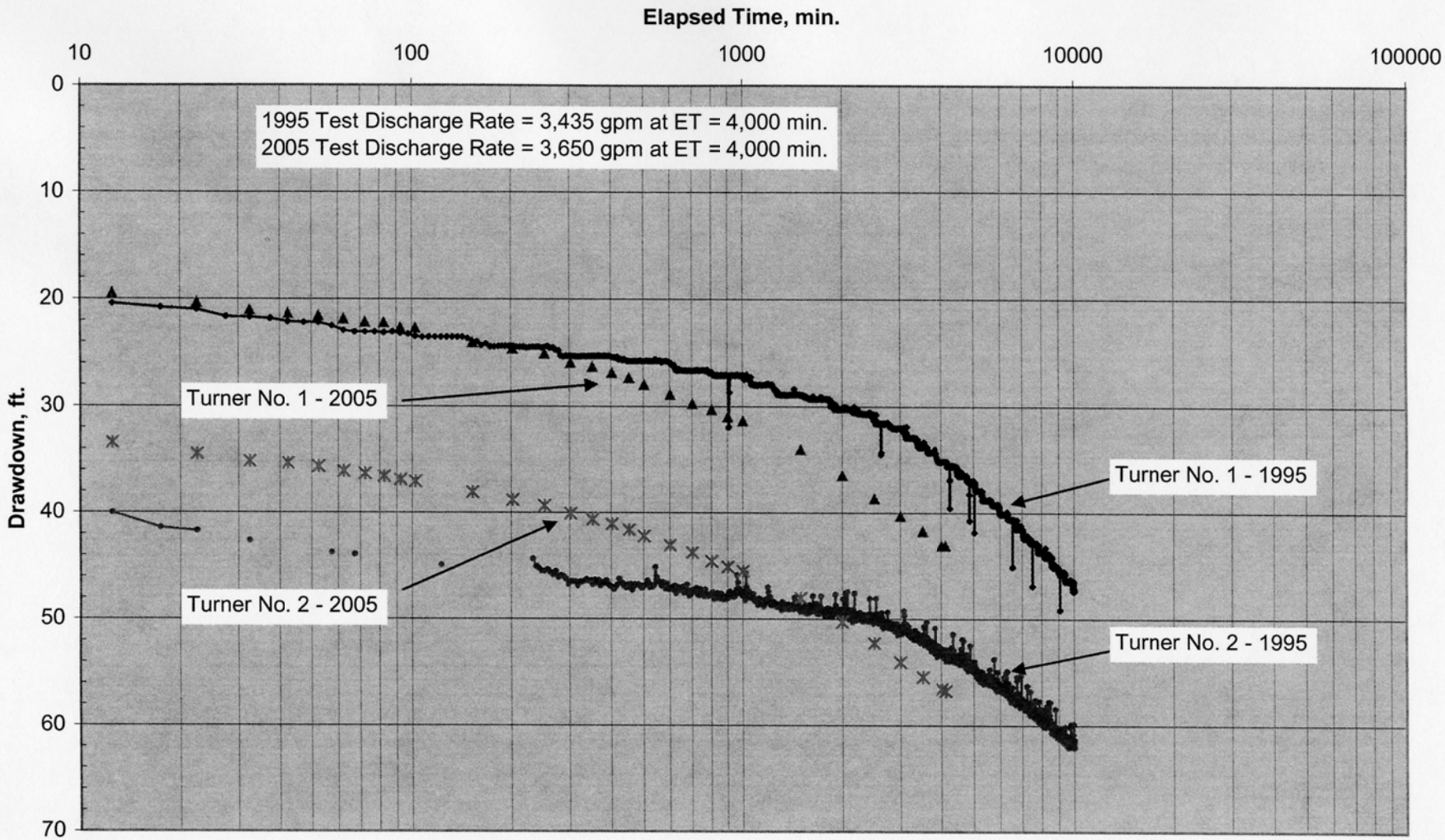
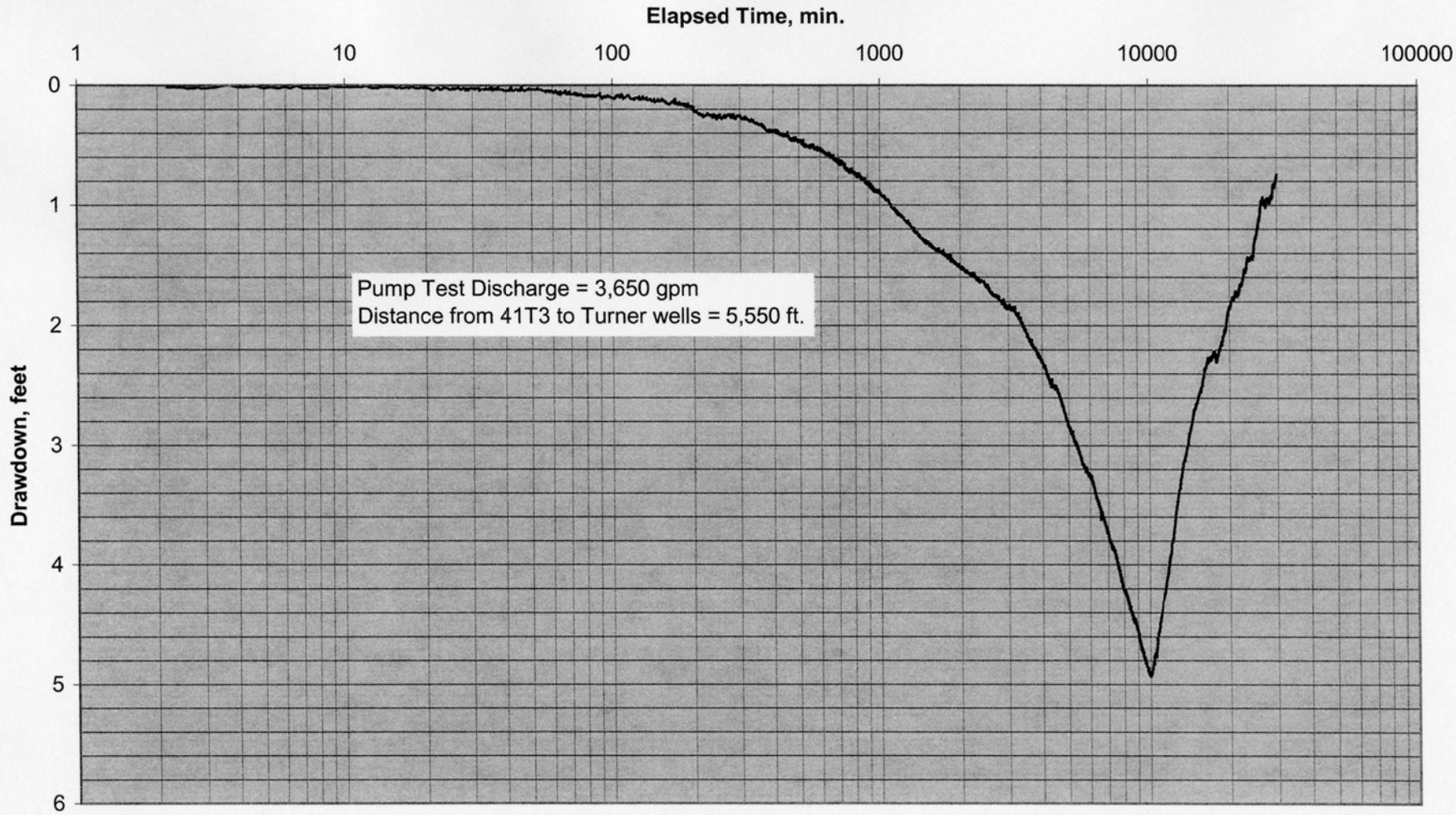


Figure 10-9: Time-Drawdown at Observation Well 41T3, September 27 to October 4, 2005, Pump Test at Turner No. 1 and Turner No. 2, Laramie Water Management Study, Level II, Wyoming Water Development Commission



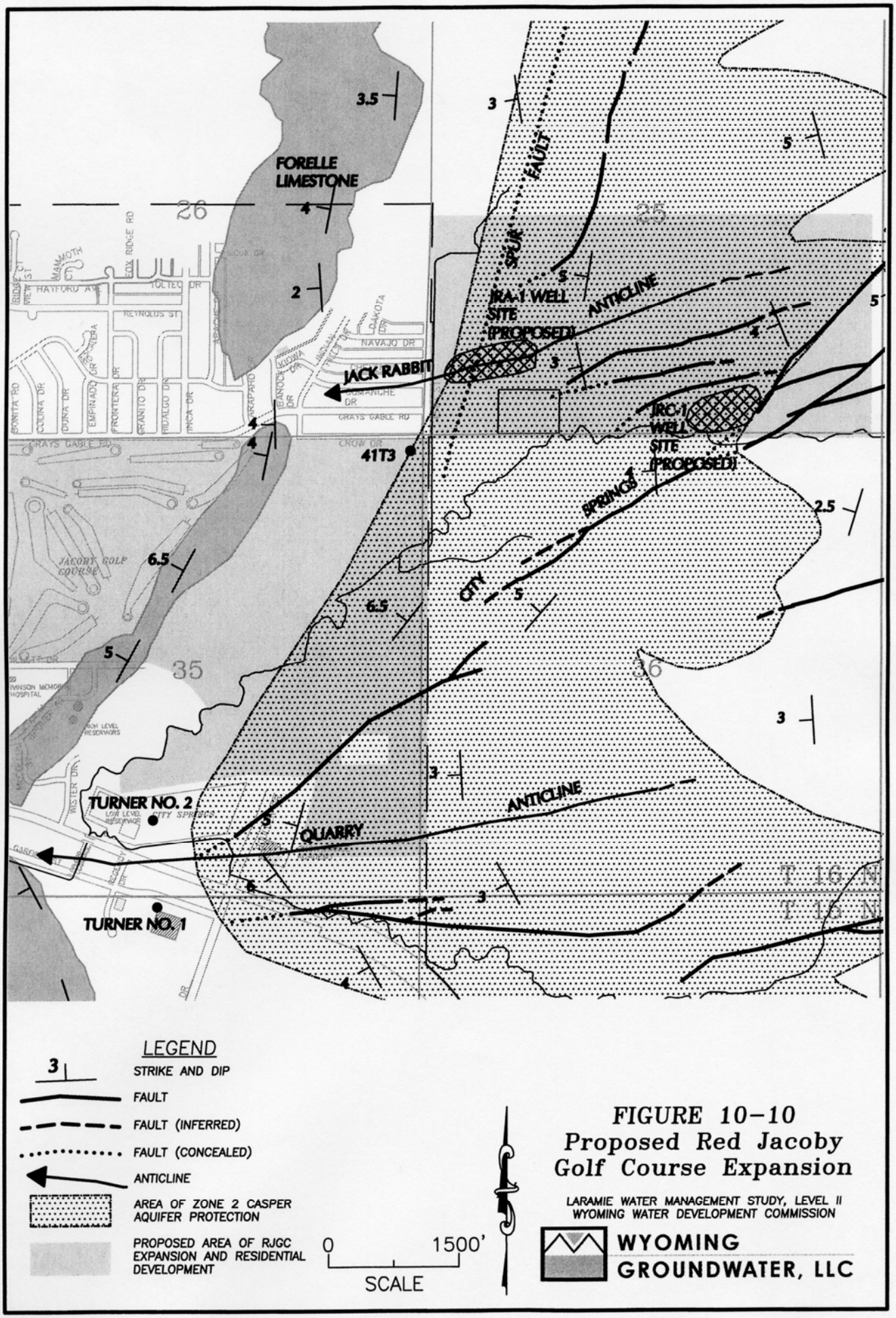


FIGURE 10-10
Proposed Red Jacoby Golf Course Expansion

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

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Figure 10-11: Total Monthly Production From Spur Wellfield - 2001 to 2005.
Laramie Water Management Study, Level II, Wyoming Water Development Commission

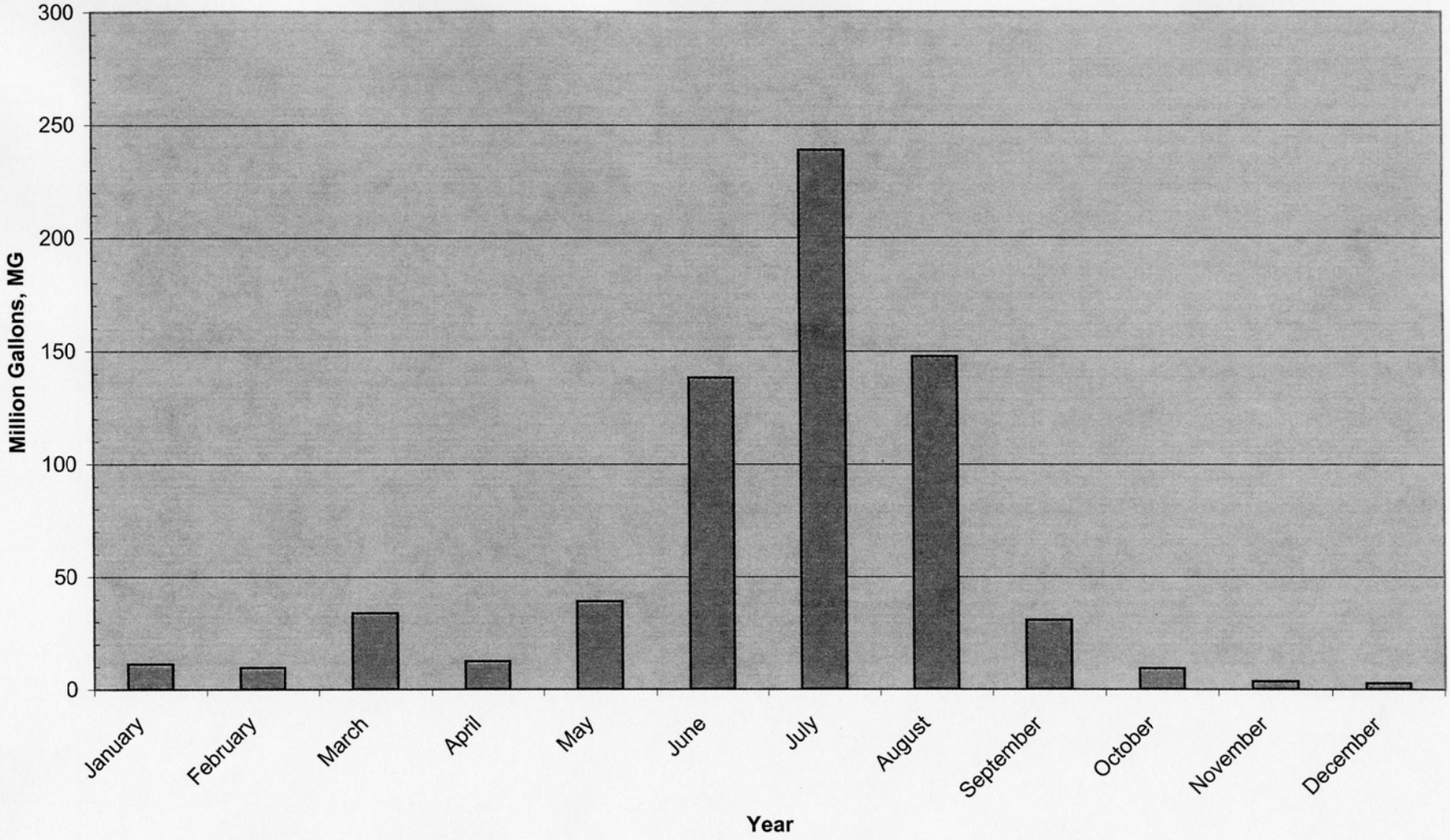


Figure 10-12: Hydrograph of Spur MW-7, 9/1999 to 6/2006
Laramie Water Management Study, Level II, Wyoming Water Development Commission

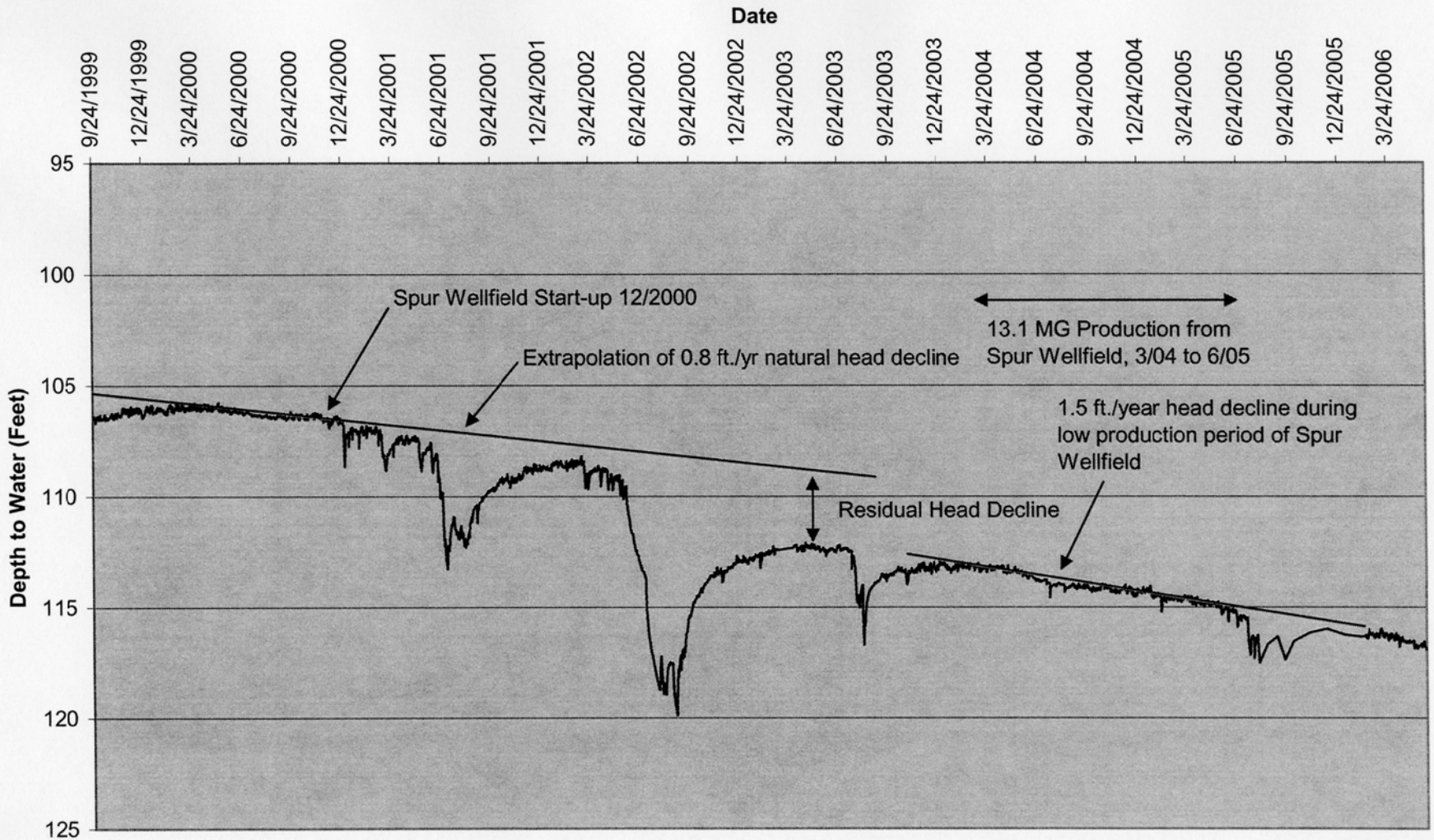
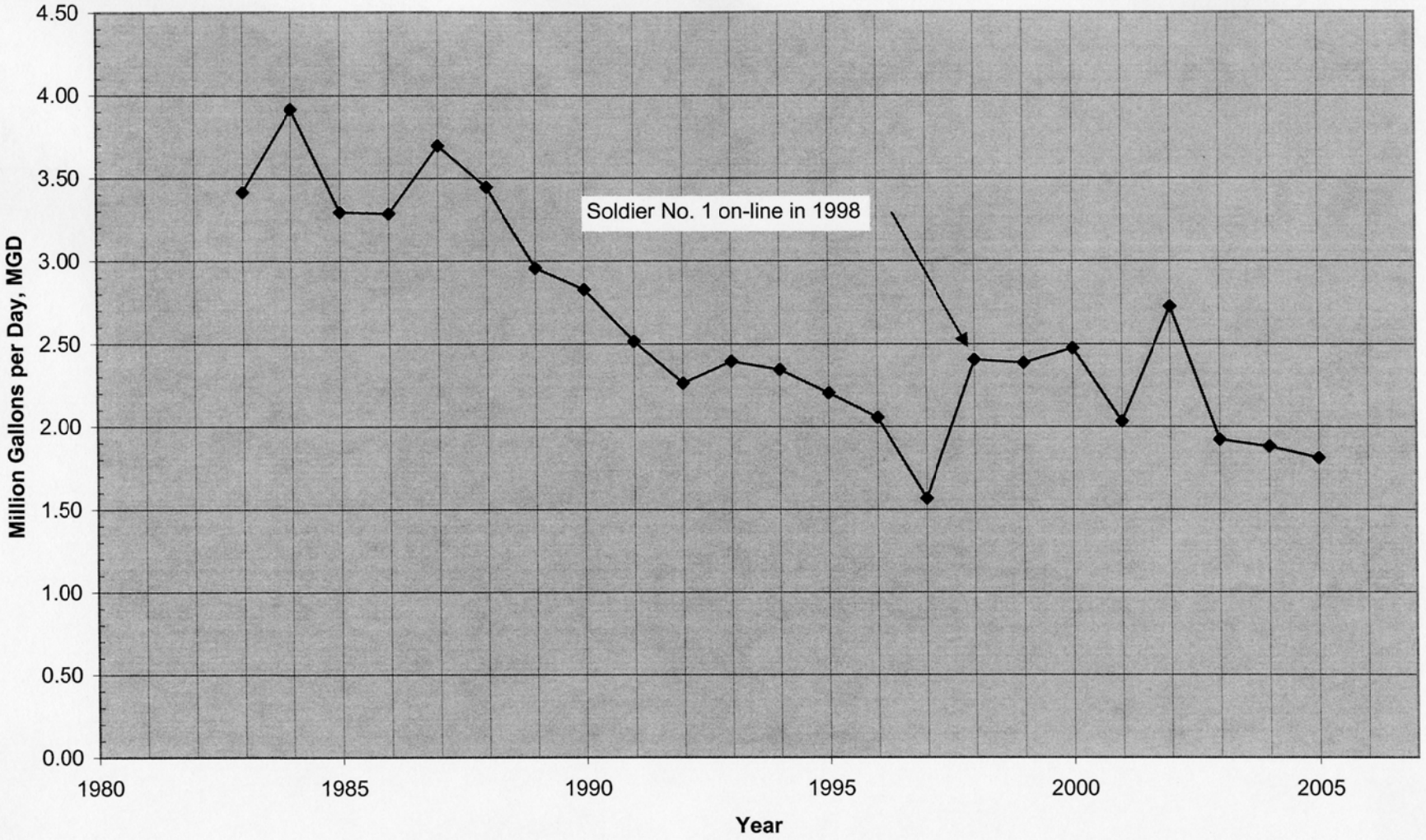
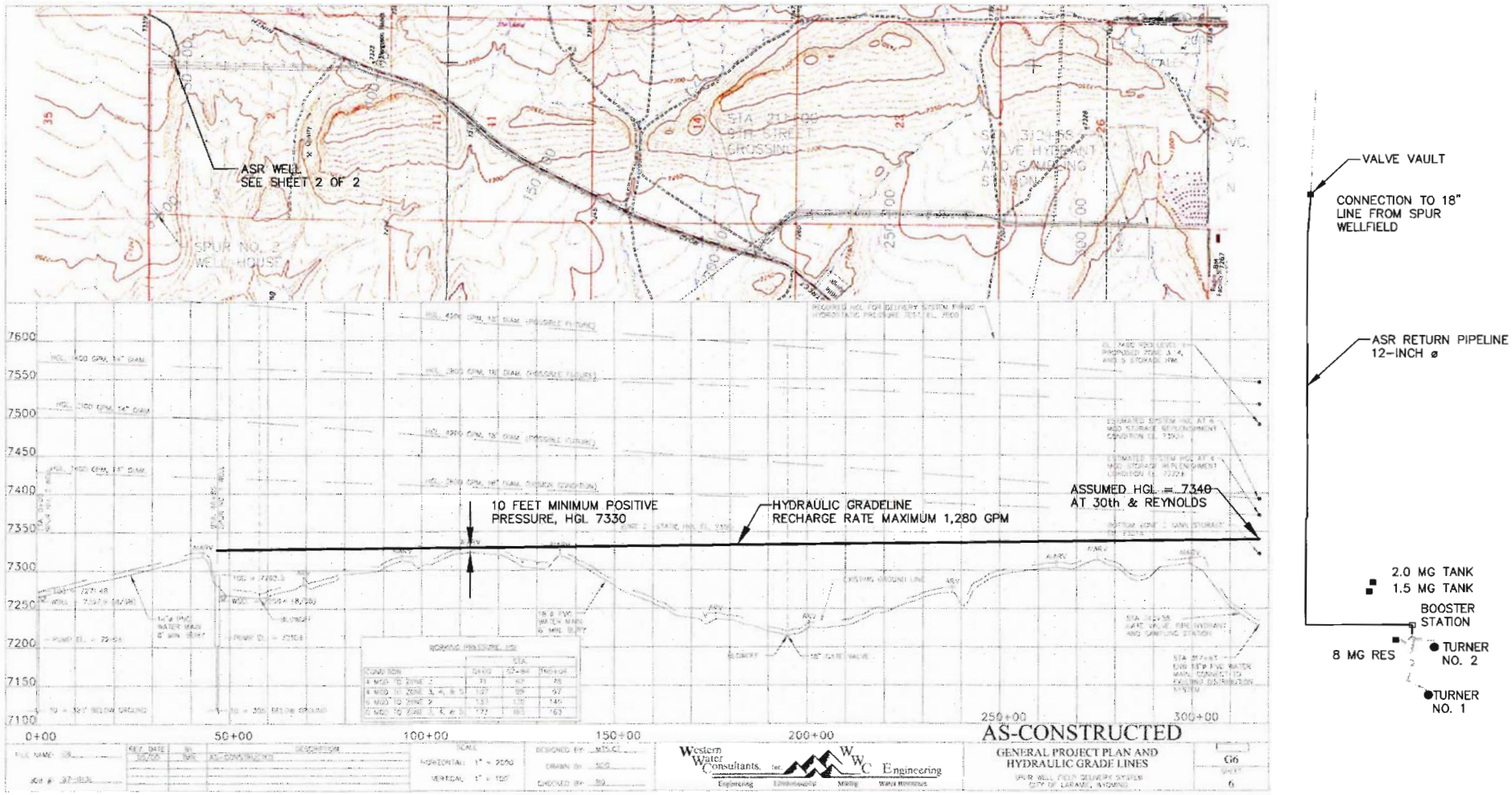


Figure 10-13: Combined Annual Production From Pope and Soldier Wellfields - 1983 to 2005.
Laramie Water Management Study, Level II, Wyoming Water Development Commission





NOT TO SCALE

FIGURE 10–14

ASR CONCEPTUAL DESIGN
SHEET 1 OF 2

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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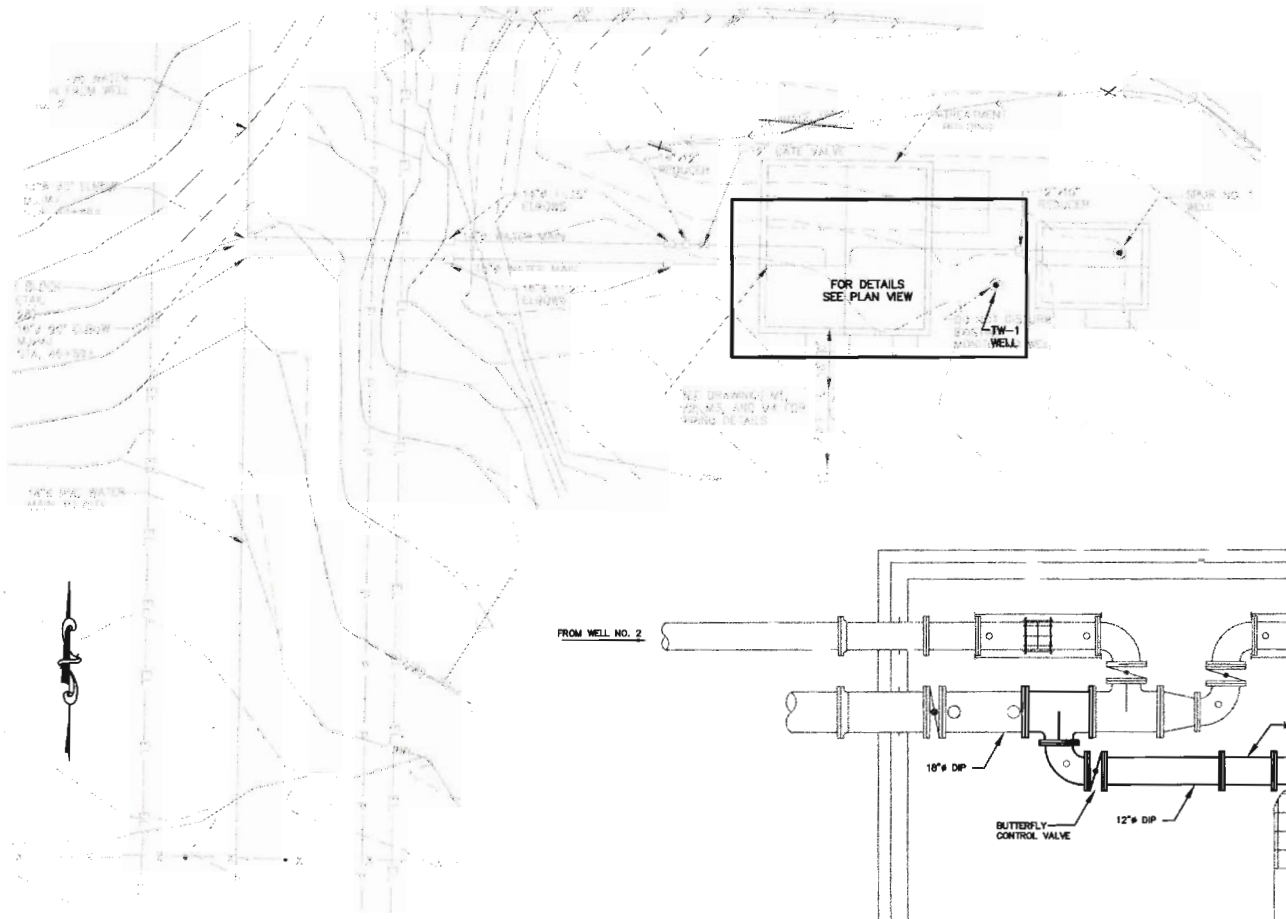
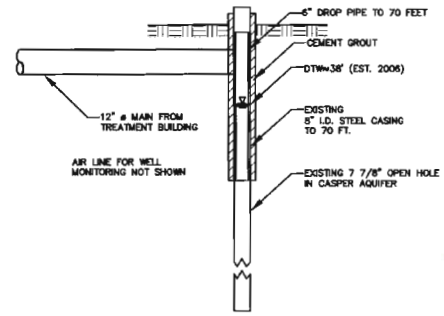
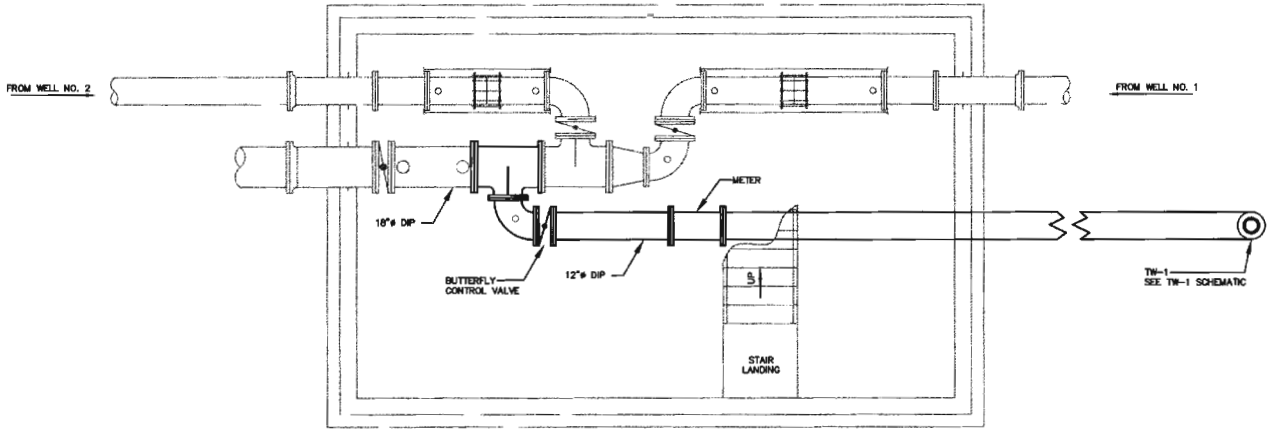




TW-1
SCHEMATIC



PLAN

FIGURE 10-15
ASR CONCEPTUAL DESIGN
SHEET 2 OF 2

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WWC ENGINEERING

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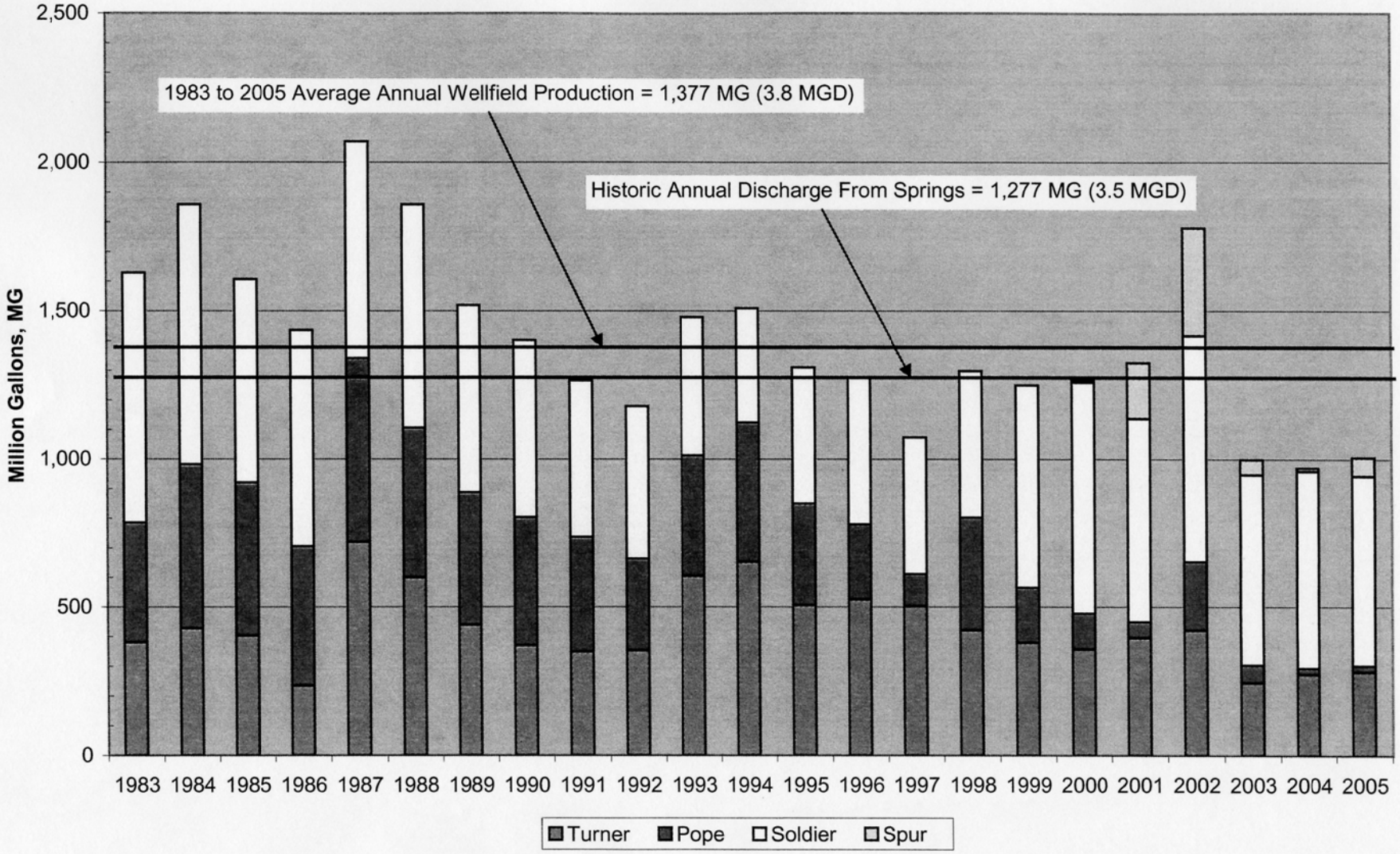
Figure 10-16: Annual Wellfield Production - 1983 to 2005.
Laramie Water Management Study, Level II, Wyoming Water Development Commission



CHAPTER 11.0
WATER SUPPLY ELEMENT

11.0 WATER SUPPLY ELEMENT

11.1 Introduction

This Chapter describes the first of three Water System Master Plan Elements: the Water Supply Element. The Water Supply Element, combined with the TD&S (Chapter 12) and Operations (Chapter 13) Elements define the cost side of the Water System Master Plan presented in Chapter 14. Figure 14-1 shows the relationship of these items.

The Water Supply Element presents the specific water supply projects and water resource protection activities that are recommended to meet the forecasted municipal water demands outlined in Chapter 4. The projects are listed in Table 11-2. These projects have been selected using the following information:

- The water supply strategies presented in Chapter 5,
- The Short list of preferred projects described in Chapter 5, and
- Refinements to the Short List that are documented in Chapters 6, 8, 9 and 10.

11.2 Water Supply Capabilities

Table 11-1 presents a summary of the water production capabilities for the components of the City's existing and recommended water supply projects. This information is the result of the work presented in the previous chapters and updated discussions with City Staff, This table shows the average day, summer average day, and peak day water production capabilities of each component. This information is different than that presented in the Monolith Ranch Water Rights Management Plan (MRWRMP), because after further discussion the project team (City and Consultants) felt that the summer three month production capability of the resources was a potential constraint that should be closely examined when performing water supply planning.

11.3 Water Supply Development Plan

Table 11-2 graphically shows the recommended sequence and schedule of water supply projects over a 30-year planning horizon (2006 – 2035). The timing of supply improvement projects is dictated by the projected water supply deficit. As the population,

shown at the top of the table increases, so does the projected demand. At some point in time, one of the three water supply capabilities (average day, peak summer, or peak day) is exceeded by the demand. At that time, a new water supply project needs to be activated. The sequencing of projects is similar to that performed in the MRWRMP; however, the number of supply projects is fewer. This is because the target population is less than that used in 2004. As shown in Table 11-2, there is only one water supply project needed to expand supply in the 20-year planning horizon. That project includes improvements at the Turner Wellfield area. This project includes the development of an aquifer storage and recovery (ASR) program at the Spur Wellfield. Although the ASR component would not increase water supply, it would help maintain the reliability of the existing Spur resource at a cost much less than developing a new resource in a distant location, such as Simpson Springs.

Table 11-2 presents several other projects that do not directly expand the treated water supply of the City, including the Laramie River Pipeline Project and Water Treatment Plant Improvements. These two projects are needed for other reasons, as explained in Chapters 8 and 6 respectively.

Finally, Table 11-2 shows that the Park Irrigation with groundwater project should be advanced to eventually be fully implemented just beyond the planning horizon of 20 years. The City should not interpret this portion of the table too literally without review of the alternative irrigation water evaluation in Chapter 9. It is entirely possible that irrigation with raw surface water, reuse water, or continued irrigation with potable water may be the most feasible. A new evaluation of these alternatives should be performed 5 to 10 years or sooner if actual demands exceed projections.

The City can customize the activities and sequence the construction of these recommended projects differently yet continue on a schedule to meet the water demands of the City. These types of changes can be accommodated as long as the City follows their historic position of developing water projects ahead of demand, and maintains the important water supply balance between surface and groundwater developments.

11.4 Water Supply Element

Table 11-3 presents a summary of the projects and cost estimates for the water supply element of the Water System Master Plan. This list of projects includes those that are needed to meet the needed supply improvements shown on Table 11-2 and several projects that the City staff had been planning to accomplish in the coming years. These projects were identified in the 2005-2006 budget sheets of the City (Appendix 14A), and typically include such items as equipment at the water treatment plant. The specific projects are also indicated in the spreadsheets that support the Master planning work presented in Chapter 14.

11.5 Environmental Report

The contract scope of work requires that an environmental report be compiled to comply with NEPA requirements. The purpose of this report is to provide a summation of the potential impacts to a long list of resources, such as flood plains, cultural resources etc., that might be impacted by projects that arise from the efforts of this study, whether WWDC funded at Level III, or otherwise. The process of obtaining determinations from affected agencies (e.g. USF&WS, USACOE, etc.) involved mailing letters and collecting responses. A summary of the responses, and copies of the letters, are provided in Appendix 11A.

TABLES AND FIGURES

Table 11-1 - Summary of Water Supply Capability

	Capability, MGD					
	Average Daily Supply		Average Summer Supply		Peak Day Capacity	
	Minimum Reliable[1]	Used For Planning	Minimum Reliable[1]	Used For Planning	Rated Peak	Used For Planning
EXISTING WATER RESOURCES						
Laramie River - Existing Diversion Right	6.00	6.00	6.00	6.00	6.47	16.00[4]
Turner Wells (City Springs)	1.60	3.40[2]	1.60	5.41[2]	4.00	
Pope Wells	2.18[7]		3.71[3]		5.00	
Soldier Well						
Spur Wells	NA		0.70[6]		4.00	
TOTAL	9.78	9.40	12.01	11.41	19.47	16.00
POTENTIAL WATER RESOURCES						
Pipeline To River, Plant Upgrades and Booster Station.		2.78		2.78		2.78
Simpson Well		0.50		1.00[8]		2.00
Turner Well Field Modifications		0.40		0.80[8]		1.60
Park Irrigation - Groundwater		NA		1.68[5]		1.68[5]

Notes:

1 Minimum reliable supplies are the reliably available surface water flows and spring discharges that would be lost downstream if not captured and used immediately. Assumes Pipeline installed from WTP to Laramie River

2 Planning value is 90% or aggregate minimum

3 Based on 1998, 1999, 2000, 2002 Average use.
Rated peak values are as follows:
River
- Assumes all but 1/100 year type river hydrology, summer diversion with 30% loss, no Sodergreen benefit or clearwell storage

Soldier and Pope Wells
- This value is the maximum that the Pope Soldier pipeline can deliver within a pressure constraint.
- This flow rate was observed in 1998 startup.

Spur Wells
- Instantaneous production maximum observed in 2000 Startup.

Turner Wells

4 This planning value is based on 1/04 discussion with Mike Lytle as part of the 2004 MRWRMP. He felt that 16 mgd is the reliable peak capability of the combined sources.

5 Represents irrigation requirement for groundwater use at parks presented in Chapter 9.

6 Based on average projected decline on a 17 year schedule until groundwater agreements are expired.

7 Based on 1992-2005 Average.

8 Assumed at 2 times the average day supply.

Table 11-2 - Water Supply Development and Protection Plan Summary

Year		2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	Un-Scheduled
Projected Service Area Population		30,032	30,295	30,558	30,822	31,085	31,348	31,579	31,810	32,042	32,273	32,504	32,727	32,951	33,174	33,398	33,621	33,820	34,019	34,219	34,418	34,617	34,816	35,015	35,215	35,414	35,613	35,812	36,011	36,211	36,410	36,609	
Demands, MGD																																	
Peak Day	504	15.14	15.27	15.40	15.53	15.67	15.80	15.92	16.03	16.15	16.27	16.38	16.49	16.61	16.72	16.83	16.94	17.05	17.15	17.25	17.35	17.45	17.55	17.65	17.75	17.85	17.95	18.05	18.15	18.25	18.35	18.45	
Ave Summer Day	331	9.94	10.03	10.11	10.20	10.29	10.38	10.45	10.53	10.61	10.68	10.76	10.83	10.91	10.98	11.05	11.13	11.19	11.26	11.33	11.39	11.46	11.52	11.59	11.66	11.72	11.79	11.85	11.92	11.99	12.05	12.12	
Ave Day	210	6.31	6.36	6.42	6.47	6.53	6.58	6.63	6.68	6.73	6.78	6.83	6.87	6.92	6.97	7.01	7.06	7.10	7.14	7.18	7.23	7.27	7.31	7.35	7.40	7.44	7.48	7.52	7.56	7.60	7.65	7.69	
Supply, MGD Note 5																																	
Peak Day		16.00	16.00	16.00	16.00	16.00	16.00	16.00	17.60	17.60	17.60	17.80	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	17.60	19.28	19.28	19.28	19.28	19.28	19.28	19.28	19.28	19.28	
Ave Summer Day		11.41	11.41	11.41	11.41	11.41	11.41	11.41	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	12.21	13.89	13.89	13.89	13.89	13.89	13.89	13.89	13.89	13.89	
Ave Day		9.40	9.40	9.40	9.40	9.40	9.40	9.40	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	9.80	10.35	10.35	10.35	10.35	
Surplus Supply, MGD																																	
Peak Day		0.86	0.73	0.60	0.47	0.33	0.20	0.08	1.57	1.45	1.33	1.22	1.11	0.99	0.88	0.77	0.66	0.55	0.45	0.35	0.25	0.15	0.05	1.63	1.53	1.43	1.33	1.23	1.13	1.03	0.93	0.83	
Ave Summer Day		1.47	1.38	1.30	1.21	1.12	1.03	0.96	1.68	1.60	1.53	1.45	1.38	1.30	1.23	1.16	1.08	1.02	0.95	0.88	0.82	0.75	0.69	2.30	2.23	2.17	2.10	2.04	1.97	1.90	1.84	1.77	
Ave Day		3.09	3.04	2.98	2.93	2.87	2.82	2.77	3.12	3.07	3.02	2.97	2.93	2.88	2.83	2.79	2.74	2.70	2.66	2.61	2.57	2.53	2.49	2.45	2.40	2.36	2.32	2.28	2.79	2.75	2.70	2.66	

Resource	Project	Additional Water Provided: Peak Day mgd	Ave Summer Day - from Table 11-1 mgd	Ave Day mgd	Notes
Monolith Ranch					
	Dowlin Ditch Water Rights Maintenance				Note 1,2
	Goforth Reservoir Rehabilitation				Note 1
	Five Mile Creek/Harney Creek Irrigation Rehabilitation				Note 1
	Park Irrigation with Surface Water	2.00	1.66	0.66	Note 3
Laramie River					
	Pipeline - River to WTP				Note 4
	WTP Upgrades				
	Booster Station	2.78	2.78	2.78	
	Security Improvements (Surface and Groundwater)				
	Watershed Protection Plan				
Groundwater					
	Turner Modifications and ASR Project	1.60	0.80	0.40	
	Spur Well Field	4.00	0.70	N/A	Note 7
	Simpson Springs	2.00	1.00	0.50	
	Park Irrigation with Groundwater	1.66	1.66	0.66	Note 3
	Wellhead and Aquifer Protection				

End of the 20-year planning horizon

Notes

1. See detailed discussion in the Monolith Ranch Water Rights Management Plan (Fassett, 2004). These projects protect water resource assets of the Monolith Ranch.
2. These prerequisite actions, studies and ongoing work are leading to a potential transfer of 2,000 to 3,000 AF/Year.
3. This project is beneficial because it effectively reduces the peak and average day demands on the treated water supply. Demand reductions are propotional to the irrigated acreage. Chapter 9 does not demostrate that groundwater development is prefered over continued use of potable water. The need for this project, or other alternative, is beyond the 20 year planning horizon of the water system plan.
4. Project L1 without L2 is beneficial and recommended. L1 by itself provides water supply security during drought conditions. L1 and L2 combined provide additional supply.
5. Water supply capability is presented on Table 11-1.
6. Projected Service Area Population is Laramie Comp Plan Estimate plus 798 person estimate for special service areas.
7. User Agreement expires, Spur Well pumping operation may be changed.

Legend

- Indicates diligent progress and accelerated project costs towards bringing a new water supply or porject on line.
- ■ Indicates periodic progress addressing administrative and prerequisite items related to the project, including water rights maintenance. (Typically less cost intensive than construction).
- ● Indicates critical project completion milestone to overcome projected supply deficit.

Table 11-3 Summary of Capital Improvements for the Water Supply Element of the Water System Master Plan

Projects	2006 Estimated Capital Cost($)		Comments
	Planned Items 20 years	Unplanned Items	
1. Resource Protection			
a) Homeland security	200,000	-	
b) Well-head and aquifer protection	-	-	This project has annual costs assigned in the Master Plan
c) Watershed protection	-	-	This project has annual costs assigned in the Master Plan
d) Water rights (Monolith)	-	-	This project has annual costs assigned in the Master Plan
e) Dowlin Ditch Rights	233,200	-	
f) Goforth Reservoir (drop for C)	501,500	-	
g) 5 Mile/Harney Creek Rehab. (drop for C)	262,700	-	
h) Undefined Project	-	-	
	$1,197,400	$0	
2. Future Supply Development			
a) City Springs/Turner Wells/ASR	3,630,000	-	
b) River Pipeline	7,700,000	-	
c) WTP replacement	-	18,000,000	
d) WTP Booster Station	-	3,000,000	
e) Raw Water Distribution (Parks - Groundwater)	-	7,600,000	
f) Simpson Springs	-	4,776,000	
g) Low Pressure Treatment @ Wye	-	11,000,000	Assumes groundwater contamination
h) Low Pressure Treatment @ Turner	-	9,900,000	Assumes groundwater contamination
i) Low Pressure Treatment @ Spur	-	7,600,000	Assumes groundwater contamination
j) Undefined Project	-	-	
	$11,330,000	$61,876,000	
3. Miscellaneous City Projects			
a) WTP Storage Bldg.	25,000	-	
b) Backwash Reuse	80,000	-	
c) Chlorine Generators	700,000	-	
d) Pope 1 Sanitary Seal	110,000	-	
e) Chemical Storage Bldg.	30,000	-	
f) Equipment Addition	225,000	-	
g) Painting of 2 tanks	230,000	-	
h) 2007 Large meter replacement	134,000	-	
i) Short-term WTP improvements	2,565,000	-	
j) Undefined Project	-	-	
	$4,099,000	$0	
Total Capital Improvement Cost	$16,626,400	$61,876,000	

Note 1: Under different Master Planning scenarios, certain improvements are not included.

Note 2: Project Number corresponds to the project number presented in Master Plan Appendix 14.

CHAPTER 12.0
TRANSMISSION, DISTRIBUTION AND STORAGE ELEMENT

12.0 TRANSMISSION, DISTRIBUTION AND STORAGE ELEMENT

12.1 Introduction

This Chapter describes the second of four Water System Master Plan Elements: the Transmission, Distribution and Storage (TD&S) Element. The TD&S Element is combined with the Water Supply (Chapter 11) and the Operations (Chapter 13) Elements to define the cost side of the Water System Master Plan presented in Chapter 14. Figure 14-1 shows the relationship of these items.

The TD&S Element defines a plan to make the capital upgrades to the transmission, distribution and storage system that were identified in Chapter 7 as being needed to meet TD&S deficiencies.

12.2 TD&S Element Plan

Table 12-1 presents the TD&S Element Plan. The table itemizes the projects and estimated costs for projects that correct deficiencies in the transmission, storage, and distribution system. The TD&S Plan assumes that these projects will be uniformly implemented over a 20-year period.

TABLES AND FIGURES

Table 12-1: Summary of Capital Improvements for the Transmission, Distribution, and Storage Element of the Water System Master Plan

	Projects	2006 Estimated Base Cost ($)	Comments
1.	Capital Improvements needed to meet zone1/zone2 needs		
a)	Peak hour upgrades	15,200,000	
b)	Fire suppression upgrades (drop for budget scenario C)	9,000,000	Requires that Peak Hour upgrades project be complete.
c)	Unspecified Project	-	
	Total for Zone1/Zone2 Upgrade	$24,200,000	
2.	Replacement Program		
a)	Transmission Mains	-	Upgrades to 14" -16" Grand Lines in 1b.
b)	Distribution Lines-high priority (1)	5,060,000	Figure 7-3
c)	medium priority (2)	10,900,000	Figure 7-3
d)	lower priority (3)	13,800,000	Figure 7-3
e)	Tanks	-	Painting in Table 11-3.
f)	Pumps and Equipment	-	
	Total for Replacement Program	$29,760,000	
	Total Transmission, Distribution, and Storage	$53,960,000	

Note: Certain Items are included or excluded from the various Master Planning scenarios, either by adjusting time of commencement, or by specific exclusion.

CHAPTER 13.0
OPERATIONS ELEMENT

13.0 OPERATIONS ELEMENT

13.1 Introduction

This Chapter describes the third of four Water System Master Plan Elements: the Operations Element. The Operations Element is combined with the Water Supply (Chapter 11) and the TD&S (Chapter 12) Elements to define the cost side of the Water System Master Plan presented in Chapter 14. Figure 14-1 shows the relationship of these items.

The Operations Element outlines the operational and maintenance related activities and costs associated with operation of the Utility. Because this study did not devote a large amount of resource to defining this Element, approximations have been made, but we believe they are entirely appropriate for the long range planning that the Water System Master Plan addresses.

13.2 Definition

For the purposes of the Water System Master Plan, the Operations Element is assumed to include all labor, equipment, management, training, miscellaneous supplies, labor benefits, fuel and electrical power, and other non capital items included in the City's budget in the categories indicated in Appendix 14A.

In addition to the typically "budgeted" items of the City, the Operations Element includes the activities and costs needed to elevate the operations side of the Utility to an industry benchmark level. A full presentation of the benchmark standard, the activities, and costs is presented in the following sections

13.3 QualServe Introduction

In 2004 the Laramie Utility Division participated in the QualServe Benchmarking Performance Program sponsored by the American Water Works Association (AWWA). Water and wastewater performance indicators for the year 2003 were identified for the Laramie Utility and submitted to AWWA. Laramie's performance indicators were included in a total sample size of 186 utilities.

The primary objective of this program is to assess the performance of water and wastewater utilities using a variety of measures. These measures are designed to help participating organizations improve their operational efficiency and effectiveness. The utility managers will use this information to determine where the utility's performance resides within the industry peer group. High-level indicators are selected as the starting point for the system because they are more likely to be recognizable and applicable at large numbers of utilities. Participants in the survey have the opportunity to comment on the next steps beyond the beginning of this benchmarking. The survey format represents the result of efforts of various organizations and individuals. AWWA / AWWARF staff brought together representatives from various organizations to develop the performance indicators. A narrower project scope was proposed as a start so participating utilities would have opportunities to decide which indicators had the most meaning to them, and those administering the proposed measurement system could learn how to build, finance, manage and sustain an effective data delivery system. Development of a more detailed measurement system is planned for the future. Twenty-three performance indicators were initially selected. The QualServe business systems were chosen as an organizing framework to guide the design effort so the initial performance indicators database would be familiar to the many utilities participating in the program.

Laramie's smaller size has an effect on its rating for some categories. Laramie's water and wastewater utility serves an estimated population of 32,000. Of the 186 systems included in the survey, 20% were smaller than Laramie and 80% were larger. Larger utilities have an advantage of economy of scale.

The approach taken in this report was to evaluate the QualServe Benchmarking Performance Program categories that Laramie ranked in the bottom quartile and determine what it would take to move into the median quartile.

Laramie's Water system is summarized as follows;

Residential Service Accounts	7,503
Commercial Service Accounts	435
Total Service Accounts	7,938

Population Served	32,000
System Capacity	20 mgd
Average Daily Demand	6 mgd
Water Utility Employees	17
Average Residential Water Bill	$16.05 / month (2003)

The average residential water bill reported here is exactly that reported by the City in 2003. It is not comparable to estimated water rates presented in Chapter 14.

Total Liabilities	$25,806,348
Total Assets	$62,188,072
Distribution System Water Loss	6.0%
Total Miles of Distribution Piping	160
Total number of Leaks and Breaks	178

13.4 QualServe Factors

13.4.1 Risk Management Planning

In the category of risk management planning, the Laramie Utility Division gave itself the following rating, "The activity is implemented, but there is room for substantial improvement" (3 points). The definition for a median rating is, "The activity is largely implemented, but there is room for improvement" (4 points).

Required action; Meet with the staff to identify specifically where risk management planning is deficient and then act on the findings.

Additional Cost; Estimate $10,000 per year to implement additional safety measures.

13.4.2 Training Hours per Employee

The Laramie Utility Division had an average of twenty training hours per employee during 2003. The median value for all participating utilities was 22.6 hours.

Required Action; provide three hours of additional training per year per employee (eighty-seven hours for a total of twenty-nine employees for water and wastewater).

Additional Cost; estimate $150 per training hour for cost of lost time, registration, travel, meals, etc. This equates to $13,000 per year.

13.4.3 Customer Accounts per Employee

The Laramie Utility Division has 7,938 customer accounts served by seventeen water department employees. This equates to 467 accounts per employee. The median value for all participating utilities was 470.

Required Action; None. Laramie is very close to the median. This is a difficult category for a small water system to compete in since the larger systems have better economy of scale. All things considered, Laramie's number of accounts per employee is very good.

Additional Cost; None

13.4.4 Disruption of Water Service Rate per 1,000 Customers

Laramie is in the bottom quartile for five out of six categories for disruption of water service. This is primarily attributable to a high level of water main breaks due to corroded cast iron and ductile iron water mains. These water mains need to be replaced. Cost and time table for water main replacement is addressed in System Renewal / Replacement Ratio

13.4.5 Debt Ratio

The debt ratio is the ratio of total liabilities to total assets. Total liabilities are the total amount of dollars owed to others. They include outstanding bonds, outstanding long-term debt, outstanding short-term debt, payments owed to others, accounts payable and deposits collected from customers. Total assets are the entire resources of the utility. They include accounts receivable, cash, inventories, service delivery facilities (less depreciation), cost of easements, cost of water rights and all other items of value owned by the utility.

Laramie's debt ratio is 0.41 defined by $25,806,248 of liabilities and total assets of $62,188,072. The median ratio is 0.36. For Laramie to obtain the median ratio (assuming Laramie's assets do not increase) Laramie would need to reduce its debt by $3,418,550 (target of $22,387,700 for 0.36 ratio).

Required Action; Reduce the amount of debt owed by the water utility. While this is a goal it may not be achieved by the City given the limits on revenue and the overwhelming infrastructure needs.

Additional Cost; $200,000 per year for the next twenty years.

13.4.6 System Renewal / Replacement Ratio (%)

This item includes replacement of water pipelines, mains, treatment facilities and pumping.

Laramie has made significant improvements to pumping stations since the 2003 Qualserve survey. Laramie is currently replacing the remaining older pumping stations with the East Side Tank Project. The High /Low pumping station is being replaced by the Wister Drive Pumping Station. The Imperial Heights Pumping Station was demolished and a new building is being built in the same location. The pumps are being removed from the Indian Hills Pumping Station and it is being converted to a pressure control station. The pumps are being removed from the Alta Vista Pumping Station and it is being converted to a pressure control station. The Grant Street and Airport Pumping Stations were built in 2001. New pumps and piping were installed in the University Pumping Station in 2001. In summary, all of Laramie's pumping stations are in relatively new condition and, if the survey were to be done again, Laramie would probably score in the top quartile for pumping stations.

Laramie's water treatment plant was built in 1964. It has had many upgrades including the addition of ozone disinfection, Superpulsator clarifier, air scour backwash, filter-to-waste piping and powdered activated carbon feed. The age of the plant has not resulted in unsatisfactory water quality. The opposite has occurred; the plant has a history of producing exceptional water quality. This is attributable to the dedication of the operators. The hydraulics of the plant are limited to 5 feet of fall through plant's hydraulic profile. The plant will need significant upgrade or replacement within the next twenty years.

Laramie's distribution system experiences a relatively high number of water main breaks resulting in a high number of disruptions of water service. This is primarily attributable to exterior corrosion of water mains in areas with corrosive soils. Gypsum soils

(typically gray in color) are the most corrosive, the red silty soils being the least corrosive. Corrosive soil promotes galvanic corrosion on cast iron and ductile water mains. Unfortunately, the corrosive nature of these soils was not determined until a considerable quantity of unprotected cast iron and ductile iron pipe had been installed. Conversion to PVC pipe for new installations was done in approximately 1980 or 1981 according to Mr. Foster White, the distribution system operator at that time. Loose wrap polyethylene was not used to protect cast or ductile iron pipe in the Laramie system. A program for the replacement of existing cast and ductile iron water mains was begun in 1996 but was limited to less than 1,000 feet per year due to lack of funds. A water line replacement charge of $3.40 per residential service per month was initiated in 2004. This equates to $350,000 per year which results in approximately 2,000 feet of replacement.

The AWWA recommends a water main replacement rate of 1.5% per year based on an estimated useful life of 67 years. For Laramie's 160 miles of the distribution system this equates to 2.5 miles per year. Therefore, Laramie is falling behind each year by approximately 2 miles. A catch up period needs to be initiated to make up for the back log that has built up. This could be done at the rate of 5 miles (3.3%) per year for the next 15 years. This accelerated replacement could concentrate on areas of the greatest corrosion. Then the AWWA recommended rate of 1.5% per year could be used there after. Current estimated cost for water main replacement is $150 per lineal foot.

Required Action; Replacement of water mains.

Additional Cost; Cost estimates for addressing this need are presented in Chapter 7.

13.4.7 Return on Assets

This item represents net income (-$1,210,055) as a percentage of total assets ($62,188,072). The Laramie water utility had a net loss for 2003. Laramie's Return on Assets was minus 1.9 %. The median value for all participating utilities was 2.3 %. For Laramie this would represent a net income of $1,430,300. This would be an increase of $2,640,400 over 2003.

Required Action; Increase net income by $2,640,400 over 2003. Income increase required for water main replacement will correct this deficiency.

13.4.8 Water Distribution System Integrity

This item consists of the number of leaks and pipe breaks per 100 miles of water main. Leaks include openings in distribution system pipe, valves, hydrant, appurtenance or service connections that are continuously losing water. Breaks include physical damage to a pipe, valve hydrant, or other appurtenance which results in an abrupt loss of water. Laramie is in the bottom quartile for five out of six categories for disruption of water service.

Laramie's score of 111.3 is very close to the bottom quartile value of 112.3. The median valve is 52.5.

This item is closely related to system renewal and replacement. If corroded pipe is not replaced, then a median rating can not be attained.

Required Action; Laramie would need to cut its leaks and breaks in half to attain a median value.

Additional Cost; See System Renewal / Replacement Ratio

13.4.9 Operation & Maintenance Cost Ratios

This item has three categories; O&M cost per account, O&M cost per MG processed and direct cost of treatment per MG. Laramie was deficient in only one of these categories, O&M cost per account. Laramie's O&M cost was $326 per account. The top, median and bottom values for all participating utilities were $162 per account, $260 per account and $405 per account.

Required Action; None, This is a difficult category for a small water system to compete in since the larger systems have better economy of scale. Laramie's O&M cost per account appear acceptable in comparison to other utilities, however, it is deficient in terms of system renewal and replacement.

Additional Cost; See System Renewal / Replacement Ratio

13.5 Summary

As explained in Section 13.2, the Operations Element includes two items:

- The annual cost of labor, equipment, and materials that the City currently budgets, and
- Estimated costs to elevate the level of water service to industry average as measured by the AWWA QUALSERVE performance benchmarking program.

Table 13-1 summarizes the Operations Element, itemizing the expenses or estimated costs.

TABLES AND FIGURES

Table 13-1: Summary of Annual Costs for the Operations Element of the Water System Master Plan

	Annual Operating Costs	Budget FY 2005	Assumed O&M for Master Plan FY 2006
1	Total Personnel	1,212,575	1,212,575
2	Contractual support	741,383	741,383
3	Materials/Supplies	606,800	606,800
4	Equipment/Cap. Replacement	923,054	923,054
5	Total Existing Water System Debt.	1,355,000	1,355,000
6	Qualserve Improvements (Section 13.4.1 and 13.4.2)	N/A	25,000
	Total O&M (Lines 1 through 6)	$4,838,811	$4,863,811

Note: All the above items are included with all Master Planning scenarios.

CHAPTER 14.0
WATER SYSTEM MASTER PLAN

14.0 WATER SYSTEM MASTER PLAN

14.1 Introduction

A primary objective of this project is to produce a useful Water System Master Plan that the City can use to help guide decisions regarding capital, operational and financing needs with the objective of providing a high level of water supply service to existing and future customers.

The preceding three chapters presented evaluations and information related to the three cost related Elements of the water system master plan. This chapter presents the fourth and final Element: Revenues. All four Elements are evaluated with a simple financial accounting model to estimate the approximate revenue structure that should be in place to recover the costs for operating the water utility.

The Master Plan developed as part of this project is not explicitly comprehensive. As an example, our work has not directly evaluated a number of the Utility Department functions that are integral to the water system's capability and capacity, such as operator certification, managerial organization, cross connection control program, and customer complaint program. These programs all contribute to high quality service and protection of utility customer health. Because we have not evaluated these programs, we do not offer recommendations for improvement or for additional financial support, if it is even needed. However, the Master Plan indirectly accounts for these functions. That is done by assuming that the programs "not evaluated" and corresponding City budgets are adequate in scope and sufficiently funded. In other words, the approximation that we make is that utility department budgets are adequate to pay for all of the projects and programs not explicitly identified in the Water System Master Plan.

Figure 14-1 presents the proposed organization of the Water System Master Plan. The Plan addresses four basic elements of the water supply system, including Water Supply; the Transmission, Distribution, and Storage System; Operations and Revenues. Each of these main elements is divided into subsections. Although the organization of the Plan is different than the organization of the Utility Department's Annual Budget sheets, the objective is the same: to account for system costs and revenues in an organized meaningful way.

14.2 Water System Master Plan Tool

This section describes the water system master plan tool (Tool). The Tool integrates proposed activities, capital and operational budgets, scheduling, and a revenue structure to pay for the activities related to the present and future operation of the City's water system. This Tool is a business plan, or accounting model, that is focused on the City Water Department, which is operated as a sustaining enterprise. The Tool accounts for most of the capital and operational needs for providing a high level of water supply service, while at the same time generating sufficient revenue to be self supporting.

The Tool is a series of simple spreadsheets and it accounts for the expenses and revenues needed to sustain the system. The expenses, such as water supply expansions, are scheduled to occur when they are estimated to be needed. The Tool does not take the place of other planning methods used by the Utility Department or City.

Appendix 14B provides an in depth explanation of the projects and assumptions that are addressed in these planning elements. Several of the key assumptions include:

- Planning horizon is 20 years
- System costs should be fully recovered by a combination of water use fees, including Plant Investment, monthly meter base rate, water demand, main replacement, and special use fees. The special use fees can include the commonly used capital facilities taxation approach.
- Grants will be available to fund 67% of the capital projects (Transmission, Storage and Treatment) excluding water distribution system upgrades. Grants for water treatment and distribution system improvements would be at 50%.
- State Revolving Fund Loans at 2.5% and a term of 20 years will be used to finance capital improvements not covered by grants.
- The evaluation accounts for the existing loans that the Utility Department is refinancing.

14.3 Scenarios and Strategies

The Water System Master Plan tool was used to evaluate several planning scenarios and strategies for funding infrastructure improvements. Table 14-1 presents the results of all these evaluations in terms of a proposed water rate structure. The reported rate structure for each scenario is an average for the entire 20 year planning horizon, which is also the suggested rate for the 10th year. The current water rate structure is also escalated for inflation to the 10th year, and is used as a basis of comparison. As an alternative, Table 14-1 also presents the budget shortfall for each scenario that may have to be funded through alternative means such as a Capital Facilities Tax. The following sections describe the scenarios that were evaluated. Table 14-2 is provided to illustrate water rates for comparable Cities in Wyoming.

14.3.1 Scenario A: All Improvements and Full Growth

This scenario estimates the rate structure needed to construct all the improvements identified in this plan while experiencing the target growth at the planning horizon. Projected costs and income are assumed to increase by a fixed inflationary rate. In addition, the cost of the water main replacement program is targeted by the water main replacement special assessment fee. No attempt was made to reduce the debt to asset ratio to the levels suggested by the Qualserve recommendations in Chapter 13. Finally, the basic rate structure was based on the current rate structure, where similar percentages of income are derived from the monthly meter base rate and the water usage fees.

14.3.2 Scenario B: All Improvements – No Growth, No Supply Development

This scenario evaluates the situation where population growth is flat and all of the identified improvements are constructed, except for the water supply improvements. For this scenario, the projected water supply needs are kept at present levels. Because there is no growth, we assumed that the Plant Investment Fee income would be negligible.

14.3.3 Scenario C: Exclude Lower Priority Projects.

Projects not included in the cost structure for this scenario include the Monolith Projects Goforth and Harney as well as the Priority No. 3 water main replacement project.

14.3.4 Scenario D: Conservation - No Supply Development

One way to manage the system is to limit the water supplies to their current capabilities and to implement the conservation measures and water rate structures required to stabilize demand in the face of increasing population. This scenario is the same as Scenario A, except the increases to the water rates are targeted to the usage fee (rate per 1000 gallons), and additional water conservation efforts are implemented, but the expenses of additional supply development are eliminated. As a result, a factor for reduction in water usage is introduced to compensate for conservation efforts. As a base assumption, we reduce the water usage by 10% and report the resulting rate structure.

14.3.5 Scenario E: Addition of Groundwater Treatment, if required.

This scenario reflects the cost impact of adding treatment for the water produced by the wells at the Turner, Wellfield, and the Wye (Pope and Soldier). It involves an additional capital cost as well as on-going treatment costs. These projects are only included in Scenario E.

14.4 Summary

Work presented in the previous sections provides the following summary findings:

- If the City implements water rate structure increases that equal inflation, then additional revenue will be needed to fund the Master Plan. The additional revenue can be obtained through rate increases that exceed the inflationary increases or by alternative revenue sources such as a capital facilities tax. This needed revenue varies between 1.3 and 3.1 million $/year depending on actual growth, changing water demands and other factors outside the City's control. For planning purposes, the City should consider this needed annual supplemental revenue to be about $3 million.
- An alternative approach to obtaining revenues through a special use tax is to raise water rates beyond the amounts needed to keep pace with inflation. This work has shown that those rate increases vary between 31% and 65% percent of the project inflation adjusted rate structure (Table 12-1).

Table 14-1 Summary of Rate Structure and Master Water System Plan Scenerios (Dollars)

	Water Rates (dollars)						
	Scenario (Average for 20 years or year 10)						
	Existing 2006	Existing w/inflation (average or year 10)	Full Buildout	No Pop. Growth	High Priority Only	Conservation	Full Buildout and GW Treatment
Rate Structure		BASE	A	B	C	D	E
Plant Investment Fee 3/4" Tap Only	$3,021	$3,867	$3,867	$3,867	$3,867	$3,867	$3,867
Water Tap Service Charge	$13.14	$16.82	$21.83 (+30%)	$23.13 (+38%)	$20.79 (+24%)	$16.82 (+0%)	$23.57 (+40%)
Water Use Charge per 1,000 gal	$2.21	$2.83	$3.67 (+30%)	$3.89 (+38%)	$3.50 (+24%)	$4.08 (+44%)	$3.96 (+40%)
Water Main Replacement Charge	$4.08	$5.22	$19.65 (+276%)	$21.09 (+304%)	$10.49 (+101%)	$19.65 (+276%)	$19.65 (+276%)
Estimated Average Water Bill (Note 2)	$40.14	$51.38	$79.55 (+55%)	$84.55 (+65%)	$67.55 (+31%)	$78.79 (+53%)	$84.32 (+64%)
Equivalent Annual Deficit using inflation-adjusted current rates only (in Thousands $)			-$2,546K	-$3,121K	-$1,297K	-$2,467K	-$3,042K

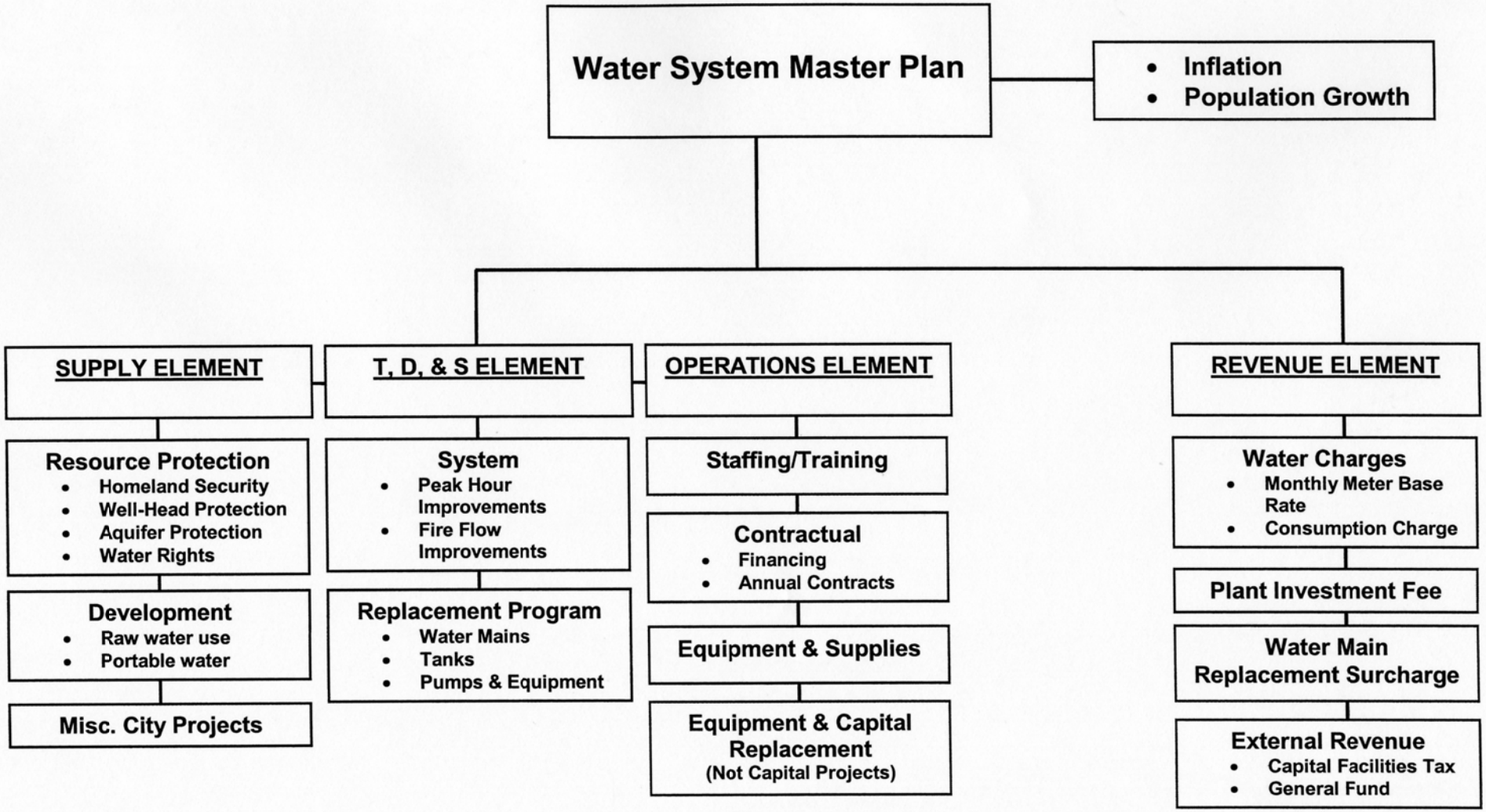
Note 1: These scenarios do not comply with the debt/asset ratio recommencation in Chapter 13.
Note 2: Based on 7,000 gallons per month useage.
Note 3: The Master Plan Scenario Evaluations assume an Annual Inflation rate 2.5%.

Table 14-2 Ranking of Water Rates in Various Locations in Wyoming[1]

City	Average Cost/Month ($)
Cody	34.98
Laramie	32.69
Rock Springs	28.69
Cheyenne	24.91
Sheridan	24.38
Riverton	24.02
Casper	19.87
Evanston	17.17
Gillette	14.42
Average:	24.57

(1) Based on 7,000 gal./month consumption

Figure 14-1 Water System Master Plan Schematic



TABLES AND FIGURES

CHAPTER 15.0
RECOMMENDATIONS

15.0 RECOMMENDATIONS

15.1 Recommendations

1. Obtain a resolution from the City Council that supports a comprehensive water system master plan and financing structure to correct existing water infrastructure deficiencies, to provide supplies for growing demand, and to support economic development. Key to that plan is a commitment to water rate increases that follow inflation.

2. Apply for a WWDC Level II Study grant from the WWDC to perform field investigations and additional analysis for the objective of controlling spring discharge at the City Springs and to field test the feasibility of an aquifer storage and recovery program in the Spur Wellfield.

3. Apply for a WWDC Level II Study grant from the WWDC to check all GIS data in the City water main database. The study program should include the collection of sufficient system monitoring data such that hydraulic model calibration can be performed.

4. Apply for a WWDC Level III grant to begin the final design and construction of the Laramie River Pipeline.

5. Implement the Casper Aquifer Protection Plan and enforce aquifer protection ordinance. Continue participation with the Environmental Advisory Committee, the WDEQ, the County, and University of Wyoming to facilitate CAPP support and enforcement.

6. Continue to implement and develop monitoring programs in the Casper Aquifer. Either hire a staff person or a local consultant to perform annual data collection and reporting for this program.

7. The City should request that the Laramie Economic Development Corporation market the fact that the City of Laramie has the potential water supply capacity to support businesses that need large amounts of water. The City has water to sell and needs revenue to support the water enterprise fund. A specific volume or rate of water and the value of that water remains to be determined. A water marketing study should be performed.

8. The City should define a water treatment contingency plan that will provide immediate supply relief if the Casper Aquifer supplies do not meet federal drinking water standards, from either contamination or changing regulations.

9. The City should approach the senior water right holder west of the present Laramie River point of diversion to see if they are willing to sell the water right and or the land at a fair market value.

10. At this time, the City should continue to irrigate large green spaces with treated potable water.

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REFERENCES CITED

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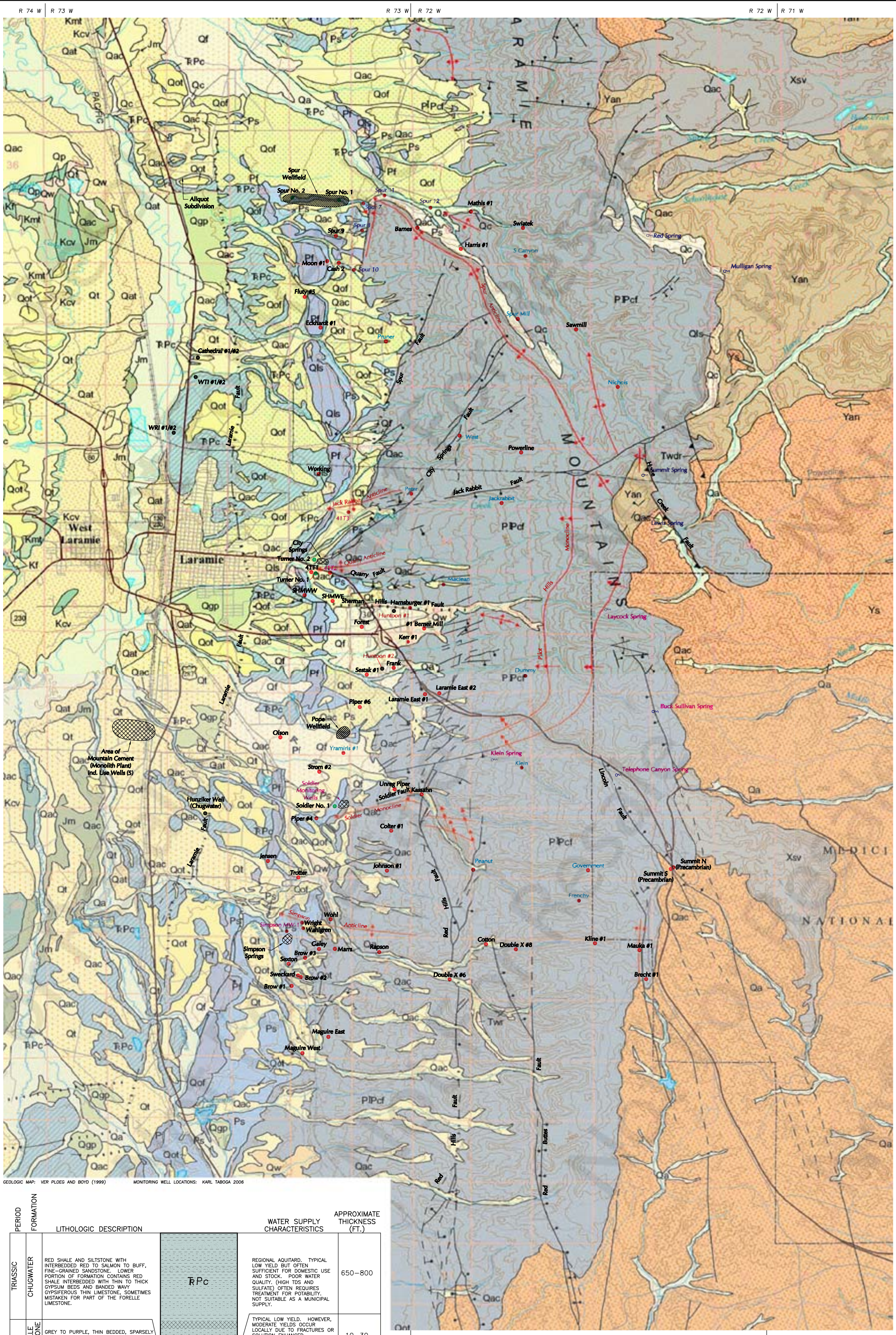
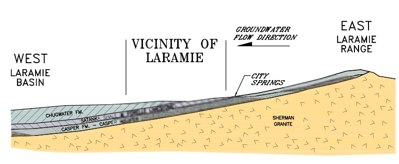


PERIOD	FORMATION	LITHOLOGIC DESCRIPTION			WATER SUPPLY CHARACTERISTICS	APPROXIMATE THICKNESS (FT.)
TRIASSIC	CHUGWATER	RED SHALE AND SILTSTONE WITH INTERBEDDED RED TO SALMON TO BUFF, FINE-GRAINED SANDSTONE. LOWER PORTION OF FORMATION CONTAINS RED SHALE INTERBEDDED WITH THIN TO THICK GYPSUM BEDS AND BANDED WAVY GYPSIFEROUS THIN LIMESTONE, SOMETIMES MISTAKEN FOR PART OF THE FORELLE LIMESTONE.		ȾRPc	REGIONAL AQUITARD. TYPICAL LOW YIELD BUT OFTEN SUFFICIENT FOR DOMESTIC USE AND STOCK. POOR WATER QUALITY. (HIGH TDS AND SULFATE) OFTEN REQUIRES TREATMENT FOR POTABILITY. NOT SUITABLE AS A MUNICIPAL SUPPLY.	650–800
PERMIAN	FORELLE LIMESTONE	GREY TO PURPLE, THIN BEDDED, SPARSELY FOSSILIFEROUS LIMESTONE LOCALLY INTERBEDDED WITH RED SILTSTONE AND THIN GYPSUM LAMINATIONS.		Pf	TYPICAL LOW YIELD. HOWEVER, MODERATE YIELDS OCCUR LOCALLY DUE TO FRACTURES OR SOLUTION ENHANCED PERMEABILITY. WATER QUALITY SUITABLE FOR IRRIGATION AND STOCK WATERING.	10–30
PERMIAN	SATANKA SHALE	RED SILTSTONE AND SHALE (OFTEN BANDED WITH WHITE AND OCHER COLOR ZONES), SOFT SANDSTONE, THIN LIMESTONES, AND LOCAL GYPSUM BEDS, ESPECIALLY NEAR THE TOP. BUFF TO ORANGE TO RED, FINE-GRAINED SANDSTONE WITH RIPPLE MARKS COMMON NEAR BASE OF UNIT. UNCONFORMITY		Ps	REGIONAL AQUITARD. TYPICAL LOW YIELD. SANDSTONES IN LOWER PART HAVE YIELD/AND WATER QUALITY (LOW TDS, LOW SULFATE) SUITABLE FOR DOMESTIC USE. WATER QUALITY IN UPPER PART IS POOR (HIGH TDS, HIGH SULFATE) DUE TO DISSOLUTION OF GYPSUM.	250–300
PERMIAN / PENNSYL-VANIAN	CASPER (INCLUDES FOUNTAIN FM.)	BUFF TO REDDISH, CALCAREOUS TO QUARTZITIC, VERY FINE-TO COARSE-GRAINED, WELL CEMENTED SUBAKOSIC SANDSTONE INTERBEDDED WITH BUFF TO PURPLISH-GRAY LIMESTONE AND DOLOMITE BEDS, USUALLY MICRITIC AND LOCALLY FOSSILIFEROUS. AS MANY AS 10 DIFFERENT LIMESTONE OR DOLOMITE BEDS, WHICH THIN TO THE SOUTH AND WEST OF LARAMIE. INTERTONGUES WITH UNDERLAYING FOUNTAIN FORMATION, WHICH IS LESS THAN 50 FEET THICK AND DOES NOT CROP OUT IN THE VICINITY OF LARAMIE. THE CASPER FM. HAS BEEN SUBDIVIDED INTO 5 INFORMAL MEMBERS BY LUNDY (1978). UNCONFORMITY	EPSILON DELTA GAMMA BETA ALPHA	PPcf	REGIONAL AQUIFER. HIGH YIELDS OCCUR LOCALLY DUE TO FRACTURES AND SOLUTION ENHANCED PERMEABILITY. LOW TO MODERATE YIELDS IN UNFRACTURED SANDSTONE. PROVIDES LARGE QUANTITIES OF EXCELLENT QUALITY WATER TO THE CITY OF LARAMIE MUNICIPAL WATER SYSTEM.	600–700
PRE-CAMBRIAN	SHERMAN GRANITE	IGNEOUS CRYSTALINE ROCK CONSISTING PRIMARILY OF GRANITE WITH GNEISS, ANORTHOSITE, AND GABBRO INTRUSIONS		Xsv Ys Yan	IMPERMEABLE CRYSTALLINE MATRIX. FRACTURES PROVIDE WATER TO DOMESTIC WELLS. EXCELLENT WATER QUALITY.	∞

VERTICAL SCALE: 1"=300 FT.

MODIFIED FROM LUNDY (1978)
LITHOLOGIC DESCRIPTIONS FROM VER PLOEG (1995, 1996, 1998)



EXPLANATION
NOT TO SCALE

SATURATED CASPER FM. = CASPER AQUIFER

UNSATURATED CASPER FM.

SCHEMATIC WEST–EAST CROSS–SECTION THROUGH THE LARAMIE RANGE IN THE VICINITY OF LARAMIE, WYOMING.

LEGEND

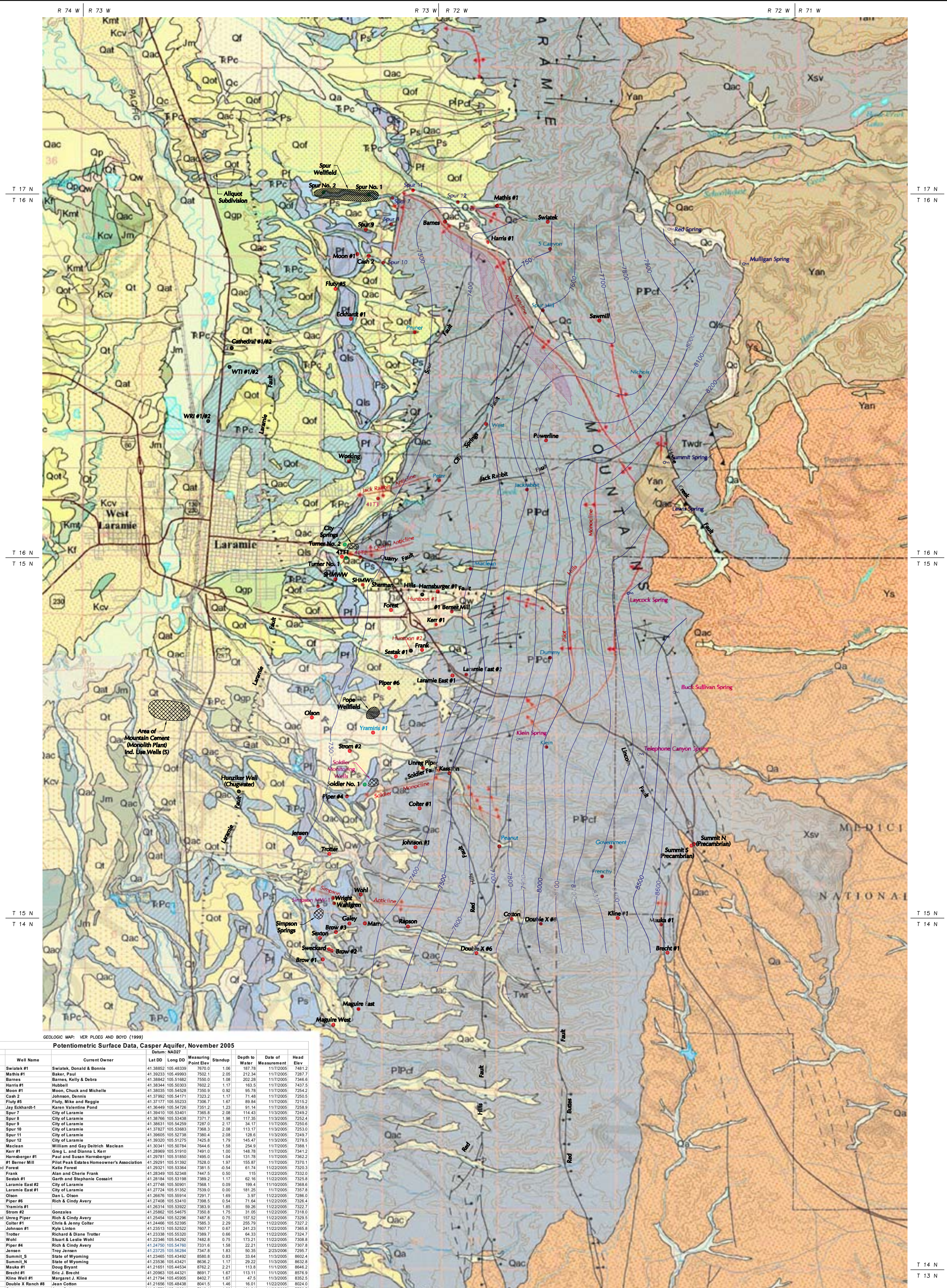
5 Canyon	CAMP MONITORING WELLS (AS OF 2006)
Spur 12	SPUR WELLFIELD AGREEMENT MONITORING WELLS
Huntoon #1	USGS/SEO MONITORING WELLS
41T3	WELL/SPRING RECOMMENDED FOR CAMP EXPANSION
● (red)	TABOGA MONITORING WELLS
● (green)	MUNICIPAL PRODUCTION WELL
(spring symbol)	SPRING
(fault symbol)	FAULT; BAR AND BALL ON DOWNTHROWN SIDE
(anticline symbol)	ANTICLINE
(monocline symbol)	MONOCLINE

ALL WELLS COMPLETED IN CASPER AQUIFER UNLESS NOTED OTHERWISE.

PLATE 10-1
Geologic Map
with Well Locations

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC



Potentiometric Surface Data, Casper Aquifer, November 2005									
			Datum: NAD27						
Permit #	Well Name	Current Owner	Lat DD	Long DD	Measuring Point Elev	Standup	Depth to Water	Date of Measurement	Head Elev
98089W	Swiatek #1	Swiatek, Donald & Bonnie	41.38852	105.48339	7670.0	1.06	187.78	11/7/2005	7481.2
1356519W	Mathis #1	Baker, Paul	41.39233	105.49993	7502.1	2.05	212.34	11/7/2005	7287.7
90548W	Barnes	Barnes, Kelly & Debra	41.38842	105.51682	7550.0	1.08	202.28	11/7/2005	7346.6
91395W	Harris #1	Hubbell	41.38344	105.50303	7602.2	1.17	163.5	11/7/2005	7437.5
102613W	Moon #1	Moon, Chuck and Michelle	41.38035	105.54528	7350.9	0.92	95.78	11/7/2005	7254.2
25335P	Cash 2	Johnson, Dennis	41.37992	105.54171	7323.2	1.17	71.48	11/7/2005	7250.5
112724W	Fluty #5	Fluty, Mike and Reggie	41.37177	105.55233	7306.7	1.67	89.84	11/7/2005	7215.2
143036W	Jay Eckhardt-1	Karen Valentine Pond	41.36449	105.54726	7351.2	1.23	91.14	11/7/2005	7258.9
106525W	Spur 7	City of Laramie	41.39410	105.53401	7365.8	2.08	114.43	11/3/2005	7249.2
106526W	Spur 8	City of Laramie	41.38766	105.53438	7371.7	1.98	117.35	11/3/2005	7252.4
106527W	Spur 9	City of Laramie	41.38631	105.54259	7287.0	2.17	34.17	11/7/2005	7250.6
106528W	Spur 10	City of Laramie	41.37827	105.53683	7368.3	2.08	113.17	11/3/2005	7253.0
106529W	Spur 11	City of Laramie	41.39605	105.52738	7380.4	2.08	128.6	11/3/2005	7249.7
106530W	Spur 12	City of Laramie	41.39320	105.51275	7425.8	1.79	145.47	11/3/2005	7278.5
104799W	Maclean	William and Gay Deitrich Maclean	41.30341	105.50784	7644.6	1.58	254.9	11/7/2005	7388.1
106649W	Kerr #1	Greg L. and Dianna L Kerr	41.28969	105.51910	7491.0	1.00	148.78	11/7/2005	7341.2
75242W	Harnsberger #1	Paul and Susan Harnsberger	41.29781	105.51850	7495.0	1.04	131.78	11/7/2005	7362.2
8764P	#1 Berner Mill	Pilot Peak Estates Homeowner's Association	41.29291	105.51392	7528.0	1.97	155.87	11/7/2005	7370.1
Unregistered	Forest	Katie Forest	41.29321	105.53364	7381.5	-0.54	61.74	11/22/2005	7320.3
Unknown	Frank	Alan and Cherie Frank	41.28349	105.52348	7447.5	0.50	115	11/22/2005	7332.0
49142W	Sestak #1	Garth and Stephanie Cossairt	41.28184	105.53198	7389.2	1.17	62.16	11/22/2005	7325.8
98131W	Laramie East #2	City of Laramie	41.27748	105.50901	7568.1	0.09	199.4	11/10/2005	7368.6
98132W	Laramie East #1	City of Laramie	41.27724	105.51352	7539.0	0.00	181.25	11/7/2005	7357.8
100005W	Olson	Dan L. Olson	41.26676	105.55914	7291.7	1.69	3.97	11/22/2005	7286.0
16922P	Piper #6	Rich & Cindy Avery	41.27408	105.53410	7398.5	0.54	71.64	11/22/2005	7326.4
30940W	Yramiris #1		41.26314	105.53922	7383.9	1.85	59.26	11/22/2005	7322.7
39385W	Strom #2	Gonzales	41.25862	105.54675	7350.8	1.75	31.05	11/22/2005	7318.0
Unregistered	Unreg Piper	Rich & Cindy Avery	41.25454	105.52296	7487.8	0.75	157.52	11/22/2005	7329.5
94870W	Colter #1	Chris & Jenny Colter	41.24466	105.52395	7585.3	2.29	255.79	11/22/2005	7327.2
94924	Johnson #1	Kyle Linton	41.23513	105.52522	7607.7	0.67	241.23	11/22/2005	7365.8
105088	Trotter	Richard & Diane Trotter	41.23338	105.55320	7389.7	0.66	64.33	11/22/2005	7324.7
109771	Wohl	Stuart & Leslie Wohl	41.22346	105.54292	7482.8	0.75	173.21	11/22/2005	7308.8
16920P	Piper #4	Rich & Cindy Avery	41.24750	105.54760	7331.6	1.58	22.21	11/22/2005	7307.8
126866	Jensen	Troy Jensen	41.23725	105.56284	7347.8	1.83	50.35	2/23/2006	7295.7
2181W	Summit_S	State of Wyoming	41.23465	105.43492	8580.8	0.83	33.64	11/3/2005	8602.4
2180W	Summit_N	State of Wyoming	41.23536	105.43421	8636.2	1.17	29.22	11/3/2005	8632.8
98779W	Mauka #1	Doug Bryant	41.21651	105.44534	8762.2	2.21	113.8	11/1/2005	8646.2
148804W	Brecht #1	Eric J. Brecht	41.20963	105.44321	8691.7	1.67	113.11	11/1/2005	8576.9
115992W	Kline Well #1	Margaret J. Kline	41.21794	105.45905	8402.7	1.67	47.5	11/3/2005	8352.5
19564P	Double X Ranch #8	Jean Cotton	41.21656	105.48438	8041.5	1.46	16.01	11/22/2005	8024.0
127132W	Cotton	Jean Cotton	41.21773	105.49381	7919.1	1.08	161.34	11/22/2005	7756.7
19565P	Double X Ranch #6	Jean Cotton	41.20930	105.50522	7739.1	1.08	27.9	11/22/2005	7710.1
149013W	Rapson	Dave J. Rapson & Shelly Fahnanstiel	41.21568	105.52750	7620.1	1.14	165.92	11/22/2005	7453.1
8767P	Government	WLC	41.23550	105.46173	8366.7	1.69	39.42	11/26/2005	8325.6
8766P	Frenchy	WLC	41.22823	105.46460	8436.9	0.92	72.52	11/13/2005	8363.5
8772P	Peanut	WLC	41.23546	105.49799	7778.2	2.17	28.71	11/10/2005	7747.3
8769P	Kassahn	WLC	41.25335	105.51441	7540.4	1.38	45.33	11/10/2005	7493.7
8770P	Klein	WLC	41.25985	105.48294	8111.4	1.42	87.58	11/10/2005	8022.4
8768P	Jackrabbit	WLC	41.32290	105.48968	7849.0	0.00	272	11/21/2005	7577.0
8765P	Dummy	WLC	41.28176	105.48186	7963.1	0.08	76.65	11/20/2005	7886.4
8777P	West	WLC	41.33890	105.50303	7914.5	1.45	427.65	11/20/2005	7485.4
80874P	Powerline	WLC	41.33500	105.48358	8149.4	2.38	164.82	11/20/2005	7982.2
15315P	Peter		41.32501	105.51832	7601.7	1.67	274.38	11/3/2005	7325.6
8778P	Working	WLC	41.32958	105.54756	7331.3	3.33	82.73	11/20/2005	7245.3
8773P	Pruner	WLC	41.36127	105.52655	7478.3	1.33	223.42	11/21/2005	7253.6
8771P	Nichols	WLC	41.35075	105.45313	8042.3	2.31	309.93	11/20/2005	7730.1
8776P	Spur Mill	WLC	41.36681	105.48489	7799.0	1.00	193.97	11/20/2005	7604.0
8775P	Sawmill	WLC	41.36440	105.46640	7873.5	0.50	210.76	11/20/2005	7662.2
8774P	S Canyon	WLC	41.38183	105.48258	7673.9	3.92	174.47	11/20/2005	7495.5
5767W	Brow #1		41.20751	105.55511			51.48	12/29/2005	7338.5
5768W	Brow #2		41.20963	105.55223			68.21	12/29/2005	7353.8
5769W	Brow #3		41.21423	105.55090			52.29	10/24/2006	7352.7
729828W	Sexton		41.21277	105.55607			34.64	10/24/2006	7345.4
105082W	Simpson Springs		41.22055	105.55679			28.25	10/25/2005	7350.8
38304W	Galey		41.21635	105.54652			151.04	10/24/2006	7344.0
38303W	Marrs		41.21605	105.54058			157.05	2/23/2006	7381.0
75328W	Sweckard		41.20999	105.55309			61.7	10/24/2006	7359.3
3480P	Maguire East		41.19542	105.54338			117.99	10/25/2005	7382.0
69166W	Maguire West		41.19149	105.55154			148.3	12/29/2005	7356.7
163598W	Wahlgren		41.22128	105.55158			170.03	10/25/2005	7330.0
104443W	Wright		41.22257	105.55201			155.78	10/25/2005	7341.2
99779W	SHMWE	City of Laramie	41.29933	105.54291			24.14	11/3/2005	7295.9
99778W	SHMWW	City of Laramie	41.30066	105.55177			15.31	11/3/2005	7264.7
158C	41T3	City of Laramie	41.32051	105.53809			70.22	11/3/2005	7287.8
156C	41T1	City of Laramie	41.30617	105.54970	7273.2		0.34	11/3/2005	7267.7
157C	41T2	City of Laramie	41.30606	105.54377	7305.0		30.23	11/3/2005	7270.8
	Red Spring		41.38686	105.44389					8025.0
	Telephone Spring		41.25823	105.45290					8320.0
	Mulligan Spring		41.37844	105.41948					8070.0
	Lewis Spring		41.31941	105.44437					8280.0
	Laycock Spring		41.29759	105.45657					8402.0
	Klein Spring		41.26168	105.49216					7840.0
	Summit Spring		41.32970	105.44500					8320.0
	Buck Sullivan Spring		41.27340	105.44140					8590.0

DATA SOURCE: KARL TABOGA, 2006

LEGEND

- 8000 — POTENTIOMETRIC SURFACE CONTOUR, FT. AMSL (100' CONTOUR INTERVAL)
- S Canyon — CAMP MONITORING WELLS (AS OF 2006)
- Spur 12 — SPUR WELLFIELD AGREEMENT MONITORING WELLS
- Huntoon #1 — USGS/SEO MONITORING WELLS
- 41T3 — WELL/SPRING RECOMMENDED FOR CAMP EXPANSION
- TABOGA MONITORING WELLS
- MUNICIPAL PRODUCTION WELL
- SPRING
- AREA OF UNSATURATED CASPER FORMATION DUE TO STRUCTURAL PRECAMBRIAN HIGH, (THOMPSON, 1979; WWC, 1997A)
- FAULT; BAR AND BALL ON DOWNTHROWN SIDE
- ANTICLINE
- MONOCLINE

ALL WELLS COMPLETED IN CASPER AQUIFER UNLESS NOTED OTHERWISE.

0 4000'
SCALE

PLATE 10-2
Potentiometric Surface Map of Casper Aquifer, November 2005

LARAMIE WATER MANAGEMENT STUDY, LEVEL II
WYOMING WATER DEVELOPMENT COMMISSION

WYOMING GROUNDWATER, LLC

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