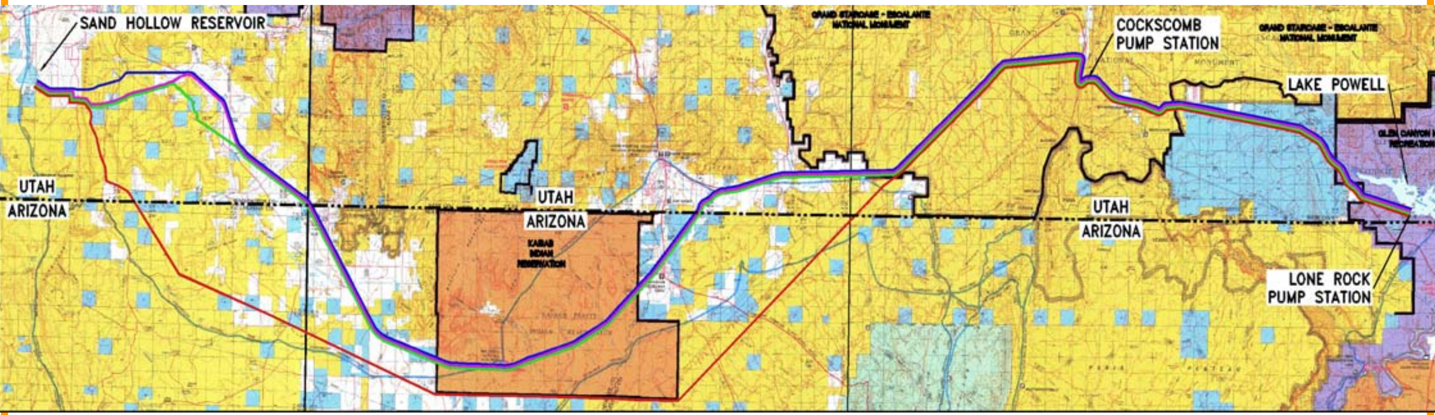

Lake Powell Pipeline Feasibility Study-Supplemental Analysis of the Hurricane Cliffs, the Cockscomb, and Alternate Alignments

Volume 1 of 2
Executive Summary & Feasibility Report

Prepared for:

Washington County Water Conservancy District

September, 2003

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Lake Powell Pipeline Feasibility Study

Supplemental Analysis of the Hurricane Cliffs, the Cockscomb, and Alternate Alignments

Volume 1 of 2

Executive Summary

And Feasibility Report

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Table of Contents

Executive Summary S-1
System Parameters S-1
Pipeline Alternative Alignments S-2
Pumping Stations S-2
Hydropower Facilities S-3
Recommended Alternatives S-3
Chapter 1 - Introduction 1-1
Project Description 1-1
Purpose of Study 1-2
Project Background 1-2
System Parameters 1-2
Pipeline Alternative Alignments 1-3
Pumping Stations 1-3
Hydropower Facilities 1-4
Scope of Work 1-4
Evaluate Alternative Pipeline Alignments through the Hurricane Cliffs and Cockscomb 1-4
Pumping Stations Preliminary Design 1-5
Proposed Hydropower Facilities 1-5
Additional Services 1-5
Authorization of Work 1-6
Chapter 2 - Hurricane Cliffs 2-1
Location 2-1
Site Conditions and Topography 2-2
Geology 2-6
Seismic Setting 2-8
Geotechnical and Engineering Considerations 2-9
Shaft and Tunnel 2-9
Cut and Cover 2-9
Surface Support 2-10

Pipeline Alignment Alternatives at Hurricane Cliffs 2-11

Hurricane Cliffs Alignments 2-12
Hydraulic Profiles 2-19
Discussion........ 2-19
Hurricane Cliffs to Sand Hollow 2-20
Power Requirements and Generation Potential - Considerations for Pipeline Alignments 2-20
Cost Estimates 2-22
Preferred Construction Alternative 2-25

Chapter 3 – The Cockscomb 3-1

Location and Introduction 3-1

Site Conditions and Topography 3-3

Geology 3-6

Seismic Setting 3-9

Geotechnical Considerations 3-9

Tunnel Geotechnical Considerations 3-10
Cut and Cover Geotechnical Considerations 3-10
Surface Support Geotechnical Considerations 3-11

Pipeline Alignment Alternatives 3-11

Approach to the Cockscomb Alignments and Engineering Profiles 3-11
Cockscomb Alignments 3-12
Hydraulic Profiles 3-16
Opinion of Probable Costs 3-16
Preferred Construction Alternative Through the Cockscomb 3-18

Chapter 4 – Highway 389 Near Pipe Springs National Monument 4-1

Chapter 5 - Lone Rock Pumping Station (Lake Powell) 5-1

Lone Rock Pumping Station Operation and Maintenance Costs 5-2

Selected Location 5-3

Chapter 6 - Cockscomb Pumping Station 6-1

Location 6-1

East Side of Cockscomb-North of U.S. Highway 89 6-1
East Side of Cockscomb-South of U.S. Highway 89 6-3
West Side of Cockscomb 6-4

General Design Concept 6-5

Pumping Station Configuration 6-5

Power Service Connection 6-6
Operation and Maintenance Costs 6-7
Selected Location 6-7

Chapter 7 - Potential Hydropower Facilities 7-1
General 7-1
Alternatives Studied – Hurricane Cliffs and Sand Hollow 7-2
Power Generation at Telegraph Flats 7-2
Hydro Turbine Generators 7-3
Penstock Configuration – Sand Hollow and Hurricane Cliffs 7-4
Load Peaking Option 7-5
Evaluation of Data 7-5
Operation and Maintenance Cost 7-6
Hydroelectric Power Conclusions 7-7

Chapter 8 - Reservoirs 8-1
General 8-1
Telegraph Flats 8-1
Hurricane Cliffs Reregulating Reservoir 8-1
Little Creek Mountain Regulating Reservoir (Alternative 12) 8-2
Sand Hollow Powerhouse Surge Vent 8-3
Opinion of Probable Cost of Reservoirs 8-3

Chapter 9 - Archaeological and Cultural Resources Reconnaissance 9-1
Land Use Designations 9-1

Chapter 10 – Recommendations and Conclusions – Lone Rock Pumping Station to Sand Hollow Reservoir 10-1
Hurricane Cliffs Alignments 10-2
Cockscomb Alignments 10-5

Principal References

Appendix

List of Tables

Table

2-1	Estimated Capital Costs of the 12 Alternatives	2-23
2-2	Estimated Present Worth Costs of the 12 Alternatives	2-24
3-1	Cockscomb Tunnel, Shaft, and Pipeline Costs	3-17
8-1	Staging Reservoir Summary	8-2
10-1	Top Ten Based on Total Capital Cost	10-1
10-2	Top Ten Based on Net Present Worth	10-2

List of Figures

Figure

1-1	Project Vicinity Map	1-1
2-1	Hurricane Cliffs – View North Toward Frog Hollow	2-1
2-2	Valley Area Between Hurricane Cliffs and Sand Hollow Reservoir	2-2
2-3	Base Area of Hurricane Cliffs at About 3000 South	2-3
2-4	Hurricane Cliffs at Grass Valley	2-5
2-5	Crest Area of Alternate Alignment at the Honeymoon Trail on the Arizona Border	2-5
2-6	Drainage Area East of Hurricane Cliffs	2-6
2-7	Hurricane Cliffs Looking North from Near the Arizona Border	2-7
3-1	Cockscomb at U.S. Highway 89 – Looking East	3-2
3-2	Cockscomb at U.S. Highway 89 – Looking East	3-2
3-3	West Cove (Foreground) Looking East From Cockscomb Along Power Line Tunnel Alignment	3-4
3-4	Road Cut Into FiveMile Valley (Looking West) – Sand Gulch Left of Road	3-5
3-5	Drainage Channel Cut Into West Slope of Cockscomb (Looking East From Base of Slope)	3-6
3-6	Bedrock Exposed in the Eastern Slope of the Cockscomb	3-7
3-7	Uniformly Dipping Bedrock Units	3-8
3-8	Navajo Sandstone	3-8
3-9	Kayenta Formation Near Base of Western Slope	3-9
3-10	Embankment at Catsair Canyon	3-13
3-11	Tunnel Portal Locations at East Side of Cockscomb	3-14

3-12 Tunnel Portal and Pumping Station Site at East Side of Cockscomb 3-15

6-1 Pumping Station Site – North of Highway Embankment 6-2

6-2 Pumping Station Site – South of Highway Embankment (Beyond West Cove Wash) 6-3

7-5 Pelton Turbine Installation 7-3

7-6 Francis Turbine Installation 7-4

Volume Two

Drawing No.

TG-1	Overall Alignments Topographic Maps…………………………………	1 of 3
		2 of 3
		3 of 3
HGL-1	Baseline Gould Reservoir Hydraulic Grade Line………………………	1 of 3
		2 of 3
		3 of 3
HGL-2	Baseline Willow Spring Hydraulic Grade Line…………………………	1 of 3
		2 of 3
		3 of 3
HGL-3	Baseline-Gould Spring-Grass Valley Hydraulic Grade Line……………	1 of 3
		2 of 3
		3 of 3
HGL-4	Baseline-Gould Spring-Willow Spring Hydraulic Grade Line…………	1 of 3
		2 of 3
		3 of 3
HGL-5	Baseline-Gould Spring-Mollie's Nipple Hydraulic Grade Line…………	1 of 3
		2 of 3
		3 of 3
HGL-6	Baseline-Colorado City-West Little Creek Hydraulic Grade Line………	1 of 3
		2 of 3
		3 of 3

HGL-7	Baseline-Colorado City-Honeymoon Trail Hydraulic Grade Line……...	1 of 3
		2 of 3
		3 of 3
HGL-8	Baseline-Pipe Springs-West Little Creek Hydraulic Grade Line………..	1 of 3
		2 of 3
		3 of 3
HGL-9	Baseline-Pipe Springs-Honeymoon Trail Hydraulic Grade Line……….	1 of 3
		2 of 3
		3 of 3
HGL-10	South Kaibab-Honeymoon Trail Hydraulic Grade Line………………...	1 of 3
		2 of 3
		3 of 3
HGL-11	South Kaibab-West Little Creek Alignment Hydraulic Grade Line……	1 of 3
		2 of 3
		3 of 3
HGL-12	Baseline Little Creek Mtn. Gould Reservoir Hydraulic Grade Line……	1 of 3
		2 of 3
		3 of 3
HC-1	Hurricane Cliffs Willow Spring Alingment Plan and Profile with Aerial Image	
HC-2	Hurricane Cliffs Mollie's Nipple #1 Alignment Plan and Profile with Aerial Image	
HC-3	Hurricane Cliffs Mollie's Nipple #2 Alignment Plan and Profile with Aerial Image	
HC-4	Hurricane Cliffs Mollie's Nipple #3 Alignment Plan and Profile with Aerial Image	
HC-5	Hurricane Cliffs Gould Spring Alignment Plan and Profile with Aerial Image	

HC-6	Hurricane Cliffs Gould Reservoir Alignment Plan and Profile with Aerial Image	
CK-1	Cockscomb Alternate Alignments with 7.5 Min. Quad Images	
LU-1	Overall Alignments – Land Use Map………………………………………..…	1 of 3
		2 of 3
		3 of 3
REC-1	Recommended Alignment(s) – Topograhic Map	
REC-2	Recommended Alignment(s) – Topograhic Map	
6-1	Cockscomb Pump Station…………………………………………………...	1 of 2
		2 of 2
7-1	Typical Base Load Hydropower Facility…………………………………….	1 of 4
		2 of 2
7-2	Typical Base Load Hydropower Facility…………………………………….	1 of 2
		2 of 2

Executive Summary

This *Lake Powell Pipeline Feasibility Study – Supplemental Analysis of the Hurricane Cliffs, the Cockscomb, and Alternate Alignments* provides the Washington County Water Conservancy District (WCWCD) with analyses for the Lake Powell Pipeline at two specific locations with challenging engineering and geologic features.

The main objectives of this report are to identify alternate alignments at the Cockscomb and Hurricane Cliffs and to make a recommendation for an alignment to be pursued further. This study identifies alignment options at both locations, analyzes pipeline, tunneling and open cut alternatives, pumping stations, hydropower generating facilities and peaking reservoirs; updates capital and operational costs of the pumping stations; and projects revenue to be generated by the hydropower facilities. In addition, the project cost of the entire pipeline between Lake Powell and the WCWCD is updated in the study.

System Parameters

- Pumping capacity at Lake Powell and a similarly sized pumping station at the Cockscomb: 80,000 A-F/year.
- Water delivery to Kane County Water Conservancy District (KCWCD): 10,000 A-F/year.
- Water delivery to WCWCD: 70,000 A-F/year.
- For the purpose of comparing alignment alternatives, it was assumed that deliveries through the pipeline would be made at a constant rate year-round.

Pumping Stations

The Lone Rock Pumping Station at Lake Powell will pump approximately 26 miles to the Cockscomb Pumping Station. Each station will pump approximately one-half of the total system head. The Bureau of Reclamation report entitled *Preliminary Design and Cost Estimate for Lone Rock Pumping Station*, dated January 2002, considered five possible locations for a pumping station at Lake Powell and recommended the Lone Rock location, identified in the report as Site 3. This *Supplemental Analysis* updates both pumping station capacity and project costs from the Bureau's report.

The Cockscomb Pumping Station may be located on either the east or west side of the Cockscomb. Constructing the pumping station on the west side increases the pumping head for the Lone Rock Pumping Station by 400 feet and reduces the head for the Cockscomb Pumping Station by a like amount if the pipeline is aligned either in the state highway or in a tunnel at approximately the same slope. Hydraulic analyses included in this report are based on the pumping station being located on the east side of the Cockscomb. It is recommended that the Cockscomb Pumping Station be located on the east side of the Cockscomb.

The Cockscomb

The Cockscomb, located adjacent to the Cockscomb Pump Station on U.S. Highway 89, is an approximate 400 foot incline in elevation over a relatively short distance (3 miles). The alignment alternatives for this area include combinations of open cut trenching, tunneling, and shafts. According to the opinions of probable cost, the most cost effective method to handle this obstacle would be to use a method of drill and blast tunneling.

Drill and blast tunneling would eliminate the need for shaft construction and minimize the length of open cut trenching. The opinion of probable cost for this method of constructing a pipeline over the Cockscomb is approximately $8 million, which is 12% less expensive than the next most cost effective method. To reduce the amount of new surface disturbance resulting from the construction, the next most cost effective method was selected.

Open-cut trenching is the same method of construction proposed to be used throughout the majority of the remainder of the pipeline. Some modifications to the standard method of trenching will be required through the Cockscomb. These changes require special rock-saws and extensive traffic control. The opinion of probable cost of this method of constructing a pipeline over the Cockscomb is approximately $9 million.

Although the additional $1 million difference in opinion of probable costs is significant to the construction over the Cockscomb itself, it is less than 0.4 % of the overall capital costs of the pipeline. In consideration of the environment and associated habitat, the recommended construction method following U.S. Highway 89 is open-cut trenching. Following the highway alignment will not create additional disturbance to the environment. Open-cut trenching will allow for a more controlled construction process while being less intrusive to the surrounding area.

Hurricane Cliffs

Unlike the Cockscomb, the Hurricane Cliffs area is a significantly more complex design feature. The Cockscomb alternates all have the same starting and ending locations, they all include the same elevation changes, and they all start with the same hydraulic conditions. In contrast, the Hurricane Cliffs alternates have as many as four different hydraulic conditions, all with different starting and ending points and varying cliff drop-offs that vary from 760-feet to 1,160-feet. In order to make a comparison between each alternative, the Hurricane Cliffs alternates were analyzed independently as a part of the pipeline alignment evaluation process. Each alignment had unique hydraulic conditions and was evaluated separately before comparing them.

This process required the analysis of each of the alternates as independent features. A hydraulic grade line (HGL) was developed for each of the twelve alignment alternatives considered. The HGL development produced a tabular and graphical representation of each alignment, including a profile of the pipeline. For each alternative the cost of piping and appurtenances was developed. The HGLs evolved into an opinion of probable cost with options for base load or peak load hydropower plants and options for various combinations of hydropower plants. The guiding principle for hydraulic selection was maximum production of hydropower generation with minimized piping costs. This allowed comparisons based on the efficiency of each of the pipelines, including diameter, wall thickness and various combinations of hydropower plants.

A few of the alignment alternatives lost substantial amounts of energy because of their topography and hydraulic characteristics. This was due in some cases to the placement of the hydropower plants relative to location and elevation to the peaking reservoirs. Generally the closer the hydropower plants proximity to the peaking reservoir, with the greatest elevation drop, the greater the potential energy recovery. This condition had a negative impact on alignments that have flatter slopes and lower elevation drops around the Hurricane Cliffs.

Several of the alignment alternatives required pressure reducing mechanisms to reduce pressure to an acceptable level in the pipelines. Wherever feasible, hydroelectric plants replaced the pressure reducing valves. The goal of not wasting the potential energy of the pipelines advanced these alignments ahead of other alignments that wasted energy. The more efficient hydropower plants were often larger and located in more remote areas. The larger hydropower plants have higher capital costs, but the benefits of minimizing the loss of energy outweighed the capital costs. This is self-evident when the present worth of the alignments is compared to the capital costs.

Similar to the hydroelectric energy recovery analysis, the number of hydroelectric plants considered for each alignment influenced the decision making process. The number of plants on most alignments included either one or two hydroelectric plants. To maximize power revenues a third power plant option was also considered for Alternative No. 12. Various numbers of power plants were evaluated for Alternative 12. The present worth evaluation indicated two power plants produced the lowest value. All of the alignments included a plant at the Sand Hollow Reservoir with the plant at the base of the Hurricane Cliffs being an alternate. In comparing various combinations of hydroelectric plants, the elimination of a plant at the Hurricane Cliffs produces a significant cost savings, but was offset by the higher cost of the pipe between the Hurricane Cliffs and the Sand Hollow Reservoir, which required a higher class of pipe.

The type of hydroelectric plant was also significant in selecting the preferred alternative. There are two types of hydroelectric power plants: base load and peak load. Base load plants are “run of the river” type plants and have less capital cost. The benefits of the power they produce is less however, since they produce a majority of their energy at times when the demand is lower. This type of base load energy produces less revenue than a plant generating during the peak hours. A peak load hydroelectric plant runs during times of peak electric load and generates power when the demand is the highest. Peak load plants are generally larger with significantly higher capital costs. To evaluate the revenues developed by both plant types, it was assumed that a three-mil price differential between peak and base generation would exist during the life of the project. If this price differential is not realized, then base load plants may become the preferred alternative.

The proposed project consisting of pump stations and hydroelectric power plants will need to be connected into the existing powergrid system in the area. The concept of exchange should be considered in future studies. This concept involves exchanging power generation for power requirements along the pipeline and with the existing power grids. This would require agreements with the western area power authority and local energy purveyors.

All of the factors discussed above impacted the decision making process of the Hurricane Cliffs alignment. The initial analysis expanded from identifying a tunnel and shaft location to determining the alignment of the pipeline to produce the largest hydroelectric potential. The analysis also took into consideration the number and type of hydroelectric power plants. The revenue stream also offsets the capital cost of peak load hydropower facilities.

Pipeline Alternative Alignments

Twelve alignments (HGL-1 through HGL-12) are evaluated between Lake Powell and Sand Hollow Reservoir for the purpose of locating an appropriate crossing of the Hurricane Cliffs:

- Ten alignments are generally located within state highway ROW from Lake Powell through the Kaibab Indian Reservation.
- Two alignments are located within federal, state, and private property south of the Kaibab Indian Reservation.
- A land use map is prepared reflecting all 12 alignments.

Four alternative alignments are evaluated at the Cockscomb.

- Three tunnel alignments include options for steep tunneling and for tunnel and shaft.
- One open cut alignment is located within the U.S. Highway 89 ROW.

Seven locations for crossing the Hurricane Cliffs are evaluated. The 12 pipeline alternatives identified above converge at these seven Hurricane Cliffs locations.

Two alternatives are evaluated between the Hurricane Cliffs and the Sand Hollow Reservoir. These two alignments connect the Sand Hollow Reservoir with the seven Hurricane Cliffs locations.

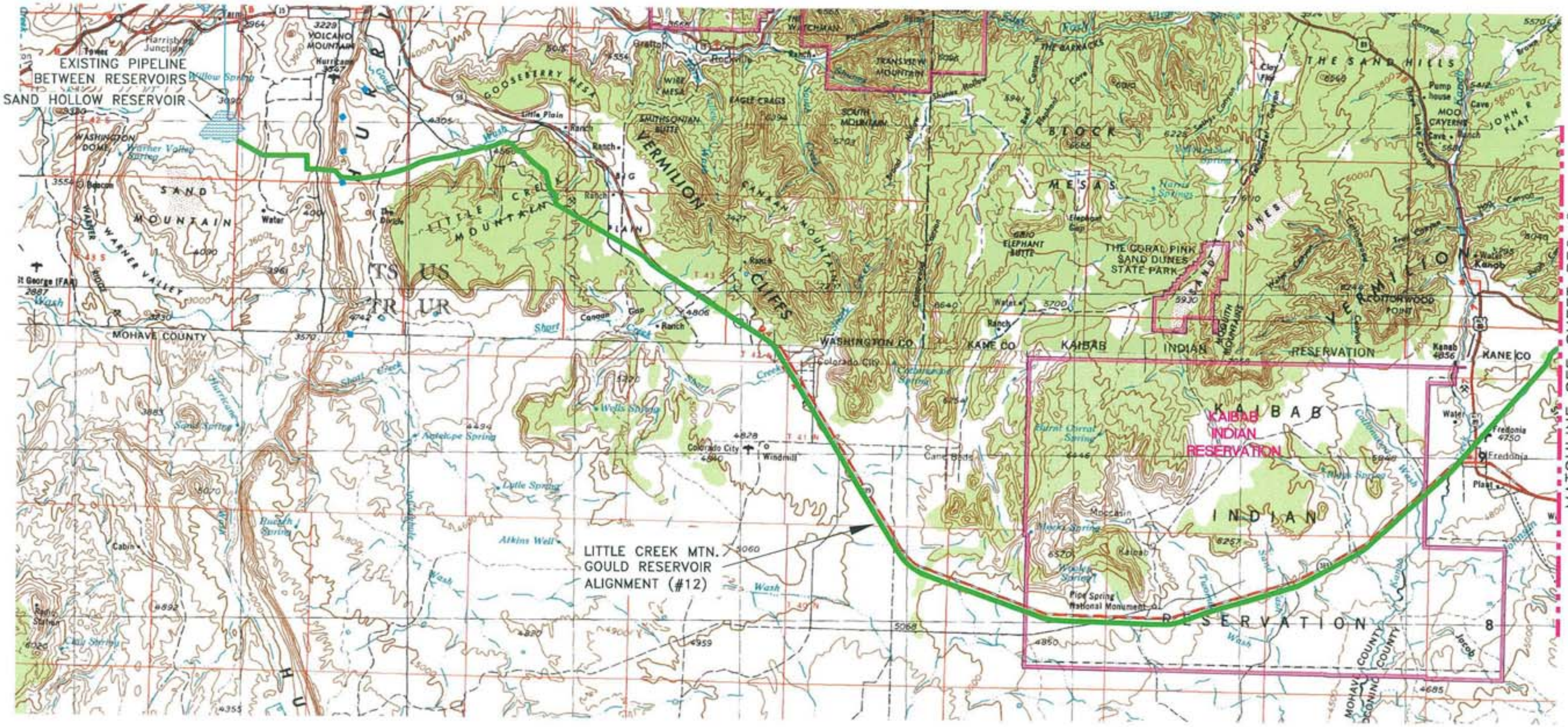
Recommended Alternative

The determination of the most appropriate method and location for traversing the Hurricane Cliffs included the development of 12 distinct alignments. These alignments reflect five cliff crossings and the subsequent alignment combinations easterly to intersect the “baseline” alignment along U.S. Highway 89. Analyses of the hydraulics in order to establish costs for the pipelines resulted in four hydraulic operational scenarios for each alignment. These 48 combinations are ranked on a present worth basis.

Analysis of Table 1 in Appendix 2, which shows the ranking of each of the 48 alignment alternatives, indicates only slight differences between the top four alignment alternatives. The present worth difference between Alternative No. 12 with two peaking hydroelectric facilities and Alternative No. 1 with one peaking hydroelectric facility is $16,206,000, which represents a 4.2% differential. A difference of only 12% exists in the present worth values for a peaking facility with 2 hydroelectric plants (Alternative No. 12) compared to a base load facility with 2 hydroelectric plants (Alternative No. 1). This difference was created largely by the assumption that a 3-mil differential would exist between the value of peaking power versus base load power. If this differential is not realized during the life of the project then the difference, based upon present worth values, will decrease.

Because the differentials noted above are relatively small and were based upon reconnaissance-level data, additional investigations should be made to refine the present worth analyses. The ranking of the alignment alternatives shown in Table 1 in appendix 2 indicate the top four alternatives as: Alternative No. 12, Alternative No. 11, Alternative no. 3 and Alternative No. 1, all with peaking hydroelectric facilities. The top ranking alignments with base load hydroelectric facilities are: Alternative No. 11, Alternative No. 12, Alternative No. 1 and Alternative No. 3. Because these four alternatives were the highest ranked they should be considered in future analyses.

In summary, the No. 12 Alignment with the Cockscomb Highway alignment alternative has the lowest present worth value, geographic features, environmental concerns, and hydroelectric considerations. According to the opinions of probable cost the most cost effective way to build this pipeline in a present worth amount is approximately $370 million by using Alignment No. 12. A map showing this alignment follows.



LEGEND:

RECOMMENDED ALIGNMENT

GRAPHIC SCALE

(IN FEET)
1 inch = 10000ft.

MATCHLINE SEE SHEET REC-2

ORIGINAL SCALE IN INCHES

REV	DATE	DESCRIPTION	APP

DESIGNED BY: AER
DRAWN BY: PSF
CHECKED BY:
DATE: 3/17/03

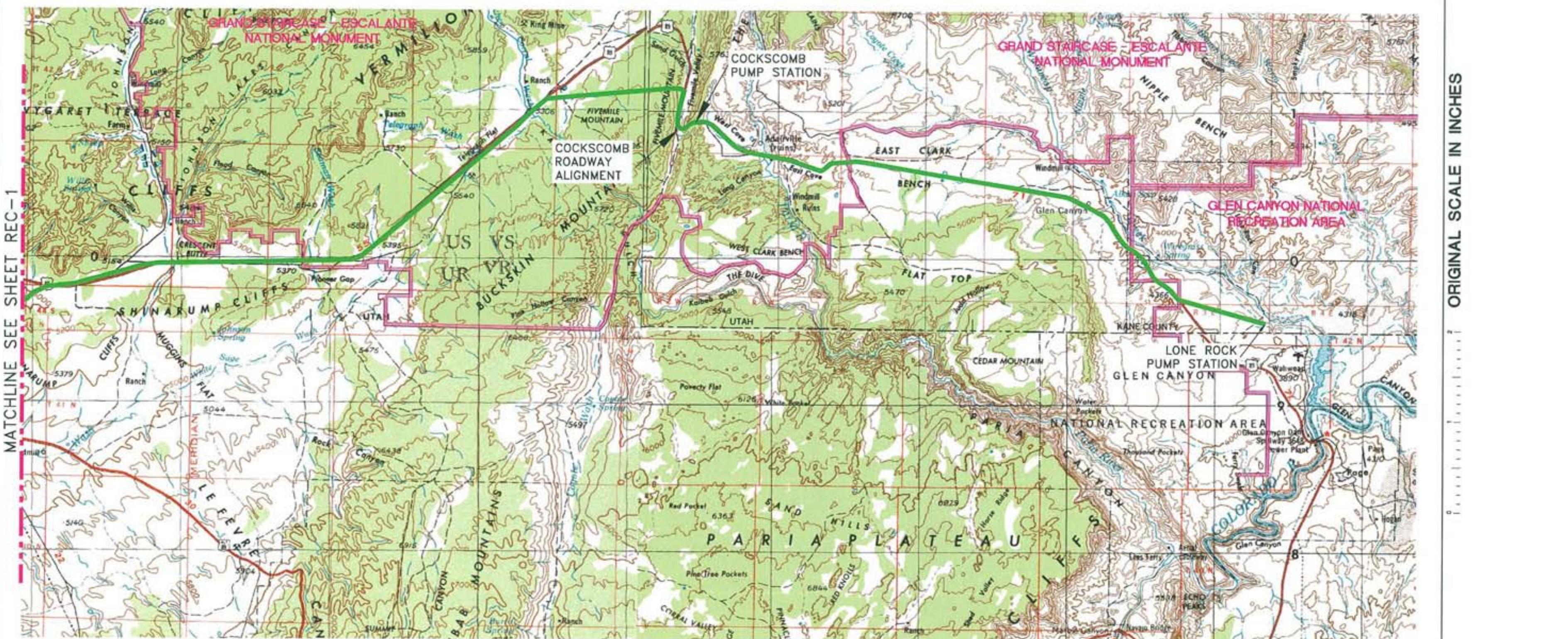
BOYLE ENGINEERING CORPORATION

Washington County Water Conservancy District

LAKE POWELL PIPELINE FEASIBILITY STUDY

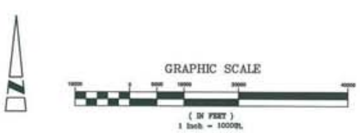
RECOMMENDED ALIGNMENT TOPOGRAPHIC MAP

REC-1



LEGEND:

RECOMMENDED ALIGNMENT



DESIGNED BY	AER
DRAWN BY	PSF
DATE	3/17/03

BOYLE ENGINEERING CORPORATION

Washington County Water Conservancy District

LAKE POWELL PIPELINE FEASIBILITY STUDY

RECOMMENDED ALIGNMENT TOPOGRAPHIC MAP

REC-2

Chapter 1 - Introduction

Project Description

The *Lake Powell Pipeline Feasibility Study – Supplemental Analysis of the Hurricane Cliffs, the Cockscomb, and Alternate Alignments* was authorized by the WCWCD to provide detailed engineering analyses of the Lake Powell Pipeline at two specific locations. The study identifies alignment options at the Hurricane Cliffs and the Cockscomb. The proposed Lake Powell Pipeline is approximately 120 miles long, originating at Lake Powell 1 mile north of Lone Rock Road (7 miles north of Glen Canyon Dam) and delivering water to the Sand Hollow Reservoir, which is about 10 miles east of St. George, Utah. The proposed Lake Powell Pipeline generally follows the existing U.S. Highways 89 and 59 in Utah and Highway 389 in Arizona, staying within the existing highway ROW as much as possible.

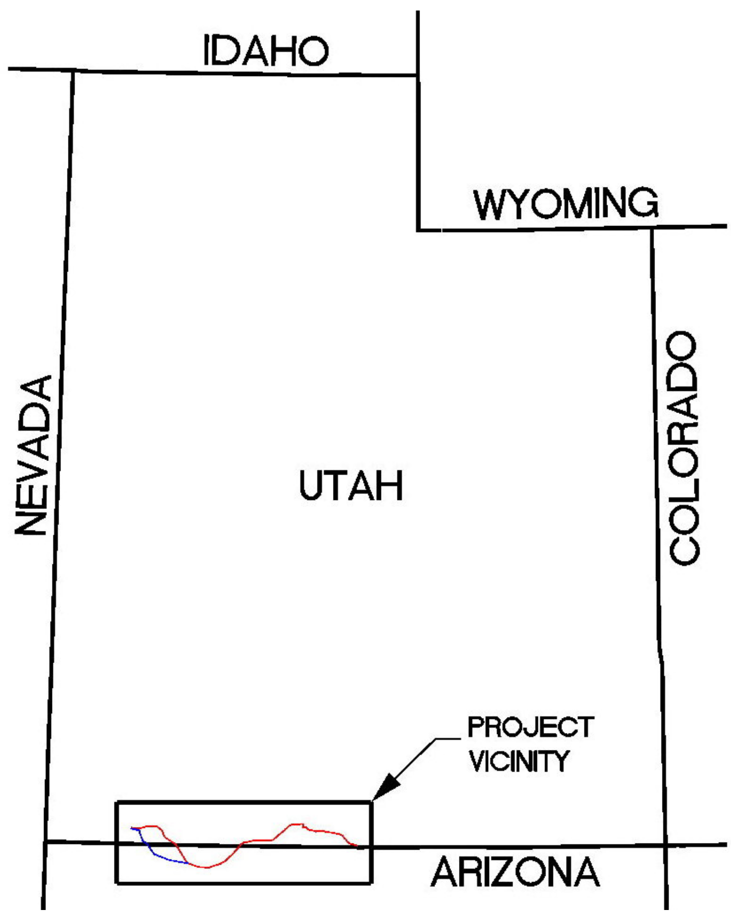


Figure 1-1: Project Vicinity Map

Purpose of Study

The Lake Powell Pipeline Feasibility Study identifies alignment options at the Hurricane Cliffs and the Cockscomb; analyzes pipeline tunneling and open cut alternatives, pumping stations, hydropower generating facilities, and peaking reservoirs; updates capital and operational costs of the pumping stations; and projects revenue to be generated by the hydropower facilities. In addition, the study updates the project cost of the entire pipeline between Lake Powell and the WCWCD.

Project Background

The previous Lake Powell Pipeline Feasibility Study, prepared by Boyle Engineering Corporation in 1995, identified alignments for delivering 60,000 acre-feet per year (A-F/year) to the WCWCD which serves St. George, Utah. Subsequent to the 1995 study, the District increased the quantity to 70,000 A-F/year. As discussed in the previous report, the KCWCD anticipates utilizing another 10,000 A-F/year. Therefore, the pipeline and both pumping stations require capacity for 80,000 A-F/year from Lake Powell to the point of delivery for the KCWCD. For this study, system design parameters for the pipeline and pumping stations anticipate continuous year-round flow.

Separate from but related to this study, Boyle is preparing a *Supplemental Analysis for Water Delivery to the Central Iron County Water Conservancy District* (CICWCD). This related study evaluates, on a feasibility level, possible alignment alternatives and associated additional project costs for supplying the CICWCD with 20,000 A-F/year through the Lake Powell Pipeline. To supply the CICWCD with the 20,000 A-F/year, at least some, if not all, of the capacity of the Lake Powell Pipeline and related facilities will need to be increased (to 100,000 A-F/year to the KCWCD and then 90,000 A-F/year to Sand Hollow Reservoir) if that project proceeds to final design. All capital costs, pumping station and hydropower operational costs, and hydropower revenue projections are evaluated on an "over and above" basis, meaning the cost of **increasing** the Lake Powell Pipeline system capacity to serve the CICWCD is estimated. Those increased costs are not included in the cost analyses for this study for WCWCD.

System Parameters

- Pumping capacity at Lake Powell and the Cockscomb: 80,000 A-F/year at a continuous, constant rate.
- Pipeline size between Lake Powell and the first hydropower "peaking" / surge reservoir: 60-inches in diameter. For base load hydropower facilities the downstream pipeline to the Sand Hollow Reservoir will continue at 60-inch diameter. For peaking hydropower plants, the downstream pipeline diameter will be increased to 75-inches.
- Water delivery to KCWCD: 10,000 A-F/year.
- Water delivery to WCWCD: 70,000 A-F/year.

Pipeline Alternative Alignments

Twelve alignments (HGL-1 through HGL-12) are evaluated between Lake Powell and the Sand Hollow Reservoir:

- Ten alignments are generally located within state highway ROW from Lake Powell through the Kaibab Indian Reservation.
- Two alignments are located within federal, state, and private property south of the Kaibab Indian Reservation.
- A land use map is included reflecting all 12 alignments.

Four alternative alignments are evaluated at the Cockscomb:

- Three tunnel alignments include options for steep tunneling and for tunnel and shaft.
- One open cut alignment is located within the U.S. Highway 89 ROW.

Seven alignments (HC-1 through HC-6 and the Honeymoon Trail) for crossing the Hurricane Cliffs were evaluated. The 12 pipeline alternatives identified above converge at these seven Hurricane Cliffs locations.

Two alternatives are evaluated between the Hurricane Cliffs and the Sand Hollow Reservoir. These two alignments connect the Sand Hollow Reservoir with the seven Hurricane Cliffs locations.

Pumping Stations

The Lone Rock Pumping Station at Lake Powell will pump approximately 26 miles to the Cockscomb Pumping Station. Each station will pump approximately one-half of the total system head. The Bureau of Reclamation report entitled *Preliminary Design and Cost Estimate for Lone Rock Pumping Station*, dated January 2002, considered five possible locations for a pumping station at Lake Powell and recommended the Lone Rock location, identified in the report as Site 3. This *Supplemental Analysis* updates both pumping station capacity and project costs from the Bureau's report.

The Cockscomb Pumping Station may be located on either the east or west side of the Cockscomb. Constructing the pumping station on the west side increases the pumping head for the Lone Rock Pumping Station by 400 feet and reduces the head for the Cockscomb Pumping Station by a like amount if the pipeline is aligned either in the state highway or in a tunnel at approximately the same slope. Constructing the pumping station on the west side does not affect the pumping head for the Lone Rock Pumping Station if the pipeline is aligned in a tunnel of relatively flat profile. Hydraulic analyses are based on the pumping station being located on the east side of the Cockscomb.

Hydropower Facilities

Two hydropower generating facilities are considered for alignments HGL-1 through HGL-11.

- Both base load and peaking plants are evaluated.
- One generating plant is located at the bottom of the Hurricane Cliffs and the second at Sand Hollow Reservoir.

Alignment HGL-12 includes a third hydropower generating facility at Little Creek Mountain.

A peaking reservoir on top of the Hurricane Cliffs will serve the peaking plants at the bottom of the Hurricane Cliffs.

A peaking reservoir on top of Little Creek Mountain will serve the third peaking plant in Alignment HGL-12.

A peaking / surge reservoir is not considered necessary at the Sand Hollow hydropower facility. The plant will be designed with a by-pass pipeline around the generation facility, which will discharge directly into the existing Sand Hollow Reservoir under unusual or surge conditions.

Scope of Work

Evaluate Alternative Pipeline Alignments through the Hurricane Cliffs and Cockscomb

1. Seven alternative alignments at the Hurricane Cliffs have been developed, investigated in the field, and plotted in plan and profile. See alignment photos in Appendix 3.3. Discussion of these alignments is included below.
2. Four alternative alignments at the Cockscomb were developed, investigated in the field, plotted in plan and profile, and an opinion of project costs prepared for steep grade tunneling, tunnel and shaft construction, and open cut excavation along U.S. Highway 89. See alignment photos in Appendix 3.2. Discussion of these alignments is included below.
3. Twelve alignment combinations are analyzed and mapped in plan and profile. See Volume 2.
4. Alignment lengths of the resulting overall pipeline alignments vary from approximately 637,000 feet (120.64 miles) to 664,000 feet (125.76 miles).
5. An estimated hydraulic grade line (HGL) has been developed for each alignment, establishing preliminary pipe pressure along the entire length of each alignment. The pipe pressure was utilized in preparation of the cost opinions.
6. Estimated construction and O&M costs have been prepared for all alignment alternatives. See Appendix 2.

Pumping Stations Preliminary Design

1. Preliminary design layout of the Lone Rock and Cockscomb pumping stations is shown in Volume 2 and the power requirements for both stations are identified.

2. Potential sources of power are identified.

3. Alternative Cockscomb Pumping Station sites are identified in Volume 2.

4. Pumping station 'head' is incorporated into each hydraulic grade line (HGL) profile.

5. An opinion of project capital costs is expressed in Appendix 2.

6. Estimated operational costs (power and maintenance) are presented.

Proposed Hydropower Facilities

1. Available head (pressure) is determined for seven potential hydroelectric facility locations along the Hurricane Cliffs and one location on Little Creek Mountain.

2. Hydropower generating facility capacity is identified for base load and peaking plants at each proposed facility. Peaking facilities are anticipated to operate and sell power eight hours per day during the 11:00 am to 7:00 pm maximum power demand period.

3. Annual energy output is estimated for base load and peaking plants.

4. Annual energy revenue is estimated at $0.03, $0.04, $0.05, and $0.06 per kilowatt-hour (kwh).

5. Penstock diameters and lengths are determined.

6. Opinions of probable project costs are prepared.

7. Estimated operational costs are shown.

Additional Services

Additional Services Authorized on September 9, 2002

1. For pipeline and related infrastructure sizing, increase the quantity of Lake Powell water to be delivered to the WCWCD to 70,000 A-F/year (from 60,000 A-F/year).

2. Prepare aerial maps with 10-foot contours of the Hurricane Cliffs, including establishing the necessary survey control. Alpha Engineering Company performed this work in conjunction with an unrelated project in the area.

3. Incorporate the Hurricane Cliffs alternative alignments into the 10-foot contour maps.

4. Evaluate additional off-road alternative alignments, including hydraulic conditions, hydropower generation options, and related revenue and costs as follows:

    a. Off road alignment(s) from US Highway 89, east of Kanab, Utah, to/along the southern boundary of the Kaibab Indian Reservation.

    b. Alignment(s) down the Hurricane Cliffs along the Honeymoon Trail.

Additional Services Authorized December 13, 2002

5. Evaluate an additional alignment that includes increased hydropower generation and related reservoir capacity, which utilizes available total head, and analyze generating facility revenue and costs.

Additional Services Authorized February 13, 2002

6. Prepare and deliver a presentation regarding the proposed project on February 19, 2003, at the Colorado River Steering Committee Meeting in Boulder City, Nevada.

Authorization of Work

This work was authorized on July 25, 2002, based upon Boyle's proposal dated May 22, 2002.

Chapter 2 - Hurricane Cliffs

Location

The Hurricane Cliffs are a geomorphic expression of the Hurricane fault, which extends from Cedar City, Utah, south to the Grand Canyon area in Arizona. The primary alternate alignments for the Lake Powell Pipeline crossing the Hurricane Cliffs are located from 2 to 6 miles south of Hurricane, Utah, beginning just north of the Frog Hollow drainage (see Figure 2-1). Another location is at the Utah and Arizona border approximately 12 miles south of Hurricane. Sand Hollow Reservoir, the termination point of the pipeline, is located about 3-½ miles west of the primary alternate alignments.

Figure 2-1: Hurricane Cliffs – View North Toward Frog Hollow

Site Conditions and Topography

The base of the cliffs in the areas of the primary alternate pipeline alignments forms the eastern boundary of a broad alluvial valley. The contact runs at about Elevation 3400 feet in the area of the alternate alignments. The valley gently slopes northward into a drainage that is tributary to the Virgin River just north and west of Hurricane. The base of the cliffs at the southern alternate alignment (at the Arizona border) is also the boundary of a broad alluvial valley, but one that slopes southwesterly into the Fort Pearce Wash. The contact in this area of the cliffs is about Elevation 3500 feet. Topography along the selected alternate pipeline routes from the base of the cliffs to Sand Hollow Reservoir is relatively flat with ground slopes generally less than 3.5 percent. The southern alignments cross over the valley divide and descend into the reservoir basin at a 15 percent grade for a vertical distance of about 300 feet before transitioning to a 2 percent grade to the reservoir. The northern alignments are somewhat flatter overall but descend into the reservoir basin at a 20 to 25 percent grade through a vertical drop of about 120 feet before flattening to about 3.5 percent grade to the reservoir (see Figure 2-2).

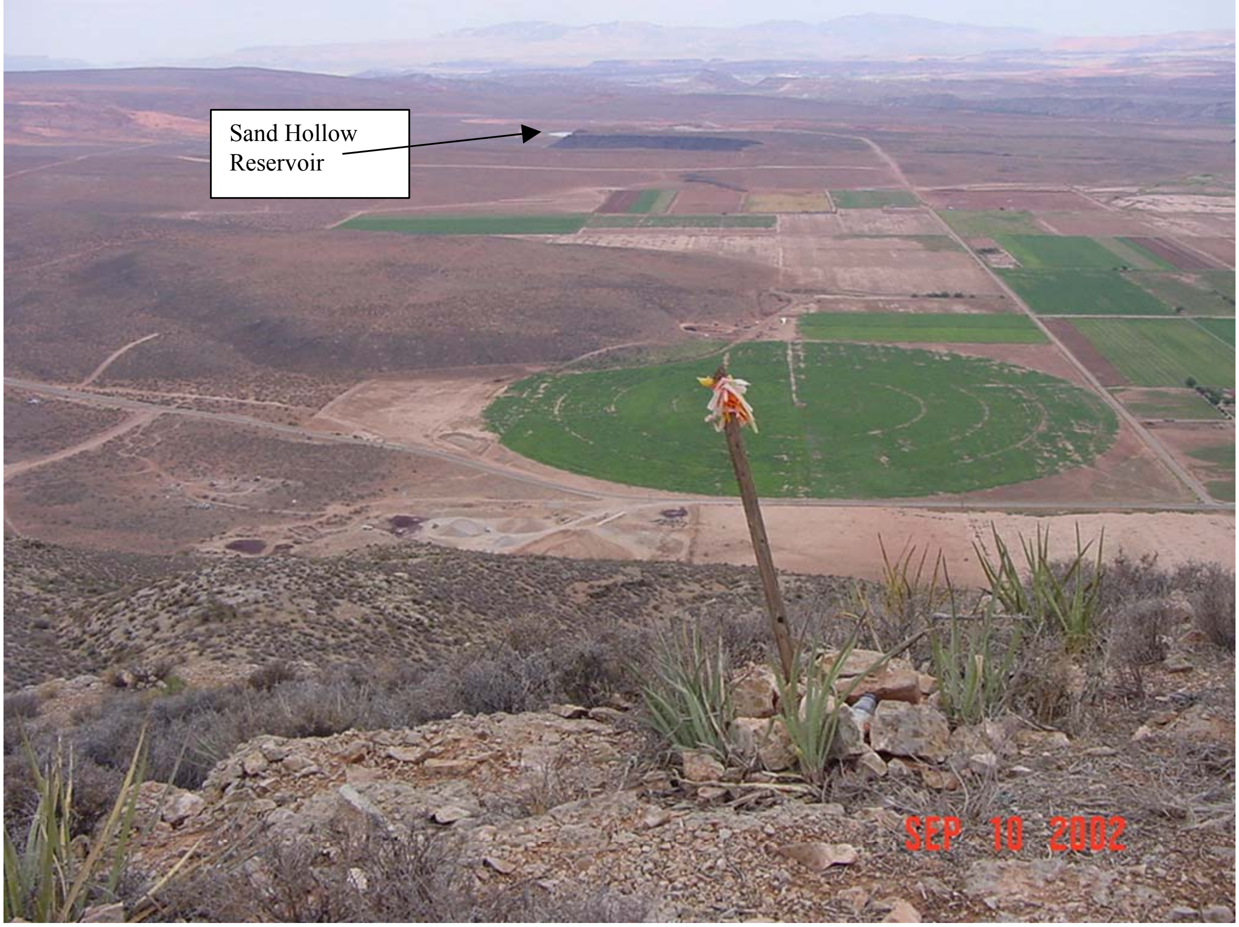


Figure 2-2: Valley Area Between Hurricane Cliffs and Sand Hollow Reservoir

The toe area of the cliffs is generally covered with unconsolidated material that has accumulated from weathering and erosion of the cliff materials (see Figure 2-3). Profile plots of the cliff face at the alternate alignments show the slope of the material surface to be concave in shape with the toe area running out at about 2H:1V or flatter and the upper area sloping from the cliff face at 1H:1V and steeper. This rounded shape is likely due to some apparent cohesiveness and angular cobbles in the soil matrix allowing for the steeper slopes and runoff down the cliff face depositing a "delta" of fines, sands, and gravel to create the flatter toe slopes. The toe area of the unconsolidated material merges into the relatively flat alluvial valley that abuts the cliffs in the area of the alternate alignments. The material slopes range from about 50 feet to more than 150 feet in vertical height up to the cliff face. The depth of unconsolidated material below the ground surface may be highly variable. It is likely to be several tens of feet based on an observation of a gravel pit at the base of the cliff in the area of the alternate alignments at about 3000 South. The depth of this unconsolidated material will need to be determined with future geotechnical explorations if alignments are selected in this area. The depth of this unconsolidated material will need to be determined with future geotechnical explorations if alignments are selected in this area. The continuity of the material along the base of the cliff is interrupted by minor erosion channels from localized drainages down the face of the cliffs. A major drainage, Frog Hollow, cuts through the full height of the cliffs at the north end of the alternate alignments. The northern most alignment is located just north of the canyon created by Frog Hollow. The Frog Hollow drainage channel turns northward along the base of the cliffs in this area, resulting in minimal unconsolidated material at the base of the cliff along at the northern alternate alignment.

Figure 2-3: Base Area of Hurricane Cliffs at about 3000 South

The Hurricane Cliffs exhibit a vertical relief varying from 750 feet up to about 1330 feet at the different alternate alignments. The slope of the cliffs is reflective of the differential movement between bedrock units on the uplift side of the Hurricane Fault and weathering and erosion of the softer bedrock units. The resulting topography is typical cliff and bench with two to three distinct zones reflective of the different rock formations exposed in the cliffs (see Figure 2-4). Within the zones, the vertical relief between benches is near vertical. The benches appear to be at about 1.5H:1V slopes reflecting angle-of-repose slopes consisting of a colluvium mantle overlying the softer, more weathered and degraded bedrock units.

Debris from the more durable bedrock in the upper vertical slopes is present on the surface of the colluvium mantles. The complete slope of the cliffs ranges from 1.3H:1V to 2H:1V in the areas of the alternate alignments.

The crest elevation of the cliffs undulates with the high points consisting of the more resistant bedrock in the uppermost "bench and cliff" zone. The "bench" section of this upper zone is fairly uniform in thickness and slope along the crest of the cliffs in the areas of interest. This uniformity and slope gives the appearance that the high points are offset eastward from the top of the Hurricane Cliffs but are the highest point of the cliffs. The crest elevation at the northern alternate alignment (north side of Frog Hollow) is about Elevation 4120.

Southward from Frog Hollow, the ridge rises to a peak elevation of about 4650 feet. The alternate alignments just south of this peak are at a crest elevation of about 4450 feet. Continuing south along the crest, peaks rise to about Elevation 4950 feet or higher (see Figure 2-4). The alternate alignments in this area lie between the peaks at a crest elevation of about 4700 feet. The southern alternate alignment at the Arizona border, in what is known as the Honeymoon Trail, crosses the Hurricane Cliffs via a drainage that cuts through the crest at about Elevation 4500 feet (see Figure 2-5).

The walls of the cliffs consist of highly jointed and fragmented rock. Near vertical shear planes and open joints parallel to the strike of the cliffs have resulted in standing slabs of rock along the cliff face. In most areas, there are multiple slabs several tens of feet thick that appear to be "peeling" away from the face. Float and debris from collapsed slabs are present on the slope. The stability of materials exposed in the cliff face has continually changed over time due to wind and runoff erosion, weathering, and the long-term slip rate of the Hurricane Fault. In addition, the stability of the face of the cliff will continue to be affected by seismic activity along the fault, including the potential for surface ruptures in the event of large earthquakes along the fault as discussed below.

The east side of the crest is moderately sloping terrain from the flanks of the peaks. The slopes form the western edge of a broad north sloping drainage basin. The drainage basin topography is relatively flat and gently sloping towards Frog Hollow (see Figure 2-6).

Figure 2-4: Hurricane Cliffs at Grass Valley

Figure 2-5: Crest Area of Alternate Alignment at the Honeymoon Trail on the Arizona Border

Figure 2-6: Drainage Area East of Hurricane Cliffs

Geology

The Hurricane Cliffs are a result of normal faulting along the westward dipping Hurricane Fault and are considered to be a fault-line scarp that traces the Hurricane Fault. The cliffs are the up-thrown side of the fault and are made of older bedrock formations compared to the near surface bedrocks on the downthrown side and westward from the cliffs.

The Hurricane Fault can be traced for about 150 miles through southwestern Utah and Northern Arizona. It is divided into several segments along its trace. It is considered to be within the transition zone from the Colorado Plateau geomorphic province and the Basin and Range Province to the west of the fault zone. The fault trace from north of Hurricane, Utah, to about 7 miles south of the Arizona border, identified as the Anderson Junction Segment, is considered to be the tectonic boundary between the two provinces (see Figure 2-7). The alternate pipeline alignments are located across this segment of the fault.

The Hurricane Cliffs are also considered the western boundary of the "Grand Staircase," a series of topographic benches and cliffs that rise from south to north from the North Rim of the Grand Canyon to the top of the Paunsaugunt Plateau in southern Utah. The staircase spans from southwest Utah along the Hurricane Fault eastward to the eastern boundary of the East Kaibab monocline (commonly known as The Cockscomb). The geologic features of the significant benches and riser cliffs are also observed in the Grand Canyon, Zion, and Bryce Canyon National Parks. The northeast area of the staircase is located in the Grand Staircase-Escalante National Monument located in southern Utah.

Figure 2-7: Hurricane Cliffs Looking North from Near the Arizona Border - Fault/shear trace visible in right foreground; Little Creek Terrace in upper right background.

The bedrock exposed in the Grand Staircase range from the upper formations of the Permian time period (Kaibab Formation limestone and Toroweap Formation) at the southern Kaibab Plateau to the Tertiary Period (Claron Formation limestone). This same range of formations is observed in the Hurricane Cliffs from south to north. At the southern end of the cliffs, Pennsylvanian limestone of the Callville Formation is observed in the cliff wall. Remnant caps of Quaternary basalts are present throughout the staircase and extend over into the eastern portion of the Basin and Range Province. The offset of the basalt flows and caps across the Hurricane Fault is indicative of the recent faulting along the Hurricane Cliffs.

Bedrocks exposed in the Hurricane Cliffs in the areas of the alternate pipeline alignments generally range from the older Permian formations along the base of the cliffs up to Triassic

Moenkopi Formation in the upper elevations of the cliffs. Basalt caps and possible vents or cinder cones are present along the crest line. The Toroweap Formation and limestone of the Kaibab Formation overlie the Queantoweap Sandstone in the base of the cliffs. The interbedded sedimentary rocks of the Moenkopi Formation form the upper, more moderately sloping portion of the cliffs. Locally, along the strike of the cliffs, the bedrock units tilt gently eastward. Regionally, the units dip in a northward direction. A more detailed description of the bedrock stratigraphy of the cliffs is presented in the tunneling feasibility report in Appendix 4.

The bedrock near the surface west of the Hurricane Cliffs is primarily Jurassic period formations consisting of Navajo Sandstone and bedrock units of the Carmel Formation. Quaternary basalt flows cap some of the higher topographic features near and west of the Hurricane Fault trace (see Figure 2-2). In the area of the alternate pipeline alignments, the basalt flows are absent from the base of the cliffs at the proposed alignment locations.

Seismic Setting

The Hurricane Fault is one of the longest and most active faults in the southwest Utah – northwest Arizona area. It is located within the southern end of the Intermountain Seismic Belt. The fault is a large normal, west dipping fault that originated in late Cenozoic time and continued movement well into the Quaternary time period. Evidence of Holocene Fault movement occurs in some areas of the fault, but the cited evidence is not continuous along the fault or within the segments of the fault. Based on recent studies, the fault can be divided into segments that exhibit faulting and movement independent of one another. Characteristics of the upper three segments of the fault, Anderson Junction, Ash Creek, and Cedar City (from south to north), will have the most effect on the Lake Powell Pipeline Project.

In summary, the following points concerning the Hurricane Fault and its Anderson Junction segment are presented with respect to Lake Powell Pipeline Project:

- Evidence of Holocene Fault movement occurs in areas along the fault but is not continuous or necessarily related to the same seismic event. On the Anderson Junction Fault segment evidence was found of a single fault rupture occurrence in very late Quaternary or possibly early Holocene time in Cottonwood Canyon in northern Arizona.

- The long-term fault slip rate along the Anderson Junction segment is estimated to have slowed for an overall long-term average of 0.4 to 0.6 millimeters (mm)/year to a current estimate of 0.21 mm/year. Based upon the reduced estimated slip rates, the recurrence interval for surface faulting along the Hurricane Fault in southern Utah is likely several thousand years and can be possibly be more than 10,000 years.

- The maximum moment magnitude earthquake along the Anderson Junction segment of the proposed pipeline is estimated to be between M 6.8 and M 6.9. To the north along the Ash Creek Segment, it is estimated at to be about M 6.9 to 7.1.

Near-field ground accelerations generated by these events have not been estimated for this level of the pipeline study and are appropriate for the preliminary design phase.

Geotechnical and Engineering Considerations

In general, the bedrock materials appear competent. No geologic conditions were identified that would compromise the overall feasibility of the alternative alignments, but the rugged terrain and presence of the Hurricane Fault zone with its potential seismic loads will likely require specialized design features. The exception to this is the Hurricane Fault zone and the potential seismic design loads to a structure within and immediately adjacent to the fault zone. The geotechnical considerations for the pipeline at the Hurricane Fault zone will be a function of the construction alternative selected for the pipeline. The three construction alternatives for this portion of the Lake Powell Pipeline project include:

- A drop shaft east of the cliff face down to a horizontal tunnel that is terminated below grade west of the base of the cliff.
- Cut and cover (burial) over the crest and down the face of the cliff.
- Surface support of the pipeline over the crest and down the face of the cliff.

These alternatives and the cost for each one are discussed below, outlining geotechnical and engineering considerations that can influence the feasibility and costs of the alternatives.

Shaft and Tunnel

This construction alternative will likely have the fewest geotechnical concerns of the alternatives. The drop shaft east of the cliffs can be located such that it is outside of the major physical influences of the Hurricane Fault. The bedrock conditions on either side of the fault zone are such that tunnel and shaft excavations are neither problematic nor is groundwater anticipated to be a problem.

The greatest concern with this option is the design and construction of the tunnel crossing the Hurricane Fault (or fault zone). The fault zone will likely consist of highly fractured bedrock and possibly soil-like materials (fault gouge) requiring additional ground support for stability. As discussed above, the cliff face consists of sheared and fractured bedrock slabs within and immediately adjacent to the fault zone. Therefore, if the tunnel exits at the base of the cliffs (rather than crossing through the fault zone below grade), portal development will require additional stabilization of the slope above the portal. Associated with crossing through the fault or construction of an above-grade portal will be the seismic stability of the structure(s). The long-term slip rate of the fault is about 0.21 mm/year. There is also the potential for surface fault rupture in addition to the impacts of ground acceleration. These are most exaggerated in the option of a near-surface pipeline exit of the cliffs that will require an above-grade portal.

Cut and Cover

The cut and cover option for pipeline construction down the face of the cliffs will entail several geotechnical and construction challenges. These challenges include:

- Construction and vertical alignment over steep, rugged, and relatively inaccessible terrain requiring special construction techniques.
- Construction procedures and scheduling and temporary pipeline support.
- Potentially deep excavations to found the pipeline outside of the fault zone.
- Selection and design of an alignment to minimize the cut requirements.
- Slope stability and pipeline stability in the event of a large, near-source earthquake.
- Surface fault rupture in the vicinity of the pipeline.
- Concrete or soil cement trench backfill for long-term pipe cover stability.

Construction of the buried pipeline within the fault zone or near surface materials in the cliff face is not recommended for many reasons, including:

- The discontinuity of materials and rock units within the fault zone and along the face of the cliffs resulting in variable pipe support conditions.
- The continuous changing of the slope face due to erosion and seismic activity within project area.
- The difficulty of excavating such a steep trench with conventional excavation equipment.
- The difficulty in backfilling the trench on such steep slopes. Even with concrete backfill, the formwork to retain the concrete would be expensive.

Considering these geologic and construction challenges, the cut and cover alternative was dismissed as significantly less practical and more expensive than a tunneled approach. Consequently, no cost estimates were prepared for this alternative.

Surface Support

This option for pipeline construction will also encounter many challenges similar to the cut and cover option. However, additional concerns related to support anchoring and seismic stability further contribute to the challenges of this option. The significant concern with this option is the stability/reliability of the anchoring system of the pipeline supports under seismic loading conditions. In general, the bedrock materials appear competent with respect to supporting the pipeline and static stability of the anchoring system. If the anchors are founded within the fault zone, then the system is left “floating” within the fault zone with no resistance to movement during a seismic event that results in surface fault rupture in the area of the pipeline. In placing the anchors through the fault zone, damage to the anchor and support system is a concern with any movement within the fault zone. The feasibility of these two options can be increased if future field explorations result in the identification of an alignment where the base of the cliff is east of the fault zone.

In summary, the tunnel and shaft option offers the least critical geotechnical concerns with respect to design and construction. The cut and cover and surface support options exhibit the most critical geotechnical concerns with respect to seismic stability of the pipeline. The feasibility of these two options can be increased if future field explorations result in identification of an alignment where the base of the cliffs is east of the fault zone. This will enable a perpendicular crossing of the fault zone and enhance the seismic stability of the pipeline.

Pipeline Alignment Alternatives at Hurricane Cliffs

In 1994, WCWCD commissioned a purpose and need study to both quantify the current and future county-wide water needs and to identify potential water resource projects to meet those needs. That report was to "be considered a dynamic tool for water development, and [should] be reviewed and updated periodically as…experience is gained." Subsequent to the purpose and need study, a Lake Powell Pipeline Feasibility Study was also completed. The March 1995 purpose and need study and the Lake Powell Pipeline Feasibility Study reports were updated in 1998. The 1998 update addressed an additional 10,000 A-F/year needed by KCWCD, which had prepared a water resources master plan (WRMP) in 1997. The 1998 update added the KCWCD demands to the WCWCD demands to result in a pipeline sized to deliver 80,000 A-F/year.

A favored alignment was identified which recommended two pumping stations and hydroelectric power generation at the base of the Hurricane Cliffs. To further evaluate the favored alignment, this current *Supplemental Analysis* project was commenced to identify alternative methods of construction and routing locations for the proposed Lake Powell Pipeline and related pumping station and hydropower facilities at the Cockscomb and Hurricane Cliffs. Integral with identification of alternative methods of construction at these two locations, development of preliminary sizing for the recommended facilities was necessary to estimate probable capital and life cycle costs. Those costs were utilized for purposes of evaluating alternatives for construction of the recommended alternatives.

Alignment development proceeded by obtaining and reviewing existing, readily available topographic and ownership mapping. Also, selected topographic information was field verified.

Initial selection of site(s) and alignments down the cliffs was made in preparation for field reconnaissance. Evaluation of identified alignment alternatives from the proposed peaking reservoir sites to Sand Hollow Reservoir was performed, and additional alignment opportunities were developed.

Appropriate hydraulic conditions are developed in this current study as the basis for cost comparisons and refinement of reservoir locations. The surge conditions developed by power generation are also reviewed. For all alignments, power generation options affected the selection of the size and the site of the Hurricane Cliffs Reservoir and influenced selection of additional proposed alternatives for evaluation. Hydraulic calculations demonstrate the significant amount of remaining head (pressure) as the pipeline approaches the Cliffs. A surge reservoir is required whether the hydropower facilities are constructed as base load or peaking. With peaking hydro generation plants, the surge reservoir will also serve as a peaking reservoir. However, in all alignments, the amount of remaining pressure in the pipeline is sufficiently large to require pressure-reducing facilities. Alternatives to constructing a pressure reducing facility near the surge reservoir are discussed in later sections of this report.

The diameter of the pipeline necessary to deliver water for each power generation option is determined. The penstock downstream of the peaking reservoir is calculated to carry three times the flow as the penstock for the base load options (8 hours per day flow versus 24 hours per day). As part of this effort, power generation sites at the base of the Hurricane Cliffs and at the Sand Hollow Reservoir are selected. Power generation options for each alignment are developed considering alternative approaches. These are discussed further in later sections of this report.

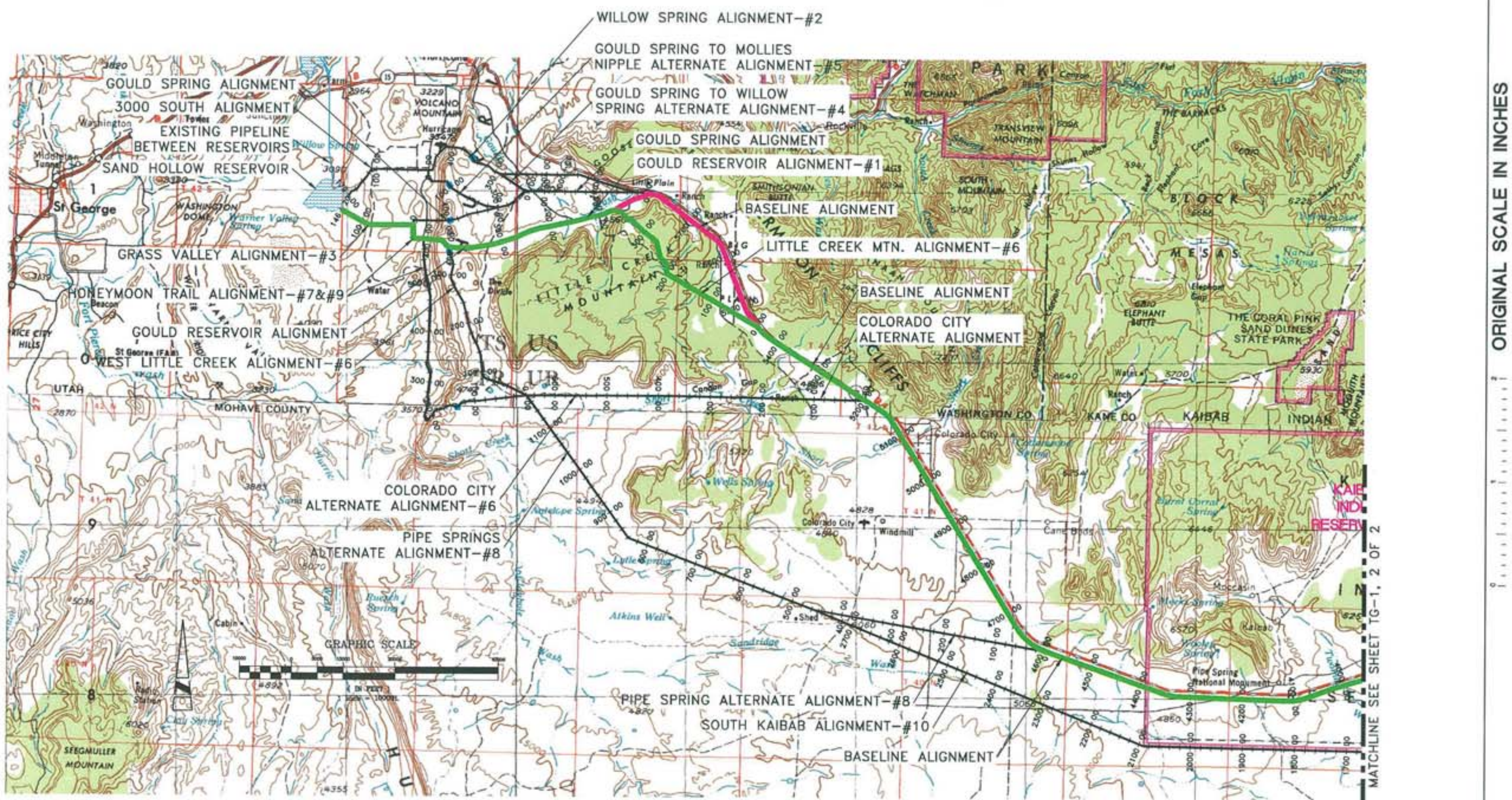
Geology and geotechnical data review and field reconnaissance were performed concurrently with the alignment reconnaissance. A summary of the geologic conditions which affect the selection of the alignments was discussed previously. Haley and Aldrich's *Tunnel Feasibility Report* is included as Appendix 4.

Hurricane Cliffs Alignments

Initial alignment selection is based on field reconnaissance as described above, with the primary criterion of constructability. Locations are selected for traversing the cliffs, which appeared to provide opportunities for siting the proposed hydroelectric power plant at the base of the cliffs and, at the same time, provided construction space for a peaking reservoir at the top of the cliffs. Consideration is also given to minimizing the length of pipeline to discharge into Sand Hollow Reservoir. Based upon the selection of the cliff-crossing locations, the alignments approaching the cliffs from the east are developed. Where possible, the alignments are modified to keep the elevation as high as possible in order to keep the pressure as low as practical.

For each alignment a hydraulic profile is developed, initially to establish the cost of the pipe. Additional hydraulic facilities are identified which will be necessary for each alignment. These include standpipes and pressure-reducing facilities to control the operating and surge pressures, which are unique to each alignment. Hydraulics are developed in order to determine the pressure and, thus, the cost of the pipe for each alignment. In Alignments 1 through 12, the pressure in the pipeline as it discharges to the peaking / surge reservoir must be reduced, subsequently "wasting" the available head. Subsequently, the hydroelectric power generation potential of the project was maximized and Alignment 12 was developed.

The twelve alignments identified during the field reconnaissance and subsequent development of the hydraulic profiles are described in detail below and are shown on the attached map. Please note that in previous reports, the pipeline stationing and description of the alignments originated at Sand Hollow Reservoir. This has been reversed for this report to originate at Lone Rock Pumping Station. The hydraulic calculations follow the direction the water flows (is pumped). This stationing can be utilized for preliminary and final design.



DESIGN BY: AER	BOYLE ENGINEERING CORPORATION	Washington County Water Conservancy District	LAKE POWELL PIPELINE FEASIBILITY STUDY
DRAWN BY: PSF			OVERALL ALIGNMENTS TOPOGRAPHIC MAP
DATE: 6/16/03			DRAWING NO. TG-1, SHEET 1 OF 3

ORIGINAL SCALE IN INCHES

AER

PSF

6/16/03

BOYLE ENGINEERING CORPORATION

Washington County Water Conservancy District

LAKE POWELL PIPELINE FEASIBILITY STUDY

OVERALL ALIGNMENTS
TOPOGRAPHIC MAP

TG-1

2 of 3

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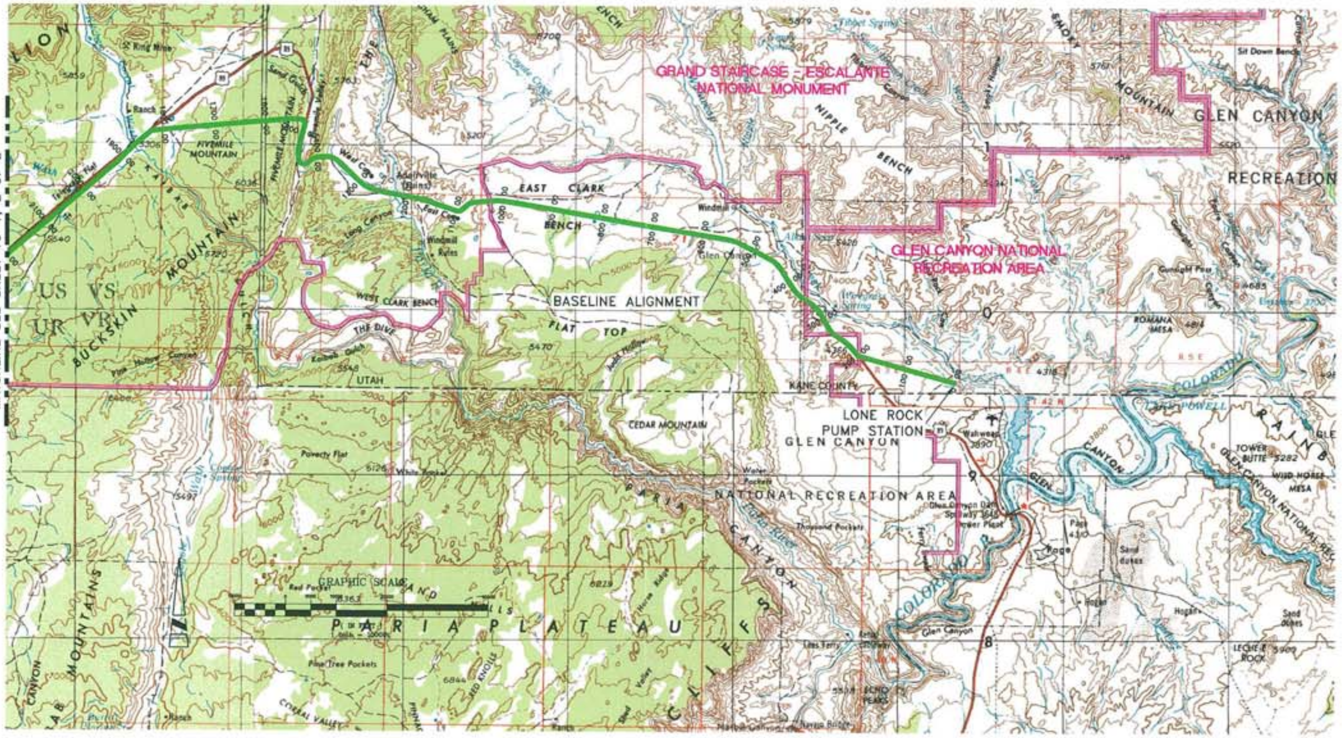

ORIGINAL SCALE IN INCHES

AER	BOYLE	Washington County Water Conservancy District
PSF		LAKE POWELL PIPELINE FEASIBILITY STUDY
6/16/03		OVERALL ALIGNMENTS TOPOGRAPHIC MAP

TG-1

3 of 3

1. Gould Reservoir Alignment

The Gould Reservoir pipeline alignment is 122.14 miles long and is a modification of the baseline (preferred) alignment as described in the previous reports. It originates as do all of the alignments at Lake Powell 1 mile north of Lone Rock Road (7 miles north of Glen Canyon Dam) and ends at Sand Hollow Reservoir 10 miles east of St. George, Utah. It generally follows existing two-lane highways (U.S. Highway 89 and 89A, Arizona 389, and Utah 59), which appear to have ample existing ROW for construction. It traverses relatively flat silty-sandy desert terrain with sparse grasses, brush, and occasional pinion-juniper, with the exception of the portion of the alignment near the Hurricane Cliffs.

Within the Kaibab Indian Reservation this alignment remains within the existing highway ROW. To the extent possible, except for a portion within the Grand Staircase Escalante Wilderness, Alignment 1 avoids wilderness areas, wilderness study areas, national forests, and other known sensitive lands. Since the 1998 report, the Grand Staircase Escalante Wilderness was proclaimed by then-president Clinton. It is our understanding that a corridor 800 feet wide along U.S. Highway 89 was reserved for utilities. This alignment remains within that corridor. The alignment is shown in Figure HGL-1, Volume 2.

At approximately Station 5800+00, the pipeline leaves the highway ROW and heads westerly towards the Hurricane Cliffs following the toe of South Little Creek Mountain. The alignment avoids crossing the deeply incised canyon of Frog Hollow. A short, steep drop in elevation will be required at Gould Reservoir, but other than that, the pipe elevation is kept as high as possible in order to keep the design pressure in the pipe as low as practical. Once crossing Gould Reservoir's drainage basin, the alignment approaches the south slope of the southernmost of the five prominent knobs atop the Hurricane Cliffs east of Grass Valley. A pressure-reducing facility and peaking reservoir would be constructed just behind the cliffs. The pipeline would drop in a vertical shaft behind the cliff face, exiting below grade at the proposed hydroelectric generating facility at the toe of the cliffs. Note that the pressure-reducing facility will waste substantial head at the top of Hurricane Cliffs. (The spreadsheets in Appendix 2 indicate the wasted head for all alignments.) The power plant discharge pipeline will then continue west along the road just south of the existing Grass Valley Airport, then north about ½ mile to the section line and thence west to Sand Hollow Reservoir.

Hydraulic facilities required for the Gould Reservoir Alignment (in addition to those described above) include the pumping stations at Lake Powell and the Cockscomb, a standpipe at Telegraph Flats, a pressure-reducing facility on Telegraph Saddle at approximately Station 2300+00, a standpipe at the top of the cliffs at Sand Hollow, and a hydroelectric generating power plant at the base of the cliffs and/or at Sand Hollow. The hydraulic profile, including a schematic of the hydraulic facilities necessary for this alignment, is also shown in Figure HGL-1, Volume 2.

2. Willow Spring Reservoir Alignment

The Willow Spring Reservoir pipeline alignment is 122.2 miles long and is substantially the same as the preferred (baseline) alignment described in the previous studies. Like the Gould

Reservoir Alignment, it originates at Lake Powell 1 mile north of Lone Rock Road and ends at Sand Hollow Reservoir 10 miles east of St. George, Utah. It is the same as the Gould Reservoir Alignment, except that from Station 5800+00 it continues westerly along Highway 59 until approximately Station 5918+00. It leaves the highway ROW and heads almost due west towards Willow Spring and the Hurricane Cliffs. A short crossing of the Frog Hollow Canyon is required about 1 mile west of Willow Spring.

The pipeline follows the ridgeline between Gould Wash and Frog Hollow to the cliffs. A shaft and short tunnel will be used to traverse the cliffs, with a powerhouse at the base of the cliffs east of the Hurricane Airport. The power plant discharge pipeline will continue south along existing roads to 3000 South, thence west along 3000 South to Sand Hollow Reservoir. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-2, Volume 2.

Hydraulic facilities required for the Willow Spring Alignment are the same as for the Gould Reservoir Alignment. Note, in this alignment, the pressure-reducing facility will also waste a significant amount of head at the top of Hurricane Cliffs. (This is because the cliffs are much lower in elevation at Frog Hollow.)

3. Gould Spring - Grass Valley Alignment

The Gould Spring-Grass Valley pipeline alignment is 121.6 miles long. It differs from the Gould Reservoir pipeline alignment in that instead of keeping to a higher elevation along the toe of the Little Creek Mountain, it heads directly west to Gould Spring. From Gould Spring, the alignment heads southwest across Gould Reservoir's drainage basin, approaching the south slope of the third-from-the north of the five prominent knobs atop the Hurricane Cliffs east of Grass Valley. A pressure-reducing facility and peaking reservoir would be constructed just behind the cliffs. The pipeline would drop in a vertical shaft behind the cliff face, exiting below grade at the proposed hydroelectric generating facility at the toe of the cliffs. Note the pressure-reducing facility is required to waste head at the top of Hurricane Cliffs. The power plant discharge pipeline will continue west across the existing Grass Valley Airport (Sky Ranch), then south about 1/8 mile to the section line and thence west to Sand Hollow Reservoir.

Hydraulic facilities required for the Gould Spring - Grass Valley Alignment are the same as for the Gould Reservoir Alignment. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment is shown in Figure HGL-3, Volume 2.

4. Gould Spring - Willow Spring Alignment

The Gould Spring - Willow Spring pipeline alignment is 122.3 miles long and is very similar to the Willow Spring Reservoir pipeline alignment. It departs from Highway 59 at approximately Station 5802+00 and heads directly west to Gould Spring, crossing Gould Wash at a more favorable elevation. The alignment continues northwesterly along the ridge separating Frog Hollow and Gould Wash, joining the Gould Spring - Willow Spring pipeline alignment. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment is shown in Figure HGL-4, Volume 2.

5. Gould Spring - Mollies Nipple

The Gould Spring - Mollies Nipple pipeline alignment is 118.1 miles long, the shortest of the alignment alternatives. It is identical to the Gould Spring – Willow Spring pipeline alignment, until it departs from that alignment about 1 mile southwest of Gould Spring. In order to favorably cross Workmans Wash, the alignment heads northwest to the cliffs just south of the feature named Mollies Nipple. Three shaft locations have been identified on the ridge crest, with the southernmost location being the lowest cost alternative. There is a convenient location for a regulating reservoir in an incision of the Frog Hollow drainage immediately to the east of the southernmost shaft location and about ¼ mile to the southeast.

At the base of the cliffs, there is an existing sand and gravel operation. This pre-excavated site, if favorably located relative to the Hurricane fault (which will have to be determined in a later study), would be a good location for the hydroelectric power plant. The power plant discharge pipeline will continue north about ¼ mile along the Grass Valley Road thence west to Sand Hollow Reservoir in 3000 South.

Hydraulic facilities would be the same as the Gould Spring – Willow Spring pipeline alignment. Note that the pressure-reducing facility will waste approximately 712 feet of head at the top of Hurricane Cliffs. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-5, Volume 2.

6. Colorado City - West Little Creek Alignment

The Colorado City - West Little Creek pipeline alignment is 122.2 miles long. This alignment is significantly different than the above-described alignments, departing from the Highway 59 alignment just north of Colorado City at approximately Station 5200+00. The pipeline would head directly west, following the section line, in open grazing country. Until reaching the southwestern toe of Little Creek Mountain, a road would have to be bladed for construction access. At the southwestern toe of Little Creek Mountain, the pipeline follows an existing BLM road north, to intersect the Gould Reservoir Alignment. The alignment from that point is identical to the Gould Reservoir Alignment, including its hydraulic facilities.

Hydraulic facilities would be the same as the Gould Reservoir Alignment. Note the pressure-reducing facility will waste a varying amount of head at the top of Hurricane Cliffs due to varying length of pipeline. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment is shown in Figure HGL-6, Volume 2.

7. Colorado City - Honeymoon Trail Alignment

The Colorado City - Honeymoon Trail pipeline alignment is 125.5 miles long, the longest of the alignment alternatives. This alignment, like the above-described Colorado City - West

Little Creek alignment, departs from Highway 59 just north of Colorado City at approximately Station 5200+00. At the southwestern toe of Little Creek Mountain, instead of following the existing BLM road north, the alignment continues southwesterly back into Arizona, to the crest of the cliffs. A pressure-reducing facility and peaking reservoir would be constructed just behind the cliffs.

The pipeline will follow the existing trail down the cliffs, which approximately follows the historic Honeymoon Trail. (In some places, the trail and the historic trail appear to be coincident.) The proposed hydroelectric generating facility will be located at the toe of the cliffs. No power transmission facilities are located nearby, so if this alignment is selected, the cost of installing power lines for approximately 12 miles (to Grass Valley) will be required. The power plant discharge pipeline will continue north along the Grass Valley Road approximately 12 miles, joining the Gould Reservoir pipeline alignment, and coincident with it west to Sand Hollow Reservoir.

Note that the pressure-reducing facility will waste approximately 644 feet of head at the top of Hurricane Cliffs. Note also that this alignment requires an additional pressure-reducing facility at the top of the Sand Hollow Cliffs to dissipate the energy head due to the higher elevation of the power plant, versus the overflow elevation of the Sand Hollow surge shaft. It is estimated that this loss of head is 125 feet. It may be possible to reduce this in pipe friction through the use of smaller-diameter pipe between those points; however, its practicality would need to be determined during preliminary engineering if this alternative is selected. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-7, Volume 2.

8. Pipe Springs - West Little Creek Alignment

The Pipe Springs - West Little Creek pipeline alignment is 120.6 miles long. This alignment departs from Highway 389 in Arizona at approximately Station 4590+00 in order to stay south of Lost Spring Mountain in Arizona. Like the two Colorado City alignments described above, the pipeline would traverse open grazing country. Until reaching the southwestern toe of Little Creek Mountain, a road would have to be bladed for construction access. At the southwestern toe of Little Creek Mountain, the pipeline follows the same existing BLM road north as the Colorado City - West Little Creek Alignment, to intersect the Gould Reservoir Alignment. The alignment from that point is identical to the Gould Reservoir Alignment, including its hydraulic facilities.

Hydraulic facilities would be the same as the Gould Reservoir Alignment. A possibility exists for a gravity vent at approximately Station 4600+00, which might allow some reduction in pipeline design pressures downstream of that point. Without the gravity vent, the pressure-reducing facility at the top of Hurricane Cliffs will waste approximately 622 feet of head. This alignment has to cross lower elevations than the Colorado City alignments, and thus there is more pipe of higher-design pressure required. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment is shown in Figure HGL-8, Volume 2.

9. Pipe Springs - Honeymoon Trail Alignment

The Pipe Springs - Honeymoon Trail pipeline alignment is 123.9 miles long. It is a modification of the above-described Pipe Springs - West Little Creek pipeline alignment but, instead of continuing north, heads west upon intersecting and following the Honeymoon Trail Alignment. Hydraulic facilities would be the same as for the Colorado City - Honeymoon Trail Alignment, except the estimated head loss at the pressure-reducing facility is 822 feet. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-9, Volume 2.

10. South Kaibab - Honeymoon Trail Alignment

The South Kaibab - Honeymoon Trail pipeline alignment is 125.8 miles long. This alignment was developed at the request of WCWCD. The alignment was selected to maximize the length of the pipeline away from developed roads, assuming that access and construction would be economical. The alignment departs from the baseline alignment east of Kanab, downstream of the Telegraph Flat pressure-reducing facility, at approximately Station 2380+00. The alignment continues along the southwesterly alignment of U.S. Highway 89, crossing into Arizona, and heads toward the southeast corner of the Kaibab Indian Reservation. It follows the southern boundary of the Indian reservation, then turns northwesterly along a long tangent towards the southwestern edge of Lost Spring Mountain. From that point, it is coincident with the Pipe Springs - Honeymoon Trail pipeline alignment. The majority of the alignment is in open grazing country. Until reaching the southwestern toe of Little Creek Mountain, a road would have to be bladed for construction access. From the point of departure at U.S. Highway 89 east of Kanab, intermediate access is nonexistent, so all travel would have to be along roads constructed along the pipeline alignment. This alignment would require a longer 21-inch diameter pipeline to provide 10,000 A-F/year to the KCWCD than along U.S. Highway 89 from the Baseline Alignment.

Hydraulic facilities would be the same as for the Colorado City - Honeymoon Trail Alignment, except for the estimated head loss at the pressure-reducing facility. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-10, Volume 2.

11. South Kaibab - West Little Creek Alignment

The South Kaibab - West Little Creek pipeline alignment is 122.5 miles long. It is identical to the South Kaibab - Honeymoon Trail Alignment described above, except instead of following the Honeymoon Trail west over the Hurricane Cliffs, it follows the Colorado City - West Little Creek pipeline alignment in the existing BLM road north. This alignment would also require a longer 21-inch diameter pipeline to provide 10,000 A-F/year to KCWCD than along U. S. Highway 89 from the Baseline Alignment.

Hydraulic facilities would be the same as for the Colorado City - West Little Creek pipeline alignment. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-11, Volume 2.

12. Little Creek Mountain - Gould Reservoir Alignment

The Little Creek Mountain - Gould Reservoir pipeline alignment is 121.3 miles long. This alignment is developed to maximize the static head available to generate electricity. In development of the 11 alignments described above, notwithstanding the alignment-related considerations, which affect pipe installation costs, the elevation of each alignment requires significant loss of head at the top of Hurricane Cliffs. In each alignment, the elevation at the top of the cliffs is significantly below the pipeline high point at Telegraph Flat. That elevation difference, less friction loss, is the head, which is otherwise, wasted emptying into the regulating reservoir.

An initial attempt to reduce this loss on the Gould Reservoir Alignment was made in two ways. In one option, the available head is reduced by a third hydroelectric power generating facility located somewhere between Highway 59 and Gould Springs. To function correctly, a standpipe and reservoir of sufficient volume to minimize surge pressures is required. The overflow of the standpipe will have to be at an elevation above the static HGL elevation of 5699 feet (or the elevation of the standpipe at Telegraph Flat). There is no geographic feature close by this alignment, thus a pair of pipelines (in and out) would have to be constructed to some point on Little Creek Mountain, where a small regulating reservoir could be constructed. Some of the cost of these pipelines would be offset by the reduction in design pressure of the pipeline between the South Little Creek Mountain powerhouse and the Hurricane Cliffs regulating reservoir. This option is costly, and the further the pipeline alignment is from the high elevations of South Little Creek Mountain, the more costly it is to add a third power generation facility.

Another attempt to reduce this available head on the Gould Reservoir Alignment was made by increasing friction losses by reducing the diameter of the pipeline. From the turnout to Kanab, the pipeline diameter may be reduced to 54 inches, followed by a reduction to 48 inches at approximately Station 4118+00. This has the effect of significantly reducing the remaining head at the Hurricane Cliffs Reservoir, but with 77 feet of head still remaining and a need to deal with pressure heads up to the static HGL, a pressure-reducing facility is still required. A sensitivity analysis was made considering an increase in the surface roughness of the pipe from the assumed[1] Manning's "n". If the "n" value is increased to 0.0114, the pipeline will still flow, with a maximum head at maximum flow rate of only 3 feet below ideal. But if the roughness is greater, the possibility is great that the pipeline capacity will be significantly reduced.

Considering the significant cost to reduce the pressure in the above-described 11 alignments without added benefit, the Little Creek Mountain - Gould Reservoir Alignment is developed. This alignment follows the baseline alignment until approximately Station 5461+00, except no pressure-reducing facility is included west of Telegraph Flat. Only a gravity surge vent is included at the high point atop Telegraph Flat. This maximizes the pressure head available at the third hydroelectric facility. At Station 5461+00, the pipeline alignment diverges northwesterly from Highway 59 and ascends the south slopes of Little Creek Mountain. Near the top of the mountain a reservoir is included with an overflow elevation greater than

[1] Please refer to the 1995 report for a discussion of the selection of pipe roughness used.

the static HGL. A penstock would be constructed northerly from the reservoir to a powerhouse at the base of the north side of Little Creek Mountain. From thence the alignment follows the Gould Reservoir Alignment.

This alignment, although adding another reservoir, substitutes a hydroelectric generating facility for two pressure-reducing facilities. It maximizes the generating potential of the pipeline. The alignment and hydraulic profile, including a schematic of the facilities necessary for this alignment, is shown in Figure HGL-12, Volume 2.

Hydraulic Profiles

Each of the 12 alignments described in detail above are significantly affected by the hydraulics of the pipeline. As an aid in determining the pipeline operating pressure, profiles are prepared for each alignment, and the resulting pressure was determined for inclusion in the cost opinion for each alternative. The following hydraulic profiles are included in Appendix 1, Volume 2.

- Gould Reservoir Alignment; Figure HGL-1.
- Willow Spring Alignment; Figure HGL-2.
- Gould Spring-Grass Valley Alignment; Figure HGL-3.
- Gould Spring-Willow Spring Alignment; Figure HGL-4.
- Gould Spring-Mollies Nipple; Figure HGL-5.
- Colorado City - West Little Creek Alignment; Figure HGL-6.
- Colorado City - Honeymoon Trail Alignment; Figure HGL-7.
- Pipe Springs - West Little Creek Alignment; Figure HGL-8.
- Pipe Springs - Honeymoon Trail Alignment; Figure HGL-9.
- South Kaibab - Honeymoon Trail Alignment; Figure HGL-10.
- South Kaibab - West Little Creek Alignment; Figure HGL-11.
- Little Creek Mountain - Gould Reservoir Alignment; Figure HGL-12.

Discussion

Each alignment is based upon the following considerations:

1. The water must be lifted twice, at the Lone Rock Pumping Station and at the Cockscomb Pumping Station, to get over the high point between Lake Powell and Sand Hollow Reservoir.
2. The project is to deliver 70,000 A-F/year to Sand Hollow Reservoir and 10,000 A-F/year to Kanab.
3. Hydroelectric power is to be generated at Hurricane Cliffs and/or the Sand Hollow Reservoir and elsewhere where practical.

4. The alignments are to stay within the public ROW where practical.
5. Minimize the construction disruption to the public.
6. Minimize the long-term project costs.
7. Maintain as high an elevation as practical while keeping below the operating HGL at maximum flow rates, in order to minimize internal pipeline design pressures.
8. Develop alignments with pipeline hydraulics that results in an operable system, while minimizing the effects of surge. See discussion in "Power Requirements and Generation Potential - Considerations for Pipeline Alignments" below.

Hurricane Cliffs to Sand Hollow

Alignments are evaluated from the base of Hurricane Cliffs (and the proposed hydroelectric power generating facilities) to the Sand Hollow Reservoir. As discussed in the alignment descriptions above, the principal approaches to Sand Hollow Reservoir follow public roads and section lines with dedicated public ROW. Exceptions are the alignment across the Grass Valley Airport and east of the Hurricane Airport. For the Gould Springs Alignment, the powerhouse site is east of the Grass Valley Airport (Sky Ranch). It would be more economical to construct directly across, or tunnel under, this private airport, via an easement, than to go around. For the Gould Springs and Willow Springs alignments that have a powerhouse east of the Hurricane Airport, an easement appears to be necessary to traverse the approximately 1.5-mile distance south to 3000 South.

Power Requirements and Generation Potential - Considerations for Pipeline Alignments

In developing the 12 pipeline alignments described above, hydraulic profiles for the 12 identified alignments are prepared. Those hydraulic profiles, initially, are developed for the purpose of determining the pressure and, thus, the cost of the pipeline component for each alternative. In development of those hydraulic profiles, it became apparent that notwithstanding the *alignment-related* considerations, which affected pipe, installed costs, the elevation consequences on the hydraulics needed to be addressed. In particular, without significant revision to the already-developed alignments, the following considerations had to be resolved when reducing pressure by hydroelectric power generation:

1. When the powerhouse wicket gate (or cone valve) is opened, an adjacent body of water must be available with a free water surface. Otherwise the entire upstream pipeline system would try to accelerate and the pipeline would collapse under the vacuum created. This is affected by the peaking reservoir at the top of Hurricane Cliffs. An additional surge chamber/standpipe had to be added at the Sand Hollow Powerhouse for this purpose.

2. When the powerhouse wicket gate (or cone valve) is closed, an adjacent free water surface must be available to provide pressure relief. Otherwise, the resulting significant water hammer from the sudden stop of the column of water filling the

pipeline would tend to burst the pipe. This is also accomplished by the peaking reservoir at the top of Hurricane Cliffs. The surge chamber/standpipe added at the Sand Hollow Powerhouse also accomplishes this purpose.

3. Reduction of head must either be through friction losses (smaller pipe or high head loss sleeve valves) or through generation of power. It cannot be accomplished by merely spilling into a reservoir. If oriented upwards, the fountain of water (depending on the nozzle) would reach a height equal to the available head.

4. The pipeline must be designed for the maximum static head (with the valves shut) plus any surge pressures. The 12 alignments are compared on the basis of the ultimate operating head. This comparison determines if the operating HGL will be above the existing elevations at the intermediate high points.

When evaluating the alignments using only powerhouses at Sand Hollow and at the base of the Hurricane Cliffs, most of the alignments showed losses of a significant amount of head at the "peaking reservoir" above Hurricane Cliffs. Without some mechanical means of head loss, the net effect of discharging the pipeline into the peaking reservoir would be like a fountain lifting in altitude approximately equal to the head loss. This is of course not practical. This head has to be dissipated by one of two methods: addition of another powerhouse or (less economically) a pressure-reducing facility. As discussed previously, although potentially less capital costs, a poor third choice would be reduction of the pipe diameter to waste the head through friction loss.

Each alignment alternative shows a significant head loss prior to emptying into the peaking reservoir. This is accomplished by a pressure-reducing facility, similar to the one proposed in most of the alignment alternatives at Telegraph Flat. These head losses are substantial. The Gould Reservoir Alignment shows an HGL loss of 488 feet at the Hurricane Cliffs Peaking Reservoir. Significant capital cost reduction could be affected if the pressure-reducing facility could be avoided.

The cost spreadsheet for the Gould Reservoir Alignment was modified to determine the size reduction necessary in the pipeline to dissipate all the head prior to the Hurricane Cliffs Peaking Reservoir. It was determined that notwithstanding a pipeline reduction to 54 inches at the Kanab turnout and 48 inches near Colorado City, a head of 77 feet would still have to be reduced or the reservoir freeboard would have to be 77 feet higher to accommodate the loss.[2] At Hurricane Cliffs, the reservoir freeboard elevations are limited, so the head must still be dissipated through a pressure-reducing facility.

An alternative for pressure reduction is to add another hydroelectric facility. This hydropower facility would also need to have a branch surge-attenuation pipeline extending up to sufficient elevation to address Items 1, 2, and 4 above, with sufficient volume for storage at the top to be effective. The alignments close by Little Creek Mountain appear to be the most economical. The alignments which are further away from adequate reservoir locations at an elevation height which allows adequate freeboard above static HGL will be more difficult to make work. In-line

[2] Please note that the hydraulic analysis is very sensitive to Manning's "n" when smaller diameter pipe is used. In the above analysis, if the "n" is changed to 0.014, the water will not flow over the high points. Thus if reduction in diameter was selected, much greater refinement of the hydraulic analysis would be appropriate.

reservoirs may be feasible if a slight detour is considered in the alignment. As a result of this, Alignment 12 was developed, as discussed previously.

Cost Estimates

Cost opinions are prepared, in a format similar to those prepared in the 1995 and 1998 studies. This format is retained for consistency. The interest rate used in the 1995 and 1998 planning studies was 4.13 percent based upon the State of Utah's formula for economic evaluation of capital improvement projects. The current interest rate used by the State of Utah Division of Water Resources is 3.9 % and is the percentage incorporated in this Study.

The State of Utah's planning level assumptions for the economic life of cast-iron pipe facilities were also the primary basis of selecting the economic life of the Lake Powell Pipeline Project in the 1995 and 1998 studies. The state generally uses an economic life for pipelines and pumping stations of 50 and 20 years, respectively. Since over 80 percent of the capital costs of this project arise from pipelines and less than 20 percent from pumping stations and hydro stations, the weighted economic life of this project is about 46 years. However, for simplicity, a 40-year life was used as an average for all project facilities. This is about 4 percent more conservative than the 46-year life. These numbers are retained for this study. Cost opinions are detailed in Appendix 2 for each alignment alternative. Recent bid prices for similarly sized steel pipelines have shown significant declines, resulting in significant savings to owners. It is assumed for this study that these recent cost trends are a temporary phenomena and not included in the cost estimates herein.

The following table summarizes the estimated capital cost of the 12 alternatives:

Table 2-1: Estimated Capital Costs of the 12 Alternatives

ID	Alignment Description (see note 1)	Option	Total Capital Costs	Rank
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	290,464,000	7
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	318,714,000	33
1	Gould Reservoir Alignment, 2 PS's, 1 Hydro	Base Load	292,895,000	12
1	Gould Reservoir Alignment, 2 PS's, 1 Hydro	Peaking	317,654,000	30
2	Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	290,161,000	5
2	Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	313,971,000	22
2	Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	290,181,000	6
2	Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	309,664,000	21
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Base Load	290,880,000	9
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Peaking	319,176,000	34
3	Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Base Load	292,992,000	13
3	Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Peaking	317,329,000	29
4	Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	284,592,000	2
4	Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	308,221,000	20
4	Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	284,302,000	1
4	Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	303,643,000	19
5	Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Base Load	292,097,000	10
5	Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Peaking	317,959,000	31
5	Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Base Load	294,009,000	14
5	Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Peaking	316,388,000	27
6	Colorado City - West Little Creek 2 PS's, 2 Hydro	Base Load	294,993,000	15
6	Colorado City - West Little Creek 2 PS's, 2 Hydro	Peaking	323,324,000	40
6	Colorado City - West Little Creek 2 PS's, 1 Hydro	Base Load	296,665,000	17
6	Colorado City - West Little Creek 2 PS's, 1 Hydro	Peaking	320,769,000	37
7	Colorado City - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	292,598,000	11
7	Colorado City - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	321,939,000	39
7	Colorado City - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	301,311,000	18
7	Colorado City - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	327,691,000	41
8	Pipe Springs - West Little Creek 2 PS's, 2 Hydro	Base Load	319,959,000	35
8	Pipe Springs - West Little Creek 2 PS's, 2 Hydro	Peaking	347,991,000	43
8	Pipe Springs - West Little Creek 2 PS's, 1 Hydro	Base Load	320,482,000	36
8	Pipe Springs - West Little Creek 2 PS's, 1 Hydro	Peaking	343,593,000	42
9	Pipe Springs - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	318,526,000	32
9	Pipe Springs - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	348,112,000	44
9	Pipe Springs - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	362,374,000	47
9	Pipe Springs - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	395,615,000	48
10	South Kaibab - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	286,577,000	3
10	South Kaibab - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	315,960,000	24
10	South Kaibab - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	295,202,000	16
10	South Kaibab - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	321,687,000	38
11	South Kaibab - West Little Creek 2 PS's, 2 Hydro	Base Load	288,992,000	4
11	South Kaibab - West Little Creek 2 PS's, 2 Hydro	Peaking	317,117,000	28
11	South Kaibab - West Little Creek 2 PS's, 1 Hydro	Base Load	290,467,000	8

Table 2-1: Estimated Capital Costs of the 12 Alternatives				
ID	**Alignment Description (see note 1)**	**Option**	**Total Capital Costs**	**Rank**
11	South Kaibab - West Little Creek 2 PS's, 1 Hydro	Peaking	314,581,000	23
12	Little Creek Mtn. Gould Reservoir 2 PS's, 3 Hydro	Base Load	316,020,000	26
12	Little Creek Mtn. Gould Reservoir 2 PS's, 3 Hydro	Peaking	362,219,000	46
12	Little Creek Mtn. Gould Reservoir 2 PS's, 2 Hydro	Base Load	315,916,000	24
12	Little Creek Mtn. Gould Reservoir 2 PS's, 2 Hydro	Peaking	353,925,000	45

The following table summarizes the estimated present worth cost of the 12 alternatives:

Table 2-2: Estimated Present Worth Costs of the 12 Alternatives				
ID	**Alignment Description**		**Present Worth**	**Rank**
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	416,011,000	23
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	387,364,000	9
1	Gould Reservoir Alignment, 2 PS's, 1 Hydro	Base Load	417,719,000	26
1	Gould Reservoir Alignment, 2 PS's, 1 Hydro	Peaking	385,300,000	6
2	Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	436,984,000	42
2	Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	425,314,000	33
2	Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	436,261,000	41
2	Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	421,007,000	31
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Base Load	416,427,000	24
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Peaking	386,802,000	7
3	Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Base Load	417,816,000	27
3	Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Peaking	384,975,000	5
4	Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	431,451,000	39
4	Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	419,564,000	29
4	Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	430,382,000	38
4	Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	413,539,000	17
5	Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Base Load	426,444,000	35
5	Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Peaking	406,017,000	12
5	Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Base Load	428,356,000	37
5	Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Peaking	402,959,000	11
6	Colorado City - West Little Creek 2 PS's, 2 Hydro	Base Load	420,540,000	30
6	Colorado City - West Little Creek 2 PS's, 2 Hydro	Peaking	390,508,000	10
6	Colorado City - West Little Creek 2 PS's, 1 Hydro	Base Load	421,489,000	32
6	Colorado City - West Little Creek 2 PS's, 1 Hydro	Peaking	386,928,000	8
7	Colorado City - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	426,202,000	34
7	Colorado City - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	412,890,000	16
7	Colorado City - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	434,915,000	40
7	Colorado City - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	417,175,000	25
8	Pipe Springs - West Little Creek 2 PS's, 2 Hydro	Base Load	445,506,000	45
8	Pipe Springs - West Little Creek 2 PS's, 2 Hydro	Peaking	415,175,000	20

Table 2-2: Estimated Present Worth Costs of the 12 Alternatives				
ID	**Alignment Description**		**Present Worth**	**Rank**
8	Pipe Springs - West Little Creek 2 PS's, 1 Hydro	Base Load	445,306,000	44
8	Pipe Springs - West Little Creek 2 PS's, 1 Hydro	Peaking	409,752,000	14
9	Pipe Springs - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	452,130,000	46
9	Pipe Springs - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	439,063,000	43
9	Pipe Springs - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	482,778,000	48
9	Pipe Springs - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	467,600,000	47
10	South Kaibab - Honeymoon Trail 2 PS's, 2 Hydro	Base Load	419,457,000	28
10	South Kaibab - Honeymoon Trail 2 PS's, 2 Hydro	Peaking	406,911,000	13
10	South Kaibab - Honeymoon Trail 2 PS's, 1 Hydro	Base Load	427,339,000	36
10	South Kaibab - Honeymoon Trail 2 PS's, 1 Hydro	Peaking	411,171,000	15
11	South Kaibab - West Little Creek 2 PS's, 2 Hydro	Base Load	413,816,000	18
11	South Kaibab - West Little Creek 2 PS's, 2 Hydro	Peaking	384,301,000	4
11	South Kaibab - West Little Creek 2 PS's, 1 Hydro	Base Load	415,291,000	20
11	South Kaibab - West Little Creek 2 PS's, 1 Hydro	Peaking	380,740,000	3
12	Little Creek Mtn. Gould Reservoir 2 PS's, 3 Hydro	Base Load	415,911,000	22
12	Little Creek Mtn. Gould Reservoir 2 PS's, 3 Hydro	Peaking	378,834,000	2
12	Little Creek Mtn. Gould Reservoir 2 PS's, 2 Hydro	Base Load	414,584,000	19
12	Little Creek Mtn. Gould Reservoir 2 PS's, 2 Hydro	Peaking	369,094,000	1

Cost estimates summarized above are significantly affected by assumptions of:

- Interest rate (cost of money).
- Cost of electric power purchased.
- Value of electric power sold (both baseline and peak).

In addition, the capital costs do not reflect a time value of money within the construction period. That is, it is assumed that the project is constructed within one construction season. The present worth analyses assume uniform operation of the facilities. Both of these assumptions were made for simplicity in determining the lowest cost alternative as a basis for selecting the most appropriate alignment for crossing the Hurricane Cliffs. Further refinement of the cost opinions for the purposes of comparing alignment alternatives is not necessary.

Preferred Construction Alternative

The alignment alternatives considered comparable (HGL-1 through HGL-11) are the initial alignments evaluated in this study. In all eleven alignments, four options were compared: one and two hydropower facilities with base load and peaking facilities on each alignment. Thus, initially, there were 44 options evaluated. Due to the amount of head (pressure) which must be hydraulically wasted in all of the eleven alternatives (through pressure control facilities), a twelfth alignment (HGL-12) is developed which demonstrates the long term benefits of the revenue generated by a hydropower generating facility utilizing the available pressure rather than wasting the pressure through a pressure reducing facility. Alignment HGL-12 also includes four options similar to the other eleven alternatives.

The peaking hydropower plants are substantially larger than base load facilities resulting in significantly more capital costs than the base load plants. A third hydropower plant on Alignment 12 dramatically increases the capital cost of that alternative. The opinions of capital costs developed in this study show a feasibility level construction estimate plus a “planning level” contingency and administration and engineering costs. The alignment with the least capital costs is Gould Spring – Willow Spring Alignment 4. The 18 alignments with the least capital costs all include base load hydro plants. Specifically, the 18 lowest cost alternatives are within 6.0 percent of the lowest cost alternative. The 10 least costly alternatives are within 3.0 percent or $8.2 million. An opinion of probable capital cost for each alignment is shown in Table 2-1.

To analyze the benefits resulting from the hydroelectric generation, net annulized costs were developed for each alternative. Using these results, a present worth value was developed for both peaking and base load hydroelectric generation. Alignment R, Little Creek Mountain-Gould Reservoir, involving two hydroelectric plants produced the lowest present worth values. An opinion of probable present worth costs is shown in Table 2-2.

Chapter 3 – The Cockscomb

Location and Introduction

No practical alignment for the Lake Powell Pipeline exists which will avoid a geologic feature known as the Cockscomb. The Cockscomb is the common name for what geologists refer to as the East Kaibab monocline. It is a prominent south-southwest to north-northeast trending geologic feature located in south central Utah. The prominent exposure of the Cockscomb runs through Kane County, Utah, from about the Arizona state line up to the Kane and Garfield County line. It is about 31 miles east of Kanab, Utah. The Cockscomb is recognized by geologists as the eastern boundary of the Grand Staircase.

The Lake Powell Pipeline follows U.S. Highway 89 where it cuts through the Cockscomb approximately 26 miles west of Lake Powell. Identification of alternative methods of construction at this location is necessary not only from an engineering feasibility standpoint but to facilitate development of preliminary sizing and an opinion of probable capital and life cycle costs. Those costs are utilized in the cost evaluation for the overall alignment comparisons described in the previous section.

Review of existing, readily available topographic mapping indicates a strong possibility that tunneling is a viable option to open-cut construction along U.S. Highway 89. Three alternative alignments are identified, with the intention of determining the feasibility of constructing a tunnel as a means of crossing the Cockscomb. The area showing the tunnel through the Cockscomb is shown in Figures 3-1 and 3-2. A field reconnaissance accomplished on September 10, 2002, allowed pipeline, tunnel, and geologic engineers to examine the area. In addition, the proposed pumping station sites adjacent to the Cockscomb were examined. Subsequent to the field reconnaissance, a feasibility evaluation for the tunnel alignments was prepared by Haley and Aldrich, Inc. Haley and Aldrich's *Tunnel Feasibility Report* is included as Appendix 4.

Figure 3-1: Cockscomb at U.S. Highway 89 - Looking East

Figure 3-2: Cockscomb at U.S. Highway 89 - Looking East

Site Conditions and Topography

The Cockscomb appears as a ridgeline protruding from the desert floor in the area of the alternative pipeline alignments. From the east, the upper area of West Cove, a broad, relatively flat-lying valley between the Cockscomb and the Rim Rocks butts against the base of the Cockscomb. West Cove is a southeasterly draining valley that feeds the Sand Gulch drainage. It is generally flat with local topography created by sand bars and poorly to well-defined drainage patterns leading into Sand Gulch. Sand Gulch drains into the Paria River about 3 miles east of the Cockscomb (see Figure 3-3). The base of the Cockscomb along West Cove is about Elevation 4600 feet.

The east slopes of the Cockscomb in this area rise at about a 4 to 5H:1V slope and steepen to about 2 to 2.5H:1V near the crest. The crest elevation in this area is about an average Elevation 5300 feet with peaks along the crest from about Elevation 5320 feet near the road cut for U.S. Highway 89 up to Elevation 5460 feet. The road grade for U.S. Highway 89 runs through the Cockscomb and primarily follows the canyon created by the Sand Gulch drainage. It turns southwest in the canyon and then cuts westward through the wall of the canyon at about Elevation 4880 feet and enters into Fivemile Valley (see Figure 3-4). The western slope of the Cockscomb is more rugged and steeper than the eastern slope and has a base elevation along the Fivemile Valley contact about 300 feet higher in elevation than the base on the east side. The average grade of the west slope is about 2.5 to 3H:1V in the area of the alternative pipeline alignments. Fivemile Valley is a relatively narrow, flat-lying valley between the Cockscomb and the base of Fivemile Mountain to the west. Sand Gulch drains southward through Fivemile Valley in the area of the alternative pipeline alignments.

The dip of the bedrocks in this section of the Cockscomb is moderate to steep. The east slope surface generally parallels the bedding plans of the bedrock. Runoff down the east slope appears to be generally sheet flow with only a few defined channels incised down the face of the slope. In the mid and upper reaches of the slope, the topography becomes more undulated as alternating units of soft and durable bedrock are crossed moving up the slope. The western slope is more rugged from erosion and channeling of the slope. Two significant erosion channels exist in the western slope of the Cockscomb in the area of the alternative pipeline alignments. The southern of the two channels (closest to U.S. Highway 89) is the larger of the two channels (see Figure 3-5). Also, old exploration roads and pads have been cut across the face of the western slope.

The alternate Cockscomb pipeline alignments are located within the Cockscomb Wilderness Study Area (WSA) within the Grand Staircase-Escalante National Monument. However, the area of the pipeline alignments has been reported as lacking wilderness characteristics. This is primarily due to the notable land disturbances from U.S. Highway 89 north to the major power line. The area lacking the wilderness characteristics covers about 1,100 acres in the southwest corner of the WSA bounded by U.S. Highway 89 on the south and west sides.

Figure 3-3: West Cove (foreground) Looking East from Cockscomb Along Power Line Tunnel Alignment

Figure 3-4: Road Cut Into Fivemile Valley (Looking West) - Sand Gulch Left of Road

Figure 3-5: Drainage Channel Cut Into West Slope of Cockscomb (Looking East From Base of Slope)

Geology

The structure of the Cockscomb runs south to north with a slight eastward trend. Bedrock in the Cockscomb dips to the east with a moderately steep inclination. Older bedrock units are typically exposed in the southern end of the Cockscomb, with progressively younger units appearing northward along the structure. (Note: this is consistent with the progression of units in the Grand Staircase from south to north.)

Early mapping of the Cockscomb in the area of the alternative pipeline alignments shows the bedrock to be predominantly made up of the Kayenta formation sandstones in the base of the western slope and the overlying Navajo Sandstone formation in the upper western slopes, the crest area, and down the face of the eastern slope. Bedrock of the Moenave formation is identified in a small area at the base of the western slope just north of the alignments. Just south of the area, bedrock is identified as Moenkopi formation units. The member units of the Moenkopi formation are not differentiated on the map.

A layer of Carmel formation bedrock overlays the lower portion of the east slope of the Cockscomb. The bedrock units are not differentiated on the available geology map; however, based on site observation and units mapped elsewhere along the Cockscomb, the light colored bedrock and dark blocks of material shown in Figures 3-2 and 3-7 are likely the limestone and blocks of the mudstones of the Judd Hollow Tongue unit of the Carmel formation.

The observed geology map shows the eastern slope bedrock to exhibit about a 35-degree dip. Two sets of near vertical jointing patterns predominantly striking from north to north-northwest are indicated at about midslope on the eastern side. An undetermined lineation is shown to link the two sets of joints. A fault along the Cockscomb is shown to be located at about midway along the western slope, with parallel fault structures to the west at the base and in Fivemile Valley.

Observation of the road cuts along U.S. Highway 89 show the dip of the bedrock to be relatively consistent with no signs of secondary folding or displacement. It was also observed that the different units within the Kayenta and Navajo formations include softer layers more susceptible to weathering upon exposure (Figures 3-6 through 3-9). No problematic units (with respect to tunnel or cut and cover construction) were observed in the road cut exposures.

Figure 3-6: Bedrock Exposed in the Eastern Slope of the Cockscomb

Figure 3-7: Uniformly Dipping Bedrock Units - Navajo Sandstone (left) and Carmel Formation (Judd Hollow Tongue) (right)

Figure 3-8: Navajo Sandstone

Figure 3-9: Kayenta Formation Near Base of Western Slope

Seismic Setting

There is no active faulting in the vicinity of the Cockscomb; however, the site may be subject to ground motions from regional tectonic activity. No regional earthquake studies were completed to estimate the likely or maximum ground motions at the site. For this study, it is anticipated low ground accelerations will impact the site. A more detailed review of the seismic setting of the project area is recommended to estimate the maximum credible earthquake (MCE) and estimated ground acceleration as part of subsequent design studies for the pipeline through the Cockscomb area and, more importantly, the Cockscomb Pumping Station.

Geotechnical Considerations

In general, the bedrock materials appear competent. Site conditions appear such that there are no obvious geotechnical concerns that will require special attention in the design of the pipeline or its support system. The geotechnical considerations for the pipeline at the Cockscomb will be a function of the construction alternative selected for the pipeline. The construction alternatives for this portion of the pipeline are similar to those identified for the Hurricane Cliffs:

- A tunnel through the Cockscomb.
- Cut and cover (burial) over the slopes of the Cockscomb or along U.S. Highway 89.
- Surface support of the pipeline over the slopes of the Cockscomb.

Tunnel Geotechnical Considerations

Two tunnel options are considered for construction of the pipeline through the Cockscomb, along three alignments. One tunnel option is a steeply graded tunnel from the base of the east slope to the base of the west slope. The other tunnel option is a relatively flat sloped tunnel beginning at the base of the east side of the Cockscomb with a vertical riser (or shaft) on the west side of the Cockscomb to bring the pipeline back to the surface. No specific geotechnical concerns have been identified as problematic for either option. There are a few conditions, however, worth noting that may impact the final design of the tunnel option but are not necessarily considered negative to selection of either tunnel option.

On the east slope portal, further consideration will have to be given to the dip of the bedrock and stability of the overhanging bedrock. Field explorations may find the slope material on the east side to be massive enough that this will not be a concern. The west portal stability will also require attention in the field exploration and characterizing the near surface bedrock. For the option of the vertical rise on the west slope, positioning the riser to avoid faulting in the Fivemile Valley will ease design and construction, but care will be needed not to impact the highway with its location.

The alternating hardness of the bedrock layers and potential blockiness may impact tunneling techniques, support design, and the rate of progress for a selected tunneling method. However, the ground conditions are not anticipated to be a negative setback to the tunneling option in terms of cost impacts or overall construction schedules.

Cut and Cover Geotechnical Considerations

The cut and cover option for pipeline construction over the Cockscomb will entail several geotechnical and construction challenges. These challenges include:

- Excavation procedures through alternating hard and soft bedrock units.
- Construction and vertical alignment over locally steep, rugged terrain with limited access and undulating topographic features.
- Selection and design of an alignment to minimize the rock cut requirements.
- Trench backfill stability in steeper areas.

No slope or ground conditions (such as landslides, slump blocks, or debris flows) were noted that will otherwise result in stability problems during construction or operation of the pipeline.

Considering these challenges as compared to the much easier alignment along U.S. Highway 89 and the much less disruptive tunnel alignments, this alternative was dismissed from further consideration. No cost opinion was developed accordingly.

Surface Support Geotechnical Considerations

This option for pipeline construction will encounter challenges similar to the cut and cover option. However, one factor is a potential design concern for this option. It is the stability/reliability of the anchoring system of the pipeline supports, particularly on the western slope of the Cockscomb. In general, the bedrock materials appear competent with respect to supporting the pipeline and stability of the anchoring system. However, anchor design on the west slope will likely be affected by the softer bedrock units more so than on the eastern slope. On the western slope, tension anchors may potentially be oriented along the plane of softer material as opposed to across the planes of the bedrock materials. The anchor designs will need to account for the differences in the event surface support or the pipeline over the Cockscomb is the selected alternative.

On the eastern slope, tension or rock anchors will generally be embedded across the bedrock units and bedding planes. Anchors oriented in this manner typically exhibit more resistance to being pulled out of the ground. Usually, there is no preferred plane of weakness parallel to the anchor (such as bedding planes or a lens of weak material) and the layers of bedrock act as a series of beams being stressed by the anchor. Therefore, weaker/softer lenses are support/reinforced by the stronger more stiff units.

On the west slope, the anchors will be oriented more in line with (parallel to) the dip of the units. In this case, it is possible for an anchor to be completely within a weaker unit. This situation can be accounted for in the anchor design but will result in various lengths along the alignment or over design in many of the anchors, assuming the anchor design is based on worst-case conditions. For this reason alone an above-grade construction option is not recommended.

Pipeline Alignment Alternatives

Approach to the Cockscomb Alignments and Engineering Profiles

With the elimination of the above-grade construction of the pipeline on the hydraulic and geologic considerations discussed above, the two construction alternatives for this portion of the project are:

- A tunnel through the Cockscomb.
- Cut and cover (burial) within the ROW of U.S. Highway 89.

Cockscomb Alignments

The four alignments identified during the field reconnaissance and subsequent development of the hydraulic profiles is described in detail below. The four alignment alternatives are shown in Figure CK-1 in Volume 2.

Baseline Alignment A – U.S. Highway 89

Alignment A, used as the baseline alignment for stationing purposes, follows U.S. Highway 89 as it approaches the Cockscomb from the east. If the Cockscomb Pumping Station is constructed on the south side of the highway, the pipeline will continue past the pumping station, climbing the highway embankment to the paved section. If the Cockscomb Pumping Station is constructed on the north side of the highway, the pipeline, at approximately Station 1360+00, would continue west out of the pumping station up the highway embankment at about Station 1380+50 to the paved section.

Once on the highway embankment, the construction almost immediately enters a rock cut, and then gets quite close to the sand gulch in fill. This fill is of concern for scour undermining the road (and pipeline). As shown in Figure 3-10, the Sand Gulch has undermined the highway in the past and has been a source of maintenance expense for the highway department. (Note the placement of rails and auto bodies.)

Figure 3-10: Embankment at Catsair Canyon

Continuing west, the pipeline and highway alternatively traverse cut and fills, until traversing a deep cut into the west side of the Cockscomb. At that transition the pipeline is again in a high fill, crossing over to the west side of the Fivemile Valley.

Two alignment alternatives exist. One is to keep the pipeline alignment in the shoulder of the highway. This is feasible on the south shoulder, except at the fill at approximately Station 1390+00, where the risk of erosion is the greatest. At that point, it would be best to realign the pipeline to the north shoulder. At the west slope of the Cockscomb, the pipeline would cross the highway and follow the upstream shoulder of the embankment to the west side of the Fivemile Valley.

Another alignment option is to keep the pipeline in the centerline of the highway. This is attractive because the traffic control options would be consistent throughout the canyon, and the pipe costs would be the lowest, avoiding elbows. Repaving width and traffic control requirements would have to be negotiated with the Utah Department of Transportation, but it is anticipated that flag-control convoys would be most appropriate.

A significant advantage to the highway alignment is that little or no land would be disturbed outside the already-disturbed area of influence from the highway.

Tunnel Alignment B

The first tunnel alignment was chosen based upon the location of the portals. The eastern portal of Tunnel Alignment B is immediately proximate to the pumping station site on the north side of the highway. The amount of discharge manifold piping required is the least of any of these alternatives. The western portal is located in a small side canyon, which is shown in Figure 3-5. This portal location was selected to minimize visibility of portal development and any permanent feature (such as an access vault). A pumping station located on the west side of the Cockscomb could be out-of-sight within this side canyon. Drainage would have to be addressed to keep from locally eroding the ground away from the pipeline at that portal. The alignment would continue west from that point across the broad Fivemile Valley to join the highway alignment.

Figure 3-11 Tunnel Portal Locations at East Side of Cockscomb

This alignment alternative is approximately 4,106 feet shorter than the highway alignment. The savings due to reduced length translates into a significant per-foot premium in cost for the tunnel, which could be paid and still effect considerable savings. The alignment falls outside of the easement reserved for utilities adjacent to the highway when the Clinton administration proclaimed the Escalante-Grand Staircase Wilderness. An easement would have to be obtained should this alignment be selected.

Tunnel Alignment C

The second tunnel alignment (Alternative C) was chosen based upon reducing the length of the tunnel from Alternative B. The alignment is similar to alignment Alternative B, except that it is a projection of the highway alignment assuming it does not follow the curve at Station 1360+00. If the Cockscomb Pumping Station was close to the portal, it would have to be located to the south of the alignment. This area is less than desirable because of the curve in the adjacent gully. The lateral scour is progressing south and additional cost in providing bank protection would be necessary. The tunnel length is greater, but the total length is 1,725 feet shorter than Alternative B.

Figure 3-12 Tunnel Portal and Pumping Station Site at East Side of Cockscomb (C & C-1)

Tunnel Alignment C-1

The second tunnel alignment (Alternative C-1) was chosen based upon keeping the pipeline within the (presumably prescriptive) ROW that exists for the power line, which traverses the Cockscomb in a northwesterly direction. This alignment is the shortest of all the Cockscomb alignments, yet is the longest tunnel. It also crosses the geologic strata at a more oblique angle, as opposed to a much more normal approach of Alignments B and C. These may be considerations in tunneling support design, although at this level of detail the cost implications are not quantifiable. Alternative C-1 is 6,297 feet shorter than the all-highway alignment.

The portal location is not favorable for this alignment. It is located at a change of geologic strata and is subject to flooding from both a local canyon and the larger drainage area to the east of the Cockscomb. Further, there is no suitable pumping station site immediately proximate. A more feasible site would be at about Station 1380+00, or well within the view of the motorists on U.S. Highway 89, if kept on the alignment.

Hydraulic Profiles

The four alignments described above are each based upon the assumption that the Cockscomb Pumping Station is located on the east side of the Cockscomb, as described in Chapter 6. The hydraulic profiles are illustrated on Figure Ck-1 in Volume 2. The pipeline pressures would be the highest immediately downstream of the pumping station as it traverses the Cockscomb either on the highway alignment or within one of the tunnel alignments. If the pumping station was located on the west side, the lift at Lone Rock would have to be greater, increasing the cost of the pipeline between the two pumping stations. An option was investigated for a relatively shallow tunnel through the Cockscomb, but the pumping station configuration would have to be completely different. This would have negative effect on both the capital and maintenance costs of the two pumping stations. This pumping station siting significantly favors the tunnel alternatives with the steep slopes, which would also favor drill-and-blast construction.

Opinion of Probable Costs

Cost opinions were prepared on a similar basis to those prepared in the 1995 and 1998 studies. The format was retained for consistency. Cost opinions are detailed in Appendix 2 for each alignment alternative.

The following table summarizes the estimated cost of the four alternatives:

Table 3-1: Cockscomb Tunnel, Shaft, and Pipeline Costs

ID	Description	(mi)	($/lf)	Cost ($)	Notes	Rank
A	U.S. Highway 89	3.14		9,060,000	5,6,7,9,10	7
B	Tunnel & shaft through West Portal Site 1	2.36	1300	10,140,000	1,4,5,8	10
	Tunnel & shaft through West Portal Site 1		900	8,400,000	3,4,5,8	5
B	Tunnel through West Portal Site 1	2.36	1755	11,450,000	2,5,8	13
	Tunnel through West Portal Site 1		900	8,030,000	3,5,8	1
B	Tunnel & shaft through West Portal Site 2	2.36	1300	11,470,000	1,4,5,8	14
	Tunnel & shaft through West Portal Site 2		900	9,330,000	3,4,5,8	9
B	Tunnel through West Portal Site 2	2.36	1755	13,450,000	2,5,8	17
	Tunnel through West Portal Site 2		900	9,160,000	3,5,8	8
C	Tunnel & shaft through West Portal Site 3	2.04	1300	10,640,000	1,4,5,8	11
	Tunnel & shaft through West Portal Site 3		900	8,480,000	3,4,5,8	6
C	Tunnel through West Portal Site 3	2.04	1755	12,550,000	2,5,8	15
	Tunnel through West Portal Site 3		900	8,240,000	3,5,8	3
C-1	Tunnel & shaft through West Portal Site 4	1.95	1300	10,690,000	1,4,5,8	12
	Tunnel & shaft through West Portal Site 4		900	8,330,000	3,4,5,8	4
C-1	Tunnel through West Portal Site 4	1.95	1755	12,680,000	2,5,8	16
	Tunnel through West Portal Site 4		900	8,060,000	3,5,8	2

Notes:

1. Normal grade (2%) machine tunneling = $1,300/lf per Haley & Aldrich Report.
2. Steep grade (6-8%) machine tunneling = $1,755/lf per Haley & Aldrich Report.
3. Drill and blast tunneling = $900/lf per Haley & Aldrich Report.
4. Vertical Raise Bore = $700/vf per Haley & Aldrich Report.
5. Pipe cost based on pumping station located at 1370+00, a lift of 1,310 feet, mannings "n" of 0.0110, 60-inch diameter pipe, and average pipe cost within applicable pipe type ranges.
6. Road cut costs assumes a 12-foot-wide patch with 8 inches of concrete ($3/square foot), 12-inch base material and 6 inches of asphalt ($2.50/square foot), plus 30% remote factor.
7. Traffic control cost assumes 60 days with two arrow boards ($350/day), two signals ($750/day), eight signs ($40/day), and 200 feet of temporary concrete barricades ($1,000/day).
8. Portal development = $50,000 for each side or $100,000 per tunnel/shaft options per Haley & Aldrich report.
9. Rock saw or rock trenching machine to cut an 11-foot deep and 7-foot wide trench for a 60-inch diameter pipe. A 30-inch rock saw ($25/lf) would take three passes to create the 7-foot-wide trench.
10. Assume that the pipeline would follow the bedrock on either side of the road and that a rock saw or blasting would be required 75% of the road cut in the canyon.
11. All alignments begin and end at common points

Preferred Construction Alternative Through the Cockscomb

Previous discussion regarding the comparison of costs of construction through the Cockscomb described the cost benefit of reducing the length of high-pressure pipe immediately downstream of the Cockscomb Pumping Station. The three alternatives to the open cut excavation within U.S. Highway 89 are all tunneling options with greater unit (per foot) costs related to the tunnels and portal development. To properly compare the alternatives, cost estimates were prepared beginning and ending at common points. The tunneling alternatives may be constructed either on flatter slopes with tunneling machines or on steeper grades using more manual labor, as discussed in this section. The tunnels constructed by equipment will each require a vertical shaft at the west portal with its associated costs. Thus, the evaluation of the tunneling options is an analysis of whether the reduced length of each alignment offsets the additional cost for tunneling.

The three alignments compared to the U.S. Highway 89 open cut alignment include 16 options for tunnel slope (grade) and portal and shaft location. Based on an opinion of probable cost prepared by Haley & Aldrich, Inc., in all alternatives, the steeper sloped tunnel is more cost effective than the flatter slope tunnel that requires a vertical shaft.

The U.S. Highway 89 Alignment A is approximately 3.14 miles in length and includes no tunneling costs. Costs for traffic control, pavement repair, and trenching through rock are included in the $9.06 million estimate. The least expensive alignment ($8.03 million) is Tunnel B through Portal Site 1 and is $1.03 million less than the highway alignment. Alignment B through Portal 1 is shown on Figure 3-1. This alignment is 2.36 miles in length and includes a 3,684-foot tunnel. Alignment C-1 through Portal 4 at $8.06 million is substantially equal in capital cost to Alignment B. This alignment is 1.95 miles in length but has a tunnel, which is 4,986 feet in length. Tunnel Alignment C is not significantly greater in capital costs at 2.6 percent above the lowest cost alignment.

Although the $1.03 million difference between Alignment B, drill and blast method, and the highway alignment is significant with regard to the costs of the Cockscomb portion itself it is not automatically the preferred alignment. There are other considerations that are difficult to quantify but are extremely relevant to this site. The Cockscomb is located in the Grand Staircase – Escalante National Forest that involves an environmental aspect, which may not be considered otherwise.

Although drill and blast tunneling would have a minimal impact on the environment, the potential for damage and risk associated with the adjacent environment and habitat may make this alternative less desirable that a method which has a minimal environmental impact.

There are also a significant number of geologic unknowns regarding the tunneling options that have not been evaluated sufficiently to ultimately make a recommendation. There may need to be measures in place to avoid such things as faulting but without extensive investigations this is difficult to determine the level of such measures.

In the overall spectrum of the project, the $1 million difference between the drill and blast tunneling and the traditional open cut highway portion is less that 0.4% of the cost of the overall project. Thus it is recommended that the Highway 89 right-of-way is the preferred alignment through cockscomb due to the potentially sensitive areas surrounding the Cockscomb.

Chapter 4 – Highway 389 Near Pipe Springs National Monument

The proposed Lake Powell Pipeline generally follows the existing U.S. Highways 89 and 59 in Utah and Highway 389 in Arizona, staying within the existing highway ROW as much as possible. During the course of the study while identifying alignment options at the Hurricane Cliffs and the Cockscomb, Boyle Engineering Corporation was asked to also evaluate alternative alignments south of Little Creek Mountain (Alignments HGL-6 and HGL-7) and Lost Spring Mountain (Alignments HGL-8 and HGL-9). As the alignments evaluated stayed further south and more in undeveloped land than along the highway alignment, two alignments (HGL-10 and HGL-11) were developed to follow the southern boundary of the Kaibab Indian Reservation, instead of following the highway past Pipe Springs.

The following are considered advantages to Alignments HGL-10 and HGL-11:

- Long straight reaches of pipeline with minimal expense in pipe fabrication (for elbows and bevels) except for crossing drainages.
- Significantly reduced traffic control costs.
- Reduced pressure (at lower elevation) leads to lower cost pipe per foot for long distances.
- Avoidance of construction through Fredonia.
- Avoidance of construction through Pipe Springs (and potential objection from NPS).
- Avoidance of construction through Colorado City.

The following are considered disadvantages to Alignments HGL-10 and HGL-11:

- Increased cost due to increased length.
- Increased cost to obtain easements as opposed to construction within highway ROW.
- Anticipated reduced environmental objection to construction within existing, disturbed ROW compared to previously undisturbed lands.
- Significantly increased length in pipeline to deliver 10,000 A-F/year to KCWCD.
- High elevations near the operating HGL at three or more places puts potential flow restriction into system. Detailed mapping will be required, but at the contours shown on existing mapping, the two alignments appear to be feasible. Gravity vents are appropriate at the indicated locations.

- Increased cost to deliver pipe and materials along the alignment due to significant distances from all-weather roads.
- Increased travel time for construction workers because of significant distances from all-weather roads.
- Increased maintenance cost due to a lack of immediate proximity to all-weather paved highways.

The cost opinion prepared to compare the alignment alternatives across the Hurricane Cliffs could not address all of the above items. It addresses the increased cost in pipe due to the increased length and addresses the reduced unit cost of portions of the pipeline that will operate at low pressures (particularly between approximately Stations 4700+00 and 5300+00). The cost difference between construction in open country and open country adjacent to the highway could not be quantified without more information about the surficial geology. That would allow cost of access road construction and travel time analyses to be compared with construction adjacent to the highway. For purposes of comparison of alignment alternatives only, those costs were considered to be equivalent. However, it is conjectured that the access costs may be significantly more than the avoided cost of traffic control along the highway alignment.

Chapter 5 - Lone Rock Pumping Station (Lake Powell)

In 1995, Boyle prepared a report for the WCWCD evaluating the concept of transferring 70,000 A-F of water per year from Lake Powell of which 60,000 A-F/year is to be delivered to St. George, Utah. The report recommended a pumping station on Lake Powell that will lift the water to a second pumping station at the Cockscomb. The Cockscomb Pumping Station will lift the water over the Telegraph Flat divide, which will be sufficient to transport it all the way to Sand Hollow Reservoir.

In January 2002, the Bureau of Reclamation issued the report titled "Preliminary Design and Cost Estimate for Lone Rock Pump Station." The Bureau report evaluated five potential sites for a pumping station on Lake Powell based upon recommendations from the 1995 Boyle report. The Bureau recommended a location known as the Lone Rock site. It is located on the south shoreline of Wahweep Bay as shown in Appendix 5.

The Bureau report also included a conceptual design and cost estimate for a pumping station on the recommended site. The recommended design consisted of the following components or features:

- A lake intake structure.
- An approximately 200-foot-deep vertical shaft below the pumping station. (The vertical shaft will be used as a sump for eight variable head vertical turbine pumps, pumping from a forebay near the ground surface.)
- An approximately 240-foot horizontal tunnel from the lake intake structure to the vertical shaft. (A lake tap will have to be constructed if the water level remains high.)
- Nine 5,550-gallon-per-minute (gpm), 1,150-foot vertical turbine pumps mounted above the forebay.
- Pneumatic surge system consisting of four buried tanks and air compressor/control system.
- Sixteen-inch cone valves for isolation and pump control valves on each pump discharge.
- A 30-inch cone valve for isolation and a sleeve valve for breaking head on a drain line on the main pipe header.

Layout drawings for the pumping station from the preliminary design report are included in Appendix 5.

As noted earlier, the design flow for the purposes of this report is 80,000 A-F/year. Therefore, the design capacity of the proposed Lone Rock Pumping Station has been increased by 10,000 A-F/year. This has been accomplished by providing one additional high pressure vertical turbine pump and increasing the capacity of the eight variable head pumps by 700 gpm each.

More detailed hydraulic analysis of the pipeline from Lake Powell to the east side of the Cockscomb indicates that the head of each pump needs to increase from 1,150 feet (as shown in the 1995 report) to 1,280 feet. This will require an additional stage for each pump and increase in the motor size from 2,000 horsepower to 2,250 horsepower.

Installation of an additional pump will require the building length to increase by a minimum of 10 feet. Because the motor sizes will be increasing as well and the space between pumps was fairly limited, the overall building length should be increased by approximately 30 feet to allow for more room to access and maintain the pumps.

While the Bureau report did not include butterfly valves to isolate the surge tanks, consideration during final design should be given to including these valves. As described in the Bureau report, in the event there is a problem with the surge tanks, the pipeline from Lake Powell to the Cockscomb will have to be drained and the pumping station will have to remain out of service. At a minimum, a single isolation valve downstream of the surge tanks should be installed. However, this will not allow pumping station operation during repair of the surge tank.

Costs for a 30-inch cone valve on each surge tank inlet/outlet have been included in the updated cost estimate. This is because the Bureau uses cone valves for isolation purposes, so it is consistent with that approach for conceptual design purposes. If a butterfly valve to handle 600 pounds per square inch (psi) is less expensive than a cone valve, then it should be specified as a contractor-selected material alternative. There are Class 300 butterfly valves (usually metal seated) that can handle pressures up to 740 psi. Manufacturers include Bray, Adams, and Vanessa. A 30-inch, Class 300, cast steel, flanged butterfly valve as manufactured by Adams or Vanessa costs $50,000 to $60,000 plus Contractor's mark-up and installation.

The cost estimate provided in the Bureau report has been updated to include the additional features. Both cost estimates are included in Appendix 2 for comparison.

Lone Rock Pumping Station Operation and Maintenance Costs

Estimated power costs for the Lone Rock Pumping Station are based on $0.0365 cents per kilowatt-hour per information provided by Garkane Energy, which is included in Appendix 6. The pumping station will run constantly throughout the year except for periods of shutdown for maintenance or repair. This maintenance period could be anticipated to be a total of two weeks during the year. Full capacity power usage of the pumping station will be 15.6 megawatts. Yearly power usage will be approximately 131,000 megawatt-hours. Power cost will be approximately $4.80 million per year.

Maintenance costs for pumping stations are estimated to be 2 percent of the initial capital cost. This includes manufacturer's recommended overhauls of equipment, cleaning, periodic inspections, lubrications, adjustments, and miscellaneous building and appurtenances maintenance. Therefore, annual maintenance cost of the Lone Rock Pumping Station is anticipated to be approximately $240,000 per year. Daily operations costs will vary depending upon the level of instrumentation and control built into the system. As the pumping station can be controlled and monitored remotely, the operations costs will decrease. However, because the two pumping stations must be operated together, a highly sophisticated level of instrumentation is expected. The location of the control center will be determined in the future. Total operations and maintenance costs will be approximately $5 million dollars per year.

Selected Location

The selected site for the Lone Rock Pumping Station in this analysis is on the south shoreline of Wahweep Bay, as identified by the Bureau of Reclamation in their report entitled “Preliminary Design and Cost Estimate for Lone Rock Pump Station.” If, however, during preliminary design, it is determined that constraints exist which indicate a preferable location for either the Lone Rock or Cockscomb pumping stations, alternate sites may require a redesign of both the Lone Rock and Cockscomb pumping stations. It is not believed relocating the pumping stations impacts the alignment comparisons.

Chapter 6 - Cockscomb Pumping Station

Location

Three sites are evaluated for possible locations of the pumping station in the Cockscomb vicinity as shown on Figure CK-1 in Volume 2. The two alternatives located on the east side of the Cockscomb are very similar. At this stage of study, the hydraulics of these two east side options are considered to be the same. However it should be noted that the site on the south side of the highway requires two highway crossings for the pipeline alignment, resulting in higher pipeline cost. Due to its higher elevation (approximately 400 feet), the west side pumping station results in significantly different hydraulic conditions for the highway alignment or the steeply sloping tunnel profile. The hydraulic conditions for the shallow sloping tunnel profile are substantially similar to the two east side alternatives, except for the difference in length of the pipeline served by each pumping station. The design features and benefits of both an east side and west side pumping station are discussed in the following sections.

East Side of Cockscomb-North of U. S. Highway 89

The proposed site on the north side of U.S. Highway 89 lies at the foot of the highway embankment and the steeply dipping east slope of the Cockscomb Figure 6-1. Access to the site will be via the existing turnout and gate on the north side of the road, at approximately Station 1370+00. An all-weather access road parallel to the highway embankment will need at least one culvert to cross the West Cove stream alignment. Fencing on both sides of the highway, and within the site, indicates that cattle grazing is possible; therefore, it should be anticipated that the site will be fenced, with cattle guards at each gate.

Site drainage will be to the east into the well-established West Cove drainage, which crosses under the highway embankment in a large reinforced concrete structure. A hydrologic study should be completed to determine the lateral scour potential of the West Cove Wash, in order to minimize expenditure for bank protection. Local drainage down the east face of the Cockscomb, and highway drainage must also be diverted away from the site.

Soil conditions appear to be favorable for construction of a large pumping station. The surficial soils are loose silty sand, evidence of degradation of the surrounding rock features. It is anticipated for cost estimating purposes that spread foundations would be applicable, but this must be confirmed during preliminary engineering.

The Lake Powell Pipeline approach from the east is anticipated within the highway and/or within the existing easement reserved for utilities. It is most economical for the pipeline to be located along the north side where the depth of highway embankment is low as the pipeline approaches the pumping station site. It is anticipated that this site is situated favorably for all alignments discussed in Chapter 3. Should alternative pumping station sites be chosen, the pipeline alignments should be adjusted accordingly.

Electric power for the pumping station is anticipated from the east, in a new power line of approximately 5 miles in length. This power line must cross the existing power line that is approximately parallel to the highway. It is not anticipated that there will be a physical conflict between the two facilities.

A culinary water supply to the pumping station will be necessary for the operators. It is anticipated that the Lake Powell Pipeline, a raw water source, can be tapped and locally treated much more economically than trying to develop a well on-site. Similarly, sanitation is anticipated to be limited to a single restroom, with leach field and septic tank.

Construction considerations which may affect the overall cost of the facility include additional travel time for the construction workers, the potential for sculpted or colored concrete to minimize the visual effect of the facility, the lack of nearby water for use during construction, and the lack of nearby concrete materials. These should be evaluated during preliminary design engineering.

Figure 6-1: Pumping Station Site – North of Highway Embankment

East Side of Cockscomb-South of U.S. Highway 89

The proposed site on the south side of U.S. Highway 89 (Figure 6-2) lies at the southern foot of the highway embankment and between the two branches of the West Cove Wash, which cross the highway. The site is bounded on the south by the much larger Catsair Canyon Wash. Access to the site is via the existing turnout and gate on the south side of the road, at approximately Station 1370+00. An all-weather access driveway parallel to the highway embankment will suffice. Fencing on both sides of the highway and adjacent to the Catsair Canyon Wash indicates that cattle grazing is possible; therefore, it should be anticipated that the site will also need to be fenced, with cattle guards at the gate.

Figure 6-2: Pumping Station Site – South of Highway Embankment (Beyond West Cove Wash)

Site drainage will be to the south into the well-established Catsair Canyon Wash. Hydrologic study should be made to determine the lateral scour potential of the Catsair Canyon Wash, in order to minimize expenditure for bank protection. It does not appear that there is significant drainage from the highway onto the site.

Soil conditions appear to be similar to the north site, so the same considerations will apply here too.

The Lake Powell Pipeline approach is anticipated from the east on the south side of the highway within the existing easement reserved for utilities and can remain parallel to the highway all the way to the site. It is anticipated that this site is situated favorably for all of the alignments discussed in Chapter 3; however, the highway would have to be crossed if any of the tunnel alignments are chosen. Because of the large highway culvert for West Cove Wash, it may be more economical to have the discharge pipeline within the highway embankment east of the first cut, in order to be above the crown of the culvert. Otherwise, additional rock cut may be necessary if the highway alignment is chosen.

Electric power for the pumping station is anticipated from the same location as the north alternative; however, the highway will have to be crossed by the power lines. Water supply and sanitation is anticipated to be the same as the north alternative.

This site is much more exposed than the proposed site north of the highway embankment, but its site development costs appear to be slightly lower.

West Side of Cockscomb

The site on the west side of the Cockscomb becomes an option if one of the alignments for a tunnel through the Cockscomb is selected. Two options are available for the tunnel, which is described in more detail in other parts of this report. The first alternative will be to install a tunnel sloping up at about 6 to 8 percent (depending on the alignment option) from the east side to the west side of the Cockscomb into a forebay. The pumping station forebay will be approximately 20 feet deep as shown schematically in Figures 6-1 and 6-2 in Volume 2. This will require each of the pumps at the Lone Rock Pumping Station to be designed to pump an additional 400 feet of head resulting in approximately a 500-horsepower increase in motor size. However, the size of the pumps in the Cockscomb will be decreased in size by the same amount.

A second alternative is to install the pipeline through the Cockscomb within a tunnel on a relatively shallow slope (less than 3 percent). This will result in the need for a vertical shaft on the west side of the Cockscomb. The pumping station will be constructed over this shaft, with the tunnel effectively functioning as the forebay. No change would be required to the Lone Rock Pumping Station, but the suction lift of the Cockscomb Pumping Station will be approximately 400 feet. One other concept is to connect the shaft to a shallow forebay, similar to the pumping station described previously with the higher sloping tunnel. Again, this will require the pumps in the Lone Rock Pumping Station to be increased in head capacity by approximately 300 feet.

The second option for the low tunnel alternative is to install low head (300-foot) pumps above the shaft, using it as a forebay to pump into another forebay closer to grade. In this forebay, higher head pumps will be installed to pump into the pipeline. This arrangement is similar to the Lone Rock Pumping Station described previously. However, the low head pumps will not have to be designed to operate at large variations in head as will be necessary at the Lone Rock Pumping Station and, therefore, can be constant speed pumps. A detailed hydraulic analysis will be required to ensure proper operation of the low head pumps in the tunnel and evaluate the flow characteristics in the upper forebay.

This west side of the Cockscomb alternative will allow the pumping station to be well hidden. The preferred site is in a small draw at the base of the Cockscomb that is fairly well shielded from the highway. The pumping station can be partially buried in this location.

General Design Concept

The preliminary design concepts for the Cockscomb Pumping Station are similar to the design concept utilized in the proposed Lone Rock Pumping Station. This is beneficial from an operational standpoint because the two pumping stations will operate in series. That is, the Lone Rock Pumping Station must be operating in order to provide water for the Cockscomb Pumping Station to operate. Controls of the two pumping stations will likely be connected to facilitate coordinated operations. Pumps from each pumping station may be paired to operate together in order to match capacities. It is also likely that the same staff will operate both pumping stations. Therefore, similarity in design and equipment will simplify operations and maintenance. There may also be cost savings in purchasing of equipment.

Pumping Station Configuration

The proposed pumping station will consist of an underground concrete forebay to house 10 vertical turbine pumps (equal to the number of high head pumps in the Lone Rock Pumping Station). The pipeline will flow into the forebay to the pumps. Baffles between the pumps are proposed to prevent vortexing from one pump's operation to affect operation of adjacent pumps. During preliminary design of the pumping station, a hydraulic analysis of the wet well design and pump hydraulics will be required to finalize the forebay size and internal flow paths. (The Hydraulics Institute standard ANSI/HI 9.8 *Pump Intake Design* recommends that forebays be hydraulically modeled if the pump capacity exceeds 5,000 gpm each. Thus, this station should definitely be modeled.)

The pumping head required for these pumping stations is approximately 1,310 feet. This is relatively close to the pumping head required at the Lone Rock Pumping Station (1,280 feet). Therefore, the main components can be the same, with only different impeller trims in order to match the hydraulic conditions. Again, this will aid in maintaining the equipment because the same spare parts can be utilized for both pumping stations.

Each pump will be connected to a main header with a 16-inch-diameter pipe. A cone valve for isolation and pump control will be installed between each pump and the main manifold piping. The Bureau of Reclamation had used cone valves for this application. This is proposed for the Cockscomb Pumping Station to maintain consistency.

The manifold will also include a 30-inch drain line with cone valve for isolation and sleeve valve for energy dissipation in order to drain the pipeline back into the wet well. Again this is maintaining consistency with what the Bureau did at the Lone Rock Pumping Station.

If draining the pipeline is anticipated to be a frequent occurrence, consideration to having the pumps designed to run backwards, generating power and draining back to Lake Powell might be given during preliminary engineering and coordinated with the Bureau. It is anticipated at this stage that it would be very infrequent, so power generation would not be attractive. However, if the pumps are designed to dissipate the energy, the branch and valves could be eliminated. Boyle engineered a reverse-flow hydroelectric installation for the Foothills Pumping Station for the Southern Nevada Water Authority (SNWA). The reverse running pump concept is now under construction. To allow this reverse running operation, the electrical system is at a significantly increased cost. Foothills Pumping Station has seven 2,500-horsepower pumps. The cost to allow the reverse running operation (almost entirely electrical work) was over $2 million. If the draining is infrequent, there is no economic benefit in installing the reverse running pump system.

Connected to the pumping station discharge manifold are four buried surge tanks. The piping from the main discharge line to the surge tanks includes a 30-inch cone valve to allow the tanks to be isolated. These valves and the controls for the surge system will be installed in an underground vault. The system will operate as follows.

The proposed surge tanks will be filled with approximately half water and half pressurized air equal to the hydraulic grade in the system. In the event of power failure, the pumps will shut down and stop introducing water into the pipeline. The momentum of the water in the pipeline will try to carry it away from the pumping station. Without such a surge system, this will tend to result in column separation (vacuum condition) in the pipeline. When the velocity of the water slows to a stop, the water will be pulled back to fill the vacuum at extremely high speeds. This can result in extremely high pressures that can damage the piping and equipment. However, with a surge tank system, the water in the tank leaves the tank and fills the vacuum that normally will be created. This lowers the pressure in the surge tank. As the water column slows down, it will eventually reverse flow and flow back into the surge tank, compressing the air. This cycle repeats several times. Detailed hydraulic analysis is required during preliminary design to properly size the surge tank and appurtenant control devices.

Power Service Connection

Power for the pumping station at each proposed location will be supplied via one of the high voltage lines near the site as shown on Figure CK-1 in Volume 2. Garkane Energy has a 138-kV line with an approximate capacity to power the additional 21,000 horsepower. This will be just enough power to run the pumping station; however, more detailed analysis will be needed for confirmation during preliminary design. Overhead power lines will have to be installed to each line at a cost of approximately $125,000 per mile. A switching station will be required at the point of connection to the existing power lines, at an estimated cost of $600,000. At the pumping station, a substation will be required to reduce power service to medium voltage (4,160 volts) to run the pumps. The cost of the substation is also estimated at $600,000. These costs were provided by Garkane Power as shown in the correspondence from Garkane Energy dated November 14, 2001, which is included in Appendix 7.

Operation and Maintenance Costs

Power costs for the east side Cockscomb Pumping Station are based on $0.0365 cents per kilowatt-hour per information provided by Garkane Energy. The pumping station will run constantly throughout the year except for periods of shutdown for maintenance or repair. This maintenance period is anticipated to be a total of two weeks during the year. Full capacity power usage of the pumping station will be 15.9 megawatts. Yearly power usage will be approximately 134,000 megawatt-hours. Power cost will be $4.89 million per year.

Maintenance costs for each of the pumping stations have been estimated to be 2 percent of the initial capital cost. This includes manufacturer's recommended overhauls of equipment, cleaning, periodic inspections, lubrications, adjustments, and miscellaneous building and appurtenances maintenance. Therefore, annual maintenance cost of the Lone Rock Pumping Station is anticipated to be approximately $140,000 per year. Daily operations costs will vary depending upon the level of instrumentation and control built into the system. As the pumping station can be controlled and monitored remotely, the operations costs will decrease. However, because the two pumping stations must be operated together, a highly sophisticated level of instrumentation is expected. The location of the control center will be determined in the future. Total operations and maintenance costs will be approximately $5 million dollars per year.

Selected Location

The selected site for the Cockscomb Pumping Station in this analysis is on the east side of the Cockscomb and north of U.S. Highway 89 for the reasons discussed above. However, during preliminary design, it may be determined that constraints exist which indicate a preferable location for the Cockscomb Pumping Station on the west side of the Cockscomb. This alternative site may require a redesign of both the Lone Rock and Cockscomb pumping stations. It is not believed relocating the pumping stations impacts the alignment comparisons.

Chapter 7 - Potential Hydropower Facilities

General

Electrical generation of electricity has been incorporated in many water supply systems, especially in systems where the terminal sections of the pipeline operate under high pressures and the energy needs to be dissipated as it is discharged. Hydraulic turbines are used to dissipate the energy and generate revenue instead of otherwise incurring the cost for expensive energy dissipating valves or structures. Hydraulic turbines can be selected to suit any available discharge and pressure, and power output is directly proportional to these two parameters.

The proposed Lake Powell Pipeline at the Hurricane Cliffs and at other locations along the approximately 120-mile-long alternative alignments will have high pressures (head) that can result in compact electromechanical equipment (turbines and generators) and powerhouse structure. In addition, at the Hurricane Cliffs, the load center is close-by resulting in a short electrical transmission line. Also, the currently planned water delivery is to be made at a constant flow rate, which is an advantage over many other potential projects where widely fluctuating flows can cause seasonal loss of revenue or disruptions during low or high flows.

Hydroelectric power generation on the Lake Powell Pipeline, no matter which alignment is chosen, will not only require the additional construction of a powerhouse, substation, and transmission line, but will require installation of surge attenuation (or peaking) reservoirs. The powerhouse arrangement typically will be as shown in Volume 2. The two arrangements are intended to illustrate the various capacity plants under consideration. Figures 7-1 and 7-2 in Volume 2 are typical for the smaller capacity plants and Figures 7-3 and 7-4 for the larger. Drawings for all of the alternatives studied have not been prepared due to the similarity in form if not capacity.

The “footprints” for the power plants are on the order of 6,000 square feet to 8,000 square feet, depending on installed capacity excluding extensive office space, control rooms, or maintenance shops. With provisions for typical indoor facilities, outside switch yard, access roads, etc., total land area required for construction, excluding pipeline, will likely be 2 to 3 acres depending on installed capacity, unless special provisions are made. Feasibility-level powerhouse costs have been estimated using a combination of existing, similar project construction cost, major equipment budget prices, and cost curves. The cost estimates include equipment and structures for the powerhouse, switchyard, and transmission line. The following items are included in other portions of the project, thus have not been included in the cost estimate for the power generation facilities:

- Reregulating reservoir with outlet works.
- Spillway.

- Penstock inlet works.
- Shaft and tunnel.
- Energy dissipating equipment (or structures).
- Access roads.

Also not included in the hydro cost estimates are the costs of obtaining permits and a Federal Energy Regulatory Commission license, if this is required.

Alternatives Studied – Hurricane Cliffs and Sand Hollow

The overall arrangement will be to construct a reregulating reservoir above Hurricane Cliffs. The reservoir will receive the water pumped from Lake Powell and hold it in temporary storage to satisfy the daily water supply schedule. An intake at this reservoir will allow water to be drawn into the conduit for delivery to Sand Hollow reservoir.

Normally, it will be most economical to construct a single powerhouse to utilize the total head available between the reregulating reservoir at the top of Hurricane Cliffs and Sand Hollow. However, due to the high head and long, high pressure conduit from the base of the cliffs, consideration was given to constructing one powerhouse at the base of the cliffs and a second powerhouse, utilizing a low pressure conduit, at Sand Hollow. The powerhouses will operate in tandem, the water from the Hurricane Cliffs powerhouse discharging directly into the lower pipeline to Sand Hollow. A third option is to construct another powerhouse upstream of Hurricane Cliffs. The basic options considered for feasibility study are summarized as:

- **Option 1.** A powerhouse at Sand Hollow receiving water directly from a continuous pipeline (penstock) or shaft/rock tunnel beginning at a reregulating reservoir at the top of Hurricane Cliffs.
- **Option 2.** Two powerhouses in series, one at the base of Hurricane Cliffs and the second at Sand Hollow.
- **Option 3.** Two or three powerhouses in series, one at the base of Little Creek Mountain (Alternative 12), one at the base of Hurricane Cliffs, and / or the third at Sand Hollow.

Power Generation at Telegraph Flats

The pressure-reducing facility at Telegraph Flats is conceptualized as having two parallel sleeve valves, each a different size to handle a range of flows, with the combination sized to handle the maximum flow rate. Power generation at this facility will be based on current analysis of hydraulic transients (see Chapter 2 for a discussion of these general considerations). A branch pipeline could begin at a tee and proceed up the cliffs to the north, but they are 3 miles away and within the Grand Staircase - Escalante National Monument. An alternative to this is to construct a reservoir at the top of Telegraph Flat. The Cockscomb Pumping Station would lift the water to that reservoir. The pipeline to the west would gradually descend to an elevation 140 feet lower, where the pressure- reducing facility would be constructed. It would consist of the two sleeve valves described above, plus a turbine in parallel. The additional cost of the reservoir at Telegraph Flat would have to be added to costs shown in this study; however, total project costs would be reduced by the cost of the pressure-reducing facility. Because there are system-wide operational benefits to that, further consideration is warranted.

Hydro Turbine Generators

The type of hydro turbine selected for the high-pressure hydro power plants is the impulse (or Pelton) type. Figure 7-5 shows an example of a Pelton turbine. This design provides excellent efficiency and dependability at these heads and can be equipped with one or multiple jets depending on flow and/or power variation requirements. In the proposed powerhouses, a twinjet configuration is recommended for economy. The smaller capacity plants will have a horizontal shaft axis, whereas the larger capacity plants may also be vertical shaft. The generators will be synchronous type with static excitation. Overall anticipated efficiency will be about 89 percent.

The turbines selected for the lower head plants at Sand Hollow for Option 2 and at Telegraph Flat will be of the Francis or cross flow type in a horizontal axis arrangement, also with synchronous generator. Figure 7-6 shows an example of a Francis turbine. The Francis type will have better efficiency but a higher capital cost than the cross flow type.

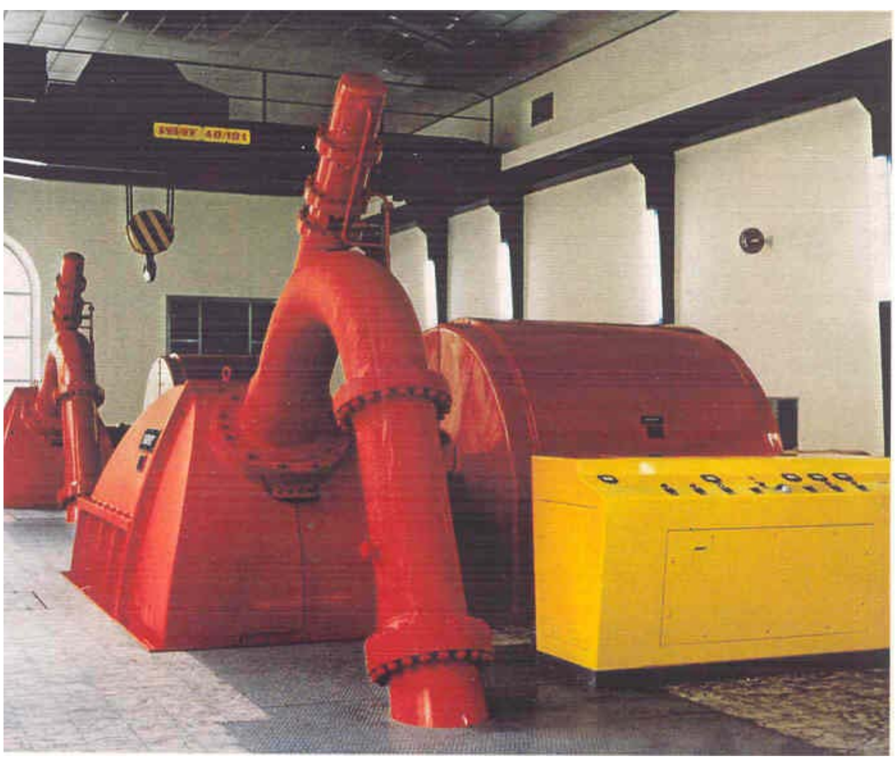

Figure 7-5: Pelton Turbine Installation

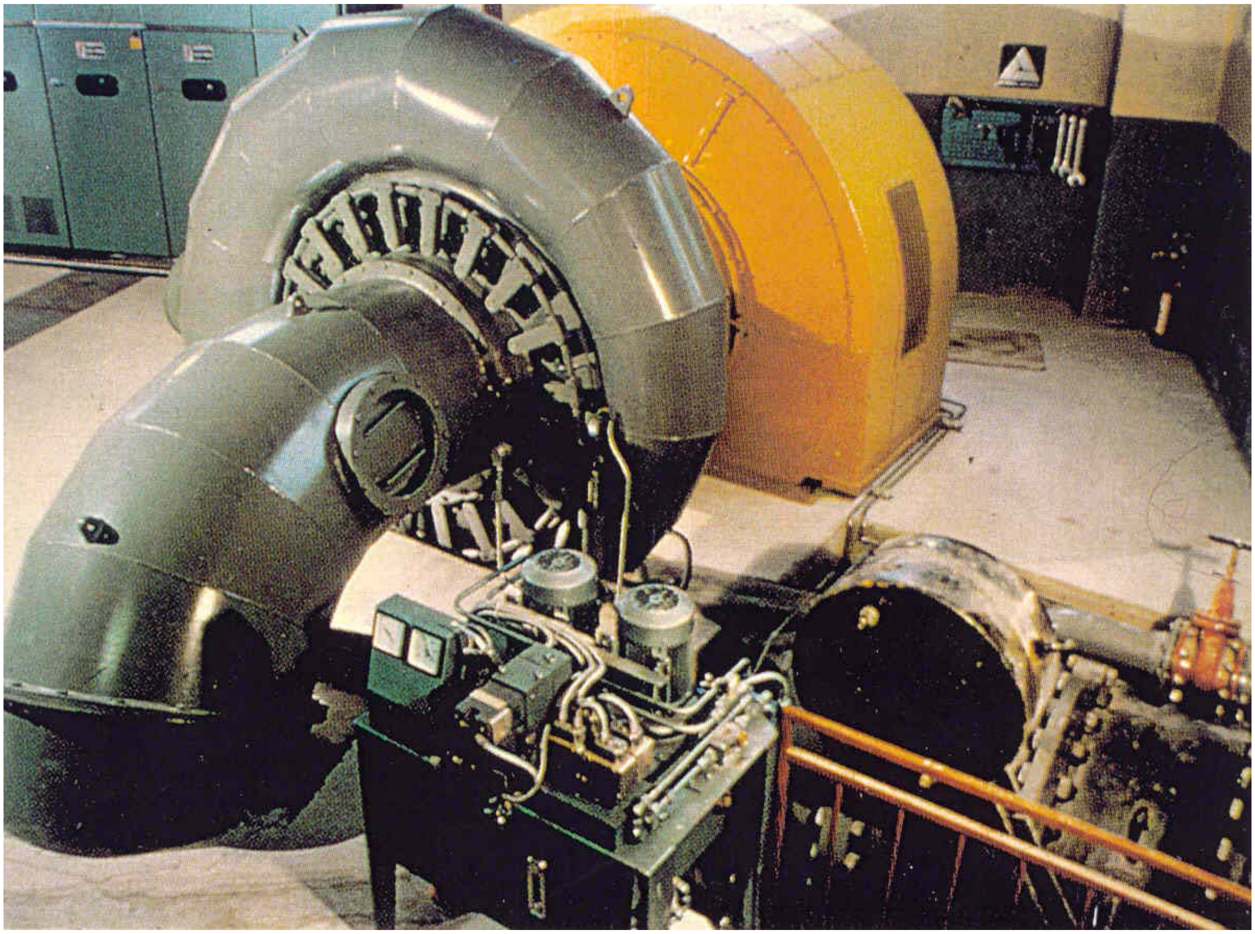

Figure 7-6: Francis Turbine Installation

Penstock Configuration – Sand Hollow and Hurricane Cliffs

The conduit may be a surface or a cut and cover pipeline or a shaft and tunnel or a combination of these depending on terrain, geology, and cost. The relative cost and other construction aspects of a surface pipeline versus shaft and tunnel are being studied separate from this hydropower evaluation as part of the main pipeline evaluation. However, differences in alternatives such as peaking versus nonpeaking plants and the number and location of powerhouses, affect the design pressure or diameter of the penstocks. In order to evaluate the affect of hydropower options on the penstocks, the hydropower costs include the difference in cost of the penstock with hydropower facilities and the cost of the penstock without the hydropower facilities.

A gravity vent and/or other surge control will be required on the Sand Hollow Powerhouse penstock. As described earlier, a gravity vent/surge control will be located and sized to minimize upstream surge pressures in the Grass Valley Pipeline and to provide a free water surface/surge attenuation when the wicket gates (or cone valves) are closed. The gravity vent/surge control should be sized with a capacity to sustain fluctuations in operation between the two powerhouses (base load or peaking) and to have adequate capacity for surge attenuation.

Because of its proximity to the Sand Hollow Reservoir, an overflow pipeline can be constructed of RCP to convey spills without causing erosion.

Load Peaking Option

Because WCWCD will have total control of the water delivery schedule, there is the further option of installing sufficient capacity to operate the hydropower facilities as peaking plants. The peaking plants will generate power daily, exclusively at times of peak demand on the electric power system. At such times, the energy (and possibly capacity) rates are typically at a premium and may justify installing a higher capacity plant. The water conduit will be more expensive due to the larger flow capacity requirement. These differences have been incorporated into the cost evaluations as discussed previously.

Both base load and peaking plants at one and two locations have been studied for all of the alignment alternatives assuming eight hours of peaking generation per day throughout the year (future studies may warrant analysis of weekly cycling and pumped storage options). Because the water delivery is initiated by pumping from Lake Powell, the pumping schedule will need to be factored into the evaluation of the peaking alternatives. The pumping cycle may be able to take advantage of lower off-peak energy rates if so, a larger reregulating reservoir may be required at the top of Hurricane Cliffs to accommodate the greater water volume being held in storage prior to peaking generation.

The pipeline cost difference between the non-hydro water supply conduit (constant 5-foot diameter) and the larger penstock generally needed (by reason of head loss reduction) for the hydropower peaking options has also been estimated. The penstock pipe diameter for all of the Options 1 and 2, 24-hour/day delivery (base load) alternatives have been held constant at 60 inches. The penstock pipe diameter for the eight-hour/day peaking plants is sized for a water flow velocity of 10 feet per second (fps). This results in a pipe diameter of 75 inches for the flow rate of 70,000 A-F/year.

As demonstrated in reviewing the economic analysis of the peaking facilities, the concept of over sizing lines is a sound concept assuming the differential in rates of returns. In future evaluations consideration should likewasie be given to ver sixing the lines to all “off-peak” pumping. Typically off-peak rates are lower and may offset the additional cost of upsizing lines and facilities to take advantage of this lower rate feature. This would allow 4 to 8 hours without pumping during the daily cycle.

Evaluation of Data

Table 10 in Appendix 2 gives details of the hydropower data for base load generating facilities shown in each alignment alternative. Table 11 in Appendix 2 indicates the same information for peaking facilities. This information includes installed capacity (megawatts [MW]) and annual energy production (kwh). Figures 12 through 23 show annual energy values, estimated construction cost, and annual O&M cost. Table 9 shows the estimated penstock costs for the peaking alternatives.

Due to the long planning and construction schedule for the pipeline, definitive rates for sale of base load and peaking power cannot be determined. Future negotiations on a contract for power required by and produced by this project may be several years in the future. Based on 2003 costs shown in this report and a discount rate of 3.9% over 40 years, the differential rates between the base load and peaking power needs to be approximately $0.02 per kwh to justify the additional expenditure for the peaking facility. Otherwise, base load plants become more cost effective.

A common criteria used to select hydroelectric projects for further study is the unit cost of the installation in $/kw. The lowest unit cost installation is indicated to be that of the peaking alternative for the two-powerhouse option for the Gould Spring Alignment, with the Little Creek Mountain Alignment running a close second. The two-hydropower plant alternatives benefit from the significantly reduced cost of the lower penstock due to its length (~4 miles) and low working pressure in the pipeline.

A unit cost of around $1,000/kw is considered economically to be a very attractive project. Pumped storage peaking plants costing $2,000/kw and more have been built, so the majority of the projects studied can be given serious consideration for investment. The exceptions are the Honeymoon Trail Alignment options.

An alternative method of screening for hydro project feasibility is to use the unit cost in $/kwh. The unit cost in $/kwh is often used for comparisons with other forms of generation where fuel is required, such as combustion turbines and thermal base-load plants.

The Lake Powell water supply pipeline in itself can be likened to a pumped storage project even though power generation is not a primary function. In a pumped storage project, the water is pumped to a higher elevation during the night and on weekends to take advantage of low cost pumping energy. The water remains in a storage reservoir until there is a demand for peaking power during the day. At that time, it is released for generation through one or more turbines.

Separate pumps and turbines were typically used at one time for such facilities but these have been replaced with reversible pump turbines that can pump and generate through the same machine. Pumped storage projects today recycle the same water over and over between an upper and lower reservoir, whereas at the Lake Powell Pipeline Project the water will be used only once. That is because the pumps and turbines will be at opposite ends of the pipeline, and the water will be used for M&I purposes.

It is important to note that the peaking alternatives are anticipated to operate for 8 hours per day, whereas base load alternatives will be in operation 24 hours per day. The higher capacity of the peaking plants due to this schedule distorts the unit cost value compared to the base load plants. The energy generated by both plant types is essentially equal, but revenues may be substantially different due to the anticipated higher value of peaking energy.

Although the capital costs of the peaking plants are almost double that of the base load plants, this may not be so significant when the value of energy is factored in. During future benefit cost analysis actual negotiated rates from power suppliers can be used to make this comparison. Without reasonably firm numbers for the baseload and peak power rates, a decision cannot be made regarding whether one of the peaking options should be selected.

Operation and Maintenance Cost

O&M cost for a hydroelectric plant can have many variables such as whether or not the plant is fully automated, the type and quality of equipment installed, the frequency of operation, frequency of overhaul, etc. Statistical studies have been performed of some or all aspects of hydroelectric plant O&M cost. For example, the U.S. Bureau of Reclamation has developed the "Replacements" Manual that predicts the service life of a large selection of hydroelectric equipment components and structures and assigns a relative cost to replace them.

Another statistical study was performed in 1985 by Ontario Hydro using annual cost data published by the U.S. Department of Energy entitled "Historical Plant Cost and Annual Production Expenses for Selected Electric Plants." The database for the 430 hydro plants regulated by the FERC included as separate items: maintenance, operation, and capital expenditures. The costs included powerhouse mechanical, hydraulic, and electric equipment; all structures; reservoirs, dams, and waterways; supervision; and engineering. The database extended to 1985 and plant ages of up to 85 years. The operations cost will be significantly reduced, if not eliminated, for new hydro plants because they will be fully automated and, therefore, will not require operators staffing the plant. In the database, there is a mix of fully attended, fully automated, and semi-automated plants.

The approach used in this report is based on a statistical analysis presented in Hydro Review, which is based on actual O&M data reported to FERC for all hydropower facilities in the United States. The O&M cost for any given year of operation is calculated based on the following equation:

$$\text{O\&M Cost} = 0.63 \times \text{Plant Capacity in kw} \times (4.83 \times 0.00239 \times \text{Plant Age in Years}^2)$$

In order to calculate the annualized O&M cost for the period of analysis (40 years), the O&M cost is made for each year, annualized and then summed for the period.

Hydroelectric Power Conclusions

At this feasibility stage, it can be concluded that, with the exception of the Honeymoon Trail alignment, the hydropower options and especially the peaking plants appear to be economically attractive on a $/kw basis. Full economic analyses of the cost and revenue streams are recommended.

Chapter 8 - Reservoirs

General

Each of the proposed pipeline alignments will include one or more reservoirs along its route. The reservoirs anticipated include a power plant staging/reregulating reservoir above the Hurricane Cliffs Powerplant, a power plant surge control standpipe/gravity vent above the Sand Hollow Powerplant, a surge attenuating reservoir at the Little Creek Mountain Powerplant (for many alignment alternatives in lieu of a pressure-reducing facility) and a possible regulating reservoir or standpipe at Telegraph Flat.

As discussed in Chapter 7, a free-water-surface reservoir will be necessary upstream of each hydropower plant. However, there are additional reasons for maintaining free water surfaces along the pipeline alignment. In particular, where the HGL elevation is near the top of the pipe, ordinary operational fluctuations due to differences between demand withdrawals and pumping will result in pressure variations in the pipeline. For most of the pipeline, this is not an important issue, but where the HGL approaches the high points in the pipeline, the result of the HGL below the top of the pipe is vacuum. The vacuum condition is usually regulated with vacuum relief valves, supplemented with one-way check valves. In practice, these valves would open and shut with great rapidity. Even with "anti-slamming" valves installed, these will be higher maintenance items than necessary.

Telegraph Flats

An alternative to a reservoir for the free-water-surface at Telegraph Flats is to construct the pipeline with a standpipe. The overflow elevation of the standpipe very effectively limits the pressure in the pipeline between that point and the Cockscomb Pumping Station. With a standpipe at Telegraph Flats the amount of energy needed to lift the water is not inadvertently wasted on pumping the water to any elevation greater than that absolutely necessary to get it "over the hill" on its way to Sand Hollow Reservoir. A standpipe also eliminates vacuum in the pipeline between Cockscomb Pumping Station and any downstream control, such as a hydro-powerplant. Once a standpipe is placed in the system, the downstream operation of valves controls the pipeline. Additional standpipes should be installed at local high points, as the hydraulics are refined during preliminary engineering.

Hurricane Cliffs Reregulating Reservoir

The power plant staging/reregulating reservoir at the Hurricane Cliffs will be sized for one day of operation at the maximum pumping rate. This equates to a storage capacity of about 192 A-F excluding allowance for dead storage and freeboard requirements for local runoff/flood storage. Based on the topography east of the Hurricane Cliffs crest, a reservoir of this capacity may be sited either in existing drainages or as cut and fill ponds located to achieve a higher reservoir invert than in the natural drainages.

The rugged topography lends itself to siting reservoirs along the pipeline alignments. If future design alternatives require a larger storage capacity, multiple locations are likely to be available for storage ponds created by cut and fill but will become more limited for conventional dam and reservoir layouts in natural drainages.

Reservoir locations for each of the alternative pipeline alignments are identified in Figures HC-1 through HC-6 in Appendix 2 and are summarized in Table 8-1. Some alignments have multiple reservoir siting options. Staging reservoirs sited for alternative pipeline alignments in Volume 2, Figures HC-2, HC-3, and HC-4 are the same due to the close proximity of the alignments to one another. The locations of the potential reservoir sites are shown on each of the alignment plan views and are intended to demonstrate the feasibility of the site location and approximate invert elevations with respect to power generation. The locations and layouts are conceptual and are not optimized in regards to crest alignment and capacity, geotechnical design, cost per A-F of storage, or piping to/from the reservoir. It is assumed that the staging reservoir layout will be optimized as part of preliminary and final design of the Lake Powell Pipeline Project.

Table 8-1: Staging Reservoir Summary

Alignment Alternative	Alternative ID	Crest Length (feet)	Invert Elevation (feet)	Depth (feet)	Type of Facility
HC-1	A	700	4400	100	Dam+Fill
	B	2300	4190	40	Cut-fill
HC-2 to 4	A	300	4400	50	Dam+C/F
	B	1200	4400	50	Dam+C/F
	C	1460	4370	70	Dam+Fill
	D	1500	4400	40	Cut-Fill
	E	1400	4370	50	Cut-Fill
HC-5	A	840	4630	70	Dam
	B	800	4520	80	Dam
	C	1180	4600	60	Cut-Fill
HC-6	A	1120	4640	60	Cut-Fill
	B	900	4610	52	Dam
	C	600	4600	42	Dam

Little Creek Mountain Regulating Reservoir (Alternative 12)

The power plant staging/reregulating reservoir at Little Creek Mountain will be sized for the same one day of operation capacity as described for the Hurricane Cliffs reregulating reservoir if a suitable site is identified. The minimum elevation of the reservoir has to be above the maximum static HGL elevation when the isolation valve is closed. This may require a branch pipeline, which extends up to the necessary elevation. Based on the topography of the Little Creek Mountain Cliffs which face north, a reservoir of this capacity may be sited either in existing drainages or as a cut and fill pond located to achieve a higher reservoir invert than in the natural drainages.

Sand Hollow Powerhouse Surge Vent

A surge vent will be required at the top of the Sand Hollow Powerhouse penstock. As described earlier, this surge vent is to be sized to minimize upstream surge pressures in the Grass Valley Pipeline and to provide a free water surface/surge attenuation when the wicket gates (or cone valves) are closed. It need not be sized to provide the same capacity as the reregulating reservoir. It should be sized to have operational capacity to sustain fluctuations in operation between the two powerhouses and to have adequate capacity for surge attenuation. Because of its proximity to the Sand Hollow Reservoir, an overflow pipeline can be constructed of RCP to convey spills without causing erosion.

Opinion of Probable Cost of Reservoirs

Based on experience in quantifying costs for small water storage facilities (less than 500 A-F) similar to these layouts, a budget level unit cost can be used for site development and earthwork (excluding piping, outlet works, and design/construction contingencies). The cost is approximately $4,600 per A-F of storage. This cost includes provisions for synthetic lining installation. Provided foundation conditions are suitable and no synthetic liner is required for containment, the unit earthwork cost of storage will be on the order of $2,500 to $3,000 per A-F.

The estimated unit costs are based on generalized balanced cut and fill configurations used to create small storage ponds. In other studies by Boyle that considered small capacity reservoirs, it was found that unit costs for dams with small storage capacity are expensive and generally match the unit cost estimates for an equivalent capacity cut and fill pond. In final design, the actual costs for site development and earthwork will probably be reduced from this initial estimate of costs.

Chapter 9 - Archaeological and Cultural Resources Reconnaissance

The 1995 study concluded that the project alignment appeared to be relatively environmentally benign because the vast majority of the project is within existing desert highway ROW. Detailed environmental evaluations were not included in the scope of either that or this study. However, a preliminary archaeological and cultural resource desktop reconnaissance was performed at the Hurricane Cliffs and at the Cockscomb by Intersearch, Inc., to identify potential archaeological and other sensitive areas.

Land Use Designations

The project facilities traverse the following types of designated land uses:

- **BLM Administered Public Lands, State (Utah and Arizona) Lands and Private Lands**. The vast majority of the pipeline alignments traverse BLM administered state and private lands. These land use designations are considered low project impediments. Figure LU-1 in Appendix 1 indicates general land usage for the selected alignments.

- **Indian Reservation Land.** All of the alternate alignments except for the South Kaibab – West Little Creek and South Kaibab – Honeymoon Trail alignments pass through the Kaibab Indian Reservation. However, the alignments stay within the existing Arizona Highway 389 ROW where it crosses the Kaibab Indian Reservation.

- **Wilderness Areas, Wilderness Study Areas, National Forests, Parks, and Monuments.** Since the 1998 report, the Grand Staircase Escalante Wilderness was proclaimed by then-president Clinton. It is our understanding that a corridor 800 feet wide along U.S. Highway 89 was reserved for utilities. The U.S. Highway 89 alignment remains within that corridor. The Cockscomb Pumping Station alternatives and alternate Cockscomb pipeline alignments are located within the Cockscomb Wilderness Study Area within the Grand Staircase-Escalante National Monument. This area may be considered to have environmental sensitivity.

- **Glen Canyon National Recreation Area.** The Lake Powell Pumping Station will be constructed within this recreation area. This is not deemed to be a project limiting constraint.

Mapping reviewed as part of this study includes Arizona Strip District Maps (Figure 4-3), BLM Surface Management Status Maps (’83-Kanab, ’87-Smoky Mountain, and ’83-St. George), and the BLM Arizona Strip Field Office Visitor Map, 4th edition.

An archeological records search was conducted by Intersearch, Inc., on the Hurricane Cliffs section of the proposed Lake Powell Pipeline. A records search conducted in the BLM files involved USGS 7.5-foot topographic maps including Washington Dome, Hurricane, The Divide, Little Creek Mountain, Smithsonian Butte, and Hildale is included in Appendix 5.

Many portions of the proposed Lake Powell Pipeline have been previously inventoried for cultural resources, particularly the portion adjacent to SR 59. Some mitigation work has also been conducted along that portion in association with the Hildale Utilities Corridor (1993B and 1994), but additional work may be appropriate during the preliminary engineering phase of this project. The portion of the proposed corridor which runs through Canaan Gap probably has the highest potential for encountering significant archeological resources, and some have already been recorded there. It is likely that additional sites will be found in this section, and additional archaeological investigations will be necessary.

A Class III records search was also conducted on the Cockscomb section of the proposed Lake Powell Pipeline. The project involved a total of approximately 15.5 miles of the pipeline alignment located in Sections 24 through 26, T42S, R3W; Sections 19 through 25, T42S, R2W; and Sections 30 and 31, T42S, R1W, generally south of U.S. Highway 89. A records search was conducted with the aid of the Kanab Field Office and Grand Staircase-Escalante National Monument archeologist in the BLM files. Three power line corridor studies have previously been conducted.

All three of the previously conducted power line corridor cultural resource inventories carried out within the area of the Cockscomb section of the proposed Lake Powell Pipeline corridor recorded significant prehistoric archeological sites. Most of the recorded sites are located north of the proposed pipeline corridor, and they include larger Virgin Anasazi habitation sites and Formative and Southern Paiute campsites. This suggests that the portion of the proposed corridor crossing the Fivemile Mountain area may encounter cultural resources similar to those recorded by the 1974 and 1997 Garkane power line surveys, i.e., large campsites. A small portion of the proposed pipeline corridor in Section 24, T42S, R2W may have been addressed, in part, by the 1988 power line inventory, but the remainder of the route has not been surveyed. It is likely that additional archaeological investigations will be necessary during the preliminary engineering phase of the project for this portion of the pipeline also.

Chapter 10 - Recommendations and Conclusions – Lone Rock Pumping Station to Sand Hollow Reservoir

The potential pipeline alignements were evaluated on a reconnaissance level, considering capital costs, operation and maintenance costs, environmental disturbance, geotechnical features, land use and right of way. As stated previously, this report compared alignment alternatives at two locations; The Cockscomb and the Hurrican Cliffs.

Hurricane Cliffs Alignments

Comparing alignments with probable costs within the accuracy of pre-feasibility level estimates (15 percent contingency) suggests further evaluation is necessary for selection of the most cost-effective alternative. Due to the revenue potential from power generation, discussed elsewhere in this report, factors beyond capital costs are critical to selecting an alignment and hydropower generating option.

For purposes of further evaluation, based solely on capital costs, the 10 least cost alternative alignments deserve consideration. These 10 alternatives and their respective capital costs, listed in Table 10-2, include:

Table 10-1: Top Ten Based on Total Capital Cost

ID	Alignment Description		Capital Cost	Rank
4	Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	284,302,000	1
4	Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	284,592,000	2
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	286,577,000	3
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	288,992,000	4
2	Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	290,161,000	5
2	Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	290,181,000	6
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	290,467,000	7
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	290,464,000	8
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Base Load	290,880,000	9
5	Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Base Load	292,097,000	10

Examination of Table 10-2 indicates that the base load hydropower alternatives are the lowest capital cost. This is understandable because the storage requirements are lower and the hydroelectric plants are much smaller and less expensive than the peaking hydropower alternatives. The top 10 are separated by $7,795,000 or about 3 percent of the estimated capital cost of the project.

The two lowest cost alternatives on a capital cost basis appear to be the Gould Spring – Willow Spring Alignment (HGL-4) with one and two hydroelectric plants. This alignment is similar to the preferred alternative described in the 1995 report. The fifth and sixth lowest cost alternatives are, generally, the preferred alternative from the 1995 report (HGL-2). One disadvantage to this alignment is the unknown public reception to construction of a power plant, electric substation, and power lines adjacent to a new residential neighborhood. However, four of the six lowest capital cost alignments are substantially the same as the 1995 preferred alignment.

The second and third lowest capital cost alternatives are Alignments HGL-10 and HGL-11, which are longer than the other alignments. Their relative cost advantage is based upon the assumption that elimination of traffic control throughout much of the construction project would offset the significant reduction in accessibility to the alignment. More importantly, they do not recognize two cost components critical to the selection of either: the significantly increased cost of the pipeline to deliver 10,000 A-F/year to the KCWCD and the unidentified cost of the off-road alignments. Adding the cost of the KCWCD pipeline to the cost of Alignments HGL-10 and HGL-11 increases their project costs such that these two alignments are not in the 10 least capital cost alignments and should be removed from further consideration.

For purposes of economic evaluation, the 10 least cost alternatives based on a present worth basis are ranked in Table 10-3.

Table 10-2: Top Ten Based on Net Present Worth

ID	Alignment Description		Present Worth	Rank
12	Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	369,094,000	1
12	Little Creek Mtn. Gould Reservoir Alignment, 2 PS’s 3 Hydro	Peaking	378,834,000	2
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	380,834,000	3
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	384,301,000	4
3	Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Peaking	384,975,000	5
1	Gould Reservoir Alignment, 2 PS's, 1 Hydro	Peaking	385,300,000	6
3	Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Peaking	386,802,000	7
6	Colorado City – West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	386,928,000	8
1	Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	387,364,000	9
6	Colorado City – West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	390,508,000	10

The present worth analysis was based upon the following assumptions:

- Uniform cost of power and power rates throughout the life of the project.
- Uniform demand for water throughout the life of the project.

Neither of these assumptions would be valid if the purpose of this study was to determine the economic viability and benefit of the Lake Powell Pipeline Project. However, for the purpose of comparing alignment alternatives, these assumptions significantly reduced the analysis of the probable costs.

The first and second ranked alignments, based on present worth analysis, are HGL-12, with two and with three hydropower facilities. HGL-12, as described earlier, was developed to address system hydraulics and the generation of electric power. HGL-12 is a modification of HGL-3.

HGL-11 with peaking power plants is ranked third and fourth in this present worth analysis. As previously discussed, HGL-11 was ranked fourth on the lowest capital cost basis; however, due to the uncertainty of obtaining rights-of-ways and easements and the additional cost of a longer pipeline to serve the KCWCD, its ranking is misleading.

Tables 10-2 and 10-3 indicate HGL-1 and HGL-3 are in the top 10 for both comparisons. These two alignments are approximately 4.0% less cost effective based on present worth analysis. HGL 1&3 are similar in their overall alignment except for a portion of the alignment above Hurricane Cliffs. The significance of HGL-3 being ranked high in both total capital costs and present worth analysis is that HGL-12 is based on HGL-3 with the addition of a hydropower facility to maximize the energy recovery of the pipeline.

The present worth analysis is the preferred measure of recommendation since the total capital cost analysis does not take into consideration energy recovery. The lowest cost alternative, based upon present worth is alignment No. 12 with two hydroelectric facilities.

The lowest cost alternatives, based upon present worth, for base load hydroelectric units were alternatives 11, 12, 1, and 3. This is supportive of this overall results since the assumption used with regard to rates for power are variable and often require negotiations in order to be established.

In conclusion additional evaluation should involve Alignment 12 with both two and three hydropower facilities and based on peak and base load hydropower options.

Recommendation:

The Cockscomb

In Chapter 3, the Cockscomb, several alignments were analyzed but a certain type of tunneling was overwhelmingly favored. This method is known as drill and blast tunneling. The top six of the overall eighteen were of this type of tunneling with an open cut highway alignment behind it. The cost difference between open cut and tunneling was significant to this portion of the pipeline but was insignificant to the overall project. Although drill and blast tunneling was favored, the open cut highway alignment was recommended because of constructability geologic, and potential environmental concerns.

Hurricane Cliffs

Similar to the Cockscomb, the Hurricane Cliffs decision was not based on the cost of the least expensive method of traversing the feature. The Hurricane Cliffs recommended alignment involved an overall hydraulic analysis along with an opinion of probable cost and a hydroelectric revenue production comparison for all 12 alignments and 48 hydroelectric options. The hydraulic analysis and associated opinions of probable cost were considered throughout the alignments and involved the major appurtenances, features, and different pressure classes throughout the pipeline. The opinions of probable cost were compared by using both total capital cost and present worth analyses. The hydroelectric portion of the analysis took into consideration multiple hydroelectric power plants, both base load and peak load plants, and penstocks associated with the specific alignment.

Based on present worth analysis the lowest cost alignment is Alignment 12. Alignment 12 is similar to many of the other option except for the utilization of a third hydropower facility, which maximized the recovery of the potential hydropower energy.

Principal References

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"Utah Wilderness Study Area"; www.ut.blm.gov/wilderness/wprt/wprtscCockscomb.html

Appendix

1. "Intentionally Left Blank"

2. Cost Opinion Spreadsheets

3. Site Photos

   3.1 Lone Rock Pumping Station
   3.2 Cockscomb
   3.3 Hurricane Cliffs
   3.4 Honeymoon Trail

4. Tunnel Feasibility Report for Lake Powell Pipeline Feasibility Study, Washington County Water Conservancy District, Washington County, UT, by Haley & Aldrich, Inc., File No. 28818-000, dated December 2002

5. Preliminary Design and Cost Estimate for Lone Rock Pump Station by Bureau of Reclamation Provo Area Office, dated January 2002

6. Archaeological Investigations

   6.1 Archaeological Records Search – Washington County Section
   6.2 Archaeological Class III Records Search – Cockscomb Section
   6.3 An Archeological Records Search - Mohave County, Utah

7. Correspondence

   Garkane Memo dated November 14, 2001.

Table 1
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Alignments Comparison Ranked by Net Present Worth. Base Load and Peaking Hydropower Powerhouse Included.

ID	Alignment Description		Capital Costs: Pipeline	Capital Costs: Other (Pump Stations, Reservoirs, Pressure Reducing Facilities, and Hydropower Powerhouses)	Capital Costs: Subtotal	Capital Costs: Contingency	Capital Costs: Engineering & Administration	Capital Costs: Total Capital Costs	Capital Costs: Rank Based on Capital Costs	Annualized Costs: Year 1 Annual Costs (with an energy value of 3 cents for base load and 6 cents for peak load hydropower)	Annualized Costs: Rank Based on Year 1 Annual Costs	Annualized Costs: Total Annualized Capital Costs	Annualized Costs: Net Annualized Costs	Annualized Costs: Rank Based on Net Annual Costs	Present Worth: Present Worth of Year 1 Annual Costs	Present Worth: Net Present Worth	Present Worth: Rank Based on Net Present Worth
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	189,599,565	72,567,272	262,167,000	52,433,000	39,325,000	353,925,000	45	755,000	1	13,049,000	13,804,000	1	15,169,000	369,094,000	1
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 3 Hydro	Peaking	184,257,368	84,052,268	268,310,000	53,662,000	40,247,000	362,219,000	46	827,000	2	13,355,000	14,182,000	2	16,615,000	378,834,000	2
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	176,437,943	56,584,565	233,023,000	46,605,000	34,953,000	314,581,000	23	3,293,000	3	11,599,000	14,892,000	3	66,159,000	380,740,000	3
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	167,473,045	67,428,987	234,902,000	46,980,000	35,235,000	317,117,000	28	3,344,000	6	11,692,000	15,036,000	4	67,184,000	384,301,000	4
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Peaking	178,473,438	56,584,565	235,058,000	47,012,000	35,259,000	317,329,000	29	3,367,000	10	11,700,000	15,067,000	5	67,646,000	384,975,000	5
1	Baseline - Gould Reservoir Alignment, 2 PS's, 1 Hydro	Peaking	178,714,172	56,584,565	235,299,000	47,060,000	35,295,000	317,654,000	30	3,367,000	10	11,712,000	15,079,000	6	67,646,000	385,300,000	6
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Peaking	168,965,913	67,460,948	236,427,000	47,285,000	35,464,000	319,176,000	34	3,366,000	9	11,768,000	15,134,000	8	67,626,000	386,802,000	7
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	181,022,260	56,584,565	237,607,000	47,521,000	35,641,000	320,769,000	37	3,293,000	3	11,827,000	15,120,000	7	66,159,000	386,928,000	8
1	Baseline - Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	168,807,814	67,276,255	236,084,000	47,217,000	35,413,000	318,714,000	33	3,417,000	12	11,751,000	15,168,000	9	68,650,000	387,364,000	9
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	172,068,781	67,430,171	239,499,000	47,900,000	35,925,000	323,324,000	40	3,344,000	6	11,921,000	15,265,000	10	67,184,000	390,508,000	10
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Peaking	179,278,304	55,083,565	234,362,000	46,872,000	35,154,000	316,388,000	27	4,309,000	14	11,665,000	15,974,000	12	86,571,000	402,959,000	11
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Peaking	170,733,913	64,790,929	235,525,000	47,105,000	35,329,000	317,959,000	31	4,383,000	15	11,723,000	16,106,000	13	88,058,000	406,017,000	12
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	168,562,197	65,481,565	234,044,000	46,809,000	35,107,000	315,960,000	25	4,527,000	18	11,649,000	16,176,000	15	90,951,000	406,911,000	13
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	198,428,759	56,084,565	254,513,000	50,903,000	38,177,000	343,593,000	42	3,293,000	3	12,668,000	15,961,000	11	66,159,000	409,752,000	14
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	183,432,585	54,854,565	238,287,000	47,657,000	35,743,000	321,687,000	38	4,454,000	16	11,861,000	16,315,000	16	89,484,000	411,171,000	15
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	172,991,825	65,481,565	238,473,000	47,695,000	35,771,000	321,939,000	39	4,527,000	18	11,870,000	16,397,000	17	90,951,000	412,890,000	16
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	171,898,184	53,022,565	224,921,000	44,984,000	33,738,000	303,643,000	19	5,470,000	23	11,195,000	16,665,000	21	109,896,000	413,539,000	17
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	165,468,664	48,598,987	214,068,000	42,814,000	32,110,000	288,992,000	4	6,213,000	28	10,655,000	16,868,000	22	124,824,000	413,816,000	18
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	183,127,581	50,514,272	233,642,000	46,728,000	35,046,000	315,416,000	24	4,936,000	21	11,629,000	16,565,000	19	99,168,000	414,584,000	19
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	190,921,553	66,849,679	257,771,000	51,554,000	38,666,000	347,991,000	43	3,344,000	6	12,830,000	16,174,000	14	67,184,000	415,175,000	20
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	171,244,008	43,916,565	215,161,000	43,032,000	32,274,000	290,467,000	8	6,213,000	28	10,709,000	16,922,000	24	124,824,000	415,291,000	21
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 3 Hydro	Base Load	178,322,840	55,766,268	234,089,000	46,818,000	35,113,000	316,020,000	26	4,972,000	22	11,652,000	16,624,000	20	99,891,000	415,911,000	22
1	Baseline - Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	166,660,214	48,498,255	215,158,000	43,032,000	32,274,000	290,464,000	7	6,249,000	34	10,709,000	16,958,000	25	125,547,000	416,011,000	23
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Base Load	166,989,796	48,476,948	215,467,000	43,093,000	32,320,000	290,880,000	9	6,249,000	34	10,725,000	16,974,000	27	125,547,000	416,427,000	24
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	187,879,764	54,854,565	242,734,000	48,547,000	36,410,000	327,691,000	41	4,454,000	16	12,082,000	16,536,000	18	89,484,000	417,175,000	25
1	Baseline - Gould Reservoir Alignment, 2 PS's, 1 Hydro	Base Load	173,042,062	43,916,565	216,959,000	43,392,000	32,544,000	292,895,000	12	6,213,000	28	10,799,000	17,012,000	28	124,824,000	417,719,000	26
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Base Load	173,114,709	43,916,565	217,031,000	43,406,000	32,555,000	292,992,000	13	6,213,000	28	10,803,000	17,016,000	29	124,824,000	417,816,000	27
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	163,820,720	48,458,565	212,279,000	42,456,000	31,842,000	286,577,000	3	6,614,000	39	10,566,000	17,180,000	33	132,880,000	419,457,000	28
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	166,460,555	61,851,766	228,312,000	45,662,000	34,247,000	308,221,000	20	5,542,000	24	11,364,000	16,906,000	23	111,343,000	419,564,000	29
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	170,067,251	48,446,171	218,513,000	43,703,000	32,777,000	294,993,000	15	6,249,000	34	10,876,000	17,125,000	31	125,547,000	420,540,000	30
2	Baseline - Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	176,540,900	52,840,565	229,381,000	45,876,000	34,407,000	309,664,000	21	5,542,000	24	11,417,000	16,959,000	26	111,343,000	421,007,000	31
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	175,835,238	43,916,565	219,752,000	43,950,000	32,963,000	296,665,000	17	6,213,000	28	10,938,000	17,151,000	32	124,824,000	421,489,000	32
2	Baseline - Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	170,670,405	61,900,298	232,571,000	46,514,000	34,886,000	313,971,000	22	5,542,000	24	11,576,000	17,118,000	30	111,343,000	425,314,000	33
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	168,432,913	48,306,565	216,739,000	43,348,000	32,511,000	292,598,000	11	6,650,000	40	10,788,000	17,438,000	35	133,604,000	426,202,000	34
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Base Load	168,765,757	47,601,929	216,368,000	43,274,000	32,455,000	292,097,000	10	6,687,000	43	10,770,000	17,457,000	36	134,347,000	426,444,000	35
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	175,251,671	43,416,565	218,668,000	43,734,000	32,800,000	295,202,000	16	6,577,000	38	10,884,000	17,461,000	37	132,137,000	427,339,000	36
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Base Load	174,562,891	43,221,565	217,784,000	43,557,000	32,668,000	294,009,000	14	6,687,000	43	10,840,000	17,527,000	38	134,347,000	428,356,000	37
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	168,236,974	42,356,565	210,594,000	42,119,000	31,589,000	284,302,000	1	7,271,000	45	10,482,000	17,753,000	39	146,080,000	430,382,000	38
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	164,733,959	46,074,766	210,809,000	42,162,000	31,621,000	284,592,000	2	7,308,000	47	10,493,000	17,801,000	41	146,823,000	431,415,000	39
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	179,883,149	43,309,565	223,193,000	44,639,000	33,479,000	301,311,000	18	6,650,000	40	11,109,000	17,759,000	40	133,604,000	434,915,000	40
2	Baseline - Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	172,592,536	42,356,565	214,949,000	42,990,000	32,242,000	290,181,000	6	7,271,000	45	10,699,000	17,970,000	42	146,080,000	436,261,000	41
2	Baseline - Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	168,810,660	46,123,298	214,934,000	42,987,000	32,240,000	290,161,000	5	7,308,000	47	10,698,000	18,006,000	43	146,823,000	436,984,000	42
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	192,878,970	64,981,565	257,861,000	51,572,000	38,679,000	348,112,000	44	4,527,000	18	12,835,000	17,362,000	34	90,951,000	439,063,000	43
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	193,977,121	43,416,565	237,394,000	47,479,000	35,609,000	320,482,000	36	6,213,000	28	11,816,000	18,029,000	44	124,824,000	445,306,000	44
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	189,140,847	47,865,679	237,007,000	47,401,000	35,551,000	319,959,000	35	6,249,000	34	11,797,000	18,046,000	45	125,547,000	445,506,000	45
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	188,138,281	47,806,565	235,945,000	47,189,000	35,392,000	318,526,000	32	6,650,000	40	11,744,000	18,394,000	47	133,604,000	452,130,000	46
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	237,315,153	55,732,565	293,048,000	58,610,000	43,957,000	395,615,000	48	3,583,000	13	14,586,000	18,169,000	46	71,985,000	467,600,000	47
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	224,731,506	43,693,565	268,425,000	53,685,000	40,264,000	362,374,000	47	5,993,000	27	13,361,000	19,354,000	48	120,404,000	482,778,000	48

Table 2
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Overall Alignment Comparison. Baseline and Peaking Hydropower Powerhouse Included.

			Capital Costs							Annualized Costs					Present Worth		
ID	Alignment Description		Pipeline	Other (Pump Stations, Reservoirs, Pressure Reducing Facilities, and Hydropower Powerhouses)	Subtotal	Contingency	Engineering & Administration	**Total Capital Costs**	Rank Based on Capital Costs	Year 1 Annual Costs	Rank Based on Year 1 Annual Costs	Total Annualized Capital Costs	**Net Annualized Costs**	Rank Based on Net Annual Costs	Present Worth of Year 1 Annual Costs	**Net Present Worth**	Rank Based on Net Present Worth
1	Baseline - Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	166,660,214	48,498,255	215,158,000	43,032,000	32,274,000	290,464,000	7	6,249,000	34	10,709,000	16,958,000	25	125,547,000	416,011,000	23
1	Baseline - Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	168,807,814	67,276,255	236,084,000	47,217,000	35,413,000	318,714,000	33	3,417,000	12	11,751,000	15,168,000	9	68,650,000	387,364,000	9
1	Baseline - Gould Reservoir Alignment, 2 PS's, 1 Hydro	Base Load	173,042,062	43,916,565	216,959,000	43,392,000	32,544,000	292,895,000	12	6,213,000	28	10,799,000	17,012,000	28	124,824,000	417,719,000	26
1	Baseline - Gould Reservoir Alignment, 2 PS's, 1 Hydro	Peaking	178,714,172	56,584,565	235,299,000	47,060,000	35,295,000	317,654,000	30	3,367,000	10	11,712,000	15,079,000	6	67,646,000	385,300,000	6
2	Baseline - Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	168,810,660	46,123,298	214,934,000	42,987,000	32,240,000	290,161,000	5	7,308,000	47	10,698,000	18,006,000	43	146,823,000	436,984,000	42
2	Baseline - Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	170,670,405	61,900,298	232,571,000	46,514,000	34,886,000	313,971,000	22	5,542,000	24	11,576,000	17,118,000	30	111,343,000	425,314,000	33
2	Baseline - Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	172,592,536	42,356,565	214,949,000	42,990,000	32,242,000	290,181,000	6	7,271,000	45	10,699,000	17,970,000	42	146,080,000	436,261,000	41
2	Baseline - Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	176,540,900	52,840,565	229,381,000	45,876,000	34,407,000	309,664,000	21	5,542,000	24	11,417,000	16,959,000	26	111,343,000	421,007,000	31
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Base Load	166,989,796	48,476,948	215,467,000	43,093,000	32,320,000	290,880,000	9	6,249,000	34	10,725,000	16,974,000	27	125,547,000	416,427,000	24
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 2 Hydro	Peaking	168,965,913	67,460,948	236,427,000	47,285,000	35,464,000	319,176,000	34	3,366,000	9	11,768,000	15,134,000	8	67,626,000	386,802,000	7
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Base Load	173,114,709	43,916,565	217,031,000	43,406,000	32,555,000	292,992,000	13	6,213,000	28	10,803,000	17,016,000	29	124,824,000	417,816,000	27
3	Baseline - Gould Spring- Grass Valley Alignment, 2 PS's, 1 Hydro	Peaking	178,473,438	56,584,565	235,058,000	47,012,000	35,259,000	317,329,000	29	3,367,000	10	11,700,000	15,067,000	5	67,646,000	384,975,000	5
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Base Load	164,733,959	46,074,766	210,809,000	42,162,000	31,621,000	284,592,000	2	7,308,000	47	10,493,000	17,801,000	41	146,823,000	431,415,000	39
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 2 Hydro	Peaking	166,460,555	61,851,766	228,312,000	45,662,000	34,247,000	308,221,000	20	5,542,000	24	11,364,000	16,906,000	23	111,343,000	419,564,000	29
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Base Load	168,236,974	42,356,565	210,594,000	42,119,000	31,589,000	284,302,000	1	7,271,000	45	10,482,000	17,753,000	39	146,080,000	430,382,000	38
4	Baseline - Gould Spring- Willow Spring Alignment, 2 PS's, 1 Hydro	Peaking	171,898,184	53,022,565	224,921,000	44,984,000	33,738,000	303,643,000	19	5,470,000	23	11,195,000	16,665,000	21	109,896,000	413,539,000	17
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Base Load	168,765,757	47,601,929	216,368,000	43,274,000	32,455,000	292,097,000	10	6,687,000	43	10,770,000	17,457,000	36	134,347,000	426,444,000	35
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 2 Hydro	Peaking	170,733,913	64,790,929	235,525,000	47,105,000	35,329,000	317,959,000	31	4,383,000	15	11,723,000	16,106,000	13	88,058,000	406,017,000	12
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Base Load	174,562,891	43,221,565	217,784,000	43,557,000	32,668,000	294,009,000	14	6,687,000	43	10,840,000	17,527,000	38	134,347,000	428,356,000	37
5	Baseline - Gould Spring- Mollies Nipple, 2 PS's, 1 Hydro	Peaking	179,278,304	55,083,565	234,362,000	46,872,000	35,154,000	316,388,000	27	4,309,000	14	11,665,000	15,974,000	12	86,571,000	402,959,000	11
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	170,067,251	48,446,171	218,513,000	43,703,000	32,777,000	294,993,000	15	6,249,000	34	10,876,000	17,125,000	31	125,547,000	420,540,000	30
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	172,068,781	67,430,171	239,499,000	47,900,000	35,925,000	323,324,000	40	3,344,000	6	11,921,000	15,265,000	10	67,184,000	390,508,000	10
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	175,835,238	43,916,565	219,752,000	43,950,000	32,963,000	296,665,000	17	6,213,000	28	10,938,000	17,151,000	32	124,824,000	421,489,000	32
6	Baseline - Colorado City - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	181,022,260	56,584,565	237,607,000	47,521,000	35,641,000	320,769,000	37	3,293,000	3	11,827,000	15,120,000	7	66,159,000	386,928,000	8
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	168,432,913	48,306,565	216,739,000	43,348,000	32,511,000	292,598,000	11	6,650,000	40	10,788,000	17,438,000	35	133,604,000	426,202,000	34
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	172,991,825	65,481,565	238,473,000	47,695,000	35,771,000	321,939,000	39	4,527,000	18	11,870,000	16,397,000	17	90,951,000	412,890,000	16
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	179,883,149	43,309,565	223,193,000	44,639,000	33,479,000	301,311,000	18	6,650,000	40	11,109,000	17,759,000	40	133,604,000	434,915,000	40
7	Baseline - Colorado City - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	187,879,764	54,854,565	242,734,000	48,547,000	36,410,000	327,691,000	41	4,454,000	16	12,082,000	16,536,000	18	89,484,000	417,175,000	25
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	189,140,847	47,865,679	237,007,000	47,401,000	35,551,000	319,959,000	35	6,249,000	34	11,797,000	18,046,000	45	125,547,000	445,506,000	45
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	190,921,553	66,849,679	257,771,000	51,554,000	38,666,000	347,991,000	43	3,344,000	6	12,830,000	16,174,000	14	67,184,000	415,175,000	20
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	193,977,121	43,416,565	237,394,000	47,479,000	35,609,000	320,482,000	36	6,213,000	28	11,816,000	18,029,000	44	124,824,000	445,306,000	44
8	Baseline - Pipe Springs - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	198,428,759	56,084,565	254,513,000	50,903,000	38,177,000	343,593,000	42	3,293,000	3	12,668,000	15,961,000	11	66,159,000	409,752,000	14
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	188,138,281	47,806,565	235,945,000	47,189,000	35,392,000	318,526,000	32	6,650,000	40	11,744,000	18,394,000	47	133,604,000	452,130,000	46
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	192,878,970	64,981,565	257,861,000	51,572,000	38,679,000	348,112,000	44	4,527,000	18	12,835,000	17,362,000	34	90,951,000	439,063,000	43
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	224,731,506	43,693,565	268,425,000	53,685,000	40,264,000	362,374,000	47	5,993,000	27	13,361,000	19,354,000	48	120,404,000	482,778,000	48
9	Baseline - Pipe Springs - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	237,315,153	55,732,565	293,048,000	58,610,000	43,957,000	395,615,000	48	3,583,000	13	14,586,000	18,169,000	46	71,985,000	467,600,000	47
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Base Load	163,820,720	48,458,565	212,279,000	42,456,000	31,842,000	286,577,000	3	6,614,000	39	10,566,000	17,180,000	33	132,880,000	419,457,000	28
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 2 Hydro	Peaking	168,562,197	65,481,565	234,044,000	46,809,000	35,107,000	315,960,000	25	4,527,000	18	11,649,000	16,176,000	15	90,951,000	406,911,000	13
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Base Load	175,251,671	43,416,565	218,668,000	43,734,000	32,800,000	295,202,000	16	6,577,000	38	10,884,000	17,461,000	37	132,137,000	427,339,000	36
10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, 1 Hydro	Peaking	183,432,585	54,854,565	238,287,000	47,657,000	35,743,000	321,687,000	38	4,454,000	16	11,861,000	16,315,000	16	89,484,000	411,171,000	15
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Base Load	165,468,664	48,598,987	214,068,000	42,814,000	32,110,000	288,992,000	4	6,213,000	28	10,655,000	16,868,000	22	124,824,000	413,816,000	18
11	South Kaibab - West Little Creek Alignment, 2 PS's, 2 Hydro	Peaking	167,473,045	67,428,987	234,902,000	46,980,000	35,235,000	317,117,000	28	3,344,000	6	11,692,000	15,036,000	4	67,184,000	384,301,000	4
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Base Load	171,244,008	43,916,565	215,161,000	43,032,000	32,274,000	290,467,000	8	6,213,000	28	10,709,000	16,922,000	24	124,824,000	415,291,000	21
11	South Kaibab - West Little Creek Alignment, 2 PS's, 1 Hydro	Peaking	176,437,943	56,584,565	233,023,000	46,605,000	34,953,000	314,581,000	23	3,293,000	3	11,599,000	14,892,000	3	66,159,000	380,740,000	3
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 3 Hydro	Base Load	178,322,840	55,766,268	234,089,000	46,818,000	35,113,000	316,020,000	26	4,972,000	22	11,652,000	16,624,000	20	99,891,000	415,911,000	22
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 3 Hydro	Peaking	184,257,368	84,052,268	268,310,000	53,662,000	40,247,000	362,219,000	46	827,000	2	13,355,000	14,182,000	2	16,615,000	378,834,000	2
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 2 Hydro	Base Load	183,127,581	50,514,272	233,642,000	46,728,000	35,046,000	315,416,000	24	4,936,000	21	11,629,000	16,565,000	19	99,168,000	414,584,000	19
12	Baseline - Little Creek Mtn. Gould Reservoir Alignment, 2 PS's, 2 Hydro	Peaking	189,599,565	72,567,272	262,167,000	52,433,000	39,325,000	353,925,000	45	755,000	1	13,049,000	13,804,000	1	15,169,000	369,094,000	1

Note: All alignments begin and end at the same points

Table 3

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Miscellaneous Variables

Variable	Units	Value	Comments
Financial			
Interest Rate	%	3.90%	
Loan Term	yrs	40	
Contingency	%	20%	
Engineering & Administration	%	15%	
Hydropower Facilities			
Energy Value	$/kwh	0.06	For Peak Hydropower
Energy Value	$/kwh	0.03	For Base Load Hydropower
Power Transmission Costs	$/mi	125,000	
Pump Stations			
Pump Efficiency	%	90%	
Average Energy Cost	$/kwh	0.0365	For Pumping Cost
Operation & Maintenance	%	2%	Multiply by Capital Cost
Reservoir			
Capital Cost	$/af	4600	
Reservoir Volume	AF	192	Based on 24 hours of storage.
Pipeline			
Mannings "n"		0.011	

Table 4
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost
Lone Rock Pump Station

Site Work	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
24 Ft. dia. vertical shaft	190	FT	$ 4,600	$ 874,000
84" Lined tunnel	375	FT	$ 2,400	$ 900,000
24 Ft. wide gravel road	8500	FT	$ 29	$ 246,500
Excavation	40000	CY	$ 12	$ 480,000
Backfill	10000	CY	$ 2	$ 20,000
Switch yard berm	25000	CY	$ 6	$ 150,000
Switch yard fence	500	FT	$ 92	$ 46,000
			Total	**$ 2,716,500**

Concrete				
Reinforced concrete *	2470	CY	$ 450	$ 1,111,500
Waterstops	1	LS	$ 10,000	$ 10,000
Hollow core precast concrete deck *	8500	SQFT	$ 6	$ 52,275
Camouflage concrete	300	CY	$ 500	$ 150,000
			Total	**$ 1,323,775**

Metals				
16" Dia steel pipe *	130	FT	$ 38	$ 4,940
30" Dia steel pipe	35	FT	$ 158	$ 5,530
Pipe manifold & piping specials *	1	LS	$ 630,000	$ 630,000
Stainless steel liner for sleeve valve	1	LS	$ 110,000	$ 110,000
Misc. Metalwork	1	LS	$ 20,000	$ 20,000
Structural steel W 12 x 87	272	FT	$ 48	$ 13,056
Structural steel W 12 x 54	370	FT	$ 70	$ 25,900
Floor grating - medium duty	5000	SQFT	$ 16	$ 80,000
5 Ft. dia screens	4	EACH	$ 20,000	$ 80,000
Screen assembly	1	LS	$ 20,000	$ 20,000
Paint - primer & finish coats - metal	50	GAL	$ 45	$ 2,250
Steel doors	6	EACH	$ 302	$ 1,812
			Total	**$ 993,488**

Mechanical				
560 psi, 5500 gpm pumps *	10	EACH	$ 150,000	$ 1,500,000
Variable head, 6200 gpm pumps *	8	EACH	$ 77,000	$ 616,000
Low head check valves	8	EACH	$ 2,000	$ 16,000
Sluice gate	7	EACH	$ 3,000	$ 21,000
Rotary pump control valves	10	EACH	$ 40,000	$ 400,000
Flow meters	1	LS	$ 149,000	$ 149,000
16", 500 psi cone valves	10	EACH	$ 37,000	$ 370,000
30", 500 psi cone valve	5	EACH	$ 95,000	$ 475,000
30", 500 psi sleeve valve	1	EACH	$ 215,000	$ 215,000
Surge suppression system	1	LS	$ 800,000	$ 800,000
Model study for circular sump	1	LS	$ 100,000	$ 100,000
HVAC	7700	SQFT	$ 5	$ 37,114
			Total	**$ 4,699,114**

Table 4
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Electrical						
Overhead powerline	5.2	MILE	$	125,000	$	650,000
Buried powerline	2.6	MILE	$	1,000,000	$	2,600,000
Switching stations	2	EACH	$	600,000	$	1,200,000
Lighting & misc. electrical	7700	SQFT	$	6	$	48,125
230-KV Power circuit breaker	1	EACH	$	300,000	$	300,000
230:4.16 KV Transformer: 25 MVA - 3 phase	1	EACH	$	600,000	$	600,000
5 KV Metal-Clad switch gear line up	1	LS	$	337,000	$	337,000
480 VAC Dist panel with 400 A bus	1	EACH	$	6,900	$	6,900
4.16 KV:480, 350 KVA - 3 phase transformer	1	EACH	$	32,000	$	32,000
Motor control for 2000 HP motor	9	EACH	$	27,000	$	243,000
480 VAC Variable speed drives for 300 HP pumps	8	EACH	$	45,000	$	360,000
5 KV Metal-Clad switch gear line up - inside	1	LS	$	310,000	$	310,000
480 VAC Dist. Panel with 400A Bus - inside *	1	EACH	$	8,000	$	8,000
480 VAC Variable frequency drive *	8	EACH	$	80,000	$	640,000
350 HP Motors *	8	EACH	$	32,000	$	256,000
2250 HP Motors *	10	EACH	$	150,000	$	1,500,000
			Total		**$**	**9,091,025**
Subtotal					**$**	**18,823,902**
Mobilization	5%				$	941,195
Total					**$**	**19,765,097**

* item size or quantity changed to upgrade capacity from 70,000 AF/Yr to 80,000 AF/Yr

Table 5
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Cockscomb Pump Station

Site Work	**Quantity**	**Unit**	**Unit Cost**	**Total Cost**
Excavation	10300	CY	$ 12	$ 123,600
Backfill	5400	CY	$ 2	$ 10,800
Fencing	720	FT	$ 92	$ 66,240
25 ft wide gravel access drive	5000	FT	$ 29	$ 145,000
			Total	**$ 345,640**
Concrete				
Wet well, foundation and floor slab	1500	CY	$ 460	$ 690,000
Surge tank vault	200	CY	$ 460	$ 92,000
			Total	**$ 782,000**
Building Components				
Prefabricated building	7280	SQFT	$ 100	$ 728,000
Skylights	10	EACH	$ 4,000	$ 40,000
Grating	1810	SQFT	$ 16	$ 28,960
			Total	**$ 796,960**
Mechanical				
Vertical turbine pumps	10	EACH	$ 150,000	$ 1,500,000
Exposed piping in the building				
16" Steel piping	200	FT	$ 58	$ 11,600
30" Steel piping	50	FT	$ 128	$ 6,400
60" Steel piping	80	FT	$ 415	$ 33,200
Pipe specials	1	ALL	$ 300,000	$ 300,000
Buried 60" steel piping	80	FT	$ 790	$ 63,200
30" Cone Valves	5	EACH	$ 95,000	$ 475,000
30" Sleeve valve (stainless steel lined)	1	EACH	$ 325,000	$ 325,000
16" Cone Valves	10	EACH	$ 37,000	$ 370,000
16" Pump Control Valve	10	EACH	$ 40,000	$ 400,000
Flow meter	1	EACH	$ 30,000	$ 30,000
Surge tanks and control system	1	EACH	$ 1,150,000	$ 1,150,000
HVAC	7300	SQFT	$ 5	$ 36,500
			Total	**$ 4,700,900**
Electrical				
Overhead Power (138 kV)	3	MILES	$ 125,000	$ 375,000
Switching stations	2	EACH	$ 600,000	$ 1,200,000
Lighting & misc. electrical	7300	SQFT	$ 6	$ 45,625
138-KV Power circuit breaker	1	EACH	$ 300,000	$ 300,000
138:4.16 KV Transformer: 25 MVA - 3 phase	1	EACH	$ 600,000	$ 600,000
5 KV Metal-Clad switch gear line up	1	LS	$ 337,000	$ 337,000
4.16 KV:480, 350 KVA - 3 phase transformer	1	EACH	$ 32,000	$ 32,000
Motor control for 2000 HP motor	9	EACH	$ 27,000	$ 243,000
480 VAC Dist. Panel with 400A Bus - inside	1	EACH	$ 6,900	$ 6,900
2250 HP Motors	10	EACH	$ 150,000	$ 1,500,000
			Total	**$ 4,639,525**
Subtotal				**$ 11,265,025**
Mobilization	5%			$ 563,251
Total				**$ 11,828,276**

Table 6

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Cockscomb Tunnel, Shaft, and Pipeline Costs

		Alignment Information (See Note 11)							$$$	$$$		$$$	Tunnel and Shaft Information						$$$	$$$			$$$	$$$	$$$	$$$	$$$	
		Beg. Sta	Beg. Elev.	Ending Sta.	Ending Elev.	Length	Length	Road Cut Length	Cost for Road Const.	Cost for Traffic Control	Rock Saw Length	Cost of Rock Saw	Beg. Sta	Beg. Elev.	Ending Sta.	Ending Elev.	Slope	Tunnel Length	Tunnel Cost	Tunnel Pipe Cost	Shaft	Shaft Depth	Shaft Cost	Shaft Pipe Cost	Portal Dev.	Other Pipe Cost	Total Cost	Notes
ID	Description	(ft)	(ft)	(ft)	(ft)	(ft)	(mi)	(lf)	($/lf)	($/ls)	(lf)	($/lf)	(ft)	(ft)	(ft)	(ft)	(%)	(lf)	($/lf)	($/ft)	(Y/N)	(vf)	($/vf)	($/ft)	($)	($/ft)	($)	
A	Highway 89	1361+10	4504	1526+94	4598	16584	3.14	7200	70	128,400	5400	75	1383+16	4538												8,018,000	9,060,000	5,6,7,9,10
B	Tunnel & Shaft through West Portal Site 1	1361+10	4504	1485+87	4598	12477	2.36						1383+16	4538	1420+00	4975	2.0	3684	1300	519	Y	363	700	445	50000	2,975,000	10,140,000	1,4,5,8
	Tunnel & Shaft through West Portal Site 1																		900	446					50000		8,400,000	3,4,5,8
B	Tunnel through West Portal Site 1	1361+10	4504	1485+87	4598	12477	2.36						1383+16	4538	1420+00	4975	11.9	3684	1755	519	N	0	0	0	100000	2,975,000	11,450,000	2,5,8
	Tunnel through West Portal Site 1																		900	446					100000		8,030,000	3,5,8
B	Tunnel & Shaft through West Portal Site 2	1361+10	4504	1485+87	4598	12477	2.36						1383+16	4538	1430+29	4820	2.0	4713	1300	519	Y	188	700	445	50000	2,635,000	11,470,000	1,4,5,8
	Tunnel & Shaft through West Portal Site 2																		900	464					50000		9,330,000	3,4,5,8
B	Tunnel through West Portal Site 2	1361+10	4504	1485+87	4598	12477	2.36						1383+16	4538	1430+29	4820	6.0	4713	1755	519	N	0	0	0	100000	2,635,000	13,450,000	2,5,8
	Tunnel through West Portal Site 2																		900	464					100000		9,160,000	3,5,8
C	Tunnel & Shaft through West Portal Site 3	1361+10	4504	1468+62	4598	10752	2.04						1387+23	4546	1434+63	4893	2.0	4740	1300	519	Y	252	700	445	50000	1,675,000	10,640,000	1,4,5,8
	Tunnel & Shaft through West Portal Site 3																		900	464					50000		8,480,000	3,4,5,8
C	Tunnel through West Portal Site 3	1361+10	4504	1468+62	4598	10752	2.04						1387+23	4546	1434+63	4893	7.3	4740	1755	519	N	0	0	0	100000	1,675,000	12,550,000	2,5,8
	Tunnel through West Portal Site 3																		900	464					100000		8,240,000	3,5,8
C-1	Tunnel & Shaft through West Portal Site 4	1361+10	4504	1464+05	4598	10295	1.95						1388+86	4549	1438+72	4932	2.0	4986	1300	519	Y	283	700	445	50000	1,244,000	10,690,000	1,4,5,8
	Tunnel & Shaft through West Portal Site 4																		900	446					50000		8,330,000	3,4,5,8
C-1	Tunnel through West Portal Site 4	1361+10	4504	1464+05	4598	10295	1.95						1388+86	4549	1438+72	4932	7.7	4986	1755	519	N	0	0	0	100000	1,244,000	12,680,000	2,5,8
	Tunnel through West Portal Site 4																		900	446					100000		8,060,000	3,5,8

Lowest Total Cost: 8,030,000

Next Lowest Total Cost: 8,060,000

Notes:
1. Normal grade (2%) machine tunneling = $1,300/lf per Haley & Aldrich Report.
2. Steep grade (6-8%) machine tunneling = $1,755/lf per Haley & Aldrich Report.
3. Drill and blast tunneling = $900/lf per Haley & Aldrich Report.
4. Vertical Raise Bore = $700/vf per Haley & Aldrich Report.
5. Pipe Cost based on Pump Station located at 1370+00, a lift of 1310 ft, mannings "n" of 0.0110, 60" dia. Pipe, and average pipe cost within applicable pipe type ranges.
6. Road cut costs assumes a 12' wide patch with 8" of conc. ($3/sf), 12" base material and 6" of asph. ($2.50/sf), plus 30% remote factor.
7. Traffic control costs assumes 60 days with 2 arrow boards ($350/day), 2 signals ($750/day), 8 signs ($40/day), 200' of temporary conc. barricades ($1000/day).
8. Portal development = $50,000 for each side or $100,000 per tunnel/shaft options per Haley & Aldrich Report.
9. Rock saw or rock trenching machine to cut a 11' deep and 7' wide trench for a 60" diameter pipe. A 30" rock saw ($25/lf) takes three passes to create the 7' wide trench.
10. Assume the pipeline follows the bedrock on either side of the road and a rock saw or blasting would be required for 75% of the road cut in the canyon.
11. All alignments begin and end at common points

Variable	Units	Value	Comments
Flow Rate	AF/Yr	80000	
Pipe Size	in	60	
Flow Rate	cfs	111	
Design Velocity	fps	5.6	
Mannings "n"		0.011	
Hydraulic Grade Slope	%	0.1288	
Hydraulic Grade Elev.	ft	4644	Before Pump Station
Station	ft	1370+00	At Pump Station
Surface Elev.	ft	4510	At Pump Station
Pump Head	ft	1310	At Pump Station

Table 7
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Hurricane Cliffs Tunnel, Shaft, and Pipeline Costs

			Pipeline Information							Tunnel and Shaft Information													
															$$$	$$$			$$$	$$$	$$$	$$$	
		Hydropower Type	Penstock Size	Velocity	HGL Slope	Ground Elevation	HGL Elevation	Flow Rate	Beg. Sta	Beg. Elev.	Ending Sta.	Ending Elev.	Slope	Tunnel Length	Tunnel Cost	Tunnel Pipe Cost	Shaft	Shaft Depth	Shaft Cost	Shaft Pipe Cost	Portal Dev.	Total Cost	Notes
ID	Description		(in)	(fps)	(%)	(ft)	(ft)	(cfs)	(ft)	(ft)	(ft)	(ft)	(%)	(lf)	($/lf)	($/lf)	(Y/N)	(vf)	($/vf)	($/vf)	($)	($)	
HC-1	Willow Spring Alignment	Base Load	60	5	0.09860038	3380	4137	97	6195+00	4139	6211+50	3380	2.0	1650	1300	303	Y	726	700	243.5	300000	3,630,000	1,3,4,5
		Peak	75	9	0.26994027	3380	4133	290								431				338		3,910,000	2,3,4,5
HC-2	Mollies Nipple #1 Alignment	Base Load	60	5	0.09860038	3432	4420	97	6230+71	4423	6249+37	3432	2.0	1866	1300	372	Y	954	700	278	300000	4,350,000	1,3,4,5
		Peak	75	9	0.26994027	3432	4415	290								538				391.5		4,770,000	2,3,4,5
HC-3	Mollies Nipple #2 Alignment	Base Load	60	5	0.09860038	3431	4456	97	6217+42	4459	6239+02	3431	2.0	2160	1300	372	Y	985	700	278	300000	4,870,000	1,3,4,5
		Peak	75	9	0.26994027	3431	4451	290								538				391.5		5,340,000	2,3,4,5
HC-4	Mollies Nipple #3 Alignment	Base Load	60	5	0.09860038	3452	4454	97	6212+05	4457	6231+76	3452	2.0	1971	1300	372	Y	966	700	278	300000	4,540,000	1,3,4,5
		Peak	75	9	0.26994027	3452	4449	290								538				391.5		4,980,000	2,3,4,5
HC-5	Gould Spring Alignment	Base Load	60	5	0.09860038	3566	4712	97	6204+00	4715	6223+01	3566	2.0	1901	1300	408	Y	1111	700	296	300000	4,650,000	1,3,4,5
		Peak	75	9	0.26994027	3566	4707	290								594				419.5		5,140,000	2,3,4,5
HC-6	Gould Reservoir Alignment	Base Load	60	5	0.09860038	3560	4715	97	6221+29	4718	6243+32	3560	2.0	2203	1300	445	Y	1114	700	314.5	300000	5,270,000	1,3,4,5
		Peak	75	9	0.26994027	3560	4709	290								650				447.5		5,870,000	2,3,4,5

Notes:

1. Normal grade (2%) machine tunneling = $1,300/lf per Haley & Aldrich Report.
2. Drill and blast tunneling = $900/lf per Haley & Aldrich Report.
3. Vertical Raise Bore = $700/vf per Haley & Aldrich Report.
4. Portal development = $300,000 per tunnel per Haley & Aldrich Report.
5. All alignments do not begin and end at similar points.

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70000	
Mannings "n"		0.011	
75" Penstock			Base Load Hydropower Plants
Flow Rate	AFY	70000	
Pipe Size	in	**75**	
Flow Rate	cfs	290	
Design Velocity	fps	9.5	
60" Penstock			Peak Load Hydropower Plants
Flow Rate	AFY	70000	
Pipe Size	in	**60**	
Flow Rate	cfs	97	
Design Velocity	fps	4.9	

Table 8
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

60" Pipe Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	80000	
Pipe Size	in	**60**	
Flow Rate	cfs	111	
Design Velocity	fps	5.6	
Design Stress	psi	21000	Upper limit for cement mortar lining
Mortar Lining Thk.	in	0.50	
Cost of Steel	$/lb	0.18	
Unit Weight of Steel	lbm/ft^3	490	
Lining and Coating	$/sf	1.30	Cement Mortar Lined and Coated
Minimum D/t ratio		240	Upper limit for cement mortar coated pipelines

Conceptual Level Pipe Cost								
Pressure Class	Steel Thickness	Steel	Fabrication	Lining and Coating	Shipping	Installation	Total	Type
psi	in	$/lf	$/lf	$/lf	$/lf	$/lf	$/lf	
50	0.25	30.22	72.54	20.76	16.00	44.00	**183.52**	Rubber Gasket Joints
100	0.25	30.22	72.54	20.76	16.00	44.00	**183.52**	
150	0.25	30.22	72.54	20.76	16.00	44.00	**183.52**	
200	0.29	34.54	82.90	20.76	16.00	44.00	**198.20**	
250	0.36	43.18	103.62	20.76	16.00	52.43	**235.99**	Welded Lap Joints
300	0.44	51.81	124.35	20.76	16.00	56.14	**269.05**	
350	0.51	60.45	145.07	20.76	16.00	60.52	**302.79**	
400	0.58	69.08	165.79	20.76	16.00	65.57	**337.21**	
450	0.65	77.72	186.52	20.76	16.00	71.30	**372.30**	
500	0.73	86.35	207.24	20.76	16.00	77.71	**408.06**	
550	0.80	94.99	227.97	20.76	16.00	84.79	**444.50**	
600	0.87	103.62	248.69	20.76	16.00	92.54	**481.61**	
650	0.94	112.26	269.42	20.76	16.00	100.97	**519.40**	
700	1.02	120.89	290.14	20.76	16.00	110.07	**557.86**	
750	1.09	129.53	310.87	20.76	16.00	119.84	**597.00**	
800	1.16	138.16	331.59	20.76	16.00	130.29	**636.81**	
850	1.23	146.80	352.31	20.76	16.00	141.42	**677.29**	
900	1.31	155.43	621.73	20.76	16.00	153.22	**967.14**	Fabricated Steel Cans
950	1.38	164.07	656.27	20.76	16.00	165.69	**1022.79**	
1000	1.45	172.70	690.81	20.76	16.00	178.83	**1079.11**	
1050	1.53	181.34	725.35	20.76	16.00	192.65	**1136.10**	
1100	1.60	189.97	759.89	20.76	16.00	207.15	**1193.78**	

Table 9

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

75" Pipe Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70000	
Pipe Size	in	**75**	
Flow Rate	cfs	97	
Design Velocity	fps	3.2	
Design Stress	psi	21000	Upper limit for cement mortar lining
Mortar Lining Thk.	in	0.50	
Cost of Steel	$/lb	0.18	
Unit Weight of Steel	lbm/ft^3	490	
Lining and Coating	$/sf	1.30	Cement Mortar Lined and Coated
Minimum D/t ratio		240	Upper limit for cement mortar coated pipelines

Conceptual Level Pipe Cost								
Pressure Class	Steel Thickness	Steel	Fabrication	Lining and Coating	Shipping	Installation	Total	Type
psi	in	$/lf	$/lf	$/lf	$/lf	$/lf	$/lf	
50	0.32	46.91	112.59	25.87	16.00	44.00	**245.37**	Rubber Gasket Joints
100	0.32	46.91	112.59	25.87	16.00	44.00	**245.37**	
150	0.32	46.91	112.59	25.87	16.00	44.00	**245.37**	
200	0.36	53.62	128.68	25.87	16.00	52.37	**276.53**	Welded Lap Joints
250	0.45	67.02	160.85	25.87	16.00	57.08	**326.82**	
300	0.54	80.42	193.02	25.87	16.00	62.84	**378.15**	
350	0.63	93.83	225.19	25.87	16.00	69.64	**430.52**	
400	0.72	107.23	257.36	25.87	16.00	77.49	**483.94**	
450	0.81	120.64	289.53	25.87	16.00	86.38	**538.41**	
500	0.90	134.04	321.70	25.87	16.00	96.32	**593.93**	
550	1.00	147.44	353.87	25.87	16.00	107.31	**650.49**	
600	1.09	160.85	386.04	25.87	16.00	119.35	**708.10**	
650	1.18	174.25	418.21	25.87	16.00	132.43	**766.75**	
700	1.27	187.66	450.38	25.87	16.00	146.56	**826.46**	Fabricated Steel Cans
750	1.36	201.06	482.55	25.87	16.00	161.73	**887.20**	
800	1.45	214.47	514.72	25.87	16.00	177.95	**949.00**	
850	1.54	227.87	546.89	25.87	16.00	195.22	**1011.84**	
900	1.63	241.27	965.09	25.87	16.00	213.53	**1461.76**	
950	1.72	254.68	1018.71	25.87	16.00	232.89	**1548.15**	
1000	1.81	268.08	1072.33	25.87	16.00	253.30	**1635.57**	
1050	1.90	281.49	1125.94	25.87	16.00	274.75	**1724.05**	
1100	1.99	294.89	1179.56	25.87	16.00	297.25	**1813.57**	

Table 10

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Base Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	96.7	
Energy Value	$/kwh	0.03	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Base Load Hydropower Costs

Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
300	3000	2238	2.2	18,477,000	**4,270,000**	**7,000**	**554,000**
320	3200	2387	2.4	19,707,000	**4,477,000**	**7,000**	**591,000**
340	3400	2536	2.5	20,937,000	**4,539,000**	**8,000**	**628,000**
360	3600	2686	2.7	22,176,000	**4,747,000**	**8,000**	**665,000**
380	3800	2835	2.8	23,406,000	**4,805,000**	**9,000**	**702,000**
400	4000	2984	3.0	24,636,000	**5,000,000**	**9,000**	**739,000**
420	4200	3133	3.1	25,866,000	**5,054,000**	**9,000**	**776,000**
440	4400	3282	3.3	27,096,000	**5,238,000**	**10,000**	**813,000**
460	4600	3432	3.4	28,335,000	**5,288,000**	**10,000**	**850,000**
480	4800	3581	3.6	29,565,000	**5,462,000**	**11,000**	**887,000**
500	5000	3730	3.7	30,795,000	**5,509,000**	**11,000**	**924,000**
520	5200	3879	3.9	32,025,000	**5,663,000**	**12,000**	**961,000**
540	5400	4028	4.0	33,255,000	**5,708,000**	**12,000**	**998,000**
560	5600	4178	4.2	34,494,000	**5,867,000**	**13,000**	**1,035,000**
580	5800	4327	4.3	35,724,000	**5,909,000**	**13,000**	**1,072,000**
600	6000	4476	4.5	36,954,000	**6,061,000**	**14,000**	**1,109,000**
620	6200	4625	4.6	38,184,000	**6,101,000**	**14,000**	**1,146,000**
640	6400	4774	4.8	39,414,000	**6,248,000**	**15,000**	**1,182,000**
660	6600	4924	4.9	40,653,000	**6,286,000**	**15,000**	**1,220,000**
680	6800	5073	5.1	41,883,000	**6,427,000**	**16,000**	**1,256,000**
700	7000	5222	5.2	43,113,000	**6,463,000**	**16,000**	**1,293,000**
720	7200	5371	5.4	44,343,000	**6,589,000**	**16,000**	**1,330,000**
740	7400	5520	5.5	45,573,000	**6,624,000**	**17,000**	**1,367,000**
760	7600	5670	5.7	46,812,000	**6,755,000**	**17,000**	**1,404,000**
780	7800	5819	5.8	48,042,000	**6,789,000**	**18,000**	**1,441,000**
800	8000	5968	6.0	49,272,000	**6,916,000**	**18,000**	**1,478,000**
820	8200	6117	6.1	50,502,000	**6,949,000**	**19,000**	**1,515,000**
840	8400	6266	6.3	51,732,000	**7,072,000**	**19,000**	**1,552,000**
860	8600	6416	6.4	52,970,000	**7,103,000**	**19,000**	**1,589,000**

Table 10

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Base Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	96.7	
Energy Value	$/kwh	0.03	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Base Load Hydropower Costs							
Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
880	8800	6565	6.6	54,201,000	**7,223,000**	**20,000**	**1,626,000**
900	9000	6714	6.7	55,431,000	**7,253,000**	**20,000**	**1,663,000**
920	9200	6863	6.9	56,661,000	**7,369,000**	**21,000**	**1,700,000**
940	9400	7012	7.0	57,891,000	**7,389,000**	**21,000**	**1,737,000**
960	9600	7162	7.2	59,129,000	**7,502,000**	**22,000**	**1,774,000**
980	9800	7311	7.3	60,360,000	**7,530,000**	**22,000**	**1,811,000**
1000	10000	7460	7.5	61,590,000	**7,640,000**	**23,000**	**1,848,000**
1020	10200	7609	7.6	62,820,000	**7,668,000**	**23,000**	**1,885,000**
1040	10400	7758	7.8	64,050,000	**7,775,000**	**24,000**	**1,922,000**
1060	10600	7908	7.9	65,288,000	**7,802,000**	**24,000**	**1,959,000**
1080	10800	8057	8.1	66,519,000	**7,906,000**	**25,000**	**1,996,000**
1100	11000	8206	8.2	67,749,000	**7,932,000**	**25,000**	**2,032,000**
1120	11200	8355	8.4	68,979,000	**8,034,000**	**26,000**	**2,069,000**
1140	11400	8504	8.5	70,209,000	**8,051,000**	**26,000**	**2,106,000**
1160	11600	8654	8.7	71,447,000	**8,151,000**	**26,000**	**2,143,000**
1180	11800	8803	8.8	72,678,000	**8,176,000**	**27,000**	**2,180,000**
1200	12000	8952	9.0	73,908,000	**8,273,000**	**27,000**	**2,217,000**
1220	12200	9101	9.1	75,138,000	**8,297,000**	**28,000**	**2,254,000**
1240	12400	9250	9.3	76,368,000	**8,393,000**	**28,000**	**2,291,000**
1260	12600	9400	9.4	77,606,000	**8,416,000**	**29,000**	**2,328,000**
1280	12800	9549	9.5	78,837,000	**8,439,000**	**29,000**	**2,365,000**
1300	13000	9698	9.7	80,067,000	**8,532,000**	**30,000**	**2,402,000**
1320	13200	9847	9.8	81,297,000	**8,555,000**	**30,000**	**2,439,000**
1340	13400	9996	10.0	82,527,000	**8,638,000**	**30,000**	**2,476,000**
1360	13600	10146	10.1	83,765,000	**8,660,000**	**31,000**	**2,513,000**
1380	13800	10295	10.3	84,996,000	**8,750,000**	**31,000**	**2,550,000**
1400	14000	10444	10.4	86,226,000	**8,771,000**	**32,000**	**2,587,000**
1420	14200	10593	10.6	87,456,000	**8,859,000**	**32,000**	**2,624,000**
1440	14400	10742	10.7	88,686,000	**8,880,000**	**33,000**	**2,661,000**

Table 10

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Base Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	96.7	
Energy Value	$/kwh	0.03	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Base Load Hydropower Costs

Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
1460	14600	10892	10.9	89,924,000	**8,966,000**	**33,000**	**2,698,000**
1480	14799	11040	11.0	91,146,000	**8,987,000**	**33,000**	**2,734,000**
1500	14999	11189	11.2	92,376,000	**9,071,000**	**34,000**	**2,771,000**
1520	15199	11338	11.3	93,607,000	**9,091,000**	**34,000**	**2,808,000**
1540	15399	11488	11.5	94,845,000	**9,167,000**	**35,000**	**2,845,000**
1560	15599	11637	11.6	96,075,000	**9,187,000**	**35,000**	**2,882,000**
1580	15799	11786	11.8	97,305,000	**9,268,000**	**36,000**	**2,919,000**
1600	15999	11935	11.9	98,535,000	**9,288,000**	**36,000**	**2,956,000**
1620	16199	12084	12.1	99,766,000	**9,368,000**	**37,000**	**2,993,000**
1640	16399	12234	12.2	101,004,000	**9,387,000**	**37,000**	**3,030,000**
1660	16599	12383	12.4	102,234,000	**9,466,000**	**38,000**	**3,067,000**
1680	16799	12532	12.5	103,464,000	**9,484,000**	**38,000**	**3,104,000**
1700	16999	12681	12.7	104,694,000	**9,562,000**	**39,000**	**3,141,000**
1720	17199	12830	12.8	105,924,000	**9,580,000**	**39,000**	**3,178,000**
1740	17399	12980	13.0	107,163,000	**9,656,000**	**40,000**	**3,215,000**
1760	17599	13129	13.1	108,393,000	**9,667,000**	**40,000**	**3,252,000**
1780	17799	13278	13.3	109,623,000	**9,743,000**	**40,000**	**3,289,000**
1800	17999	13427	13.4	110,853,000	**9,760,000**	**41,000**	**3,326,000**

* An efficiency rating of 88% was used for calculating the turbine power

** O&M cost based on an article published in 'Hydro Review' which comprised of a statistical analysis of actual O&M costs. For all US hydro plants reporting to the FERC: O&M in $US = .63xKW(4.83+.00239x(age in years)^2), for each future year.

Table 11

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Peak Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	290.1	peak flow at 8 hrs./day
Energy Value	$/kwh	0.06	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Peak Load Hydropower Costs

Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
300	9000	6714	6.7	18,477,000	**10,754,000**	**20,000**	**1,109,000**
320	9600	7162	7.2	19,710,000	**11,113,000**	**22,000**	**1,183,000**
340	10200	7609	7.6	20,940,000	**11,374,000**	**23,000**	**1,256,000**
360	10800	8057	8.1	22,173,000	**11,746,000**	**25,000**	**1,330,000**
380	11400	8504	8.5	23,403,000	**11,987,000**	**26,000**	**1,404,000**
400	12000	8952	9.0	24,636,000	**12,334,000**	**27,000**	**1,478,000**
420	12600	9400	9.4	25,869,000	**12,559,000**	**29,000**	**1,552,000**
440	13200	9847	9.8	27,099,000	**12,779,000**	**30,000**	**1,626,000**
460	13800	10295	10.3	28,332,000	**13,097,000**	**31,000**	**1,700,000**
480	14400	10742	10.7	29,562,000	**13,303,000**	**33,000**	**1,774,000**
500	14999	11189	11.2	30,792,000	**13,604,000**	**34,000**	**1,848,000**
520	15599	11637	11.6	32,025,000	**13,767,000**	**35,000**	**1,922,000**
540	16199	12084	12.1	33,255,000	**14,052,000**	**37,000**	**1,995,000**
560	16799	12532	12.5	34,488,000	**14,238,000**	**38,000**	**2,069,000**
580	17399	12980	13.0	35,721,000	**14,510,000**	**40,000**	**2,143,000**
600	17999	13427	13.4	36,951,000	**14,687,000**	**41,000**	**2,217,000**
620	18599	13875	13.9	38,184,000	**14,947,000**	**42,000**	**2,291,000**
640	19199	14322	14.3	39,414,000	**15,115,000**	**44,000**	**2,365,000**
660	19799	14770	14.8	40,647,000	**15,365,000**	**45,000**	**2,439,000**
680	20399	15218	15.2	41,880,000	**15,526,000**	**46,000**	**2,513,000**
700	20999	15665	15.7	43,110,000	**15,765,000**	**48,000**	**2,587,000**
720	21599	16113	16.1	44,343,000	**15,893,000**	**49,000**	**2,661,000**
740	22199	16560	16.6	45,573,000	**16,123,000**	**51,000**	**2,734,000**
760	22799	17008	17.0	46,806,000	**16,272,000**	**52,000**	**2,808,000**
780	23399	17456	17.5	48,039,000	**16,494,000**	**53,000**	**2,882,000**
800	23999	17903	17.9	49,269,000	**16,638,000**	**54,000**	**2,956,000**
820	24599	18351	18.4	50,502,000	**16,853,000**	**56,000**	**3,030,000**
840	25199	18798	18.8	51,732,000	**16,991,000**	**57,000**	**3,104,000**

Table 11

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Peak Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	290.1	peak flow at 8 hrs./day
Energy Value	$/kwh	0.06	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Peak Load Hydropower Costs

Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
860	25799	19246	19.2	52,965,000	**17,127,000**	**58,000**	**3,178,000**
880	26399	19694	19.7	54,198,000	**17,332,000**	**60,000**	**3,252,000**
900	26999	20141	20.1	55,428,000	**17,464,000**	**61,000**	**3,326,000**
920	27599	20589	20.6	56,661,000	**17,662,000**	**63,000**	**3,400,000**
940	28199	21036	21.0	57,891,000	**17,766,000**	**64,000**	**3,473,000**
960	28799	21484	21.5	59,124,000	**17,959,000**	**65,000**	**3,547,000**
980	29399	21932	21.9	60,357,000	**18,083,000**	**67,000**	**3,621,000**
1000	29999	22379	22.4	61,587,000	**18,270,000**	**68,000**	**3,695,000**
1020	30599	22827	22.8	62,820,000	**18,390,000**	**69,000**	**3,769,000**
1040	31199	23274	23.3	64,050,000	**18,572,000**	**71,000**	**3,843,000**
1060	31799	23722	23.7	65,283,000	**18,689,000**	**72,000**	**3,917,000**
1080	32399	24170	24.2	66,516,000	**18,866,000**	**74,000**	**3,991,000**
1100	32999	24617	24.6	67,746,000	**18,980,000**	**75,000**	**4,065,000**
1120	33599	25065	25.1	68,979,000	**19,152,000**	**76,000**	**4,139,000**
1140	34199	25512	25.5	70,209,000	**19,241,000**	**78,000**	**4,213,000**
1160	34799	25960	26.0	71,442,000	**19,409,000**	**79,000**	**4,287,000**
1180	35399	26408	26.4	72,675,000	**19,517,000**	**80,000**	**4,361,000**
1200	35999	26855	26.9	73,905,000	**19,681,000**	**82,000**	**4,434,000**
1220	36599	27303	27.3	75,138,000	**19,786,000**	**83,000**	**4,508,000**
1240	37199	27750	27.8	76,368,000	**19,947,000**	**85,000**	**4,582,000**
1260	37799	28198	28.2	77,601,000	**20,049,000**	**86,000**	**4,656,000**
1280	38399	28646	28.6	78,834,000	**20,150,000**	**87,000**	**4,730,000**
1300	38999	29093	29.1	80,064,000	**20,305,000**	**89,000**	**4,804,000**
1320	39599	29541	29.5	81,297,000	**20,404,000**	**90,000**	**4,878,000**
1340	40199	29988	30.0	82,527,000	**20,537,000**	**91,000**	**4,952,000**
1360	40799	30436	30.4	83,760,000	**20,633,000**	**93,000**	**5,026,000**
1380	41399	30884	30.9	84,993,000	**20,782,000**	**94,000**	**5,100,000**
1400	41999	31331	31.3	86,223,000	**20,877,000**	**95,000**	**5,173,000**

Table 11

Lake Powell Pipeline Feasibility Study

Opinion of Probable Cost

Peak Load Hydropower Costs

Variable	Units	Value	Comments
Flow Rate	AF/Yr	70,000	
Flow Rate	cfs	290.1	peak flow at 8 hrs./day
Energy Value	$/kwh	0.06	
Annual Cost @ year		1	
Net Head Increment		20	

Conceptual Level Peak Load Hydropower Costs							
Net Head	Turbine Power*	Plant Output	Plant Capacity	Energy Output	Capital Powerhouse Cost	Annual O&M Cost**	Annual Energy Revenue
ft	hp	KW	MW	KWH/yr	$	$	$
1420	42599	31779	31.8	87,456,000	**21,022,000**	**97,000**	**5,247,000**
1440	43199	32226	32.2	88,686,000	**21,115,000**	**98,000**	**5,321,000**
1460	43799	32674	32.7	89,919,000	**21,257,000**	**100,000**	**5,395,000**
1480	44398	33121	33.1	91,149,000	**21,348,000**	**101,000**	**5,469,000**
1500	44998	33569	33.6	92,382,000	**21,488,000**	**102,000**	**5,543,000**
1520	45598	34016	34.0	93,612,000	**21,576,000**	**104,000**	**5,617,000**
1540	46198	34464	34.5	94,845,000	**21,695,000**	**105,000**	**5,691,000**
1560	46798	34911	34.9	96,075,000	**21,782,000**	**106,000**	**5,765,000**
1580	47398	35359	35.4	97,308,000	**21,916,000**	**108,000**	**5,838,000**
1600	47998	35807	35.8	98,541,000	**22,002,000**	**109,000**	**5,912,000**
1620	48598	36254	36.3	99,771,000	**22,134,000**	**111,000**	**5,986,000**
1640	49198	36702	36.7	101,004,000	**22,217,000**	**112,000**	**6,060,000**
1660	49798	37149	37.1	102,234,000	**22,300,000**	**113,000**	**6,134,000**
1680	50398	37597	37.6	103,467,000	**22,429,000**	**114,000**	**6,208,000**
1700	50998	38045	38.0	104,700,000	**22,510,000**	**116,000**	**6,282,000**
1720	51598	38492	38.5	105,930,000	**22,636,000**	**117,000**	**6,356,000**
1740	52198	38940	38.9	107,163,000	**22,716,000**	**118,000**	**6,430,000**
1760	52798	39387	39.4	108,393,000	**22,824,000**	**120,000**	**6,504,000**
1780	53398	39835	39.8	109,626,000	**22,902,000**	**121,000**	**6,578,000**
1800	53998	40283	40.3	110,859,000	**23,024,000**	**123,000**	**6,652,000**

* An efficiency rating of 88% was used for calculating the turbine power

** O&M cost based on an article published in 'Hydro Review' which comprised of a statistical analysis of actual O&M costs. For all US hydro plants reporting to the FERC: O&M in $US = .63xKW(4.83+.00239x(age in years)^2), for each future year.

Table 12
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

1	*Gould Reservoir Alignment*													80,000	AF/Yr		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Pipeline Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs......															19,765,097	
00+00	Energy Costs......																4,255,000
00+00	O &M Costs......																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs......															11,828,276	
1370+00	Energy Costs......																4,355,000
1370+00	O &M Costs......																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00......														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility......															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5290+00	100.19	60	4.92	0.0986	198	4920	5377	200			1.00	1.05	208		3,935,333		
5461+00	103.43	60	4.92	0.0986	236	4890	5360	250			1.00	1.05	248		4,240,830		
5559+00	105.28	60	4.92	0.0986	198	4890	5351	200			1.00	1.05	208		2,039,464		
5800+00	109.85	60	4.92	0.0986	269	4660	5327	300			1.00	1.05	284		6,840,788		
	Gould Reservoir Alignment																
5817+00	110.17	60	4.92	0.0986	269	4640	5325	300			1.01	1.05	284		483,076		
6170+00	116.86	60	4.92	0.0986	269	4610	5291	300			1.00	1.05	283		9,976,673		
6221+00	117.82	60	4.92	0.0986	236	4718	5286	250			1.01	1.05	250		1,277,011		
6221+00	Pressure Reducing Facility......															500,000	
	HL=	568	ft	Reduction in pipeline head (pressure													
	Gravity Vents at 2 locations......															100,000	
6221+00	Peaking Reservoir......															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**157,021,497**	**33,575,565**	**9,242,000**

Table 12
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

1	Gould Reservoir Alignment													80,000	AF/Yr		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Pipeline Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6243+00	118.24	60	4.92	0.0986		3560	4715										
6243+00	Hurricane Cliffs Hydropower Facility																
	HL=	1155	ft														
	Construction Costs															8,051,000	
	Energy Costs																-2,106,000
	Power Transmission Costs															487,689	
	O &M Costs																26,000
6388+00	120.98	60	4.92	0.0986	184	3510	3546	50			1.00	1.05	193		2,798,889		
6449+00	122.14	60	4.92	0.0986	236	3030	3540	250			1.04	1.05	257		1,569,828		
6449+00	Sand Hollow Hydropower Facility																
	HL=	510	ft														
	Construction Costs															5,509,000	
	Energy Costs																-924,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6449+00	122.14	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$9,638,716**	**$14,922,689**	**-$2,993,000**
			Ave. Unit Cost Pipe =		**4.31**	$/lf/in-dia								Total:	**$166,660,214**	**$48,498,255**	**$6,249,000**
			Ave. Unit Cost Pipe =		**258**	$/lf								Total Construction Costs:	**$215,158,468**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6243+00	118.24	75	9.45	0.2699		3560	4709										
6243+00	Hurricane Cliffs Hydropower Facility																
	HL=	1149	ft														
	Construction Costs															19,241,000	
	Energy Costs																-4,213,000
	Power Transmission Costs															487,689	
	O &M Costs																78,000
6388+00	120.98	75	9.45	0.2699	245	3510	3521	50			1.00	1.05	258		3,742,260		
6449+00	122.14	75	9.45	0.2699	327	3030	3504	250			1.04	1.05	356		2,174,057		
6449+00	Sand Hollow Hydropower Facility																
	HL=	474	ft														
	Construction Costs															13,097,000	
	Energy Costs																-1,700,000
	Power Transmission Costs															875,000	
	O &M Costs																10,000
6449+00	122.14	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$11,786,317**	**$33,700,689**	**-$5,825,000**
														Total:	**$168,807,814**	**$67,276,255**	**$3,417,000**
			Ave. Unit Cost Pipe =		**262**	$/lf								Total Construction Costs:	**$236,084,069**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6243+00	118.24	60	4.92	0.0986		3560	4715										
6388+00	120.98	60	4.92	0.0986	445	3510	4700	550			1.00	1.05	468		6,779,205		
6449+00	122.14	60	4.92	0.0986	597	3030	4694	750			1.04	1.05	651		3,971,360		
6449+00	Sand Hollow Hydropower Facility																
	HL=	1664	ft														
	Construction Costs															9,466,000	
	Energy Costs																-3,067,000
	Power Transmission Costs															875,000	
	O &M Costs																38,000
6449+00	122.14	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	**$16,020,565**	**$10,341,000**	**-$3,029,000**
			Ave. Unit Cost Pipe =		**4.47**	$/lf/in-dia								Total:	**$173,042,062**	**$43,916,565**	**$6,213,000**
			Ave. Unit Cost Pipe =		**268**	$/lf								Total Construction Costs:	**$216,958,627**		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6243+00	118.24	75	9.45	0.2699		3560	4709										
6388+00	120.98	75	9.45	0.2699	650	3510	4670	550			1.00	1.05	684		9,920,789		
6449+00	122.14	75	9.45	0.2699	887	3030	4653	750			1.04	1.05	968		5,901,885		
6449+00	Sand Hollow Hydropower Facility																
	HL=	1623	ft														
	Construction Costs															22,134,000	
	Energy Costs																-5,986,000
	Power Transmission Costs															875,000	
	O &M Costs																111,000
6449+00	122.14	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$21,692,675**	**$23,009,000**	**-$5,875,000**
														Total:	**$178,714,172**	**$56,584,565**	**$3,367,000**
			Ave. Unit Cost Pipe =		**277**	$/lf								Total Construction Costs:	**$235,298,737**		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 13
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

2	***Willow Spring Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	**110.50**	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	**1280**	4820										
00+00	Construction Costs..........															19,765,097	
00+00	Energy Costs..........																4,255,000
00+00	O &M Costs..........																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	**110.50**	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	**1310**	5954										
1370+00	Construction Costs..........															11,828,276	
1370+00	Energy Costs..........																4,355,000
1370+00	O &M Costs..........																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00..........														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility..........															500,000	
	HL=	**140**	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	**96.69**	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5290+00	100.19	60	4.92	0.0986	198	4920	5377	200			1.00	1.05	208		3,935,333		
5461+00	103.43	60	4.92	0.0986	236	4890	5360	250			1.00	1.05	248		4,240,830		
5559+00	105.28	60	4.92	0.0986	198	4890	5351	200			1.00	1.05	208		2,039,464		
5800+00	109.85	60	4.92	0.0986	269	4660	5327	300			1.00	1.05	284		6,840,788		
	Willow Spring Alignment																
5818+00	110.19	60	4.92	0.0986	269	4640	5325	300			1.01	1.05	284		511,327		
5853+00	110.85	60	4.92	0.0986	269	4640	5322	300			1.00	1.05	283		988,769		
5918+00	112.08	60	4.92	0.0986	269	4630	5315	300			1.00	1.05	283		1,837,696		
5950+00	112.69	60	4.92	0.0986	303	4510	5312	350			1.02	1.05	324		1,036,289		
5994+00	113.52	60	4.92	0.0986	337	4390	5308	400			1.01	1.05	359		1,579,011		
6147+00	116.42	60	4.92	0.0986	445	4140	5293	550			1.01	1.05	471		7,199,033		
6195+00	117.33	60	4.92	0.0986	408	4139	5288	500			1.00	1.05	429		2,056,857		
6195+00	Pressure Reducing Facility..........															500,000	
	HL=	**1149**	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations..........															100,000	
6195+00	Peaking Reservoir..........															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**160,493,719**	**33,575,565**	**9,242,000**

Table 13
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

2	***Willow Spring Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,630,000		
6211+50	117.64	60	4.92	0.0986		3380	4137										
6211+50	Hurricane Cliffs Hydropower Facility																
	HL=	757	ft														
	Construction Costs															6,624,000	
	Energy Costs																-1,367,000
	Power Transmission Costs															571,733	
	O &M Costs																17,000
6388+00	120.98	60	4.92	0.0986	184	3345	3363	50			1.00	1.05	193		3,404,435		
6453+00	122.22	60	4.92	0.0986	184	3030	3356	150			1.02	1.05	197		1,282,507		
6453+00	Sand Hollow Hydropower Facility																
	HL=	326	ft														
	Construction Costs															4,477,000	
	Energy Costs																-591,000
	Power Transmission Costs															875,000	
	O &M Costs																7,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$8,316,942**	**$12,547,733**	**-$1,934,000**
				Ave. Unit Cost Pipe =	**4.36**	$/lf/in-dia								Total:	**$168,810,660**	**$46,123,298**	**$7,308,000**
				Ave. Unit Cost Pipe =	**262**	$/lf								Total Construction Costs:	**$214,933,958**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,910,000		
6211+50	117.64	75	9.45	0.2699		3380	4133										
6211+50	Hurricane Cliffs Hydropower Facility																
	HL=	710	ft														
	Construction Costs															15,765,000	
	Energy Costs																-2,587,000
	Power Transmission Costs															571,733	
	O &M Costs																48,000
6388+00	120.98	75	9.45	0.2699	245	3345	3375	50			1.00	1.05	258		4,551,907		
6453+00	122.22	75	9.45	0.2699	245	3030	3357	150			1.02	1.05	264		1,714,779		
6453+00	Sand Hollow Hydropower Facility																
	HL=	327	ft														
	Construction Costs															11,113,000	
	Energy Costs																-1,183,000
	Power Transmission Costs															875,000	
	O &M Costs																22,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$10,176,686**	**$28,324,733**	**-$3,700,000**
														Total:	**$170,670,405**	**$61,900,298**	**$5,542,000**
				Ave. Unit Cost Pipe =	**264**	$/lf								Total Construction Costs:	**$232,570,703**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,630,000		
6211+50	117.64	60	4.92	0.0986		3380	4137										
6388+00	120.98	60	4.92	0.0986	303	3345	4119	350			1.00	1.05	318		5,617,095		
6453+00	122.22	60	4.92	0.0986	408	3030	4113	500			1.02	1.05	439		2,851,722		
6453+00	Sand Hollow Hydropower Facility																
	HL=	1083	ft														
	Construction Costs															7,906,000	
	Energy Costs																-1,996,000
	Power Transmission Costs															875,000	
	O &M Costs																25,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	**$12,098,817**	**$8,781,000**	**-$1,971,000**
				Ave. Unit Cost Pipe =	**4.46**	$/lf/in-dia								Total:	**$172,592,536**	**$42,356,565**	**$7,271,000**
				Ave. Unit Cost Pipe =	**267**	$/lf								Total Construction Costs:	**$214,949,101**		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,910,000		
6211+50	117.64	75	9.45	0.2699		3380	4133										
6388+00	120.98	75	9.45	0.2699	431	3345	4085	350			1.00	1.05	452		7,986,556		
6453+00	122.22	75	9.45	0.2699	594	3030	4067	500			1.02	1.05	639		4,150,626		
6453+00	Sand Hollow Hydropower Facility																
	HL=	1037	ft														
	Construction Costs															18,390,000	
	Energy Costs																-3,769,000
	Power Transmission Costs															875,000	
	O &M Costs																69,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$16,047,181**	**$19,265,000**	**-$3,700,000**
														Total:	**$176,540,900**	**$52,840,565**	**$5,542,000**
				Ave. Unit Cost Pipe =	**274**	$/lf								Total Construction Costs:	**$229,381,465**		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 14
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

3	Gould Spring- Grass Valley Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for			Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Slope Mult.	Appurt Mult.	Cost	Determinec	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Statior				Max Lift =	1280	4820										
00+00	Construction Costs................................															19,765,097	
00+00	Energy Costs................................																4,255,000
00+00	O &M Costs................................																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Statior				Max Lift =	1310	5954										
1370+00	Construction Costs................................															11,828,276	
1370+00	Energy Costs................................																4,355,000
1370+00	O &M Costs................................																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00................................														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility................................															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5290+00	100.19	60	4.92	0.0986	198	4920	5377	200			1.00	1.05	208		3,935,333		
5461+00	103.43	60	4.92	0.0986	236	4890	5360	250			1.00	1.05	248		4,240,830		
5559+00	105.28	60	4.92	0.0986	198	4890	5351	200			1.00	1.05	208		2,039,464		
5800+00	109.85	60	4.92	0.0986	269	4660	5327	300			1.00	1.05	284		6,840,788		
	Gould Reservoir Alignmen																
5802+00	109.89	60	4.92	0.0986	269	4640	5327	300			1.05	1.05	296		59,259		
5894+00	111.63	60	4.92	0.0986	269	4630	5318	300			1.00	1.05	283		2,600,461		
5950+00	112.69	60	4.92	0.0986	269	4640	5312	300			1.00	1.05	283		1,582,030		
5963+00	112.94	60	4.92	0.0986	337	4390	5311	400			1.02	1.05	360		468,228		
6151+00	116.50	60	4.92	0.0986	337	4380	5292	400			1.00	1.05	354		6,658,295		
6191+00	117.25	60	4.92	0.0986	269	4600	5288	300			1.03	1.05	290		1,160,681		
6204+00	117.50	60	4.92	0.0986	236	4715	5287	250			1.04	1.05	259		336,066		
	Pressure Reducing Facility................................															500,000	
	HL=	572	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations................................															100,000	
	Peaking Reservoir................................															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**158,149,756**	**33,575,565**	**9,242,000**

Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
3	***Gould Spring- Grass Valley Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost....														4,650,000		
6223+00	117.86	60	4.92	0.0986		3566	4712										
6223+00	Hurricane Cliffs Hydropower Facility																
	HL=	**1146**	ft														
	Construction Costs....															8,051,000	
	Energy Costs....																-2,106,000
	Power Transmission Costs....															466,383	
	O &M Costs....																26,000
6360+00	120.45	60	4.92	0.0986	184	3497	3552	50			1.00	1.05	193		2,646,559		
6420+00	121.59	60	4.92	0.0986	236	3030	3547	250			1.04	1.05	257		1,543,481		
6420+00	Sand Hollow Hydropower Facilit																
	HL=	**517**	ft														
	Construction Costs....															5,509,000	
	Energy Costs....																-924,000
	Power Transmission Costs....															875,000	
	O &M Costs....																11,000
6420+00	121.59	Sand Hollow Reservoi				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilitie														Subtotals:	**$8,840,040**	**$14,901,383**	**-$2,993,000**
			Ave. Unit Cost Pipe =		**4.34**	$/lf/in-dia								Total:	**$166,989,796**	**$48,476,948**	**$6,249,000**
			Ave. Unit Cost Pipe =		**260**	$/lf								Total Construction Costs	**$215,466,743**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost....														5,140,000		
6223+00	117.86	75	9.45	0.2699		3566	4707										
6223+00	Hurricane Cliffs Hydropower Facility																
	HL=	**1141**	ft														
	Construction Costs....															19,241,000	
	Energy Costs....																-4,213,000
	Power Transmission Costs....															466,383	
	O &M Costs....																78,000
6360+00	120.45	75	9.45	0.2699	245	3497	3529	50			1.00	1.05	258		3,538,588		
6420+00	121.59	75	9.45	0.2699	327	3030	3513	250			1.04	1.05	356		2,137,569		
6420+00	Sand Hollow Hydropower Facilit																
	HL=	**483**	ft														
	Construction Costs....															13,303,000	
	Energy Costs....																-1,774,000
	Power Transmission Costs....															875,000	
	O &M Costs....																33,000
6420+00	121.59	Sand Hollow Reservoi				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilitie														Subtotals:	**$10,816,157**	**$33,885,383**	**-$5,876,000**
														Total:	**$168,965,913**	**$67,460,948**	**$3,366,000**
			Ave. Unit Cost Pipe =		**263**	$/lf								Total Construction Costs	**$236,426,860**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost....														4,650,000		
6223+00	117.86	60	4.92	0.0986		3566	4712										
6360+00	120.45	60	4.92	0.0986	445	3497	4699	550			1.00	1.05	468		6,410,247		
6420+00	121.59	60	4.92	0.0986	597	3030	4693	750			1.04	1.05	651		3,904,707		
6420+00	Sand Hollow Hydropower Facilit																
	HL=	**1663**	ft														
	Construction Costs....															9,466,000	
	Energy Costs....																-3,067,000
	Power Transmission Costs....															875,000	
	O &M Costs....																38,000
6420+00	121.59	Sand Hollow Reservoi				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facilit														Subtotals:	**$14,964,953**	**$10,341,000**	**-$3,029,000**
			Ave. Unit Cost Pipe =		**4.49**	$/lf/in-dia								Total:	**$173,114,709**	**$43,916,565**	**$6,213,000**
			Ave. Unit Cost Pipe =		**270**	$/lf								Total Construction Costs	**$217,031,274**		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost....														5,140,000		
6223+00	117.86	75	9.45	0.2699		3566	4707										
6360+00	120.45	75	9.45	0.2699	650	3497	4670	550			1.00	1.05	685		9,380,850		
6420+00	121.59	75	9.45	0.2699	887	3030	4654	750			1.04	1.05	967		5,802,832		
6420+00	Sand Hollow Hydropower Facilit																
	HL=	**1624**	ft														
	Construction Costs....															22,134,000	
	Energy Costs....																-5,986,000
	Power Transmission Costs....															875,000	
	O &M Costs....																111,000
6420+00	121.59	Sand Hollow Reservoi				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facilit														Subtotals:	**$20,323,682**	**$23,009,000**	**-$5,875,000**
														Total:	**$178,473,438**	**$56,584,565**	**$3,367,000**
			Ave. Unit Cost Pipe =		**278**	$/lf								Total Construction Costs	**$235,058,003**		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plu variable length line between the two powerhouses, if applicabl

Table 15
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

4	Gould Spring- Willow Spring Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs.......															19,765,097	
00+00	Energy Costs.......																4,255,000
00+00	O &M Costs.......																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs.......															11,828,276	
1370+00	Energy Costs.......																4,355,000
1370+00	O &M Costs.......																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00.......														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility.......															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5290+00	100.19	60	4.92	0.0986	198	4920	5377	200			1.00	1.05	208		3,935,333		
5461+00	103.43	60	4.92	0.0986	236	4890	5360	250			1.00	1.05	248		4,240,830		
5559+00	105.28	60	4.92	0.0986	198	4890	5351	200			1.00	1.05	208		2,039,464		
5800+00	109.85	60	4.92	0.0986	269	4660	5327	300			1.00	1.05	284		6,840,788		
	Gould Spring - Willow Spring																
5802+00	109.89	60	4.92	0.0986	269	4640	5327	300			1.05	1.05	296		59,259		
5894+00	111.63	60	4.92	0.0986	269	4630	5318	300			1.00	1.05	283		2,600,461		
5950+00	112.69	60	4.92	0.0986	269	4640	5312	300			1.00	1.05	283		1,582,030		
5963+00	112.94	60	4.92	0.0986	337	4390	5311	400			1.02	1.05	360		468,228		
6120+00	115.91	60	4.92	0.0986	408	4180	5295	500			1.01	1.05	434		6,817,339		
	Pressure Reducing Facility.......															500,000	
	HL=	1115	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations.......															100,000	
	Peaking Reservoir.......															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**156,812,053**	**33,575,565**	**9,242,000**

Table 15
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

4	Gould Spring- Willow Spring Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,630,000		
6236+00	118.11	60	4.92	0.0986		3380	4137										
6236+00	Hurricane Cliffs Hydropower Facility																
	HL=	757	ft														
	Construction Costs															6,624,000	
	Energy Costs																-1,367,000
	Power Transmission Costs															523,201	
	O &M Costs																17,000
6394+00	121.10	60	4.92	0.0986	184	3345	3364	50			1.00	1.05	193		3,047,949		
6457+00	122.29	60	4.92	0.0986	184	3030	3358	150			1.02	1.05	197		1,243,957		
6457+00	Sand Hollow Hydropower Facility																
	HL=	328	ft														
	Construction Costs															4,477,000	
	Energy Costs																-591,000
	Power Transmission Costs															875,000	
	O &M Costs																7,000
6457+00	122.29	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	$7,921,906	$12,499,201	-$1,934,000
				Ave. Unit Cost Pipe =	4.25	$/lf/in-dia								Total:	$164,733,959	$46,074,766	$7,308,000
				Ave. Unit Cost Pipe =	255	$/lf								Total Construction Costs:	$210,808,725		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,910,000		
6236+00	118.11	75	9.45	0.2699		3380	4133										
6236+00	Hurricane Cliffs Hydropower Facility																
	HL=	710	ft														
	Construction Costs															15,765,000	
	Energy Costs																-2,587,000
	Power Transmission Costs															523,201	
	O &M Costs																48,000
6394+00	121.10	75	9.45	0.2699	245	3345	3380	50			1.00	1.05	258		4,075,267		
6457+00	122.29	75	9.45	0.2699	245	3030	3363	150			1.02	1.05	264		1,663,235		
6457+00	Sand Hollow Hydropower Facility																
	HL=	333	ft														
	Construction Costs															11,113,000	
	Energy Costs																-1,183,000
	Power Transmission Costs															875,000	
	O &M Costs																22,000
6457+00	122.29	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	$9,648,502	$28,276,201	-$3,700,000
														Total:	$166,460,555	$61,851,766	$5,542,000
				Ave. Unit Cost Pipe =	258	$/lf								Total Construction Costs:	$228,312,321		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,630,000		
6236+00	118.11	60	4.92	0.0986		3380	4137										
6394+00	121.10	60	4.92	0.0986	303	3345	4121	350			1.00	1.05	318		5,028,917		
6457+00	122.29	60	4.92	0.0986	408	3030	4115	500			1.02	1.05	439		2,766,004		
6457+00	Sand Hollow Hydropower Facility																
	HL=	1085	ft														
	Construction Costs															7,906,000	
	Energy Costs																-1,996,000
	Power Transmission Costs															875,000	
	O &M Costs																25,000
6457+00	122.29	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	$11,424,921	$8,781,000	-$1,971,000
				Ave. Unit Cost Pipe =	4.34	$/lf/in-dia								Total:	$168,236,974	$42,356,565	$7,271,000
				Ave. Unit Cost Pipe =	261	$/lf								Total Construction Costs:	$210,593,539		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														3,910,000		
6236+00	118.11	75	9.45	0.2699		3380	4133										
6394+00	121.10	75	9.45	0.2699	431	3345	4090	350			1.00	1.05	453		7,150,266		
6457+00	122.29	75	9.45	0.2699	594	3030	4073	500			1.02	1.05	639		4,025,864		
6457+00	Sand Hollow Hydropower Facility																
	HL=	1043	ft														
	Construction Costs															18,572,000	
	Energy Costs																-3,843,000
	Power Transmission Costs															875,000	
	O &M Costs																71,000
6457+00	122.29	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	$15,086,131	$19,447,000	-$3,772,000
														Total:	$171,898,184	$53,022,565	$5,470,000
				Ave. Unit Cost Pipe =	266	$/lf								Total Construction Costs:	$224,920,749		

Notes.

1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 16
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

5	Gould Spring- Mollies Nipple, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs															19,765,097	
00+00	Energy Costs																4,255,000
00+00	O &M Costs																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs															11,828,276	
1370+00	Energy Costs																4,355,000
1370+00	O &M Costs																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5290+00	100.19	60	4.92	0.0986	198	4920	5377	200			1.00	1.05	208		3,935,333		
5461+00	103.43	60	4.92	0.0986	236	4890	5360	250			1.00	1.05	248		4,240,830		
5559+00	105.28	60	4.92	0.0986	198	4890	5351	200			1.00	1.05	208		2,039,464		
5800+00	109.85	60	4.92	0.0986	269	4660	5327	300			1.00	1.05	284		6,840,788		
	Gould Spring - Mollies Nipple Alignment																
5802+00	109.89	60	4.92	0.0986	269	4640	5327	300			1.05	1.05	296		59,259		
5963+00	112.94	60	4.92	0.0986	337	4390	5311	400			1.01	1.05	357		5,744,623		
6180+00	117.05	60	4.92	0.0986	337	4370	5290	400			1.00	1.05	354		7,686,869		
6185+00	117.14	60	4.92	0.0986	337	4370	5289	400			1.00	1.05	354		177,035		
6189+00	117.22	60	4.92	0.0986	337	4370	5289	400			1.00	1.05	354		141,628		
6212+00	117.65	60	4.92	0.0986	337	4457	5286	400			1.02	1.05	361		829,621		
	Pressure Reducing Facility															500,000	
	HL=	829	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations															100,000	
	Peaking Reservoir															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**159,923,773**	**33,575,565**	**9,242,000**

Table 16
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

5	***Gould Spring- Mollies Nipple, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														4,540,000		
6232+00	118.03	60	4.92	0.0986		3452	4454										
6232+00	Hurricane Cliffs Hydropower Facility																
	HL=	**1002**	ft														
	Construction Costs															7,640,000	
	Energy Costs																-1,848,000
	Power Transmission Costs															511,364	
	O &M Costs																23,000
6385+00	120.93	60	4.92	0.0986	184	3345	3437	50			1.00	1.05	193		2,958,523		
6448+00	122.12	60	4.92	0.0986	198	3030	3431	200			1.02	1.05	213		1,343,461		
6448+00	Sand Hollow Hydropower Facility																
	HL=	**401**	ft														
	Construction Costs															5,000,000	
	Energy Costs																-739,000
	Power Transmission Costs															875,000	
	O &M Costs																9,000
6448+00	122.12	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$8,841,984**	**$14,026,364**	**-$2,555,000**
			Ave. Unit Cost Pipe =		**4.36**	$/lf/in-dia								Total:	**$168,765,757**	**$47,601,929**	**$6,687,000**
			Ave. Unit Cost Pipe =		**262**	$/lf								Total Construction Costs:	**$216,367,685**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														4,980,000		
6232+00	118.03	75	9.45	0.2699		3452	4449										
6232+00	Hurricane Cliffs Hydropower Facility																
	HL=	**997**	ft														
	Construction Costs															18,083,000	
	Energy Costs																-3,621,000
	Power Transmission Costs															511,364	
	O &M Costs																67,000
6385+00	120.93	75	9.45	0.2699	245	3345	3411	50			1.00	1.05	259		3,955,699		
6448+00	122.12	75	9.45	0.2699	277	3030	3394	200			1.02	1.05	298		1,874,441		
6448+00	Sand Hollow Hydropower Facility																
	HL=	**364**	ft														
	Construction Costs															11,746,000	
	Energy Costs																-1,330,000
	Power Transmission Costs															875,000	
	O &M Costs																25,000
6448+00	122.12	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$10,810,140**	**$31,215,364**	**-$4,859,000**
														Total:	**$170,733,913**	**$64,790,929**	**$4,383,000**
			Ave. Unit Cost Pipe =		**265**	$/lf								Total Construction Costs:	**$235,524,842**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														4,540,000		
6232+00	118.03	60	4.92	0.0986		3452	4454										
6385+00	120.93	60	4.92	0.0986	408	3345	4439	500			1.00	1.05	430		6,578,431		
6448+00	122.12	60	4.92	0.0986	519	3030	4433	650			1.02	1.05	559		3,520,688		
6448+00	Sand Hollow Hydropower Facility																
	HL=	**1403**	ft														
	Construction Costs															8,771,000	
	Energy Costs																-2,587,000
	Power Transmission Costs															875,000	
	O &M Costs																32,000
6448+00	122.12	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	**$14,639,118**	**$9,646,000**	**-$2,555,000**
			Ave. Unit Cost Pipe =		**4.51**	$/lf/in-dia								Total:	**$174,562,891**	**$43,221,565**	**$6,687,000**
			Ave. Unit Cost Pipe =		**271**	$/lf								Total Construction Costs:	**$217,784,456**		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														4,980,000		
6232+00	118.03	75	9.45	0.2699		3452	4449										
6385+00	120.93	75	9.45	0.2699	594	3345	4408	500			1.00	1.05	626		9,574,778		
6448+00	122.12	75	9.45	0.2699	708	3030	4391	600			1.02	1.05	762		4,799,753		
6448+00	Sand Hollow Hydropower Facility																
	HL=	**1361**	ft														
	Construction Costs															20,633,000	
	Energy Costs																-5,026,000
	Power Transmission Costs															875,000	
	O &M Costs																93,000
6448+00	122.12	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$19,354,531**	**$21,508,000**	**-$4,933,000**
														Total:	**$179,278,304**	**$55,083,565**	**$4,309,000**
			Ave. Unit Cost Pipe =		**278**	$/lf								Total Construction Costs:	**$234,361,869**		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus a variable length line between the two powerhouses, if applicable.

Table 17
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

6	Colorado City - West Little Creek Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs........															19,765,097	
00+00	Energy Costs........																4,255,000
00+00	O &M Costs........																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs........															11,828,276	
1370+00	Energy Costs........																4,355,000
1370+00	O &M Costs........																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00........														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility........															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5200+00	98.48	60	4.92	0.0986	198	4980	5386	200			1.00	1.05	209		2,064,433		
	Colorado City Alignment																
5216+00	98.79	60	4.92	0.0986	198	4930	5385	200			1.02	1.05	211		338,136		
5371+00	101.72	60	4.92	0.0986	269	4680	5369	300			1.01	1.05	285		4,414,004		
5860+00	110.98	60	4.92	0.0986	303	4530	5321	350			1.00	1.05	318		15,570,797		
	West Little Creek Alignment																
6041+00	114.41	60	4.92	0.0986	269	4620	5303	300			1.00	1.05	283		5,126,043		
6247+00	118.31	60	4.92	0.0986	236	4718	5283	250			1.00	1.05	248		5,116,488		
	Pressure Reducing Facility........															500,000	
	HL=	565	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations........															100,000	
	Peaking Reservoir........															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**160,858,222**	**33,575,565**	**9,242,000**

Table 17
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

6	Colorado City - West Little Creek Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6269+00	118.73	60	4.92	0.0986		3560	4715										
6269+00	Hurricane Cliffs Hydropower Facility																
	HL=	1155	ft														
	Construction Costs															8,051,000	
	Energy Costs																-2,106,000
	Power Transmission Costs															435,606	
	O &M Costs																26,000
6393+00	121.08	60	4.92	0.0986	184	3500	3548	50			1.00	1.05	193		2,395,190		
6453+00	122.22	60	4.92	0.0986	236	3030	3542	250			1.04	1.05	257		1,543,839		
6453+00	Sand Hollow Hydropower Facility																
	HL=	512	ft														
	Construction Costs															5,509,000	
	Energy Costs																-924,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	$9,209,029	$14,870,606	-$2,993,000
				Ave. Unit Cost Pipe =	4.39	$/lf/in-dia								Total:	$170,067,251	$48,446,171	$6,249,000
				Ave. Unit Cost Pipe =	264	$/lf								Total Construction Costs:	$218,513,422		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6269+00	118.73	75	9.45	0.2699		3560	4709										
6269+00	Hurricane Cliffs Hydropower Facility																
	HL=	1149	ft														
	Construction Costs															19,241,000	
	Energy Costs																-4,213,000
	Power Transmission Costs															435,606	
	O &M Costs																78,000
6393+00	121.08	75	9.45	0.2699	245	3500	3527	50			1.00	1.05	258		3,202,494		
6453+00	122.22	75	9.45	0.2699	327	3030	3510	250			1.04	1.05	356		2,138,065		
6453+00	Sand Hollow Hydropower Facility																
	HL=	480	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	$11,210,559	$33,854,606	-$5,898,000
														Total:	$172,068,781	$67,430,171	$3,344,000
				Ave. Unit Cost Pipe =	267	$/lf								Total Construction Costs:	$239,498,952		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6269+00	118.73	60	4.92	0.0986		3560	4715										
6393+00	121.08	60	4.92	0.0986	445	3500	4703	550			1.00	1.05	468		5,801,404		
6453+00	122.22	60	4.92	0.0986	597	3030	4697	750			1.04	1.05	651		3,905,613		
6453+00	Sand Hollow Hydropower Facility																
	HL=	1667	ft														
	Construction Costs															9,466,000	
	Energy Costs																-3,067,000
	Power Transmission Costs															875,000	
	O &M Costs																38,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	$14,977,017	$10,341,000	-$3,029,000
				Ave. Unit Cost Pipe =	4.54	$/lf/in-dia								Total:	$175,835,238	$43,916,565	$6,213,000
				Ave. Unit Cost Pipe =	272	$/lf								Total Construction Costs:	$219,751,804		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6269+00	118.73	75	9.45	0.2699		3560	4709										
6393+00	121.08	75	9.45	0.2699	650	3500	4676	550			1.00	1.05	685		8,489,861		
6453+00	122.22	75	9.45	0.2699	887	3030	4659	750			1.04	1.05	967		5,804,177		
6453+00	Sand Hollow Hydropower Facility																
	HL=	1629	ft														
	Construction Costs															22,134,000	
	Energy Costs																-5,986,000
	Power Transmission Costs															875,000	
	O &M Costs																37,000
6453+00	122.22	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	$20,164,038	$23,009,000	-$5,949,000
														Total:	$181,022,260	$56,584,565	$3,293,000
				Ave. Unit Cost Pipe =	281	$/lf								Total Construction Costs:	$237,606,825		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 18
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

7	***Colorado City - Honeymoon Trail Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	**110.50**	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	**1280**	4820										
00+00	Construction Costs..															19,765,097	
00+00	Energy Costs..																4,255,000
00+00	O &M Costs..																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	**110.50**	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	**1310**	5954										
1370+00	Construction Costs..															11,828,276	
1370+00	Energy Costs..																4,355,000
1370+00	O &M Costs..																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00..														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility..															500,000	
	HL=	**140**	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2678+00	50.72	60	5.63	0.1288	198	5190	5646	200			1.00	1.05	209		7,061,073		
2874+00	54.43	60	5.63	0.1288	198	5170	5621	200			1.00	1.05	208		4,081,009		
3026+00	57.31	60	5.63	0.1288	198	5150	5601	200			1.00	1.05	208		3,165,331		
3040+00	57.58	60	5.63	0.1288	236	5110	5599	250			1.01	1.05	251		351,819		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	**96.69**	cfs														
3184+00	60.30	60	4.92	0.0986	269	4900	5585	300			1.01	1.05	285		4,097,632		
3500+00	66.29	60	4.92	0.0986	337	4690	5554	400			1.00	1.05	355		11,225,743		
4066+00	77.01	60	4.92	0.0986	269	4810	5498	300			1.00	1.05	283		16,006,741		
4515+00	85.51	60	4.92	0.0986	198	5000	5454	200			1.00	1.05	209		9,363,825		
4602+00	87.16	60	4.92	0.0986	184	5220	5445	100			1.01	1.05	195		1,697,509		
4647+00	88.01	60	4.92	0.0986	184	5220	5441	100			1.00	1.05	193		867,127		
4818+00	91.25	60	4.92	0.0986	198	4970	5424	200			1.01	1.05	210		3,584,576		
4864+00	92.12	60	4.92	0.0986	198	4960	5419	200			1.00	1.05	208		958,339		
4950+00	93.75	60	4.92	0.0986	198	5040	5411	200			1.00	1.05	209		1,798,039		
5033+00	95.32	60	4.92	0.0986	198	4950	5403	200			1.01	1.05	209		1,736,641		
5101+00	96.61	60	4.92	0.0986	198	4940	5396	200			1.00	1.05	208		1,416,179		
5200+00	98.48	60	4.92	0.0986	198	4980	5386	200			1.00	1.05	209		2,064,433		
	Colorado City Alignment																
5216+00	98.79	60	4.92	0.0986	198	4930	5385	200			1.02	1.05	211		338,136		
5371+00	101.72	60	4.92	0.0986	269	4680	5369	300			1.01	1.05	285		4,414,004		
5860+00	110.98	60	4.92	0.0986	303	4530	5321	350			1.00	1.05	318		15,570,797		
	West Little Creek Alignment																
5993+00	113.50	60	4.92	0.0986	303	4530	5308	350			1.00	1.05	318		4,228,522		
	Pressure Reducing Facility..															500,000	
	HL=	**778**	ft	Reduction in pipeline head (pressure													
	Gravity Vents at 2 locations..															100,000	
	Peaking Reservoir..															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**154,844,213**	**33,575,565**	**9,242,000**

Table 18
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
7	***Colorado City - Honeymoon Trail Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
6032+00	114.24	60	4.92	0.0986	198	4100	4526	200			1.05	1.05	219		855,197		
6070+50	114.97	60	4.92	0.0986	337	3671	4522	400			1.05	1.05	373		1,437,114		
6070+50	Hurricane Cliffs Hydropower Facility																
	HL=	**851**	ft														
	Construction Costs															7,072,000	
	Energy Costs																-1,552,000
	Power Transmission Costs															875,000	
	O &M Costs																19,000
6566+00	124.36	60	4.92	0.0986	184	3500	3622	100			1.00	1.05	193		9,564,491		
6625+00	125.47	60	4.92	0.0986	269	3030	3616	300			1.04	1.05	294		1,731,898		
6625+00	Sand Hollow Hydropower Facility																
	HL=	**586**	ft														
	Construction Costs															5,909,000	
	Energy Costs																-1,072,000
	Power Transmission Costs															875,000	
	O &M Costs																13,000
6625+00	125.47	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$13,588,701**	**$14,731,000**	**-$2,592,000**
				Ave. Unit Cost Pipe =	**4.24**	$/lf/in-dia								Total:	**$168,432,913**	**$48,306,565**	**$6,650,000**
				Ave. Unit Cost Pipe =	**254**	$/lf								Total Construction Costs:	**$216,739,479**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
6032+00	114.24	75	9.45	0.2699	277	4100	4519	200			1.05	1.05	306		1,193,199		
6070+50	114.97	75	9.45	0.2699	484	3671	4509	400			1.05	1.05	536		2,062,464		
6070+50	Hurricane Cliffs Hydropower Facility																
	HL=	**838**	ft														
	Construction Costs															16,853,000	
	Energy Costs																-3,030,000
	Power Transmission Costs															875,000	
	O &M Costs																56,000
6566+00	124.36	75	9.45	0.2699	245	3500	3537	50			1.00	1.05	258		12,788,225		
6625+00	125.47	75	9.45	0.2699	327	3030	3521	250			1.04	1.05	357		2,103,724		
6625+00	Sand Hollow Hydropower Facility																
	HL=	**491**	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																33,000
6625+00	125.47	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$18,147,612**	**$31,906,000**	**-$4,715,000**
														Total:	**$172,991,825**	**$65,481,565**	**$4,527,000**
				Ave. Unit Cost Pipe =	**261**	$/lf								Total Construction Costs:	**$238,473,390**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
6032+00	114.24	60	4.92	0.0986	198	4100	4526	200			1.05	1.05	219		855,197		
6070+50	114.97	60	4.92	0.0986	337	3671	4522	400			1.05	1.05	373		1,437,114		
6566+00	124.36	60	4.92	0.0986	372	3500	4474	450			1.00	1.05	392		19,403,228		
6625+00	125.47	60	4.92	0.0986	519	3030	4468	650			1.04	1.05	567		3,343,397		
6625+00	Sand Hollow Hydropower Facility																
	HL=	**1438**	ft														
	Construction Costs															8,859,000	
	Energy Costs																-2,624,000
	Power Transmission Costs															875,000	
	O &M Costs																32,000
6625+00	125.47	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	**$25,038,936**	**$9,734,000**	**-$2,592,000**
				Ave. Unit Cost Pipe =	**4.53**	$/lf/in-dia								Total:	**$179,883,149**	**$43,309,565**	**$6,650,000**
				Ave. Unit Cost Pipe =	**272**	$/lf								Total Construction Costs:	**$223,192,714**		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
6032+00	114.24	75	9.45	0.2699	277	4100	4519	200			1.05	1.05	306		1,193,199		
6070+50	114.97	75	9.45	0.2699	484	3671	4509	400			1.05	1.05	536		2,062,464		
6566+00	124.36	75	9.45	0.2699	484	3500	4375	400			1.00	1.05	509		25,221,834		
6625+00	125.47	75	9.45	0.2699	708	3030	4359	600			1.04	1.05	773		4,558,054		
6625+00	Sand Hollow Hydropower Facility																
	HL=	**1329**	ft														
	Construction Costs															20,404,000	
	Energy Costs																-4,878,000
	Power Transmission Costs															875,000	
	O &M Costs																90,000
6625+00	125.47	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$33,035,551**	**$21,279,000**	**-$4,788,000**
														Total:	**$187,879,764**	**$54,854,565**	**$4,454,000**
				Ave. Unit Cost Pipe =	**284**	$/lf								Total Construction Costs:	**$242,734,329**		

Notes.

1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 19
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

8	*Pipe Springs - West Little Creek Alignment, 2 PS's, Hydro*														*80,000*	*AF/Yr*	
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs															19,765,097	
00+00	Energy Costs																4,255,000
00+00	O &M Costs																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs															11,828,276	
1370+00	Energy Costs																4,355,000
1370+00	O &M Costs																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2310+00	43.75	60	5.63	0.1288	198	5450	5833	200			1.03	1.05	215		64,480		
2340+00	44.32	60	5.63	0.1288	198	5450	5829	200		0.3	1.00	1.05	227		681,026		
2678+00	50.72	60	5.63	0.1288	269	5190	5786	300			1.00	1.05	284		9,585,334		
2874+00	54.43	60	5.63	0.1288	269	5170	5761	300			1.00	1.05	283		5,539,928		
3026+00	57.31	60	5.63	0.1288	269	5150	5741	300			1.00	1.05	283		4,296,905		
3040+00	57.58	60	5.63	0.1288	269	5110	5739	300			1.01	1.05	287		401,118		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3165+00	59.94	60	4.92	0.0986	337	4920	5727	400			1.01	1.05	357		4,459,391		
3500+00	66.29	60	4.92	0.0986	372	4690	5694	450			1.00	1.05	392		13,140,527		
3701+00	70.09	60	4.92	0.0986	372	4640	5674	450			1.00	1.05	391		7,867,156		
3756+00	71.14	60	4.92	0.0986	408	4630	5669	500			1.00	1.05	429		2,358,711		
4072+00	77.12	60	4.92	0.0986	337	4830	5637	400			1.00	1.05	355		11,223,979		
4300+00	81.44	60	4.92	0.0986	303	4920	5615	350			1.00	1.05	319		7,263,187		
4556+00	86.29	60	4.92	0.0986	269	5010	5590	300			1.00	1.05	283		7,244,837		
4590+00	86.93	60	4.92	0.0986	198	5160	5586	200			1.02	1.05	213		723,009		
	Pipe Springs - West Little Creek Alignment																
4595+00	87.03	60	4.92	0.0986	198	5240	5586	200			1.08	1.05	224		112,070		
4602+00	87.16	60	4.92	0.0986	184	5430	5585	100			1.13	1.05	217		152,095		
4742+00	89.81	60	4.92	0.0986	184	5230	5571	150			1.01	1.05	194		2,716,929		
4864+00	92.12	60	4.92	0.0986	198	5210	5559	200			1.00	1.05	208		2,541,005		
5013+00	94.94	60	4.92	0.0986	184	5200	5545	150			1.00	1.05	193		2,872,117		
5116+00	96.89	60	4.92	0.0986	184	5190	5534	150			1.00	1.05	193		1,985,720		
5173+00	97.97	60	4.92	0.0986	198	5180	5529	200			1.00	1.05	208		1,187,259		
5304+00	100.45	60	4.92	0.0986	269	4930	5516	300			1.01	1.05	285		3,735,966		
5341+00	101.16	60	4.92	0.0986	269	4930	5512	300			1.00	1.05	283		1,045,270		
5362+00	101.55	60	4.92	0.0986	269	4930	5510	300			1.00	1.05	283		593,261		
5514+00	104.43	60	4.92	0.0986	337	4680	5495	400			1.01	1.05	357		5,425,950		
5612+00	106.29	60	4.92	0.0986	408	4440	5486	500			1.01	1.05	434		4,250,083		
5670+00	107.39	60	4.92	0.0986	408	4430	5480	500			1.00	1.05	429		2,487,251		
5770+00	109.28	60	4.92	0.0986	372	4520	5470	450			1.00	1.05	393		3,926,701		
5970+00	113.07	60	4.92	0.0986	337	4640	5450	400			1.00	1.05	355		7,102,622		
6142+00	116.33	60	4.92	0.0986	303	4718	5433	350			1.00	1.05	319		5,480,849		
	Pressure Reducing Facility															500,000	
	HL=	715	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations															100,000	
	Peaking Reservoir															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**180,586,984**	**33,075,565**	**9,242,000**

8 *Pipe Springs - West Little Creek Alignment, 2 PS's, Hydro* — *80,000 AF/Yr*

Manning's "n" = 0.0110

Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6220+00	117.80	60	4.92	0.0986		3560	4715										
6220+00	Hurricane Cliffs Hydropower Facility																
	HL=	1155	ft														
	Construction Costs															8,051,000	
	Energy Costs																-2,106,000
	Power Transmission Costs															355,114	
	O &M Costs																26,000
6310+00	119.51	60	4.92	0.0986	184	3500	3551	50			1.00	1.05	193		1,740,025		
6370+00	120.64	60	4.92	0.0986	236	3030	3545	250			1.04	1.05	257		1,543,839		
6370+00	Sand Hollow Hydropower Facility																
	HL=	515	ft														
	Construction Costs															5,509,000	
	Energy Costs																-924,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6370+00	120.64	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	$8,553,864	$14,790,114	-$2,993,000
				Ave. Unit Cost Pipe =	4.95	$/lf/in-dia								Total:	$189,140,847	$47,865,679	$6,249,000
				Ave. Unit Cost Pipe =	297	$/lf								Total Construction Costs:	$237,006,526		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6220+00	117.80	75	9.45	0.2699		3560	4709										
6220+00	Hurricane Cliffs Hydropower Facility																
	HL=	1149	ft														
	Construction Costs															19,241,000	
	Energy Costs																-4,213,000
	Power Transmission Costs															355,114	
	O &M Costs																78,000
6310+00	119.51	75	9.45	0.2699	245	3500	3536	50			1.00	1.05	259		2,326,504		
6370+00	120.64	75	9.45	0.2699	327	3030	3520	250			1.04	1.05	356		2,138,065		
6370+00	Sand Hollow Hydropower Facility																
	HL=	490	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6370+00	120.64	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	$10,334,569	$33,774,114	-$5,898,000
														Total:	$190,921,553	$66,849,679	$3,344,000
				Ave. Unit Cost Pipe =	300	$/lf								Total Construction Costs:	$257,771,231		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6220+00	117.80	60	4.92	0.0986		3560	4715										
6310+00	119.51	60	4.92	0.0986	445	3500	4706	550			1.00	1.05	468		4,214,525		
6370+00	120.64	60	4.92	0.0986	597	3030	4700	750			1.04	1.05	651		3,905,613		
6370+00	Sand Hollow Hydropower Facility																
	HL=	1670	ft														
	Construction Costs															9,466,000	
	Energy Costs																-3,067,000
	Power Transmission Costs															875,000	
	O &M Costs																38,000
6370+00	120.64	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	$13,390,137	$10,341,000	-$3,029,000
				Ave. Unit Cost Pipe =	5.08	$/lf/in-dia								Total:	$193,977,121	$43,416,565	$6,213,000
				Ave. Unit Cost Pipe =	305	$/lf								Total Construction Costs:	$237,393,686		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6220+00	117.80	75	9.45	0.2699		3560	4709										
6310+00	119.51	75	9.45	0.2699	650	3500	4685	550			1.00	1.05	685		6,167,598		
6370+00	120.64	75	9.45	0.2699	887	3030	4669	750			1.04	1.05	967		5,804,177		
6370+00	Sand Hollow Hydropower Facility																
	HL=	1639	ft														
	Construction Costs															22,134,000	
	Energy Costs																-5,986,000
	Power Transmission Costs															875,000	
	O &M Costs																37,000
6370+00	120.64	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	$17,841,776	$23,009,000	-$5,949,000
														Total:	$198,428,759	$56,084,565	$3,293,000
				Ave. Unit Cost Pipe =	312	$/lf								Total Construction Costs:	$254,513,325		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 20
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

9	**Pipe Springs - Honeymoon Trail Alignment, 2 PS's, Hydro**													**80,000**	**AF/Yr**		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
	Q=	**110.50**	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	**1280**	4820										
00+00	Construction Costs......															19,765,097	
00+00	Energy Costs......																4,255,000
00+00	O &M Costs......																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	**110.50**	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	**1310**	5954										
1370+00	Construction Costs......															11,828,276	
1370+00	Energy Costs......																4,355,000
1370+00	O &M Costs......																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00......														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2310+00	43.75	60	5.63	0.1288	198	5450	5833	200			1.03	1.05	215		64,480		
2340+00	44.32	60	5.63	0.1288	198	5450	5829	200		0.3	1.00	1.05	227		681,026		
2678+00	50.72	60	5.63	0.1288	269	5190	5786	300			1.00	1.05	284		9,585,334		
2874+00	54.43	60	5.63	0.1288	269	5170	5761	300			1.00	1.05	283		5,539,928		
3026+00	57.31	60	5.63	0.1288	269	5150	5741	300			1.00	1.05	283		4,296,905		
3040+00	57.58	60	5.63	0.1288	269	5110	5739	300			1.01	1.05	287		401,118		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	**96.69**	cfs														
3165+00	59.94	60	4.92	0.0986	337	4920	5727	400			1.01	1.05	357		4,459,391		
3500+00	66.29	97	1.90	0.0077	372	4690	5724	450			1.00	1.05	392		13,140,527		
3701+00	70.09	60	4.92	0.0986	408	4640	5704	500			1.00	1.05	429		8,622,895		
3756+00	71.14	60	4.92	0.0986	408	4630	5699	500			1.00	1.05	429		2,358,711		
4072+00	77.12	60	4.92	0.0986	337	4830	5668	400			1.00	1.05	355		11,223,979		
4300+00	81.44	60	4.92	0.0986	303	4920	5645	350			1.00	1.05	319		7,263,187		
4556+00	86.29	60	4.92	0.0986	269	5010	5620	300			1.00	1.05	283		7,244,837		
4590+00	86.93	60	4.92	0.0986	198	5160	5617	200			1.02	1.05	213		723,009		
	Pipe Springs - West Little Creek Alignment																
4595+00	87.03	60	4.92	0.0986	198	5240	5616	200			1.08	1.05	224		112,070		
4602+00	87.16	60	4.92	0.0986	184	5430	5616	100			1.13	1.05	217		152,095		
4742+00	89.81	60	4.92	0.0986	198	5230	5602	200			1.01	1.05	210		2,934,257		
4864+00	92.12	60	4.92	0.0986	198	5210	5590	200			1.00	1.05	208		2,541,005		
5013+00	94.94	60	4.92	0.0986	198	5200	5575	200			1.00	1.05	208		3,101,858		
5116+00	96.89	60	4.92	0.0986	198	5190	5565	200			1.00	1.05	208		2,144,559		
5173+00	97.97	60	4.92	0.0986	198	5180	5559	200			1.00	1.05	208		1,187,259		
5304+00	100.45	60	4.92	0.0986	269	4930	5546	300			1.01	1.05	285		3,735,966		
5341+00	101.16	60	4.92	0.0986	269	4930	5543	300			1.00	1.05	283		1,045,270		
5362+00	101.55	60	4.92	0.0986	269	4930	5541	300			1.00	1.05	283		593,261		
5514+00	104.43	60	4.92	0.0986	337	4680	5526	400			1.01	1.05	357		5,425,950		
5612+00	106.29	60	4.92	0.0986	408	4440	5516	500			1.01	1.05	434		4,250,083		
5670+00	107.39	60	4.92	0.0986	408	4430	5510	500			1.00	1.05	429		2,487,251		
5770+00	109.28	60	4.92	0.0986	372	4520	5500	450			1.00	1.05	393		3,926,701		
5891+00	111.57	60	4.92	0.0986	372	4530	5488	450			1.00	1.05	391		4,732,024		
	Pressure Reducing Facility......															500,000	
	HL=	**958**	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations......															100,000	
	Peaking Reservoir......															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**174,097,184**	**33,075,565**	**9,242,000**

Table 20
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

9	Pipe Springs - Honeymoon Trail Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
5947+00	112.63	60	4.92	0.0986	198	4100	4524	200			1.04	1.05	216		1,209,324		
5988+00	113.41	60	4.92	0.0986	337	3671	4520	400			1.05	1.05	372		1,525,748		
5988+00	Hurricane Cliffs Hydropower Facility																
	HL=	849	ft														
	Construction Costs															7,072,000	
	Energy Costs																-1,552,000
	Power Transmission Costs															875,000	
	O &M Costs																19,000
6484+00	122.80	60	4.92	0.0986	184	3500	3622	100			1.00	1.05	193		9,574,126		
6543+00	123.92	60	4.92	0.0986	269	3030	3616	300			1.04	1.05	294		1,731,898		
6543+00	Sand Hollow Hydropower Facility																
	HL=	586	ft														
	Construction Costs															5,909,000	
	Energy Costs																-1,072,000
	Power Transmission Costs															875,000	
	O &M Costs																13,000
6543+00	123.92	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	$14,041,096	$14,731,000	-$2,592,000
				Ave. Unit Cost Pipe =	4.79	$/lf/in-dia								Total:	$188,138,281	$47,806,565	$6,650,000
				Ave. Unit Cost Pipe =	288	$/lf								Total Construction Costs:	$235,944,846		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
5947+00	112.63	75	9.45	0.2699	277	4100	4515	200			1.04	1.05	301		1,687,288		
5988+00	113.41	75	9.45	0.2699	484	3671	4504	400			1.05	1.05	534		2,189,667		
5988+00	Hurricane Cliffs Hydropower Facility																
	HL=	833	ft														
	Construction Costs															16,853,000	
	Energy Costs																-3,030,000
	Power Transmission Costs															875,000	
	O &M Costs																56,000
6484+00	122.80	75	9.45	0.2699	245	3500	3537	50			1.00	1.05	258		12,801,107		
6543+00	123.92	75	9.45	0.2699	327	3030	3521	250			1.04	1.05	357		2,103,724		
6543+00	Sand Hollow Hydropower Facility																
	HL=	491	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																33,000
6543+00	123.92	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	$18,781,786	$31,906,000	-$4,715,000
														Total:	$192,878,970	$64,981,565	$4,527,000
				Ave. Unit Cost Pipe =	295	$/lf								Total Construction Costs:	$257,860,535		
Base Load Hydropower Option at Sand Hollow Reservoir																	
5947+00	112.63	60	4.92	0.0986	303	4100	4870	350			1.01	1.05	320		19,398,291		
5988+00	113.41	60	4.92	0.0986	445	3671	4866	550			1.05	1.05	491		2,011,205		
6484+00	122.80	60	4.92	0.0986	482	3500	4817	600			1.00	1.05	507		25,125,691		
6543+00	123.92	60	4.92	0.0986	637	3030	4811	800			1.04	1.05	695		4,099,135		
6543+00	Sand Hollow Hydropower Facility																
	HL=	1781	ft														
	Construction Costs															9,743,000	
	Energy Costs																-3,289,000
	Power Transmission Costs															875,000	
	O &M Costs																40,000
6543+00	123.92	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	$50,634,322	$10,618,000	-$3,249,000
				Ave. Unit Cost Pipe =	5.72	$/lf/in-dia								Total:	$224,731,506	$43,693,565	$5,993,000
				Ave. Unit Cost Pipe =	343	$/lf								Total Construction Costs:	$268,425,071		
Peak Load Hydropower Option at Sand Hollow Reservoir																	
5947+00	112.63	75	9.45	0.2699	378	4100	4766	300			1.01	1.05	400		24,225,641		
5988+00	113.41	75	9.45	0.2699	594	3671	4755	500			1.05	1.05	655		2,687,305		
6484+00	122.80	75	9.45	0.2699	594	3500	4621	500			1.00	1.05	625		30,985,105		
6543+00	123.92	75	9.45	0.2699	826	3030	4606	700			1.04	1.05	902		5,319,917		
6543+00	Sand Hollow Hydropower Facility																
	HL=	1576	ft														
	Construction Costs															21,782,000	
	Energy Costs																-5,765,000
	Power Transmission Costs															875,000	
	O &M Costs																106,000
6543+00	123.92	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	$63,217,969	$22,657,000	-$5,659,000
														Total:	$237,315,153	$55,732,565	$3,583,000
				Ave. Unit Cost Pipe =	363	$/lf								Total Construction Costs:	$293,047,718		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 21
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

10	South Kaibab - Honeymoon Trail Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs..........															19,765,097	
00+00	Energy Costs..........																4,255,000
00+00	O &M Costs..........																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs..........															11,828,276	
1370+00	Energy Costs..........																4,355,000
1370+00	O &M Costs..........																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00..........														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility..........															500,000	
	HL=	140	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2370+00	44.89	60	5.63	0.1288	184	5450	5685	150			1.00	1.05	193		578,085		
	South Kaibab Alignment																
2380+00	45.08	60	5.63	0.1288	184	5460	5684	100			1.00	1.05	194		193,656		
2396+00	45.38	60	5.63	0.1288	184	5456	5682	100			1.00	1.05	193		308,697		
2706+00	51.25	60	5.63	0.1288	198	5190	5642	200			1.00	1.05	209		6,478,986		
2735+00	51.80	60	5.63	0.1288	236	5130	5638	250			1.01	1.05	250		725,971		
2735+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3335+00	63.16	60	4.92	0.0986	198	5130	5579	200			1.00	1.05	208		12,486,515		
3350+00	63.45	60	4.92	0.0986	198	5120	5578	200			1.00	1.05	209		313,202		
3370+00	63.83	60	4.92	0.0986	198	5120	5576	200			1.00	1.05	208		416,217		
3523+00	66.72	60	4.92	0.0986	198	5100	5561	200			1.00	1.05	208		3,186,142		
3673+00	69.56	60	4.92	0.0986	269	4860	5546	300			1.01	1.05	285		4,271,345		
3751+00	71.04	60	4.92	0.0986	337	4620	5538	400			1.02	1.05	359		2,803,916		
3765+00	71.31	60	4.92	0.0986	337	4620	5537	400			1.00	1.05	354		495,699		
3780+00	71.59	60	4.92	0.0986	337	4620	5535	400			1.00	1.05	354		531,106		
3795+00	71.88	60	4.92	0.0986	337	4620	5534	400			1.00	1.05	354		531,106		
4260+00	80.68	60	4.92	0.0986	269	4800	5488	300			1.00	1.05	283		13,161,897		
4630+00	87.69	60	4.92	0.0986	198	5000	5452	200			1.00	1.05	209		7,720,801		
4695+00	88.92	60	4.92	0.0986	184	5220	5445	100			1.02	1.05	196		1,273,537		
5007+00	94.83	60	4.92	0.0986	184	5190	5414	100			1.00	1.05	193		6,014,969		
5062+00	95.87	60	4.92	0.0986	184	5180	5409	100			1.00	1.05	193		1,060,785		
5085+00	96.31	60	4.92	0.0986	184	5180	5407	100			1.00	1.05	193		443,198		
5099+00	96.57	60	4.92	0.0986	184	5180	5405	100			1.00	1.05	193		269,773		
5140+00	97.35	60	4.92	0.0986	184	5130	5401	150			1.01	1.05	194		794,852		
	Pipe Springs Alignment																
5196+00	98.41	60	4.92	0.0986	184	5170	5396	100			1.00	1.05	193		1,082,938		
5310+00	100.57	60	4.92	0.0986	184	5160	5385	100			1.00	1.05	193		2,197,685		
5464+00	103.48	60	4.92	0.0986	198	4910	5369	200			1.01	1.05	210		3,230,781		
5626+00	106.55	60	4.92	0.0986	303	4660	5353	350			1.01	1.05	320		5,190,120		
5734+00	108.60	60	4.92	0.0986	372	4420	5343	450			1.01	1.05	395		4,268,533		
5785+00	109.56	60	4.92	0.0986	372	4410	5338	450			1.00	1.05	391		1,995,620		
5870+00	111.17	60	4.92	0.0986	337	4510	5329	400			1.01	1.05	356		3,027,251		
	Honeymoon Trail Alignment																
5993+30	113.51	60	4.92	0.0986	303	4530	5317	350			1.00	1.05	318		3,923,304		
	Pressure Reducing Facility..........															500,000	
	HL=	787	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations..........															100,000	
	Peaking Reservoir..........															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	149,793,421	33,575,565	9,242,000

Table 21
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

10	***South Kaibab - Honeymoon Trail Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
6040+00	114.39	60	3.06	0.0380	198	4100	4528	200			1.05	1.05	217		1,015,625		
6086+80	115.28	60	3.06	0.0380	337	3671	4526	400			1.04	1.05	370		1,731,333		
6086+80	Hurricane Cliffs Hydropower Facility																
	HL=	855	ft														
	Construction Costs															7,072,000	
	Energy Costs																-1,552,000
	Power Transmission Costs															875,000	
	O &M Costs																19,000
6580+00	124.62	60	3.06	0.0380	184	3500	3652	100			1.00	1.05	193		9,520,172		
6640+00	125.76	60	3.06	0.0380	269	3030	3650	300			1.04	1.05	293		1,760,169		
6640+00	Sand Hollow Hydropower Facility																
	HL=	620	ft														
	Construction Costs															6,061,000	
	Energy Costs																-1,109,000
	Power Transmission Costs															875,000	
	O &M Costs																14,000
6640+00	125.76	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$14,027,299**	**$14,883,000**	**-$2,628,000**
				Ave. Unit Cost Pipe =	**4.11**	$/lf/in-dia								Total:	**$163,820,720**	**$48,458,565**	**$6,614,000**
				Ave. Unit Cost Pipe =	**247**	$/lf								Total Construction Costs:	**$212,279,285**		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
6040+00	114.39	75	9.45	0.2699	277	4100	4517	200			1.05	1.05	303		1,417,034		
6086+80	115.28	75	9.45	0.2699	484	3671	4505	400			1.04	1.05	531		2,484,710		
6086+80	Hurricane Cliffs Hydropower Facility																
	HL=	834	ft														
	Construction Costs															16,853,000	
	Energy Costs																-3,030,000
	Power Transmission Costs															875,000	
	O &M Costs																56,000
6580+00	124.62	75	9.45	0.2699	245	3500	3538	50			1.00	1.05	258		12,728,967		
6640+00	125.76	75	9.45	0.2699	327	3030	3522	250			1.04	1.05	356		2,138,065		
6640+00	Sand Hollow Hydropower Facility																
	HL=	492	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																33,000
6640+00	125.76	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$18,768,775**	**$31,906,000**	**-$4,715,000**
														Total:	**$168,562,197**	**$65,481,565**	**$4,527,000**
				Ave. Unit Cost Pipe =	**254**	$/lf								Total Construction Costs:	**$234,043,762**		
Base Load Hydropower Option at Sand Hollow Reservoir																	
6040+00	114.39	60	3.06	0.0380	198	4100	4528	200			1.05	1.05	217		1,015,625		
6086+80	115.28	60	3.06	0.0380	337	3671	4526	400			1.04	1.05	370		1,731,333		
6580+00	124.62	60	3.06	0.0380	372	3500	4508	450			1.00	1.05	392		19,313,317		
6640+00	125.76	60	3.06	0.0380	519	3030	4505	650			1.04	1.05	566		3,397,974		
6640+00	Sand Hollow Hydropower Facility																
	HL=	1475	ft														
	Construction Costs															8,966,000	
	Energy Costs																-2,698,000
	Power Transmission Costs															875,000	
	O &M Costs																33,000
6640+00	125.76	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	**$25,458,249**	**$9,841,000**	**-$2,665,000**
				Ave. Unit Cost Pipe =	**4.40**	$/lf/in-dia								Total:	**$175,251,671**	**$43,416,565**	**$6,577,000**
				Ave. Unit Cost Pipe =	**264**	$/lf								Total Construction Costs:	**$218,668,236**		

Table 21
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

10	***South Kaibab - Honeymoon Trail Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Peak Load Hydropower Option at Sand Hollow Reservoir																	
6040+00	114.39	75	9.45	0.2699	277	4100	4517	200			1.05	1.05	303		1,417,034		
6086+80	115.28	75	9.45	0.2699	484	3671	4505	400			1.04	1.05	531		2,484,710		
6580+00	124.62	75	9.45	0.2699	484	3500	4372	400			1.00	1.05	509		25,104,961		
6640+00	125.76	75	9.45	0.2699	708	3030	4355	600			1.04	1.05	772		4,632,458		
6640+00	Sand Hollow Hydropower Facility																
	HL=	**1325**	ft														
	Construction Costs............															20,404,000	
	Energy Costs............																-4,878,000
	Power Transmission Costs............															875,000	
	O &M Costs............																90,000
6640+00	125.76	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$33,639,163**	**$21,279,000**	**-$4,788,000**
														Total:	**$183,432,585**	**$54,854,565**	**$4,454,000**
				Ave. Unit Cost Pipe =	**276**	$/lf								Total Construction Costs:	**$238,287,150**		
Notes.																	
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus																	
variable length line between the two powerhouses, if applicable																	

Table 22
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

11	***South Kaibab - West Little Creek Alignment, 2 PS's, Hydro***													***80,000***	***AF/Yr***		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	**110.50**	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	**1280**	4820										
00+00	Construction Costs................															19,765,097	
00+00	Energy Costs................																4,255,000
00+00	O &M Costs................																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	**110.50**	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	**1310**	5954										
1370+00	Construction Costs................															11,828,276	
1370+00	Energy Costs................																4,355,000
1370+00	O &M Costs................																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00................														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2307+00	Pressure Reducing Facility................															500,000	
	HL=	**140**	ft	Reduction in pipeline head (pressure)													
2310+00	43.75	60	5.63	0.1288	184	5450	5693	150			1.03	1.05	199		59,704		
2340+00	44.32	60	5.63	0.1288	184	5450	5689	150		0.3	1.00	1.05	212		634,785		
2370+00	44.89	60	5.63	0.1288	184	5450	5685	150			1.00	1.05	193		578,085		
	South Kaibab Alignment																
2380+00	45.08	60	5.63	0.1288	184	5460	5684	100			1.00	1.05	194		193,656		
2396+00	45.38	60	5.63	0.1288	184	5456	5682	100			1.00	1.05	193		308,697		
2706+00	51.25	60	5.63	0.1288	198	5190	5642	200			1.00	1.05	209		6,478,986		
2735+00	51.80	**60**	5.63	0.1288	236	5130	5638	250			1.01	1.05	250		725,971		
2735+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3335+00	63.16	60	4.92	0.0986	198	5130	5579	200			1.00	1.05	208		12,486,515		
3350+00	63.45	60	4.92	0.0986	198	5120	5578	200			1.00	1.05	209		313,202		
3370+00	63.83	60	4.92	0.0986	198	5120	5576	200			1.00	1.05	208		416,217		
3523+00	66.72	60	4.92	0.0986	198	5100	5561	200			1.00	1.05	208		3,186,142		
3673+00	69.56	60	4.92	0.0986	269	4860	5546	300			1.01	1.05	285		4,271,345		
3751+00	71.04	60	4.92	0.0986	337	4620	5538	400			1.02	1.05	359		2,803,916		
3765+00	71.31	60	4.92	0.0986	337	4620	5537	400			1.00	1.05	354		495,699		
3780+00	71.59	60	4.92	0.0986	337	4620	5535	400			1.00	1.05	354		531,106		
3795+00	71.88	60	4.92	0.0986	337	4620	5534	400			1.00	1.05	354		531,106		
4260+00	80.68	60	4.92	0.0986	269	4800	5488	300			1.00	1.05	283		13,161,897		
4630+00	87.69	60	4.92	0.0986	198	5000	5452	200			1.00	1.05	209		7,720,801		
4695+00	88.92	60	4.92	0.0986	184	5220	5445	100			1.02	1.05	196		1,273,537		
5007+00	94.83	60	4.92	0.0986	184	5190	5414	100			1.00	1.05	193		6,014,969		
5062+00	95.87	60	4.92	0.0986	184	5180	5409	100			1.00	1.05	193		1,060,785		
5085+00	96.31	60	4.92	0.0986	184	5180	5407	100			1.00	1.05	193		443,198		
5099+00	96.57	60	4.92	0.0986	184	5180	5405	100			1.00	1.05	193		269,773		
5140+00	97.35	60	4.92	0.0986	184	5130	5401	150			1.01	1.05	194		794,852		
	Pipe Springs Alignment																
5196+00	98.41	60	4.92	0.0986	184	5170	5396	100			1.00	1.05	193		1,082,938		
5310+00	100.57	60	4.92	0.0986	184	5160	5385	100			1.00	1.05	193		2,197,685		
5464+00	103.48	60	4.92	0.0986	198	4910	5369	200			1.01	1.05	210		3,230,781		
5626+00	106.55	60	4.92	0.0986	303	4660	5353	350			1.01	1.05	320		5,190,120		
5734+00	108.60	60	4.92	0.0986	372	4420	5343	450			1.01	1.05	395		4,268,533		
5785+00	109.56	60	4.92	0.0986	372	4410	5338	450			1.00	1.05	391		1,995,620		
5870+00	111.17	60	4.92	0.0986	337	4510	5329	400			1.01	1.05	356		3,027,251		
	West Little Creek Alignment																
6060+00	114.77	60	4.92	0.0986	269	4620	5311	300			1.00	1.05	283		5,383,116		
6261+50	118.59	60	4.92	0.0986	236	4718	5291	250			1.00	1.05	248		5,004,985		
	Pressure Reducing Facility................															500,000	
	HL=	**573**	ft	Reduction in pipeline head (pressure)													
	Gravity Vents at 2 locations................															100,000	
	Peaking Reservoir................															882,192	
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir at Hurricane Cliffs														Subtotals:	**156,258,218**	**33,575,565**	**9,242,000**

Table 22
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

11	South Kaibab - West Little Creek Alignment, 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
Base Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6283+50	119.01	60	4.92	0.0986		3560	4715										
6283+50	Hurricane Cliffs Hydropower Facility																
	HL=	1155	ft														
	Construction Costs															8,051,000	
	Energy Costs																-2,106,000
	Power Transmission Costs															434,422	
	O &M Costs																26,000
6405+00	121.31	60	3.06	0.0380	184	3500	3555	50			1.00	1.05	193		2,347,016		
6467+00	122.48	60	3.06	0.0380	236	3030	3553	250			1.04	1.05	257		1,593,430		
6467+00	Sand Hollow Hydropower Facility																
	HL=	523	ft														
	Construction Costs															5,663,000	
	Energy Costs																-961,000
	Power Transmission Costs															875,000	
	O &M Costs																12,000
6467+00	122.48	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	$9,210,446	$15,023,422	-$3,029,000
				Ave. Unit Cost Pipe =	4.26	$/lf/in-dia								Total:	$165,468,664	$48,598,987	$6,213,000
				Ave. Unit Cost Pipe =	256	$/lf								Total Construction Costs:	$214,067,651		
Peak Load Hydropower Option at Hurricane Cliffs and Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6283+50	119.01	75	9.45	0.2699		3560	4709										
6283+50	Hurricane Cliffs Hydropower Facility																
	HL=	1149	ft														
	Construction Costs															19,241,000	
	Energy Costs																-4,213,000
	Power Transmission Costs															434,422	
	O &M Costs																78,000
6405+00	121.31	75	9.45	0.2699	245	3500	3527	50			1.00	1.05	258		3,138,083		
6467+00	122.48	75	9.45	0.2699	327	3030	3510	250			1.04	1.05	356		2,206,743		
6467+00	Sand Hollow Hydropower Facility																
	HL=	480	ft														
	Construction Costs															13,303,000	
	Energy Costs																-1,774,000
	Power Transmission Costs															875,000	
	O &M Costs																11,000
6467+00	122.48	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	$11,214,827	$33,853,422	-$5,898,000
														Total:	$167,473,045	$67,428,987	$3,344,000
				Ave. Unit Cost Pipe =	259	$/lf								Total Construction Costs:	$234,902,032		
Base Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6283+50	119.01	60	4.92	0.0986		3560	4715										
6405+00	121.31	60	3.06	0.0380	445	3500	4710	550			1.00	1.05	468		5,684,722		
6467+00	122.48	60	3.06	0.0380	597	3030	4708	750			1.04	1.05	650		4,031,068		
6467+00	Sand Hollow Hydropower Facility																
	HL=	1678	ft														
	Construction Costs															9,466,000	
	Energy Costs																-3,067,000
	Power Transmission Costs															875,000	
	O &M Costs																38,000
6467+00	122.48	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 base load hydropower facility														Subtotals:	$14,985,790	$10,341,000	-$3,029,000
				Ave. Unit Cost Pipe =	4.41	$/lf/in-dia								Total:	$171,244,008	$43,916,565	$6,213,000
				Ave. Unit Cost Pipe =	265	$/lf								Total Construction Costs:	$215,160,573		

Table 22
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
11	**South Kaibab - West Little Creek Alignment, 2 PS's, Hydro**													**80,000**	**AF/Yr**		
Manning's "n" =				0.0110													
Peak Load Hydropower Option at Sand Hollow Reservoir																	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6283+50	119.01	75	9.45	0.2699		3560	4709										
6405+00	121.31	75	9.45	0.2699	650	3500	4676	550			1.00	1.05	685		8,319,107		
6467+00	122.48	75	9.45	0.2699	887	3030	4660	750			1.04	1.05	966		5,990,619		
6467+00	Sand Hollow Hydropower Facility																
	HL=	1630	ft														
	Construction Costs															22,134,000	
	Energy Costs																-5,986,000
	Power Transmission Costs															875,000	
	O &M Costs																37,000
6467+00	122.48	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 1 peak load hydropower facility														Subtotals:	**$20,179,725**	**$23,009,000**	**-$5,949,000**
														Total:	**$176,437,943**	**$56,584,565**	**$3,293,000**
				Ave. Unit Cost Pipe =	**273**	$/lf								Total Construction Costs:	**$233,022,508**		

Notes.

1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Table 23
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

12	Little Creek Mtn. Gould Res. Align., 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
	Q=	110.50	cfs	Lake Powell Low Elev			3540										
00+00	Lone Rock Pump Station				Max Lift =	1280	4820										
00+00	Construction Costs......															19,765,097	
00+00	Energy Costs......																4,255,000
00+00	O &M Costs......																395,000
175+00	3.31	60	5.63	0.1288	372	3875	4797	450			1.00	1.05	391		6,841,011		
468+00	8.86	60	5.63	0.1288	269	4070	4760	300		0.3	1.00	1.05	302		8,860,513		
547+00	10.36	60	5.63	0.1288	198	4290	4750	200		0.3	1.01	1.05	230		1,818,167		
650+00	12.31	60	5.63	0.1288	184	4450	4736	150		0.3	1.01	1.05	213		2,196,289		
711+00	13.47	60	5.63	0.1288	184	4500	4728	100			1.00	1.05	193		1,180,246		
1102+00	20.87	60	5.63	0.1288	184	4450	4678	100			1.00	1.05	193		7,539,185		
1246+00	23.60	60	5.63	0.1288	184	4430	4660	100			1.00	1.05	193		2,776,732		
1361+00	25.78	60	5.63	0.1288	184	4431	4645	100			1.00	1.05	193		2,215,991		
1370+00	25.95	60	5.63	0.1288	184	4432	4644	100			1.00	1.05	193		173,425		
	Q=	110.50	cfs														
1370+00	Cockscomb Pump Station				Max Lift =	1310	5954										
1370+00	Construction Costs......															11,828,276	
1370+00	Energy Costs......																4,355,000
1370+00	O &M Costs......																237,000
	Cockscomb Roadway, Tunnel, Shaft, & Pipeline Cost from Station 1361+00 to 1527+00......														8,030,000		
1527+00	28.92	60	5.63	0.1288		4598	5934										
1542+00	29.20	60	5.63	0.1288	337	5110	5932	400	0.8		1.16	1.05	468		702,662		
1555+00	29.45	60	5.63	0.1288	269	5340	5930	300	0.8		1.08	1.05	361		469,503		
1569+00	29.72	60	5.63	0.1288	198	5560	5929	200	0.8		1.08	1.05	278		389,311		
1616+00	30.61	60	5.63	0.1288	184	5760	5923	100	0.8		1.02	1.05	248		1,166,602		
1711+00	32.41	60	5.63	0.1288	198	5550	5910	200	0.8		1.01	1.05	261		2,482,827		
1825+00	34.56	60	5.63	0.1288	236	5390	5896	250	0.8		1.01	1.05	300		3,423,075		
2050+00	38.83	60	5.63	0.1288	198	5500	5867	200			1.00	1.05	209		4,693,875		
2197+00	41.61	60	5.63	0.1288	184	5690	5848	100			1.01	1.05	194		2,850,862		
2307+00	43.69	60	5.63	0.1288	198	5470	5834	200			1.01	1.05	210		2,311,973		
2310+00	43.75	60	5.63	0.1288	198	5450	5833	200			1.03	1.05	215		64,480		
2340+00	44.32	60	5.63	0.1288	198	5450	5829	200		0.3	1.00	1.05	227		681,026		
2678+00	50.72	60	5.63	0.1288	269	5190	5786	300			1.00	1.05	284		9,585,334		
2874+00	54.43	60	5.63	0.1288	269	5170	5761	300			1.00	1.05	283		5,539,928		
3026+00	57.31	60	5.63	0.1288	269	5150	5741	300			1.00	1.05	283		4,296,905		
3040+00	57.58	60	5.63	0.1288	269	5110	5739	300			1.01	1.05	287		401,118		
3040+00	Turnout to Kanab (10,000 AF)																
	Q=	96.69	cfs														
3184+00	60.30	60	4.92	0.0986	337	4900	5725	400			1.01	1.05	357		5,135,658		
3500+00	66.29	60	4.92	0.0986	372	4690	5694	450			1.00	1.05	392		12,393,889		
4066+00	77.01	60	4.92	0.0986	337	4810	5638	400			1.00	1.05	354		20,061,622		
4515+00	85.51	60	4.92	0.0986	269	5000	5594	300			1.00	1.05	283		12,711,297		
4602+00	87.16	60	4.92	0.0986	198	5220	5585	200			1.01	1.05	211		1,833,294		
4647+00	88.01	60	4.92	0.0986	198	5220	5581	200			1.00	1.05	208		936,489		
4818+00	91.25	60	4.92	0.0986	269	4970	5564	300			1.01	1.05	285		4,866,025		
4864+00	92.12	60	4.92	0.0986	269	4960	5559	300			1.00	1.05	283		1,300,936		
4950+00	93.75	60	4.92	0.0986	236	5040	5551	250			1.00	1.05	249		2,140,835		
5033+00	95.32	60	4.92	0.0986	269	4950	5543	300			1.01	1.05	284		2,357,472		
5101+00	96.61	60	4.92	0.0986	269	4940	5536	300			1.00	1.05	283		1,922,448		
5290+00	100.19	60	4.92	0.0986	269	4920	5517	300			1.00	1.05	283		5,342,174		
5461+00	103.43	60	4.92	0.0986	269	4890	5500	300			1.00	1.05	283		4,835,076		
	Little Creek Mountain Alignment																
5500+00	104.17	60	4.92	0.0986	269	4900	5497	300			1.00	1.05	283		1,103,182		
5700+00	107.95	60	4.92	0.0986	184	5255	5477	100			1.01	1.05	194		3,887,950		
5780+90	109.49	60	4.92	0.0986	184	5305	5469	100			1.00	1.05	193		1,563,711		
	Gravity Vents at 2 locations......															100,000	
	Peaking Reservoir......															882,192	
	HL=	0	ft	Loss in potential head at peaking reservo													
Total Construction and Annual Costs from Lone Rock through the Peaking Reservoir on Little Creek Mountain														Subtotals:	**163,083,099**	**32,575,565**	**9,242,000**

Table 23
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

Station (feet)	Station (miles)	Pipe Diam (in)	Vel. (fps)	HGL slope (%)	Base Pipe Cost ($/lf)	Ground Elev. (feet)	HGL Elev. (feet)	Press. Class (psi)	Add for Rock ($/lf/in)	Add for Grdwtr ($/lf/in)	Slope Mult.	Appurt Mult.	Unit Pipeline Cost ($/lf)	R/W Cost To Be Determined ($/lf)	Reach Cost ($)	Other Construction Costs ($)	Year 1 Annual Costs ($)
12	*Little Creek Mtn. Gould Res. Align., 2 PS's, Hydro*													*80,000*	*AF/Yr*		
Manning's "n" =				0.0110													
Base Load Hydropower Option at Little Creek Mtn., Hurricane Cliffs, and Sand Hollow Reservoir																	
5804+00	109.92	60	4.92	0.0986	198	5029	5467	200			1.06	1.05	220		508,640		
5807+20	109.98	60	4.92	0.0986	303	4760	5466	350			1.36	1.05	431		138,029		
5807+20	Little Creek Mountain Hydropower Facility																
	HL=	706	ft														
	Construction Costs......															6,463,000	
	Energy Costs......																-1,293,000
	Power Transmission Costs......															1,134,706	
	O &M Costs......																16,000
6000+00	113.64	60	4.92	0.0986	184	4450	4741	150			1.01	1.05	194		3,744,905		
6164+50	116.75	60	4.92	0.0986	184	4665	4725	50			1.01	1.05	194		3,190,478		
	HL=	60	ft	Loss in potential head at peaking reservoir													
	Peaking Reservoir......															882,192	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost......														5,270,000		
6286+50	119.06	60	4.92	0.0986		3560	4715										
6286+50	Hurricane Cliffs Hydropower Facility																
	HL=	1155	ft														
	Construction Costs......															8,051,000	
	Energy Costs......																-2,106,000
	Power Transmission Costs......															275,805	
	O &M Costs......																26,000
6388+00	120.98	60	4.92	0.0986	184	3510	3550	50			1.00	1.05	193		1,960,664		
6403+00	121.27	60	4.92	0.0986	236	3030	3549	250			1.15	1.05	285		427,024		
6403+00	Sand Hollow Hydropower Facility																
	HL=	519	ft														
	Construction Costs......															5,509,000	
	Energy Costs......																-924,000
	Power Transmission Costs......															875,000	
	O &M Costs......																11,000
6403+00	121.27	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 3 base load hydropower facilities														Subtotals:	$15,239,740	$23,190,703	-$4,270,000
				Ave. Unit Cost Pipe =	4.64	$/lf/in-dia								Total:	$178,322,840	$55,766,268	$4,972,000
				Ave. Unit Cost Pipe =	278	$/lf								Total Construction Costs:	$234,089,108		
Peak Load Hydropower Option at Little Creek Mtn., Hurricane Cliffs, and Sand Hollow Reservoir																	
5804+00	109.92	75	9.45	0.2699	277	5029	5463	200			1.06	3.05	892		2,061,425		
5807+20	109.98	75	9.45	0.2699	431	4760	5462	350			1.36	4.05	2366		756,978		
5807+20	Little Creek Mountain Hydropower Facility																
	HL=	700	ft														
	Construction Costs......															15,765,000	
	Energy Costs......																-2,587,000
	Power Transmission Costs......															1,134,706	
	O &M Costs......																48,000
6000+00	113.64	75	9.45	0.2699	245	4450	4710	150			1.01	1.05	260		5,007,134		
6164+50	116.75	75	9.45	0.2699	245	4665	4665	50			1.01	1.05	259		4,265,836		
	HL=	0	ft	Loss in potential head at peaking reservoir													
	Peaking Reservoir......															882,192	
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost......														5,870,000		
6286+50	119.06	75	9.45	0.2699		3560	4709										
6286+50	Hurricane Cliffs Hydropower Facility																
	HL=	1149	ft														
	Construction Costs......															19,241,000	
	Energy Costs......																-4,213,000
	Power Transmission Costs......															275,805	
	O &M Costs......																78,000
6388+00	120.98	75	9.45	0.2699	245	3510	3533	50			1.00	1.05	258		2,621,511		
6403+00	121.27	75	9.45	0.2699	327	3030	3529	250			1.15	1.05	394		591,386		
6403+00	Sand Hollow Hydropower Facility																
	HL=	499	ft														
	Construction Costs......															13,303,000	
	Energy Costs......																-1,774,000
	Power Transmission Costs......															875,000	
	O &M Costs......																33,000
6403+00	121.27	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 3 peak load hydropower facilities														Subtotals:	$21,174,269	$51,476,703	-$8,415,000
														Total:	$184,257,368	$84,052,268	$827,000
				Ave. Unit Cost Pipe =	288	$/lf								Total Construction Costs:	$268,309,636		

Table 23
Lake Powell Pipeline Feasibility Study
Opinion of Probable Cost

12	Little Creek Mtn. Gould Res. Align., 2 PS's, Hydro													80,000	AF/Yr		
Manning's "n" =				0.0110													
					Base				Add	Add			Unit	R/W Cost		Other	Year 1
		Pipe		HGL	Pipe	Ground	HGL	Press.	for	for	Slope	Appurt	Pipeline	To Be	Reach	Construction	Annual
Station	Station	Diam	Vel.	slope	Cost	Elev.	Elev.	Class	Rock	Grdwtr	Mult.	Mult.	Cost	Determined	Cost	Costs	Costs
(feet)	(miles)	(in)	(fps)	(%)	($/lf)	(feet)	(feet)	(psi)	($/lf/in)	($/lf/in)			($/lf)	($/lf)	($)	($)	($)
Base Load Hydropower Option at Little Creek Mtn. and Sand Hollow Reservoir																	
5804+00	109.92	60	4.92	0.0986	198	5029	5467	200			1.06	3.05	640		1,477,477		
5807+20	109.98	60	4.92	0.0986	303	4760	5466	350			1.36	4.05	1664		532,397		
5807+20	Little Creek Mountain Hydropower Facility																
	HL=	706	ft														
	Construction Costs															6,463,000	
	Energy Costs																-1,293,000
	Power Transmission Costs															1,134,706	
	O &M Costs																16,000
6000+00	113.64	60	4.92	0.0986	184	4450	4741	150			1.01	1.05	194		3,744,905		
6164+50	116.75	60	4.92	0.0986	184	4665	4725	50			1.01	1.05	194		3,190,478		
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,270,000		
6286+50	119.06	60	4.92	0.0986		3560	4715										
6388+00	120.98	60	4.92	0.0986	445	3510	4705	550			1.00	1.05	468		4,748,936		
6403+00	121.27	60	4.92	0.0986	597	3030	4703	750			1.15	1.05	720		1,080,288		
6403+00	Sand Hollow Hydropower Facility																
	HL=	1673	ft														
	Construction Costs															9,466,000	
	Energy Costs																-3,067,000
	Power Transmission Costs															875,000	
	O &M Costs																38,000
6403+00	121.27	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 base load hydropower facilities														Subtotals:	**$20,044,482**	**$17,938,706**	**-$4,306,000**
			Ave. Unit Cost Pipe =		**4.77**	$/lf/in-dia								Total:	**$183,127,581**	**$50,514,272**	**$4,936,000**
			Ave. Unit Cost Pipe =		**286**	$/lf								Total Construction Costs:	**$233,641,853**		
Peak Load Hydropower Option at Little Creek Mtn. and Sand Hollow Reservoir																	
5804+00	109.92	75	9.45	0.2699	277	5029	5463	200			1.06	3.05	892		2,061,425		
5807+20	109.98	75	9.45	0.2699	431	4760	5462	350			1.36	4.05	2366		756,978		
5807+20	Little Creek Mountain Hydropower Facility																
	HL=	700	ft														
	Construction Costs															15,765,000	
	Energy Costs																-2,587,000
	Power Transmission Costs															1,134,706	
	O &M Costs																48,000
6000+00	113.64	75	9.45	0.2699	245	4450	4710	150			1.01	1.05	260		5,007,134		
6164+50	116.75	75	9.45	0.2699	245	4665	4665	50			1.01	1.05	259		4,265,836		
	Hurricane Cliffs Tunnel, Shaft, & Pipeline Cost														5,870,000		
6286+50	119.06	75	9.45	0.2699		3560	4709										
6388+00	120.98	75	9.45	0.2699	650	3510	4682	550			1.00	1.05	685		6,949,664		
6403+00	121.27	75	9.45	0.2699	887	3030	4678	750			1.15	1.05	1070		1,605,429		
6403+00	Sand Hollow Hydropower Facility																
	HL=	1648	ft														
	Construction Costs															22,217,000	
	Energy Costs																-6,060,000
	Power Transmission Costs															875,000	
	O &M Costs																112,000
6403+00	121.27	Sand Hollow Reservoir				Elev =	3030										
Total Construction and Annual Costs for 2 peak load hydropower facilities														Subtotals:	**$26,516,465**	**$39,991,706**	**-$8,487,000**
														Total:	**$189,599,565**	**$72,567,272**	**$755,000**
			Ave. Unit Cost Pipe =		**296**	$/lf								Total Construction Costs:	**$262,166,836**		

Notes.
1. The transmission line is included above at a cost of $125,000 per mile installed. All options will have a 7 mile line from Sand Hollow to the load center plus variable length line between the two powerhouses, if applicable

Appendix 3.1 – Lone Rock Pumping Station

Figure 3-1.1 Lone Rock Pumping Station Location

Appendix 3.2 – Cockscomb

Figure 3.2-1 Cockscomb Highway Alternative 1

Figure 3.2-2 Cockscomb Highway Alternative 2 - Rock Excavation

Figure 3.2-3 Cockscomb Highway Alternative 3 – North Side

Figure 3.2-4 Cockscomb Highway Alternative 4 – Midway Cut

Figure 3.2-5 Cockscomb Highway Alternative 5 – Midway Fill South

Figure 3.2-6 Cockscomb Highway Alternative 6 – Midway Fill North

Figure 3.2-7 Cockscomb Highway Alternative 7 – Midway Fill South Near West Cut

Figure 3.2-8 Cockscomb Highway Alternative 8 – West Cut

Figure 3.2-9 Cockscomb Highway Alternative 9 – West Fill

Figure 3.2-10 Cockscomb East Portal – North View

Figure 3.2-11 Cockscomb East Portal – West View

Figure 3.2-12 Cockscomb East Portal North – North View

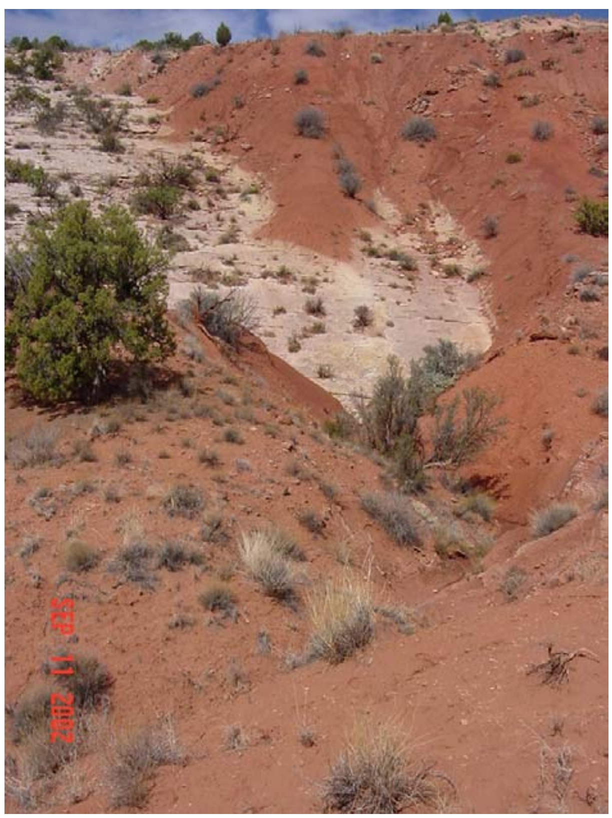


Figure 3.2-13 Cockscomb East Portal North – West View

Figure 3.2-14 Cockscomb East Portal and Pumping Station Site from Old Road Grade

Figure 3.2-15 Cockscomb – Typical of Portal Area on West Side

Appendix 3.3 – Hurricane Cliffs

Figure 3.3-1 Frog Hollow Alternative – Viewed East

Figure 3.3-2 Frog Hollow Alternative – Viewed Northeast

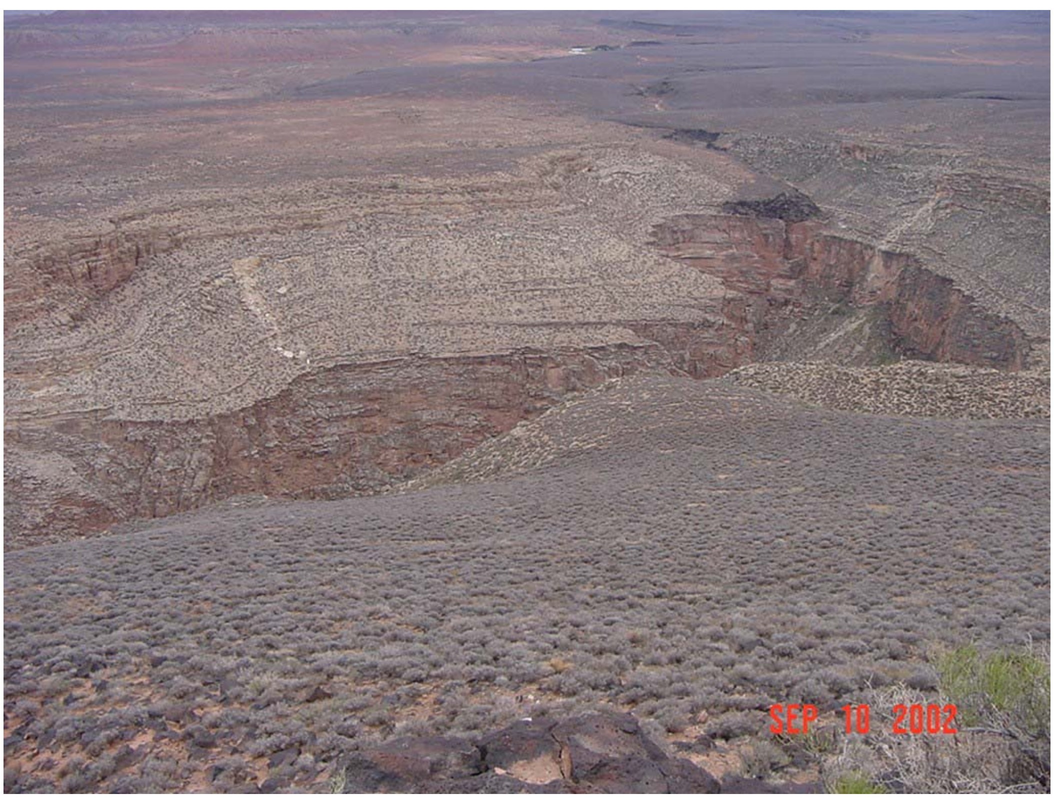


Figure 3.3-3 Frog Hollow From Mollies – Viewed East

Figure 3.3-4 Gould Springs to Willow Springs – Viewed From South

Figure 3.3-5 Gould Springs – Viewed East

Figure 3.3-6 Gould Springs Alternative

Figure 3.3-7 Gould Springs to Mollies Alternative – Viewed East

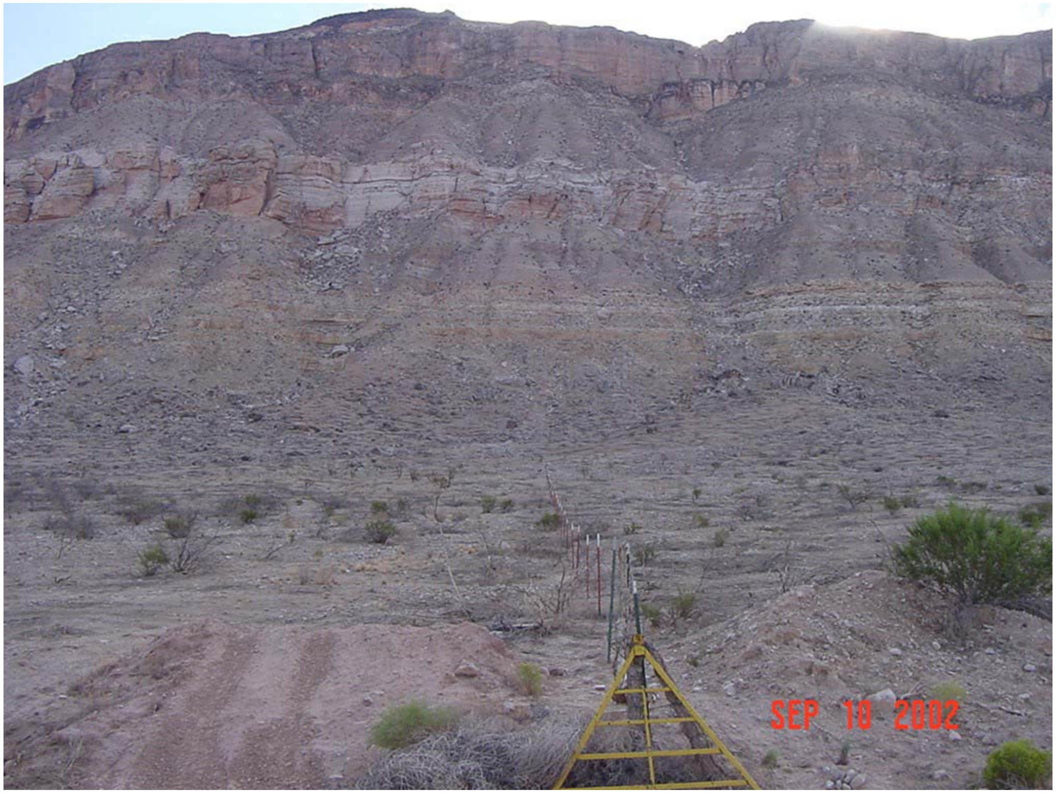


Figure 3.3-8 Grass Valley Alternative – Viewed East

Figure 3.3-9 Grass Valley Overview

Figure 3.3-10 Mollie 1 – Viewed East

Figure 3.3-11 Mollie 1 – Viewed West From Cliff

Figure 3.3-12 Mollie 2 and 3 and Gravel Pit

Figure 3.3-13 Mollies Alternatives – Viewed South

Figure 3.3-14 Penstock Options at Grass Valley

Figure 3.3-15 Steep Slopes at Mollies – Viewed South

Figure 3.3-16 Uniformity of Cliff at Goulds Spring Alternative

Figure 3.3-17 West Little Creek Alignment From Gould Reservoir Alignment – Viewed South

Figure 3.3-18 West Little Creek Alignment From Gould Reservoir Alignment – Viewed Southeast

Figure 3.3-19 3000 South Alternative – Viewed West

Appendix 3.4 – Honeymoon Trail

Figure 3.4-1 Fault at Honeymoon Trail

Figure 3.4-2 Historic Honeymoon Trail

Figure 3.4-3 Honeymoon Trail Alignment – Viewed From Cliffs

Figure 3.4-4 Honeymoon Trail Alignment – Viewed West

Figure 3.4-5 Honeymoon Trail Alignment – Viewed East From Base

Figure 3.4-6 Honeymoon Trail Alignment – Viewed East

Figure 3.4-7 Top of Honeymoon Trail

Figure 3.4-8 Open Cut or Penstock Alignment North of Honeymoon Trail

FINAL TUNNEL FEASIBILITY REPORT FOR
LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

by

Haley & Aldrich, Inc.
Denver, Colorado

for

Boyle Engineering Corporation
Denver, Colorado

File No. 28818-000
March 2003

17 March 2003
File No. 28818-000

Boyle Engineering Corporation
215 Union Boulevard
Suite 500
Lakewood, CO 80228

Attention: Mr. Don Poulter, P.E.

Subject: Final Tunnel Feasibility Report for
Lake Powell Pipeline Feasibility Study
Washington County Water Conservancy District
Washington County, Utah

Dear Don:

We are pleased to submit this final tunnel feasibility report for the subject project. The report addresses construction feasibility issues associated with the two tunneled crossings with multiple alignment alternatives, including probable excavation and support methods, shaft excavation and support, and other construction considerations. In addition, an opinion of probable construction cost is included for use in evaluation of alternatives.

This work was performed in accordance with our contract dated 5 September 2002 for the Lake Powell Pipeline Feasibility Study. The project is being conducted under the direction of the Washington County Water Conservancy District.

We appreciate the opportunity to work with you on this project. Please contact us with any questions or comments.

Sincerely yours,
HALEY & ALDRICH, INC.

Margaret A. Ganse

Margaret A. Ganse, P.E., P.G.
Associate

Tracy J. Lyman, P.E., P.G.
Principal

TABLE OF CONTENTS

				Page
LIST OF TABLES				**iv**
LIST OF FIGURES				**iv**
I.	**INTRODUCTION**			**1**
	1.01	Project Description		1
	1.02	Tunnel Crossings		1
	1.03	Purpose and Scope of Report		2
II.	**SITE AND SUBSURFACE CONDITIONS**			**3**
	2.01	Physiography and Land Use		3
	2.02	Regional Geologic Setting		3
	2.03	Site Geology		4
		A.	Hurricane Cliffs	4
		B.	Cockscomb	6
	2.04	Groundwater Conditions		7
	2.05	Anticipated Ground Behavior		7
		A.	Tunnelman's Ground Classification System for Rock	7
		B.	Tunnelman's Ground Classification System for Soil	8
III.	**FEASIBILITY OF TUNNEL AND SHAFT CONSTRUCTION**			**10**
	3.01	Feasible Tunnel Excavation Methods		10
		A.	Hurricane Cliffs Crossing	10
		B.	Cockscomb Crossing	10
	3.02	Description of Tunnel Excavation Methods		11
		A.	Drill and Blast	11
		B.	Roadheader	11
		C.	Tunnel Boring Machine	12
	3.03	Tunnel Initial Support Systems		13
		A.	Steel Ribs and Lagging	13
		B.	Rock Bolts/Straps/Wire Mesh	13
		C.	Shotcrete	13
		D.	Free Standing Ground	13
	3.04	Feasible Shaft Excavation Methods		14
		A.	Hurricane Cliffs Crossing	14
		B.	Cockscomb Crossing	14
	3.05	Description of Shaft Excavation Methods		15
		A.	Raise Bore	15
		B.	Shaft Sinking (Sequential Drill and Blast)	15
		C.	Shaft Sinking (One Phase Drill and Blast)	16
		D.	Raise Drilling	16
	3.06	Shaft Initial Support Systems		16
		A.	Circular Ring Beams and Vertical Lagging	17
		B.	Rock Bolts, Wire Mesh, and Shotcrete	17

TABLE OF CONTENTS

	3.07	Portal Development	17
	3.08	Staging and Access	17
	3.09	Power and Utility Requirements	18
	3.10	Traffic	18
	3.11	Muck Removal	18
	3.12	Instrumentation	19
	3.13	Carrier Pipe Installation and Backfill	19
IV.	**OPINION OF PROBABLE CONSTRUCTION COST**		**21**
	4.01	Unit Costs	21
	4.02	Discussion of Costs	21
		A. Shaft Excavation and Support	21
		B. Tunnel Excavation and Support	22
		C. Portal Development	22
V.	**LIMITATIONS**		**23**
VI.	**REFERENCES**		**24**

TABLES
FIGURES

TABLE OF CONTENTS

LIST OF TABLES

Table No.	Title
I	Summary of Tunnel Crossing Alternatives
II	Categories of Rock Ground Conditions
III	Categories of Soil and Soft Rock Ground Conditions

LIST OF FIGURES

Figure No.	Title
1	Hurricane Cliffs Site Locus
2	Cockscomb Site Locus
3	Willow Spring Alignment Plan and Profile
4	Mollies Alignment #1 Plan and Profile
5	Mollies Alignment #2 Plan and Profile
6	Mollies Alignment #3 Plan and Profile
7	Gould Spring Alignment Plan and Profile
8	Gould Reservoir Alignment Plan and Profile
9	Cockscomb Alternative Alignment B Plan and Profile
10	Cockscomb Alternative Alignment C Plan and Profile
11	Cockscomb Alternative Alignment C-1 Plan and Profile
12	Hurricane Cliffs Site Photographs
13	Cockscomb Site Photographs

I. INTRODUCTION

1.01 Project Description

The proposed Lake Powell Pipeline extends westerly from Lake Powell to Sand Hollow Reservoir near Hurricane, Utah. The pipeline will provide water to residents in Washington County, Utah. The proposed pipeline is part of a larger project under development by the Washington County Water Conservancy District (the District), which will also include several pump station and reservoirs.

Feasibility level design drawings prepared by Boyle Engineering Corporation (Boyle) were used as the basis for the discussions included herein (Boyle, February 2003). As the design drawings were not final at the time this report was prepared, project stationing and alignments described herein should be considered approximate, and should not be used for construction purposes. In addition, the finalized topographical survey was not incorporated into this report; please refer to Boyle's alignment drawings for actual ground surface elevations. At this feasibility level of design, the pipeline is expected to consist of 60-inch inside diameter welded steel pipe.

1.02 Tunnel Crossings

Two areas along the alignment, known as Hurricane Cliffs and the Cockscomb, are candidates for shaft and tunnel construction. These sections of the pipeline were evaluated as tunnel crossings due to the presence of a steep cliff (Hurricane Cliffs) and to avoid open trenching across a bedrock ridge (Cockscomb). Open-cut methods of trench construction are also being considered at these two sites, but evaluation of those alternatives is outside the scope of this report.

Several alignment alternatives are being considered at each site, as shown on Figures 1 and 2. The six alternatives at Hurricane Cliffs are as follows, and are shown on Figures 3 through 8:

- Willow Spring
- Mollies Number 1
- Mollies Number 2
- Mollies Number 3
- Gould Spring
- Gould Reservoir

The three alternatives at the Cockscomb are as follows, and are shown on Figures 9, 10 and 11:

- Cockscomb North Alternative
- Cockscomb South Alternative
- Cockscomb South Alternative

Table I presents a summary of the tunnel crossing alternatives, including: stationing, elevations, and approximate lengths of tunnels and shafts. The Hurricane Cliffs crossing extends in an east-west direction, beginning at a portal at the western terminus at approximate elevation 3,400 ft above mean sea level (MSL). A tunnel will be excavated from the portal, ranging in length from 1,650 ft to 2,203 ft, assuming a grade of approximately 2 percent upward towards the east. The tunnel will terminate in a deep shaft, ranging in depth from 726 ft to 1,114 ft. The inclination of the shaft would likely be vertical, but could be inclined at an angle of 30 degrees from the vertical to reduce the length of the tunnel and eliminate the 90 degree bend in the pipeline that would result from a vertical shaft. The elevation of the top of the shaft will range from approximately 4,100 to 4,700 ft. Figures 3 through 8 show the various shaft and tunnel alignments.

The Cockscomb crossing extends in an east-west direction, beginning at a portal at the eastern terminus at approximate elevation 4,500. A tunnel will be excavated from the portal, ranging in length from 3,684 ft to 4,986 ft. To tunnel across the ridge via portals located at the ground surface, the tunnel grade would be approximately 6 to 12 percent, upward towards the west. If the grade of the tunnel were to be reduced to 2 percent to facilitate mechanized tunneling, a shaft ranging from 188 to 363 ft would be required on the west side of the ridge. The elevation of the top of the shaft would range from approximately 4,800 to 5,000 ft. Figures 9, 10 and 11 show the three shaft and tunnel alignments.

1.03 Purpose and Scope of Report

The purpose of this report is to evaluate the construction feasibility of each tunnel alternative at the Hurricane Cliffs and Cockscomb sites, taking into consideration the anticipated ground conditions at each site. For the purpose of this report, it is assumed that the tunneling methods of construction will be selected. Included in this report are discussions of feasible tunneling excavation and support methods, shaft excavation and support methods, portal development, and other constructability issues for tunnels and shafts. In addition, an opinion of probable construction cost is included for use in evaluation of alternatives.

II. SITE AND SUBSURFACE CONDITIONS

2.01 Physiography and Land Use

The project alignment of the Hurricane Cliffs site is located through the Hurricane Cliffs south of Hurricane, Utah. The Hurricane Cliffs is a north to south trending fault escarpment that is continuous through the project area. This escarpment consists of a combination of steep slopes and vertical cliffs with alluvial and colluvial fans located near the base of the cliffs. This area is characterized by four physiographic zones from east to west: the flat valley, the gently slope of colluvium, the steep cliffs, and the broad uplands. Going from west to east through Hurricane Cliffs, the relatively flat ground surface (approximate elevation of 3,300 ft above sea level) of the Hurricane Fields rises gently toward an apron of colluvium that blankets the base of the cliffs. From this point, land abruptly rises at the Hurricane Cliffs due to faulting, to an approximate elevation of 4,700 ft, where the topography once again becomes relatively flat, gently sloping down to the north and east. A drainage named Frog Hollow incises through the escarpment in a northwesterly direction. Low-density residential development is located along the base of Hurricane Cliffs, near the northernmost alignment alternatives (Mollies Alignments No. 1, 2, and 3, and Willow Spring). A regional airport is also located near the base of the cliffs in this area.

The project alignment for the Cockscomb site is located through "The Cockscomb", which is a north to south trending, steeply dipping hogback ridge, which dips in an easterly to southeasterly direction. The site is located within the Grand Staircase-Escalante National Monument. Going from west to east, the hogback protrudes steeply from the relatively flat ground surface (approximate elevation of 4,900 ft) of Five Mile Valley, to an elevation of approximately 5,400 ft. The topography then descends steeply into the West Cove area, which is relatively flat and has an approximate elevation of 4,600 ft. Sand Gulch cuts across this hogback ridge and forms Catsair Canyon in the vicinity of the proposed alignments. US 89 has been developed within Catsair Canyon. Land in the project vicinity is undeveloped, being used for grazing and recreational purposes.

2.02 Regional Geologic Setting

The regional geology in the Hurricane Cliffs area consists of the transition zone between the Colorado Plateau and the Basin and Range Physiographic provinces. The dominant feature is the Hurricane Cliffs, which is a partly eroded fault scarp of the Hurricane Fault. The Hurricane Fault is a major, west-dipping normal fault within the structural and seismic transition between the Colorado Plateau and the Basin and Range province. In this transition zone, the generally sub-horizontal Paleozoic and Mesozoic strata of the Colorado Plateau are displaced hundreds to thousands of feet down-to-the-west by a series of north-trending normal faults.

The regional geology of the Cockscomb area consists of exposed Triassic, Jurassic, and Cretaceous sedimentary bedrock of the Colorado Plateau. The dominant feature is a portion of the East Kaibab monocline that has formed a steeply dipping hogback ridge, known as "The Cockscomb" that cause the northward-tilted strata to dip up to 80 degrees to the south east. Small fault-related folds of Triassic to Cretaceous-aged strata are upturned and exposed along the hinge of the monocline, along a series of ridges. The central, primary faults within these small folds show tens of ft of displacement.

2.03 Site Geology

No subsurface investigations have been conducted along the proposed alignments. However, field reconnaissance was performed by Haley & Aldrich and Boyle in September 2002. Ground conditions along the alignments were observed, and photographs taken. Typical ground conditions at Hurricane Cliffs and the Cockscomb are shown on Figures 11 and 12. Geologic information of the area was obtained from the following sources:

- "Interim Geologic Map of the Hurricane Quadrangle, Washington County, Utah" (Biek, Robert, F., Utah Geological Survey, Open-File Report 361, October 1998.
- "Structural Development and Paleoseismicity of the Hurricane Fault, Southwestern Utah and Northwestern Arizona, " prepared by the Geological Society of America for the 2002 Rocky Mountain Section Annual Meeting.
- "Geologic Map of Grand Staircase – Escalante National Monument, Utah" prepared by the Utah Geological Survey (undated).

A. Hurricane Cliffs

Interbedded strata of sedimentary rocks are well exposed at the Hurricane Cliffs site. Stratigraphy dips gently towards the east. The layers of interbedded rock are expressed in classic cliff and bench topography, with two to three distinct cliff zones observed along the cliffs. An apron of unconsolidated colluvium is located along the base of the cliffs. Direct observation of the colluvial materials was not possible due to the presence of grasses and other ground cover. However, an active sand and gravel mine is located in the colluvium deposit near the north end of the cliffs within the study area.

1. Bedrock Stratigraphy

The general bedrock stratigraphy at the Hurricane Cliffs along the proposed alignment locations consists of flat lying Permian and Triassic-age sedimentary bedrock consisting of sandstone, siltstone, limestone, and mudstone. This bedrock has been faulted by the Hurricane Fault, which has been mapped near the base of the Hurricane Cliffs and is described in more detail within this section. Quaternary basalt flows, resulting from tectonic activity associated with the Hurricane Fault, exist on top of the sedimentary bedrock in the area.

Typically, the bedrock consists of the Queantoweap Sandstone, the Toroweap Formation, the Kaibab Formation, and the Timpoweap Member of the Moenkopi Formation, which is the cap rock of the cliffs, developed principally in the Toroweap and Kaibab Formations.

The Permian Queantoweap Sandstone consists of massively bedded to cross-bedded, very fine to fine-grained sandstone that forms moderate to steep slopes.

The Permian Toroweap Formation consists of the Seligman, Brady Canyon, and Woods Ranch members. The Seligman Member consists of planar bedded, very fine-grained sandstone and siltstone that forms slopes. The Brady Canyon Member consists of a medium to coarse grained, thick to very thick bedded, even bedded limestone and cherty limestone that forms a prominent cliff. The Woods Ranch Member consists of interbedded dolomite, black chert, massive gypsum, gypsiferous mudstone, limestone, and collapse breccias that form moderate to steep slopes.

The Permian Kaibab Formation consists of the Fossil Mountain and Harrisburg members. The Fossil Mountain Member consists of light-gray, thick to very thick bedded, even bedded, fossiliferous limestone and cherty limestone and is conspicuously "black-banded" due to the presence of abundant reddish-brown, brown, and black chert, and forms a prominent cliff. The Harrisburg Member consists of interbedded gypsum, gypsiferous mudstone, and thin-bedded limestone and cherty limestone that mostly form moderate to steep slopes.

The Triassic Moenkopi Formation in the Hurricane Cliffs area consists of the Rock Canyon Conglomerate and the Timpoweap members. The Rock Canyon Conglomerate Member consists of two main rock types, a well cemented rounded pebble and cobble conglomerate found in paleovalleys, and a widespread, but thin, angular breccias. The Timpoweap Member is the widely exposed cap rock along the Hurricane Cliffs consisting of a thin to thick bedded, even bedded limestone and cherty limestone. The upper part of this member consists of thin to thick-bedded, even bedded, slightly calcareous, very fined-grained sandstone, siltstone, and mudstone.

2. Surficial Geology

Besides the exposed sedimentary and igneous bedrock, the surface geology also consists of unconsolidated Quaternary colluvium, alluvium, and eolian deposits which are well to moderately graded, clay to small boulder size material deposited in modern channels, swales, and at the base of steep slopes.

3. Hurricane Fault

The Hurricane Fault is an active normal fault that extends approximately 150 miles from Cedar City, Utah to south of the Grand Canyon in Arizona. The activity of the fault is indicated by the geomorphology of the high, steep Hurricane Cliffs, displaced Quaternary basalt flows, alluvium, and colluvium at many locations along its length. Minimal information exists about the size and frequency of large earthquakes on this fault, however the 2002 Geological Society of America paper estimates the maximum moment magnitude earthquake along the Anderson Junction segment (southern segment) of this fault to be M 6.8 to 6.9. Northern segments of the fault (Ash Creek Segment) have the maximum moment magnitude estimated to be on the order of M 6.9 to 7.1. Near field ground accelerations generated by this magnitude of event have not been performed for this feasibility level evaluation; it is recommended that additional studies be performed prior to start of preliminary design for this project.

The region has experienced numerous earthquakes in the past 100 years. The largest and most damaging events were the M 6.3 Pine Valley earthquake in 1902 and the M 5.8 St. George earthquake in 1992. The St. George earthquake probably occurred on the Hurricane Fault. This long fault is the most active fault in northwestern Arizona and southwestern Utah.

A cross section representing the geology just north of the bridge across the Virgin River on State Route 9 in Hurricane, Utah was prepared for a report and field trip entitled "Structural Development and Paleoseismicity of the Hurricane Fault, Southwestern Utah and Northwestern Arizona" prepared by the Geological Society of America for the 2002 Rocky Mountain Section Annual Meeting. In addition, the Geologic Map for the Hurricane Quadrangle shows faulting associated with the Hurricane Fault Zone to be within the colluvial slopes at the base of Hurricane Cliffs immediately west of Mollie's Nipple. Observations made during field reconnaissance suggest that fault splays are located within the cliff face, as indicated by offset slopes and irregular topography. For the purpose of this evaluation, Haley & Aldrich has assumed that the fault is located along the cliff face, and that fault gouge and highly fractured/crushed zones of rock will be encountered during portal development and along portions of the tunnel near the cliff face.

B. Cockscomb

Interbedded strata of sedimentary rocks are well exposed at the Cockscomb site. Stratigraphy dips steeply towards the east, such that the eastern side of the ridge features a dip slope. An existing road cut along the south side of the ridge provides good exposures of bedrock across the entire ridge. Limited deposits of colluvium are located along the base of the ridge on the eastern side. More extensive colluvium is present along the base of the ridge on its western side.

1. Bedrock Geology

The proposed alignments intersect "The Cockscomb" ridge. Based on the "Geologic Map of Grand Staircase – Escalante National Monument, Utah" it appears that the "backbone" of this ridge is the Jurassic Navajo Sandstone forming the east side of the ridge. The Jurassic Kayenta, Moenave, Chinle, and Moenkopi Formations exist on the western side of this ridge and in the adjacent valley to the west. The Permian Kaibab and Toroweap Formations exist further to the west of the ridge. Jurassic Entrada, Carmel, Morrison, Henrieville, Romana Mesa, and Summerville Formations exist to the east of the ridge.

Anticipated rock types along the proposed tunnel alignments are limited to the Navajo, Kayenta, and Moenave formations. The Navajo Sandstone consists of a massively cross-bedded, fine to medium-grained sandstone. The Kayenta Formation consists of thin to medium bedded siltstone and fine-grained sandstone, and mudstone. The Moenave consist of the fine-grained sandstone, siltstone, and mudstone with occasional limestone beds.

2. Surficial Geology

Besides the exposed sedimentary bedrock, the surface geology also consists of unconsolidated Quaternary colluvium, alluvium, and eolian deposits which are well to moderately graded, clay to small boulder size material deposited in modern channels, swales, and at the base of steep slopes.

2.04 Groundwater Conditions

Based upon site observations and our understanding of the geologic setting, the groundwater surface at both sites is expected to be located below tunnel grade.

2.05 Anticipated Ground Behavior

Given in the following Section is a description of how the ground will probably behave in response to normal, workmanlike tunnel and shaft construction methods. Ultimately, the final selection and execution of construction methods and equipment best suited to anticipated ground conditions along the proposed tunnels and shafts will be the contractor's responsibility. Tunnel excavation is anticipated to occur in both rock and soil, due to the presence of colluvial slopes in the vicinity of the portals. Shaft construction is anticipated to occur only in rock.

A. Tunnelman's Ground Classification System for Rock

Ground behavior during tunneling has been described in the engineering literature using several classification systems. These systems are based on quantifiable rock mass characteristics and tunneling methods and are used to characterize rock masses for tunneling purposes. Key rock mass characteristics quantified in the systems include: 1) rock hardness; 2) compressive strength; 3) orientation and spacing of rock discontinuities such as joints and fractures; 4) degree of weathering; 5) physical alteration or crushing characteristics; and 6) groundwater conditions. There is inherent uncertainty in the use of these classification systems and, therefore a high degree of conservatism is warranted in their use. Additionally, the classifications are based on a combination of factors whereas ground behavior in the tunnel can be dominated by one of the factors. Therefore, the use of these classifications must be accompanied engineering judgement and experience in similar ground conditions.

A description of the four classification systems is presented below:

- Tunneling Categories System: Three broad categories of ground relative to tunneling were presented by Deere, Merrit, and Cording. The categories of "Good", "Average to Difficult" and "Very Difficult to Hazardous" are based on general descriptions of ground conditions and on other classification systems. The authors presented general behavioral characteristics for each category and also excavation and support considerations.

- Tunnelman's System: The Tunnelman's classification system was first presented by Terzaghi (1946). The system was developed for rock and is based on key rock mass characteristics, primarily jointing, which control ground behavior. Considerable judgement is required to properly classify the rock mass and in the use of these classifications.

- Geomechanics System: The Geomechanics System was developed by Bieniawski (1973) and is based on the sum of six numbers derived from various rock mass characteristics. The resulting Rock Mass Rating (RMR) number can vary from 0 to 100 and is used to give a general classification for the rock mass. The rating can be used to estimate standup time and support requirements.

- Q-System: This was developed by Barton, Lien, and Lunde (1974) and is based on the product and quotient of six numbers derived from various rock mass characteristics. The resulting number can vary from .001 to 1,000 giving a general classification for the rock mass and it can be used to estimate support requirements.

For the purposes of this evaluation, the Tunnelman's System is used to evaluate rock conditions for shaft and tunnel excavation, as it is the most applicable method based upon the current level of information available for the rock mass. The Tunnelman's Ground Classification for Rock (Table II) attempts to categorize rock behavior to assist the engineer in selecting tunnel and shaft excavation methods and support types. The tunneling classification system was originally developed based on drill and blast excavation methods, but can be used to evaluate TBM excavation and other mechanized methods of rock excavation for tunnels and shafts. The primary difference between mechanized methods of rock excavation and drill and blast excavation is that mechanized excavation will result in less disturbance of the rock mass immediately outside the excavated tunnel envelope as compared to drill and blast excavation. Drill and blast will produce a halo of blast damaged and loosened rock that is somewhat less stable than the rock immediately surrounding a TBM-excavated tunnel.

Ground conditions within the various sedimentary units are categorized using the Terzaghi Rock Mass Descriptions as *moderately jointed* in most areas and *blocky and seamy* in some areas of weathered or more highly jointed rock. These categories are based upon visual observation of the ground and our experience with similar conditions. Such ground conditions are considered to be good media for shaft and tunnel excavation. Temporary rock support measures will be required, particularly in the zones characterized as *blocky and seamy*. If splays of the Hurricane Fault are encountered in the Hurricane Cliffs tunnel alignments, crushed and highly weathered zones of rock may be encountered, which could be characterized as *crushed*. Tunnel excavation in these areas may need to proceed using hand mining and extensive rock support until better ground is encountered.

B. Tunnelman's Ground Classification System for Soil

Selection of tunnel equipment and lining systems in soil is highly dependent on cohesion, strength, permeability and swell characteristics. Furthermore, the behavior of the soil or weak rock can be changed by the presence of water. The Tunnelman's Ground Classification for Soils (Table III) attempts to categorize soil behavior with and without the presence of groundwater to assist the engineer in selecting tunnel methods and support types. For example, sand with a certain percentage of fines may stand open for a short time or may 'ravel' slowly above the water table. Below the water table, the same soil could be expected to flow into the excavation uncontrollably. Note that a given soil can be modified from one type to another by means of ground modification methods. There are many methods of ground modification, the most common of which include dewatering or grouting.

Using the Tunnelman's Ground Classification for Soils, the colluvium is characterized primarily as *slow raveling* to *firm*, with minor areas expected to behave as *fast raveling* to *running* ground, based upon visual observation of the ground and our experience with such materials. These characterizations are based on: 1) the friable texture of the ground; 2) the slight cementation that is typically present in soils in arid climates which contributes moderate cohesion; 3) soil density; and 4) the absence of groundwater. The rate of raveling and standup time is effected by tunnel diameter as well as ground conditions. Zones of *fast raveling* or *running* ground can be challenging for tunneling, as ground support will be required very soon after excavation in order to provide a stable tunnel opening.

III. FEASIBILITY OF TUNNEL AND SHAFT CONSTRUCTION

3.01 Feasible Tunnel Excavation Methods

In this section of the report, a discussion of the feasible tunneling methods is presented for each crossing, along with Haley & Aldrich's opinion of the most likely method of tunnel excavation.

A. Hurricane Cliffs Crossing

The various alignment alternatives are located in similar ground conditions, consisting of nearly horizontally bedded sedimentary rocks. An apron of colluvium is located along the base of the cliffs, where the west portal of each alternative would be located. The length of tunnel ranges from 1,650 ft to 2,203 ft, with an approximate grade of 2 percent upward to the east.

Drill and blast tunneling is considered feasible for all alternatives, although it may not be the most economical method for Mollies No. 2 and the Gould Reservoir alignments due to their length of more than 2,000 ft. Mechanized excavation using a roadheader is considered feasible for all alternatives. Machine tunneling with a tunnel boring machine (TBM) is also considered feasible for all alternatives, although the machine would need to be taken apart and transported back through the tunnel to be removed from the West Portal. Alternatively, the TBM could be abandoned at the end of the tunnel drive, although this alternative is not considered to be likely due to the costs associated with abandoning a machine. Harder zones of cherty limestone and dolomite are to be anticipated. These zones are expected to be mineable, but will contribute to drill bit and cutter wear.

If splays of the Hurricane Fault are encountered in the Hurricane Cliffs tunnel alignments, crushed and highly weathered zones of rock may be encountered. Tunnel excavation in these areas may need to proceed using hand mining with hydraulic splitters and extensive rock support until better ground is encountered.

B. Cockscomb Crossing

The three alignment alternatives are located in similar ground conditions, consisting of steeply dipping sedimentary rocks. An apron of colluvium is located along the base of the ridge along the west side, where the West Portal of each alternative would be located. The East Portal sites are relatively free of colluvial cover. The length of the tunnel ranges from 3,684 ft to 4,986 ft, with an approximate grade of 6 to 12 percent upward to the west.

Drill and blast tunneling is considered feasible for all alternatives, although the nearly 5,000 ft length of alternatives B (west portal site 2), C, and C-1 will result in higher muck removal costs than would a shorter tunnel. Roadheader excavation is considered feasible for all alternatives. Machine tunneling with a tunnel boring machine (TBM) is considered to be less feasible for both alternatives, due to the steep grades. While the TBM itself can be modified to operate at the steep grades, specialized muck removal and track equipment (such as hoists and winches) that are not typically used by U.S. contractors would be required for the typical muck removal system by rail. A cost premium of 35 percent or more could be expected with the modified TBM/rail equipment.

TBM excavation would be more feasible if the grade of the tunnel could be reduced to less than 4 percent, and preferably to 2 percent. If the tunnel grade were reduced as described, a shaft would be required on the west side of the tunnel crossing. The depth of the shaft would be controlled by the tunnel grade.

3.02 Description of Tunnel Excavation Methods

A. Drill and Blast

In this method of rock excavation, holes are drilled into the face of the tunnel, the holes are loaded with explosives and detonated, causing the rock to fragment in a controlled manner. The fragmented rock is then excavated from the heading and the newly blasted portion of the tunnel is secured with a ground support system. The procedure is repeated until the tunnel is complete. The muck is loaded into a low-height front end loader (LHD) and transported to the portal. Rail transport of muck is also typical for tunnels of these distances. Drill and blast excavation is compatible with rock bolts, shotcrete, and steel ribs and lagging initial support methods.

The minimum excavated tunnel dimensions are expected to be approximately 9-ft by 9-ft, likely in a horseshoe-shaped configuration. Typical advance rates for drill and blast excavation are 10 ft per 10-hour shift, or 20-ft per day. Tunnel lining would likely be performed using a two-pass system, where the carrier pipe would be installed inside the tunnel after excavation and initial support is completed. The annulus between the carrier pipe and the initial support would be backfilled with controlled low strength material, such as low density cellular concrete.

Advantages to the drill and blast method of excavation include flexibility with respect to tunnel shape and low capital cost of equipment and mobilization, and flexibility in dealing with adverse ground conditions such as faults, blocky or seamy zones, etc. The main disadvantage is that drill and blast will produce a halo of blast-damaged and loosened rock that is less stable than the rock immediately surrounding a roadheader or TBM-excavated tunnel. However, this can be mitigated if initial support is installed quickly after excavation, and if the annulus is ultimately backfilled after installation of the carrier pipe. In addition, controlled blasting techniques can reduce the occurrence of the blast halo.

B. Roadheader

Roadheader construction is a specialized type of mechanical tunnel construction. The roadheader tunnel machine consists of a tracked, low-height vehicle with an operating-boom to which either a transverse or axial rotating cutting wheel is fitted with carbide cutting bits. The cutting wheel excavates the face of the tunnel by rotating at high RPM while the carbide bits cut into the rock. Gathering arms pull the muck onto a conveyor that transports the excavated rock through the machine where the muck is loaded into an LHD or a train and transported to the portal. Roadheader excavation is compatible with rock bolts, shotcrete, and steel ribs and lagging initial support methods.

The minimum excavated tunnel dimensions are expected to be approximately 9-ft by 9-ft, likely in a horseshoe-shaped configuration. Typical advance rates for roadheader excavation are 10 ft per 10-hour shift, or 20-ft per day. Tunnel lining would likely be performed in a two-pass system, where the carrier pipe would be installed inside the tunnel after excavation and initial support is completed. The annulus between the carrier pipe and the initial support would be backfilled with controlled low strength material.

Advantages to roadheader excavation include flexibility with respect to tunnel shape and moderate cost of equipment, and flexibility in dealing with adverse ground conditions such as faults, blocky or seamy zones, etc.

C. Tunnel Boring Machine

Tunnel boring machine (TBM) excavation includes the use of mechanized excavation equipment consisting of a circular shield fitted with a rotating circular cutterhead. The rotating cutterhead excavates the ground and conveys the material to a muck removal system consisting of a conveyor from the face to the back of the TBM and rail cars propelled by a winch or by locomotive. Use of a conveyor system for muck removal is also possible. The cutterhead is open to the ground. The TBM is steered with small jacks at the rear of the machine. It is advanced forward with thrust jacks pushing off grippers bearing on the rock in the tunnel side walls or, in very weak or soft rock, off of continuous lining elements installed immediately behind the TBM. Tunnel boring machine excavation is compatible with rock bolts, shotcrete, and steel ribs and lagging initial support methods.

The minimum TBM diameter is expected to be approximately 96 inches. Typical advance rates for TBM excavation are 20 to 25 ft per 10-hour shift, or 40- to 50-ft per day. Tunnel lining would likely be performed using a two-pass system, where the carrier pipe would be installed inside the tunnel after excavation and initial support is completed. The annulus between the carrier pipe and the initial support would be backfilled with controlled low strength material.

The primary advantage associated with the TBM method of excavation is the ability to limit impacts to surrounding rock; TBM excavation does not damage nearby rock like drill and blast methods. Additional advantages include a relatively fast production rate. Disadvantages of TBM excavation include the relatively high equipment and mobilization costs, limited access to the tunnel face, and relative inflexibility in dealing with adverse ground conditions such as faults, blocky or seamy ground, etc.

3.03 Tunnel Initial Support Systems

In general terms, freestanding ground or rock bolts/straps/wire mesh represent the most flexible and most cost-effective methods of initial ground support in competent rock. For less competent ground conditions, steel rib supports or a hierarchy of increasingly aggressive ground support for difficult ground conditions include; steel rib supports, steel rib supports with lagging, shotcrete with bolts, bolts and ribs, lattice girder and shotcrete, and liner plates. Selection of the initial support for the tunnels will depend on the actual rock conditions encountered and contractor preference. In all cases, the initial support is intended to provide a stable working environment until the carrier pipe is placed and backfill grout or concrete is used to backfill the annular space between the pipeline and the ground.

Examples of rock tunnel initial support considered appropriate for this project include; steel ribs and lagging, rock bolts/straps/wire mesh, shotcrete, and free-standing ground (i.e. no support). A discussion of those initial support systems is provided below:

A. Steel Ribs and Lagging

The system consists of non-expanded circular steel ribs (sets) bolted together with timber lagging installed between the sets as needed. Each set is erected in the tail shield of the TBM or behind the face of the tunnel heading. When used in conjunction with blasting or roadheader excavation, each set of steel ribs and lagging is installed on line and grade as soon as the excavation of the face progresses far enough to allow for the erection of the set. If used in conjunction with a TBM, the sets can be erected in the tail shield of the machine or just outside the tail shield.

B. Rock Bolts/Straps/Wire Mesh

This system consists of rock reinforcement, which utilizes the inherent strength of the rock mass and an arch-shaped roof to maintain a stable opening. The rock bolt typically consists of a steel or fiberglass rod placed into a drilled hole and held by friction or by grouting the annulus between the bolt and the rock. The rock bolts function to reinforce the rock mass. In less competent rock, straps or wire mesh are employed to prevent fractured rock from falling out of the tunnel roof and walls.

C. Shotcrete

Shotcrete (pneumatically applied concrete) is applied on the rock surface to maintain the integrity of the rock mass and provide additional support as necessary in zones of moderate to poor quality rock.

D. Free Standing Ground

In situations where the rock is judged competent enough to stand freely on its own without rock fallout or collapse, the excavation can be left to stand alone until the carrier pipe is installed and the annulus backfilled to provide long term resistance to rock movement.

3.04 Feasible Shaft Excavation Methods

In this section of the report, a discussion of the feasible shaft excavation methods is presented for each crossing, along with Haley & Aldrich's opinion of the most likely method of shaft excavation.

A. Hurricane Cliffs Crossing

The various alignment alternatives are located in similar ground conditions, consisting of nearly horizontally bedded sedimentary rocks. An apron of colluvium is located along the base of the cliffs, where the West Portal of each alternative would be located. The depth of the shafts ranges from approximately 726 to 1,114 ft.

Raise bore excavation is considered feasible for all alternatives, although a cost premium would be associated with an inclined shaft. Shaft sinking techniques consisting of sequential drill and blast excavation from the ground surface is also considered feasible for all alternatives and shaft inclinations, but is not expected to be the chosen method of excavation due to the shaft depths. Shaft sinking using one phase of drill and blast combined with bottom out mucking is not considered to be feasible due to the depth of the shafts. Blind boring (drilling the shaft from the ground surface to the tunnel level) is not considered feasible due to the large amount of water required during drilling. Raise drilling (drilling the shaft from the tunnel using a mini-TBM) is considered feasible for all alternatives and inclinations.

B. Cockscomb Crossing

The three alignment alternatives are located in similar ground conditions, consisting of moderately to steeply dipping sedimentary rocks. An apron of colluvium is located along the base of the ridge along the west side, where the West Portal of each alternative would be located. The East Portal sites are relatively free of colluvial cover. If the tunnel grade were reduced to allow for TBM excavation, a shaft 188 to 363 ft deep would be required.

Raise bore excavation is considered feasible for excavation, however it would not be the preferred method if the tunnel were excavated by drill and blast methods using two headings. Shaft sinking techniques consisting of sequential drill and blast excavation from the ground surface is also considered feasible for shaft excavation. Shaft sinking using one phase of drill and blast combined with bottom out mucking is considered to be feasible for shaft excavation, and may prove to be the most cost effective method. Blind boring (drilling the shaft from the ground surface to the tunnel level) is not considered feasible due to the large amount of water required during drilling. Raise drilling (drilling the shaft from the tunnel using a mini-TBM) is considered feasible as well.

3.05 Description of Shaft Excavation Methods

The selected shaft construction method must be compatible with the tunnel excavation method; the contractor is responsible for the means and methods. The following subsections contain a brief description of the shaft excavation methods considered feasible for this project.

A. Raise Bore

In this method, a pilot hole (12-in. to 14-in. diameter) would be drilled from the surface at the center of the shaft extending down into the tunnel. A full diameter raise bore cutterhead would be installed on the drill stem within the tunnel, and the drill stem would be retracted up the pilot hole, back reaming a larger hole. If the shaft were to be inclined, the excavation procedure would proceed in the same manner. Excavated rock would fall by gravity into the tunnel, where it would be removed from the portal.

The excavated diameter of the shaft is expected to be 8-ft. Typical advance rates for raise bore excavation are 60 vertical ft per day to drill the pilot bore, and 50 vertical ft per day to back ream the shaft. Advantages to raise bore techniques include its relative speed. In addition, it is not as labor intensive as shaft sinking using sequential drill and blast, and can be less expensive as a result. Potential disadvantages to raise boring include:

1. The need for the shaft to be self-supporting long enough to excavate the shaft and install any needed initial support. Preliminary evaluation of ground conditions for this project suggest that shaft stability prior to installation of initial support should be acceptable.

2. The tunnel and shaft construction must be performed sequentially, thereby potentially increasing the required construction schedule.

B. Shaft Sinking (Sequential Drill and Blast)

In this method of rock excavation, holes are drilled into the shaft bottom, the holes are loaded with explosives and detonated, causing the rock to fragment in a controlled manner. The fragmented rock is then excavated from the shaft and the newly blasted portion of the shaft is secured with a ground support system. The procedure is repeated until the shaft is complete. The muck is loaded into a bucket and hoisted out of the shaft using a crane. Drill and blast excavation is compatible with rock bolts, shotcrete, and steel ribs and lagging initial support methods.

The excavated diameter of the shaft is expected to be 8-ft if the shaft is not used for tunnel access, or 15-ft if the shaft will be used to stage tunnel construction. Typical advance rates for shaft sinking are 3 to 4 vertical ft per day, working two 10-hour shifts. Advantages to shaft sinking by the drill and blast method include:

1. The ability to install any required initial support immediately following each sequential excavation round.

2. The ability to excavate the tunnel from two headings using the shaft as access when shaft excavation is complete. Tunnel and shaft excavation can occur in parallel, thereby potentially reducing the overall project construction schedule.

A disadvantage of shaft sinking using the sequential drill and blast method is that it is relatively labor and time intensive, and thus relatively expensive when compared to mechanized methods of shaft excavation.

C. Shaft Sinking (One Phase Drill and Blast)

In this method of rock excavation, holes are drilled from the ground surface to the shaft invert elevation then the holes are loaded with explosives and detonated, causing the rock to fragment in a controlled manner. The fragmented rock is then excavated from the bottom of the shaft via the tunnel. As the muck level in the shaft is lowered, upper portions of the shaft are secured with a ground support system. Drill and blast excavation is compatible with rock bolts, shotcrete, and steel ribs and lagging initial support methods.

The excavated diameter of the shaft is expected to be 8-ft if the shaft is not used for tunnel access, or 15-ft if the shaft will be used to stage tunnel construction. Advantages to shaft sinking by the one phase drill and blast method include the relative speed of construction, and the ability to install initial ground support immediately after the shaft walls are exposed. A disadvantage of this shaft construction method is the potential difficulty in maintaining verticality of the perimeter blast holes. This difficulty is greater with greater shaft depths.

D. Raise Drilling

In this method, a mini-TBM is used from within the tunnel to drill the shaft overhead. The mini-TBM (such as BorPak by Atlas Copco) is set up underneath the shaft, and starts boring upwards through a launching tube. After the head has penetrated several ft into the rock, grippers hold the body while the head rotates and bores the rock, similar to a TBM. This technology is capable of drilling holes up to approximately 8 to 9 ft in diameter, for distances just over 1,000 ft. For this reason, this method is considered to be at the upper limits of its capabilities for the Hurricane Cliffs shafts.

Advantages to raise drilling techniques include its relative speed, and its ability to drilled inclined shafts with relative ease. In addition, it is not as labor intensive as shaft sinking, and can be less expensive as a result. The main disadvantage to raise drilling techniques is that the tunnel will not be able to be excavated in two simultaneous headings, and the tunnel and shaft construction must be performed sequentially, thereby potentially requiring a longer construction schedule.

3.06 Shaft Initial Support Systems

A discussion of various shaft lining types that are considered to be feasible for this project is provided below:

A. Circular Ring Beams and Vertical Lagging

Circular ring beams and vertical lagging is considered to be well suited to the anticipated ground conditions. The shaft should be excavatable with small equipment working within the shaft, and with drill and blast techniques. The ground is expected to be able to stand for at least 3 to 5 feet and more, in advance of the lagging placement. The lagging should be blocked as required.

B. Rock Bolts, Wire Mesh, and Shotcrete

In shafts excavated in competent rock, a regular pattern of rock bolts can be utilized to provide support. Wire mesh or shotcrete may be used in conjunction with the bolts to prohibit small blocks of loose rock from falling into the excavation.

3.07 Portal Development

A portal is required at the west end of the proposed tunnel alignments at the Hurricane Cliffs site. It is expected that an open-cut trench would proceed toward the tunnel, terminating when suitable conditions were encountered to begin tunneling. The west portal at Hurricane Cliffs will be excavated partially in soil (colluvium) and partially in rock. It is expected that the colluvium can be excavated with conventional hydraulic excavators such as backhoes and front-end loaders. Shotcrete may be utilized to stabilize the cut slopes. Blasting will likely be required for efficient bedrock excavation. To limit the extent of blast disturbance in the rock and maintain good rock mass quality, precision or controlled blasting methods are recommended. While nearly vertical bedrock walls may be excavated, spot or pattern rock bolting will be required due to jointing in the bedrock. For safety, rock cut faces will require draping with wire mesh to contain falling rocks.

Temporary support and shoring of the portal excavation is necessary only during construction and as such will be determined by the Contractor. A combination of rock bolts in the rock and ground nails and shotcrete in the colluvium would provide efficient support systems and would avoid the need for internal bracing. Minimum support requirements for the portal face include brow bolts and shotcrete in the rock in addition to other temporary support.

A portal is required at the west and east ends of the proposed tunnel alignments at the Cockscomb site. Similar conditions to those described for the Hurricane Cliffs site are expected at the portal on the west side of the Cockscomb site, and similar methods of excavation and support can be anticipated. Conditions at portal on the east side of the Cockscomb are different, consisting of little soil and steeply dipping rock exposed at the ground surface. Joints dipping at high angles may create rock blocks and wedges in the walls of the portals which could fall or slide into the excavation if not properly stabilized. These conditions can be supported using the initial support measures described for the Hurricane Cliffs site.

3.08 Staging and Access

For the Hurricane Cliffs site, tunnel construction will be staged from the west portal, or possibly from the shaft depending upon the selected shaft construction method. For the three Mollies Alternatives, the presence of low density housing must be taken into consideration when developing staging areas. However, sufficient land area for construction staging is considered to be present at all of the Hurricane Cliffs alignment alternatives. Paved roadways are present along the base of the cliffs, allowing contractor easy access to the site.

If raise bore shaft excavation techniques are utilized at Hurricane Cliffs, staging of and access to this construction operation will be more challenging than tunnel staging. Paved roadway access is available to bring the contractor from the valley up onto the cliffs, but access to the shaft site can only be partially provided by unimproved 4-wheel drive roads. Depending upon the actual shaft location, the contractor will likely need to pioneer a roadway to the site across sloping ground from the existing 4-wheel drive roads. Sufficient land area is available in the vicinity of the shaft sites, once access is provided to these areas.

For the Cockscomb site, tunnel construction will be staged from the east portal. No residential or commercial development is located in this area, however the land is part of the Grand Staircase-Escalante National Monument. For this reason, special permits and requirements may apply. An unimproved roadway is located east of the portal sites, but the contractor will need to pioneer an access road across relatively level ground to be able to access the portal location. Sufficient land area for construction staging is considered to be present at both of the Cockscomb alignment alternatives. An unimproved roadway is located immediately west of the Cockscomb, providing the contractor access to the west portals or shafts. An intermittent drainage is located west of the roadway, resulting in little land area available to stage shaft sinking operations. If the roadway is able to be closed during construction, sufficient staging area should be able to be provided on the west side.

3.09 Power and Utility Requirements

Low density residential housing is located along the base of Hurricane Cliffs. Powerlines are located along the roadway near the base of the cliffs. The contractor should be able to take a power feed off of existing power located close to all of the proposed portal locations. No powerlines were observed at the shaft sites for the Hurricane Cliffs alternatives or in the immediate vicinity of the Cockscomb site. It is expected that the contractor will need to provide generators to provide electric power in these areas.

3.10 Traffic

Vehicular traffic will be affected during tunnel construction of the tunnels. The effects are expected to be minor, being limited to the vicinity of the West Portal at the Hurricane Cliffs site and the East Portal of the Cockscomb site. The primary effect is expected to be construction traffic in and out of the staging areas. Closures of the unimproved roadway west of the Cockscomb will be required during shaft sinking or portal development activities.

3.11 Muck Removal

Based on the tunnel volume alone, between 5,000 and 6,000 cubic yards (cy) of rock is anticipated to be excavated from the Hurricane Cliffs site, and approximately 10,000 to 14,000 cy of rock is anticipated to be excavated from the Cockscomb site. These numbers assume a bulking factor of 20 percent from the theoretical volume of the proposed tunnels. Excavated rock will consist of fragmented chips and pieces "up to approximately the size of a hand" if excavated with a TBM to larger blocks up to 12 inches in maximum diameter if excavated using drill and blast techniques. Uses for the excavated rock will depend on the local market demand for fill at the time of construction. Materials that are not contaminated and possess favorable rock characteristics can generally be utilized on other construction projects as structural fills, general fills and engineered fills.

3.12 Instrumentation

Haley & Aldrich recommends a geotechnical instrumentation plan to: 1) monitor movement of the tunnel and the ground in the vicinity of tunnel and shaft and excavations during construction; and 2) monitor vibrations and air blast effects during construction. The program includes the following types of instruments:

- Convergence Point Arrays
- Surface Reference Points
- Seismographs

Convergence point arrays allow the potential inward movement of the tunnel to be monitored. They are used to determine ground behavior and reaction to tunneling, and to obtain information on tunnel stability.

Surface reference points are recommended to be located in the vicinity of the portals to monitor movements resulting from tunnel excavation. Seismographs are used to monitor drill and blast excavation, which would be appropriate if the chosen alignment is located near housing developments (such as the Mollies alternatives).

The Contractor is responsible for installation of instrumentation, taking initial or baseline readings, and continued monitoring during construction. The Contractor is required to monitor at a minimum frequency, and to copy the Owner on all data and interpretations. Furthermore, the Owner has access to the instrumentation for regular checks and verification of the Contractor's readings.

3.13 Carrier Pipe Installation and Backfill

Following excavation and initial support of the entire tunnel, the carrier pipe will be installed and the annulus backfilled. Because of the length of the tunnels and the uphill grade, the only practical method of installing the carrier pipe is piecewise, with each section transported individually and joined inside the tunnel. Jacking or pushing a completed pipe string may be possible for shorter runs, but problematic due to the length of the push and difficulties in securing the pipe during annulus backfilling. With piecewise installation, each pipe section is transported individually into the tunnel then joined and placed on pipe bedding or on a series of cradles at the desired line and grade. Each section would be blocked or secured against movement in all directions (including floatation), then the annulus backfilled with cellular concrete in increments of approximately 500-ft or less. The pipe may be filled with water during annulus backfilling to partially counteract buoyant effects from the cellular concrete. This method of pipe placement and backfilling can easily result in line and grade tolerances, for the carrier pipe, within six inches. More precise tolerance can be achieved, if needed, although at a premium cost. Pipe placement in the shafts would occur using similar methods, except that bulkheads would not be required during backfilling operations.

IV. OPINION OF PROBABLE CONSTRUCTION COST

4.01 Unit Costs

Based upon our experience with similar ground and discussions with contractors, the following unit prices are considered reasonable for this project, excluding pipe costs:

Item	Unit	Unit Cost
Shaft Excavation and Support		
Vertical Raise Bore	VF	$700
Inclined Raise Bore	VF	$945
Shaft Sinking (sequential drill and blast with rock bolts)	VF	$3,000
Shaft Sinking (one phase drill and blast with rock bolts)	VF	$2,500
Raise Drilling	VF	$1,200
Tunnel Excavation and Support		
Drill and Blast Tunneling	LF	$900
Roadheader	LF	$1,200
Machine Tunneling (normal grade)	LF	$1,300
Machine Tunneling (steep grade)	LF	$1,755
Hand Mining through fault zone	LF	$1,800
Portal Development		
Hurricane Cliffs Site	EA	$300,000
Cockscomb Site	EA	$50,000

These probable construction costs assume 2002 dollars. This estimate includes mobilization, profit, and overhead for the tunneling contractor, but does not include general site mobilization. Rock support in the tunnel is included, as well as portal development support and shaft support. Backfilling the annulus between the excavated tunnel and the carrier pipe is also included. Given the preliminary nature of these costs, it is advised that a 25 percent contingency be applied for budgeting purposes. Furthermore, the cost for portal development is highly dependent upon the actual vertical alignment of the tunnel; these values should only be used for comparison of alternatives. Haley & Aldrich recommends that the project allow flexibility in bidding with regard to construction methods to obtain the most competitive price. By doing so, the market will determine the most economical price for the project.

4.02 Discussion of Costs

A. Shaft Excavation and Support

Unit prices for shaft excavation vary due to differences in construction cycle time and associated labor costs. Shaft sinking costs are highest, as this process is labor intensive and relatively slow as compared to the other methods. Each construction operation (drilling, blasting, muck removal, initial support) occurs with every three to four ft construction phase, a time consuming process. The one phase shaft sinking cost is less than the sequential drill and blast shaft sinking method, because the main construction phases of drilling and blasting occur only once. Muck removal would occur from the bottom of the shaft in a continuous operation, while separate crews would install initial support from the top in a continuous operation.

Raise bore technology is relatively less expensive than shaft sinking, as it is machine intensive rather than labor intensive. Pilot hole drilling and back reaming are performed from the surface in a continuous operation with out the need for numerous crews. Muck removal would occur from the bottom of the shaft, using the same muck removal operation used during tunnel excavation. Barring mechanical problems, this shaft construction method is often very economical. The inclined raise bore option includes a 35 percent cost premium, to account for machine wear and slower production due to inclined drilling operations.

Raise drilling costs fall between the costs for shaft sinking and raise boring, as this method is equally dependent upon labor and equipment. Specialized equipment would need to be mobilized to the site, along with skilled operators. Muck removal would occur from the bottom of the shaft, using the same muck removal operation used during tunnel excavation.

B. Tunnel Excavation and Support

The three main methods of tunnel excavation and support (drill and blast, roadheader, and TBM) have similar unit costs. However, a 35 percent cost premium is associated with TBM tunneling along an alignment with steep grades. While the TBM itself can be modified to operate at the steep grades, specialized muck removal and track equipment (such as hoists and winches) that are not typically used by US contractors would be required for the typical muck removal system by rail. This premium does not apply to drill and blast tunneling. Unit costs for hand mining through fault zones are higher than the typical tunneling unit costs, due to the slow production rate and labor intensive nature of the operation.

C. Portal Development

Costs for portal development are highly dependent upon the Contractor's means and methods of construction. Due to the presence of colluvial deposits and fault splays along the base of Hurricane Cliffs, portal development is expected to consist of soil excavation, shotcrete, and bolting. Ground conditions along the Cockcomb consist primarily of exposed bedrock and limited colluvial cover. For this reason, portal development is expected to require less support measures, resulting in lower unit costs.

V. LIMITATIONS

This report has been prepared for specific application to the Lake Powell Pipeline Feasibility Study per agreement between Haley & Aldrich and Boyle Engineering Corporation. This report was based on our understanding of the project elements and geometry at this time and in accordance with generally accepted geotechnical-engineering practices common to the local area.

In the event that changes in the nature, design or location of the planned construction are made, the conclusions and recommendations contained in this report should not be considered valid, unless the changes are reviewed by Haley & Aldrich and the conclusions of this report are modified or verified in writing.

VI. REFERENCES

1. Boyle Engineering Corporation, Lake Powell Pipeline Feasibility Study, Alignment Drawings, February 2003.
2. Biek, Robert, F., Interim Geologic Map of the Hurricane Quadrangle, Washington County, Utah, Utah Geological Survey, Open-File Report 361, October 1998.
3. "Structural Development and Paleoseismicity of the Hurricane Fault, Southwestern Utah and Northwestern Arizona, " prepared by the Geological Society of America for the 2002 Rocky Mountain Section Annual Meeting.
4. Geologic Map of Grand Staircase – Escalante National Monument, Utah, prepared by the Utah Geological Survey (undated).

TABLE I
SUMMARY OF TUNNEL CROSSING ALTERNATIVES

Lake Powell Pipeline Feasibility Study

Mar-03

Project No. 28818-000

		Tunnel and Shaft Information						
	Cockscomb Alternatives	Beg. Sta	Beg. Elev.	Ending Sta.	Ending Elev.	Slope	Tunnel Length	Shaft Depth
ID	Description	(ft)	(ft)	(ft)	(ft)	(%)	(lf)	(vf)
B	Tunnel & Shaft through West Portal Site 1	1383+16	4538	1420+00	4975	2.0	3684	363
B	Tunnel through West Portal Site 1	1383+16	4538	1420+00	4975	11.9	3684	N
B	Tunnel & Shaft through West Portal Site 2	1383+16	4538	1430+29	4820	2.0	4713	188
B	Tunnel through West Portal Site 2	1383+16	4538	1430+29	4820	6.0	4713	N
C	Tunnel & Shaft through West Portal Site 3	1387+23	4546	1434+63	4893	2.0	4740	252
C	Tunnel through West Portal Site 3	1387+23	4546	1434+63	4893	7.3	4740	N
C-1	Tunnel & Shaft through West Portal Site 4	1388+86	4549	1438+72	4932	2.0	4986	283
C-1	Tunnel through West Portal Site 4	1388+86	4549	1438+72	4932	7.7	4986	N

		Tunnel and Shaft Information						
	Hurricane Cliffs Alternatives	Beg. Sta	Beg. Elev.	Ending Sta.	Ending Elev.	Slope	Tunnel Length	Shaft Depth
ID	Description	(ft)	(ft)	(ft)	(ft)	(%)	(lf)	(vf)
HC-1	Willow Spring Alignment	6195+00	4139	6211+50	3380	2	1650	726
HC-2	Mollies Nipple #1 Alignment	6230+71	4423	6249+37	3432	2	1866	953.7
HC-3	Mollies Nipple #2 Alignment	6217+42	4459	6239+02	3431	2	2160	984.8
HC-4	Mollies Nipple #3 Alignment	6212+05	4457	6231+76	3452	2	1971	965.6
HC-5	Gould Spring Alignment	6204+00	4715	6223+01	3566	2	1901	1111
HC-6	Gould Reservoir Alignment	6221+29	4718	6243+32	3560	2	2203	1114

TABLE II

CATEGORIES OF ROCK GROUND CONDITIONS
Lake Powell Pipeline Feasibility Study
March 2003
Project No. 28818-000

Intact – Rock contains neither joints nor hair cracks. Hence if it breaks it breaks across sound rock. On account of the injury to the rock due to blasting, spalls may drop off the roof several hours or days after the blasting. This is known as *spalling* condition. Hard, intact rocks may also be encountered in the *popping condition* involving the spontaneous and violent detachment of rock slabs form sides or roof.

Stratified – Rock consists of individual strata with little or no resistance against separation along the boundaries between strata. The strata may or may not be weakened by transverse joints. In such rock, the spalling condition is quite common.

Moderately jointed – Rock contains joints and hair cracks, but the blocks between joints are locally grown together or so intimately interlocked that vertical walls do not require lateral support. In rocks of this type both the spalling and the popping condition may be encountered.

Blocky and seamy – Rock consists of chemically intact or almost intact rock fragments which are entirely separated from each other and imperfectly interlocked. In such rock vertical walls may require support.

Crushed – But chemically intact rock has the character of a crusher run. If most or all of the fragments are as small as fine sand grains and no recementation has taken place, crushed rock below the water table exhibits the properties of a water-bearing sand.

Squeezing – Rock slowly advances into the tunnel without perceptible volume increase. Prerequisite for squeeze is a high percentage of microscopic and sub-microscopic particles of micaceous minerals or of clay minerals with a low swelling capacity.

Swelling – Rock advances into the tunnel chiefly on account of expansion. The capacity to swell seems to be limited to those rocks which contain clay minerals such as montmorillonite, with a high swelling capacity.

After Terzaghi, 1946

TABLE III

CATEGORIES OF SOILS AND SOFT ROCK GROUND CONDITIONS
Lake Powell Pipeline Feasibility Study
March 2003
Project No. 28818-000

Firm Ground – A heading may be advanced several feet or more without immediate support. Hard clays and cemented sand or gravel generally fall into this category.

Raveling Ground – After excavation, material above the tunnel or in the upper part of the working face tends to flake off and fall into the heading. In fast raveling ground, the process starts within a few minutes, otherwise the ground is slow raveling. Slightly cohesive sands, silts, and fine sands gaining their strength from apparent cohesion typically exhibit this type of behavior. Very stiff fissured clays may be raveling materials also.

Running Ground – Cohesionless, dry soils run from any unsupported vertical face until a stable slope forms at the natural angle of repose (i.e., approximately 30 degrees to 35 degrees). Running ground consists of dry, cohesionless materials, such as clean loose sand or gravel.

Flowing Ground – If seepage develops at the working face, raveling or running ground is transformed to flowing ground, which advances like a viscous fluid into the heading. Silt, sand, or gravel below the water table without a high enough clay content to develop significant cohesion will be flowing-type soils.

Squeezing Ground - Squeezing ground conditions are analogous to plastic flow, and the soil is observed to advance slowly into the tunnel excavation without any signs of fracturing. Squeezing occurs without an increase in the water content or a volume change in the soil and is governed by the soil strength in comparison to the overburden pressure. Squeezing ground may include soft to medium stiff or stiff clays depending on the overburden pressure at the tunnel depth.

Swelling Ground – A condition where the ground absorbs water, increases in volume and expands slowly into the tunnel. This may occur in highly overconsolidated clays that exhibit high volume change characteristics upon wetting.

After Terzaghi, 1950 as modified by Heuer, 1974

NOTE:
SEE APPENDIX I, DRAWINGS HC-1 THROUGH HC-6, OF "LAKE POWELL PIPELINE FEASIBILITY STUDY, SUPPLEMENTAL ANALYSIS OF THE HURRICANE CLIFFS, THE COCKSCOMB, AND ALTERNATE ALIGNMENTS" PREPARED BY BOYLE ENGINEERING, APRIL 2003.

G:\28818\REPORT\CAD\FIGURE 1 REVISED

HALEY & ALDRICH

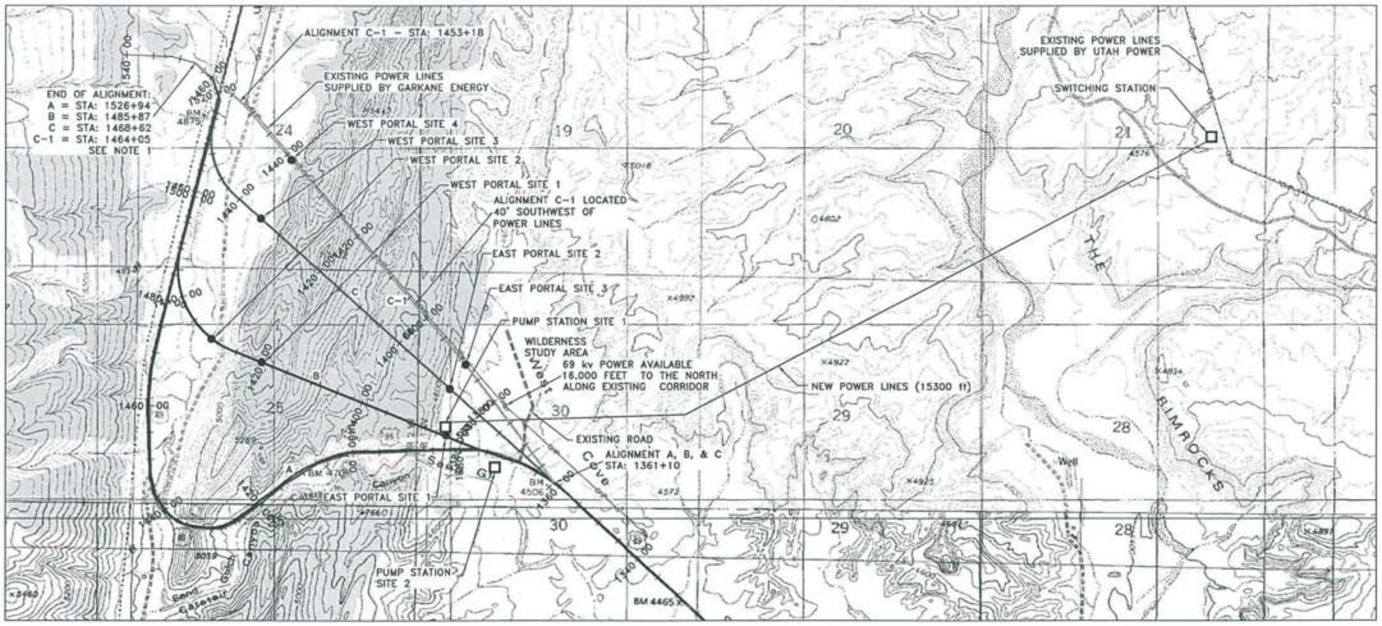
UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

HURRICANE CLIFFS
SITE LOCUS

JUNE 2003

FIGURE 1



U.S.G.S QUADRANGLE: FIVE MILE VALLEY, UTAH

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

-N-

0 1000 2000

SCALE IN FEET

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

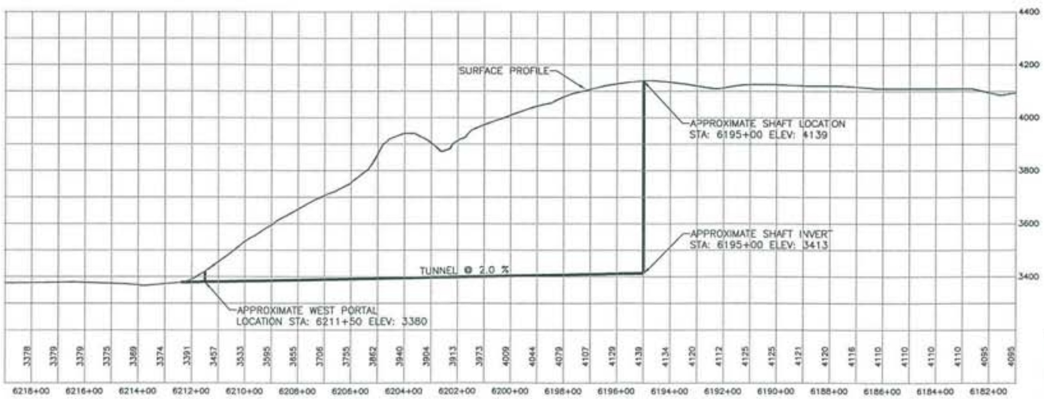
COCKSCOMB
SITE LOCUS

SCALE: AS SHOWN

MARCH 2003

FIGURE 2

3/13/2003 7:16 PM 2881800001.dwg



HORIZONTAL & VERTICAL
0 400 800
SCALE IN FEET

NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #2 (BASELINE – WILLOW SPRING ALIGNMENT)
2. THIS PLAN AND PROFILE IS SIMILAR TO THE HURRICANE CLIFFS PORTION OF ALIGNMENT #4.
3. THIS PLAN AND PROFILE IS FOR ANALYSIS OF THE HURRICANE CLIFFS TUNNEL AND SHAFT ONLY.
4. THE LOCATIONS OF THE HYDROPOWER FACILITY, WEST PORTAL, AND SHAFT ARE SUBJECT TO CHANGE.

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

WILLOW SPRING ALIGNMENT
PLAN AND PROFILE

SCALE: AS SHOWN

MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

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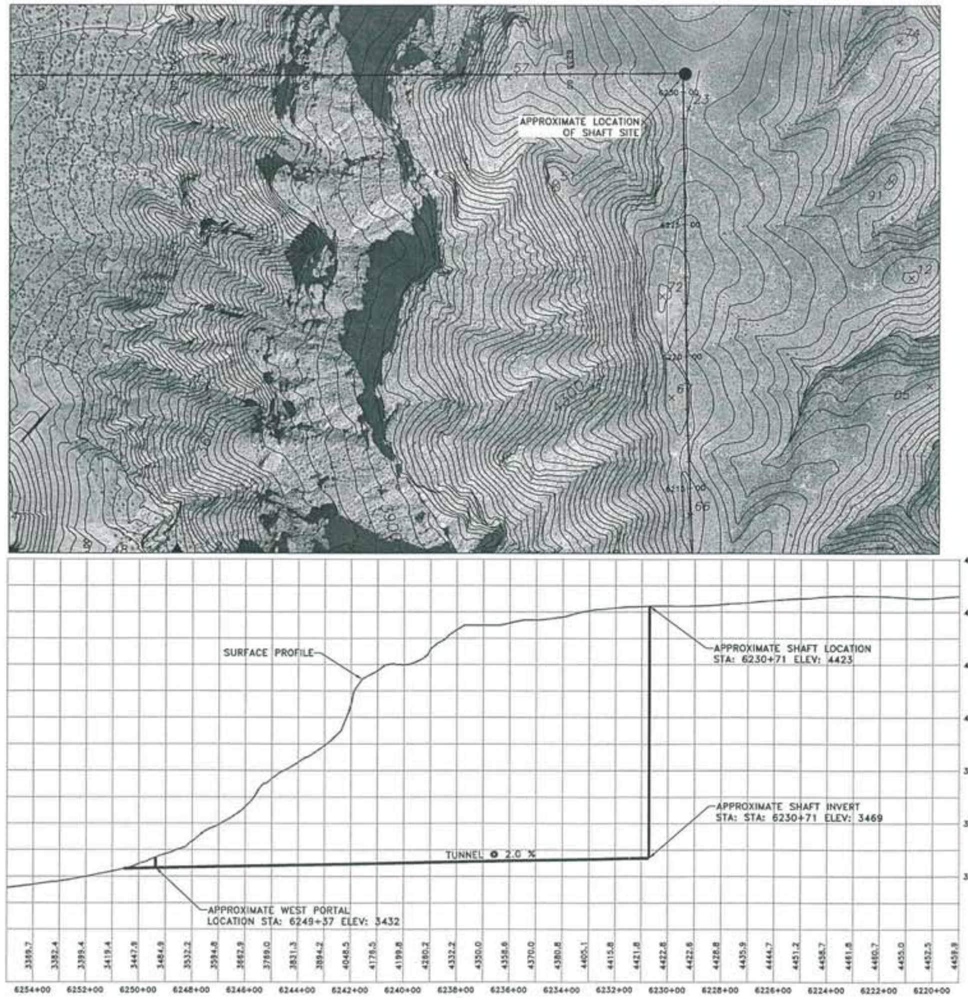
FIGURE 3



-N-

HORIZONTAL & VERTICAL

0 1000 2000

SCALE IN FEET

NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #5 (BASELINE – COULD SPRING – MOLLIES NIPPLE ALIGNMENT)

2. THIS PLAN AND PROFILE IS FOR ANALYSIS OF THE HURRICANE CLIFFS TUNNEL AND SHAFT ONLY.

3. THE LOCATIONS OF THE HYDROPOWER FACILITY, WEST PORTAL, AND SHAFT ARE SUBJECT TO CHANGE.

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

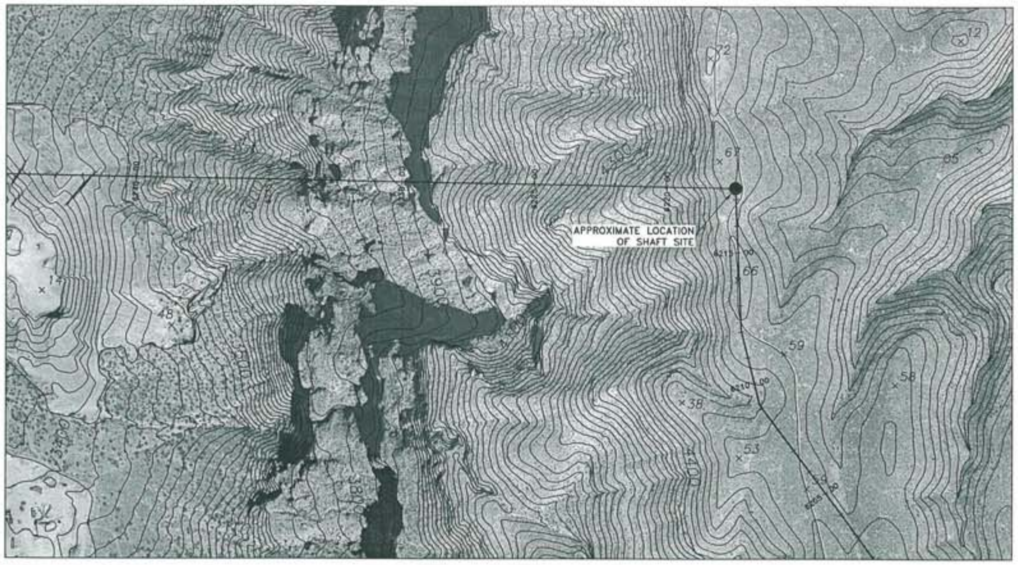
MOLLIES ALIGNMENT #1
PLAN AND PROFILE

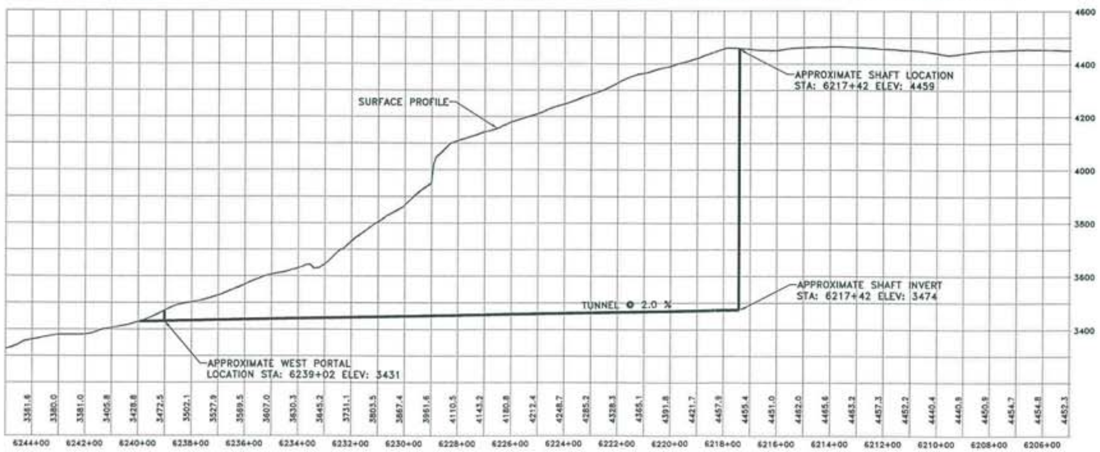
SCALE: AS SHOWN | MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

28618800003.DWG 3/14/03

FIGURE 4





-N-

HORIZONTAL & VERTICAL

0 800 1600

SCALE IN FEET

NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #5 (BASELINE – COULD SPRING – MOLLIES NIPPLE ALIGNMENT)

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HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

MOLLIES ALIGNMENT #2
PLAN AND PROFILE

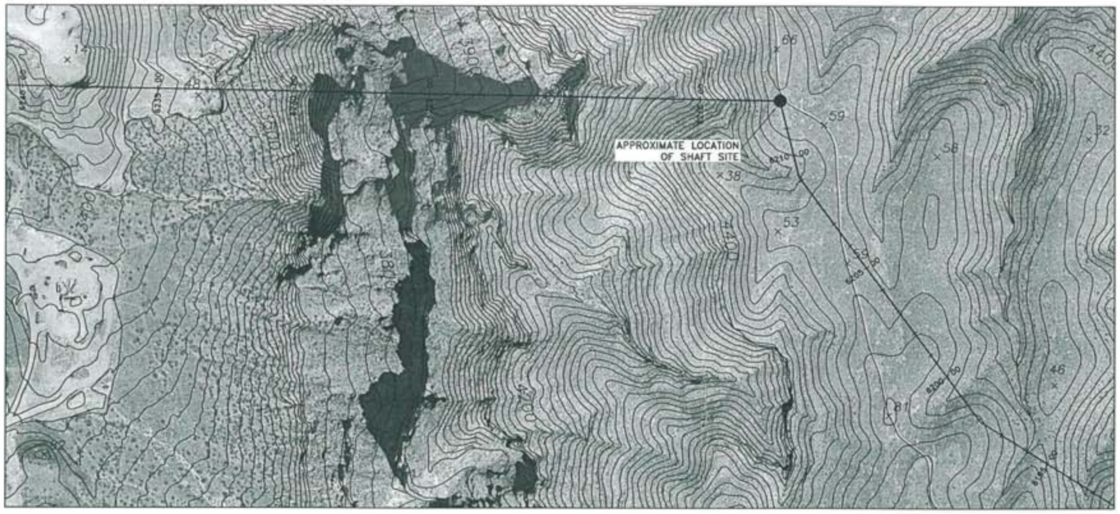
SCALE: AS SHOWN

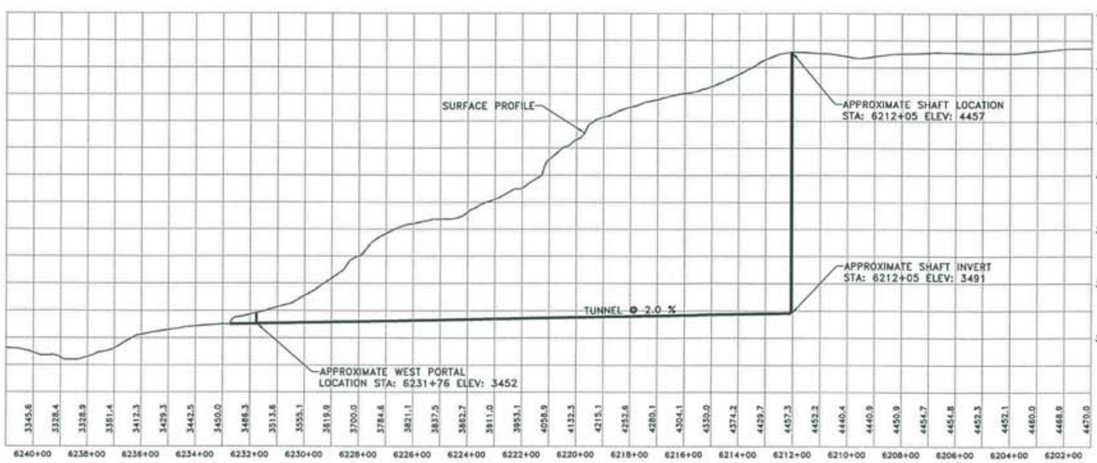
MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

28818000004.DWG

FIGURE 5





-N-

HORIZONTAL & VERTICAL

0 1000 2000

SCALE IN FEET

NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #5 (BASELINE – COULD SPRING – MOLLIES NIPPLE ALIGNMENT)

2. THIS PLAN AND PROFILE IS FOR ANALYSIS OF THE HURRICANE CLIFFS TUNNEL AND SHAFT ONLY.

3. THE LOCATIONS OF THE HYDROPOWER FACILITY, WEST PORTAL, AND SHAFT ARE SUBJECT TO CHANGE.

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

MOLLIES ALIGNMENT #3
PLAN AND PROFILE

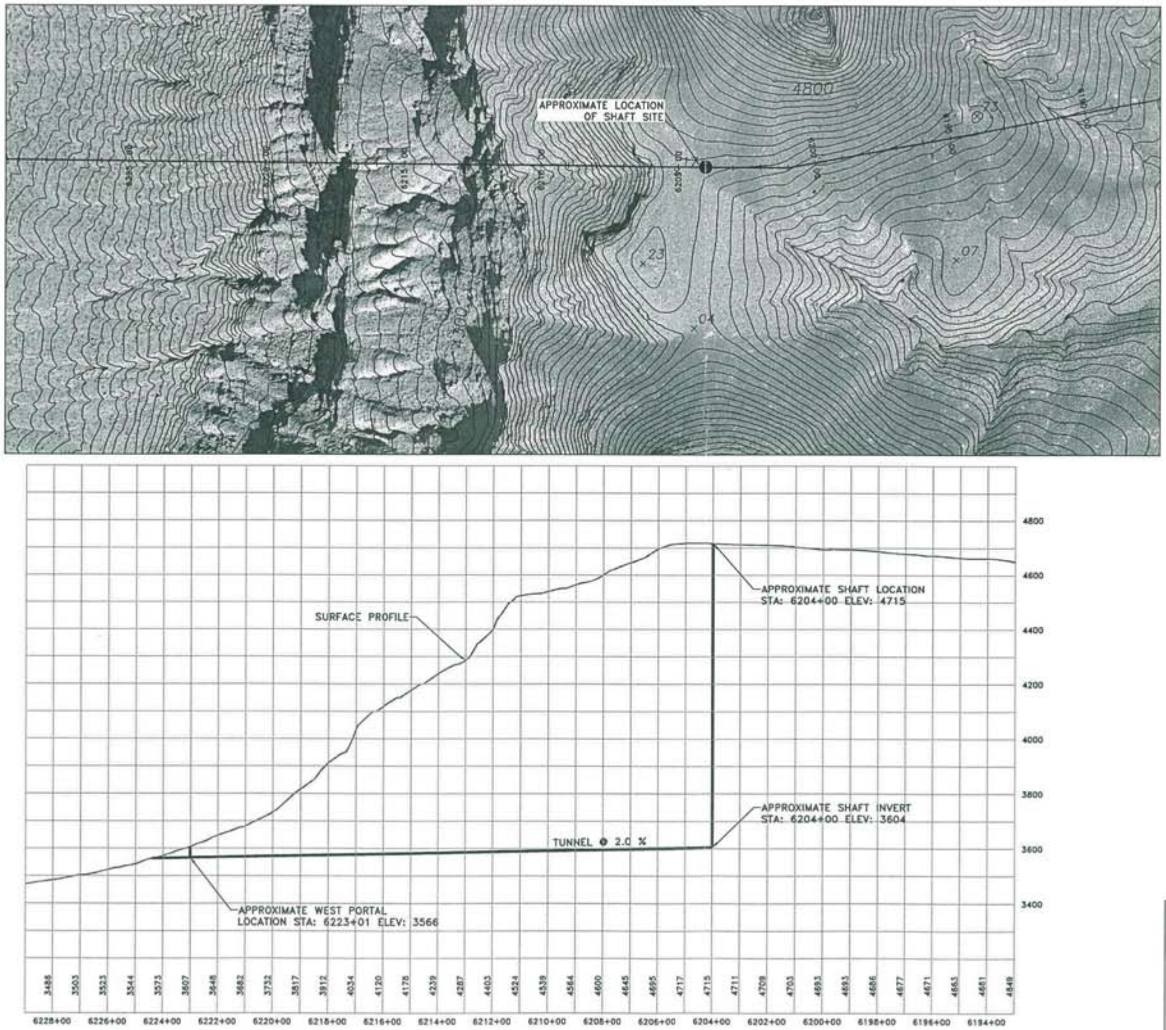
SCALE: AS SHOWN

MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

28818000005.DWG 3/14/03

FIGURE 6



-N-

HORIZONTAL & VERTICAL

0 800 1600

SCALE IN FEET

NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #3 (BASELINE – GOULD SPRING – GRASS VALLEY ALIGNMENT)

2. THIS PLAN AND PROFILE IS FOR ANALYSIS OF THE HURRICANE CLIFFS TUNNEL AND SHAFT ONLY.

3. THE LOCATIONS OF THE HYDROPOWER FACILITY, WEST PORTAL, AND SHAFT ARE SUBJECT TO CHANGE.

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LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

GOULD SPRING ALIGNMENT
PLAN AND PROFILE

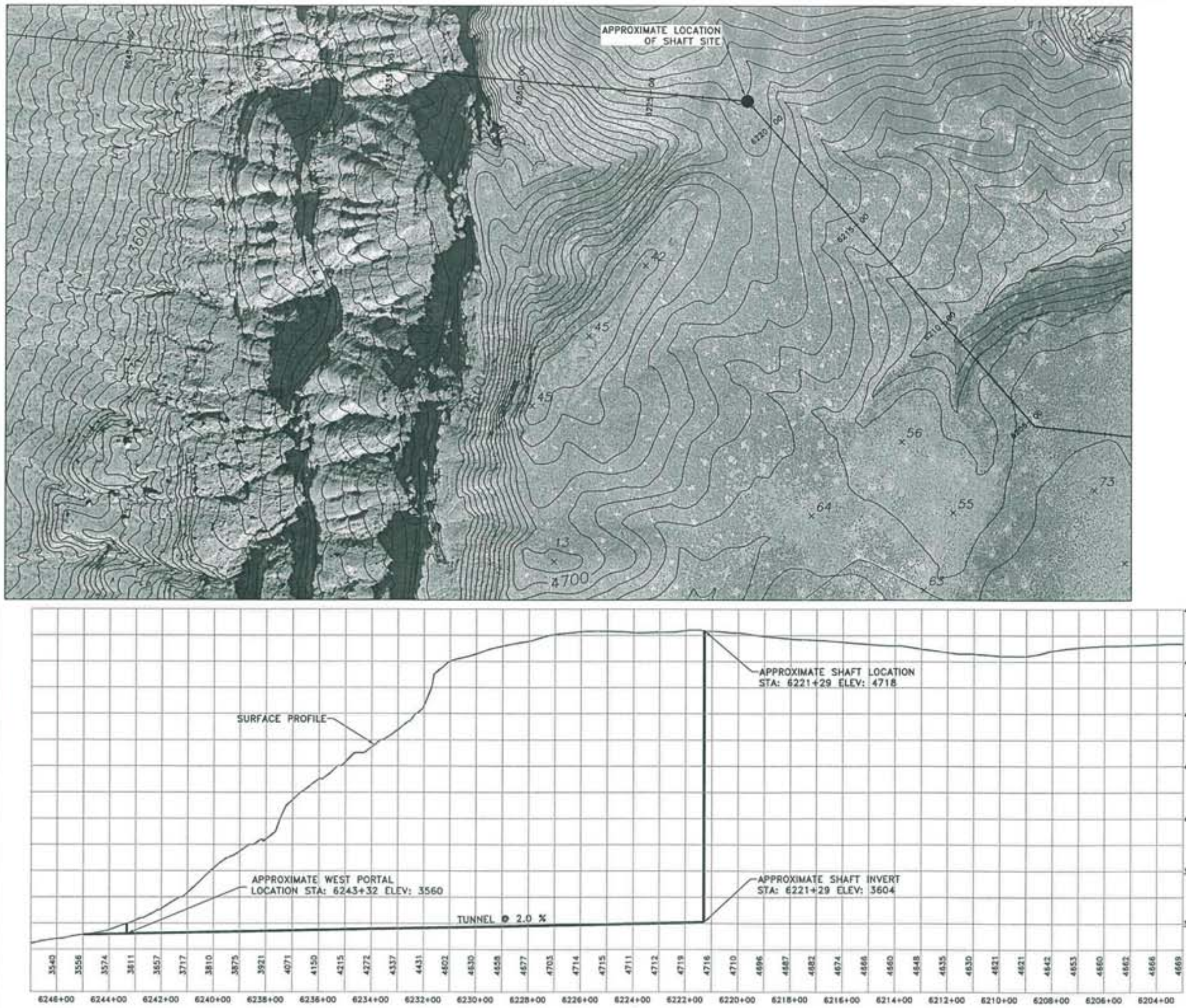
SCALE: AS SHOWN

MARCH 2003

28816000007.DWG

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

FIGURE 7



NOTES:

1. THE STATIONS ARE BASED ON ALIGNMENT #1 (BASELINE – GOULD RESERVOIR ALIGNMENT)
2. THIS PLAN AND PROFILE IS SIMILAR TO THE HURRICANE CLIFFS PORTION OF ALIGNMENT # 6, 8, 11, and 12.
3. THIS PLAN AND PROFILE IS FOR ANALYSIS OF THE HURRICANE CLIFFS TUNNEL AND SHAFT ONLY.
4. THE LOCATIONS OF THE HYDROPOWER FACILITY, WEST PORTAL, AND SHAFT ARE SUBJECT TO CHANGE.

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

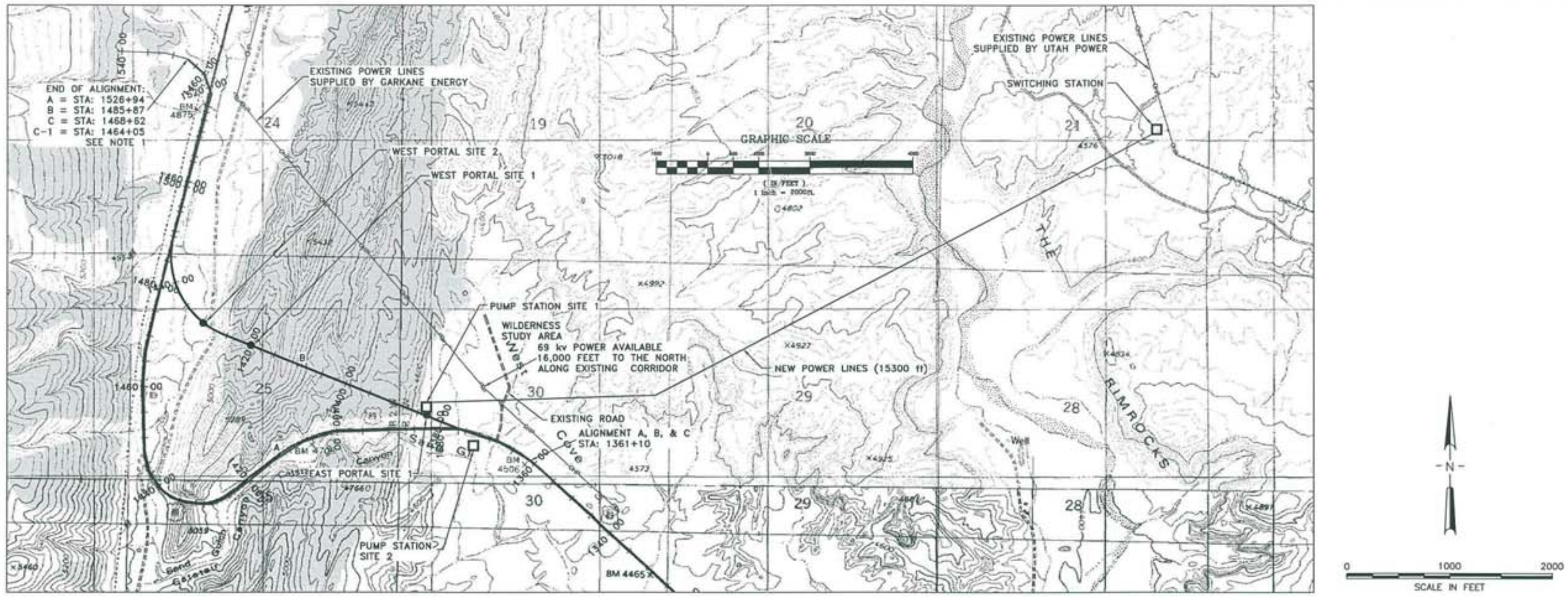
GROUND RESERVIOR ALIGNMENT PLAN AND PROFILE

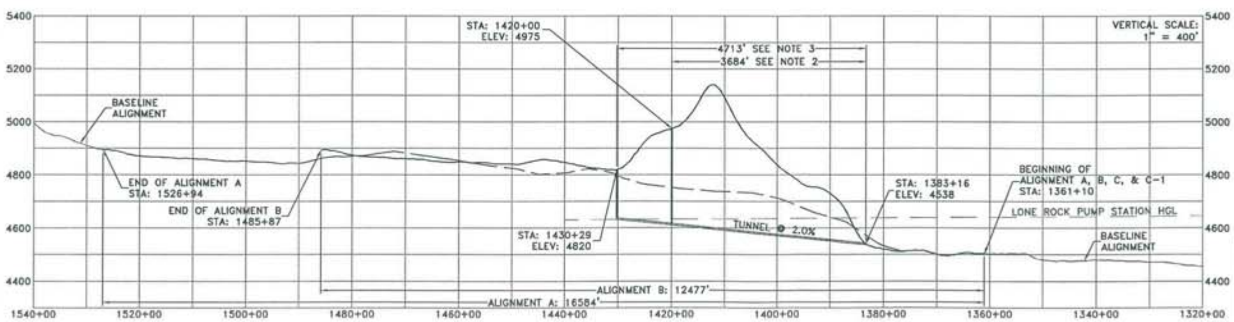
SCALE: AS SHOWN

MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

FIGURE 8





NOTES:

1. ALIGNMENT "A" IS THE OVERALL PROJECT BASELINE ALIGNMENT. THIS EXHIBIT IS FOR ANALYSIS OF THE COCKSCOMB ALTERNATIVES ONLY.

2. TUNNEL PROFILE ON ALIGNMENT B EXTENDS FROM EAST PORTAL SITE 1 TO WEST PORTAL SITE 1. REFER TO THE SPREADSHEET FOR ALIGNMENT DETAILS.

3. TUNNEL PROFILE ON ALIGNMENT B EXTENDS FROM EAST PORTAL SITE 1 TO WEST PORTAL SITE 2. REFER TO THE SPREADSHEET FOR ALIGNMENT DETAILS.

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LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

COCKSCOMB ALTERNATIVE
ALIGNMENT B
PLAN AND PROFILE

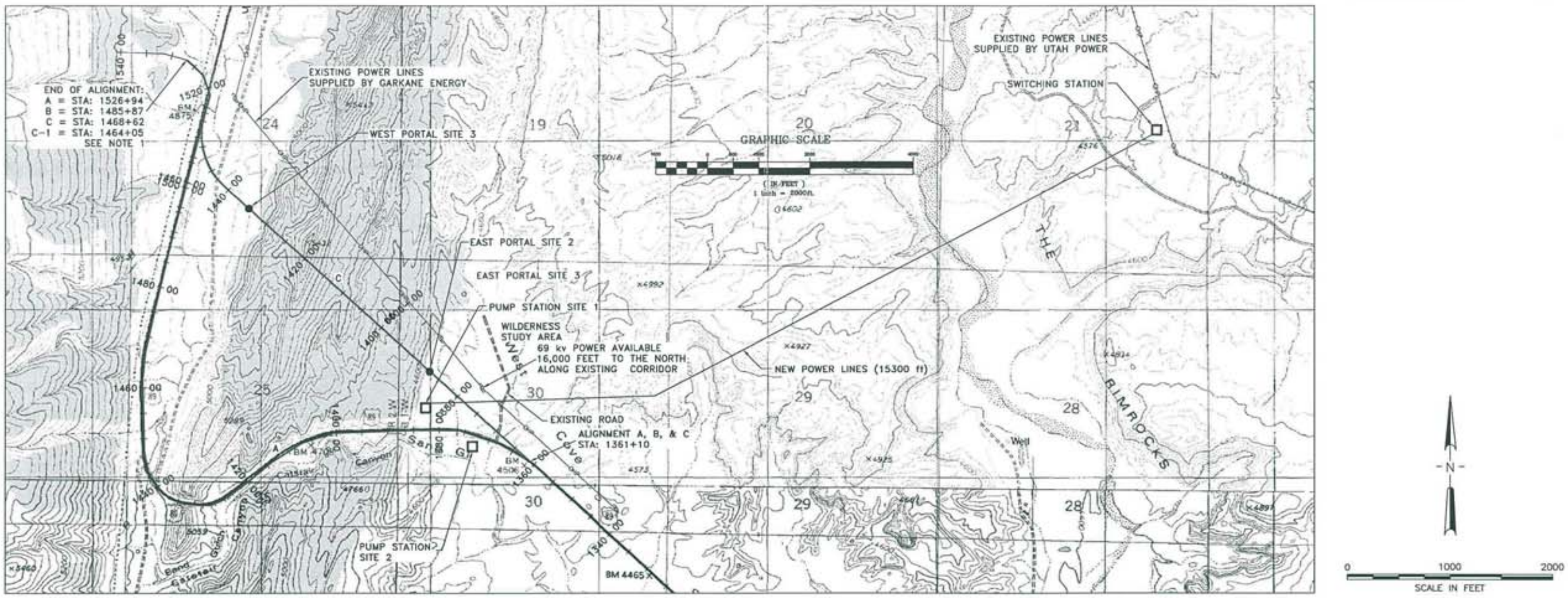
SCALE: AS SHOWN

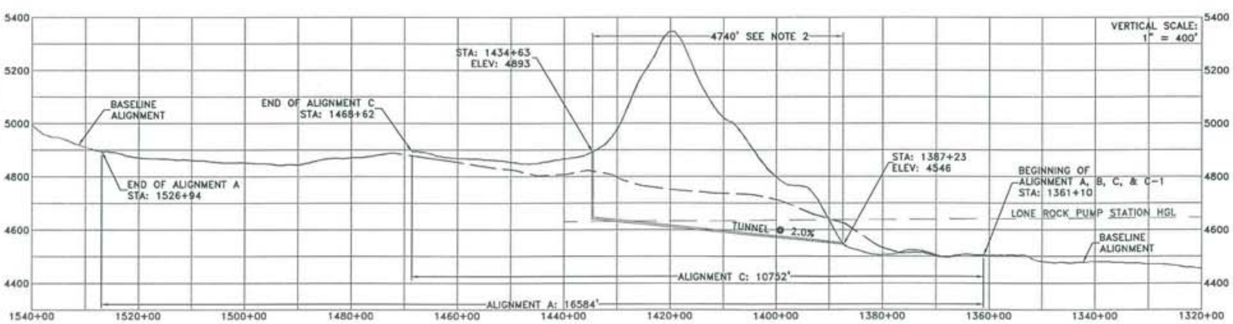
MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

26818-800009.DWG

FIGURE 9





NOTES:

1. ALIGNMENT "A" IS THE OVERALL PROJECT BASELINE ALIGNMENT. THIS EXHIBIT IS FOR ANALYSIS OF THE COCSKCOMB ALTERNATIVES ONLY.

2. TUNNEL PROFILE ON ALIGNMENT C EXTENDS FROM EAST PORTAL SITE 2 TO WEST PORTAL SITE 3. REFER TO THE SPREADSHEET FOR ALIGNMENT DETAILS.

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LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

COCKSCOMB ALTERNATIVE
ALIGNMENT C
PLAN AND PROFILE

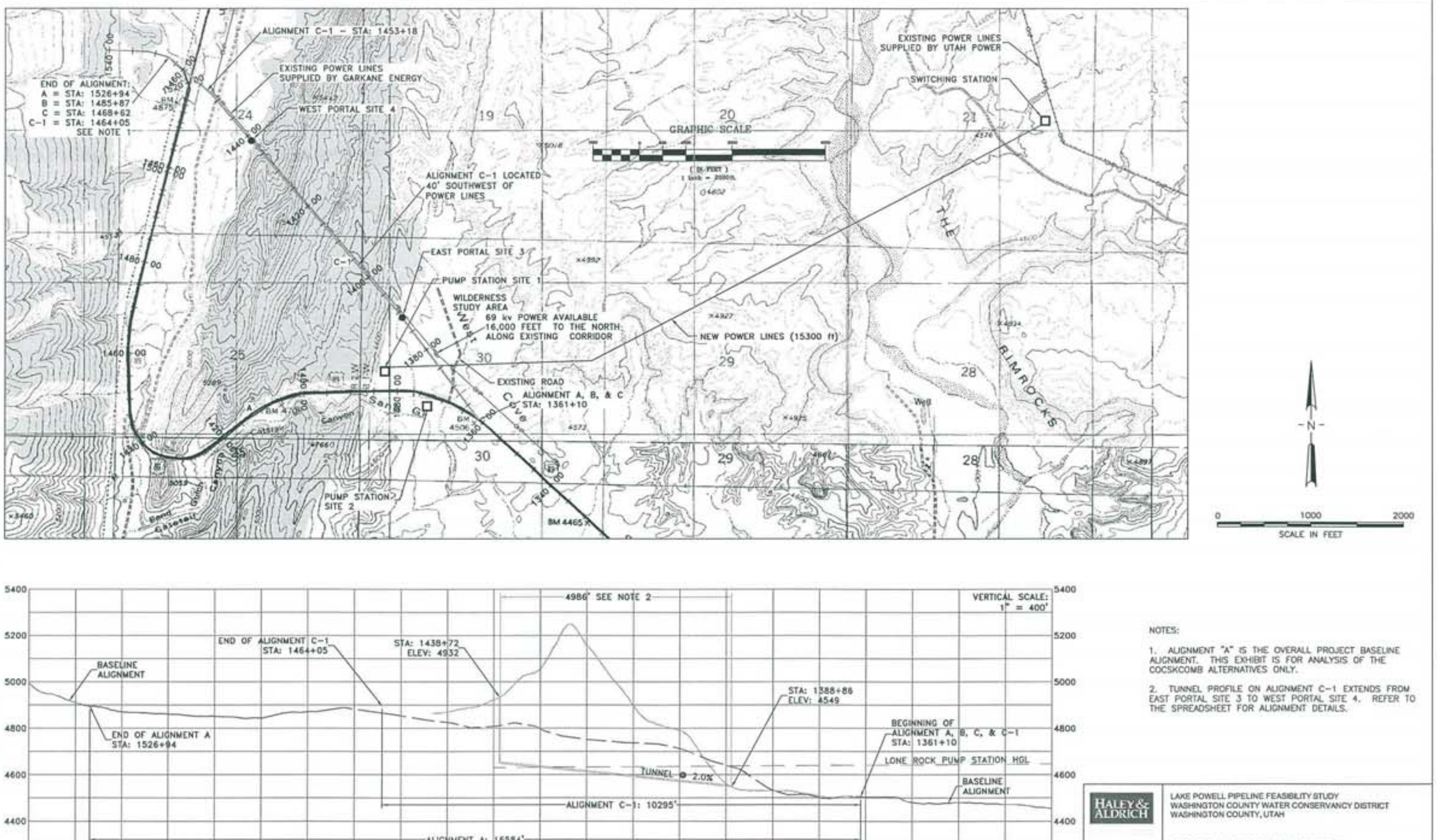
SCALE: AS SHOWN

MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

28818880010.DWG

FIGURE 10



NOTES:

1. ALIGNMENT "A" IS THE OVERALL PROJECT BASELINE ALIGNMENT. THIS EXHIBIT IS FOR ANALYSIS OF THE COCSKCOMB ALTERNATIVES ONLY.

2. TUNNEL PROFILE ON ALIGNMENT C-1 EXTENDS FROM EAST PORTAL SITE 3 TO WEST PORTAL SITE 4. REFER TO THE SPREADSHEET FOR ALIGNMENT DETAILS.

HALEY & ALDRICH

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

COCKSCOMB ALTERNATIVE
ALIGNMENT C-1
PLAN AND PROFILE

SCALE: AS SHOWN

MARCH 2003

REFERENCE: BOYLE ENGINEERING CORP., LAKE POWELL FEASIBILITY STUDY

FIGURE 11

TYPICAL APRON OF COLLUVIUM LOCATED ALONG BASE OF CLIFF.

LOOKING SOUTHWEST ALONG CLIFF FROM MOLLIES ALTERNATIVE NO. 1.

HALEY & ALDRICH

UNDERGROUND ENGINEERING & ENVIRONMENTAL SOLUTIONS

LAKE POWELL PIPELINE FEASIBILITY STUDY
WASHINGTON COUNTY WATER CONSERVANCY DISTRICT
WASHINGTON COUNTY, UTAH

HURRICANE CLIFFS
SITE PHOTOGRAPHS

MARCH 2003

FIGURE 12

G:28818\REPORT\CAD\FIG11.DWG

Preliminary Design and Cost Estimate for Lone Rock Pump Station

Prepared for: **State of Utah**
Division of Natural Resources

Prepared by: **Bureau of Reclamation**
Provo Area Office

January 2002

Table of Contents

Executive Summary 1

Introduction 2
Scope 2
Concerns 2

Background 3

Pump Station Options 3

Site Selection 4
Selection Criteria 4
Intake Elevations 5
Sites 9
Study Site 12

Water Quality 13

Geology 15

Preliminary Design 17
Environmental Concerns 17
Pumps and Pump Motors 17
Sumps 18
Piping and Valves 19
Sitework 19
Concrete 20
Electrical 20

Cost Estimates 22

Drawings 23

Renderings 24

Appendix A - City of Page, 2000 Water Quality Annual Report 25

List of Drawings

LONE ROCK PUMP STATION
PRELIMINARY DESIGN

1	Site Comparison
2	Site Comparison
3	Overview of Sites 1 through 5
4	Site 1
5	Sites 2, 3 and 4
6	Site 5
7	Site Plan - Site 2
8	Site Plan - Site 3
9	Site Plan - Site 3 - Switch Yard
10	General Section - Site 3
11	Site Plan - Site 4
12	General Section - Site 4
13	Plan
14	Section Through Pump Station
15	Roof Plan
16	Electrical Plan
17	Electrical - Single Line Diagram

Executive Summary

The proposed Lone Rock Pump Station will be the first element in the proposed Lake Powell Pipeline, which will deliver water from Lake Powell to Washington County, Utah. The pump station proposed to be located on the south shoreline of Wahweep Bay and is proposed to have a pumping capacity of 70,000 acre feet per year (approximately 98 cfs of continuous flow).

Water will be delivered to the pump station via a tunnel which will flow into a vertical shaft or well. The water in the vertical shaft will be pumped to the surface with variable head pumps which will discharge into a sump in the pump station building. High pressure pumps will take water from the sump and pump it into the pipeline. The pipeline will deliver water to the Cockscomb Pump Station which will pump the water over the summit along the pipeline alignment. For a full description of the alignment see the Lake Powell Pipeline Feasibility Study by Boyle Engineering (referred to in this document as the Boyle Report).

The preliminary design places the minimum reservoir water surface at or below 3550 feet and the intake tunnel at or below 3540 feet above mean sea level. These levels were arrived at after considering the historic record and a forecasting model.

Five pump station sites were evaluated. The sites were evaluated based on the following criteria:

1. Site access to deep water.
2. Visibility of the site.
3. Environmental impacts such as new roads, powerlines, etc.
4. Cost.

Site 1 was eliminated because it lacked reasonable access to deep water. Sites 2, 3 and 4 were evaluated further and the preliminary design was based on these three sites. Site 5 was eliminated due the higher cost of using this site.

The preliminary design uses a pump station with two sets of pumps. The first set of pumps are variable head pumps which are needed to compensate for the changes in reservoir elevation. The second set of pumps are high pressure pumps needed to pump the water approximately 1000 feet vertically to the next pump station.

Introduction

Scope

This is a study of the Lone Rock Pump Station. The study includes the Lone Rock Pump Station, switch yard, powerlines to the pump station, and access roads. The study analyzed the best pump station locations by looking at accessibility, water availability, environmental considerations, and cost. To compare location costs, the costs of pipelines from the various pump station locations to a common location just outside of the National Park Service Boundaries were included. The costs include design and construction oversite, the intake tunnel and vertical shaft, pump station building, electrical components, pumps and piping, transmission lines from the power source to the pump station, and the cost of line pipe to a common location.

Five sites were considered and three are studied in detail in this report. Due to shallow reservoir depths, the first site was eliminated. A fifth site was studied, but was eliminated due to significantly higher cost.

To determine the head required to pump water to the Cockscomb Pump Station, a hydraulic study of the pipeline up to the Cockscomb Pump Station was conducted. The results of the study were used to size the high head pumps.

During the study the Bureau of Reclamation met with the National Park Service on three separate occasions to keep the Park Service informed about the direction of the study and to receive their input and direction. Sites were viewed from a boat on the reservoir as well as on the ground, and several site options were discussed; however, the National Park Service has not committed to any site or design concept.

Concerns

Lone Rock Pump Station will be located in a popular recreational area and will have high exposure to the public. The National Park Service would like to have the pump station hidden from view as much as possible or at least have it blend in with other buildings in the area. The structure would need to be made from materials resistant to vandalism that blend well with the surroundings so as not to attract attention. Also, it will be sited to minimize visual impact to the permanent residents in the surrounding area, in particular the Green Haven Community.

Power transmission lines will need to be buried for the last two or three miles to satisfy NEPA requirements and to minimize visual impacts. Considerable power is required to run the pump station and accessing this power will be a difficult task.

Background

In 1995 Boyle Engineering conducted a study to determine if it was feasible and economical to pipe water from Lake Powell to Washington County, Utah. This study was based on a projected future shortage of at least 60,000 Acre feet per year. The study analyzed several routes and pumping plant arrangements to determine the most economical route and configuration for the pipeline. The study recommended two pump station arrangements. One arrangement would use a single lift pump station to pump water from Lake Powell to the pipeline summit. The other arrangement would use two pump stations to pump water from Lake Powell to the pipeline summit. “The options of three or more pump stations were not investigated in this study due to 1) the high cost of housing and providing power to the sites of three or more pump stations; and, 2) the already reasonably low pipe pressures on the two pump station option”[1]

Pump Station Options

The Boyle report recommended the two pump station option but left the possibility of a single pump station option open. Before proceeding to do a preliminary design using the two pump station scenario, the single pump station option was briefly investigated to determine if it had any merit.

To further explore the information provided in the March 1995 Boyle report, various pipe and pump manufacturers were contacted to find both the physical and economic limits of the one and two pumping plant options presented in the report. The one pump station option requires that water be pumped to a head of 2300 feet which results in a pressure of approximately 1000 psi (includes pipe loses). The two pump station option requires that water be pumped to a head of 1150 feet for each pump station which results in a maximum pressure of approximately 500 psi per station (includes pipe loses). A local pipe manufacturer quoted $175 per foot for 54" diameter 500 psi pipe delivered to the jobsite. They stated that 1000 psi pipe was beyond their capabilities. American Cast Iron Pipe Company quoted $490 per foot for 54" diameter 1000 psi pipe that was described as a "Roll and Weld" pipe (i.e., a sheet of steel is rolled in a press several times and then welded along the longitudinal seam). This estimate essentially

[1] Lake Powell Pipeline Feasibility Study, March, 1995 - by Boyle Engineering Corp.

agrees with the $516 per linear foot estimate for high pressure pipe in the Boyle report (the $516 figure was arrived at by using cost equations presented in the Boyle report). According to several pump manufacturer's, for flows of 98 cfs a 2300 foot lift is not possible using standard pump parts. Reducing the lift to 1150 feet is still difficult but possible.

As a result of these investigations it was decided to pursue the two pump station option.

The Boyle report examined three different pump station configurations to pump water from Lake Powell.

1. Lake Platform Pump Station
2. Two-Lift Lakeside Pump Station
3. One-Lift Lakeside Pump Station

The Lake Platform Pump Station option consists of a floating platform with vertical turbine pumps mounted on it. The Two-Lift Lakeside Pump Station option consists of a set of variable head pumps that pump water to the surface which then feeds fixed head high pressure pumps, and is the configuration pursued in this report. The Boyle Report recommends the One-Lift Lakeside Pump Station which uses one set of high pressure pumps that pump directly from a deep well sump. The one-lift option was eliminated because the diameter of the center pump shaft required for this option was too large to make it economically feasible.

Site Selection

Selection Criteria

Sites were evaluated on the basis of access to adequate water depth, cost, and environmental considerations.

To determine the required intake elevations both historical data and a forecasting model were used. A target low water elevation was then selected and the sites were evaluated based on that elevation.

The main factors affecting cost were pipeline distance to a common point and underwater tunnel distance.

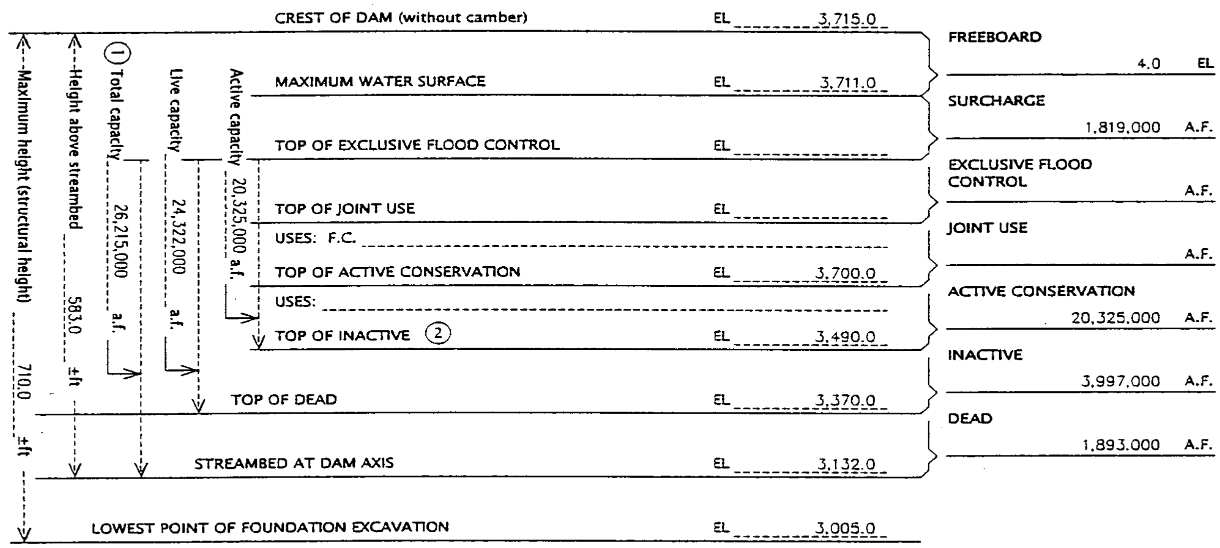
Environmental factors include visual impacts from the reservoir and surrounding areas, the distance from developed areas, and ability to fit in with surrounding terrain. Although Site 1 is the furthest distance from developed areas, Sites 2 and 3 are both

RESERVOIR CAPACITY ALLOCATIONS

TYPE OF DAM	CONCRETE ARCH	REGION	UC	STATE	ARIZONA

OPERATED BY	BUREAU OF RECLAMATION	LAKE POWELL	OPERATED BY
CREST LENGTH	1,560 FT; CREST WIDTH 25 FT	GLEN CANYON	DAM
VOLUME OF DAM	5,370,000 CU YD	COLORADO RIVER STORAGE	PROJECT
CONSTRUCTION PERIOD	1956–1966	MIDDLE RIVER	DIVISION
STREAM	COLORADO RIVER	GLEN CANYON	UNIT
RES AREA	160,784 ACRES AT EL 3,700.0	OPERATIONAL	STATUS OF DAM

ORIGINATED BY:			APPROVED BY:		
EV	UC-434	9/26/88	WLB	D-5210	8/30/89
(Initials)	*(Code)*	*(Date)*	*(Initials)*	*(Code)*	*(Date)*



① Includes 1/ 7,671,800 a.f. allowance for 76.5 year sediment deposition between STREAMBED and El. 3,700.0, of which 3,134,000 a.f. is above El. 3,490.0.

② Established by 1986 Sediment Survey and ACAP85 computer program

REFERENCES AND COMMENTS:

1/ Based on revised Area Capacity tables and the results of the 1986 Lake Powell Resurvey as contain in the Survey Reported dated December 1988.

Figure 1

located in ravines which adequately hides them from the surrounding areas. Site 4 is hidden by a hill south of the Site and also by cliffs north of the site. Site 5 is near Glen Canyon Dam and is visible from the dam and entrance to the park. A pump station in this area would be another structure similar to the dam.

Intake Elevations

To determine the pump intake elevations, the probable high and low reservoir elevations were determined using the historic record and a model developed for the Colorado River Interim Surplus Criteria Environmental Impact Statement referred to in this report as the EIS model. Pumping limitations were also considered.

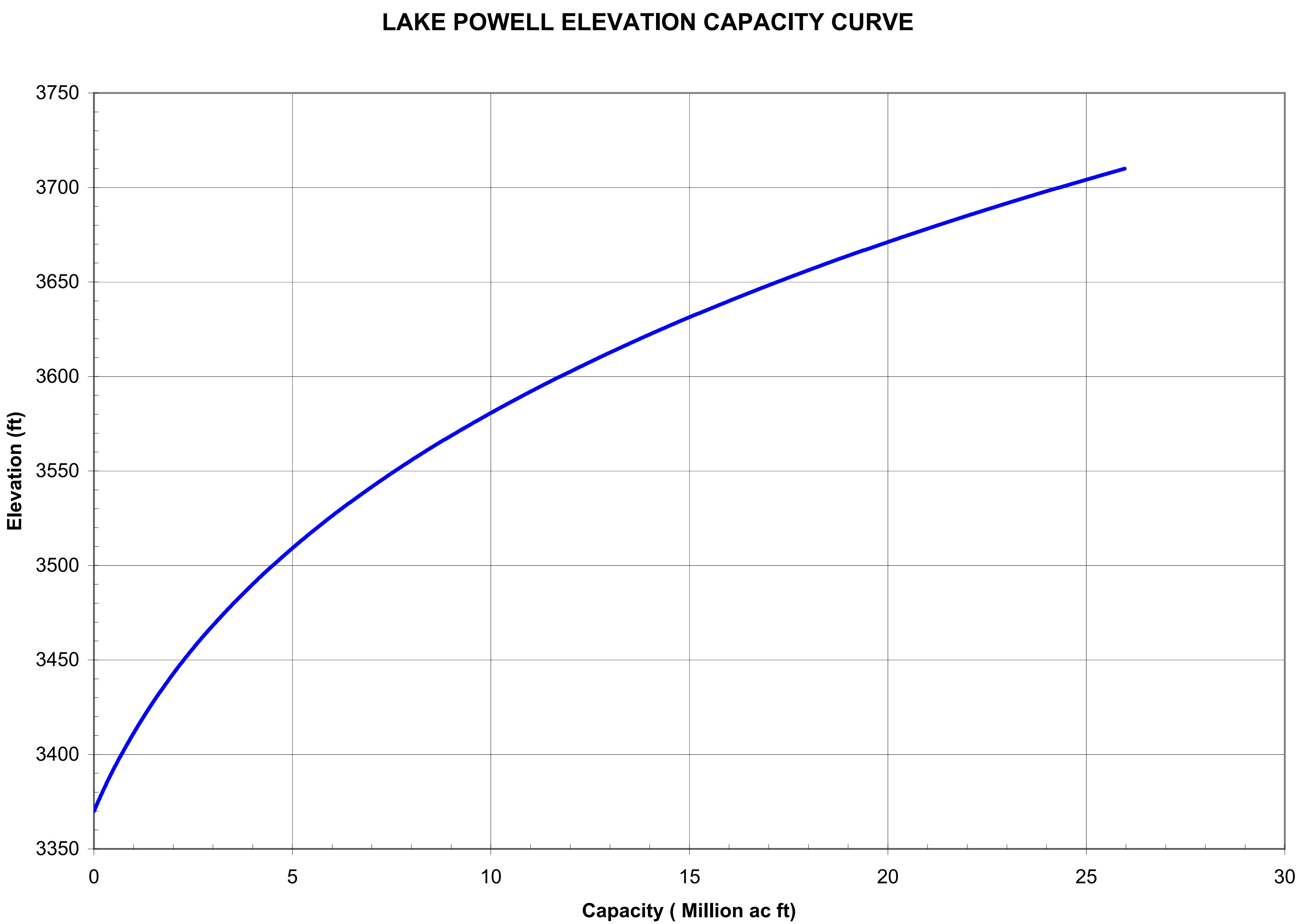
The reservoir high water elevation is set by the reservoir allocation table for Glen Canyon Dam and is placed at the top of exclusive flood control which is 3711 feet as shown in Figure 1. The historic high of 3708 feet was set in July of 1983.

It is neither economical nor practical to build a pump station that will pump from the reservoir floor; therefore, a low water elevation needed to be determined. For this report the low water elevation was determined using two criteria:

1. Historic elevations.
2. Elevations predicted using the EIS model.

The historical record is relatively short, 21 years since the lake was first filled in 1980. The historical record includes a seven-year drought through the mid 80's and early 90's, as well as the year 1983 when the reservoir was filled to capacity. The Boyle Report recommended a minimum water surface elevation of 3580 feet based on the historical record. The report further points out that at this elevation, Lake Powell is at 40 percent of its capacity as shown in Figure 3. The historical low since 1980 is 3612 feet. Figure 2 shows a record of the historic low water elevations at Lake Powell.

Figure 2



LAKE POWELL ELEVATION CAPACITY CURVE
3750
3700
3650
3600
3550
3500
3450
3400
3350
Elevation (ft)
0
5
10
15
20
25
30
Capacity (Million ac ft)

Figure 3

The EIS model uses the natural historic flows on the Colorado River and cycles the record through to simulate future inflows. The model then predicts future demand on the reservoir based on future operating criteria and determines the probability of water elevations at a particular date in time.[2]

Figure 4 shows the EIS model results for the month of July. For any given year between 2002 and 2050, a point on the 50% curve indicates a 50% chance for the lake to exceed that elevation. Likewise, the 90% curve indicates a 90% chance of exceedence for that particular year. Uncertainties increase with time thus creating a larger gap between the 50 percent and 90 percent exceedence curves as time goes on.

Probability lines for future Lake Powell water surface elevations developed through the EIS model have uncertainties associated with them. These uncertainties exist because future hydrology may differ from model hydrology, and water development in the Upper Colorado Basin may occur at a rate which differs from the schedule used in the EIS model. Uncertainties increase over time, with the greatest uncertainty occurring in the year 2050.

[2] Colorado River Interim Surplus Criteria, Environmental Impact Statement, December 2000, U.S. Department of the Interior, Bureau of Reclamation

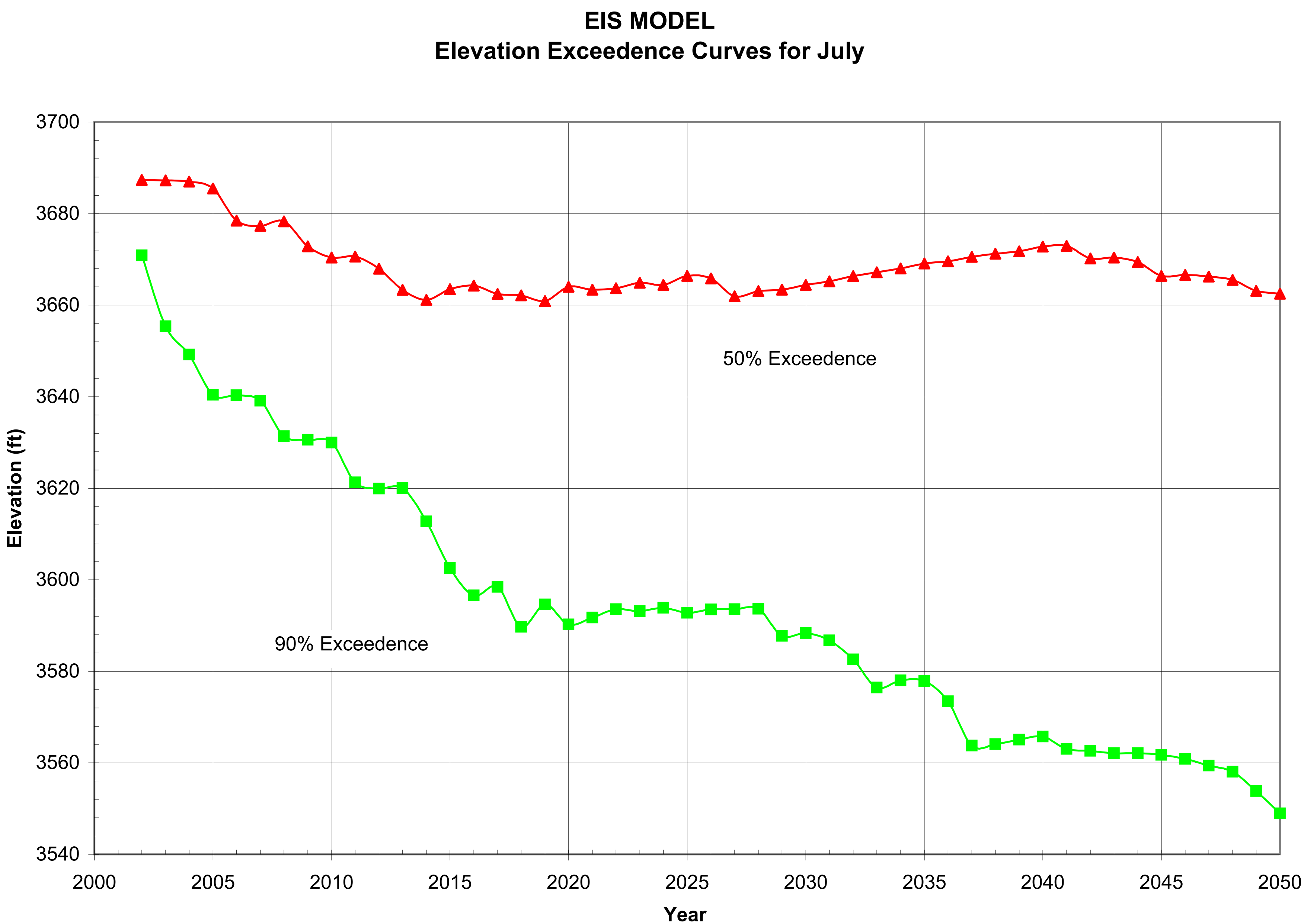

EIS MODEL
Elevation Exceedence Curves for July
50% Exceedence
90% Exceedence
Elevation (ft)
Year
3700
3680
3660
3640
3620
3600
3580
3560
3540
2000
2005
2010
2015
2020
2025
2030
2035
2040
2045
2050

Figure 4

Based on the EIS model, it was decided to place the intake invert at no higher than 3540 with the resulting low water line at 3550. This places the minimum intake elevation at or below the 90% exceedence curve for the year 2050. At 3550 Lake Powell is at 30 percent of its capacity as shown in Figure 3.

Drawing 14 and the accompanying cost estimates places the tunnel invert elevation at 3525 feet which places the low water elevation at 3546.5 feet. The minimum water surface is required to be at least 2 ½ feet above the intake screens for a screen diameter of 5 feet.

Sites

General - Five sites were evaluated. An aerial view of four of the sites is shown in Figure 6. Each site was evaluated by running the pipeline to a common point for purposes of evaluation. To reduce visual impacts, the pumping plant will be designed so that the majority of the structure will be underground or otherwise hidden from view. To evaluate each site, it was assumed that reservoir water would be accessed via a tunnel and vertical shaft. The cost of the tunnel was estimated at $2,400 per foot and the cost of the shaft at $4,600 per foot. The length of each tunnel was determined by using contour line data supplied by the National Park Service. Drawings 1 and 2 are general maps that shows the location of all 5 sites. Figure 5 is a summary of the estimated cost for each site.

Site 1 - Site 1 is the farthest northwest of the five sites. It is located in Section 36, Township 43 South, Range 3 East in the state of Utah.

To access Site 1 a gravel road would need to be constructed. The addition of a road would increase the visual impact of this site. The road would be approximately two miles in length or longer and would include a gate to prevent public access.

The site is easily viewed from the reservoir. However, it is not easily seen by the general public that stays within the developed areas of the recreation area. This site is the farthest from the Greenhaven community and is not visible from that vantage point. The terrain in this area is flat which would make hiding the pump station and switch yard difficult.

Pipeline distance for Site 1 is 11,500 feet, the shortest of all five sites. There is no adverse terrain between Site 1 and the common point so no additional cost was added to the pipeline estimate.

Reservoir depths in this area are shallow in comparison to the other three sites, and would require an extremely long tunnel (3960 feet) to access the targeted invert tunnel depth of 3540 feet. Targeting a shallower depth will impose a greater risk of not being able to pump and is not advisable. This tunnel would be nearly impossible to construct and for this reason Site 1 was eliminated from further evaluation.

Water quality is expected to be good, however; turbidity could be a problem because of loose sediment where the intake would be located.

Site 2 - Site 2 is between Sites 3 and 4. It is located in Section 6, Township 44 South, Range 4 East in the state of Utah.

There is a gravel road that ends approximately a half of a mile from the site. This road is guarded by a locked gate and fence. There is also an old dirt road (see Figure 7) that ends at the site, but this road has a soft base and will need extensive upgrading to handle construction and maintenance vehicle traffic. The roads are connected, but a fenced yard prevents access to the old dirt road. No gate or fence would be required since these features already exist.

The site is easily viewed from the reservoir but does not have the same prominence as Site 1. The site is not easily seen by the general public that stays within the developed areas of the recreation area; however, it is closer to more developed areas than Site 1. This site is not visible to the Greenhaven community because of the existing terrain. The terrain has rolling hills which facilitates a buried pump station configuration. The pump station would be placed in the side of the ravine which would obstruct the view of the station from the reservoir. The switch yard would be constructed with a surrounding berm which would also minimize the visual impacts.

Pipeline distance for Site 2 is 22,900 feet. There is gorge between Site 2 and the common point so the additional cost of a siphon crossing was added to the pipeline estimate.

Reservoir bottom depths in this area are deep. A lake bottom elevation of 3480 can be reached within 1,700 feet of the site. A tunnel length of 700 feet would be required to access the targeted 3540 depth.

Water quality is expected to be good, however; turbidity could increase during thunderstorms and similar events because the intake is located in a minor drainage.

Site 3 - Site 3 is between Sites 1 and 2. It is located in Section 1, Township 44 South, Range 3 East in the state of Utah.

There are several dirt roads that lead to the site, many of which appear to be in good condition. Any of the roads can be improved to carry construction traffic without any additional visual impact to the landscape. The pump station would require fencing because of the numerous public access roads (see Figure 8).

The site can be viewed from the reservoir but does not have the same prominence as Site 1. The site is not easily seen by the general public that stays within the developed areas of the recreation area; however, this area is used by the general public for off road vehicles. This site can be seen by the Greenhaven community but is partly hidden by a hill in which the pump station will be placed. The terrain has rolling hills which facilitates a buried pump station configuration. The pump station would be placed in the side of the ravine which would obstruct the view of the station from the reservoir. The switch yard would be constructed with a surrounding berm which would also minimize the visual impacts.

Pipeline distance for Site 3 is 19,900 feet. There is no adverse terrain between Site 3 and the common point so no additional cost was added to the pipeline estimate.

Reservoir bottom depths in this area are deep. A lake bottom elevation of 3490 can be reached within 1,500 feet of the site. A tunnel length of 375 feet would be required to access the targeted 3540 foot depth.

Water quality is expected to be good, however; turbidity could increase during thunderstorms and similar events because the intake is located in a minor drainage.

Site 4 - Site 4 is farthest east of the four sites located on the edge of Wahweap Bay. It is located in Section 6, Township 44 South, Range 4 East. in the state of Utah.

The nearest access to the site is through the National Park Service day use area east of the site. A new 2,000 foot road would be needed to access the site.

The site is not easily viewed from the reservoir because of the cliff on the reservoir side of the site. The site is not easily seen by the general public that stays within the developed areas of the recreation area. This site cannot be seen by the Greenhaven community because of a hill that hides the pump station and switchyard. The terrain has rolling hills and a cliff adjacent to the reservoir which facilitates a buried pump station configuration. The pump station would be placed on top of the cliff which would obstruct the view of the station from the reservoir. The switch yard would be constructed with a surrounding berm which would also minimize the visual impacts.

Pipeline distance for Site 4 is 25,940 feet with 4,000 feet of that in 60 inch pipe. The larger pipe is needed to offset the increased friction losses imposed by the added pipe length (See Figure 13). There are two gorges between Site 2 and the common point so the additional cost of two siphon crossings were added to the pipeline estimate.

Reservoir bottom depths in this area are the deepest of a all four Wahweap Bay sites. A lake bottom elevation of 3460 can be reached within 430 feet of the site. A tunnel length of 240 feet would be required to access the targeted 3540 foot depth. This site has the option of achieving a deeper intake elevation without a significant increase in tunnel length.

Water quality at Site 4 is expected to be better than the first three sites because it is not located in a drainage.

Site 5 - Site 5 is located about a mile north of Glen Canyon Dam on the west shore of Lake Powell. It is located in Section 13, Township 41 North, Range 8 East, in the state of Arizona.

The nearest access to the site is near the National Park Service park entrance. A new 300 foot road would be needed to access the site.

The pump station would be placed on a cliff overlooking the reservoir. The pump station would be visible from the dam and reservoir. In this location the pump station fits in well with the dam as part of the view.

Pipeline distance for Site 5 is 42,500 feet. All but 200 feet of the pipe is 60 inch pipe. The larger pipe is needed to offset the increased friction losses imposed by the added pipe length (See Figure 13).

Reservoir bottom depths in this area are the deepest of a all five sites. A lake bottom elevation of 3150 can be reached within 460 feet of the site. A tunnel length of 230 feet would be required to access the targeted 3540 foot depth. This site has the option of achieving a deeper intake elevation without a significant increase in tunnel length.

Water quality at Site 5 is expected to be as good as Site 4.

Study Site

Site 3 was selected for the purposes of this report to be the primary site of study since it has the least cost of all four credible sites. In the final selection other factors besides cost should be considered. In the end other factors such as water quality and water depth may carry more weight. Sites 2, 4, and 5 are alternates to Site 3. All of the concepts and drawings developed for Site 3 are easily made applicable to the other sites with very little modification (tunnel length and orientation). Site 1 was eliminated from further study due to shallow reservoir depths in the vicinity of the site, the impact of a new road, and the difficulty of hiding a pump station and switch yard. Site 5 was eliminated due to significantly higher costs. Drawings 3 through 6 show more detailed elevation information for all five sites.

LAKE POWELL PUMPING PLANT (SITE COMPARISON)

3540 Tunnel Invert Elevation

Pipe Prices from Means estimating guide

SITE # 1

Item	Unit	Unit Price	Quantity	Total Price
Pipeline	Lin Ft	$365	11476	$4,188,740
24 Ft Wide Gravel Road	Lin Ft	$29	11500	$333,500
84" Lined Tunnel	Lin Ft	$2,400	3960	$9,504,000
Pumping Plant	Lump Sum	$12,733,800	1	$12,733,800
Buried Powerline	Mile	$1,000,000	4.5	$4,500,000
24' Dia. Vertical Shaft	Lin Ft	$4,600	190	$874,000
Subtotal				$32,134,040
Mobilization (5%)				$1,606,702
Unlisted (5%)				$1,606,702
Contingencies (10%)				$3,213,404
Design (6%)				$1,928,042
Construction Oversite (6%)				$1,928,042
		GRAND TOTAL		$42,000,000

SITE # 2

Item	Unit	Unit Price	Quantity	Total Price
Pipeline	Lin Ft	$365	22930	$8,369,450
24 Ft Wide Gravel Road	Lin Ft	$29	4000	$116,000
84" Lined Tunnel	Lin Ft	$2,400	700	$1,680,000
Pumping Plant	Lump Sum	$12,733,800	1	$12,733,800
Siphon Crossing	Lump Sum	$50,000	1	$50,000
24' Dia. Vertical Shaft	Lin Ft	$4,600	190	$874,000
Buried Powerline	Mile	$1,000,000	2.5	$2,500,000
Subtotal				$26,323,250
Mobilization (5%)				$1,316,163
Unlisted (5%)				$1,316,163
Contingencies (10%)				$2,632,325
Design (6%)				$1,579,395
Construction Oversite (6%)				$1,579,395
		GRAND TOTAL		$35,000,000

SITE # 3

Item	Unit	Unit Price	Quantity	Total Price
Pipeline	Lin Ft	$365	19872	$7,253,280
24 Ft Wide Gravel Road	Lin Ft	$29	8500	$246,500
84" Lined Tunnel	Lin Ft	$2,400	375	$900,000
Pumping Plant	Lump Sum	$12,733,800	1	$12,733,800
24' Dia. Vertical Shaft	Lin Ft	$4,600	190	$874,000
Buried Powerline	Mile	$1,000,000	2.6	$2,600,000
Subtotal				$24,607,580
Mobilization (5%)				$1,230,379
Unlisted (5%)				$1,230,379
Contingencies (10%)				$2,460,758
Design (6%)				$1,476,455
Construction Oversite (6%)				$1,476,455
		GRAND TOTAL		$32,000,000

Figure 5

LAKE POWELL PUMPING PLANT (SITE COMPARISON)

3540 Tunnel Invert Elevation

Pipe Prices from Means estimating guide

SITE # 4

Item	Unit	Unit Price	Quantity	Total Price
Pipeline 54"	Lin Ft	$365	21940	$8,008,100
Pipeline 60"	Lin Ft	$449	4000	$1,796,000
24 Ft Wide Gravel Road	Lin Ft	$29	2000	$58,000
84" Lined Tunnel	Lin Ft	$2,400	240	$576,000
Pumping Plant	Lump Sum	$12,733,800	1	$12,733,800
Siphon Crossings	Lump Sum	$50,000	2	$100,000
24' Dia. Vertical Shaft	Lin Ft	$4,600	215	$989,000
Buried Powerline	Mile	$1,000,000	2.8	$2,800,000
Subtotal				$27,060,900
Mobilization (5%)				$1,353,045
Unlisted (5%)				$1,353,045
Contingencies (10%)				$2,706,090
Design (6%)				$1,623,654
Construction Oversite (6%)				$1,623,654

GRAND TOTAL $36,000,000

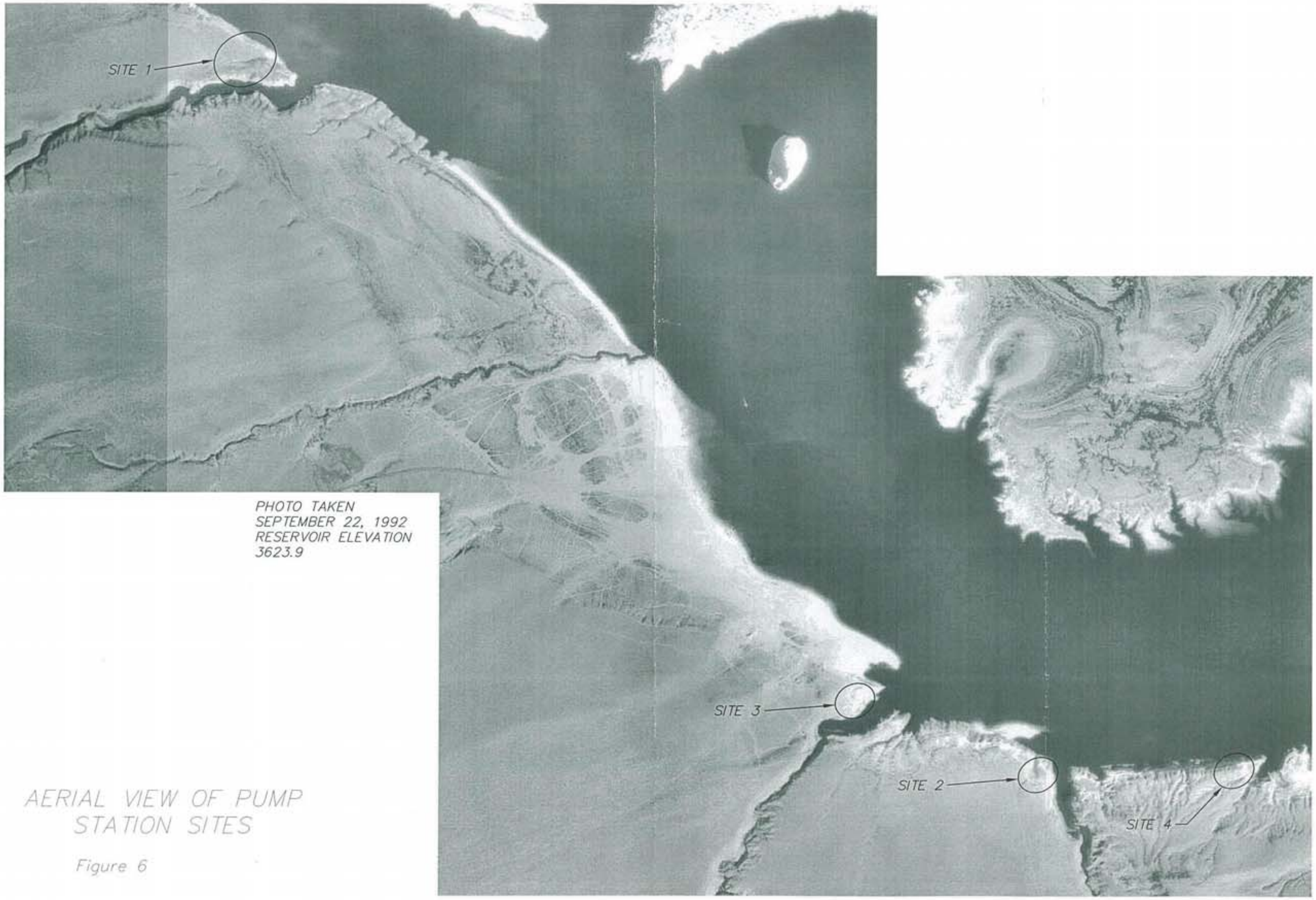
SITE # 5

Item	Unit	Unit Price	Quantity	Total Price
Pipeline 54"	Lin Ft	$365	165	$60,225
Pipeline 60"	Lin Ft	$449	42346	$19,013,354
Overhead Power Deduct	Mile	$125,000	-5.9	($737,500)
24 Ft Wide Gravel Road	Lin Ft	$29	300	$8,700
84" Lined Tunnel	Lin Ft	$2,400	230	$552,000
Pumping Plant	Lump Sum	$12,733,800	1	$12,733,800
24' Dia. Vertical Shaft	Lin Ft	$4,600	215	$989,000
Buried Powerline	Mile	$1,000,000	1.3	$1,300,000
Subtotal				$33,919,579
Mobilization (5%)				$1,695,979
Unlisted (5%)				$1,695,979
Contingencies (10%)				$3,391,958
Design (6%)				$2,035,175
Construction Oversite (6%)				$2,035,175

GRAND TOTAL $45,000,000

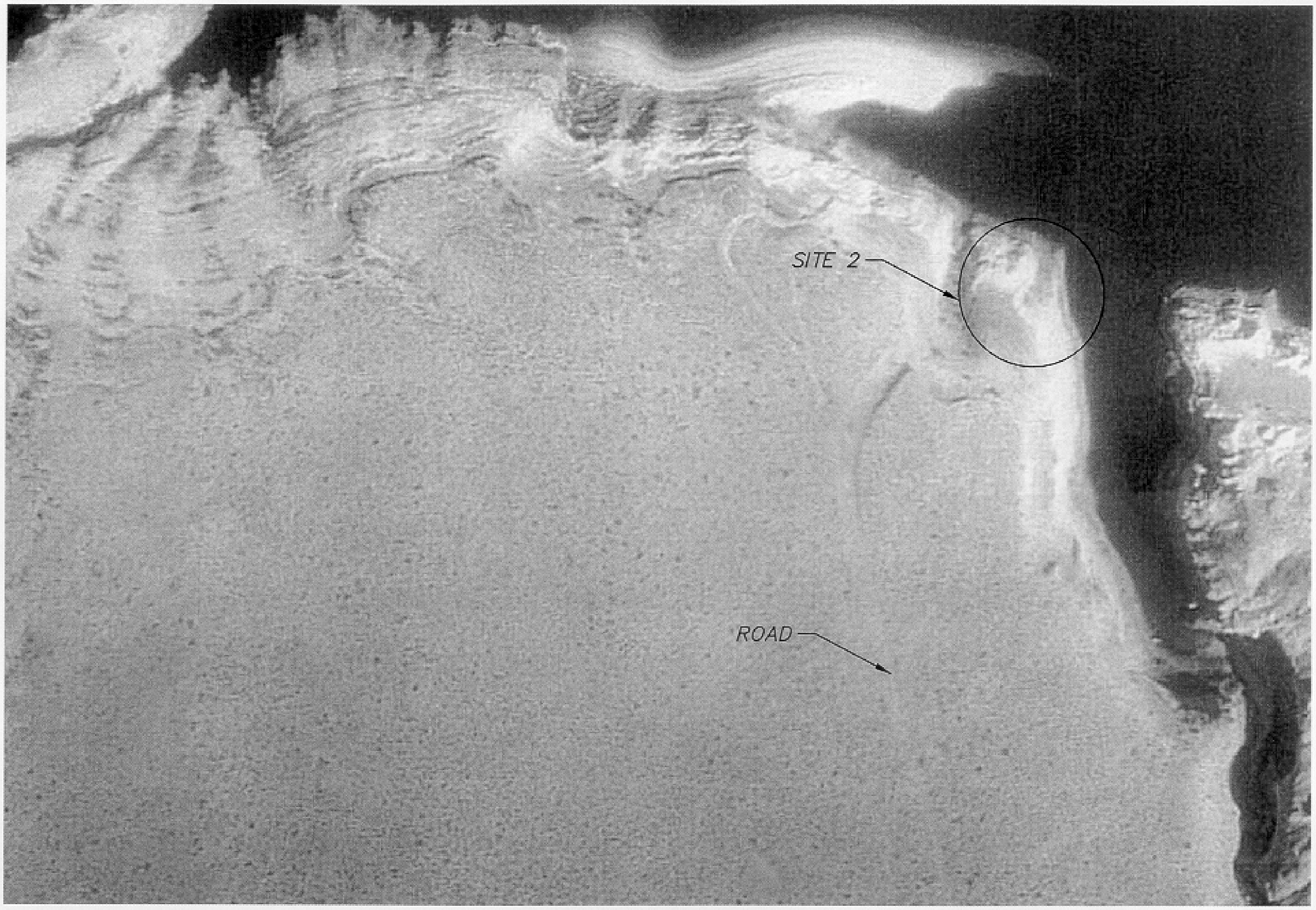
The cost of an overhead powerline is included in the base price of the pumping plant. This cost was removed from the Site #5 estimate because this line is not required since the site is close to the Glen Canyon Switch Yard.

Figure 5 (Continued)



AERIAL VIEW OF PUMP
STATION SITES

Figure 6



AERIAL VIEW OF SITE 2

Figure 7

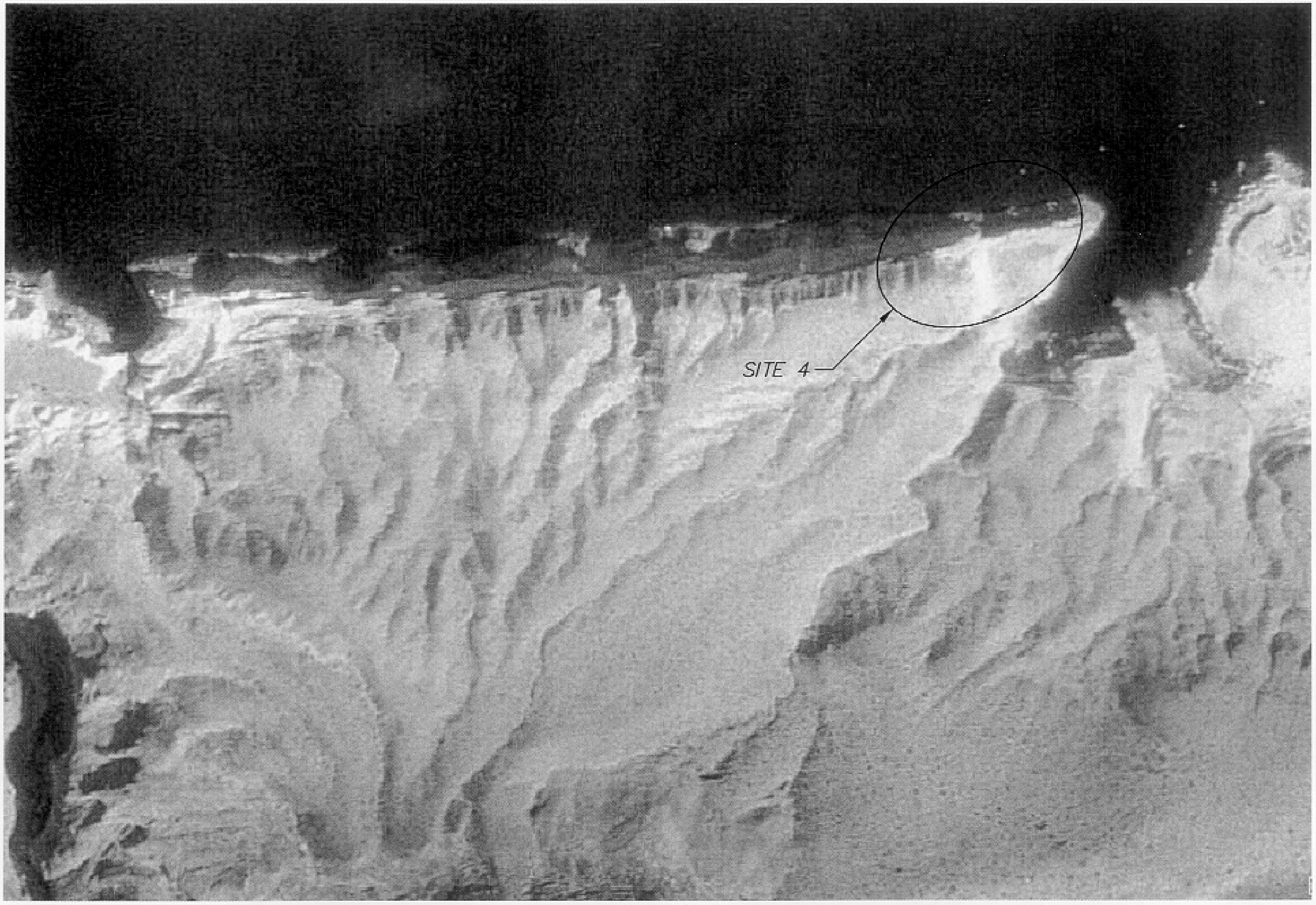
PHOTO TAKEN
SEPTEMBER 22, 1992
RESERVOIR ELEVATION
3623.9

AERIAL VIEW OF SITE 3

Figure 8

NOTE THE VAST NUMBER OF ROADS IN THE AREA

PHOTO TAKEN SEPTEMBER 22, 1992 RESERVOIR ELEVATION 3623.9



AERIAL VIEW OF SITE 4

Figure 9

PHOTO TAKEN
SEPTEMBER 22, 1992
RESERVOIR ELEVATION
3623.9

Water Quality

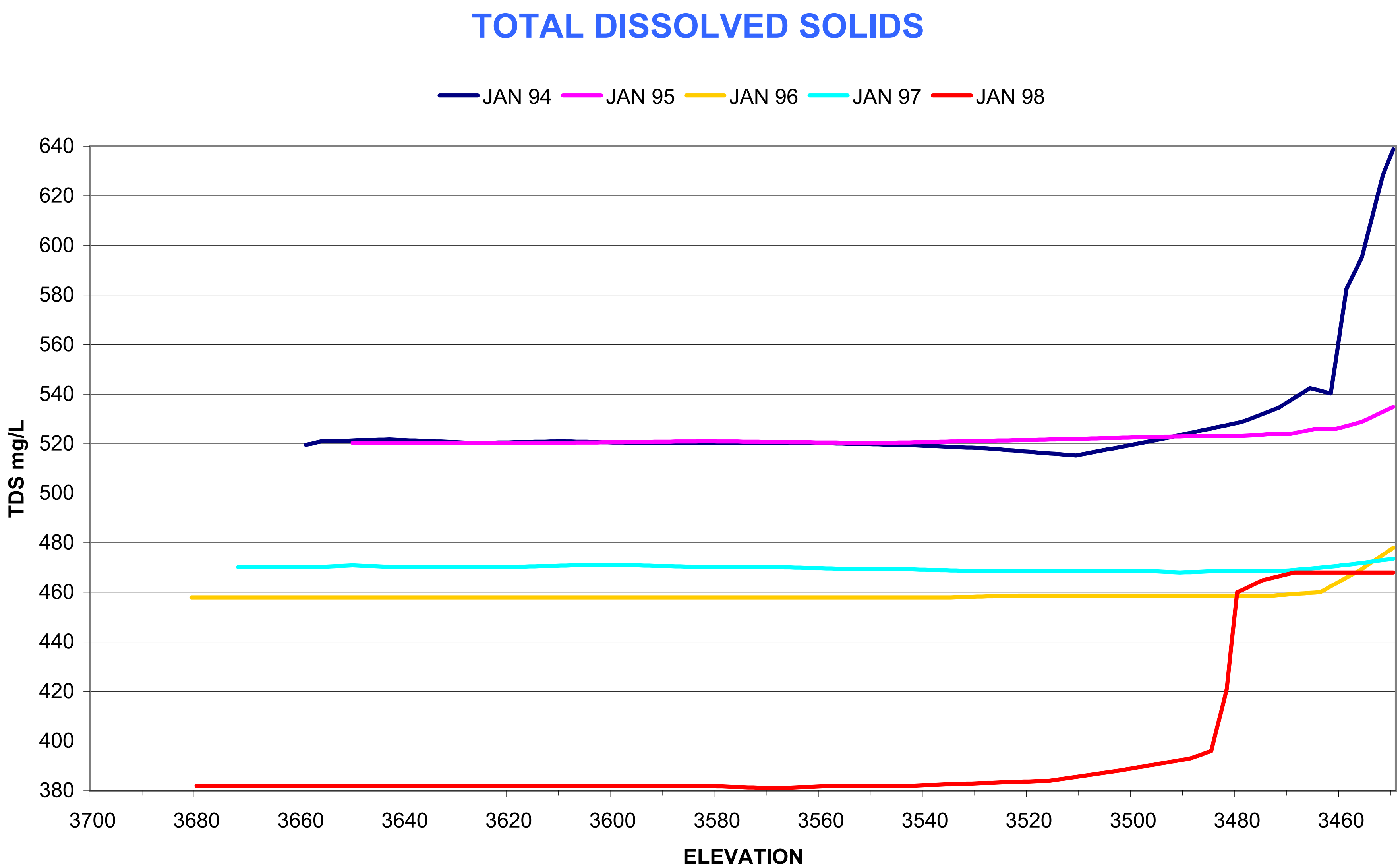
The city of Page, Arizona takes its water from Lake Powell also the city of Las Vegas, Nevada takes its water from Lake Mead which receives water released from Glen Canyon Dam.

The water treatment facilities for the city of Page chlorinate and filter the water. Plant personnel consider the incoming water to be clean. Water treatment plant personnel have also indicated that there is no odor problem with the water.

As a general rule TDS (Total Dissolved Solids) concentrations increase with depth and are higher when the reservoir elevations are low (See Figures 10 through 12). Figures 10 and 11 indicate how TDS concentrations vary with depth.

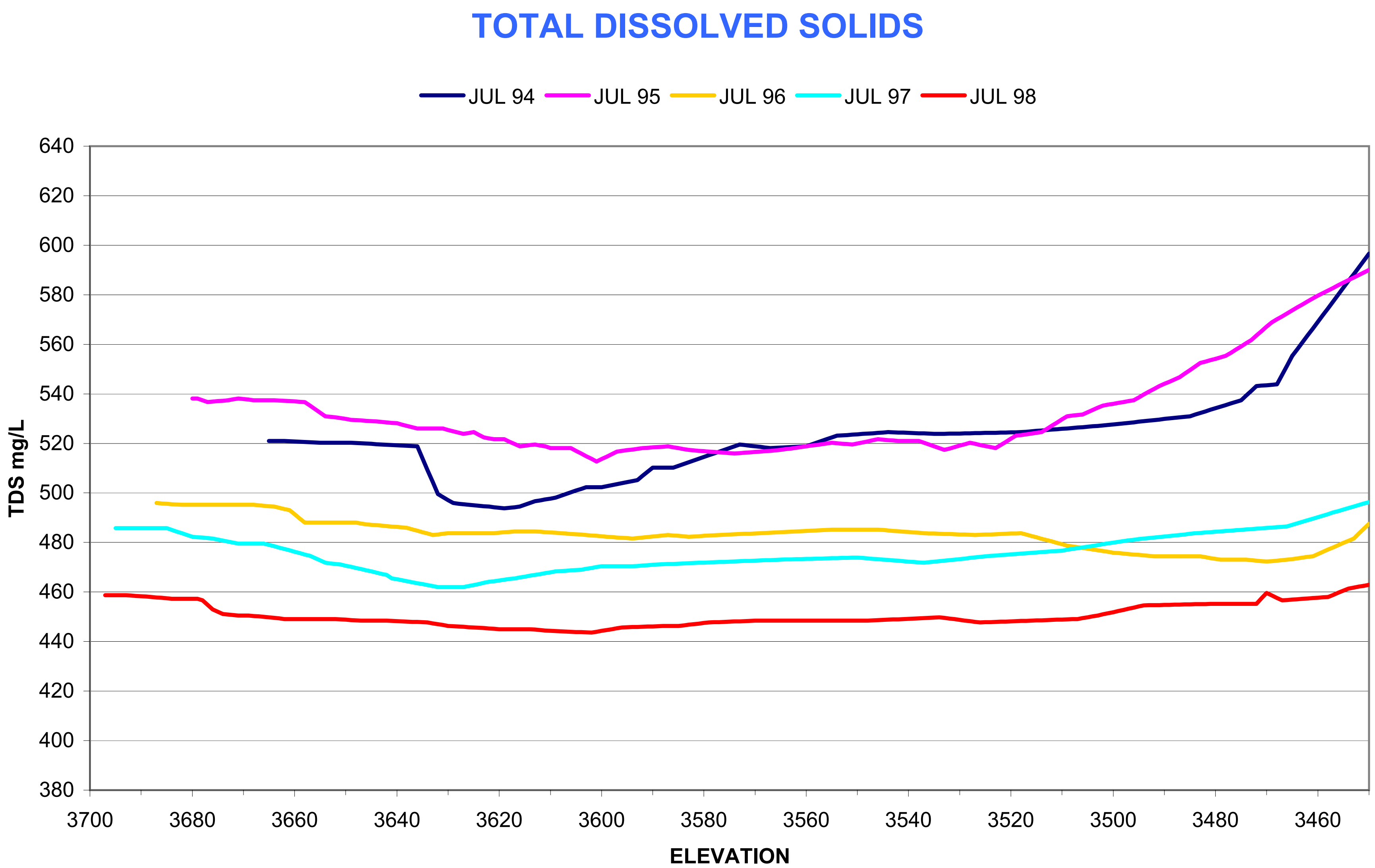
Figure 12 is a scatter plot with a best fit line through it. This Figure shows how TDS concentrations vary with reservoir elevation. The data is for the targeted intake elevation of 3540. The period of record used for this Figure is from January 1975 to September 1998.

TDS data was taken at or near the entrance to Wahweap Bay.



TOTAL DISSOLVED SOLIDS
JAN 94
JAN 95
JAN 96
JAN 97
JAN 98
TDS mg/L
640
620
600
580
560
540
520
500
480
460
440
420
400
380
3700
3680
3660
3640
3620
3600
3580
3560
3540
3520
3500
3480
3460
ELEVATION

Figure 10



TOTAL DISSOLVED SOLIDS
JUL 94
JUL 95
JUL 96
JUL 97
JUL 98
TDS mg/L
640
620
600
580
560
540
520
500
480
460
440
420
400
380
3700
3680
3660
3640
3620
3600
3580
3560
3540
3520
3500
3480
3460
ELEVATION

Figure 11

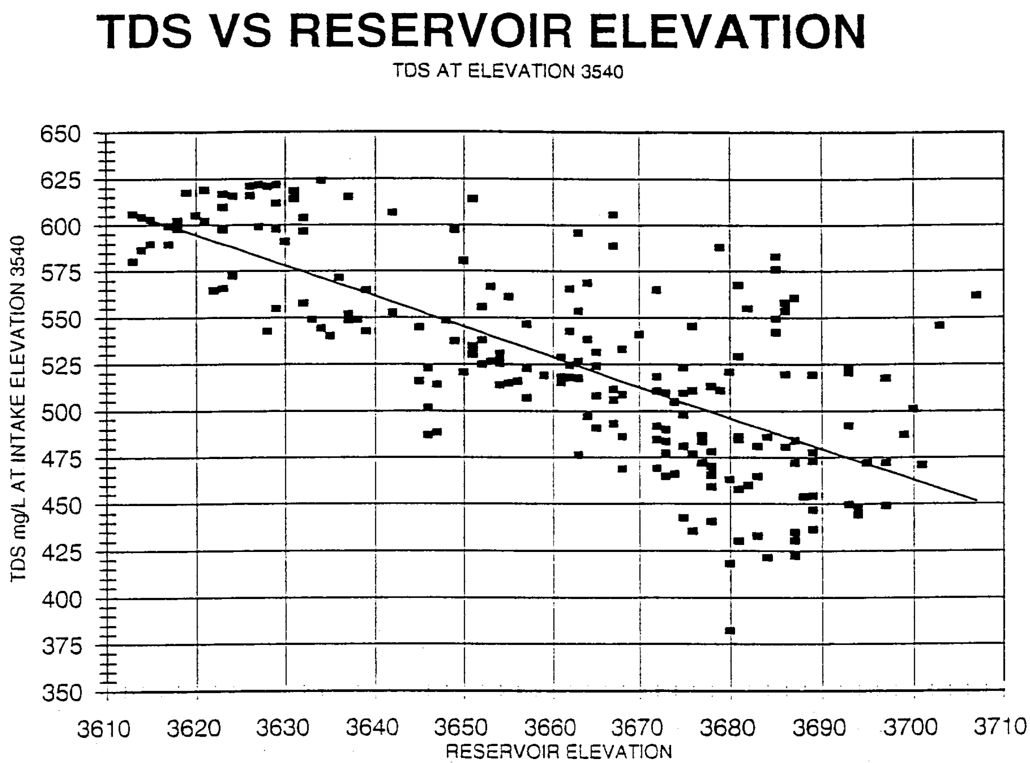


Figure 12

Once water is obtained from Lake Powell, care should be taken to keep the water as clean as possible. End water quality could be affected by a peaking power reservoir which fills and empties daily stirring up reservoir bottom sediment. Pre-treating raw water with chlorine reduces pipeline residue buildup and the need for frequent pigging of the line.

Appendix A contains a water quality report from the city of Page, Arizona.

Geology

The proposed pump station sites are located along the southern shore line of Wahweep Bay of Lake Powell. In this area, below the Holocene eolian (wind blown) sands, is the Jurassic Entrada Sandstone Formation. Along the shore line and in “windows” of the eolian sands elsewhere in the area the Entrada Sandstone is exposed on the surface. It is on this formation that the proposed pumping station (no matter which site is selected) is proposed to be constructed.

The Entrada Sandstone Formation is a very fine grained, moderately well sorted, and thinly to thickly crossbedded material. It contains minor laminated to thin-bedded siltstone and sandstone, and is generally moderately-reddish-orange. However in this area it is white to very light gray. It is generally moderately hard to soft, in some areas the sandstone weathers out into rounded forms. The Entrada Sandstone ranges from about 500 to 900 feet thick, in this vicinity it is about 640 feet thick.[3]

Below the Entrada formation is the Jurassic Carmel Formation.. The Carmel Formation is interbedded sandstone, mudstone, and siltstone. The sandstone is generally reddish-orange to reddish-brown very fine grained, poorly to moderately sorted, very thin bedded and thinly to thickly crossbedded. The mudstone and siltstone are moderate-reddish-orange to pale reddish-brown, and laminated to very thin bedded. A laminated moderate-orange-pink argillaceous limestone bed is present in the lower part. There are scarce very thin beds of grayish-purple bentonite in the formation. Clasts include rhyolite porphyry and chert of assorted colors. This formation ranges from 140 to 260 feet thick.[3]

It appears that the pumping station will be constructed on the lower part of the Entrada Formation, just above the contact with the Carmel Formation. If this true then the tunnel and shaft may be constructed in the Carmel Formation. This can be defined more clearly by drilling and/or mapping the area.

[3] United States Geological Survey, Mineral Investigations Field Study Map MF-306, Fred Peterson, 1973

Two faults have been mapped, which are oriented northwest to southeast. The maximum mapped southern extent is to the north shore of Wahweep Bay near Lone Rock. These faults appear to be normal faults, which have the down dropped block on the west.[4]

The formation bedding is nearly horizontal throughout the area, with only broad regional changes. The bedding orientation in the area of the proposed pumping plants is influenced by the Smoky Mountain Anticline to the east and the Wahweep Syncline to the west.[4]

[4] Utah Geological Survey, Open File Report 359, Interim Geologic Map of the Smoky Mountain 30' X 60' Quadrangle Kane and San Juan Counties, Utah and Coconino County, Arizona, compiled by Hellmut H. Doelling, dated December 1997.

Preliminary Design

Environmental Concerns

The Preliminary Design addresses the following environmental concerns:

1. Pump station visibility.
2. Power line visibility.

The pump station can be mostly hidden by burial. For an underground pump station the only visible features are the access hatches and the ventilation grills. Both of these items can be made less obtrusive by the application of color that matches the surrounding terrain. The access hatches can be textured with a colored concrete top coat to better blend in with the surrounding terrain. Likewise, the parts of the structure that are not buried should receive a similar but more pronounced coating that simulates the surrounding terrain (see drawing 14). Pre design and pre construction full scale mockups should be used to obtain appropriate texture and colors. Although this design is more costly than an above ground pre engineered steel building, some installation and maintenance costs can be reduced because the need for an overhead crane is eliminated.

The renderings at the end of this report show the back half of the pump station buried with the exposed portion facing the reservoir. The degree of burial is dependent upon the intake tunnel length. Longer tunnels allow the pump station to be set further back from the shoreline and further into the hillside which will hide the station better at most locations.

Power lines can also be buried to lessen the visual impact. It costs more than twice as much to bury high voltage power lines versus having overhead power lines; however, NEPA requirements dictate that this be done.

Pumps and Pump Motors

As shown on drawing 13, the pump configuration consists of variable head pumps located in the sump and high head pumps located in the pump station structure. The variable head pumps will have an impeller designed for an average reservoir elevation of 3672 feet.   Pumps then can be made to stay within their operating limits by varying the speed of the pumps to compensate for the change in reservoir elevation.

Eight variable head pumps would be located in the circular deep well, each pumping at a rate of 5,500 gallons per minute. There is no backup pump because room is limited in the sump and because the pumps will be oversized to compensate for low reservoir elevations. During normal reservoir elevations there will be enough capacity from seven pumps to allow one pump to be serviced.

Variable frequency motors will be used to drive the variable head pumps. These motors can be programmed to avoid speeds that will cause the pumps to resonate. Since the resonated speeds cannot be computed before hand, the data will need to be entered in the field after experimental runs.

Pump motors should be premium efficiency motors. In addition to paying for themselves in energy savings, premium efficiency motors last longer and have lower heat outputs. Large motors (even premium efficiency motors) produce a large amount of heat and might require water cooling.

The preliminary design shows 9 high head pumps. Eight pumps are required to meet the required flow rate of 98 cubic feet per second. The extra pump is a backup to be used if one of the other pumps has an unexpected outage. Also, it is standard practice to add a small percentage to pumping capacity to allow for pump wear between scheduled overhauls.

Approximate sizes of motors and pumps are shown on drawing 14. Pressure calculations (see Figure 13) indicate a required lift of 1150 feet (or 498 psi) for the high head pumps. Figures 14 and 15 show a pump curve and pump configuration for the high head pumps. The pump is approximately 86 percent efficient when operating under the specified conditions.

Sumps

Since no design standard exists for a circular sump with eight pumps, a model study should be undertaken before a final design can be made. The cost of the model study has been included in the estimate.

In the upper sump, baffles have been included to straighten flow for the approach to the individual pump bays. The layout of pump bays for the nine high head pumps is in accordance with the standards set forth by the Hydraulic Institute.

PRESSURE CALCULATIONS

SITE #2

Manning's "n" = 0.0110
Q = 98 cfs

Station or Item (miles)	Segment Length (feet)	Pipe Diam (in.)	K value	Velocity (fps)	Head Loss (feet)	HGL Slope (%)	Ground Elev. (feet)	HGL Elev. (feet)	Press. (psi)
95.20							4560	4602	18
95.30	528	54		6.161851	0.938084	0.1777	4520	4603	36
98.50	16896	54		6.161851	30.0187	0.1777	4370	4633	114
100.60	11088	54		6.161851	19.69977	0.1777	4470	4653	79
102.00	7392	54		6.161851	13.13318	0.1777	4640	4666	11
102.10	528	54		6.161851	0.938084	0.1777	4640	4667	12
108.70	34848	54		6.161851	61.91357	0.1777	4480	4729	108
110.50	9504	54		6.161851	16.88552	0.1777	4340	4746	176
114.30	20064	54		6.161851	35.64721	0.1777	3960	4781	355
116.50	11616	54		6.161851	20.63786	0.1777	3960	4802	364
119.40	15312	54		6.161851	27.20445	0.1777	3990	4829	363
121.57	11454	54		6.161851	20.35004	0.1777	3700	4850	497
Eight 16" pipes	20	16		8.773416	0.364685	1.8234	3700	4850	498
16" Cone valves	2.6	16	0.043	8.773416	0.051395	1.9767	3700	4850	498
16" Rotary valves	2.6	16	0	8.773416	0.047409	1.8234	3700	4850	498
Point of Pump Discharge	1	16	0	8.773416	0	0.0000	3700	4850	498

Lake Powell Pump Sta. lift (ft) = 1150

SITE #3

Manning's "n" = 0.0110
Q = 98 cfs

Station or Item (miles)	Segment Length (feet)	Pipe Diam (in.)	K value	Velocity (fps)	Head Loss (feet)	HGL Slope (%)	Ground Elev. (feet)	HGL Elev. (feet)	Press. (psi)
95.20							4560	4608	21
95.30	528	54		6.161851	0.938084	0.1777	4520	4609	38
98.50	16896	54		6.161851	30.0187	0.1777	4370	4639	116
100.60	11088	54		6.161851	19.69977	0.1777	4470	4658	81
102.00	7392	54		6.161851	13.13318	0.1777	4640	4671	14
102.10	528	54		6.161851	0.938084	0.1777	4640	4672	14
108.70	34848	54		6.161851	61.91357	0.1777	4480	4734	110
110.50	9504	54		6.161851	16.88552	0.1777	4340	4751	178
114.30	20064	54		6.161851	35.64721	0.1777	3960	4787	358
116.50	11616	54		6.161851	20.63786	0.1777	3960	4807	367
119.40	15312	54		6.161851	27.20445	0.1777	3990	4835	366
120.99	8396	54		6.161851	14.91696	0.1777	3700	4850	497
Eight 16" pipes	20	16		8.773416	0.364685	1.8234	3700	4850	498
16" Cone valves	2.6	16	0.043	8.773416	0.051395	1.9767	3700	4850	498
16" Rotary valves	2.6	16	0	8.773416	0.047409	1.8234	3700	4850	498
Point of Pump Discharge	1	16	0	8.773416	0	0.0000	3700	4850	498

Lake Powell Pump Sta. lift (ft) = 1150

Figure 13

SITE #4

Manning's "n" = 0.0110
Q = 98 cfs

Station or Item (miles)	Segment Length (feet)	Pipe Diam (in.)	K value	Velocity (fps)	Head Loss (feet)	HGL Slope (%)	Ground Elev. (feet)	HGL Elev. (feet)	Press. (psi)
95.20							4560	4600	17
95.30	528	54		6.161851	0.938084	0.1777	4520	4601	35
98.50	16896	54		6.161851	30.0187	0.1777	4370	4631	113
100.60	11088	54		6.161851	19.69977	0.1777	4470	4651	78
102.00	7392	54		6.161851	13.13318	0.1777	4640	4664	10
102.10	528	54		6.161851	0.938084	0.1777	4640	4665	11
108.70	34848	54		6.161851	61.91357	0.1777	4480	4727	107
110.50	9504	54		6.161851	16.88552	0.1777	4340	4743	175
114.30	20064	54		6.161851	35.64721	0.1777	3960	4779	354
116.50	11616	54		6.161851	20.63786	0.1777	3960	4800	363
119.40	15312	54		6.161851	27.20445	0.1777	3990	4827	362
121.38	10462	54		6.161851	18.58758	0.1777	3700	4845	496
122.14	4000	60		4.991099	4.051614	0.1013	3700	4850	497
Eight 16" pipes	20	16		8.773416	0.364685	1.8234	3700	4850	498
16" Cone valves	2.6	16	0.043	8.773416	0.051395	1.9767	3700	4850	498
16" Rotary valves	2.6	16	0	8.773416	0.047409	1.8234	3700	4850	498
Point of Pump Discharge	1	16	0	8.773416	0	0.0000	3700	4850	498

Lake Powell Pump Sta. lift (ft) = 1150

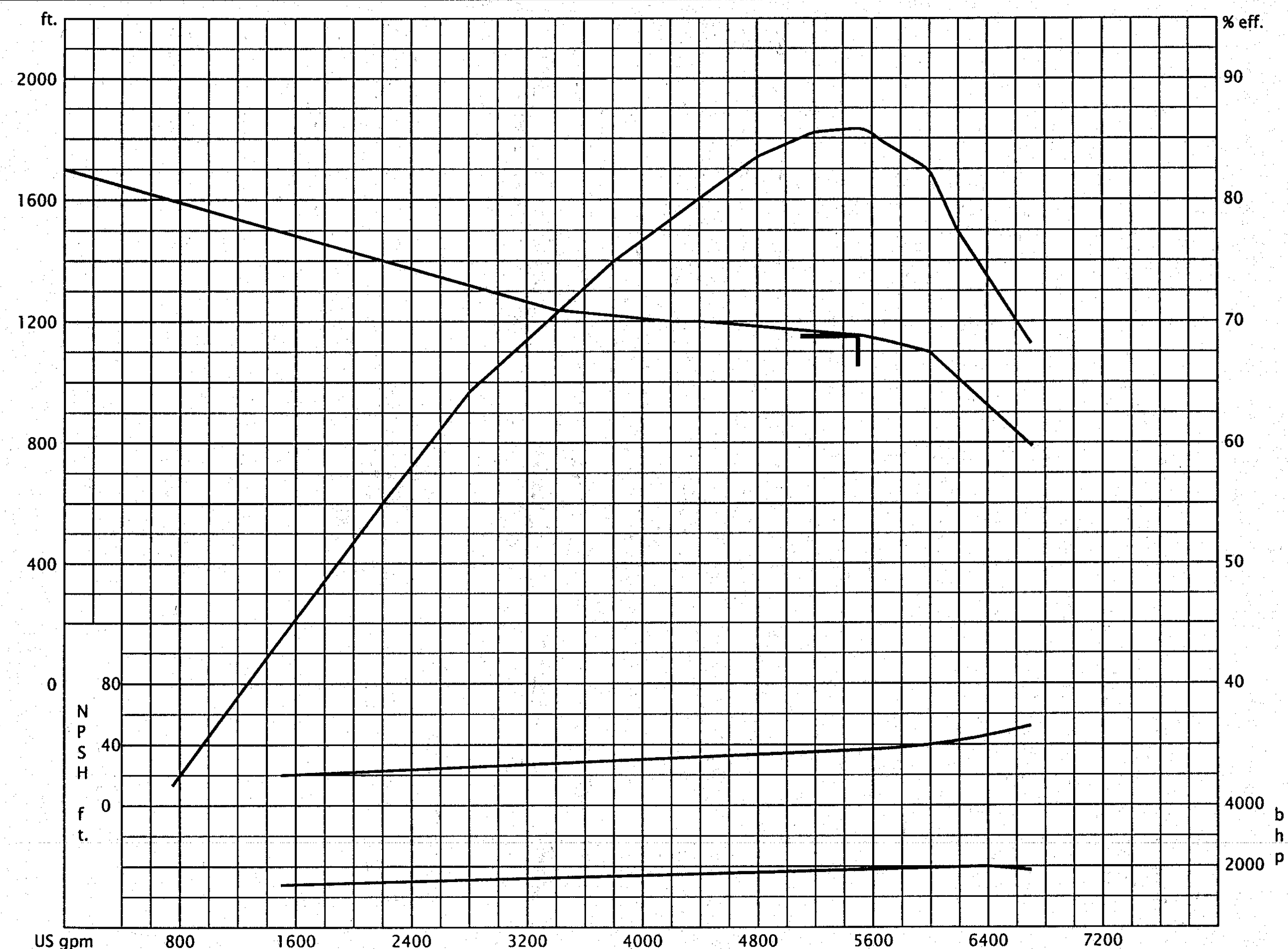
SITE #5

Manning's "n" = 0.0110
Q = 98 cfs

Station or Item (miles)	Segment Length (feet)	Pipe Diam (in.)	K value	Velocity (fps)	Head Loss (feet)	HGL Slope (%)	Ground Elev. (feet)	HGL Elev. (feet)	Press. (psi)
95.20							4560	4600	17
95.30	528	54		6.161851	0.938084	0.1777	4520	4601	35
98.50	16896	54		6.161851	30.0187	0.1777	4370	4631	113
100.60	11088	54		6.161851	19.69977	0.1777	4470	4650	78
102.00	7392	54		6.161851	13.13318	0.1777	4640	4664	10
102.10	528	54		6.161851	0.938084	0.1777	4640	4664	11
108.70	34848	54		6.161851	61.91357	0.1777	4480	4726	107
110.50	9504	54		6.161851	16.88552	0.1777	4340	4743	175
114.30	20064	54		6.161851	35.64721	0.1777	3960	4779	354
116.50	11616	54		6.161851	20.63786	0.1777	3960	4800	363
119.40	4000	54		6.161851	7.1067	0.1777	3990	4807	353
121.54	11312	60		4.991099	11.45796	0.1013	3700	4818	484
127.42	31034	60		4.991099	31.43445	0.1013	3700	4850	497
Eight 16" pipes	20	16		8.773416	0.364685	1.8234	3700	4850	498
16" Cone valves	2.6	16	0.043	8.773416	0.051395	1.9767	3700	4850	498
16" Rotary valves	2.6	16	0	8.773416	0.047409	1.8234	3700	4850	498
Point of Pump Discharge	1	16	0	8.773416	0	0.0000	3700	4850	498

Lake Powell Pump Sta. lift (ft) = 1150

Figure 13 (Continued)



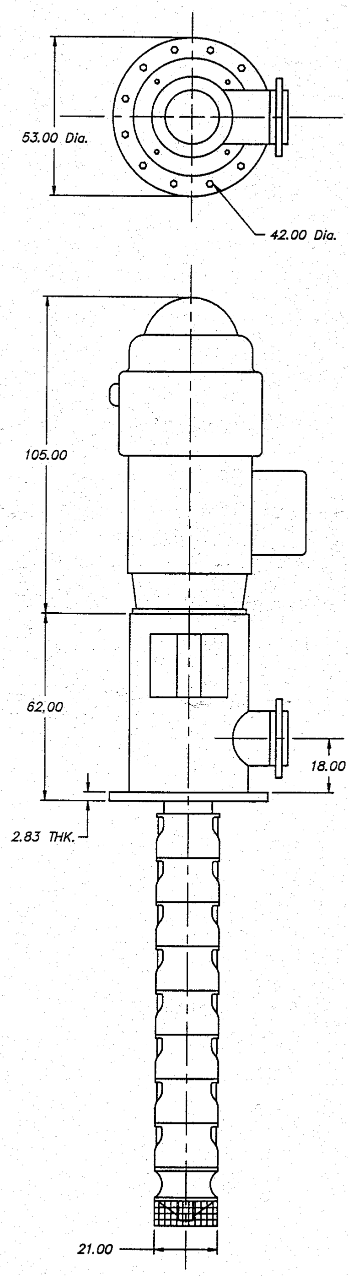
National Pump Company
Bureau of Reclamation
04/12/01
Selection file: (untitled)

National Pump Company
Catalog: 60CY CBP, vers. 1
Curve: CVE18H4P6CY
Design Point: 5500 US gpm 1150 ft.

VERT. TURBINE - 1800
Size: E18HC 8 Stg.
Speed: 1770 rpm
Impeller: 14.118 in.

Figure 14

VERTICAL TURBINE PUMP



MOTOR

2000 H.P. 3 PHASE 60 CYCLE 4180 VOLTS
1800 R.P.M., MFG. - U.S. MOTORS
VERTICAL SOLID SHAFT WITH AFS COUPLING
ENCLOSURE - WP-1

DISCHARGE HEAD

FABRICATED NATIONAL PUMP DISCHARGE HEAD
16", 300# R.F. DISCHARGE FLANGE
SHAFT SEAL - MECHANICAL SEAL

BOWL

8 STAGE E18HC BOWL ASSEMBLY
5500 USGPM @ 1150 FT. T.D.H.
BASKET STRAINER

MATERIALS

LOWER 5 BOWLS - CLASS 30 CAST IRON
UPPER 3 BOWLS - CLASS 80 DUCTILE IRON
IMPELLERS - BRONZE
BOWL SHAFT - 17-4 PH STAINLESS STEEL
DISCHARGE HEAD - FABRICATED A36 STEEL
STRAINER - GALVANIZED STEEL

NOTE: NPSH REQUIRED = 40 FEET

INFORMATION FURNISHED BY SABOL & RICE, SALT LAKE CITY, UT & NATIONAL PUMP CO., GLENDALE, AZ

Figure 15

Piping and Valves

The pipeline leaving the pump station will be designed for a service pressure of 500 psi and an additional surge pressure of 250 psi. Surge pressures should be kept well below this level to insure the continued service of the pipeline. To help reduce transient flows, surge tanks should be installed near the pump station. Pulsco (see Figure 16) calculated a total tank volume of 12,000 cubic feet (4 tanks 96 inches in inside diameter by 61 feet long each and designed to 600 psig). The estimated cost for this system is $800,000 as shown in Figure 16. This added expense can be avoided if detailed transient study shows that it is not required. Also, steel pipe is typically designed with reserve strength built into it for surge conditions.

The variable head pumps are equipped with check valves to prevent reverse-flow through the discharge pipe. Other valving may be required to throttle the pumps. Gates are provided on the wall of the deep well to provide a path to drain the sump pool for maintenance and to bypass the variable head pumps when the reservoir is in a flood stage.

For the high head pumps valves should be chosen which function well under high head and protect the pipeline from a surge. A cone or spherical valve can be used for a guard valve. The check valve should be a slow closing rotary valve that will close in the event of a pump shutdown or power failure.

There is adequate distance between the pump and manifold to accurately measure the flow rates. Metering each pump discharge line would make it possible to detect a failing pump in the system.

A sleeve valve has been incorporated in the preliminary design for draining the pipeline. Because of high pressures, a head breaking valve such as a sleeve valve will be required. Situated in front of the sleeve valve is a cone or spherical valve (shown on drawing 13 as a cone valve) which is used as a guard valve enabling the sleeve valve to be serviced while the pump station is in operation.

Sitework

Sitework includes driving a 24-foot diameter shaft. The shaft can be driven by a drill and shoot method. The three sites are remote enough that blasting in the area should not be a problem. Once the shaft is excavated, the tunnel can be excavated using an earth-pressure-balance (EPB) tunneling machine. The tunnel is then flooded and the screen assembly is lowered into place and connected to the tunnel.

PULSCO
SCOPE OF SUPPLY
U.S. Department of Interior/Provo, Utah
Lake Powell to St. George Surge Control Systems (and Air Compressor)
PULSCO REF: Q0110A6

PULSCO will provide equipment and components for installation and assembly by the Contractor. Pipes, fittings and all air piping and wiring are **not** included. PULSCO will provide submittal including layout drawings, equipment weights and dimensions, anchor bolt layout, data for sight gauge, valves, probes, and level control system including electrical schematic and wiring diagrams.

Details of the Scope of Supply are as follows:
Four 3,000 cubic-foot tanks designed for 600 psig with a 24" inlet/outlet flanged connection. The tanks are 96" (8') ID x 61 foot over-all length and will have ASME Code Stamps. Tanks include a 24" manway, one liquid level sight gage, one safety valve, two solenoid valves, ball valves for air line isolation and bypass, one check valve, one probe assembly for water level detection with control panel, one pressure gage, and one ¾" NPT air-bleed muffler. One (1) Air compressor duplex with 20 HP motors. Paint is factory-standard epoxy.

Anchor bolts lay-out will be provided but not the bolts. Tank drain valves, and other accessories not listed within are **not** included. The panels for surge tank and air compressor are supplied for field-mounting and wiring by others.

Interior will be sandblasted to SP10 and painted with 10 mils DFT Tnemec Series 20 epoxy suitable for potable water. Tank exterior will be sandblasted to SP6 and shop-coated with epoxy primer only. Exterior finish coats are to be applied in the field by the General Contractor. All other equipment is included with standard factory paint. Labor for touching-up tank exterior paint, if required because of scratching during shipment, is not included by PULSCO (by Contractor).

Services will be provided for inspection of the surge control systems along with start-up and personnel training. Tank hydro including leak tests will be done in the shop per ASME Code. Installation and wiring of the surge tanks and assembly of appurtenances are by the Contractor.

Delivery: 14 to 17 weeks after approval of PULSCO's submittal or written material release.
Estimated Budget Pricing: $800,000.

Please contact the following PULSCO engineer with any questions:

Sam Sadek of PULSCO
17815 Skypark Circle, Suite H
Irvine, CA 92614
Phone (949) 261-1717
Fax (949) 975-0532

Figure 16

exclusive of right of way costs. The existing line may need to be upgraded. It has been suggested by the power company that the 2.8 miles of underground power be delivered at 34.5kV over several circuits to save on installation costs.

Garkane's estimate for power delivery for the year 2001 for both pump stations is $41.50 per MWH. If an agreement was made in 2001 for 10 years the rate would increase by 3.8 percent per year.

The Western Area Power Administration (WAPA) has all its power currently contracted out. Congressional approval is required to obtain power from this source.

Excavation for the building and surge tanks at both sites will include rock excavation. The unit price in the estimate reflects the higher cost of rock excavation.

Road constructions for both sites include improvements to existing roads. The cost estimate for roads reflects the cost of grading and crushed rock surfacing only. The estimate assumes that new road pioneering will be kept to a minimum.

A berm will be placed around the switchyard to help hide it from view. Muck from excavating the shaft and tunnel will be placed in the switchyard berm along with some imported material.

Concrete

The unit price for reinforced concrete includes forms, labor, reinforcing bars, concrete, and other materials. The hollow core precast concrete deck is proposed as the roofing for the pump station. The deck will need to be waterproofed and receive a concrete topping. Camouflage concrete is colored and textured with the primary purpose of hiding the structure and helping it blend into the surrounding terrain. Full scale mockups will be needed to derive the appropriate color and texture combination.

Electrical

The estimate assumes electrical power will come directly from the Glen Canyon Switch Yard. Approximately two to three miles of powerline will need to be buried. Each conductor will require a separate trench. Variable frequency drives for the variable head pumps generate a large amount of heat along with the other electrical equipment housed inside the building. An HVAC system will be needed to dissipate the heat generated by electrical equipment.

Considerable power is required to run the pump station (approximately 18 MVA) and accessing this power will be a difficult task. The cost of electrical equipment (including transmission lines) is more than 45 percent of the total cost of the pump station. It is recommended that preliminary agreements to access electrical power be in place before funding and designing the project.

Power will most likely be purchased from Garkane Energy. Garkane's current delivery from the Glen Canyon Switch Yard is at 138kV. Extension of the existing 138kV line would require a switching station at each point of connection with the existing line. Switching stations currently cost approximately $600,000 per station. Garkane is currently building 138kV overhead line at a cost of approximately $125,000 per mile

ELECTRICAL

1	Overhead Powerline	MILE	$125,000.00	5.2	$650,000.00
2	Buried Powerline	MILE	$1,000,000.00	2.5	$2,500,000.00
3	Switching Stations	EACH	$600,000.00	2	$1,200,000.00
4	Lighting & Misc. Electrical	SQ FT	$6.25	7700	$48,125.00
5	230-KV Power Circuit Breaker	EACH	$300,000.00	1	$300,000.00
6	230:4.16 KV Transformer: 25 MVA - 3 Phase	EACH	$600,000.00	1	$600,000.00
7	5 KV Metal-Clad Switch Gear Line Up	LS	$337,000.00	1	$337,000.00
8	480 VAC Dist. Panel with 400A Bus	EACH	$6,900.00	1	$6,900.00
9	4.16 KV:480, 350 KVA, - 3 Phase Transformer	EACH	$32,000.00	1	$32,000.00
10	Motor Control for 2000 HP Motor	EACH	$27,000.00	9	$243,000.00
11	480 VAC Variable Speed Drive for 300 HP pum	EACH	$45,000.00	8	$360,000.00
12	5 KV Metal-Clad Switch Gear Line Up - Inside	LS	$310,000.00	1	$310,000.00
13	480 VAC Dist. Panel with 400A Bus- Inside	EACH	$6,900.00	1	$6,900.00
14	480 VAC Variable Frequency Drive	EACH	$65,000.00	8	$520,000.00
15	300 HP Motors	EACH	$27,000.00	8	$216,000.00
16	2000 HP Motors	EACH	$135,000.00	9	$1,215,000.00
				Subtotal	$8,544,925.00

TOTAL	$17,816,305.00
MOBILIZATION (5%)	$890,815.25
UNLISTED (5%)	$890,815.25
CONTINGENCIES (10%)	$1,781,630.50
DESIGN (6%)	$1,068,978.30
CONSTRUCTION OVERSITE (6%)	$1,068,978.30
IN PLACE TOTAL	$23,518,000.00

PIPELINE TO A COMMON POINT

1	Pipeline	LIN FT	$365.00	22930	$8,369,450.00
2	Siphon Crossing	LS	$50,000.00	1	$50,000.00
				Subtotal	$8,419,450.00

MOBILIZATION (5%)	$420,972.50
UNLISTED (5%)	$420,972.50
CONTINGENCIES (10%)	$841,945.00
DESIGN (6%)	$505,167.00
CONSTRUCTION OVERSITE (6%)	$505,167.00
Grand Subtotal	$11,114,000.00

IN PLACE TOTAL WITH PIPELINE TO A COMMON POINT $34,632,000.00

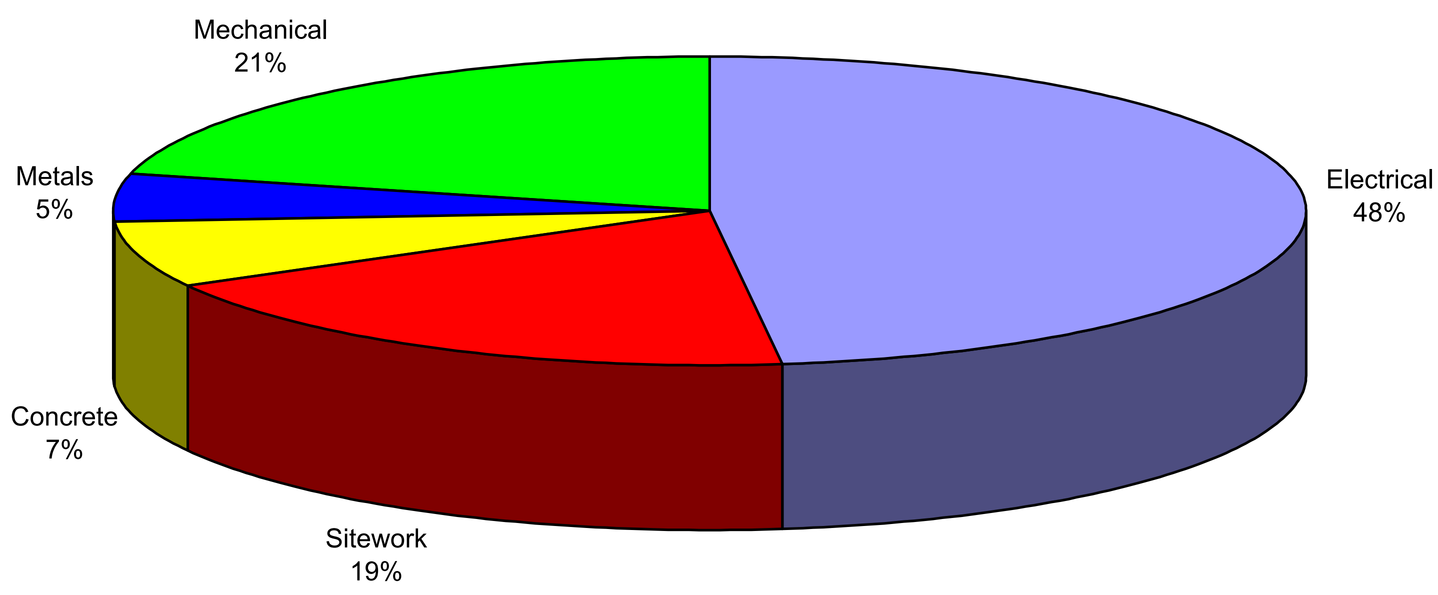
Cost Estimates

COST ESTIMATE - SITE 2

(2001 Dollars)

	Item	Unit	Unit Price	Quantity	Total Price
SITEWORK					
1	24 Ft Dia. Vertical Shaft	LIN FT	$4,600.00	190	$874,000.00
2	84" Lined Tunnel	LIN FT	$2,400.00	700	$1,680,000.00
3	24 Ft Wide Gravel Road	LIN FT	$29.00	4000	$116,000.00
4	Excavation - Building & Surge Tanks	CU YD	$12.00	40000	$480,000.00
5	Backfill - Building & Surge Tanks	CU YD	$2.00	10000	$20,000.00
6	Switch Yard Berm	CU YD	$6.00	25000	$150,000.00
7	Switch Yard Fence	LIN FT	$92.00	500	$46,000.00
				Subtotal	$3,366,000.00
CONCRETE					
1	Reinforced Concrete	CU YD	$450.00	2400	$1,080,000.00
2	Water Stops	LS	$10,000.00	1	$10,000.00
3	Hollow Core Precast Concrete Deck	SQ FT	$6.15	8000	$49,200.00
4	Camouflage Concrete	CU YD	$500.00	300	$150,000.00
				Subtotal	$1,289,200.00
METALS					
1	16" Dia Steel Pipe	LIN FT	$38.00	110	$4,180.00
2	30" Dia Steel Pipe	LIN FT	$158.00	35	$5,530.00
3	Pipe Manifold & Piping Specials	LS	$600,000.00	1	$600,000.00
4	Stainless Steel Liner for Sleeve Valve	LS	$110,000.00	1	$110,000.00
5	Misc. Metalwork	LS	$20,000.00	1	$20,000.00
6	Structural Steel W 12 x 53	LIN FT	$48.00	272	$13,056.00
7	Structural Steel W 12 x 87	LIN FT	$70.00	370	$25,900.00
8	Floor Grating - Medium Duty	SQ FT	$16.00	5000	$80,000.00
9	5 Ft. Dia. Screens	EACH	$20,000.00	4	$80,000.00
10	Screen Assembly	LS	$20,000.00	1	$20,000.00
11	Paint - Primer & Finish Coats - Metal	GAL	$45.00	50	$2,250.00
12	Steel Doors	EACH	$302.00	6	$1,812.00
				Subtotal	$958,666.00
MECHANICAL					
1	500 psi, 5500 gpm Pumps	EACH	$113,600.00	9	$1,022,400.00
2	Variable Head, 5500 gpm Pumps	EACH	$65,500.00	8	$524,000.00
3	Low Head Check Valves	EACH	$2,000.00	8	$16,000.00
4	Sluice Gate	EACH	$3,000.00	7	$21,000.00
5	Rotary Pump Control Valves, 500 psi	EACH	$40,000.00	9	$360,000.00
6	Flow Meters	LS	$134,000.00	1	$134,000.00
7	16", 500 psi Cone Valves	EACH	$37,000.00	9	$333,000.00
8	30", 500 psi Cone Valve	EACH	$95,000.00	1	$95,000.00
9	30", 500 psi Sleeve Valve	EACH	$215,000.00	1	$215,000.00
10	Surge Suppression System	LS	$800,000.00	1	$800,000.00
11	Model Study for Circular Sump	LS	$100,000.00	1	$100,000.00
12	HVAC	SQ FT	$4.82	7700	$37,114.00
				Subtotal	$3,657,514.00

SITE 2 COST MODEL



COST ESTIMATE - SITE 3

(2001 Dollars)

	Item	Unit	Unit Price	Quantity	Total Price
	SITEWORK				
1	24 Ft Dia. Vertical Shaft	LIN FT	$4,600.00	190	$874,000.00
2	84" Lined Tunnel	LIN FT	$2,400.00	375	$900,000.00
3	24 Ft Wide Gravel Road	LIN FT	$29.00	8500	$246,500.00
4	Excavation - Building & Surge Tanks	CU YD	$12.00	40000	$480,000.00
5	Backfill - Building & Surge Tanks	CU YD	$2.00	10000	$20,000.00
6	Switch Yard Berm	CU YD	$6.00	25000	$150,000.00
7	Switch Yard Fence	LIN FT	$92.00	500	$46,000.00
				Subtotal	$2,716,500.00
	CONCRETE				
1	Reinforced Concrete	CU YD	$450.00	2400	$1,080,000.00
2	Water Stops	LS	$10,000.00	1	$10,000.00
3	Hollow Core Precast Concrete Deck	SQ FT	$6.15	8000	$49,200.00
4	Camouflage Concrete	CU YD	$500.00	300	$150,000.00
				Subtotal	$1,289,200.00
	METALS				
1	16" Dia Steel Pipe	LIN FT	$38.00	110	$4,180.00
2	30" Dia Steel Pipe	LIN FT	$158.00	35	$5,530.00
3	Pipe Manifold & Piping Specials	LS	$600,000.00	1	$600,000.00
4	Stainless Steel Liner for Sleeve Valve	LS	$110,000.00	1	$110,000.00
5	Misc. Metalwork	LS	$20,000.00	1	$20,000.00
6	Structural Steel W 12 x 53	LIN FT	$48.00	272	$13,056.00
7	Structural Steel W 12 x 87	LIN FT	$70.00	370	$25,900.00
8	Floor Grating - Medium Duty	SQ FT	$16.00	5000	$80,000.00
9	5 Ft. Dia. Screens	EACH	$20,000.00	4	$80,000.00
10	Screen Assembly	LS	$20,000.00	1	$20,000.00
11	Paint - Primer & Finish Coats - Metal	GAL	$45.00	50	$2,250.00
12	Steel Doors	EACH	$302.00	6	$1,812.00
				Subtotal	$958,666.00
	MECHANICAL				
1	500 psi, 5500 gpm Pumps	EACH	$113,600.00	9	$1,022,400.00
2	Variable Head, 5500 gpm Pumps	EACH	$65,500.00	8	$524,000.00
3	Low Head Check Valves	EACH	$2,000.00	8	$16,000.00
4	Sluice Gate	EACH	$3,000.00	7	$21,000.00
5	Rotary Pump Control Valves, 500 psi	EACH	$40,000.00	9	$360,000.00
6	Flow Meters	LS	$134,000.00	1	$134,000.00
7	16", 500 psi Cone Valves	EACH	$37,000.00	9	$333,000.00
8	30", 500 psi Cone Valve	EACH	$95,000.00	1	$95,000.00
9	30", 500 psi Sleeve Valve	EACH	$215,000.00	1	$215,000.00
10	Surge Suppression System	LS	$800,000.00	1	$800,000.00
11	Model Study for Circular Sump	LS	$100,000.00	1	$100,000.00
12	HVAC	SQ FT	$4.82	7700	$37,114.00
				Subtotal	$3,657,514.00

ELECTRICAL

1	Overhead Powerline	MILE	$125,000.00	5.2	$650,000.00
2	Buried Powerline	MILE	$1,000,000.00	2.6	$2,600,000.00
3	Switching Stations	EACH	$600,000.00	2	$1,200,000.00
4	Lighting & Misc. Electrical	SQ FT	$6.25	7700	$48,125.00
5	230-KV Power Circuit Breaker	EACH	$300,000.00	1	$300,000.00
6	230:4.16 KV Transformer: 25 MVA - 3 Phase	EACH	$600,000.00	1	$600,000.00
7	5 KV Metal-Clad Switch Gear Line Up	LS	$337,000.00	1	$337,000.00
8	480 VAC Dist. Panel with 400A Bus	EACH	$6,900.00	1	$6,900.00
9	4.16 KV:480, 350 KVA, - 3 Phase Transformer	EACH	$32,000.00	1	$32,000.00
10	Motor Control for 2000 HP Motor	EACH	$27,000.00	9	$243,000.00
11	480 VAC Variable Speed Drive for 300 HP pum	EACH	$45,000.00	8	$360,000.00
12	5 KV Metal-Clad Switch Gear Line Up - Inside	LS	$310,000.00	1	$310,000.00
13	480 VAC Dist. Panel with 400A Bus- Inside	EACH	$6,900.00	1	$6,900.00
14	480 VAC Variable Frequency Drive	EACH	$65,000.00	8	$520,000.00
15	300 HP Motors	EACH	$27,000.00	8	$216,000.00
16	2000 HP Motors	EACH	$135,000.00	9	$1,215,000.00
				Subtotal	$8,644,925.00

TOTAL $17,266,805.00

MOBILIZATION (5%) $863,340.25
UNLISTED (5%) $863,340.25
CONTINGENCIES (10%) $1,726,680.50
DESIGN (6%) $1,036,008.30
CONSTRUCTION OVERSITE (6%) $1,036,008.30

IN PLACE TOTAL $22,792,000.00

PIPELINE TO A COMMON POINT

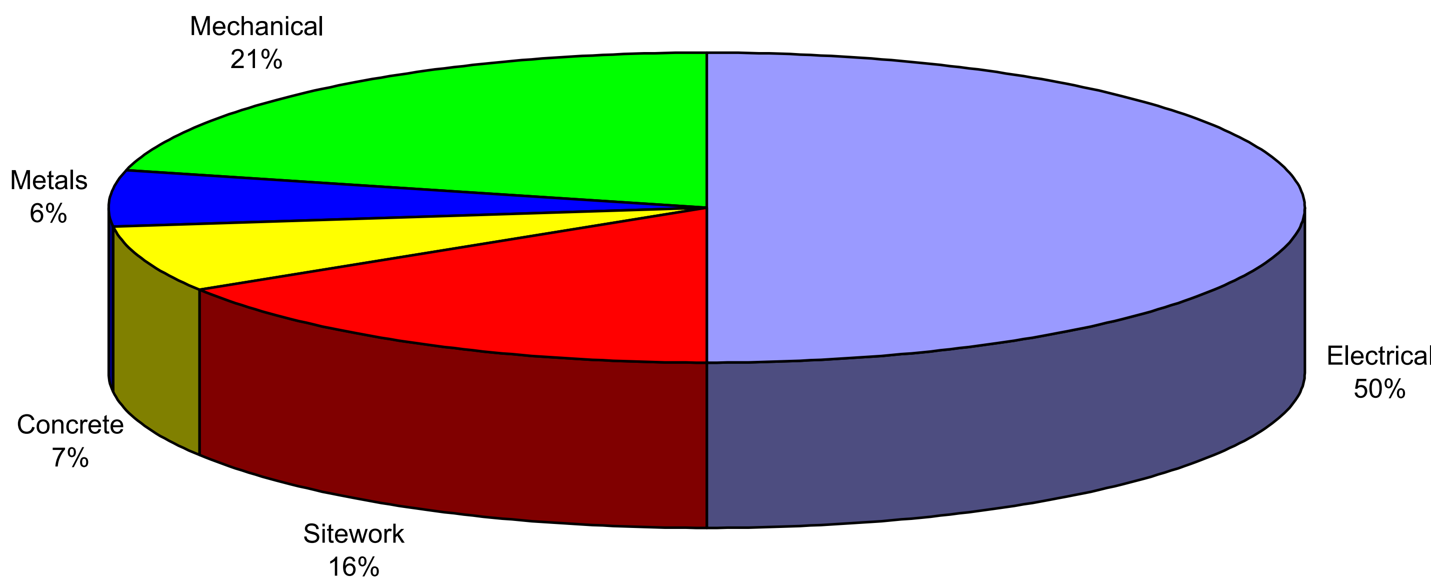
1	Pipeline "	LIN FT	$365.00	19872	$7,253,280.00
				Subtotal	$7,253,280.00

2.54

MOBILIZATION (5%) $362,664.00
UNLISTED (5%) $362,664.00
CONTINGENCIES (10%) $725,328.00
DESIGN (6%) $435,196.80
CONSTRUCTION OVERSITE (6%) $435,196.80
Grand Subtotal $9,574,000.00

IN PLACE TOTAL WITH PIPELINE TO A COMMON POINT $32,366,000.00

SITE 3 COST MODEL



COST ESTIMATE - SITE 4

(2001 Dollars)

SITEWORK

	Item	Unit	Unit Price	Quantity	Total Price
1	24 Ft Dia. Vertical Shaft	LIN FT	$4,600.00	190	$874,000.00
2	84" Lined Tunnel	LIN FT	$2,400.00	240	$576,000.00
3	24 Ft Wide Gravel Road	LIN FT	$29.00	2000	$58,000.00
4	Excavation - Building & Surge Tanks	CU YD	$12.00	50000	$600,000.00
5	Backfill - Building & Surge Tanks	CU YD	$2.00	10000	$20,000.00
6	Switch Yard Berm	CU YD	$6.00	25000	$150,000.00
7	Switch Yard Fence	LIN FT	$92.00	500	$46,000.00
				Subtotal	$2,324,000.00

CONCRETE

1	Reinforced Concrete	CU YD	$450.00	2400	$1,080,000.00
2	Water Stops	LS	$10,000.00	1	$10,000.00
3	Hollow Core Precast Concrete Deck	SQ FT	$6.15	8000	$49,200.00
4	Camouflage Concrete	CU YD	$500.00	300	$150,000.00
				Subtotal	$1,289,200.00

METALS

1	16" Dia Steel Pipe	LIN FT	$38.00	110	$4,180.00
2	30" Dia Steel Pipe	LIN FT	$158.00	35	$5,530.00
3	Pipe Manifold & Piping Specials	LS	$600,000.00	1	$600,000.00
4	Stainless Steel Liner for Sleeve Valve	LS	$110,000.00	1	$110,000.00
5	Misc. Metalwork	LS	$20,000.00	1	$20,000.00
6	Structural Steel W 12 x 53	LIN FT	$48.00	272	$13,056.00
7	Structural Steel W 12 x 87	LIN FT	$70.00	370	$25,900.00
8	Floor Grating - Medium Duty	SQ FT	$16.00	5000	$80,000.00
9	5 Ft. Dia. Screens	EACH	$20,000.00	4	$80,000.00
10	Screen Assembly	LS	$20,000.00	1	$20,000.00
11	Paint - Primer & Finish Coats - Metal	GAL	$45.00	50	$2,250.00
12	Steel Doors	EACH	$302.00	6	$1,812.00
				Subtotal	$958,666.00

MECHANICAL

1	500 psi, 5500 gpm Pumps	EACH	$113,600.00	9	$1,022,400.00
2	Variable Head, 5500 gpm Pumps	EACH	$65,500.00	8	$524,000.00
3	Low Head Check Valves	EACH	$2,000.00	8	$16,000.00
4	Sluice Gate	EACH	$3,000.00	7	$21,000.00
5	Rotary Pump Control Valves, 500 psi	EACH	$40,000.00	9	$360,000.00
6	Flow Meters	LS	$134,000.00	1	$134,000.00
7	16", 500 psi Cone Valves	EACH	$37,000.00	9	$333,000.00
8	30", 500 psi Cone Valve	EACH	$95,000.00	1	$95,000.00
9	30", 500 psi Sleeve Valve	EACH	$215,000.00	1	$215,000.00
10	Surge Suppression System	LS	$800,000.00	1	$800,000.00
11	Model Study for Circular Sump	LS	$100,000.00	1	$100,000.00
12	HVAC	SQ FT	$4.82	7700	$37,114.00
				Subtotal	$3,657,514.00

ELECTRICAL

1	Overhead Powerline	MILE	$130,000.00	5.2	$676,000.00
2	Buried Powerline	MILE	$1,000,000.00	2.8	$2,800,000.00
3	Switching Stations	EACH	$600,000.00	2	$1,200,000.00
4	Lighting & Misc. Electrical	SQ FT	$6.25	7700	$48,125.00
5	230-KV Power Circuit Breaker	EACH	$300,000.00	1	$300,000.00
6	230:4.16 KV Transformer: 25 MVA - 3 Phase	EACH	$600,000.00	1	$600,000.00
7	5 KV Metal-Clad Switch Gear Line Up	LS	$337,000.00	1	$337,000.00
8	480 VAC Dist. Panel with 400A Bus	EACH	$6,900.00	1	$6,900.00
9	4.16 KV:480, 350 KVA, - 3 Phase Transformer	EACH	$32,000.00	1	$32,000.00
10	Motor Control for 2000 HP Motor	EACH	$27,000.00	9	$243,000.00
11	480 VAC Variable Speed Drive for 300 HP pum	EACH	$45,000.00	8	$360,000.00
12	5 KV Metal-Clad Switch Gear Line Up - Inside	LS	$310,000.00	1	$310,000.00
13	480 VAC Dist. Panel with 400A Bus- Inside	EACH	$6,900.00	1	$6,900.00
14	480 VAC Variable Frequency Drive	EACH	$65,000.00	8	$520,000.00
15	300 HP Motors	EACH	$27,000.00	8	$216,000.00
16	2000 HP Motors	EACH	$135,000.00	9	$1,215,000.00
				Subtotal	$8,870,925.00

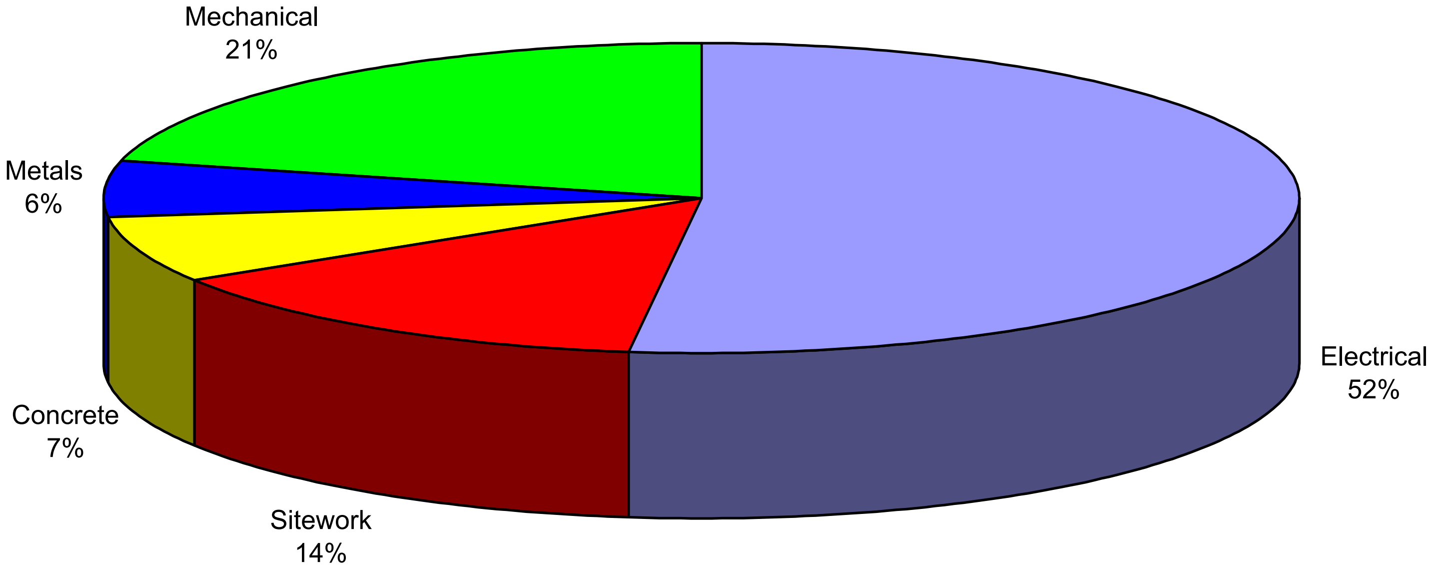
TOTAL	$17,100,305.00
MOBILIZATION (5%)	$855,015.25
UNLISTED (5%)	$855,015.25
CONTINGENCIES (10%)	$1,710,030.50
DESIGN (6%)	$1,026,018.30
CONSTRUCTION OVERSITE (6%)	$1,026,018.30
IN PLACE TOTAL	$22,572,000.00

PIPELINE TO A COMMON POINT

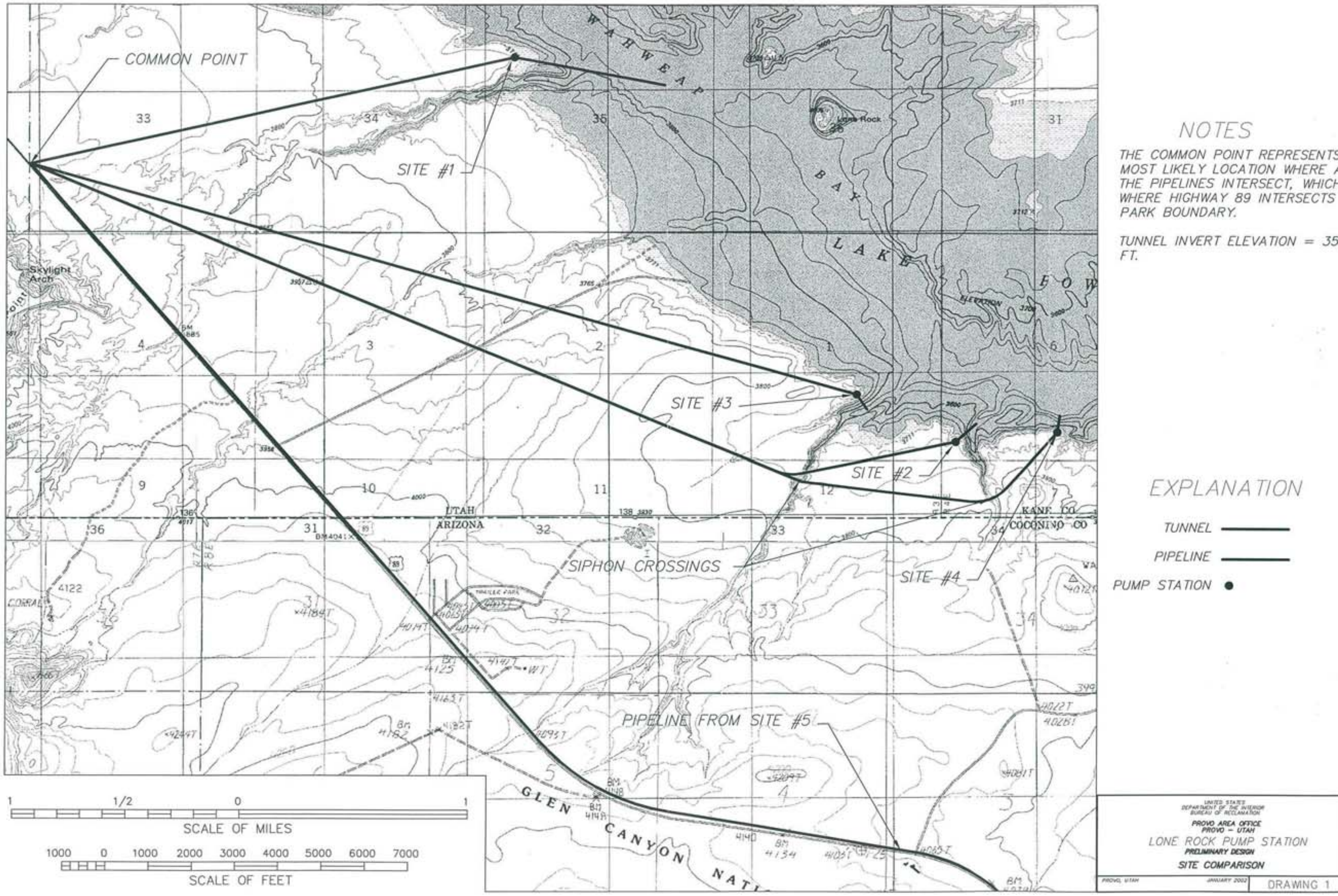
1	Pipeline 54"	LIN FT	$365.00	21940	$8,008,100.00
2	Pipeline 60"	LIN FT	$449.00	4000	$1,796,000.00
3	Siphon Crossing	LS	$50,000.00	2	$100,000.00
				Subtotal	$9,904,100.00

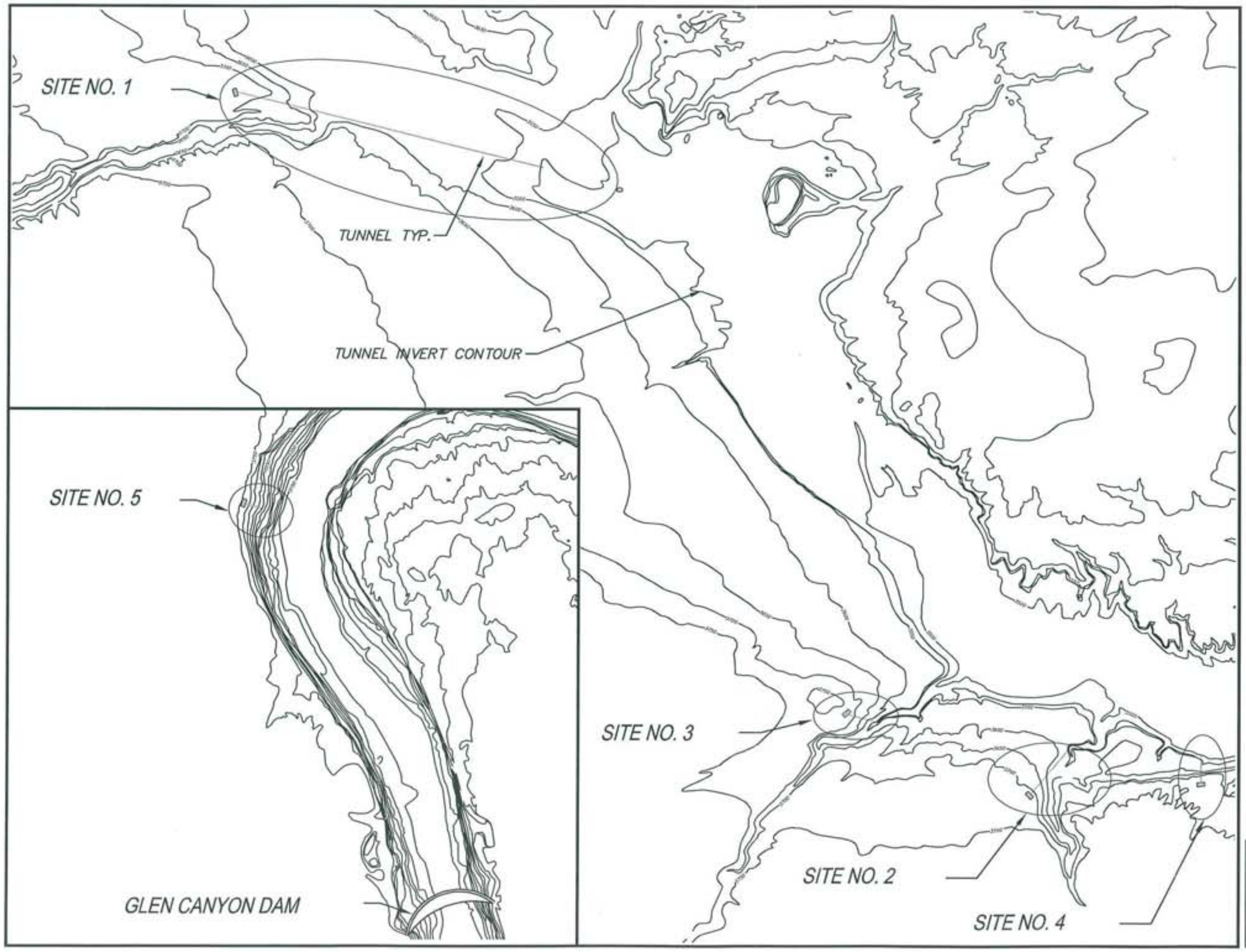
MOBILIZATION (5%)	$495,205.00
UNLISTED (5%)	$495,205.00
CONTINGENCIES (10%)	$990,410.00
DESIGN (6%)	$594,246.00
CONSTRUCTION OVERSITE (6%)	$594,246.00
Grand Subtotal	$13,073,000.00
IN PLACE TOTAL WITH PIPELINE TO A COMMON POINT	$35,645,000.00

SITE 4 COST MODEL



Drawings


COMMON POINT
SITE #1
SITE #2
SITE #3
SITE #4
SIPHON CROSSINGS
PIPELINE FROM SITE #5
WAHWEAP
BAY
LAKE
Lone Rock
Skylight Arch
UTAH
ARIZONA
KANE CO
COCONINO CO
GLEN CANYON NATI
NOTES
THE COMMON POINT REPRESENTS THE MOST LIKELY LOCATION WHERE ALL THE PIPELINES INTERSECT, WHICH IS WHERE HIGHWAY 89 INTERSECTS THE PARK BOUNDARY.
TUNNEL INVERT ELEVATION = 3540 FT.
EXPLANATION
TUNNEL
PIPELINE
PUMP STATION
1 1/2 0 1
SCALE OF MILES
1000 0 1000 2000 3000 4000 5000 6000 7000
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROVO AREA OFFICE
PROVO – UTAH
LONE ROCK PUMP STATION
PRELIMINARY DESIGN
SITE COMPARISON
PROVO, UTAH
JANUARY 2002
DRAWING 1



N.

NOTES

1. THIS DRAWING IS NOT TO SCALE.
2. SEE OTHER DRAWINGS FOR SITE DETAILS.
3. CONTOURS GENERATED FROM NPS.

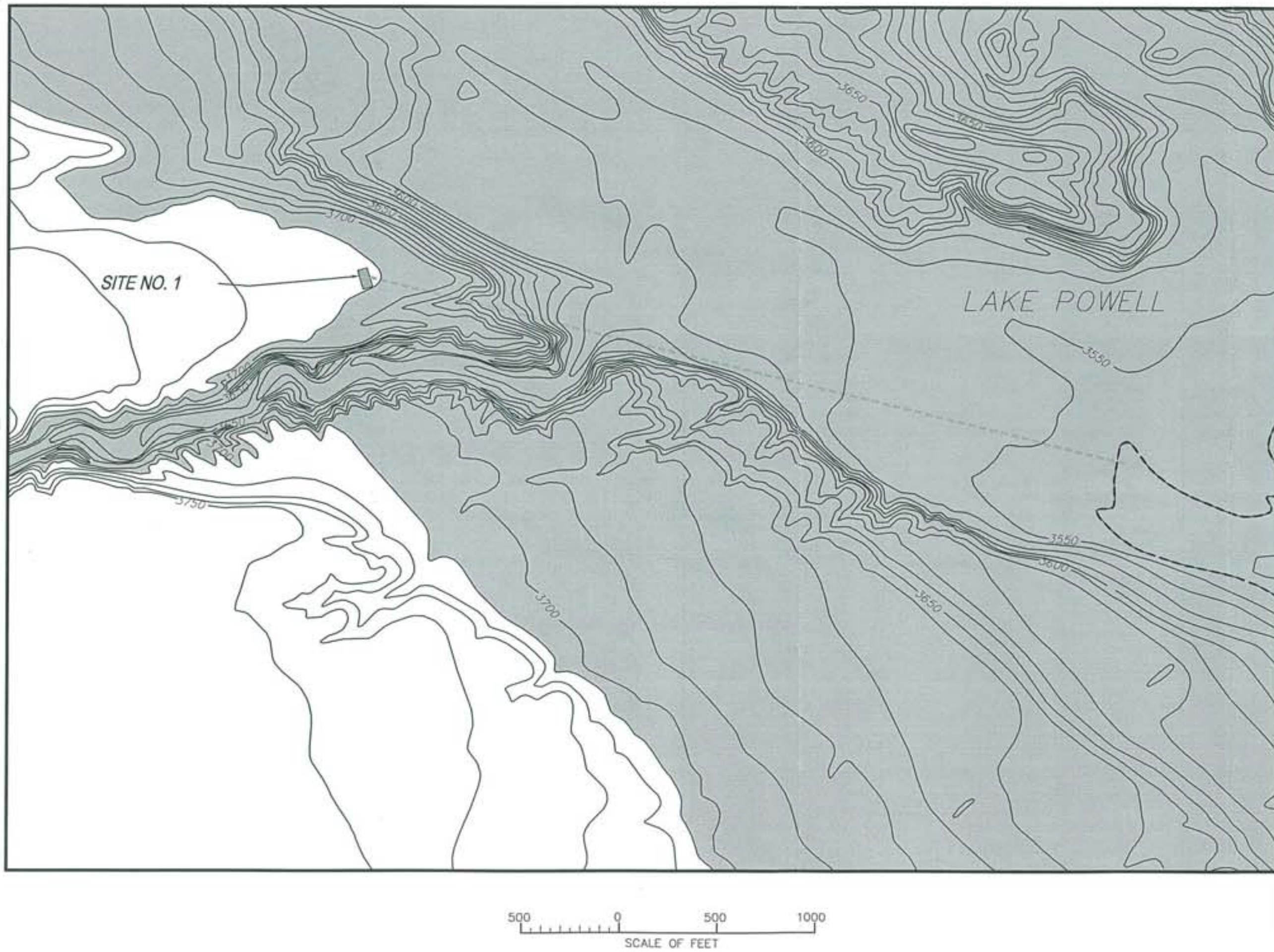
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION
PRELIMINARY DESIGN

OVERVIEW OF SITES 1 THROUGH 5

PROVO, UTAH	JANUARY 2002	DRAWING 3



N.

LEGEND

TUNNEL

PUMP STATION

TUNNEL INVERT CONTOUR

NOTES

1. CONTOUR INTERVAL IS 10 FEET.
2. MAXIMUM WATER SURFACE ELEVATION IS 3711.
3. TUNNEL INVERT ELEVATION IS 3540.

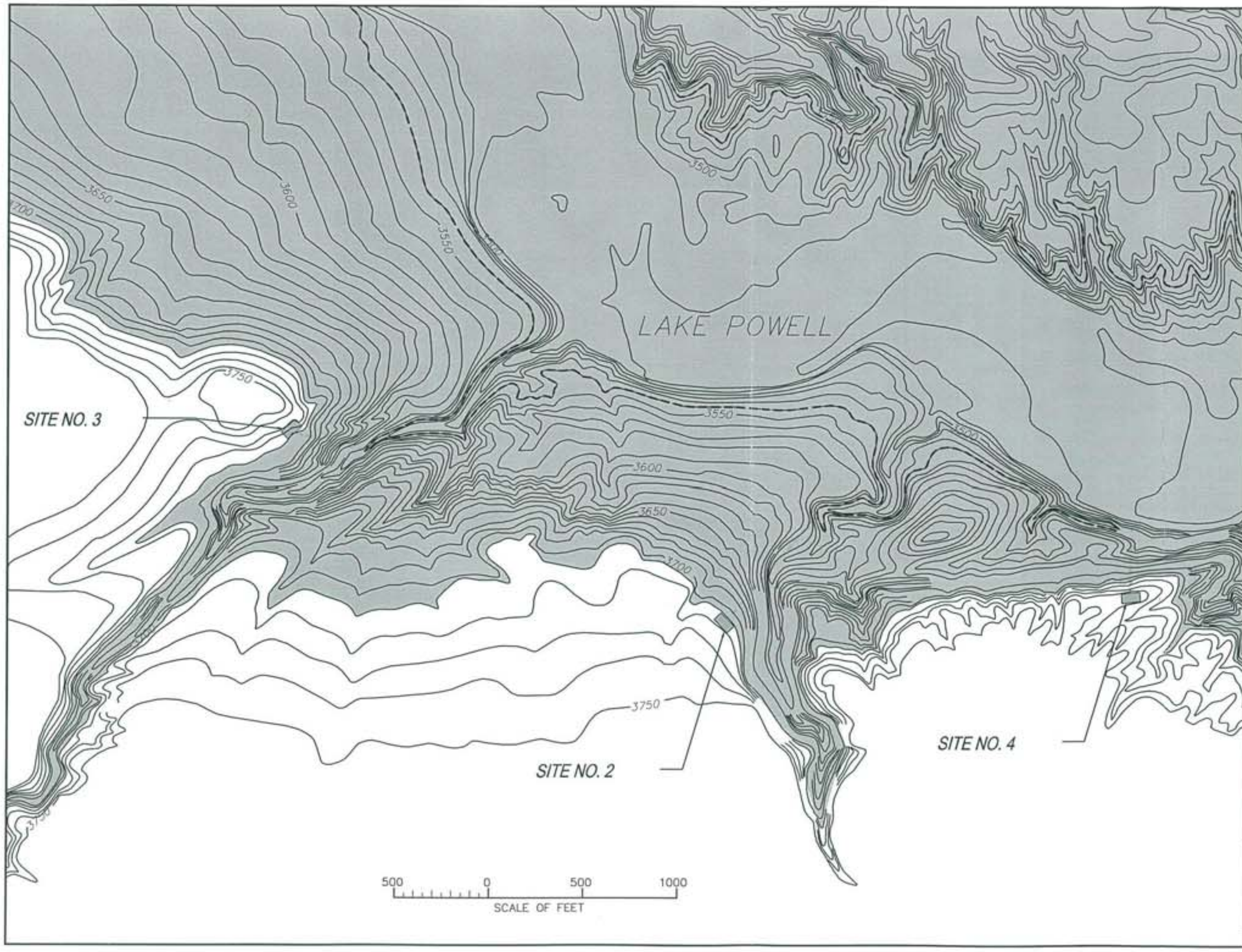
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION
PRELIMINARY DESIGN

SITE 1

PROVO, UTAH | JANUARY 2002 | DRAWING 4



N.

LEGEND

TUNNEL

PUMP STATION

TUNNEL INVERT CONTOUR

NOTES

1. CONTOUR INTERVAL IS 10 FEET.
2. MAXIMUM WATER SURFACE ELEVATION IS 3711.
3. TUNNEL INVERT ELEVATION IS 3540.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

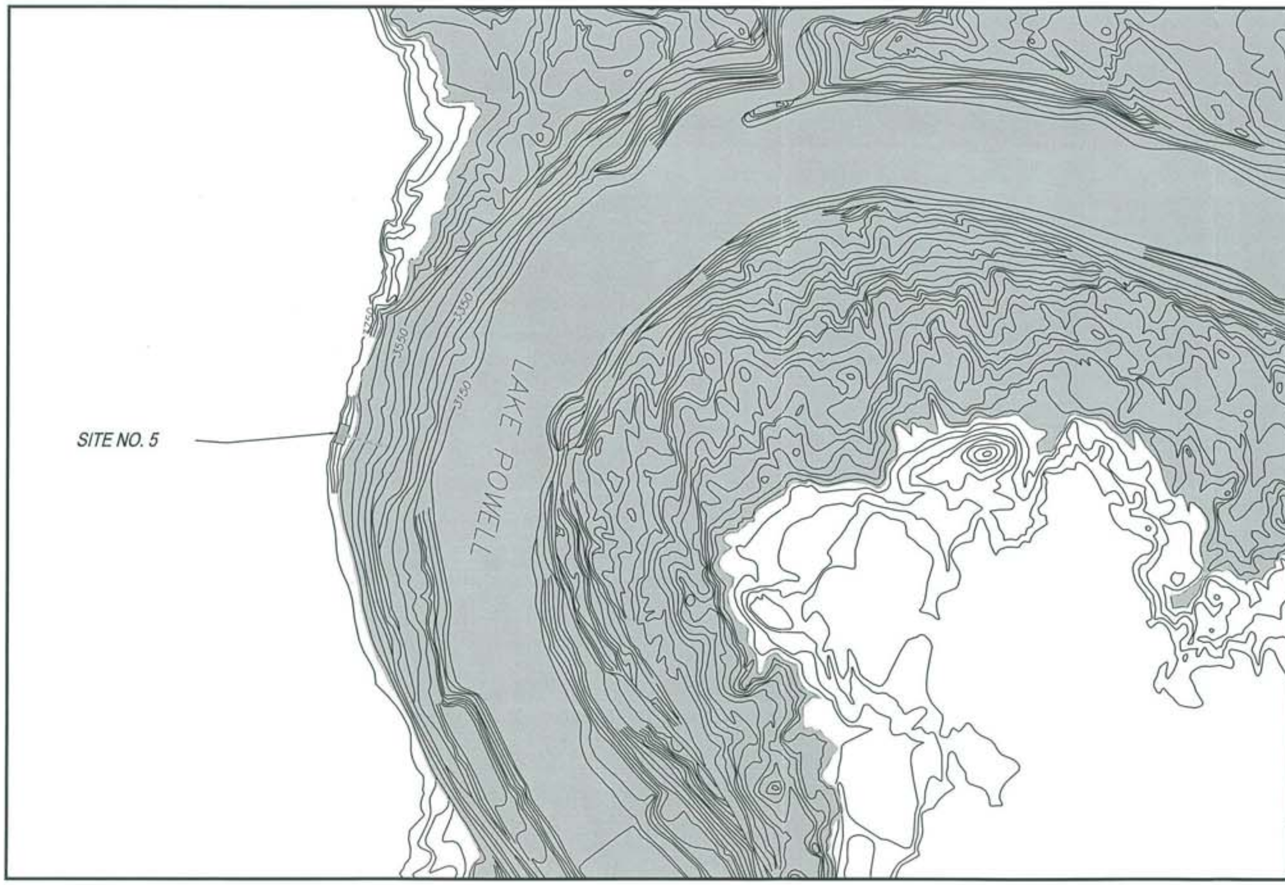
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

SITES 2, 3, AND 4

PROVO, UTAH	JANUARY 2002	DRAWING 5



500 0 500 1000
SCALE OF FEET

N.

LEGEND

TUNNEL

PUMP STATION

TUNNEL INVERT CONTOUR

NOTES

1. CONTOUR INTERVAL IS 10 FEET.
2. MAXIMUM WATER SURFACE ELEVATION IS 3711.
3. TUNNEL INVERT ELEVATION IS 3540.

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

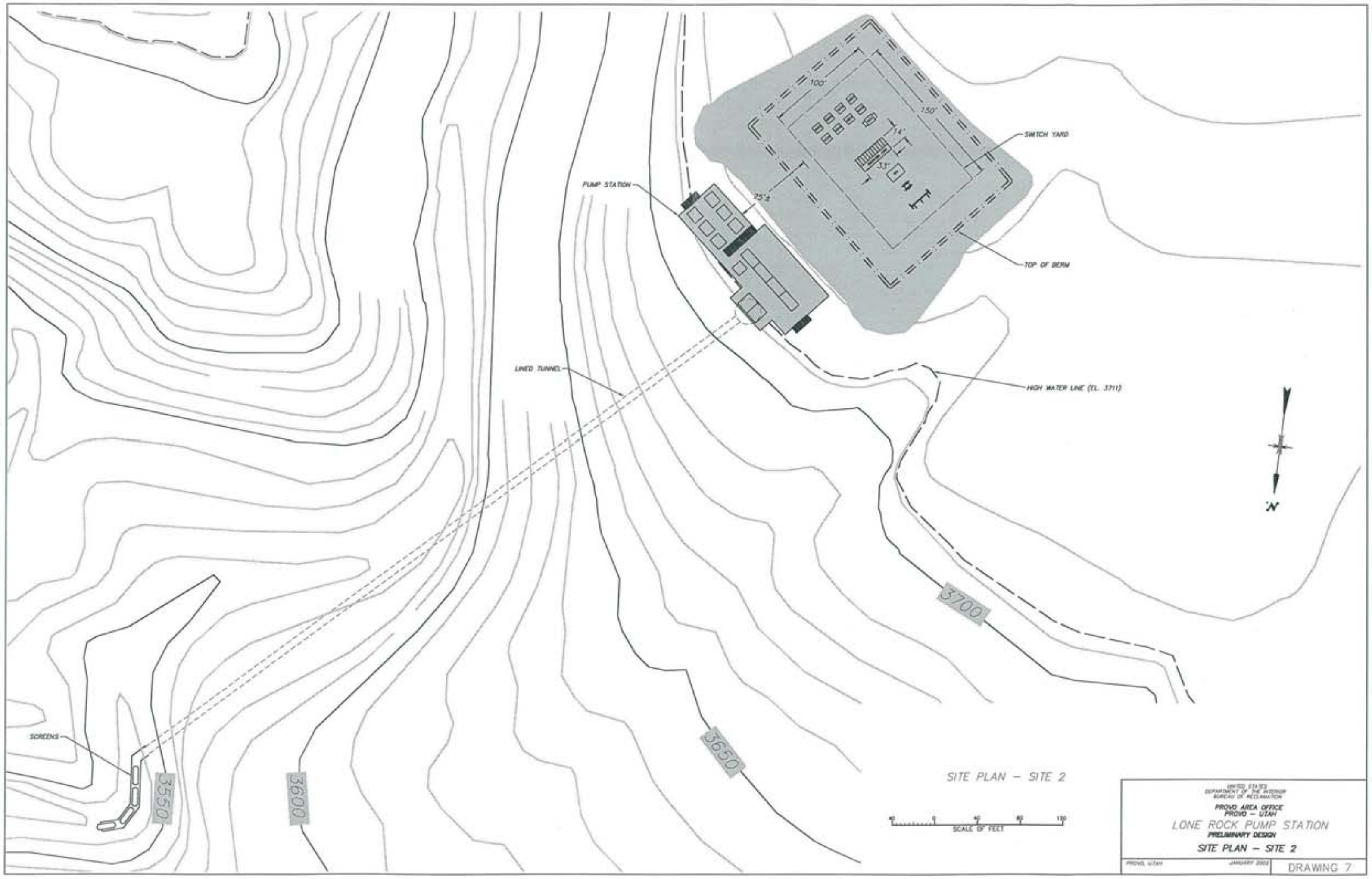
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

SITE 5

PROVO, UTAH | JANUARY 2003 | DRAWING 6



PUMP STATION
SWITCH YARD
100'
150'
14'
33'
75'±
TOP OF BERM
LINED TUNNEL
HIGH WATER LINE (EL. 3711)
N
3700
3650
3600
3550
SCREENS
SITE PLAN – SITE 2
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROVO AREA OFFICE
PROVO – UTAH
LONE ROCK PUMP STATION
PRELIMINARY DESIGN
SITE PLAN – SITE 2
PROVO, UTAH
JANUARY 2002
DRAWING 7

SITE PLAN – SITE 3

20 0 20 40 60
SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

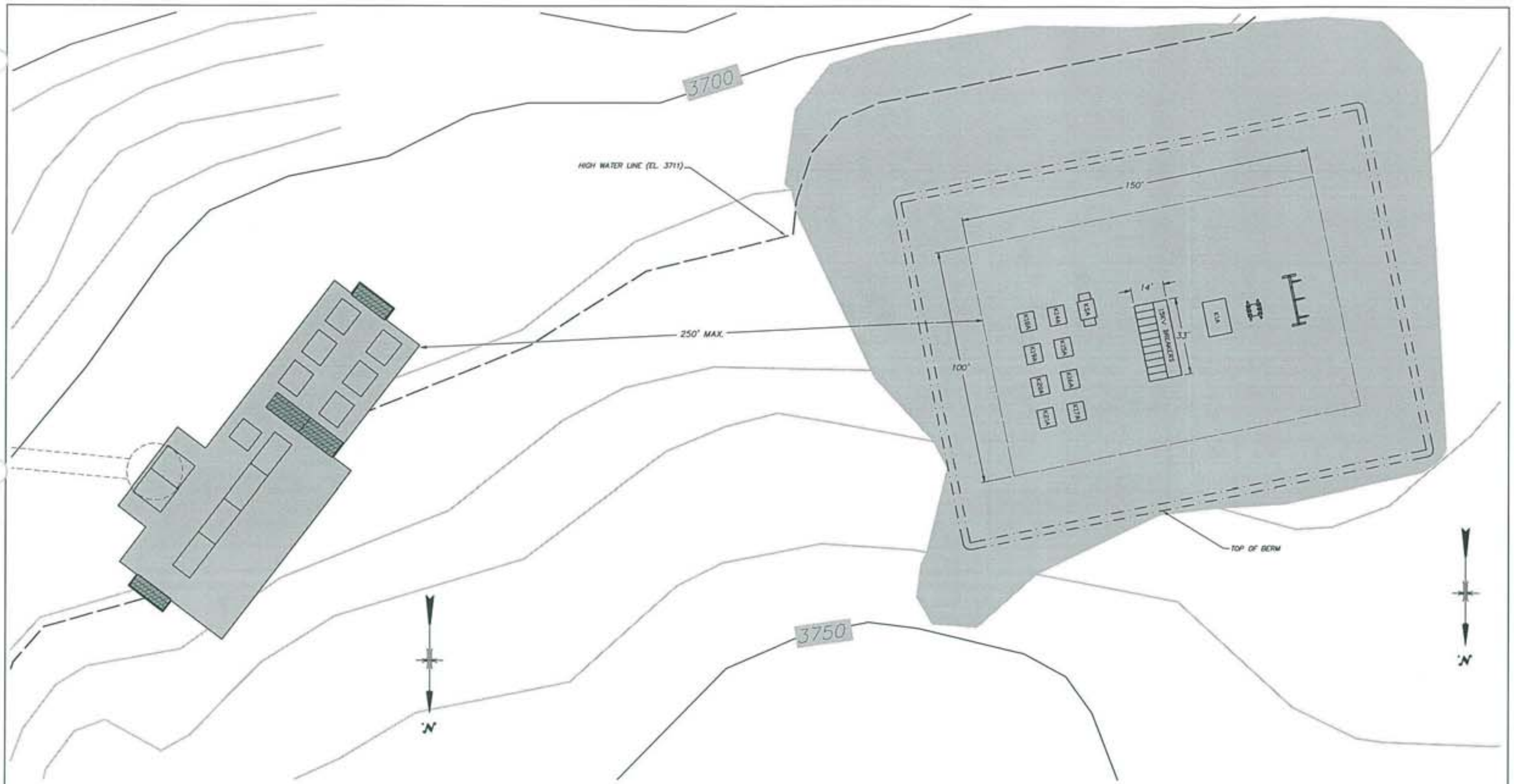
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

SITE PLAN – SITE 3

PROVO, UTAH	JANUARY 2002	DRAWING 8



SITE PLAN – SITE 3 – SWITCH YARD

SCALE OF FEET

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

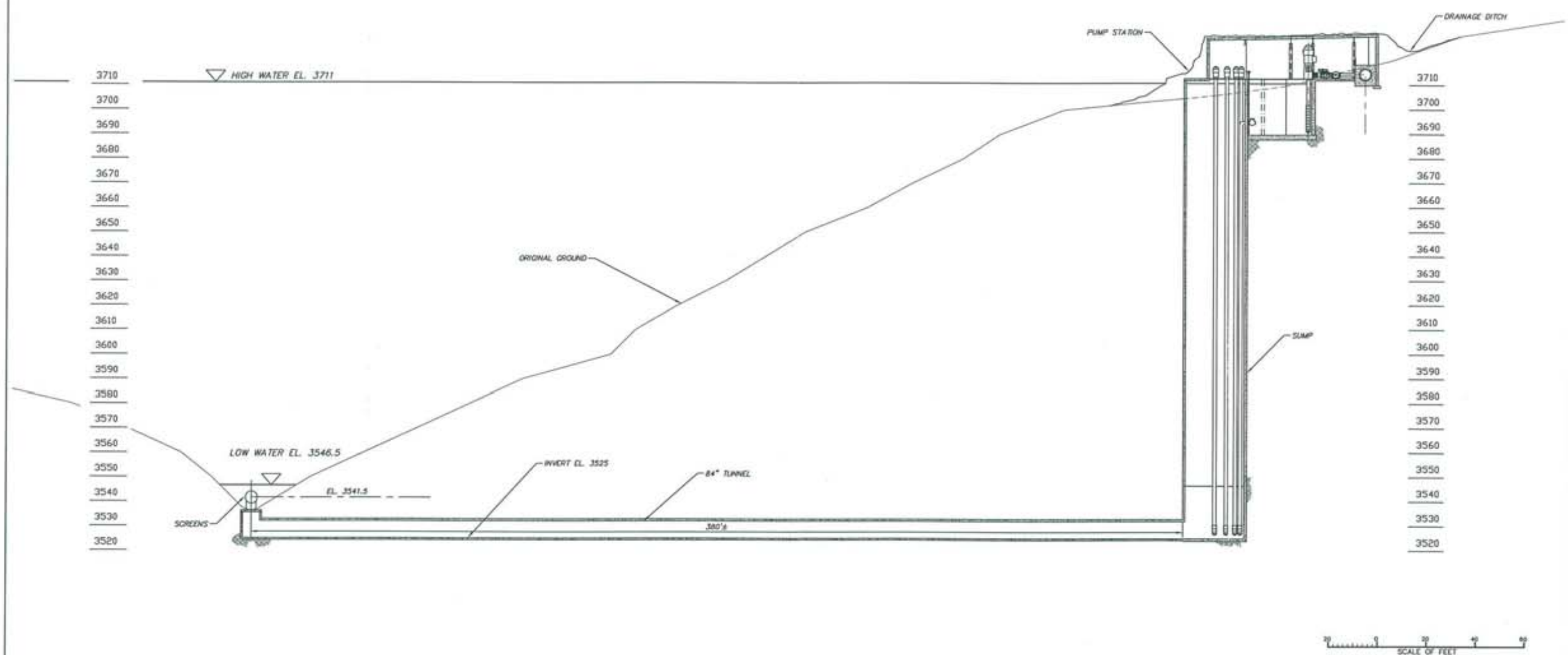
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

SITE PLAN – SITE 3 – SWITCH YARD

PROVO, UTAH	JANUARY 2002	DRAWING 9



SECTION – SITE 3

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

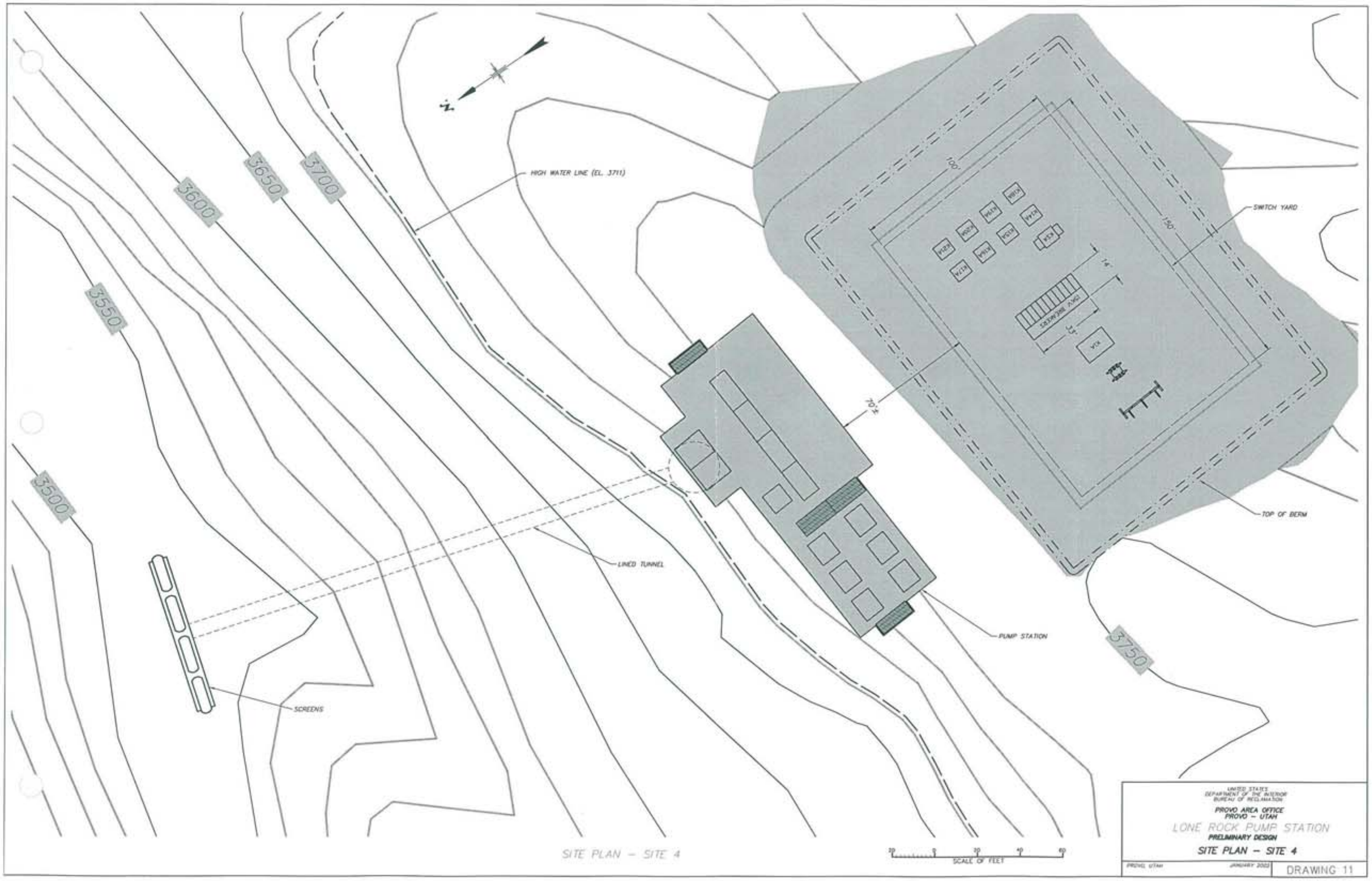
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

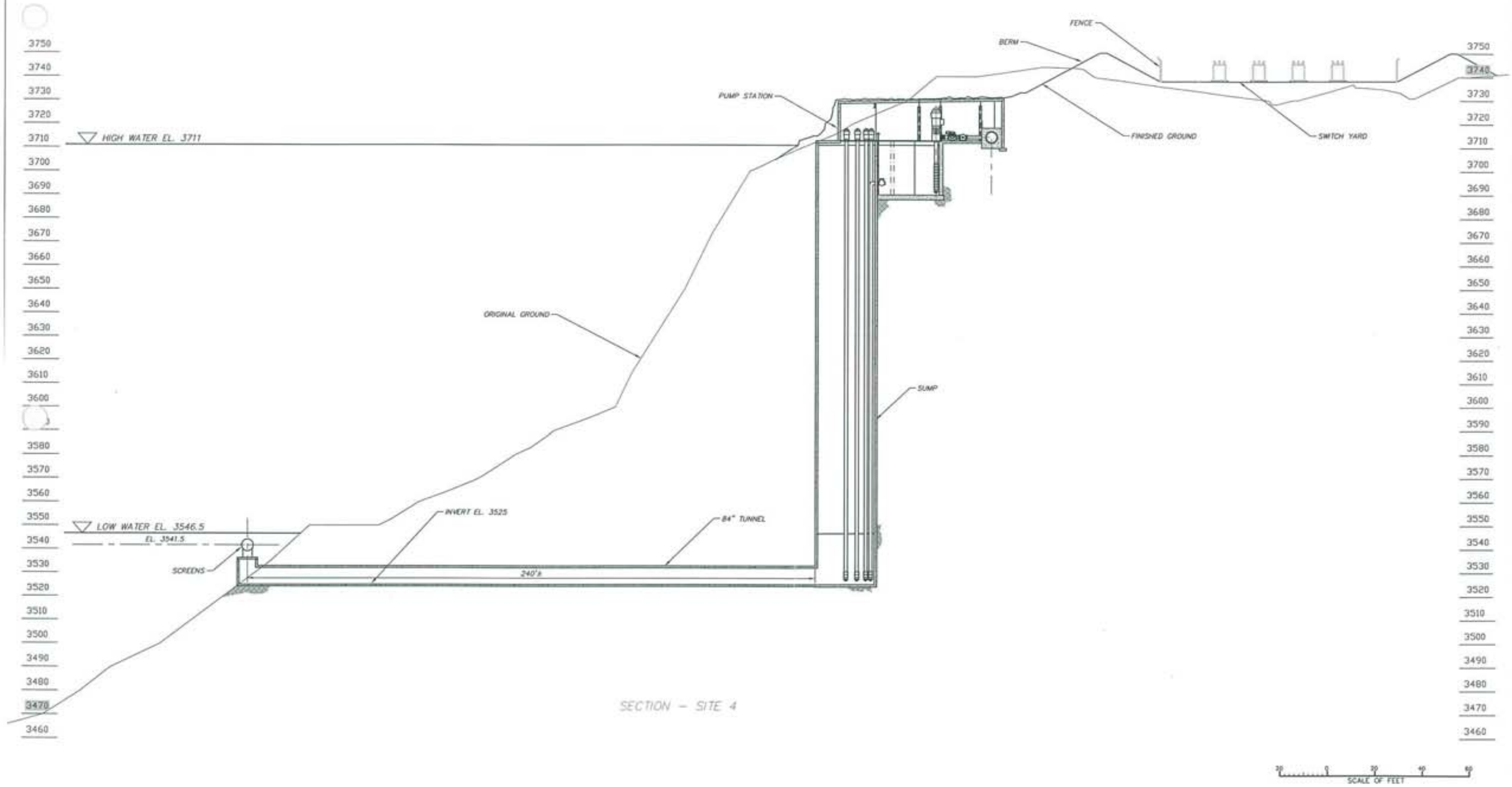
PRELIMINARY DESIGN

GENERAL SECTION – SITE 3

PROVO, UTAH | JANUARY 2002 | DRAWING 10



HIGH WATER LINE (EL. 3711)
SWITCH YARD
TOP OF BERM
LINED TUNNEL
PUMP STATION
SCREENS
3500
3550
3600
3650
3700
3750
100'
150'
70'±
SITE PLAN - SITE 4
SCALE OF FEET
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROVO AREA OFFICE
PROVO - UTAH
LONE ROCK PUMP STATION
PRELIMINARY DESIGN
SITE PLAN - SITE 4
PROVO, UTAH
DRAWING 11



SECTION – SITE 4

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

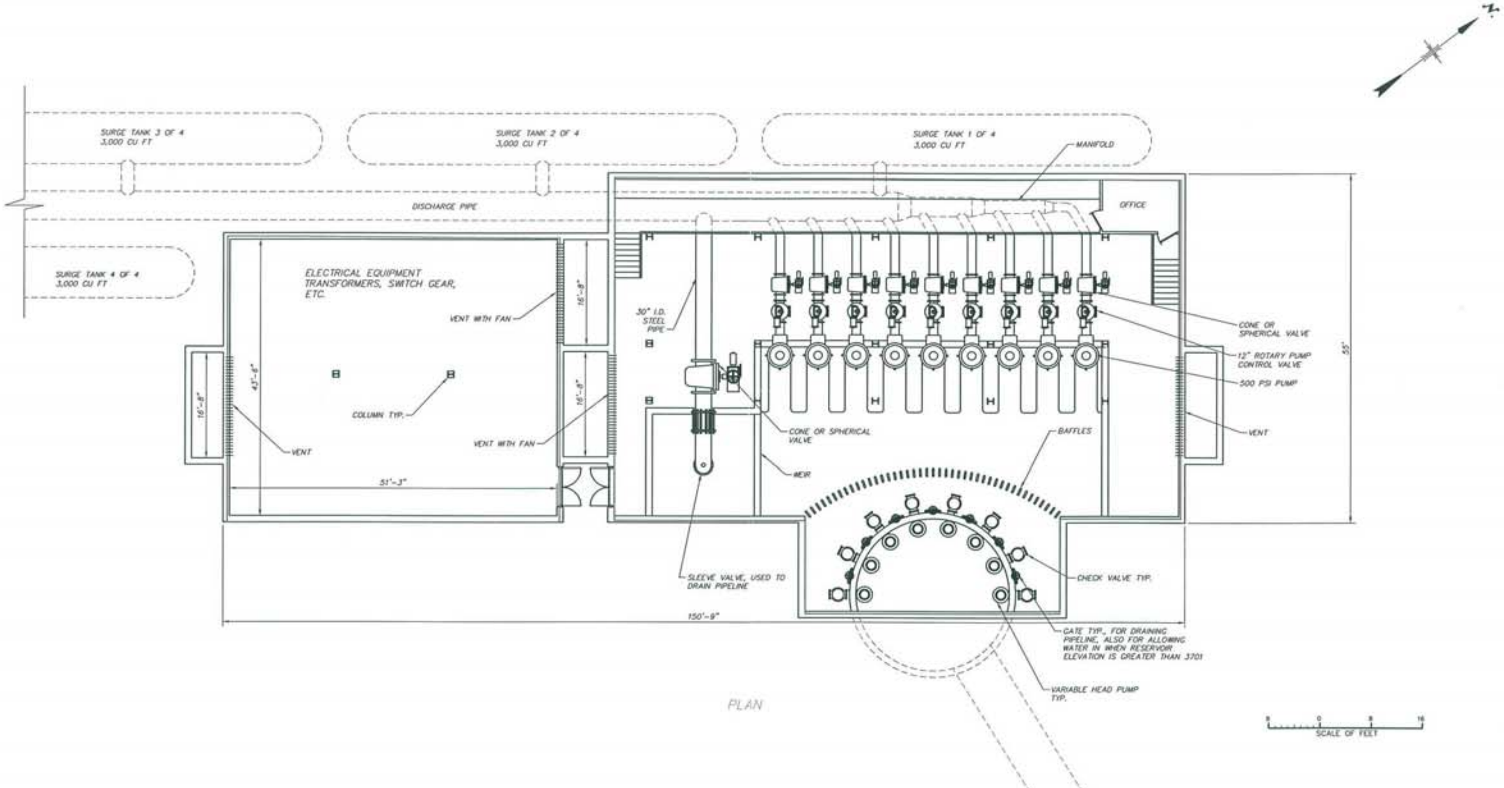
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

GENERAL SECTION – SITE 4

PROVO, UTAH | JANUARY 2002 | DRAWING 12



UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

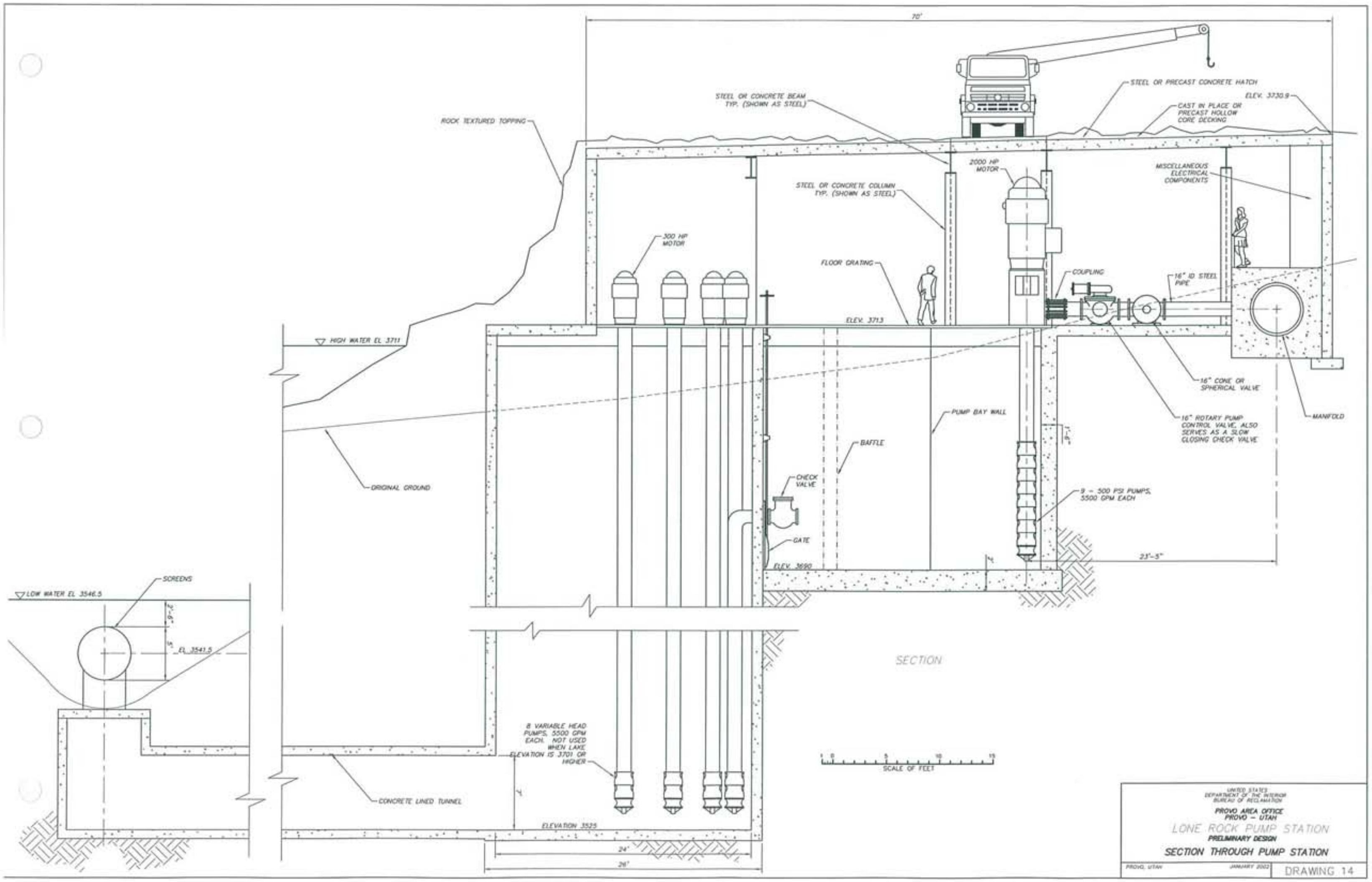
PROVO AREA OFFICE
PROVO – UTAH

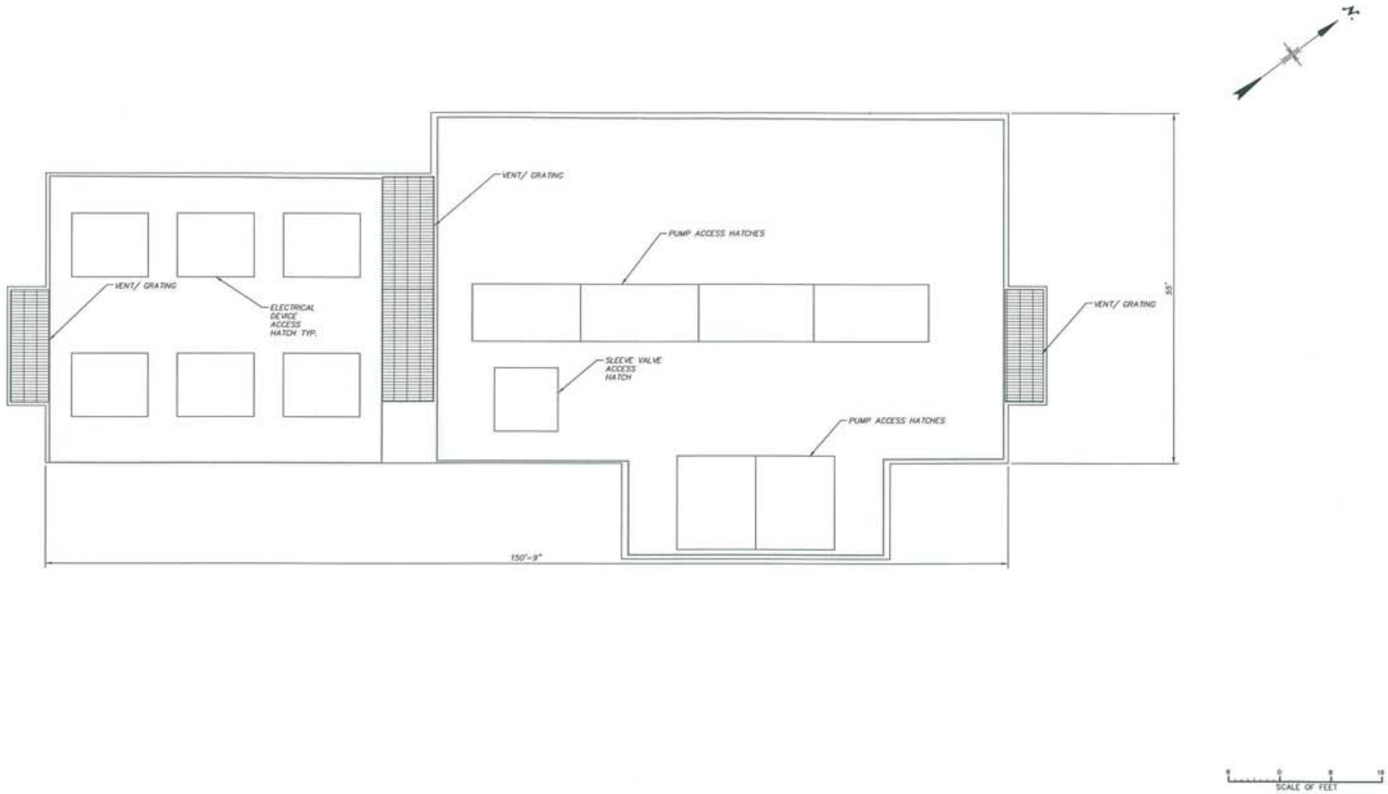
LONE ROCK PUMP STATION

PRELIMINARY DESIGN

PLAN

PROVO, UTAH	JANUARY 2002	DRAWING 13


70'
STEEL OR PRECAST CONCRETE HATCH
ELEV. 3730.9
CAST IN PLACE OR PRECAST HOLLOW CORE DECKING
STEEL OR CONCRETE BEAM TYP. (SHOWN AS STEEL)
ROCK TEXTURED TOPPING
2000 HP MOTOR
MISCELLANEOUS ELECTRICAL COMPONENTS
STEEL OR CONCRETE COLUMN TYP. (SHOWN AS STEEL)
300 HP MOTOR
FLOOR GRATING
COUPLING
16" ID STEEL PIPE
ELEV. 3713
HIGH WATER EL 3711
16" CONE OR SPHERICAL VALVE
16" ROTARY PUMP CONTROL VALVE, ALSO SERVES AS A SLOW CLOSING CHECK VALVE
MANIFOLD
PUMP BAY WALL
BAFFLE
ORIGINAL GROUND
CHECK VALVE
9 - 500 PSI PUMPS, 5500 GPM EACH
GATE
ELEV. 3690
23'-5"
SCREENS
LOW WATER EL 3546.5
EL 3541.5
SECTION
8 VARIABLE HEAD PUMPS, 5500 GPM EACH. NOT USED WHEN LAKE ELEVATION IS 3701 OR HIGHER
SCALE OF FEET
CONCRETE LINED TUNNEL
ELEVATION 3525
24'
26'
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
PROVO AREA OFFICE
PROVO - UTAH
LONE ROCK PUMP STATION
PRELIMINARY DESIGN
SECTION THROUGH PUMP STATION
PROVO, UTAH
JANUARY 2002
DRAWING 14



ROOF PLAN

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

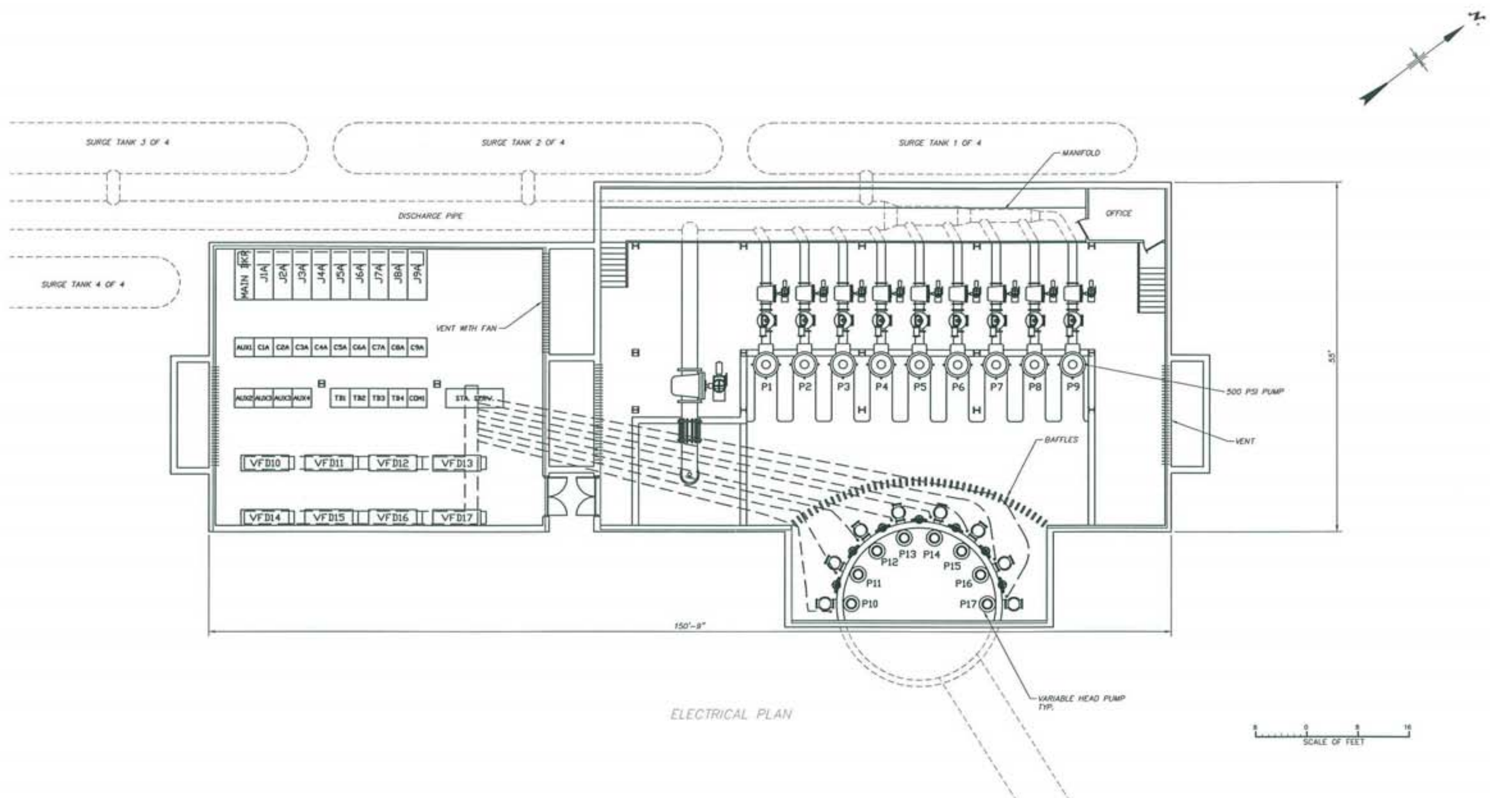
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

ROOF PLAN

PROVO, UTAH	JANUARY 2002	DRAWING 15



ELECTRICAL PLAN

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

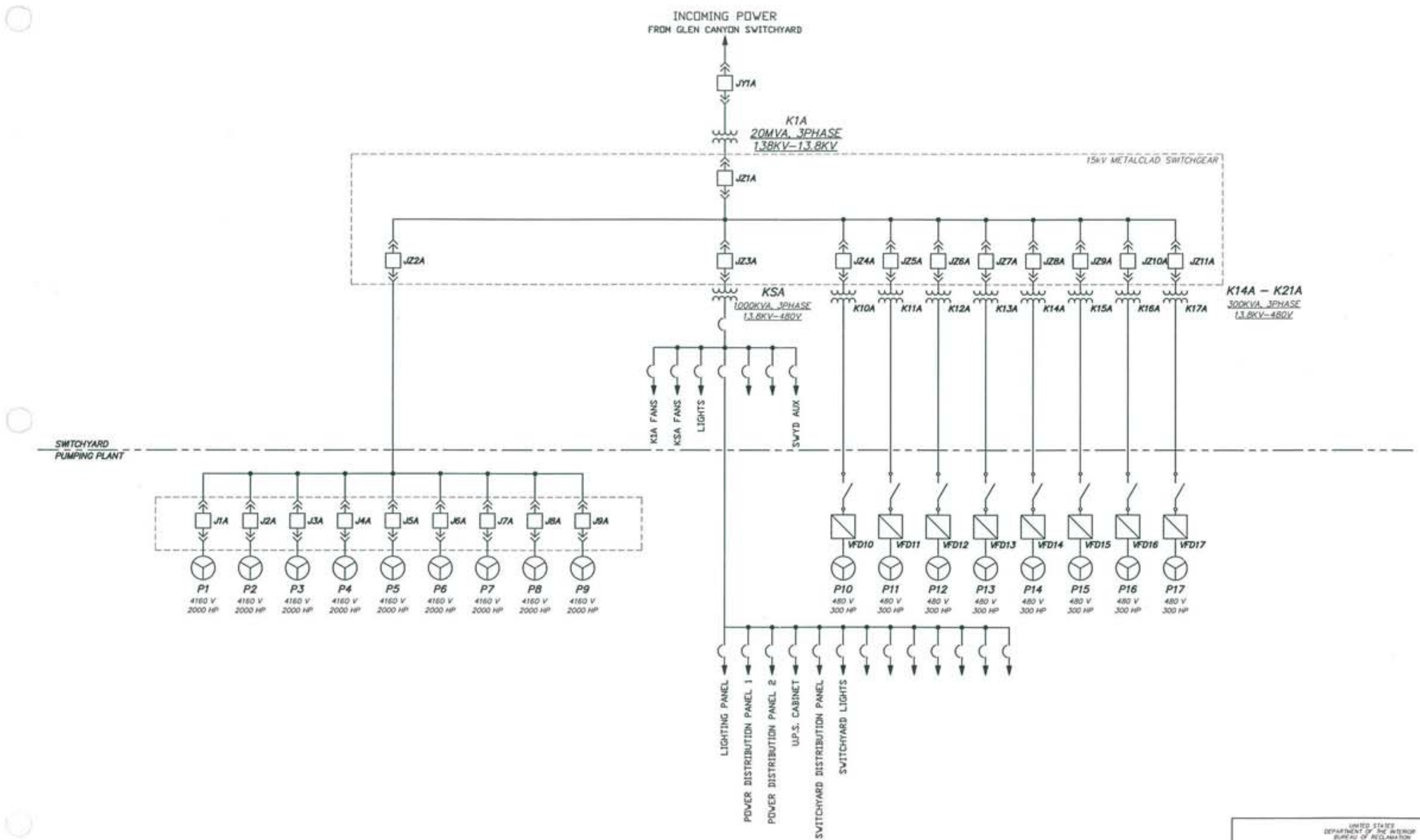
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION

PRELIMINARY DESIGN

ELECTRICAL PLAN

PROVO, UTAH	JANUARY 2002	DRAWING 16



SINGLE LINE DIAGRAM

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

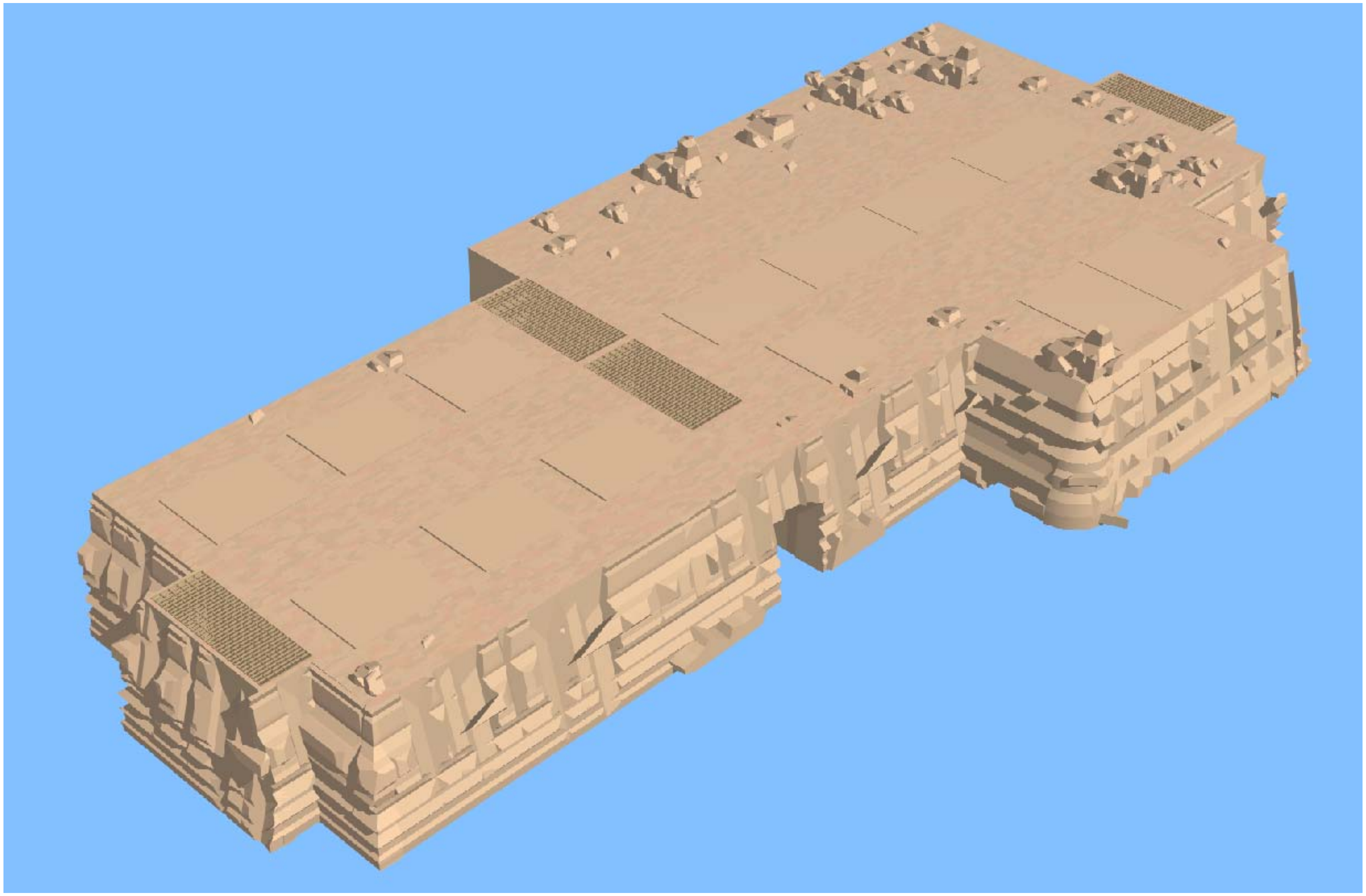
PROVO AREA OFFICE
PROVO – UTAH

LONE ROCK PUMP STATION
PRELIMINARY DESIGN

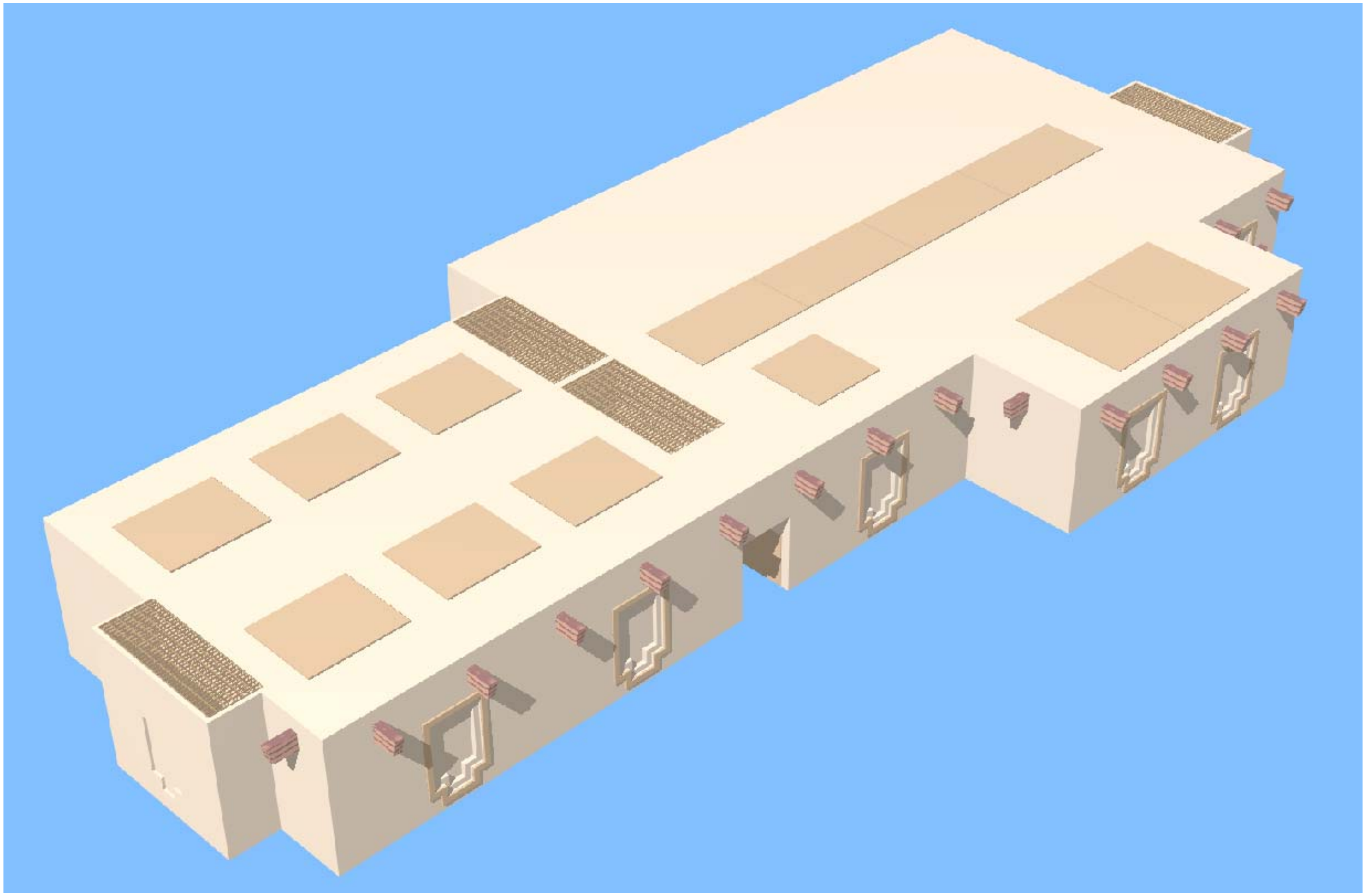
ELECTRICAL – SINGLE LINE DIAGRAM

PROVO, UTAH	JANUARY 2002	DRAWING 17

Renderings



RENDERING OF PUMP STATION WITH ROCK COVER



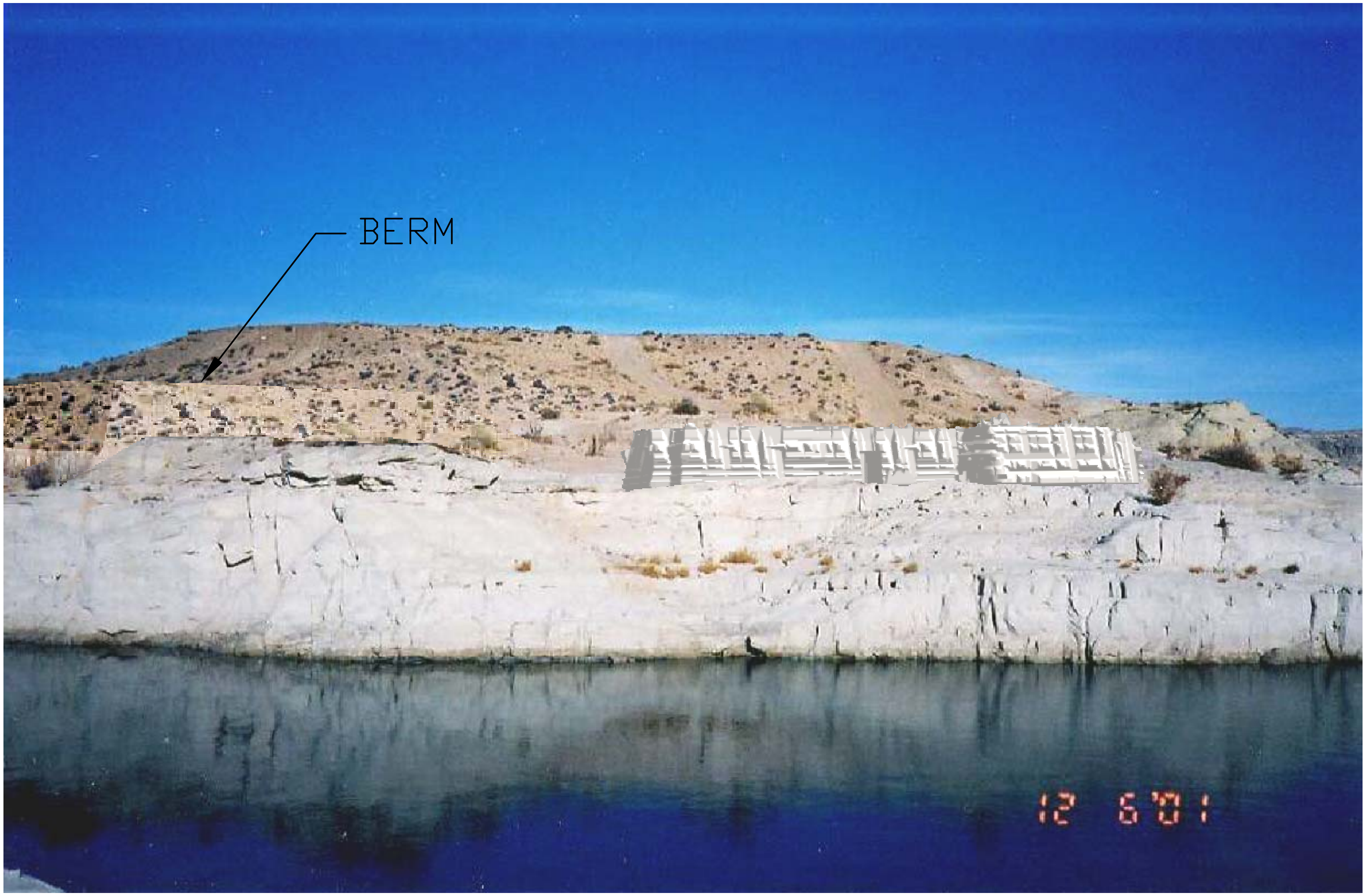
RENDERING OF PUMP STATION WITH SOUTHWEST ARCHITECTURE

SITE 2

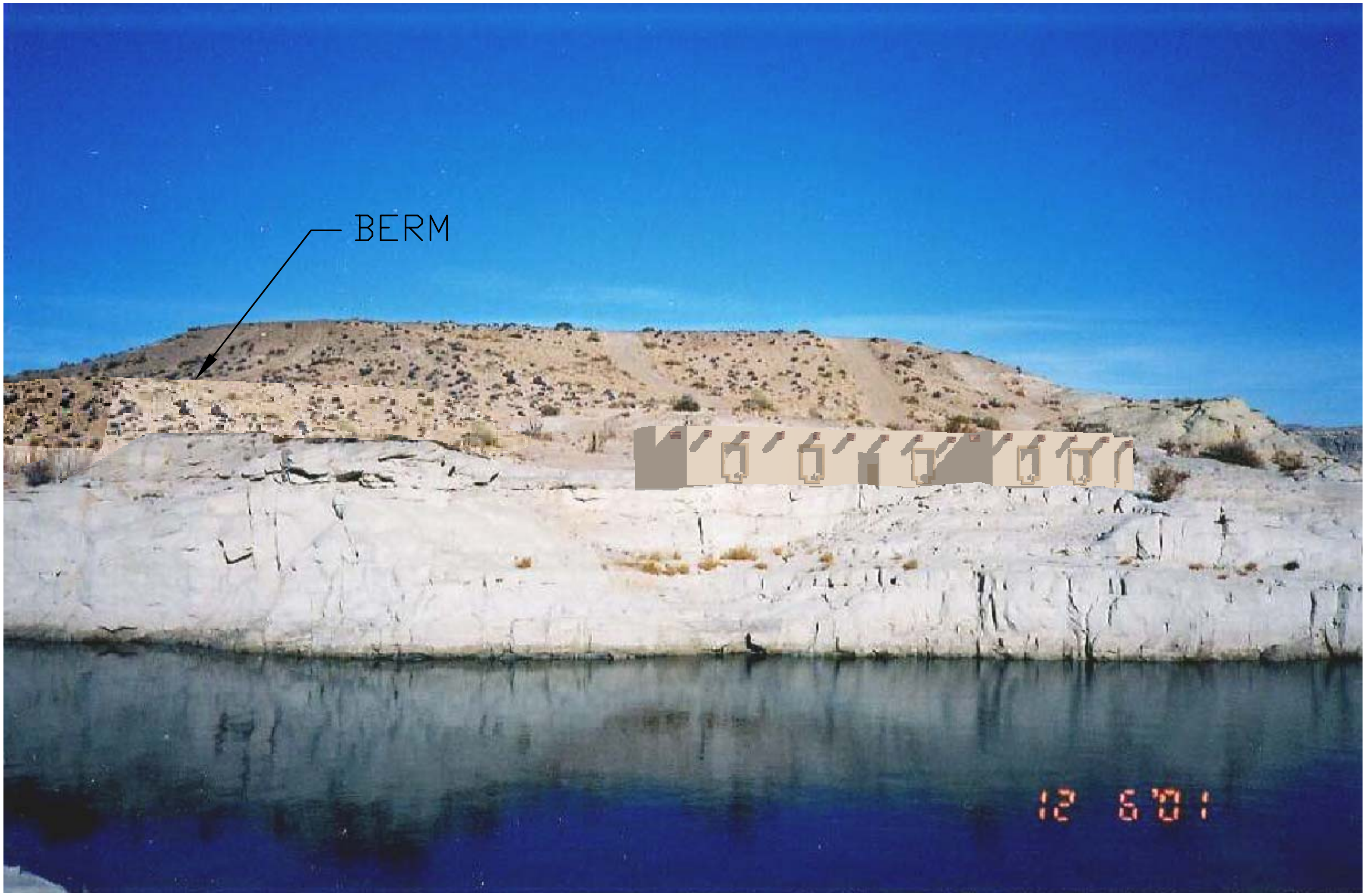
ROCK COVER AT SITE 2

SOUTHWEST ARCHITECTURE AT SITE 2

SITE 3



ROCK COVER AT SITE 3



SOUTHWEST ARCHITECTURE AT SITE 3

SITE 4

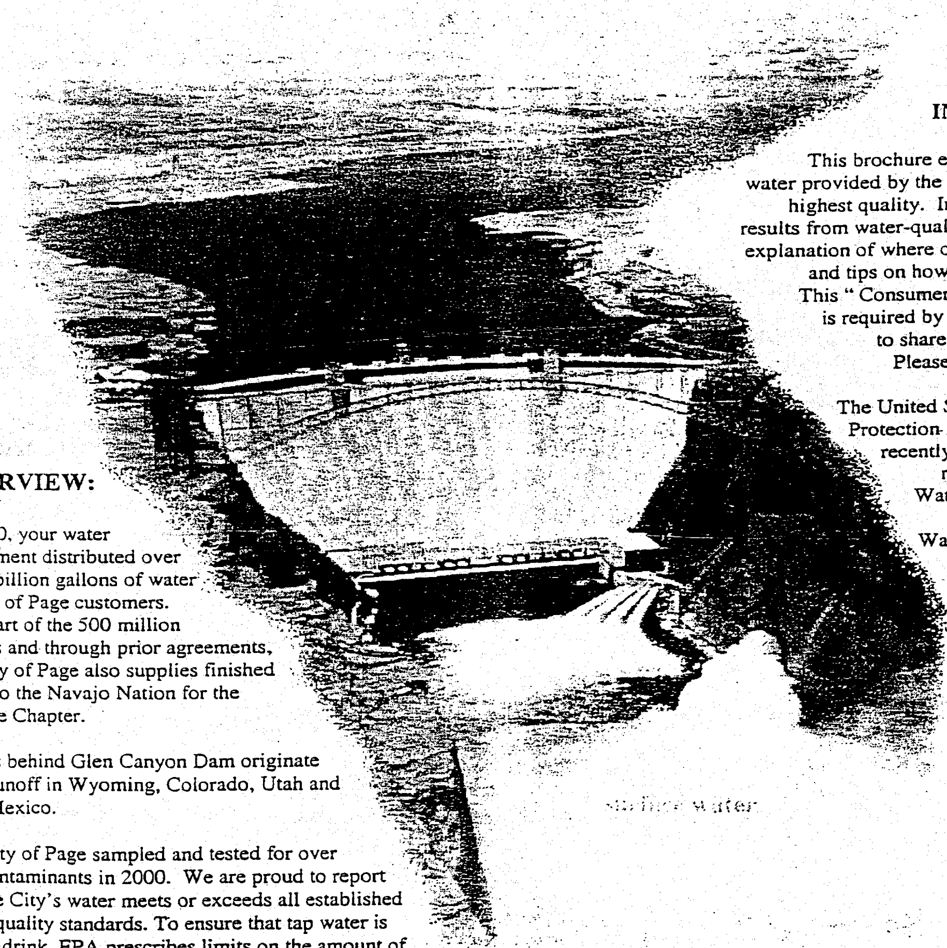
SOUTHWEST ARCHITECTURE AT SITE 4

ROCK COVER AT SITE 4

Appendix A -

City of Page, 2000 Water Quality Annual Report

City of Page,
2000 Water Quality Annual Report



INTRODUCTION:

This brochure explains how drinking water provided by the City of Page is of the highest quality. Included is a listing of results from water-quality tests as well as an explanation of where our water comes from and tips on how to interpret the data. This " Consumer Confidence Report" is required by law. We are pleased to share our results with you. Please read them carefully.

The United States Environmental Protection Agency (U.S.E.P.A.) recently finalized a new rule requiring Community Water Systems, as a part of the Safe Drinking Water Act Amendments of 1996, to produce and distribute an Annual Report addressing the quality of water they deliver. The Goal of our report is to provide information to customers so they may make personal health based decisions regarding their drinking water.

OVERVIEW:

In 2000, your water department distributed over a half billion gallons of water to City of Page customers. As a part of the 500 million gallons and through prior agreements, the City of Page also supplies finished water to the Navajo Nation for the LeChee Chapter.

Waters behind Glen Canyon Dam originate from runoff in Wyoming, Colorado, Utah and New Mexico.

The City of Page sampled and tested for over 100 contaminants in 2000. We are proud to report that the City's water meets or exceeds all established water-quality standards. To ensure that tap water is safe to drink, EPA prescribes limits on the amount of particular contaminants in water provided by public water systems.

Glen Canyon Dam, at Lake Powell, a part of the Colorado River Storage Project, is the sole source of drinking water for the City of Page.

; YOUR WATER TREATED?

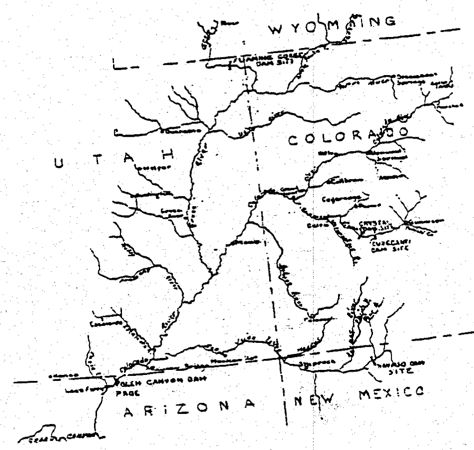
.ll water distributed by the City of Page is treated at the City's Aqua Street filter plant. Before distribution, finished water is isinfected by the addition of chlorine. *Trained and Certified* City staff treat and test the City's water. Further analytical testing is .one at various state approved and certified laboratories in compliance with State and Federal regulations.

WATERSHED PROTECTION:

As illustrated in this report, our Water Quality may be impacted by activities throughout the entire Colorado River Storage Basin. The U.S.E.P.A. will require all State Water Primacy Agencies to produce Source Water Assessments. In our community, the U.S. National Park Service, and Aramark Leisure Services Inc. have watershed protection programs directed at improving our water quality. In conjunction with the program *Page Attacks Trash*, trash tracker and beach clean-up programs are conducted regularly. NPS uniformed personnel educate and enforce water quality issues and regulations throughout the National Recreation Area. Further information may be obtained by contacting either of these agencies.

REQUIRED ADDITIONAL HEALTH INFORMATION:

The City of Page drinking water presently meets or exceeds all Federal, State and County Health safety standards. Drinking water, including bottled water, may reasonably be expected to contain at least small amounts of some contaminants. The presence of contaminants does *not* necessarily indicate those waters pose a health risk. As water travels over the surface and through the ground, it dissolves naturally occurring minerals and radioactive material, and can pick up substances resulting from the presence of animal and human activity. Contaminants that may be present in *source* water include:



1) Microbial contaminants, such as viruses and bacteria, which may come from sewage treatment plants, septic systems, agricultural livestock operations, and wildlife.
2) Inorganic contaminants, such as salts and metals, which can be naturally-occurring or result from urban storm runoff, industrial or domestic wastewater discharges, oil and gas production, mining or farming.
3) Pesticides and herbicides, which may come from a variety of sources such as agriculture, stormwater runoff, and residential uses.
4) Organic chemical contaminants, including synthetic and volatile organics, which are by-products of industrial processes and petroleum production, and can also come from gas stations, urban storm water runoff and septic systems.
5) Radioactive contaminants, which can be naturally-occurring or be the result of oil and gas production and mining activities.

Some people may be more vulnerable to contaminants in drinking water than is the general population. Immuno-compromised persons such as persons with cancer undergoing chemotherapy, persons who have undergone organ transplants, people with HIV/AIDS or other immune system disorders, some elderly, and infants can be particularly at risk. These people should seek advice, about drinking water, from their health care providers. More information about contaminants and potential health effects can be obtained by calling the Environmental Protection Agency Safe Drinking Water Hotline at 800-426-4791. If other people, such as tenants, residents, patients, students, or employees, receive water from you, it is important that you provide this notice to them by posting it in a conspicuous location or by direct hand or mail delivery.

BACKFLOW

The City of Page has an extensive Backflow Prevention Program. This program ensures the proper type, installation and maintenance of hundreds of devices. Through this program, the City ensures unwanted waters do not enter the distribution system.

EXPLANATION OF WATER QUALITY DATA TABLES:

The following tables show the substances for which the laboratory tests. Every regulated substance that we detected in the water, even in the most minute traces, is listed here. The tables contain the names of each substance, the highest level allowed by regulation (MCL), the ideal goal for public health, the amount detected, the usual sources of such contamination, and a key to units of measurement. Please note, the simple presence of a substance in drinking water does NOT necessarily indicate the drinking wat... poses a health risk. Certain quantities of some substances are essential to good health, but excessive quantities can be hazardou... Definitions of MCL and MCLG are important.

MAXIMUM CONTAMINANT LEVEL or MCL: The highest level of a contaminant allowed in drinking water. MCL's are set as close to MCLG's as feasible using the best treatment technology.

M... IUM CONTAMINANT LEVEL GOAL or MCLG: The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLG's allow for a margin of safety.

TREATMENT TECHNIQUE: A required process intended to reduce the level of a contaminant in drinking water

ACTION LEVEL: The concentration of a contaminant which, if exceeded, triggers treatment or other requirements which a water system must follow.

TURBIDITY: Turbidity is caused by suspended matter. Turbidity is an expression of the optical property that causes light to be scattered and absorbed rather than transmitted in straight lines in the sample. Light interference analytical methods are classified as nephelometric, and one system of turbidity measurement uses *nephelometric turbidity units* (NTU).

KEY to TABLES:
ppm = parts per million, or milligrams per liter(mg/l)
MCL = Maximum Contaminant Level
NTU = Nephelometric Turbidity Units
ND = None Detected
MDL = Minimum Detection Limits
ppb = parts per billion, or micrograms per liter(ug/l)
MCLG= Maximum Contaminant Level Goal
TT = Treatment TechniqueAL = Action Level
MFL = Micro Fiber Limits

Distribution System:

Contaminant	MCL	MCLG	Dist. System	Major sources in drinking water
Total Coliform Bacteria	Presence of coliform bacteria in 5% or more of monthly samples	0.0	0.0%	Naturally present in the environment
...oliform and E. coli	A routine sample and a repeat sample are total coliform positive, and one is also fecal coliform or E. coli positive.	0.0	0%	Human and animal fecal waste
Turbidity Highest single measurement Lowest monthly percentage of samples meeting the turbidity limits specified	TT (0.5NTU)	NA	0.25 NTU 100%	Soil runoff.
Total Trihalomethanes Running annual average	100ppb	0.0	38.1ppb	By-product of drinking water chlorination

Inorganic Contaminants

Contaminant	Units	MCL	MCLG	High	Major Sources in Drinking Water
Arsenic	ppb	50	NA	<0.002	Erosion of natural deposits; runoff from orchards; Runoff from glass and electronics production wastes
Asbestos	MFL	7	7	<.2	Decay of asbestos cement water mains; Erosion of natural deposits.
Barium	ppb	2,000	2,000	74	Discharge of drilling wastes; Discharge from metal refineries; Erosion of natural deposits.
Cadmium *	ppb	5	5	<0.5	Corrosion of galvanized pipes; Erosion of natural deposits; Discharge from metal refineries; runoff from waste batteries and paints.
Copper	ppb	AL=1.3	1.3	0.96	Corrosion of household plumbing systems; Erosion of natural deposits; Leaching from wood preservatives.
Fluoride	ppb	4,000	4,000	250	Erosion of natural deposits; Water additive which promotes strong teeth; Discharge from fertilizer and aluminum factories.
Lead	ppb	AL=15	0	0.03	Corrosion of household plumbing systems; Erosion of natural deposits.
...ry [...anic]	ppb	2	2	<0.20	Erosion of natural deposits; Discharge from refineries and factories; Runoff from landfills; Runoff from cropland.
Nitrate [as Nitrogen]	ppb	10,000	10,000	390	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits.
Nitrite [as Nitrogen]	ppb	1,000	1,000	<50	Runoff from fertilizer use; Leaching from septic tanks, sewage; Erosion of natural deposits.

* Cadmium: The U.S.E.P.A. has established; Some people who drink water containing cadmium in excess of the MCL over many years could experience kidney damage.

Synthetic Organic Contaminants

Contaminant	Units	MCL	MCLG	High	Major sources in Drinking Water
Atrazine	ppb	3	3	1	Runoff from herbicide used on row crops.
Chlordane	ppb	2	0	<0.5	Residue of banned termiticide.
Endrin	ppb	2	2	<0.5	Residue of banned insecticide.
Heptachlor	ppb	0.4	0	<0.2	Residue of banned termiticide.
Heptachlor epoxide	ppb	0.2	0	<0.2	Breakdown of heptachlor.
Hexachlorocyclopentadiene	ppb	50	50	2	Discharge from chemical factories.
Lindane	ppb	0.2	0.2	<0.1	Runoff/leaching from insecticide used on cattle, lumber, gardens.
Methoxychlor	ppb	40	40	<0.5	Runoff/leaching from insecticide used on fruits, vegetables, alfalfa, livestock
Simazine	ppb	4	4	.07	Herbicide runoff.

Further information may be obtained by calling Bill Markham at 520-645-4315. Citizen participation in water related issues is welcomed at regularly scheduled City Council Meetings conducted twice monthly on the 2nd and 4th Thursdays. Relative information may be obtained in advance by calling 520-645-8861.

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Engineering Department
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Boxholder
Page, AZ 86040

Appendix 6.1

An Archeological Records Search for the Lake Powell Pipeline Feasibility Study Washington County, Utah

Introduction

This report briefly summarizes the results of an archeological records search conducted by Intersearch, Inc., for Alpha Engineering Co. and the Washington County Water Conservancy District (WCWCD) concerning the Washington County section of the proposed Lake Powell Pipeline. The proposed route within Washington County involves two major corridors heading east toward Lake Powell from the Sand Hollow Reservoir, although there are also a number of possible corridors in the area directly east of the Reservoir (Figures 1 through 27). The effected lands are primarily administered by the Bureau of Land Management (BLM), Cedar City District, Dixie Field Office, but also include some sections administered by the Utah State School Trust Lands Administration and portions which affect the SR 59 right-of-way. These sections will also involve the Utah Department of Transportation. A records search was conducted in the BLM files and involved USGS 7.5-foot topographic maps which included Washington Dome, Hurricane, The Divide, Little Creek Mountain, Smithsonian Butte, and Hildale. The cultural inventory areas and the proposed Lake Powell Pipeline have been plotted on these maps.

Records Search Summary

This section of the report will address a brief summary of the relevant cultural inventories. The inventories are listed chronologically with alphabetic designations added to distinguish surveys conducted during the same year.

1974 East End Warner Valley Class 3 Survey

This was a 2,240-acre survey conducted in association with the Allen Warner Project, and it included five sections of land in the eastern end of Warner Valley. It was conducted in 1974 by Southern Utah State College, and only three sites were recorded during the survey. None of these sites are located in the present project area (Figure 7).

1975 Allen-Warner Valley Project-Alton Pipeline

This was a linear inventory covering a total of 45 miles of corridor, although only a portion is located within the present project area. The work was conducted in 1975 by Desert Research Institute-Reno. A total of 38 archeological sites were recorded during this inventory, but only a few were located in the present project area and none are directly affected by the present pipeline (Figures 7, 8, 18 through 20, and 24).

1976A Hurricane Desert Shrub No. 1 Quad

This was a 160-acre intensive survey conducted by the BLM in 1976. No sites were recorded during this inventory (Figure 6).

1976B Hurricane Desert Shrub No. 4 Quad

This was a 160-acre intensive inventory conducted by the BLM in 1976. Four sites, 42Ws588 through 42Ws591, were recorded within this area, but it is not presently affected by the proposed pipeline (Figures 12 and 13).

1976C Hurricane Desert Shrub No. 5 Quad

This was a 160-acre intensive inventory conducted by the BLM in 1976. Four sites, 42Ws593 through 42Ws596, were recorded within this area. These were all flaking stations, and they are located outside of the proposed pipeline corridor (Figures 4 and 12).

1977 Frog Hollow Debris Basin

This inventory involved a 100-acre area intensively surveyed by the BLM in 1977. No cultural resources were found within the project area (Figure 4).

1978A Frog Hollow Unauthorized Pipeline

This generally linear survey involved a water pipeline. No cultural resources were found during this inventory (Figure 4).

1978B Hurricane Sand and Gravel Road

This linear corridor was intensively surveyed by BLM archeologists in 1978. It ran for 2 miles between SR 59 and the materials pit. No cultural resources were recorded during this survey (Figure 13).

1978C Blackbrush Catchment Pipeline

This linear survey covered a 5-mile-long by 100-foot-wide corridor surveyed by BLM archeologists in 1978. No archeological sites were encountered by this survey (Figures 6 and 8).

1978D North Pasture Division Fence-Hurricane Fault

This was a linear survey conducted by the BLM in 1978. It involved a 2-mile-long by 100-foot-wide corridor, and no cultural resources were recorded by this inventory (Figure 15).

1978E Gould Pipeline-Hurricane Fault

This was a linear corridor survey covering a 3-mile-long by 100-foot-wide area. It was conducted by BLM archeologists, and no cultural resources were recorded during the inventory (Figures 4 and 15).

1979A UDOT Materials Pit

This was a 20-acre block survey conducted by the BLM in 1979. Four sites were recorded within the project area, 42Ws622 through 42Ws625. In general, these sites appear to be located outside of the present project alignment, and the sites were avoided by the materials pit (Figure 17).

1980A Hurricane Tie Fence

This survey involved a .4-mile-long fence line project surveyed by the BLM in 1980. No cultural resources were located during this inventory (Figure 3).

1980B Materials Site

This is a 40-acre block survey conducted by the BLM in 1980. No cultural resources were recorded (Figure 16).

1981A Sand Well No. 1

This 2-acre inventory was conducted by the BLM in 1981. No cultural resources were recorded during this survey (Figure 2).

1981B Trail Spring Fence

This was a 0.3-mile-long linear survey conducted by the BLM in 1981. No cultural resources were recorded by this inventory (Figure 13).

1982 Pipeline and Pump Houses Right-of-Way

This inventory consisted of 2 miles on inventory corridor conducted by the BLM in 1982. No archeological sites were recorded by this inventory (Figure 2).

1983 Section 203 Tracts

This was a block survey conducted by Centuries Research, Inc., in 1983 for the BLM. No archeological sites were recorded in the project locations around the proposed pipeline (Figure 3).

1986A Gould Pipeline Extension

This survey involved a 0.5-mile-long pipeline corridor conducted by the BLM in 1986. No cultural resources were recorded by this inventory (Figure 15).

1986B Materials Source-Sky Ranch

This small block survey consisted of a 40-acre area inventoried by Intersearch, Inc., in 1986. No cultural resources were recorded during this survey (Figure 3).

1986C Hildale Sale

This was a 160-acre block survey conducted by the BLM in 1986, involving the city of Hildale, Utah. Five sites were recorded, 42Ws2192 through 42Ws2196, and two were mitigated, 42Ws2195 and 42Ws2196 (Figure 27).

1986D Canaan Ranch 19.9-kv Survey

AK Nielson and Associates conducted this linear inventory in 1986. Three sites were recorded by the survey, 42Ws2211 through 42Ws2213, but they are not located in the present project corridor (Figures 25 and 26).

1987 Reconnaissance Survey

This was a large block survey conducted by the BLM in 1987, north of Canaan Gap. Eight sites were noted during the inventory but not recorded. None appear to be in the area of the proposed pipeline (Figure 24).

1988A Jack Eves Exchange

A 280-acre area was surveyed by the BLM in a number of locations in association with this land exchange. No sites were recorded in the proposed project area, although 42Ws1414 sits above SR 59 (Figures 24 and 25).

1988B Reservoir in Vicinity of Little Creek

This inventory was conducted by the BLM in 1988 (Figure 24).

1988C Garkane-Colorado City to Sand Mountain Power Line

This was a long linear corridor intensively surveyed by Nickens and Associates in 1988. A number of sites were recorded along this line including 42Ws2322 through 42Ws2326 and 42Ws2334 through 42Ws2336. These sites are located within the proposed pipeline corridor as it runs through Canaan Gap, and all are structural Virgin Anasazi sites that have been recommended as significant resources (Figures 2, 5, 7, 8, 18 through 20, and 24 through 26).

1993A Whitney State Lands

This inventory involved a 160-acre parcel along SR 59. It was intensively inventoried by Intersearch, Inc., in 1993 and a total of 15 sites, 42Ws2674 through 42Ws2688, were recorded. These sites are located along the proposed project corridor, but the majority appears to be outside of the pipeline corridor (Figure 21).

1993B Hildale Utilities Corridor

This was an intensive linear inventory conducted by AK Nielson and Associates in 1993. A number of sites were recorded during the inventory, and those along SR 59 may also be affected by the proposed pipeline. Recorded sites included 42Ws2715 through 42Ws2745. Many of these were recommended as significant resources, and some have been partially mitigated in association with this project (Figures 12 through 14, 16 through 17, 21 through 23, 25, and 26).

1994 Hildale Utilities Corridor-Relocation Survey

This inventory was associated with the previous project and involved some relocation of the line as it climbed out of the Hurricane Valley and over the Hurricane Cliffs. Some new sites were recorded, including 42Ws2868 through 42Ws2870 and 42Ws2887 through 42Ws2892 (Figures 12 and 13).

The Sand Hollow Reservoir area has been intensively inventoried by BYU-OPA, and a number of the involved sites have been mitigated as part of that project. That report was not immediately available for inclusion in this report but the WCWCD should have a copy on file.

Summary

Many portions of the proposed Lake Powell Pipeline have been inventoried for cultural resources, particularly the portion involved with SR 59. Some mitigation work has also been conducted along that portion in association with the Hildale Utilities Corridor (1993B and 1994), but additional work may be called for. The portion of the proposed corridor which runs through Canaan Gap probably has the highest potential for significant archeological resources, and some have already been recorded there. It is likely that additional sites will be found in this section, and additional work would be necessary.

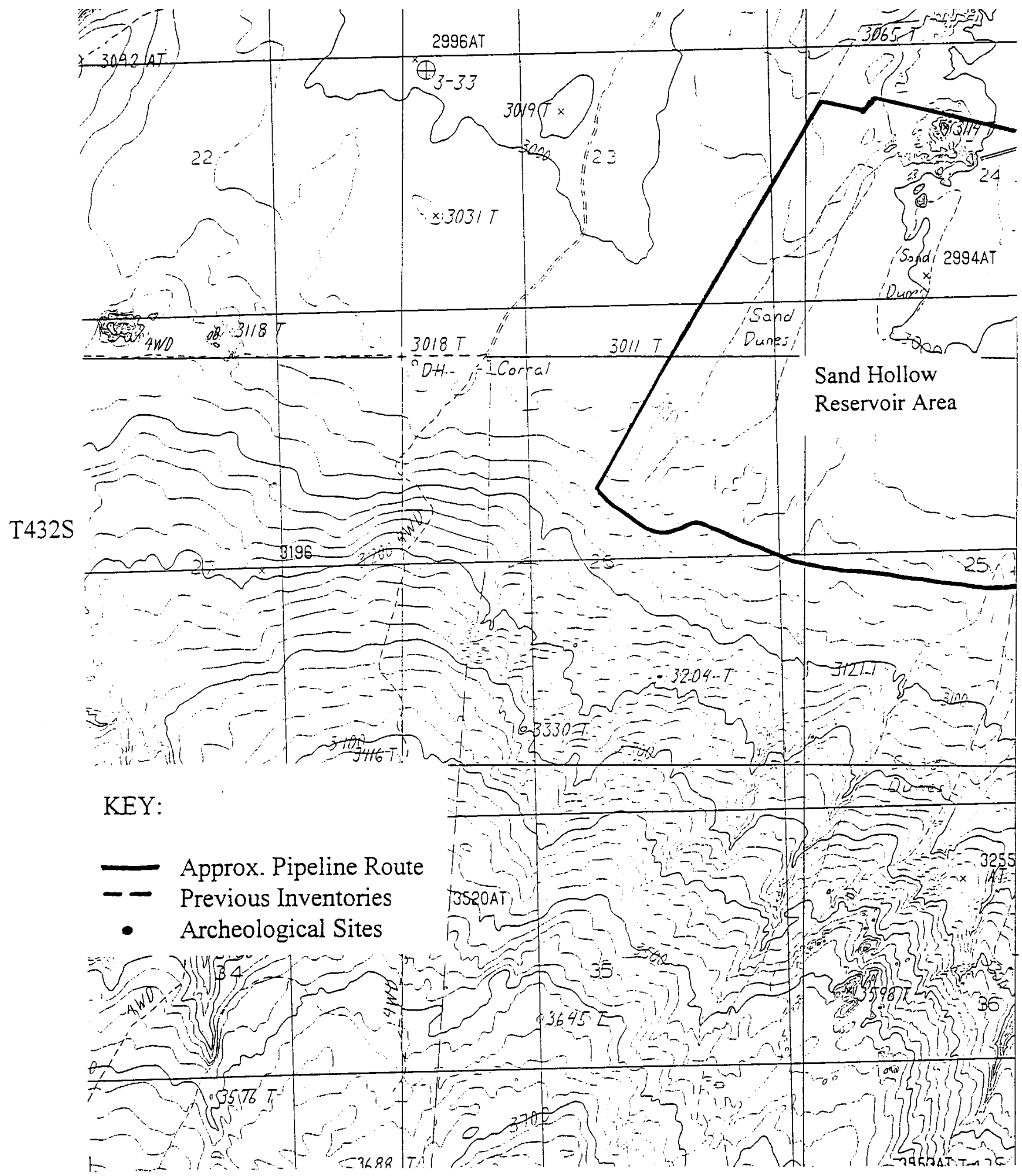

Fig. 1. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Washington Dome 7.5' (PE 1986)

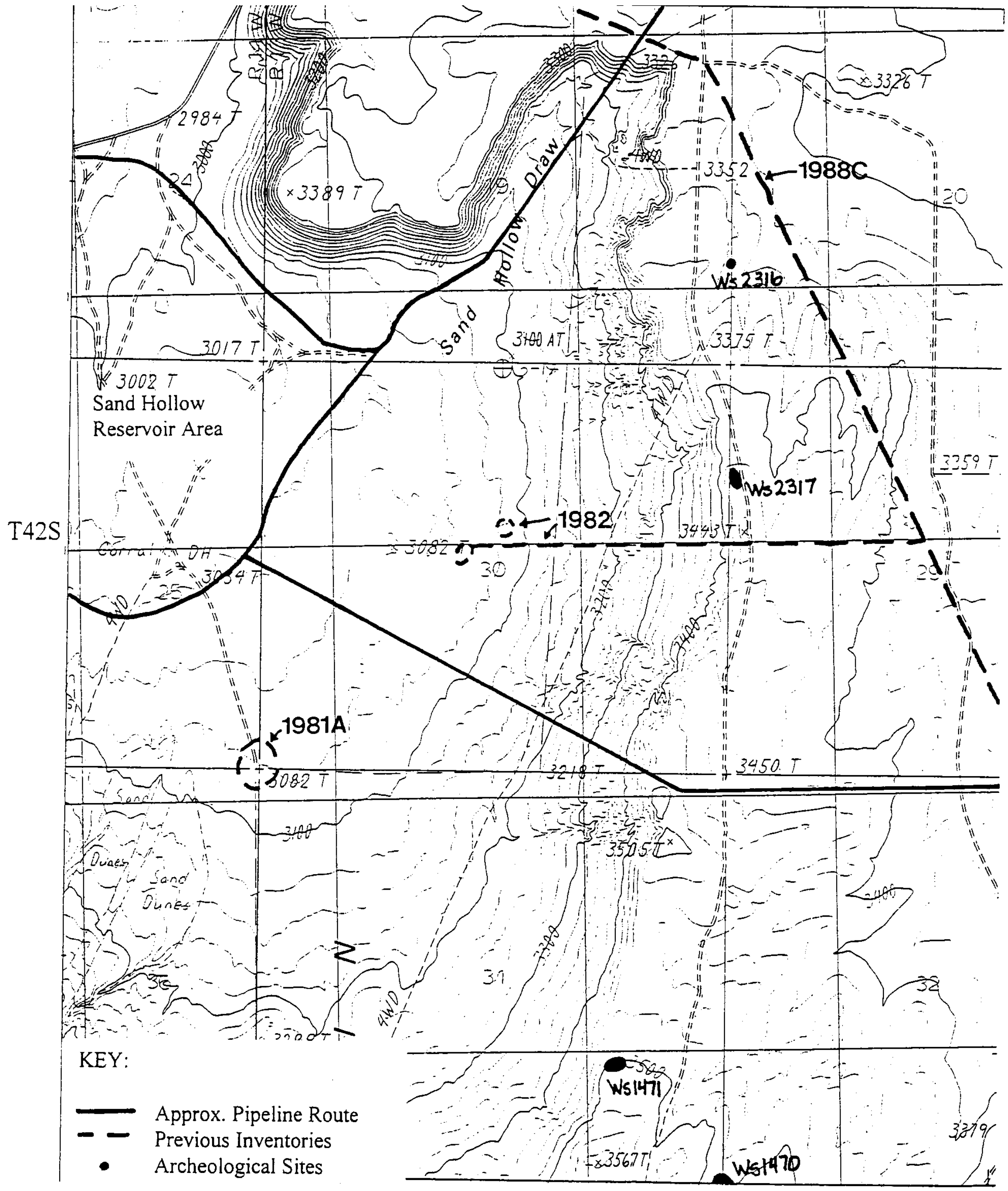

Fig. 2. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
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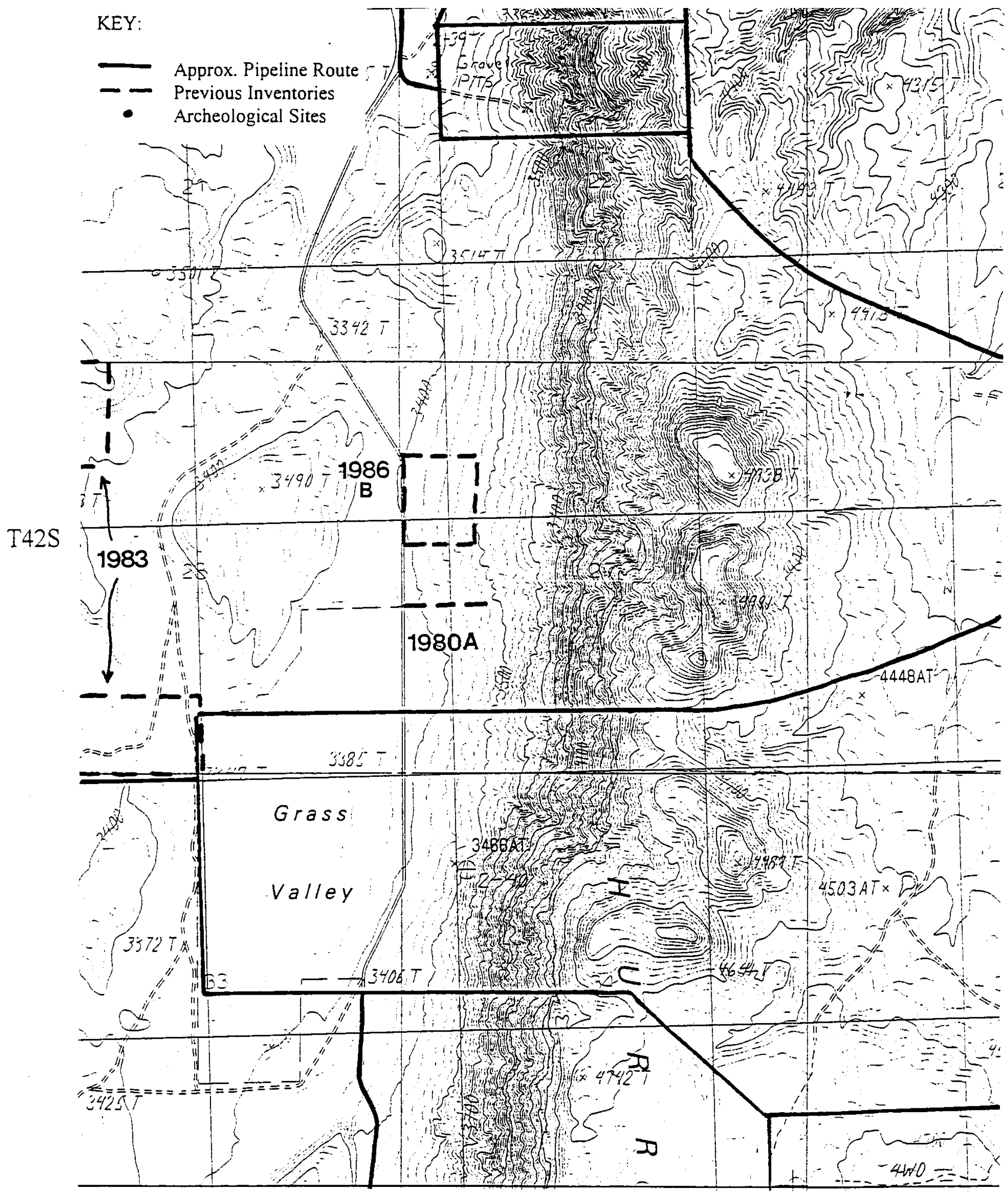

Fig. 3. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
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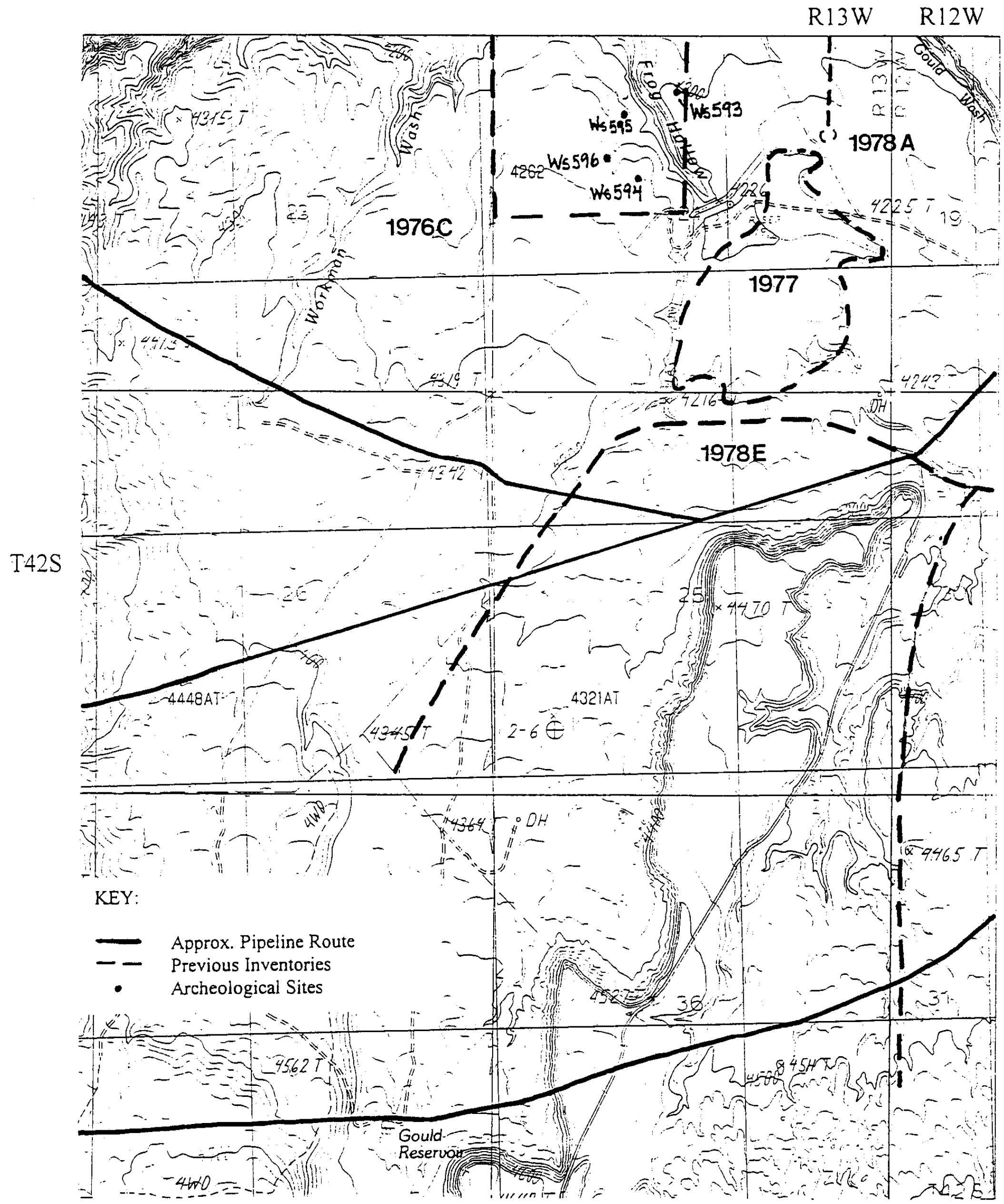

Fig. 4. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS The Divide 7.5' (PE 1986)

T43S

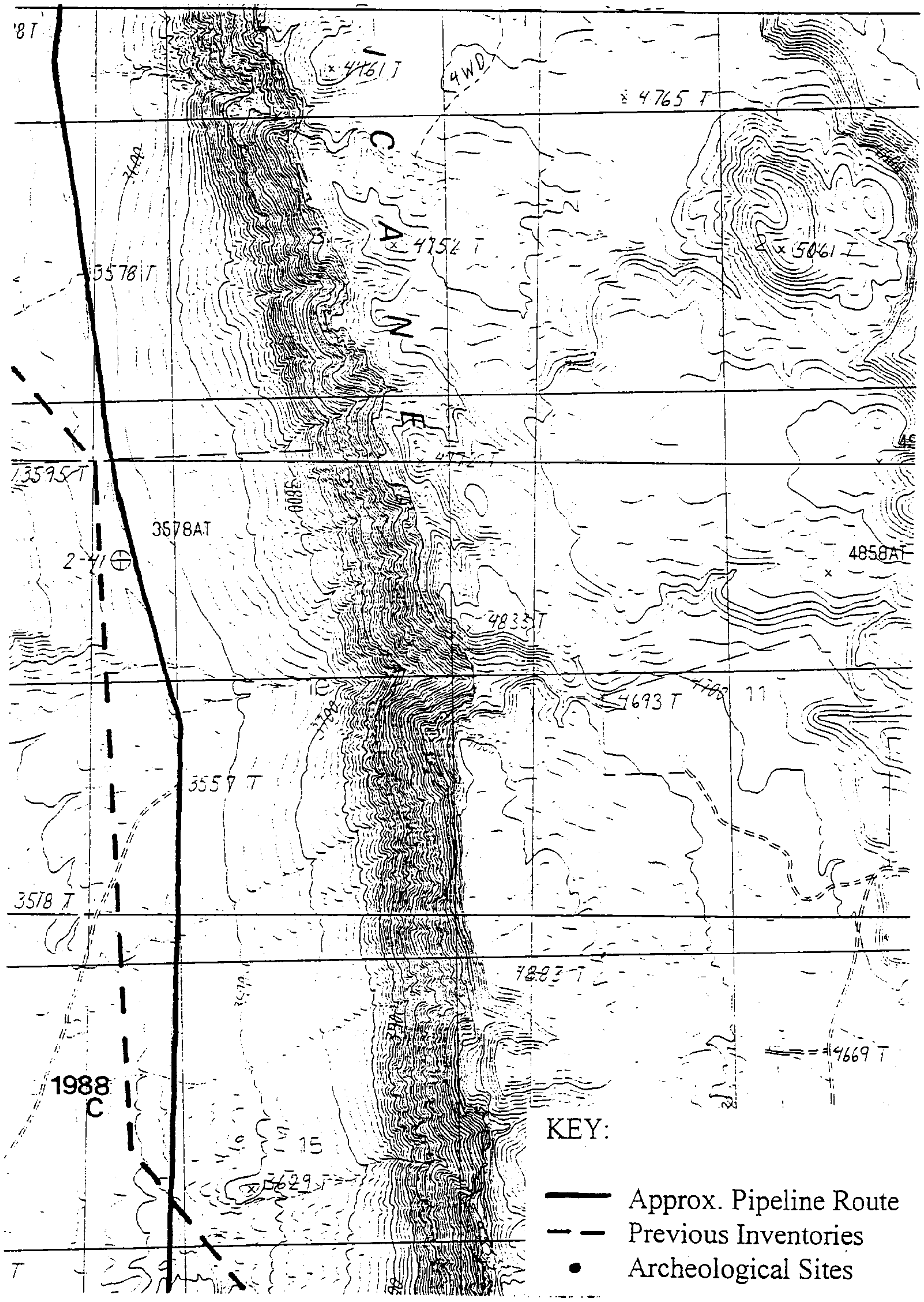

Fig. 5. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
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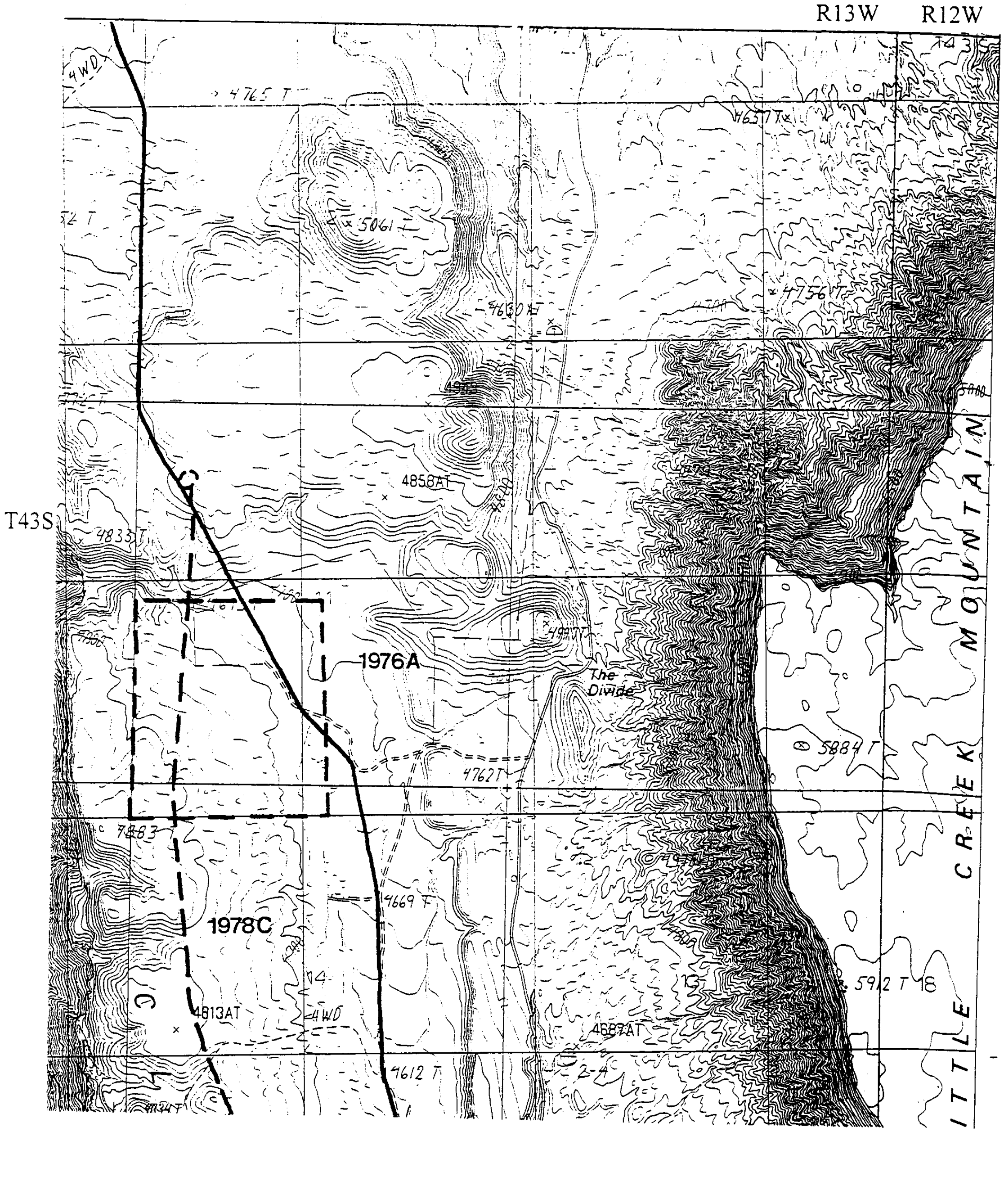

Fig. 6. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
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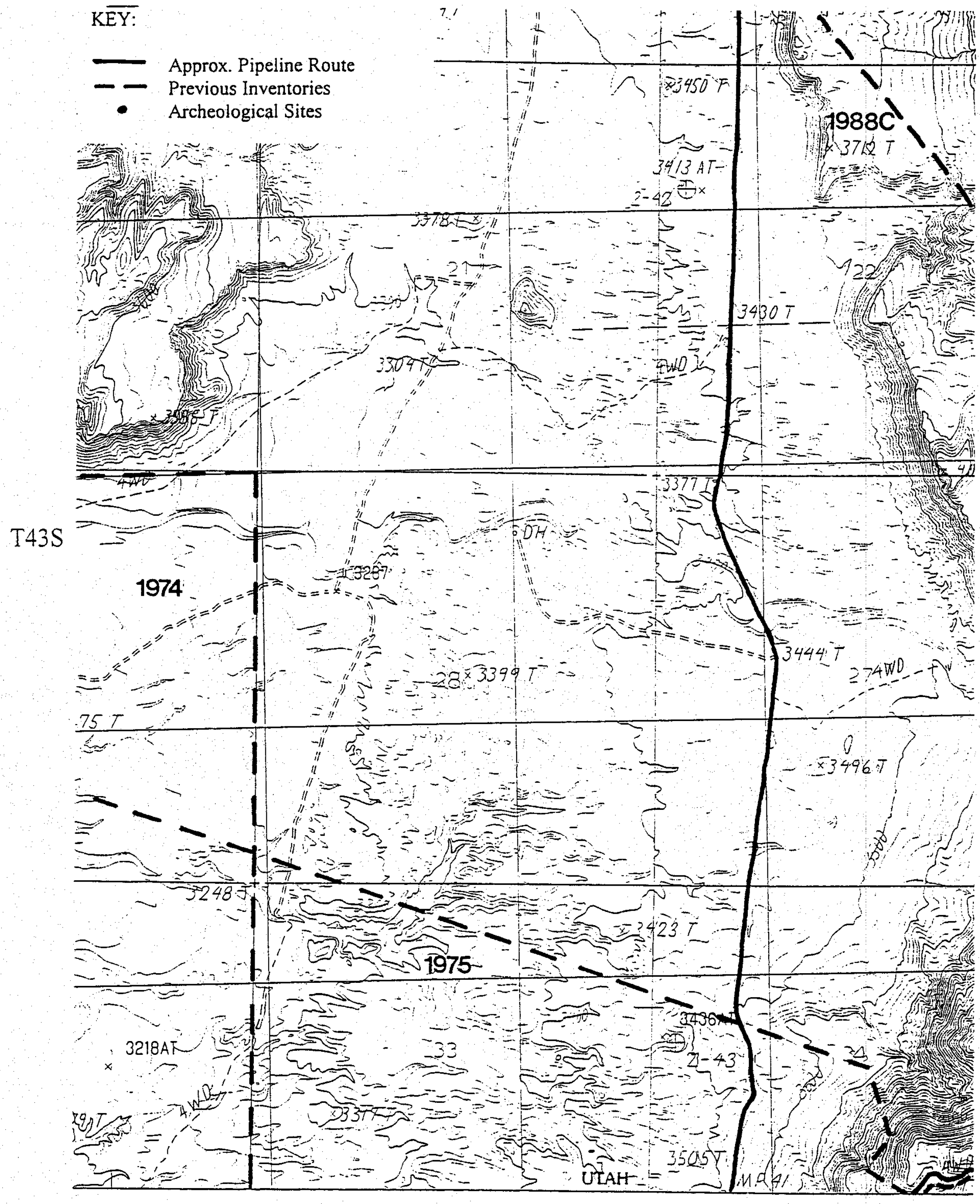


Fig. 7. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS The Divide 7.5' (PE 1986)

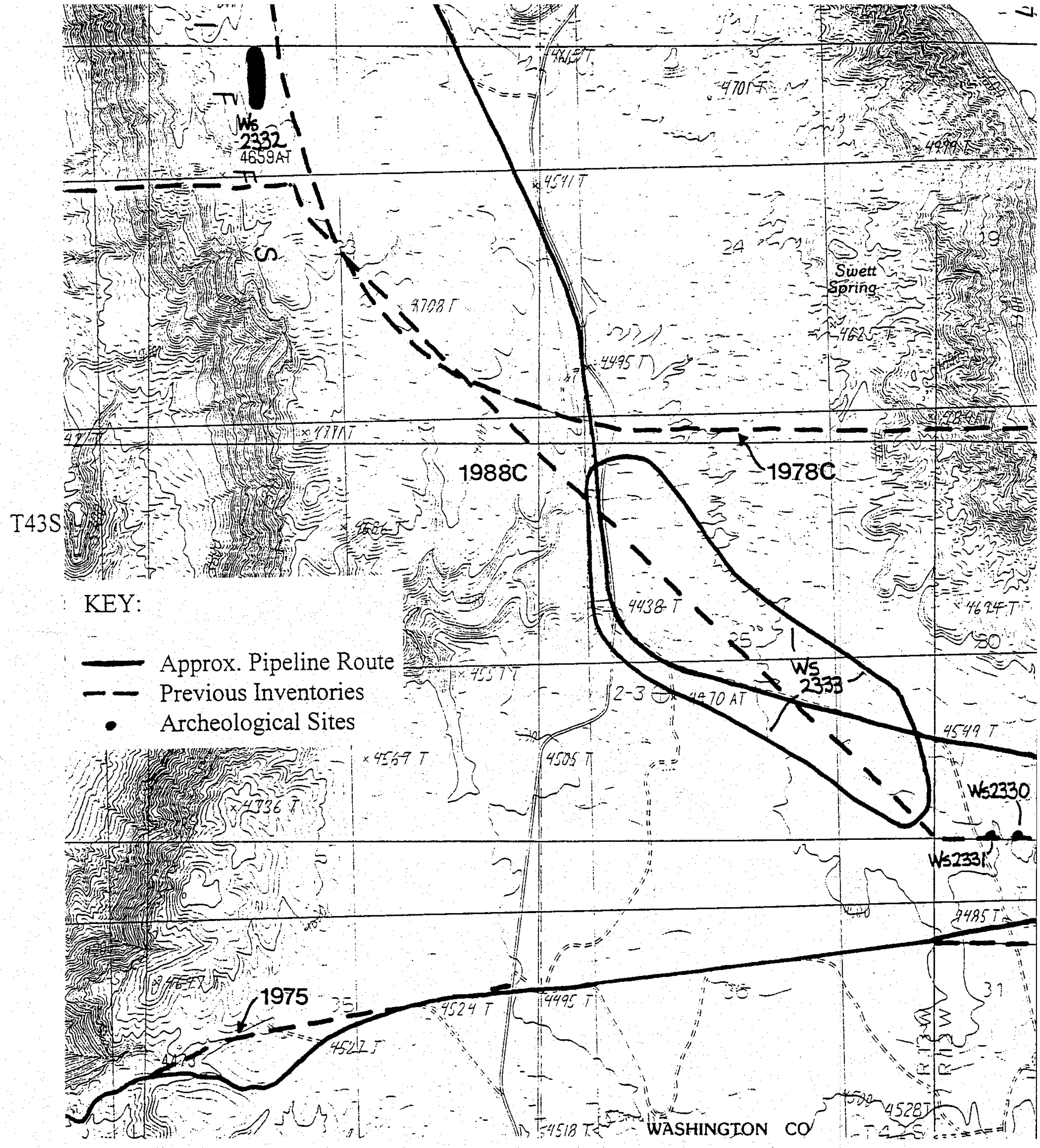


Fig. 8. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS The Divide 7.5' (PE 1986)

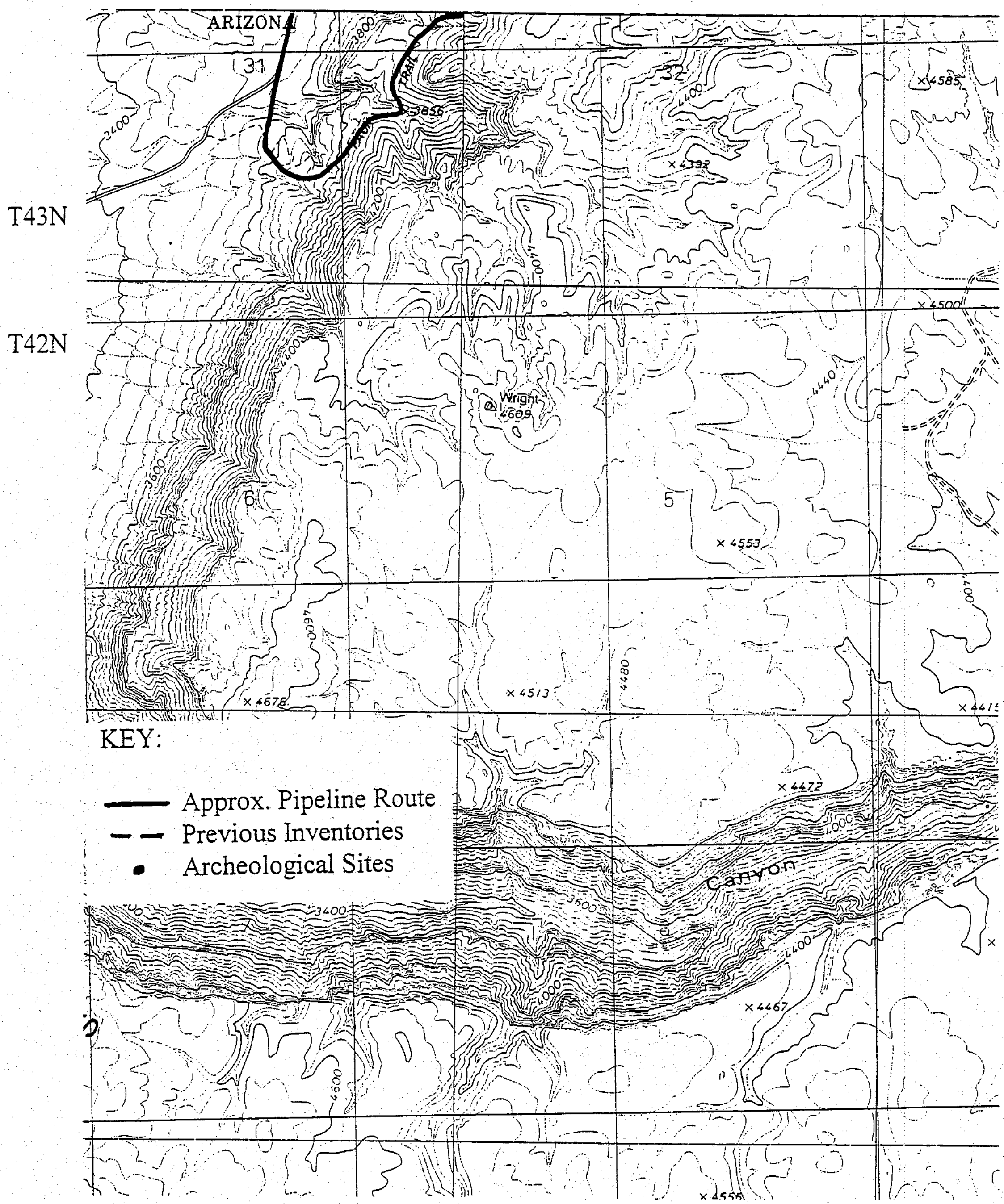


Fig. 9. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map

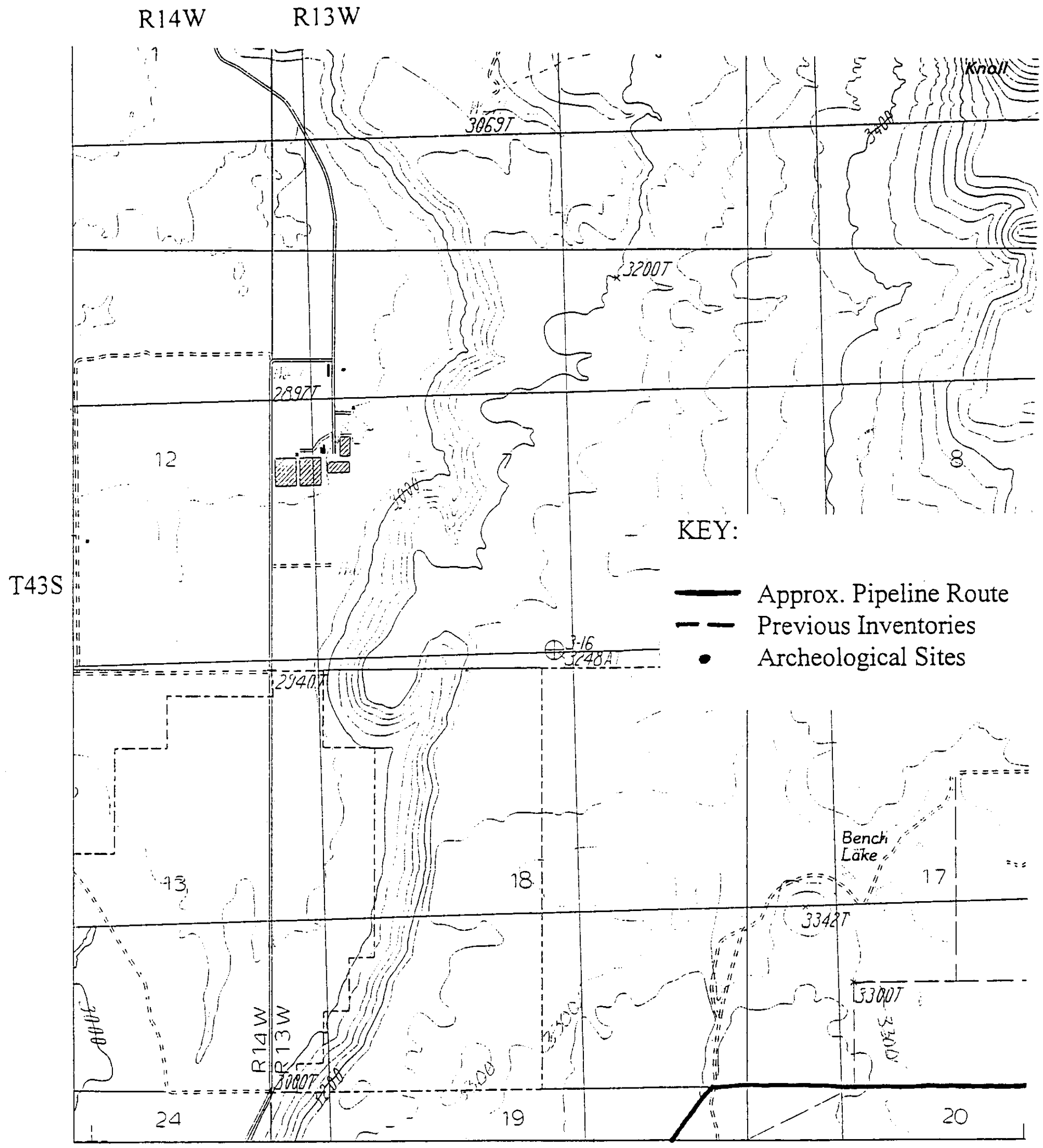


Fig. 10. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Hurricane 7.5' (PE 1986)

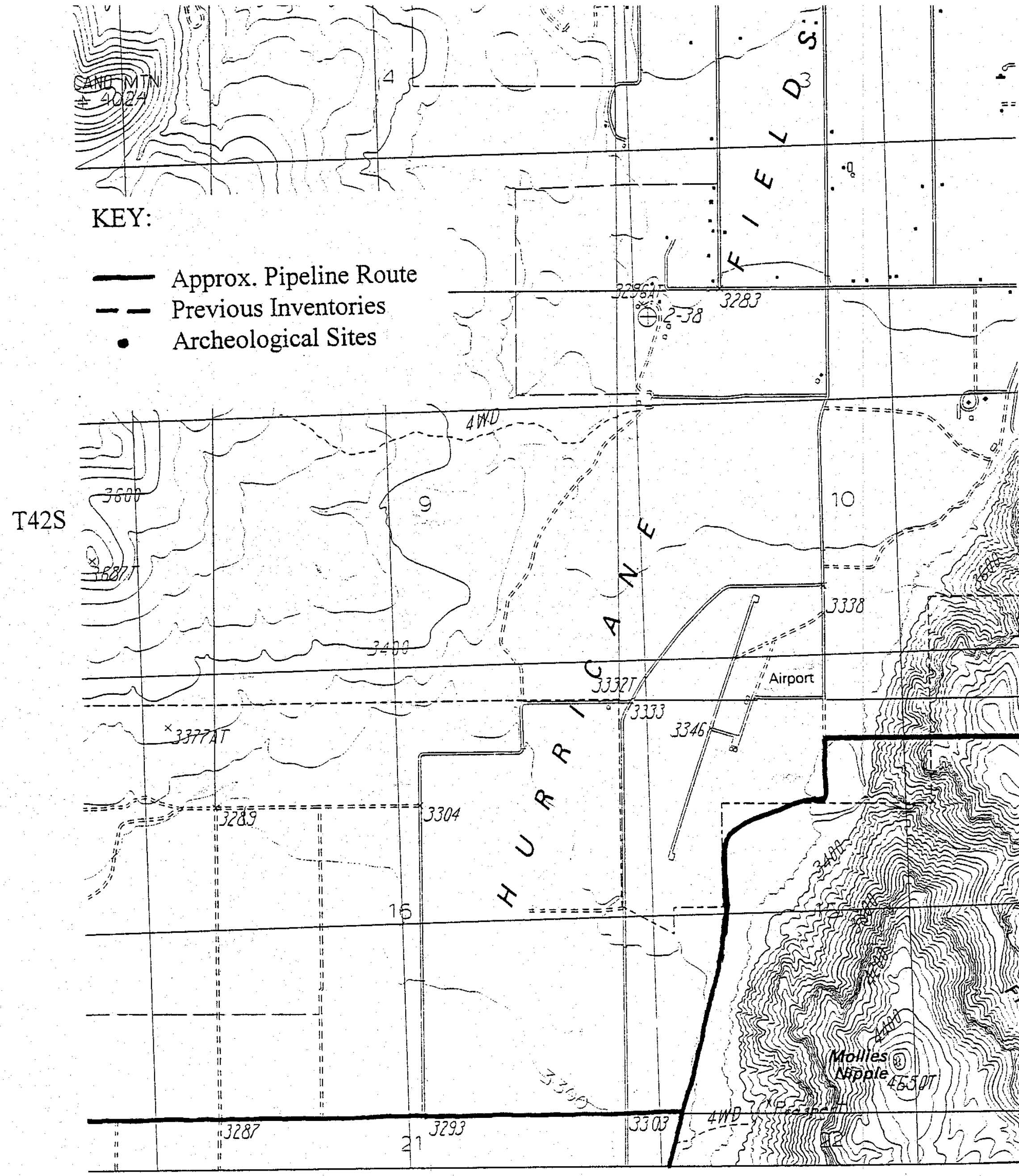


Fig. 11. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Hurricane 7.5' (PE 1986)

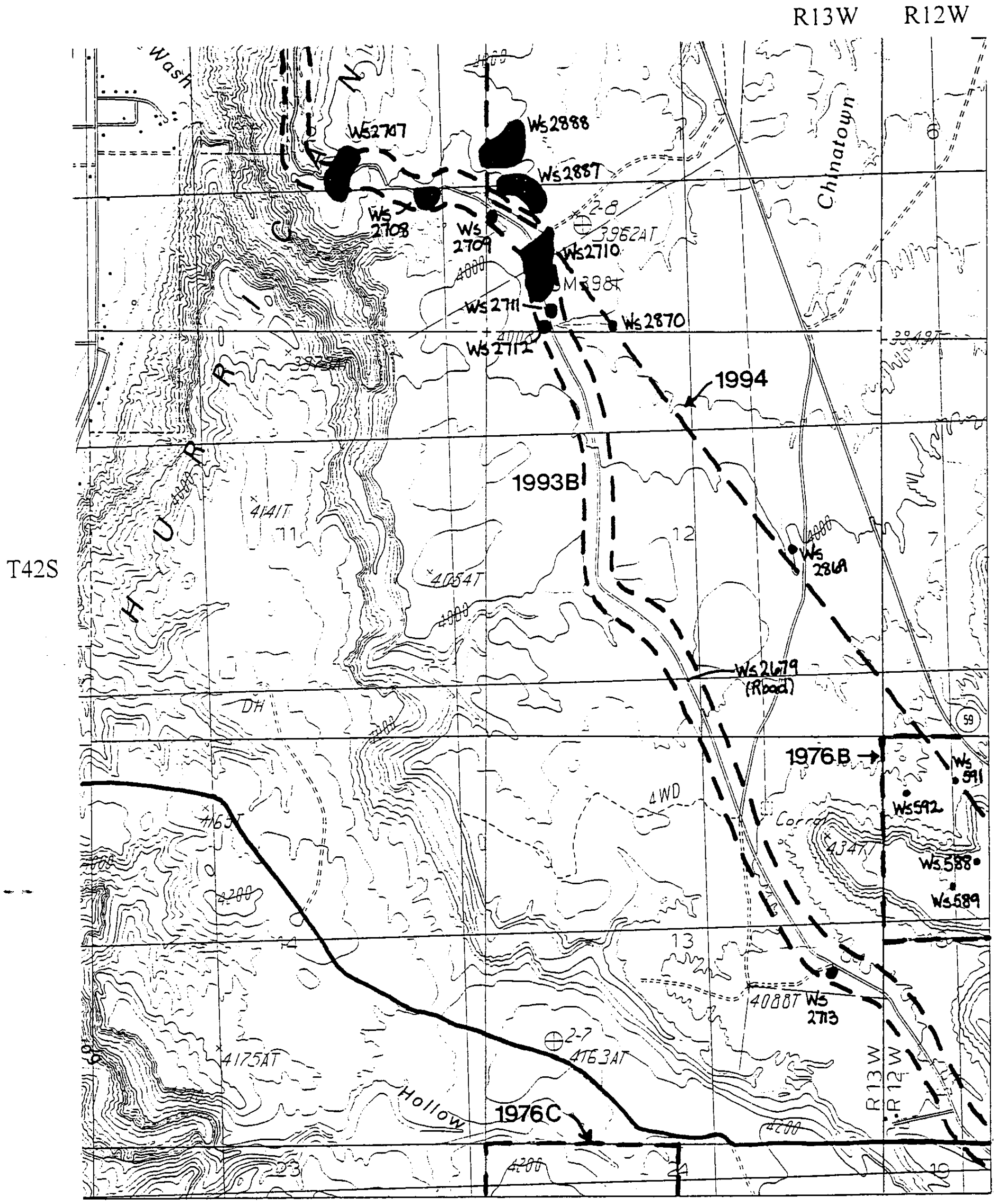


Fig. 12. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Hurricane 7.5' (PE 1986)

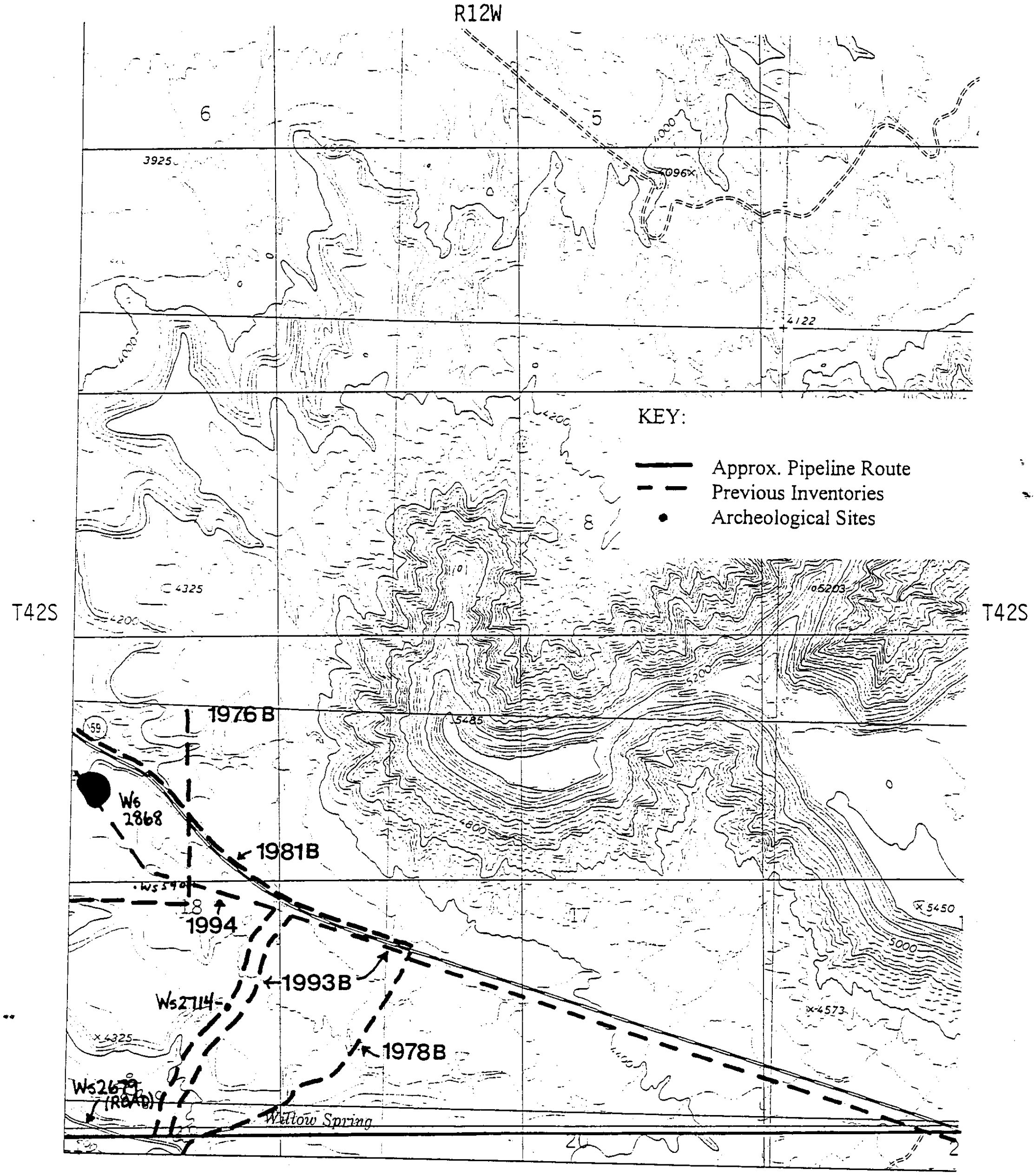


Fig. 13. Lake Powell Pipeline Project - Washington County Section
. Project, Inventory and Archeological Site Map
USGS Virgin 7.5' (1980)

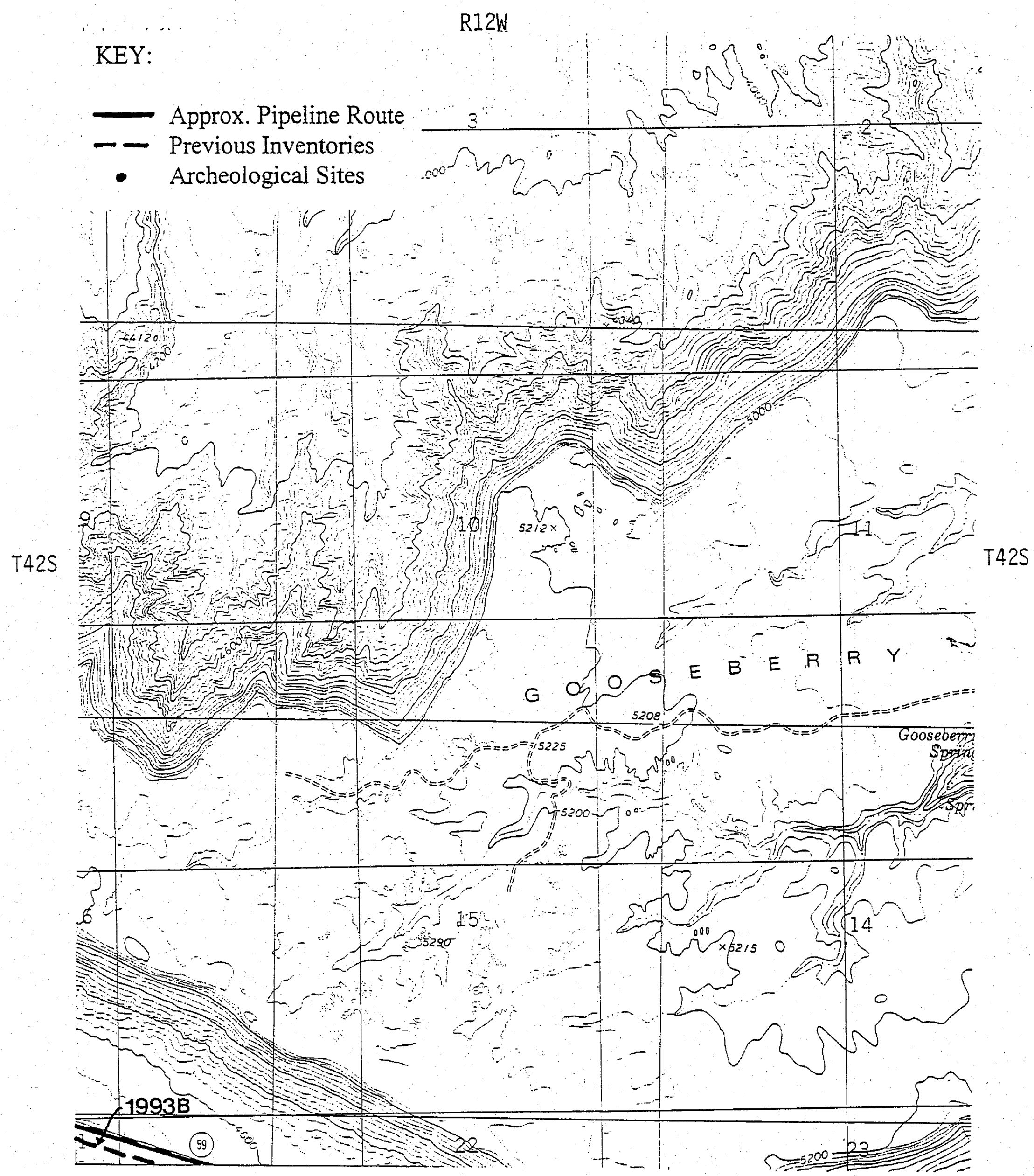


Fig. 14. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Virgin 7.5' (1980)

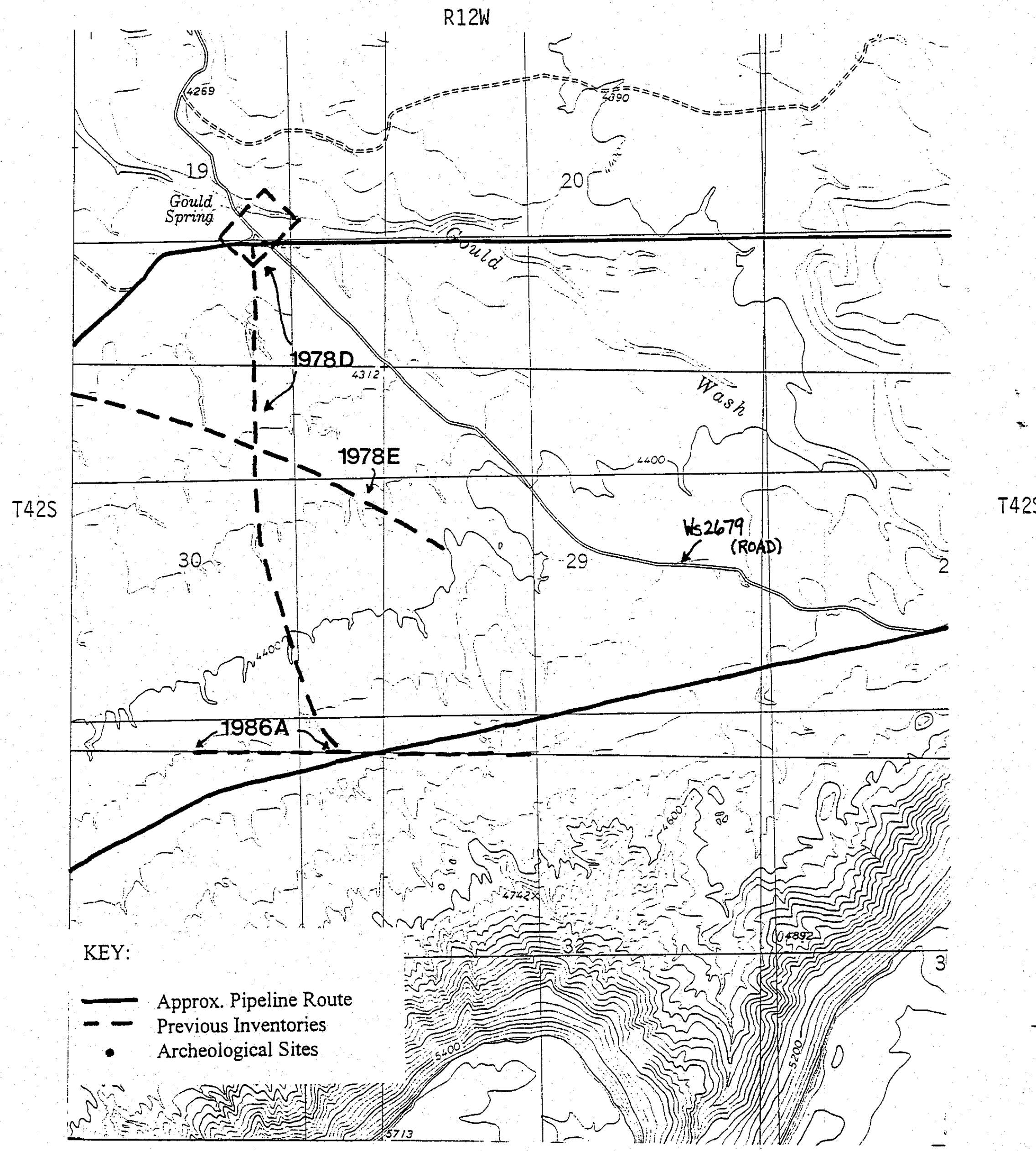


Fig. 15. Lake Powell Pipeline Project - Washington County Section
. Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

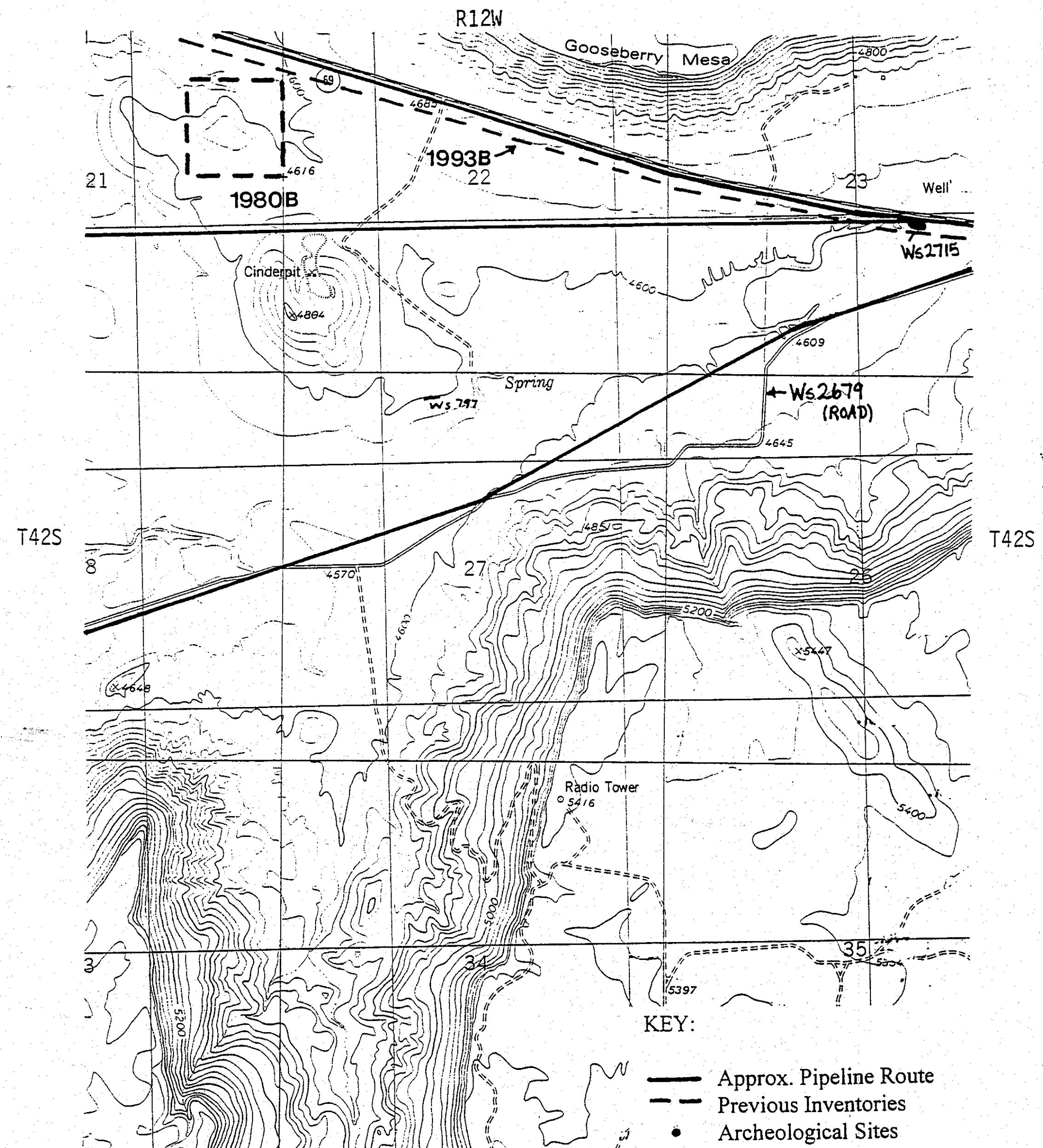


Fig. 16. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

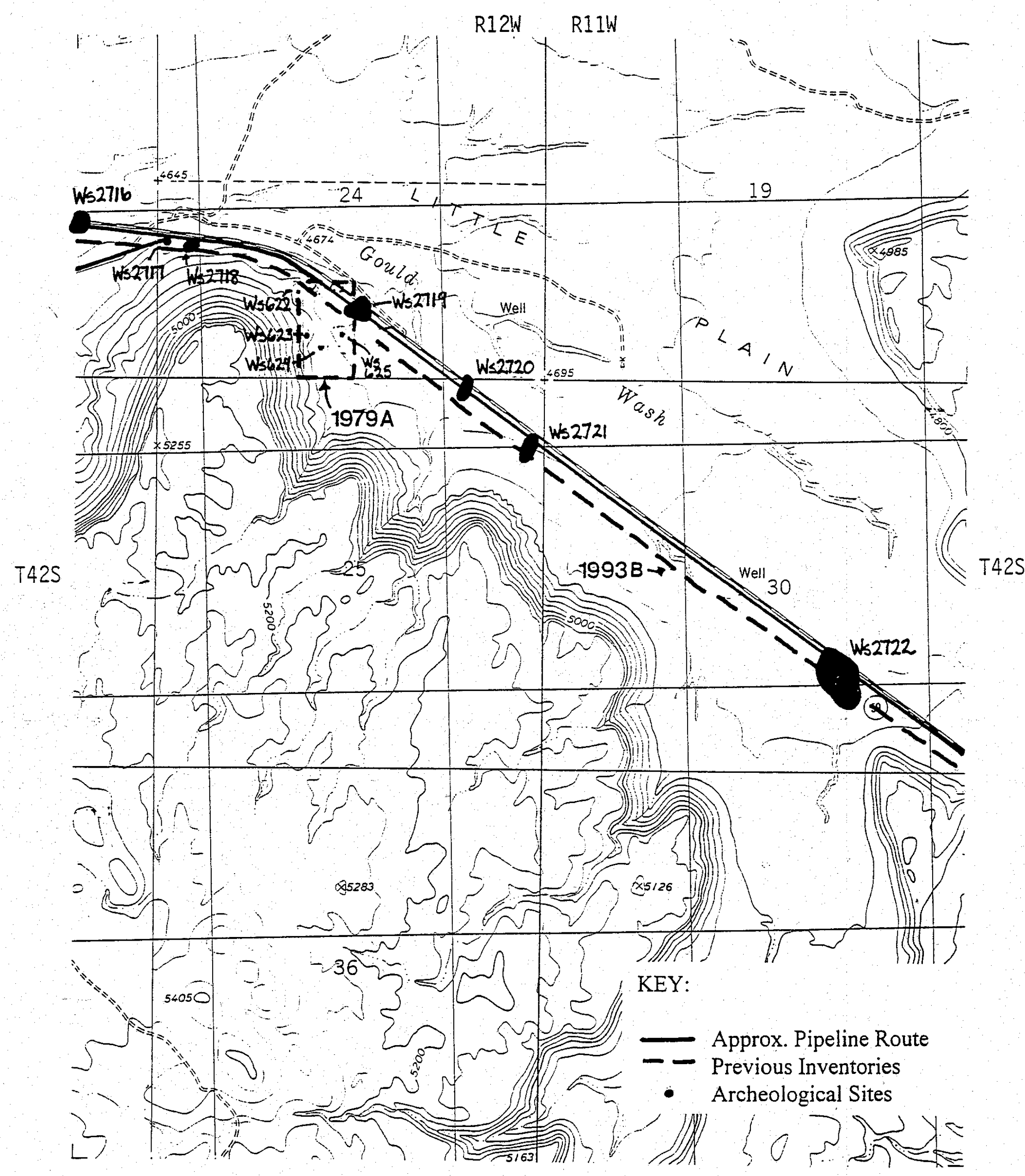


Fig. 17. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

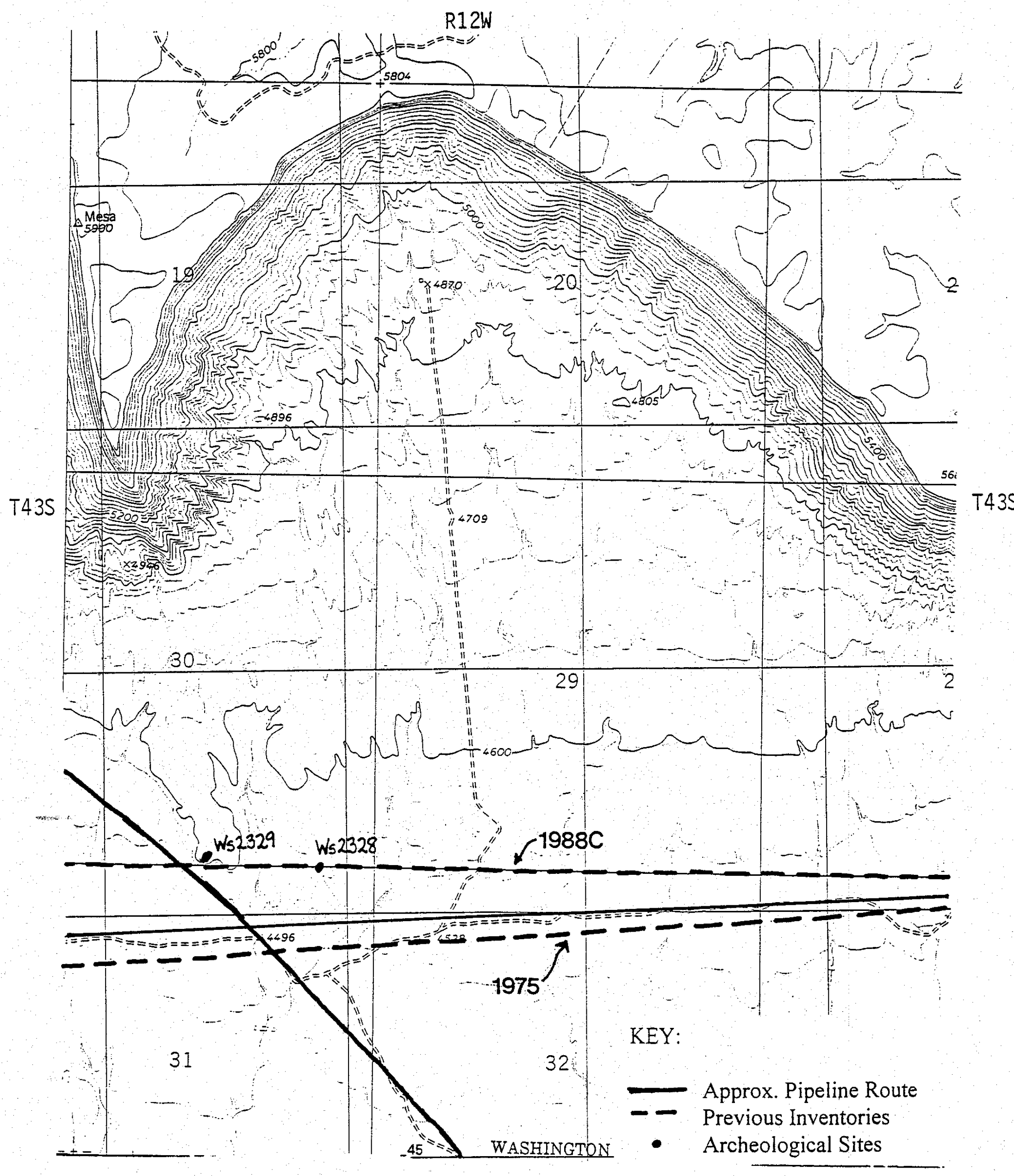


Fig. 18. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

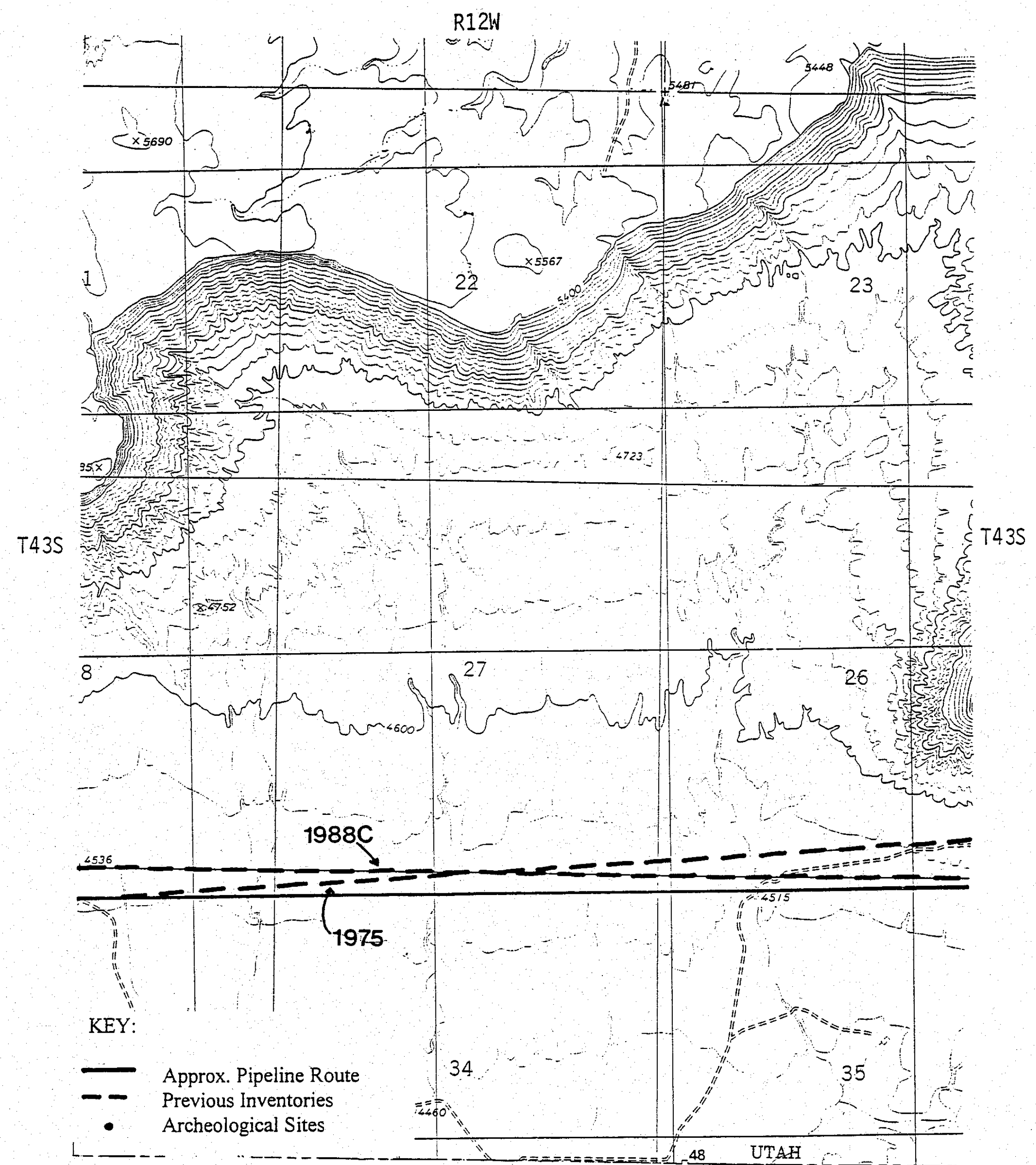


Fig. 19. Lake Powell Pipeline Project - Washington County Section
· Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

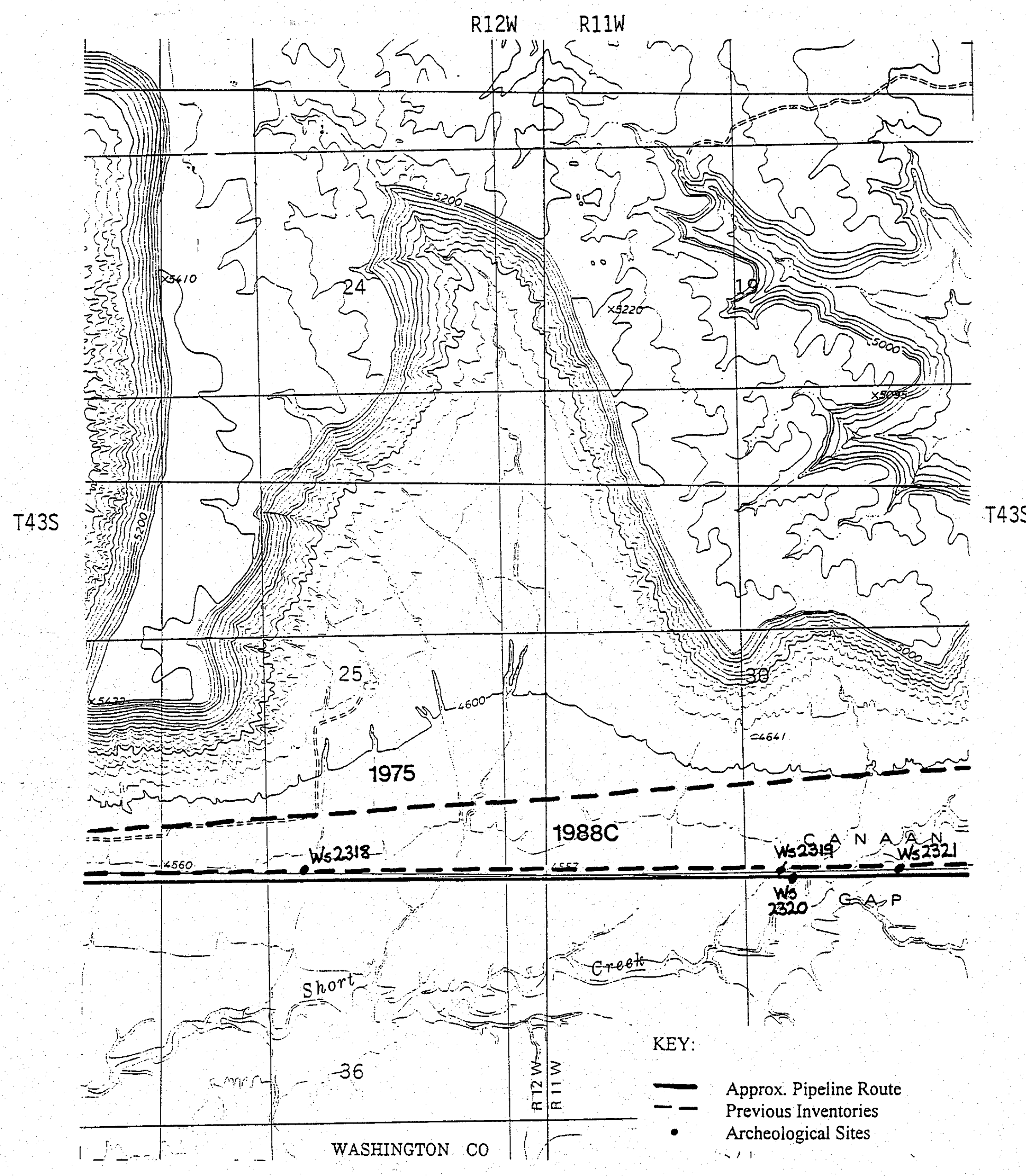


Fig. 20. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Little Creek Mountain 7.5' (1980)

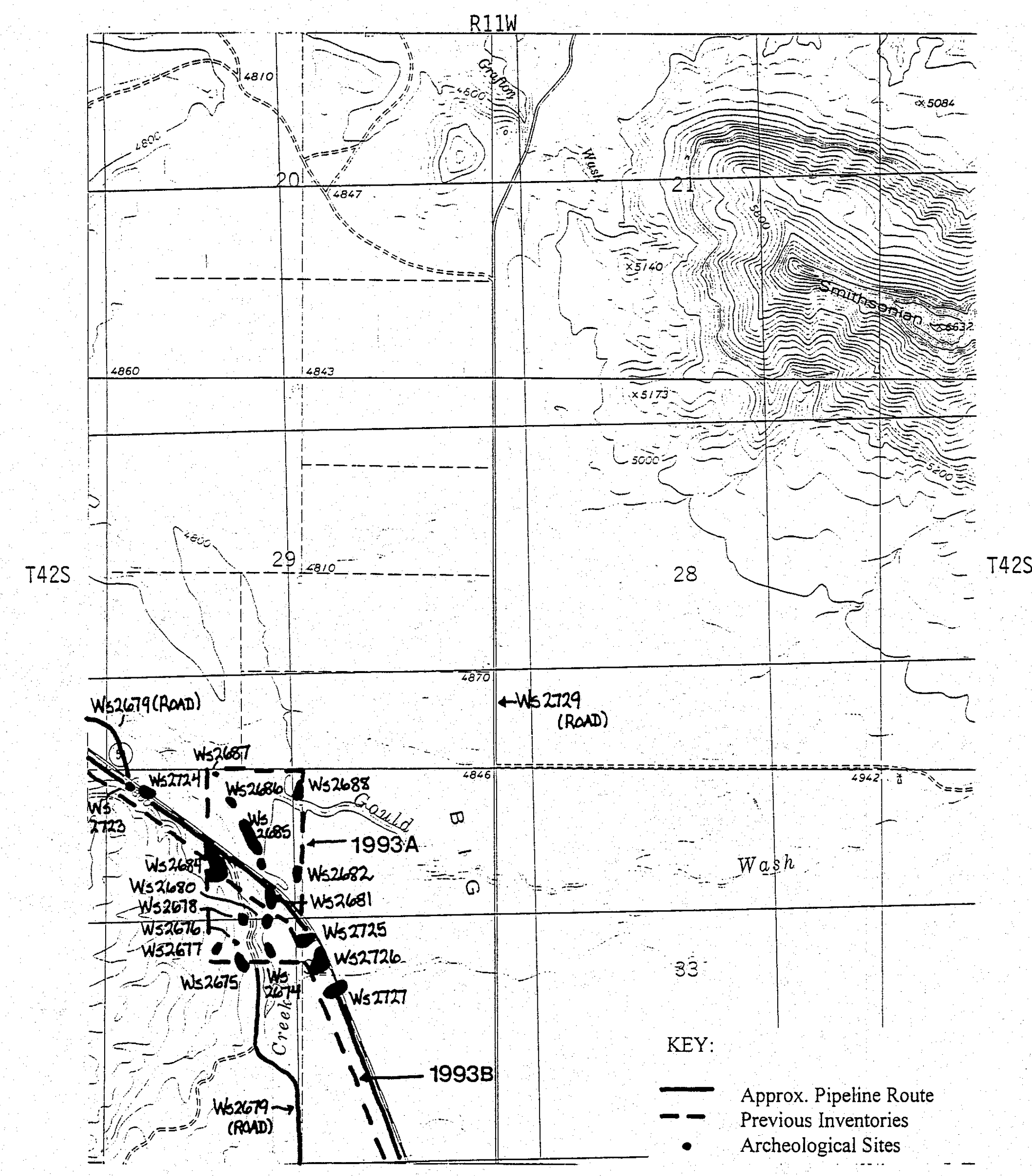


Fig. 21. Lake Powell Pipeline Project - Washington County Section Project, Inventory and Archeological Site Map USGS Smithsonian Butte 7.5' (1980)

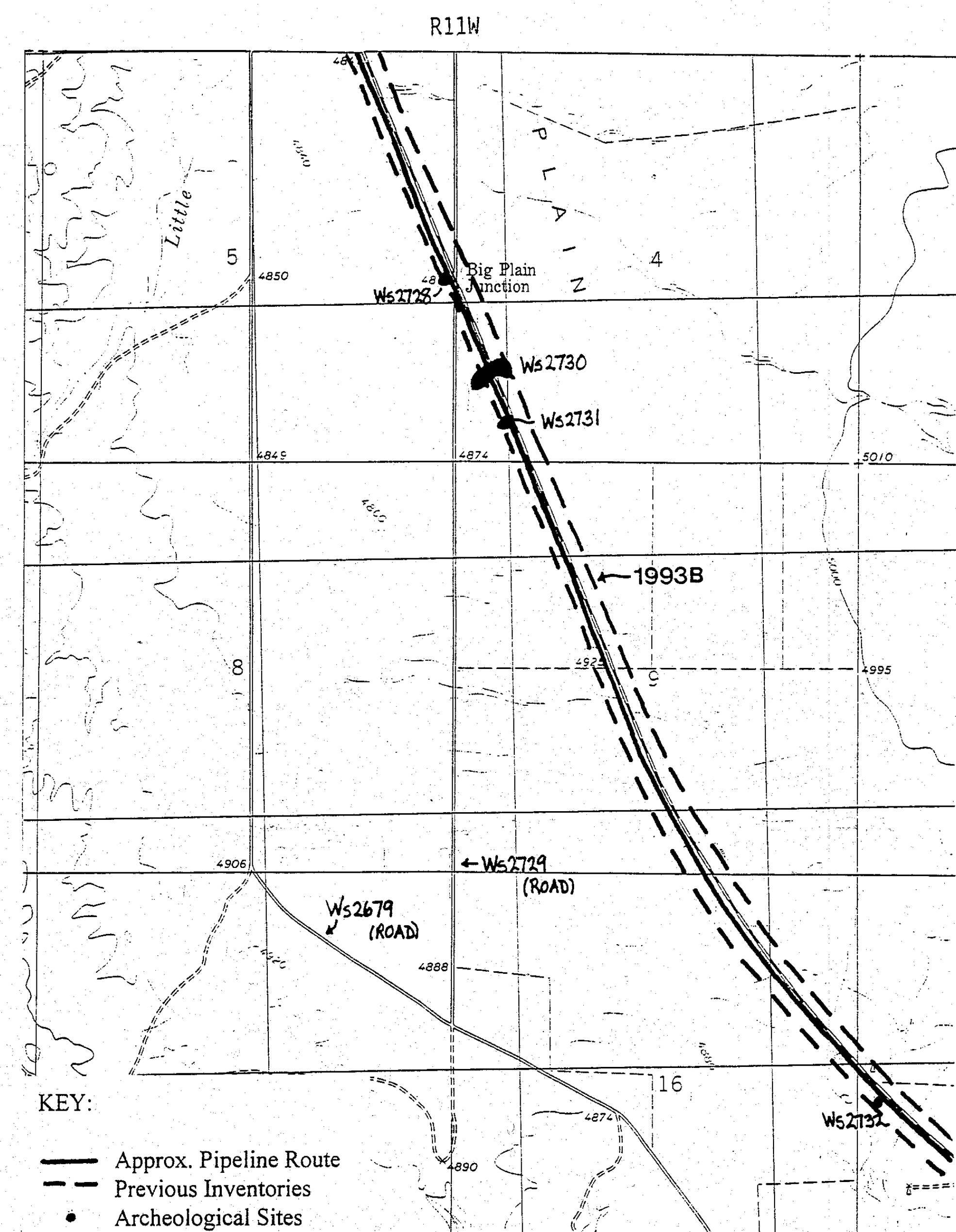


Fig. 22. Lake Powell Pipeline Project - Washington County Section Project, Inventory and Archeological Site Map
USGS Smithsonian Butte 7.5' (1980)

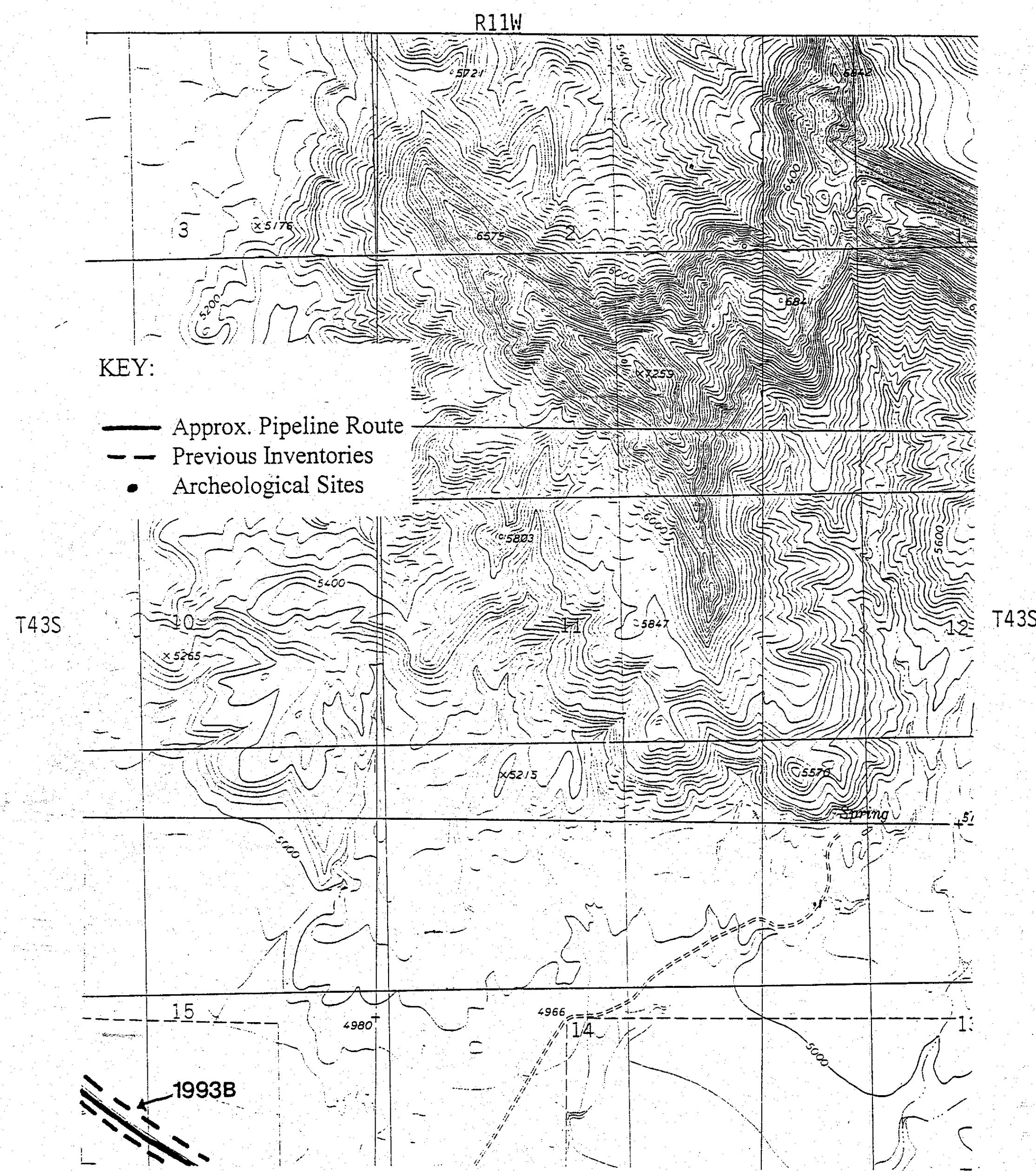


Fig. 23. Lake Powell Pipeline Project - Washington County Section Project, Inventory and Archeological Site Map
USGS Smithsonian Butte 7.5' (1980)

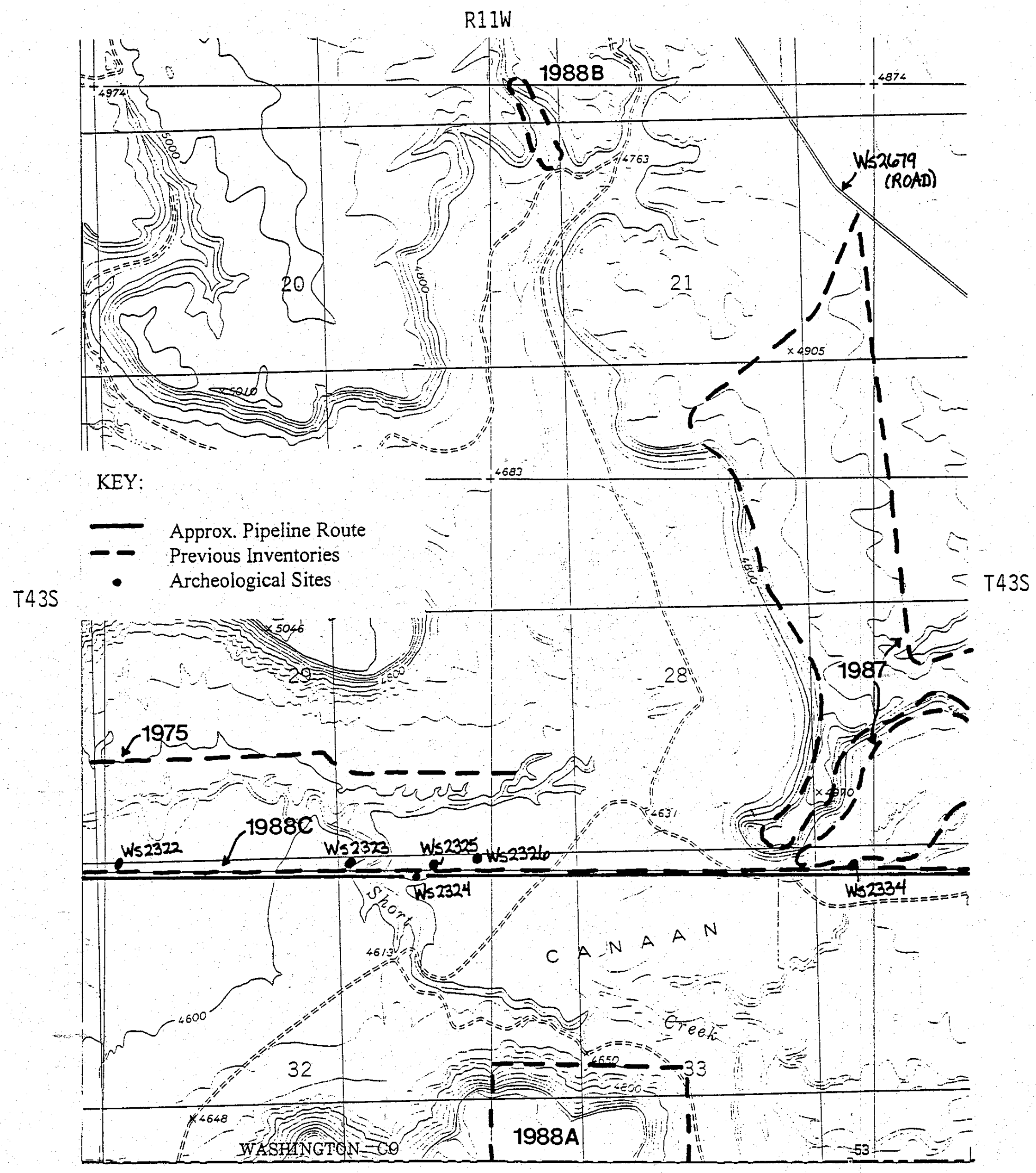


Fig. 24. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Smithsonian Butte 7.5' (1980)

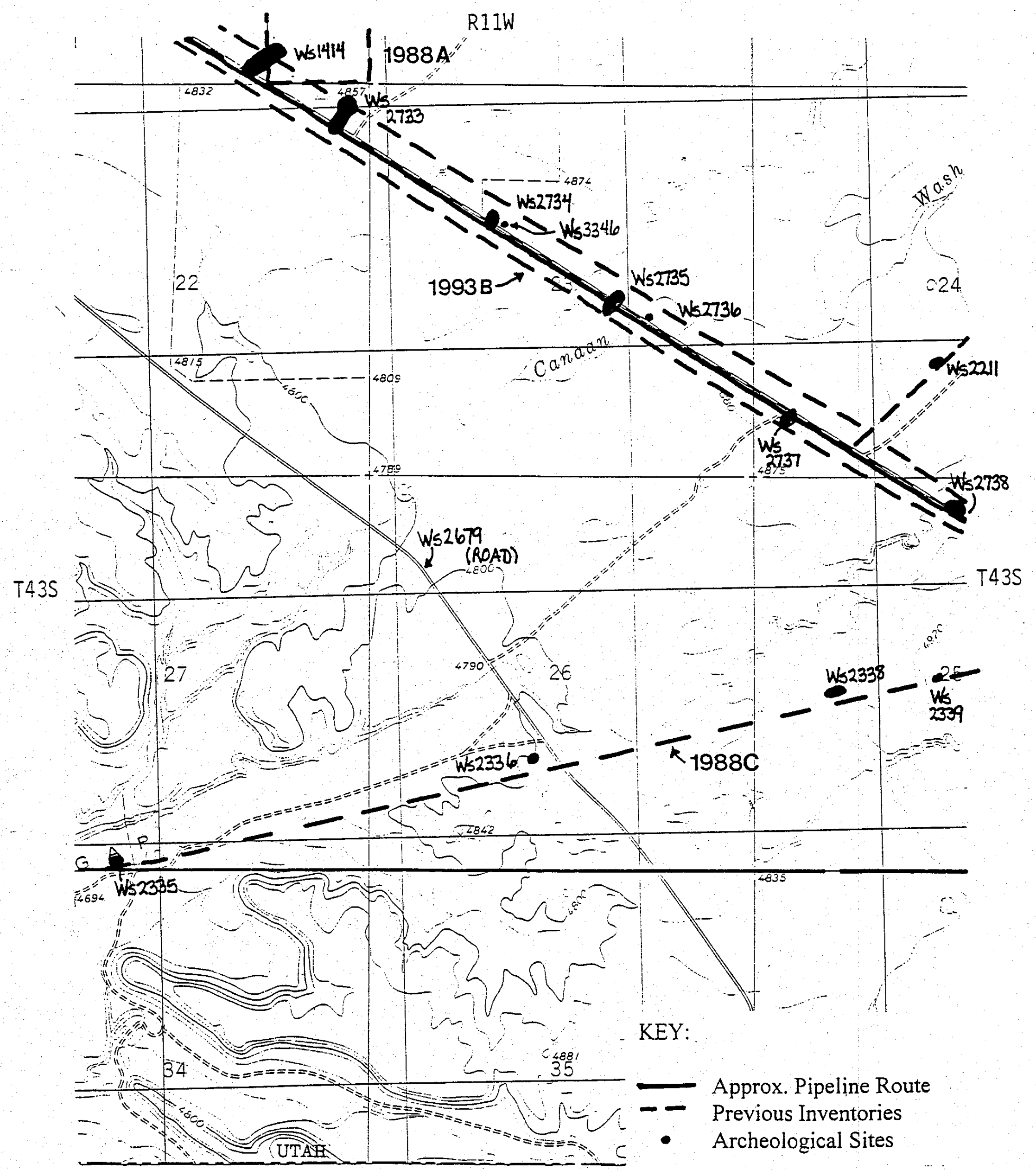


Fig. 25. Lake Powell Pipeline Project - Washington County Section Project, Inventory and Archeological Site Map
USGS Smithsonian Butte 7.5' (1980)

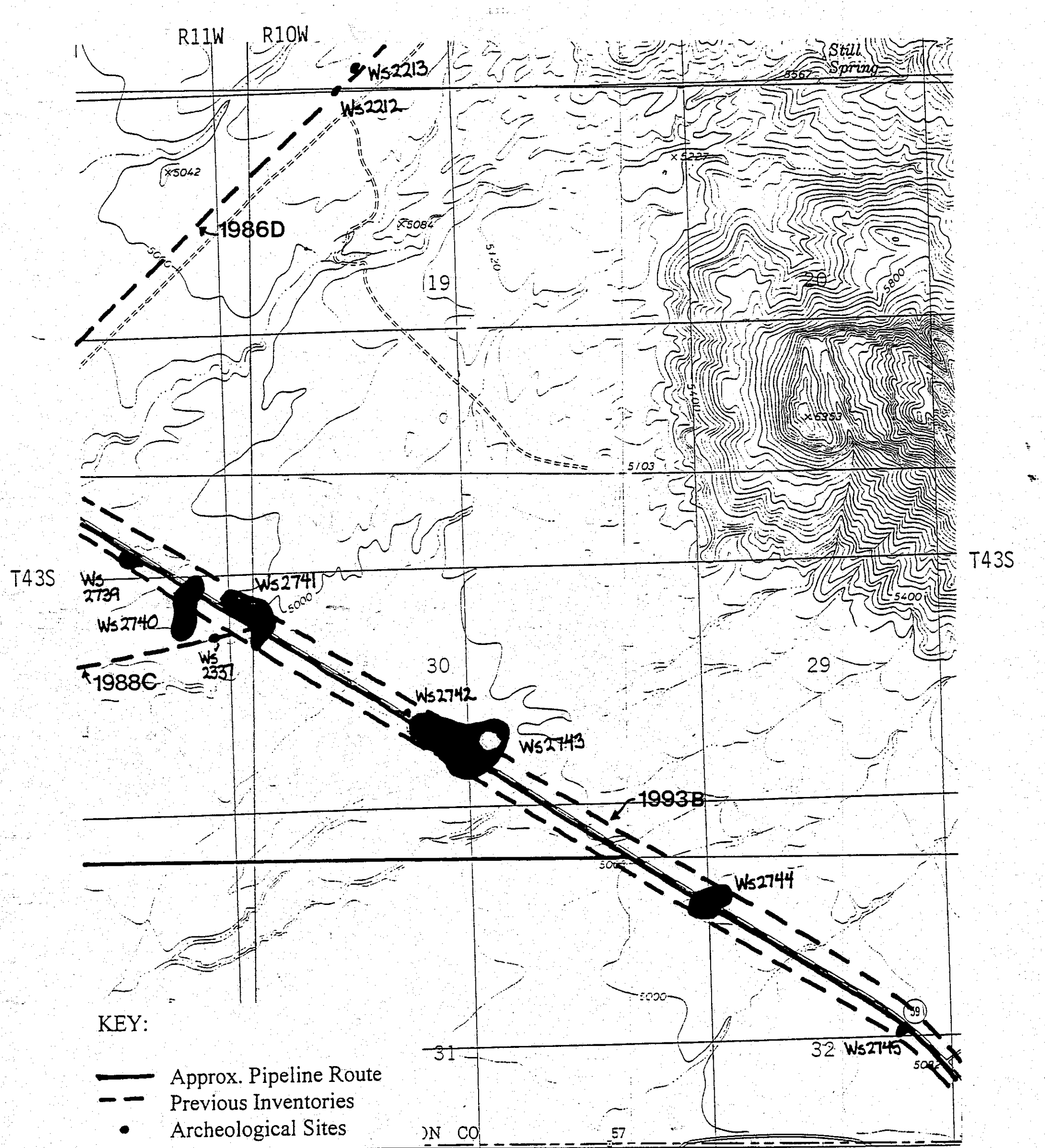


Fig. 26. Lake Powell Pipeline Project - Washington County Section
Project, Inventory and Archeological Site Map
USGS Smithsonian Butte 7.5' (1980)

Appendix 6.2

An Archeological Class III Records Search for the Lake Powell Pipeline Feasibility Study: Cockscomb Section, Kane County, Utah

Introduction

This report summarizes the results of a Class III records search conducted by Intersearch, Inc., for Alpha Engineering Co. and the Washington Water Conservancy District concerning the Cockscomb section of the proposed Lake Powell Pipeline. The Cockscomb section is located in Kane County and concerns the area surrounding the local geologic formation known as the Cockscomb. The project involved a total of ca. 15.5 miles of the pipeline easement located in Sections 24 through 26, T42S, R3W, Sections 19 through 25, T42S, R2W, and Sections 30 and 31, T42S, R1W, generally south of U.S. Highway 89. A records search was conducted with the aid of the Kanab Field Office and Grand Staircase-Escalante National Monument archeologist in the Bureau of Land Management files.

Environmental and Legal Descriptions

The records search involved a total of ca. 15.5 miles of proposed water pipeline corridor between Lake Powell to the east and the Sand Hollow Reservoir in Washington County south of Hurricane, Utah. The project alignment is located in Kane County just west of the prominent topographic feature the Cockscomb and south of the Vermilion Cliffs. The proposed project corridor climbs out of Kimball Valley into the juniper woodland onto the western flank of Fivemile Mountain and over it. It then drops down into Fivemile Valley, crosses U.S. Highway 89, and climbs over the Cockscomb with three alternative routes, all which join up in Section 30, T42S, R1W (Figures 1-3 and 6-9).

The project area ranges in elevation from 4860 feet in Fivemile Valley to a maximum of 5760 feet on Fivemile Mountain, placing it primarily within the Upper Sonoran life zone of the Grand Staircase physiographic region. Associated vegetation includes low sage, big sage, snakeweed, and rabbitbrush in the valleys and juniper woodland, low sage, ephedra, yucca, and prickly pear on the mountain. Soils in the valleys were alluvially deposited and consist of sands and reddish silts, with a minimum of gravels. On the mountain, soils were similar but generally much sandier, including dune buildup and deflation areas. It was in these areas that many of the recorded sites were encountered.

The specific legal description for the project is as follows:

SE 1/4, NE 1/4, NE 1/4	Section 26, T42S, R3W
NW 1/4, NE 1/4	Section 25

SW 1/4, SW 1/4	Section 24
S ½, N ½, SE 1/4	
S ½, NE 1/4, SE 1/4	
S ½, NW 1/4, SW 1/4	Section 19, T42S, R2W
S ½, NE 1/4, SW 1/4	
N ½, NW 1/4, SE 1/4	
N ½, NE 1/4, SE 1/4	
N ½, NW 1/4, SW 1/4	Section 20
N ½, NE 1/4, SW 1/4	
N ½, NW 1/4, SE 1/4	
N ½, NE 1/4, SE 1/4	
N ½, NW 1/4, SW 1/4	Section 21
N ½, NE 1/4, SW 1/4	
S ½, SW 1/4, NE 1/4	
S ½, SE 1/4, NE 1/4	
S ½, SW 1/4, NW 1/4	Section 22
S ½, SE 1/4, NW 1/4	
S ½, NW 1/4, NE 1/4	
S ½, NW 1/4, NE 1/4	
S ½, NW 1/4, NW 1/4	Section 23
S ½, NE 1/4, NW 1/4	
S ½, NW 1/4, NE 1/4	
S ½, NW 1/4, NE 1/4	
S ½, NW 1/4, NW 1/4	Section 24
SW 1/4, NE 1/4, NW 1/4	

Northeastern route to U.S. Highway 89:

E ½, SE 1/4, NW 1/4	Section 24, T42S, R2W
SW 1/4, SW 1/4, NE 1/4	
NW 1/4, NW 1/4, SE 1/4	
E ½, NW 1/4, SE 1/4	
W ½, SE 1/4, SE 1/4	
SE 1/4, SE 1/4, SE 1/4	
NE 1/4, NE 1/4, NE 1/4	Section 25
W ½, NW 1/4, NW 1/4	Section 30, T42S, R1W
SE 1/4, NW 1/4, NW 1/4	
NE 1/4, SW 1/4, NW 1/4	
W ½, SE 1/4, NW 1/4	

Southerly route to U.S. Highway 89:

W ½, SW 1/4, NW 1/4	Section 24, T42S, R2W
E ½, NE 1/4, SW 1/4	
E ½, SE 1/4, SW 1/4	
N ½, NE 1/4, SW 1/4	
SE 1/4, NE 1/4, SW 1/4	

W ½, NW 1/4, NW 1/4	Section 25
N ½, SE 1/4, NW 1/4	
NE 1/4, SW 1/4, NE 1/4	
S ½, SW 1/4, NE 1/4	
S ½, SW 1/4, NE 1/4	
NE 1/4, NE 1/4, SW 1/4	
N ½, NW 1/4, SW 1/4	Section 30, T42S, R1W
S ½, NE 1/4, SW 1/4	

Route along U.S. Highway 89:

W ½, SE 1/4, NW 1/4	Section 24, T42S, R2W
E ½, NW 1/4, SW 1/4	
E ½, SW 1/4, SW 1/4	
W ½, NW 1/4, NW 1/4	Section 25
W ½, SW 1/4, NW 1/4	
W ½, NW 1/4, SE 1/4	
SW 1/4, SW 1/4	
SE 1/4, SW 1/4	
NE 1/4, SW 1/4, SE 1/4	
S ½, NW 1/4, SE 1/4	
S ½, NE 1/4, SE 1/4	
S ½, NW 1/4, SW 1/4	Section 30, T42S, R1W
S ½, NE 1/4, SW 1/4	

Routes converge along U.S. Highway 89 at:

SW 1/4, SE 1/4	Section 30, T42S, R1W
SW 1/4, SE 1/4, SE 1/4	
NE 1/4, NE 1/4	Section 31

Records Search Results

Three linear cultural resource inventories have been conducted within this area, and the proposed pipeline route crosses two of the corridors. All three of the linear inventories involved power line corridors and all recorded archeological resources in the area. The following is a brief summary of the previously conducted surveys, followed by the relevant maps.

1974 BYU Garkane Power-Buckskin Microwave Line Extension

This inventory concerned a power line corridor running north along Fivemile Mountain (Figures 3-5). It commences in Section 27, T42S, R2W and joined the 1997 Intersearch inventory corridor in Section 10, T42S, R2W. A total of 24 prehistoric sites were recorded during this survey, 42Ka1270 to 42Ka1293. In general, these were small lithic scatter campsites, although some were also recorded as larger campsites, ranging from 100 to 200 square feet in area. This project intersected the 1997 Intersearch inventory, and some of the sites recorded during the 1974 project were relocated and rerecorded, including 42Ka1287, 42Ka1291, and 42Ka1293. The resurvey indicated that the sites were generally much larger then recorded on the original site forms. This would suggest that most of these sites are larger than is indicated on the forms, and the sites presently located in Section 22, T42S, R2W, where the proposed pipeline crosses, are probably bigger then the site plots indicate. In addition, the site plots should be regarded as somewhat inaccurate, as they have been transferred from 15-foot to 7.5-foot topographic maps. Presently, at least two sites, 42Ka1279 and 42Ka1280, appear to be located in areas which will be traversed by the proposed pipeline corridor.

1988 AK Nielson and Associates Paria to Glen Canyon 138-kv Powerline Survey

This inventory involved a linear power line corridor which crosses the present pipeline route in Fivemile Valley, along the western shoulder of U.S. Highway 89 (Figures 5, 7, and 8), specifically within Section 24, T42S, R2W. This inventory recorded eight sites north of the water pipeline route, within Fivemile Valley. These sites, 42Ka3405 through 42Ka3412, included both larger Formative, Virgin Anasazi, habitation sites, and campsites used by both Formative and Southern Paiute populations.

1997 Intersearch, Inc., Garkane-Buckskin to Paria 138-kv Power Line Survey (U-97-IG-0718b)

This inventory was conducted by Intersearch, Inc., for Garkane Power and it involved a number of proposed power line corridors, commencing just north of the Lake Powell Pipeline route, and crossing Fivemile Mountain 1 to 1-1/2 miles north of it (Figures 2, 4, and 5). Eighteen archeological sites were recorded along these routes including seven, 42Ka4458 through 42Ka4464, along the southern side of U.S. Highway 89 and nine in the portion crossing Fivemile Mountain. These nine included six newly recorded sites, 42Ka4465 through 42Ka4470, and three rerecorded sites, 42Ka1287, 42Ka1291, and 42Ka1293. Two new sites, 42Ka4475 and 42Ka4476, were also recorded in Fivemile Valley on the east side of U.S. Highway 89, where this project terminated as it joined an existing power line corridor. The majority of the sites recorded during this survey were Formative, Virgin Anasazi, and Southern Paiute camps, although larger Virgin Anasazi habitation sites are recorded in Fivemile Valley.

Summary

All three of the previously conducted power line corridor cultural resource inventories carried out within the area of the Cockscomb section of the proposed Lake Powell Pipeline corridor recorded significant prehistoric archeological sites. Most of the recorded sites are located north of the proposed pipeline corridor, and they include larger Virgin Anasazi habitation sites and Formative and Southern Paiute campsites. This suggests that the portion of the proposed corridor crossing the Fivemile Mountain area may encounter cultural resources similar to those recorded by the 1974 and 1997 Garkane power line surveys, i.e., large campsites. A small portion of the proposed pipeline corridor in Section 24, T42S, R2W may have been covered, in part, by the 1988 power line inventory, but the remainder of the route has not been surveyed.

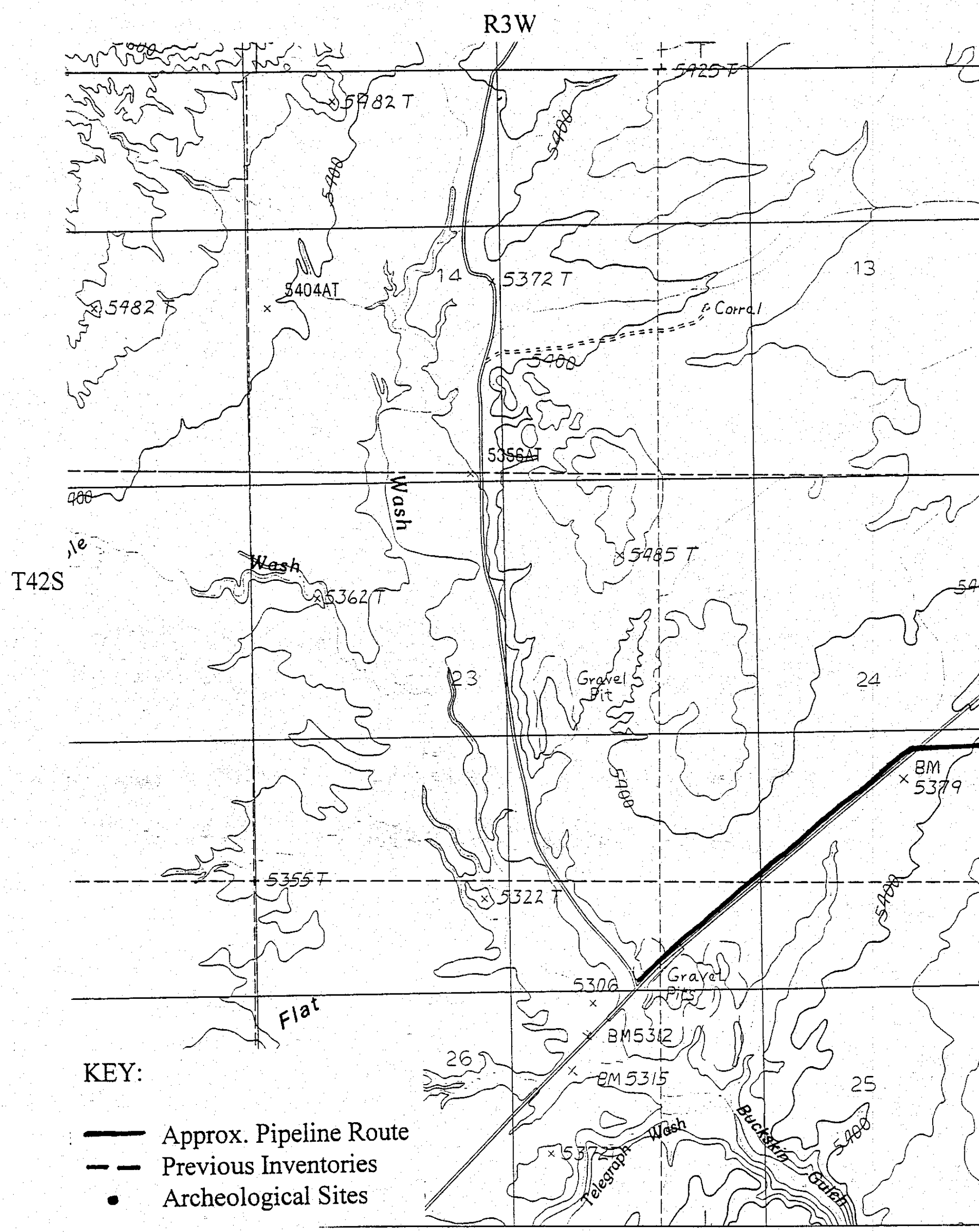


Fig. 1. Lake Powell Pipeline Project - Cockscomb Section
Project, Inventory and Archeological Site Map
USGS Eightmile Pass 7.5' (1987)

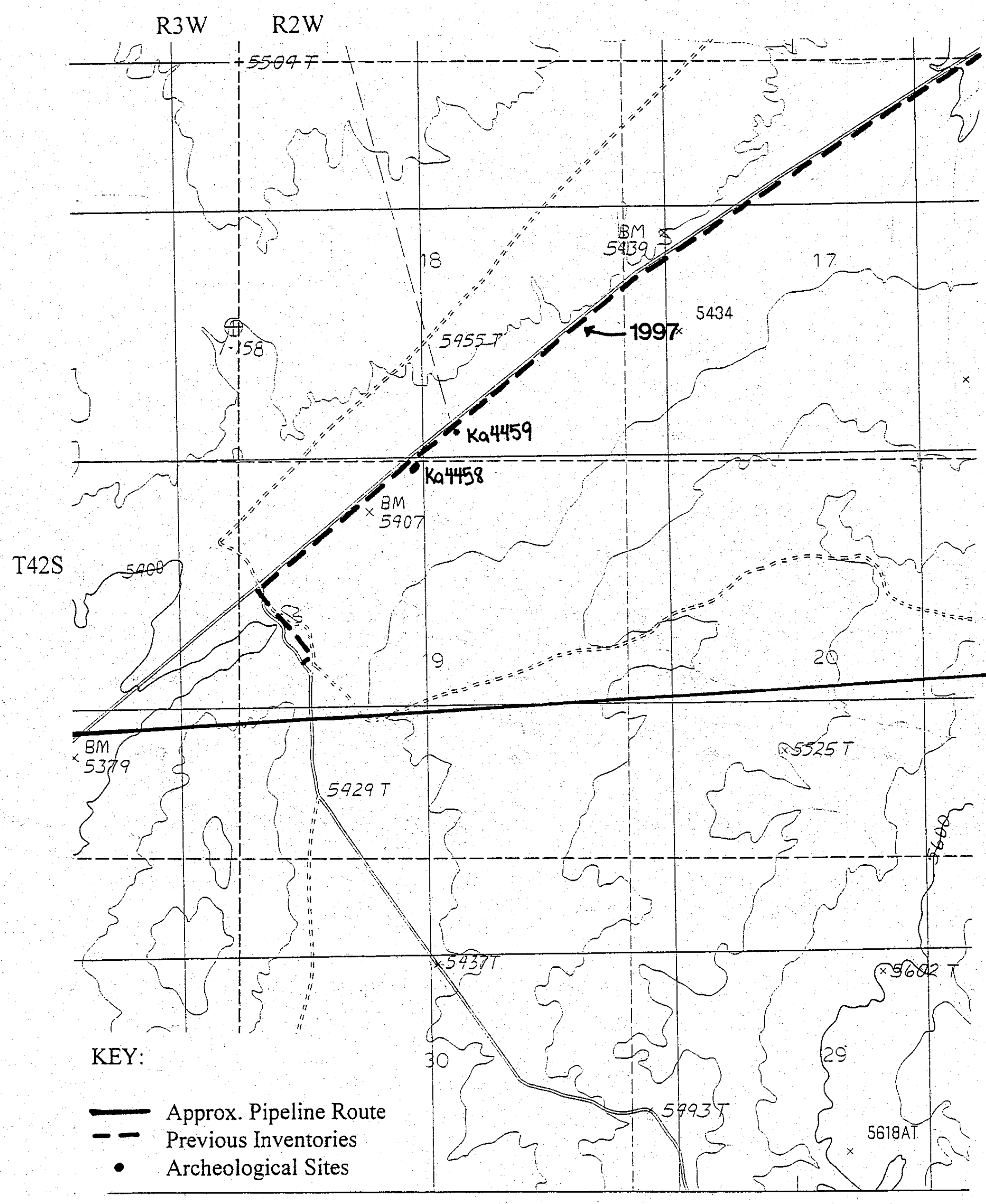


Fig. 2. Lake Powell Pipeline Project - Cockscomb Section Project, Inventory and Archeological Site Map USGS Eightmile Pass 7.5' (1987)

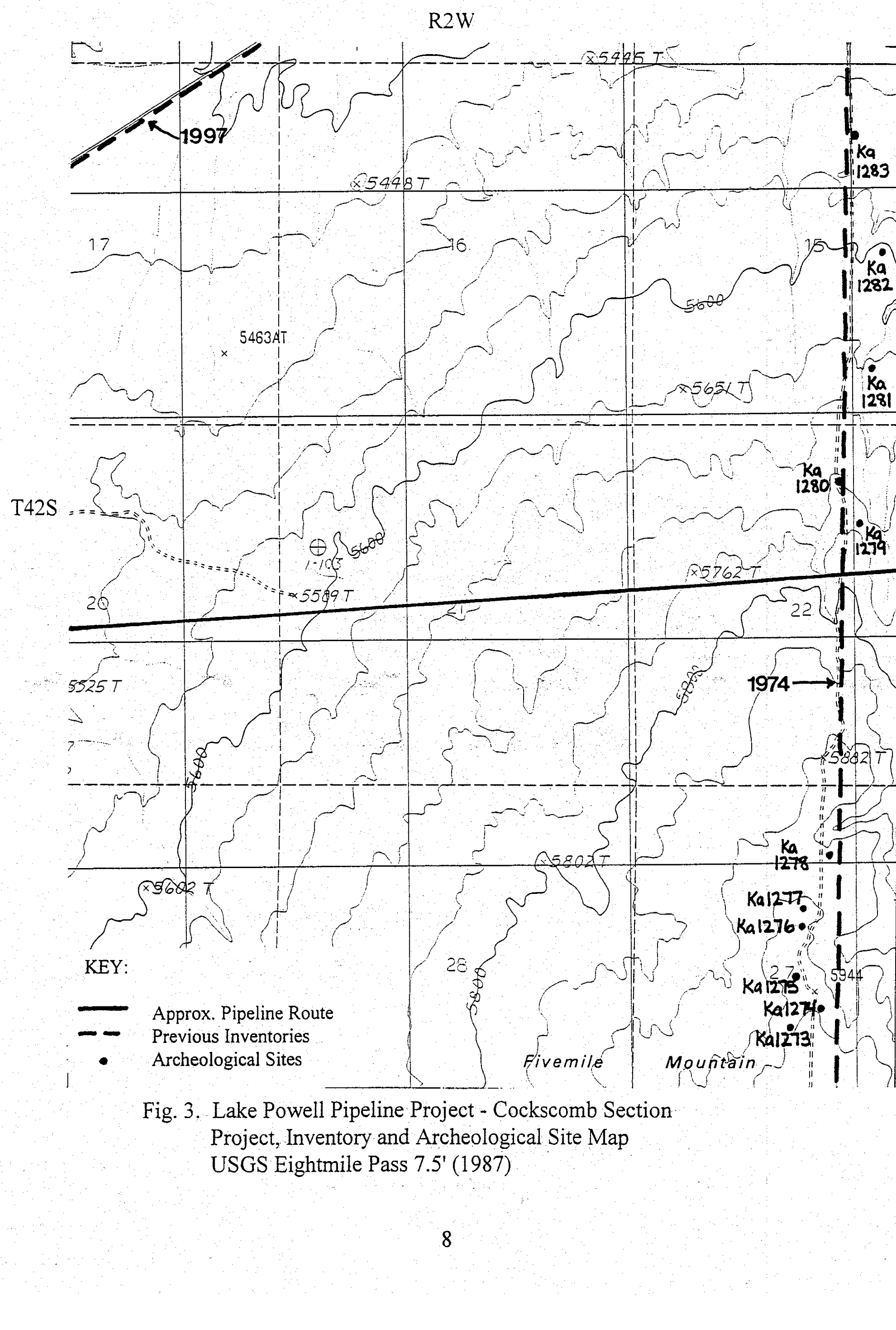


Fig. 3. Lake Powell Pipeline Project - Cockscomb Section Project, Inventory and Archeological Site Map USGS Eightmile Pass 7.5' (1987)

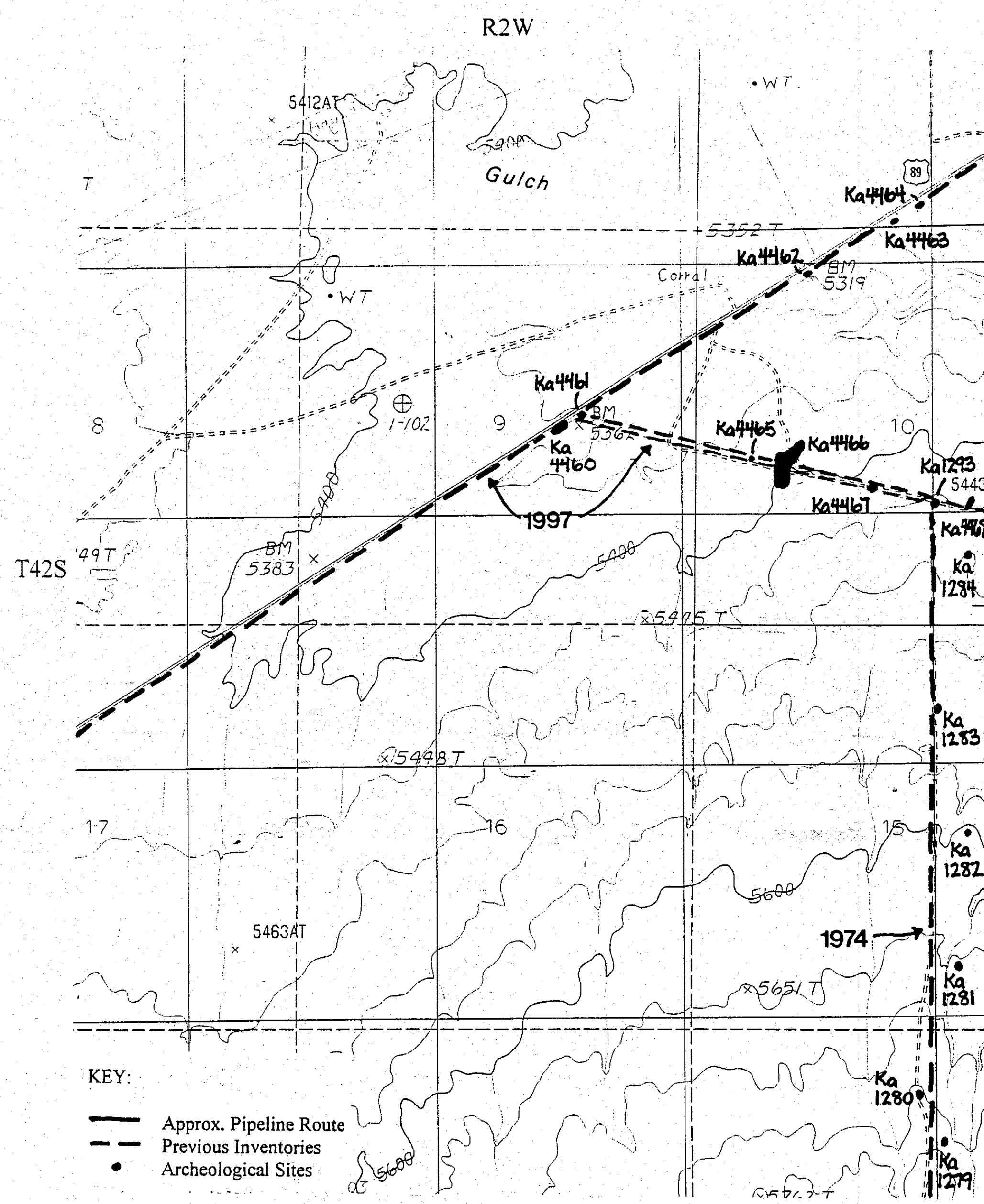


Fig. 4. Lake Powell Pipeline Project - Cockscomb Section Project, Inventory and Archeological Site Map USGS Eightmile Pass 7.5' (1987)

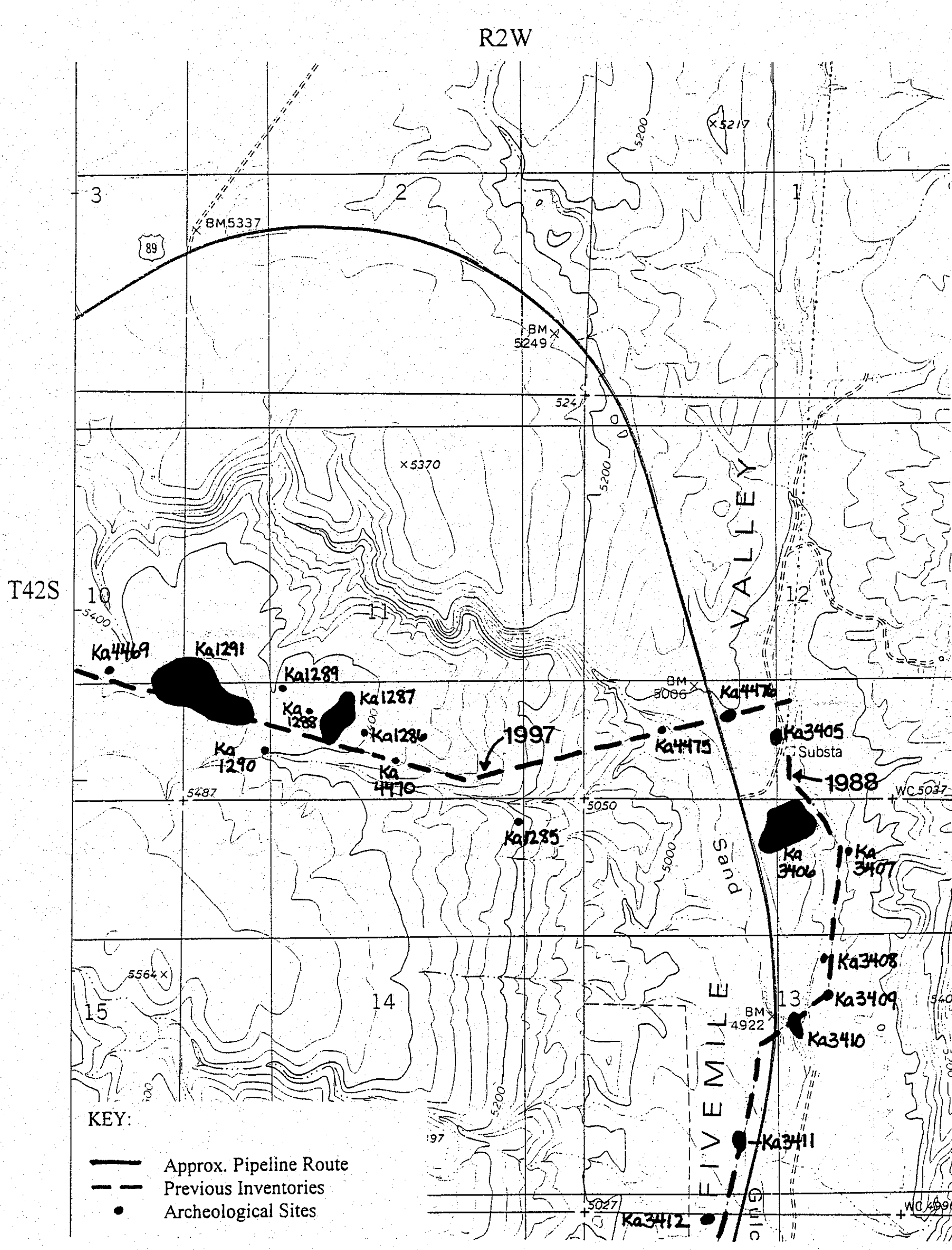
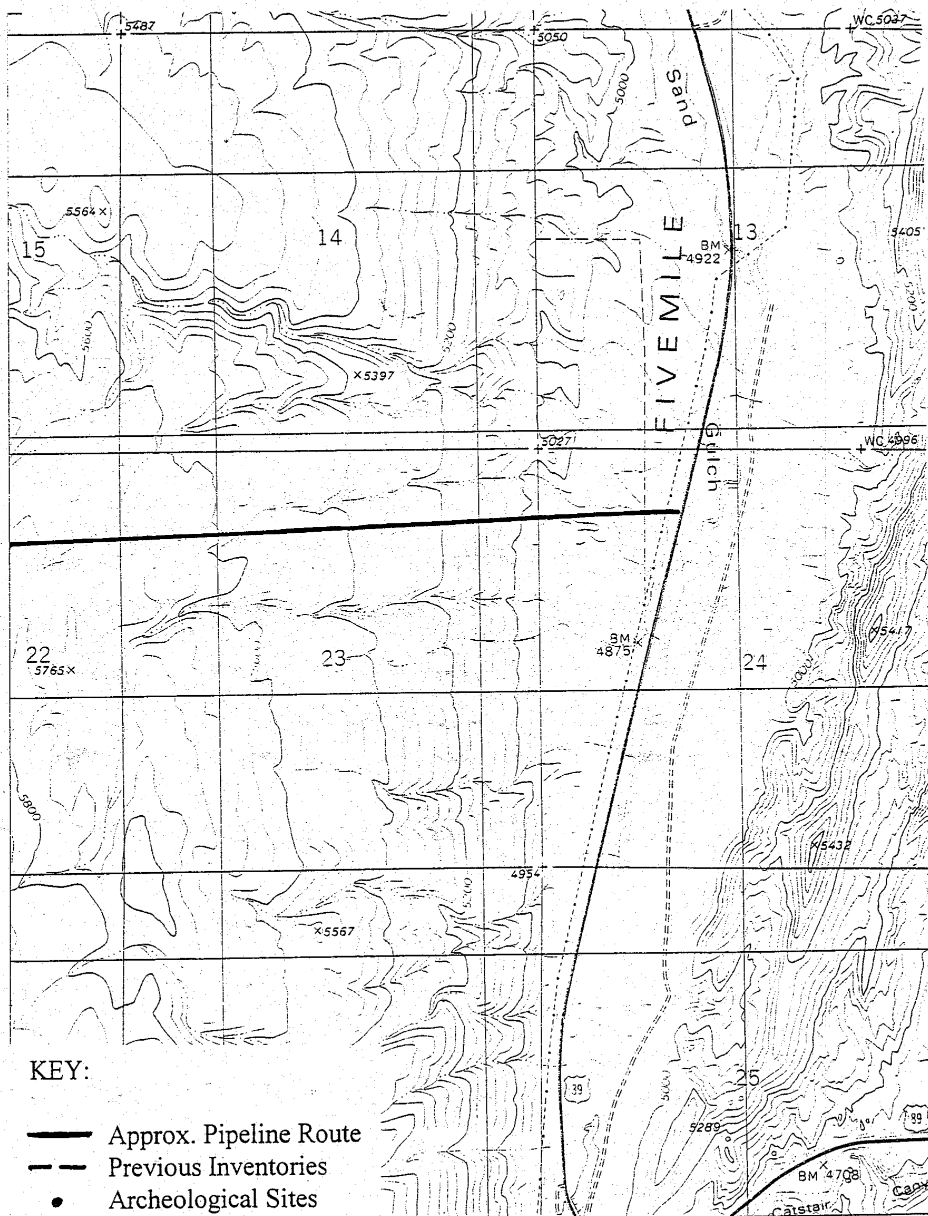


Fig. 5. Lake Powell Pipeline Project - Cockscomb Section Project, Inventory and Archeological Site Map USGS Fivemile Valley 7.5' (1981)

R2W

T42S



KEY:

Approx. Pipeline Route
Previous Inventories
Archeological Sites

Fig. 6. Lake Powell Pipeline Project - Cockscomb Section
Project, Inventory and Archeological Site Map
USGS Fivemile Valley 7.5' (1981)

R2W R1W

T42S

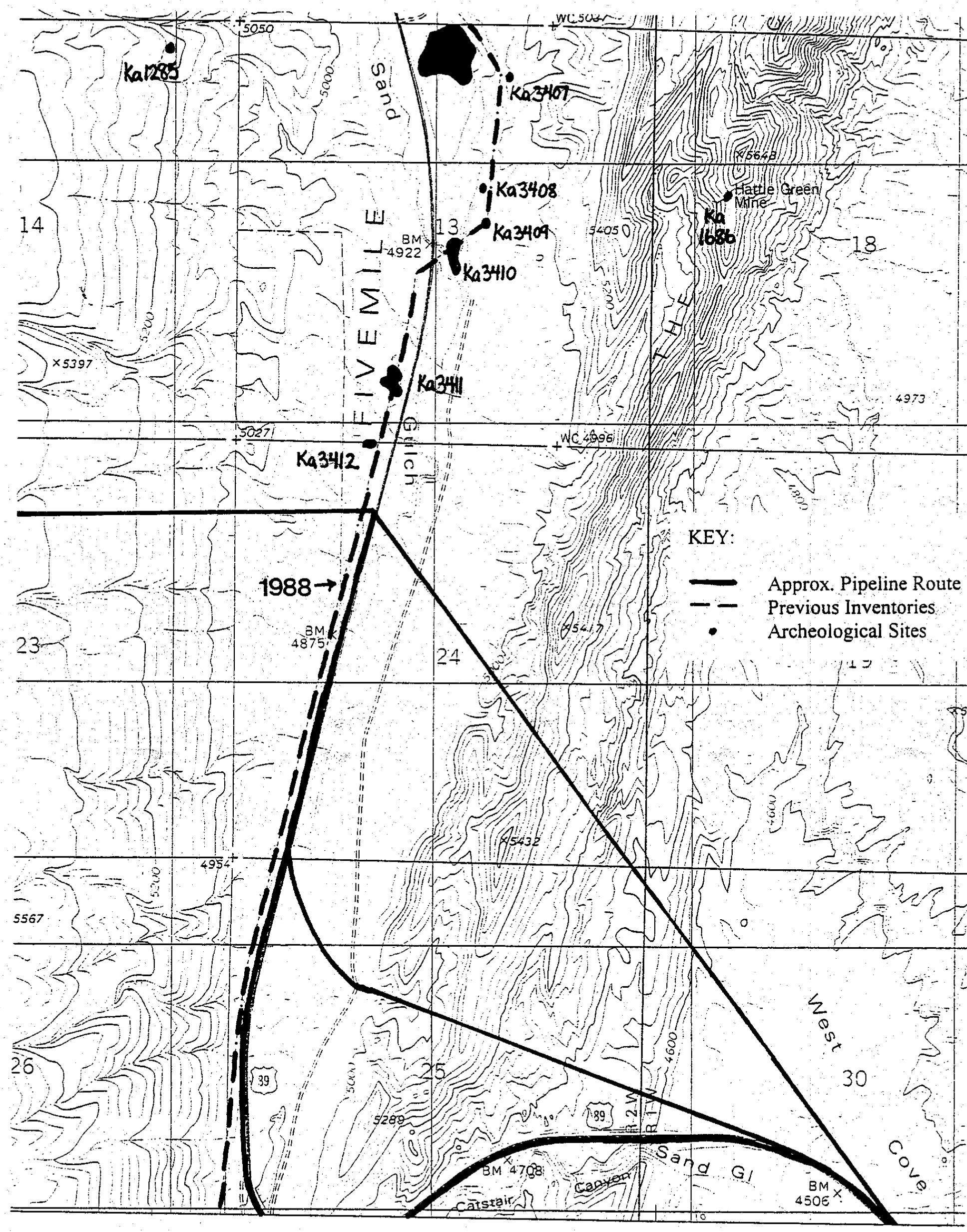


Fig. 7. Lake Powell Pipeline Project - Cockscomb Section
Project, Inventory and Archeological Site Map
USGS Fivemile Valley 7.5' (1981)

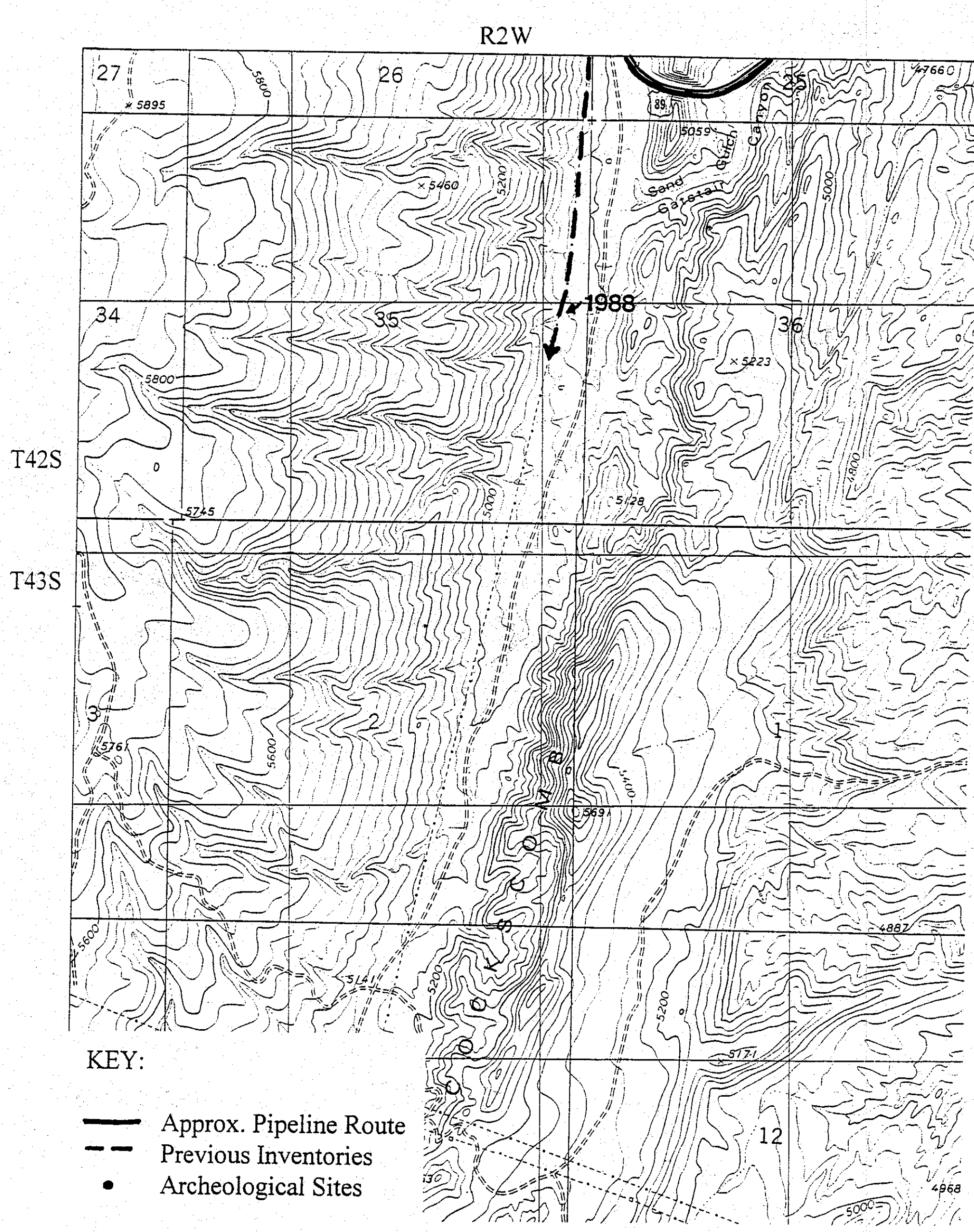
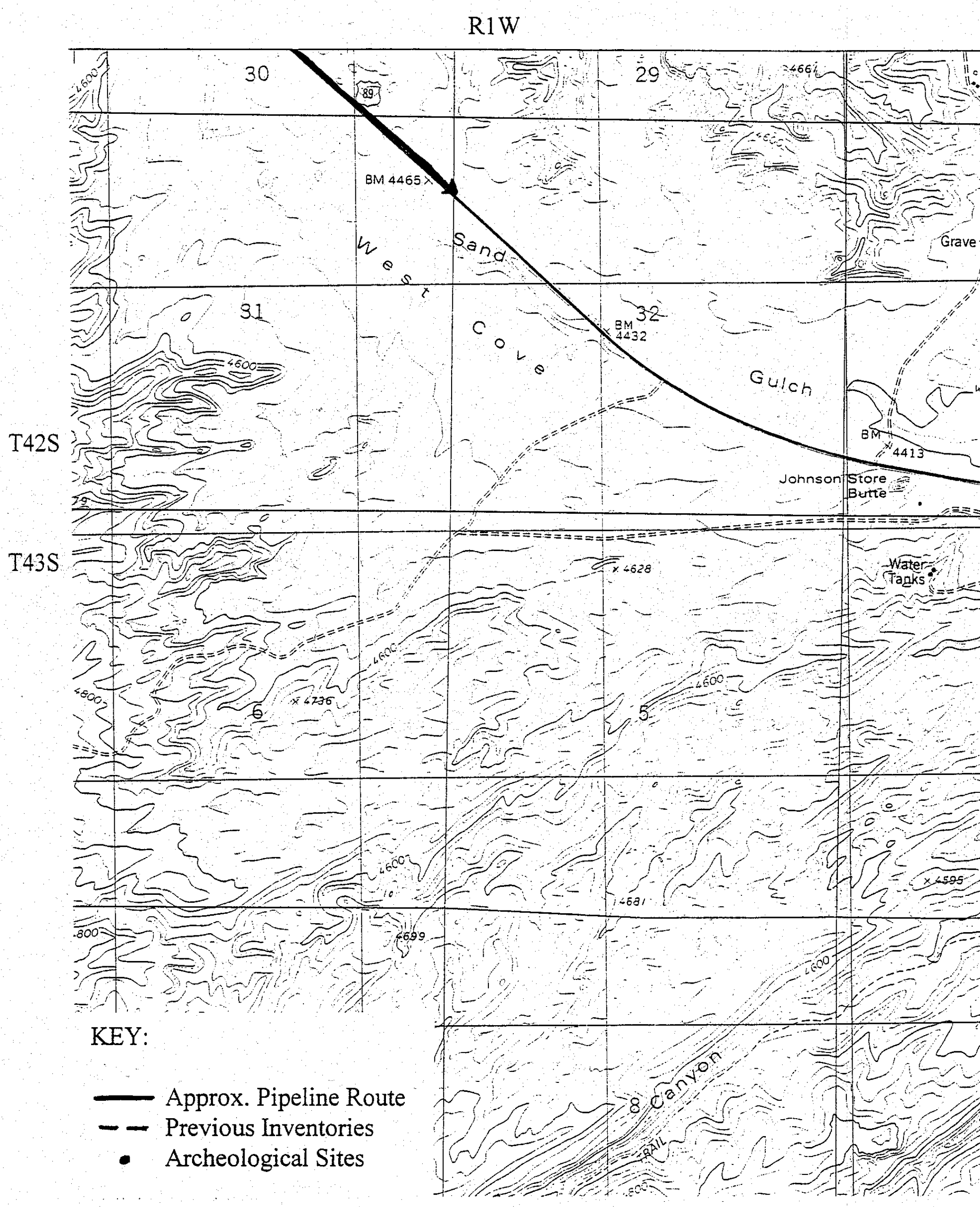


Fig. 8. Lake Powell Pipeline Project - Cockscomb Section
Project, Inventory and Archeological Site Map
USGS West Clark Bench 7.5' (1981)



KEY:

- Approx. Pipeline Route
- Previous Inventories
- Archeological Sites

Fig. 9. Lake Powell Pipeline Project - Cockscomb Section Project, Inventory and Archeological Site Map USGS West Clark Bench 7.5' (1981)

Appendix 6.3

An Archeological Records Search for the Lake Powell Pipeline Feasibility Study Mohave County, Utah

Introduction

This report briefly summarizes the results of an archeological records search conducted by Intersearch, Inc. for Alpha Engineering Co. and the Washington County Water Conservancy District (WCWCD) concerning the Mohave County section of the proposed Lake Powell Pipeline. The proposed route within Mohave County involves two major corridors between Lake Powell in Kane County, Utah to the Sand Hollow Reservoir in Washington County, Utah, (Figs. 1 through 13). The effected lands are primarily administered by the Bureau of Land Management (BLM), Arizona Strip District, Vermilion Cliffs Resource but also include some sections administered by the Arizona State Lands Administration and a considerable section which may effect the SR 59 Right-of-Way. This latter section will also involve the Arizona Department of Transportation. A records search was conducted in the Bureau of Land Management (BLM) files at the Arizona Strip office, and involved USGS 7.5' topographic maps include Rock Canyon, Lost Spring Mountain West, Lost Spring Mountain East, Maroney Well, and Pipe Valley, and USGS 15' Colorado City. The cultural inventory areas and the proposed Lake Powell pipeline have been plotted on these maps.

Records Search Summary

A brief summary of the relevant cultural inventories will be addressed by this section of the report. The inventories are listed chronologically with alphabetic designations added to distinguish surveys conducted during the same year. A total of twenty-five cultural resource inventories have been conducted in the proposed pipeline corridor, and few sites have been recorded within the immediate area.

1976 Colorado City-Hildale Wastewater Facility

This inventory involved the proposed Colorado City-Hildale Wastewater Facility, and it was conducted by Intersearch, Inc. It involved both linear corridors for the associated pipeline and 40 acre blocks for the proposed facility. Cultural resources were recorded by this inventory (Fig. 13).

1977A Cove Pipeline Project

This inventory involved a 3 mile long by 100 ft. wide linear corridor associated with the Cove Pipeline project. This survey was conducted by the BLM (Figs. 3, 4, & 5).

1977B Aiken Well Pasture Fence

This project consisted of a 4.5 mile long by 100 ft. wide linear corridor associated with the Aiken Well Pasture Fence. This inventory was conducted by the BLM (Fig. 4).

1977C

No paperwork was found for this survey which was conducted by the BLM (Figs. 3 & 4).

1982A Western Geophysical Seismic Line Survey

This inventory consisted of a number of liner corridors involved with the Western Geophysical Seismic Line survey conducted by Centuries Research, Inc. (Figs. 8, 10-12).

1982B Garkane - Hack Canyon Power Line Right-of-way

This survey involved the Garkane - Hack Canyon Power Line Right-of-way, and it also involved some mitigation outside of the present project area. Abajo Archeology conducted the archeological work (Fig. 12).

1983A Pathfinders Mines Corporation Drill Sites

This project covered 9.7 acres and involved the Pathfinders Mines Corporation Drill Sites. The work was conducted by the BLM (Fig. 3).

1983B Glazier Reservoirs

This inventory involved a 3 acre area involved with the Glazier Reservoirs. This work was conducted by the BLM (Fig. 3).

1983C Accelerated Aset Management Tracts

This survey involved the Accelerated Aset Management Tracts and it involved a total of 440 acres, including an historic cistern on Ballard property. This inventory was conducted by the BLM (Fig. 6).

1984 Glazier Dam Cross Fence

This survey concerned the Glazier Dam Cross Fence, a linear corridor that encompassed a total of 20 acres. This inventory was conducted by the BLM (Fig. 2).

1986 Short Creek Pipeline Extension

This inventory involved the Short Creek Pipeline Extension and covered a total of 20 acres. It was conducted by BLM archeologists (Fig. 6).

1987 Colorado City Industrial Park

This block survey involved the proposed Colorado City Industrial Park, and it was conducted by Intersearch, Inc. Sites were found in the proposed project area (Fig. 13).

1988A

No paperwork was found for this survey, a linear corridor, and the inventory was conducted by the BLM (Fig. 7 & 8).

1988B Mohave Community College

This was a block inventory, covering 80 acres, conducted by the BLM for the Mohave Community College R&PP (Fig. 8).

1989 Glazier Plugs

This inventory involved the Glazier Plugs, and it covered 3.7 acres. It was conducted by the BLM (Fig. 2).

1990A Cove Pipeline Corridor

This survey the Cove Pipeline corridor, measuring 2.85 miles long and covering a total of 22.3 acres. It was conducted by the BLM (Fig. 4).

1990B Garkane-Washington County Power Line

This survey involved a linear corridor covering either 17.8 or 26.8 acres, and it concerned the Garkane-Washington County power line. The inventory was conducted by the BLM (Fig. 7).

1990C Point Rock Comm.

This survey involved 15 acres and was designated Point Rock Comm. by the BLM archeologist. A large site, AZ A:4:162(BLM), was recorded in this area (Fig. 7).

1991 Glazier Plugs-Area C

The inventory concerned the Glazier Plugs-Area C, part of a water rehabilitation project. It covered roughly 6 acres (Fig. 2).

1995 Colorado City/Fredonia Land Fill Site

This inventory concerned the Colorado City/Fredonia land fill site, as well as access into the area. It covered a total of 738 acres, and was conducted by the BLM (Fig. 8).

1996 Arizona Strip Landfill Damage Assessment

This survey was conducted by SWCA, Inc. and is related to the previous project in that it involved a damage assessment in conjunction with the previously conducted survey. The project was designated as the Arizona Strip Landfill Damage Assessment, and it covered approximately 5 acres (Fig. 8).

2001 Sandridge Road Survey

This was a linear survey project conducted by the BLM and involving the Sandridge Road Survey. No cultural resources were recorded in association with the present project route (Fig. 6 & 7).

2002 USGS Trenches-Hurricane Cliffs

This was a small project involving a 22.5 acre area, part of the USGS Trenches-Hurricane Cliffs project. The survey was conducted by the BLM (Fig. 1).

SLS Arizona State Trust Lands

This was a large block survey conducted on Arizona State Trust Lands along SR 59. A number of archeological sites were recorded by this inventory in thearea of the highway (Figs. 11 & 12)

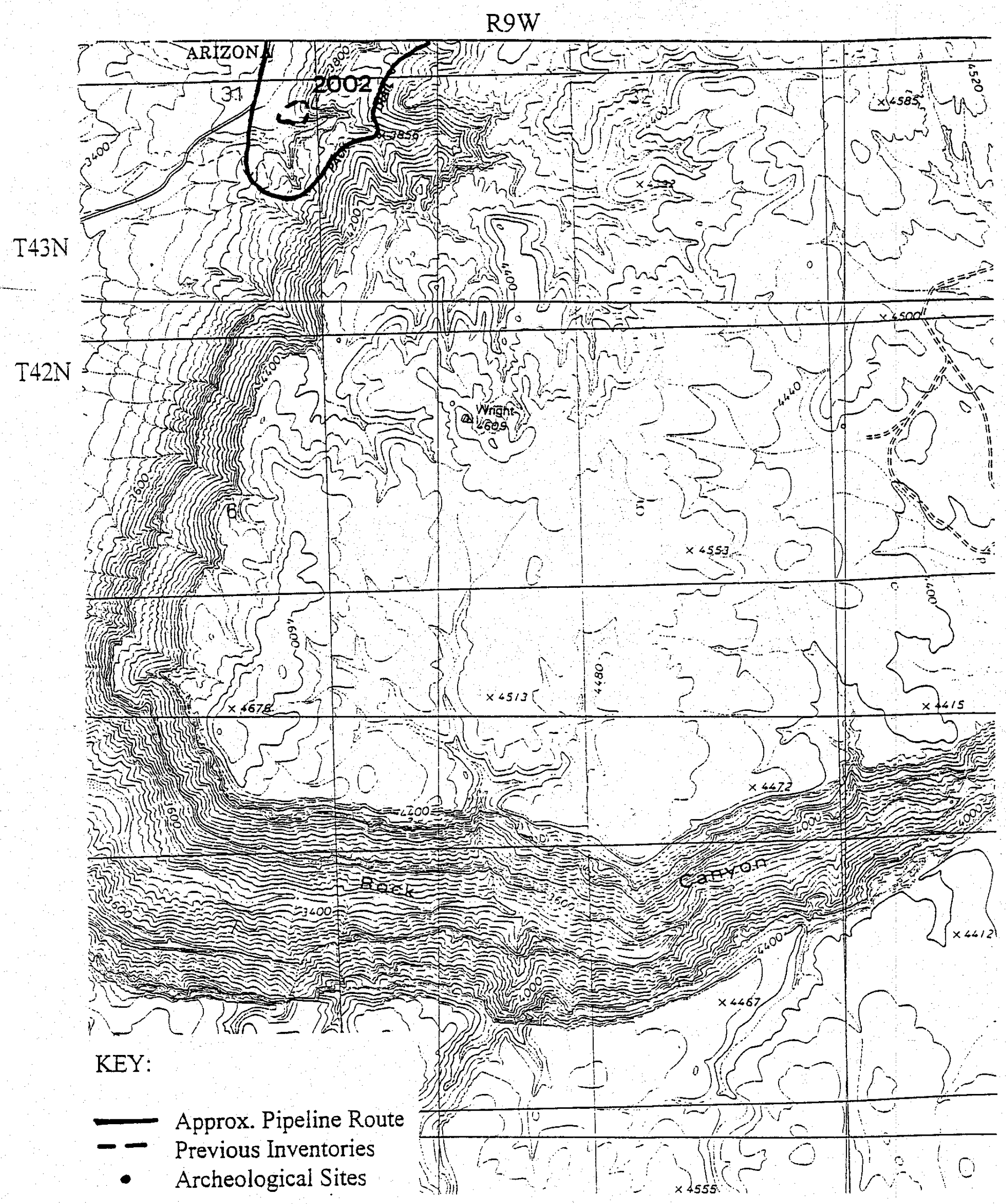


Fig. 1. Lake Powell Pipeline Project - Mohave County, Arizona Section
Project, Inventory and Archeological Site Map
USGS Rock Canyon, Arizona 7.5' (1979) A:3:NE

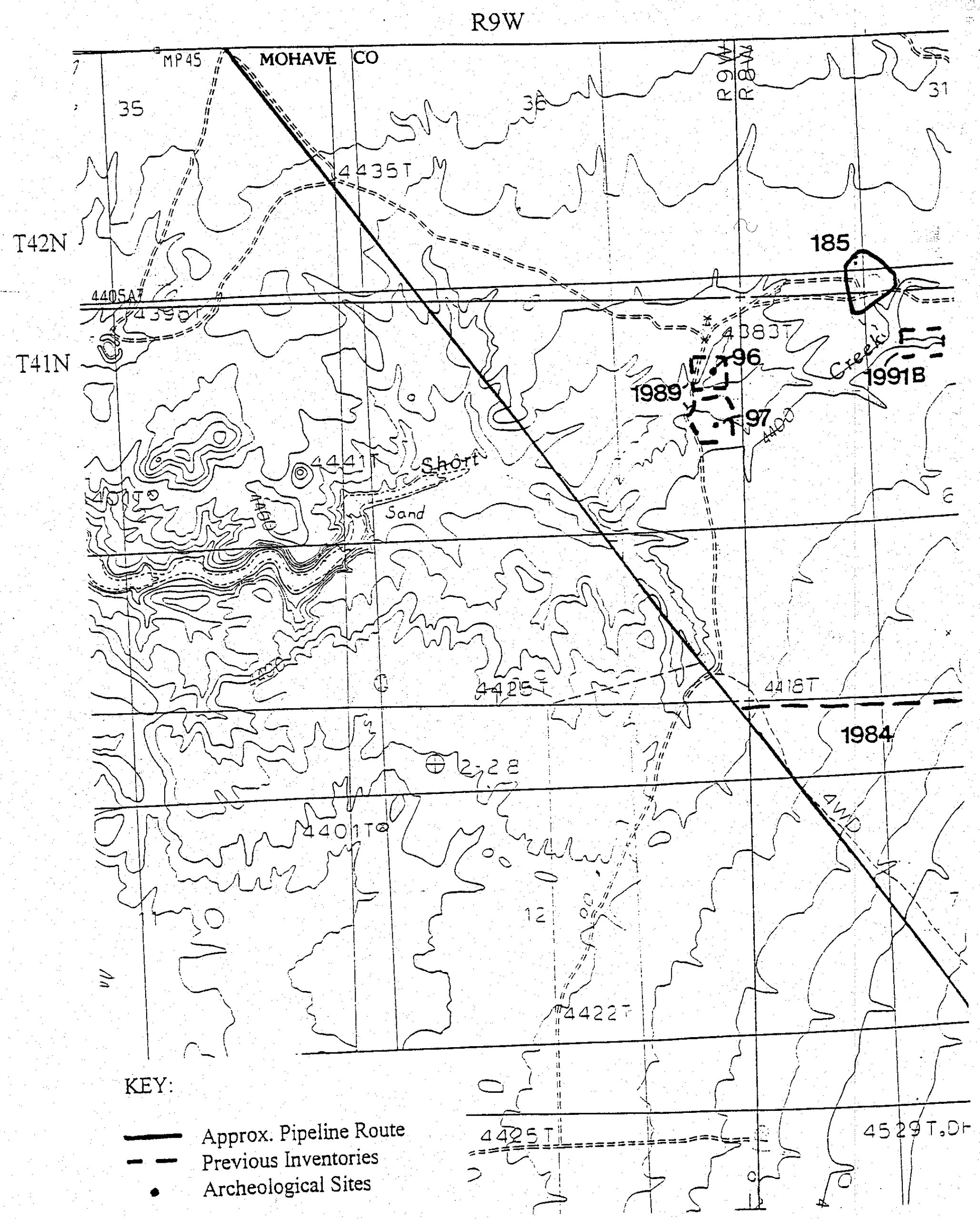


Fig. 2. Lake Powell Pipeline Project - Mojave County, Arizona Section
Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain West 7.5' (PE 1988) A:4:NW

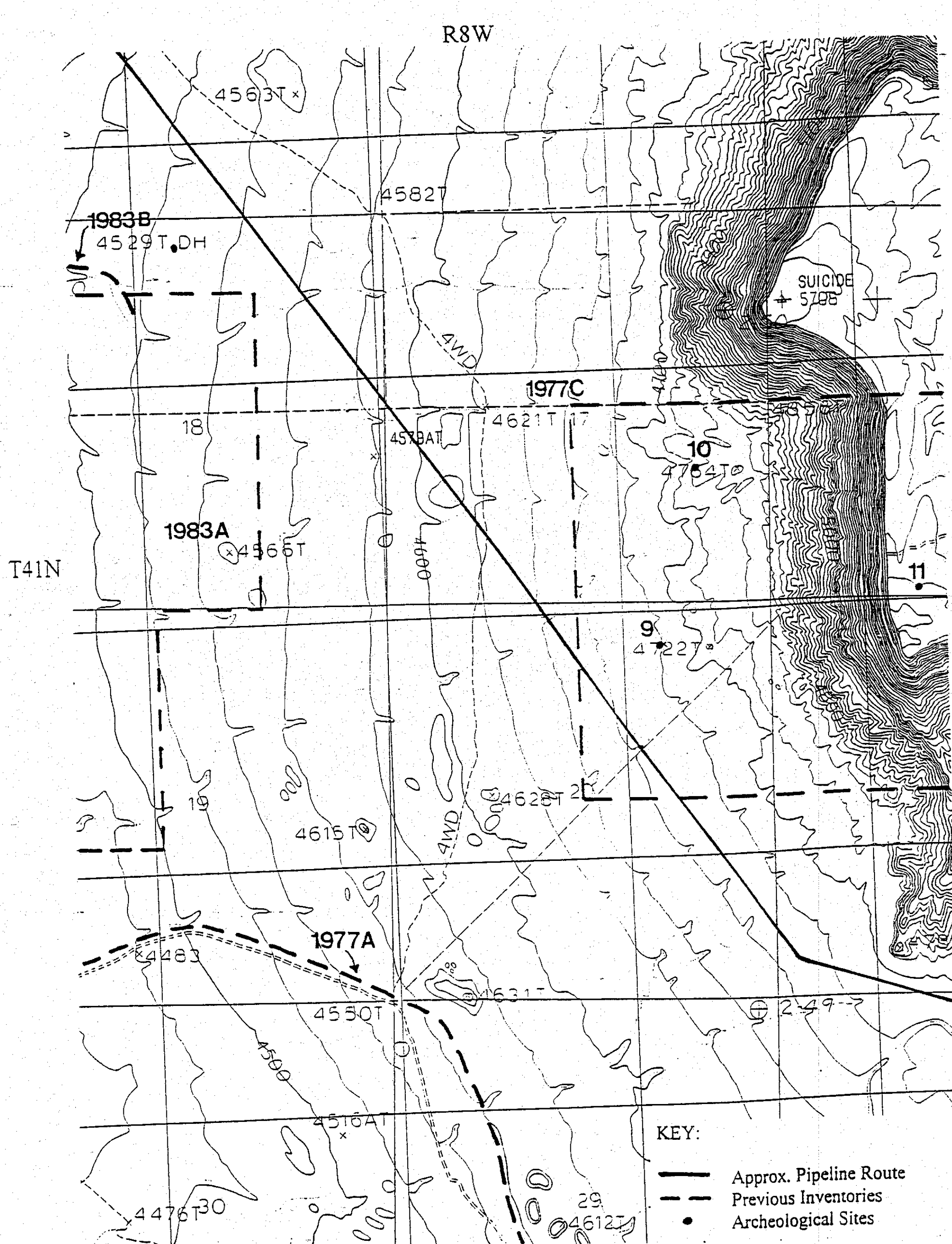


Fig. 3. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain West 7.5' (PE 1988) A:4:NW

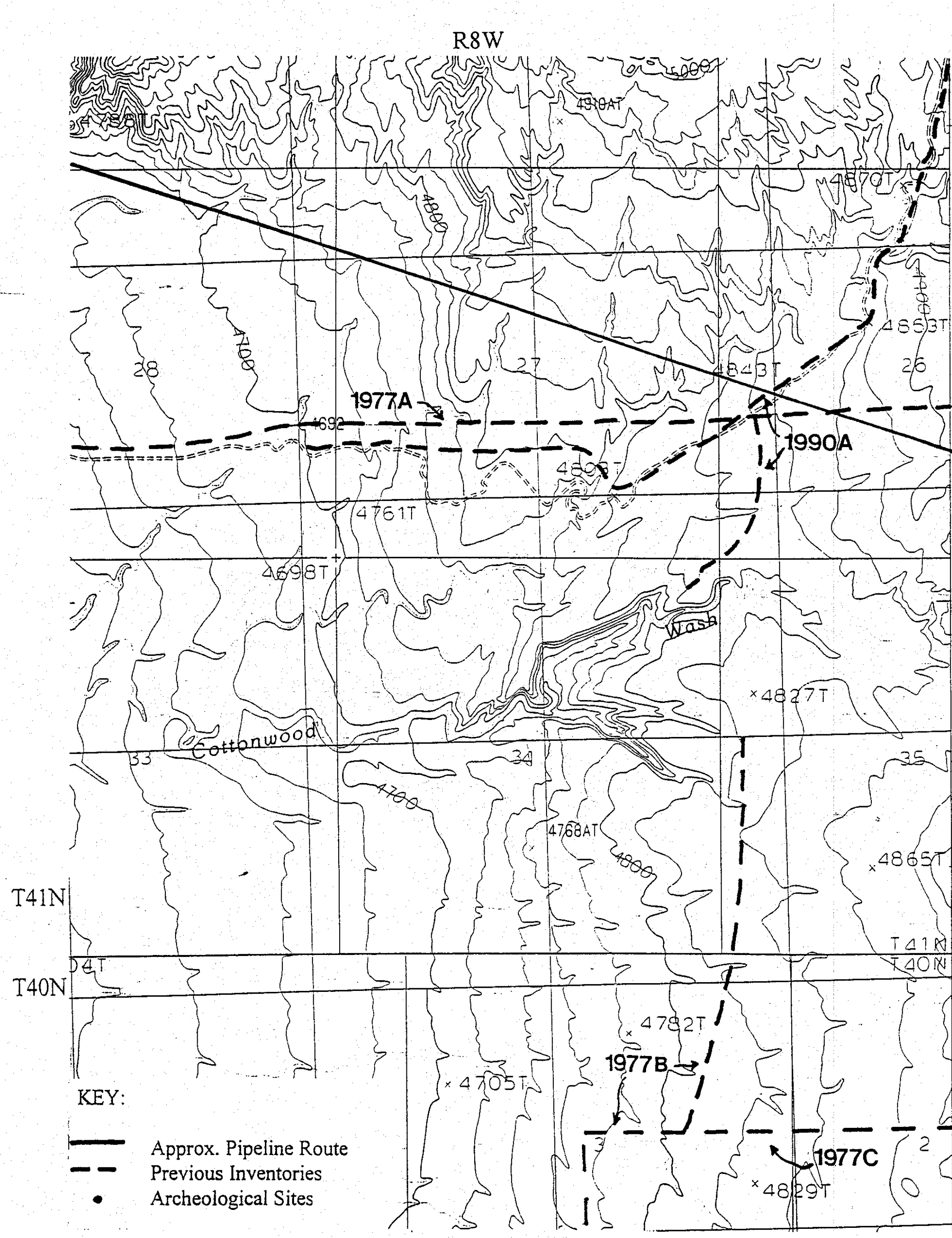


Fig. 4. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain West 7.5' (PE 1988) A:4:NW

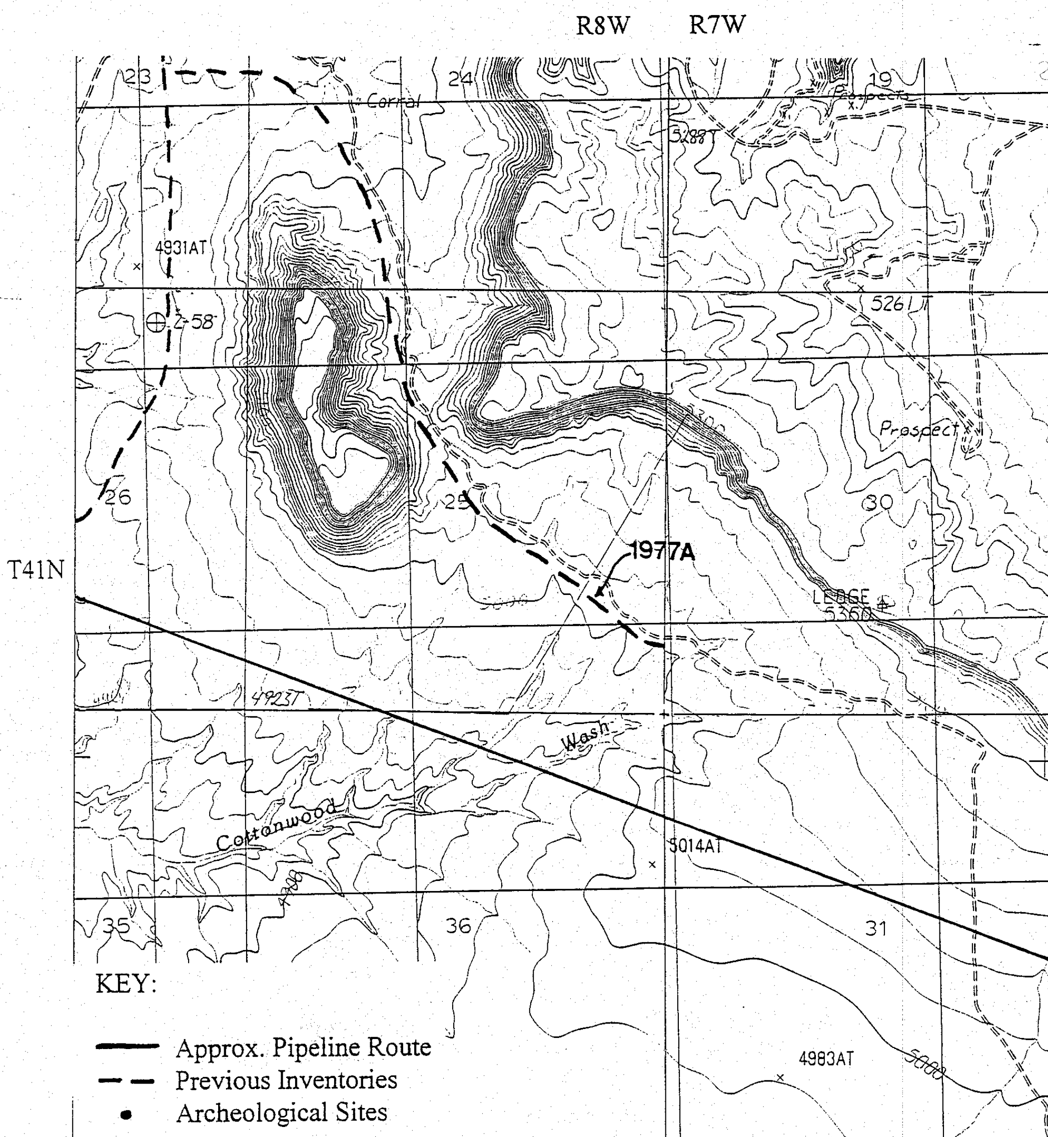


Fig. 5. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain East 7.5' (PE 1988) A:4:NE

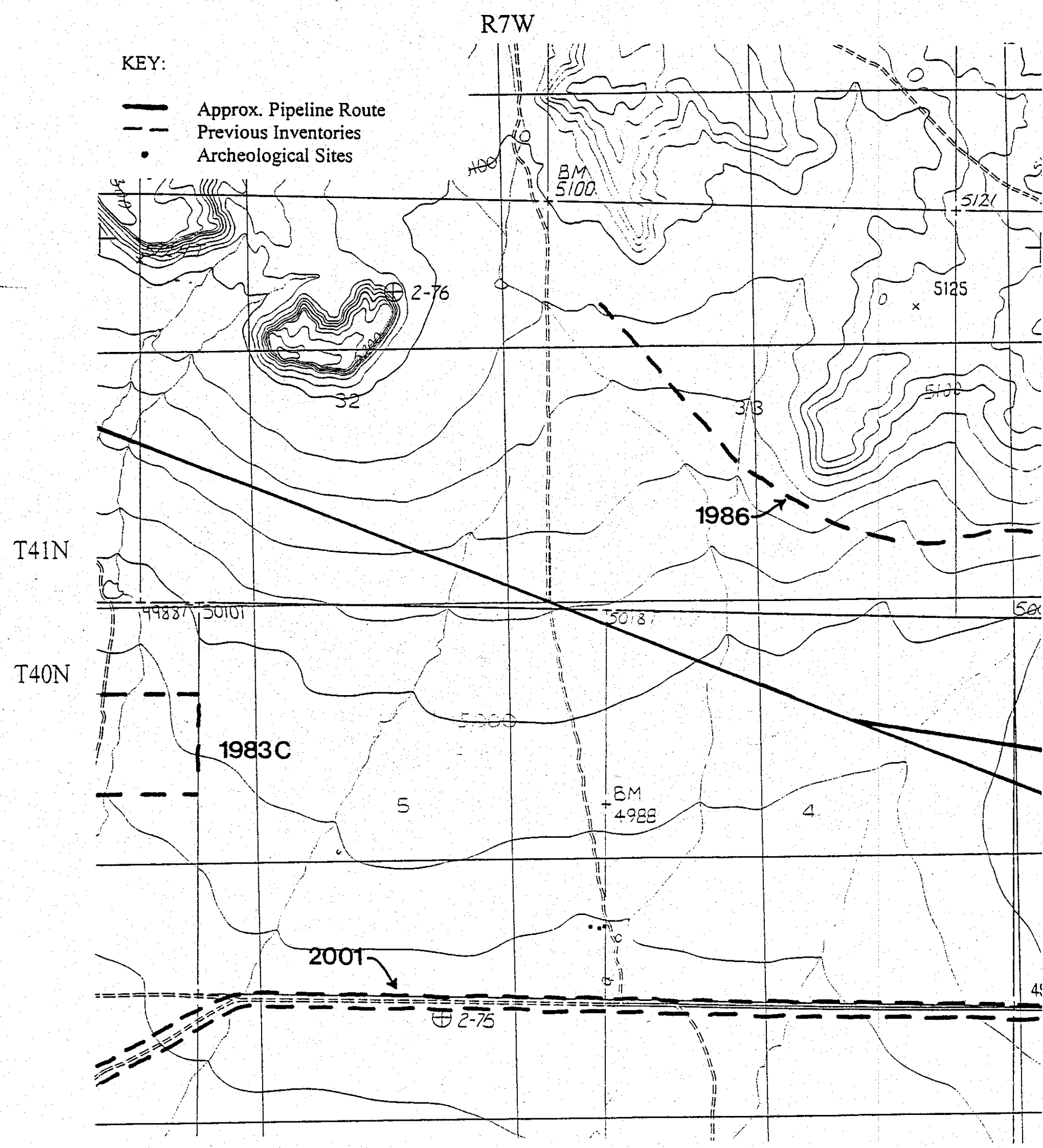


Fig. 6. Lake Powell Pipeline Project - Mojave County, Arizona Section
Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain East 7.5' (PE 1988) A:4:NE

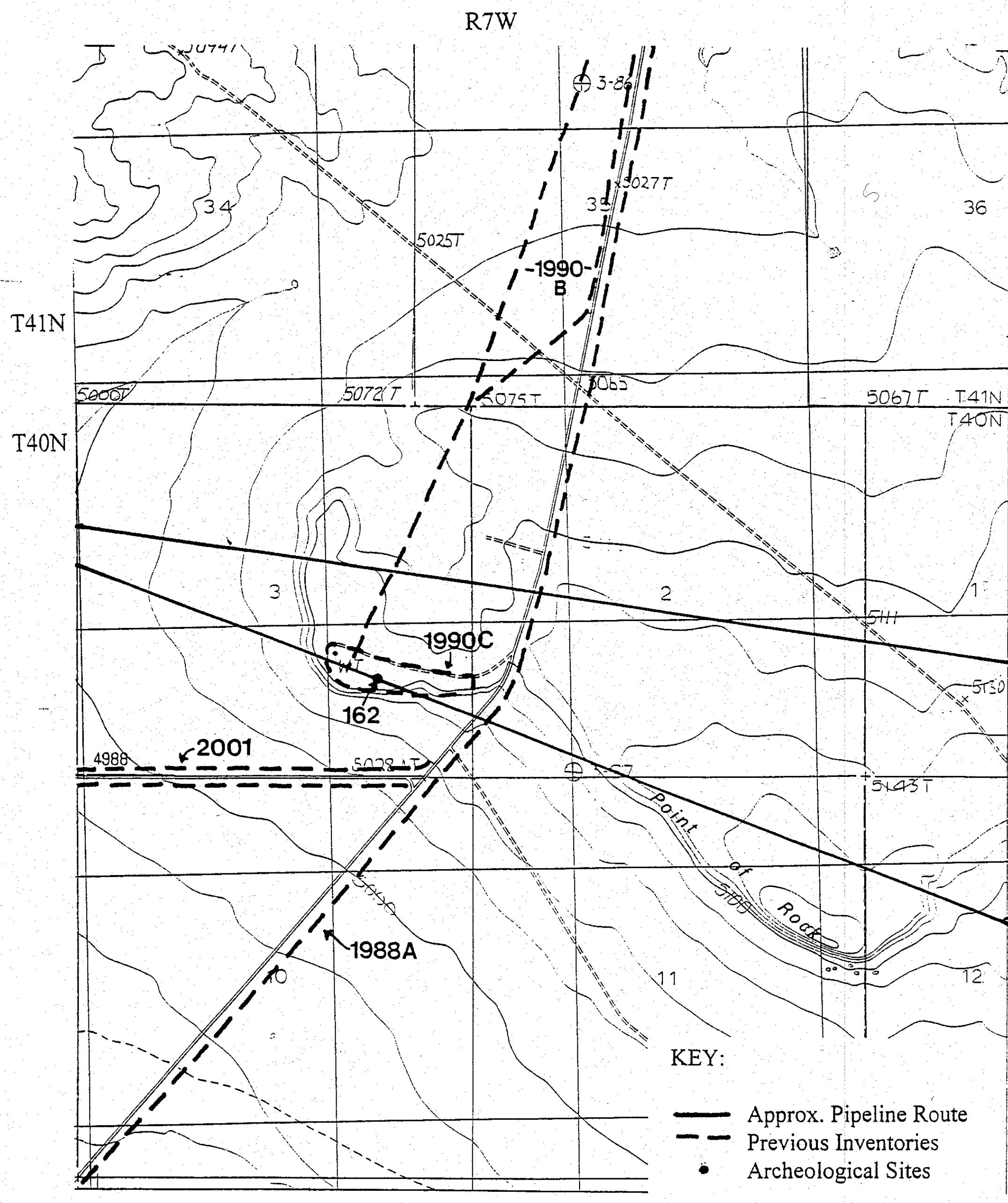


Fig. 7. Lake Powell Pipeline Project - Mojave County, Arizona Section
Project, Inventory and Archeological Site Map
USGS Lost Spring Mountain East 7.5' (PE 1988) A:4:NE

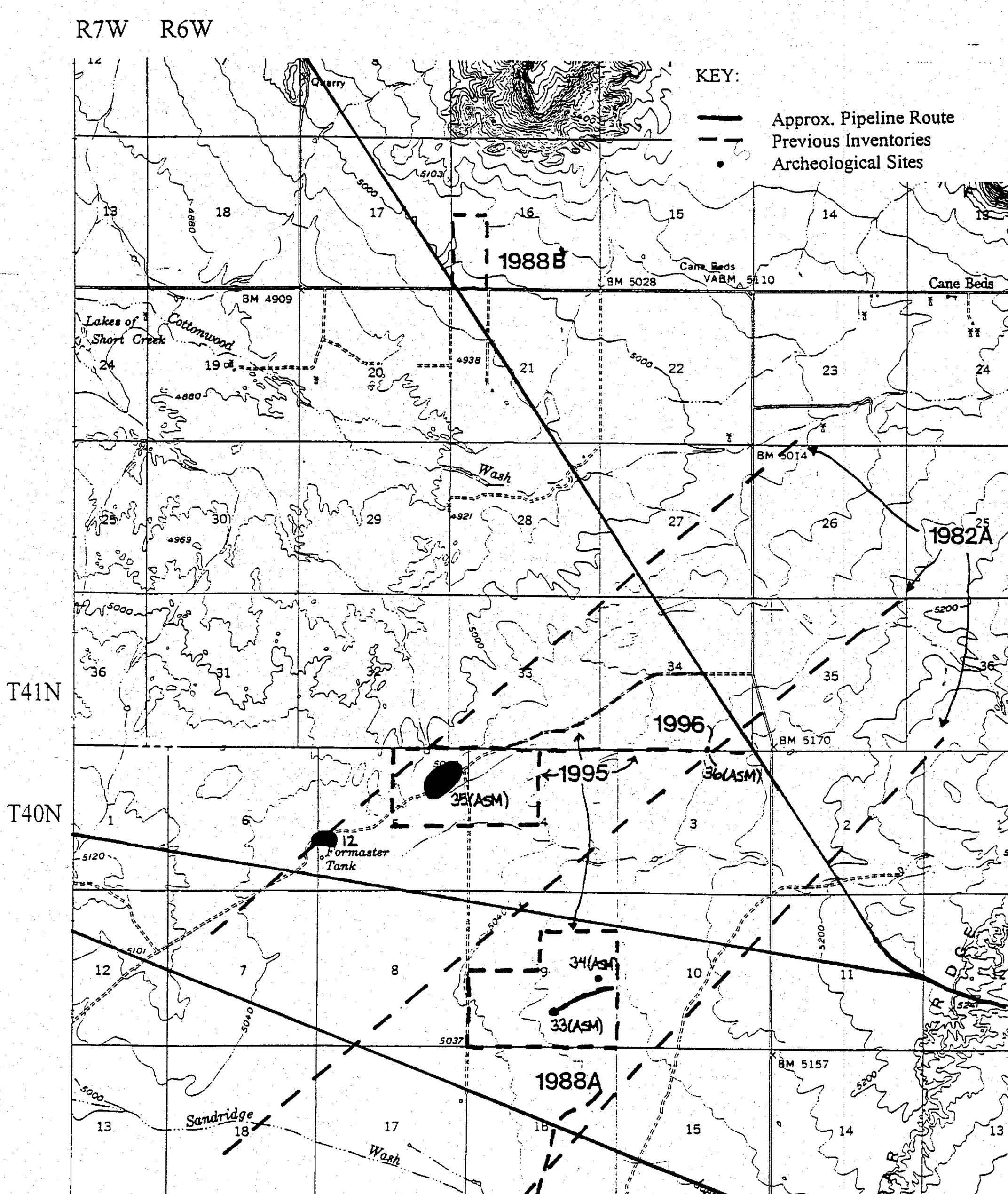


Fig. 8. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Colorado City 15' (1954) B:1:NW

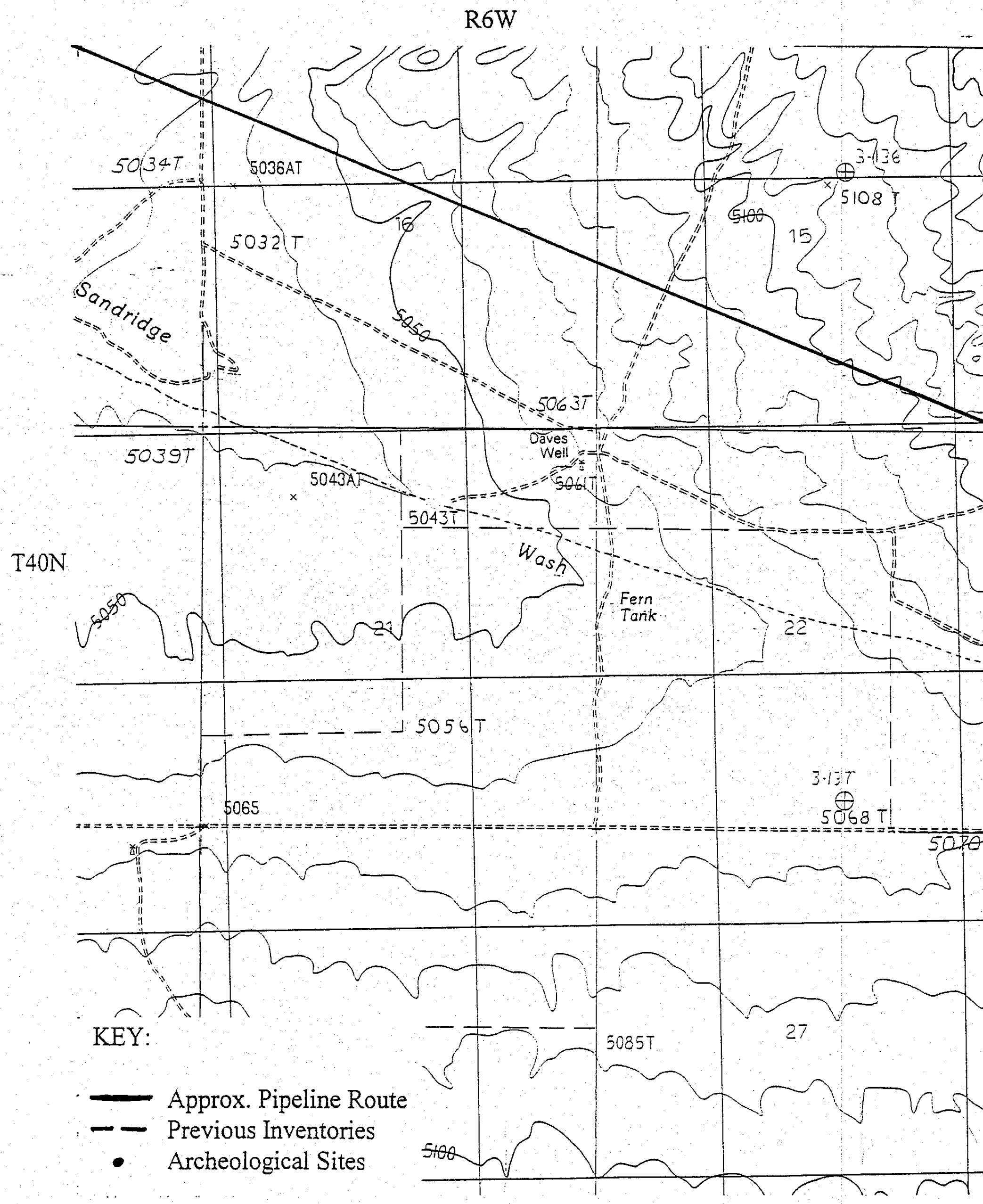


Fig. 9. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Maroney Well 7.5' (PE 1988) B:1:SW

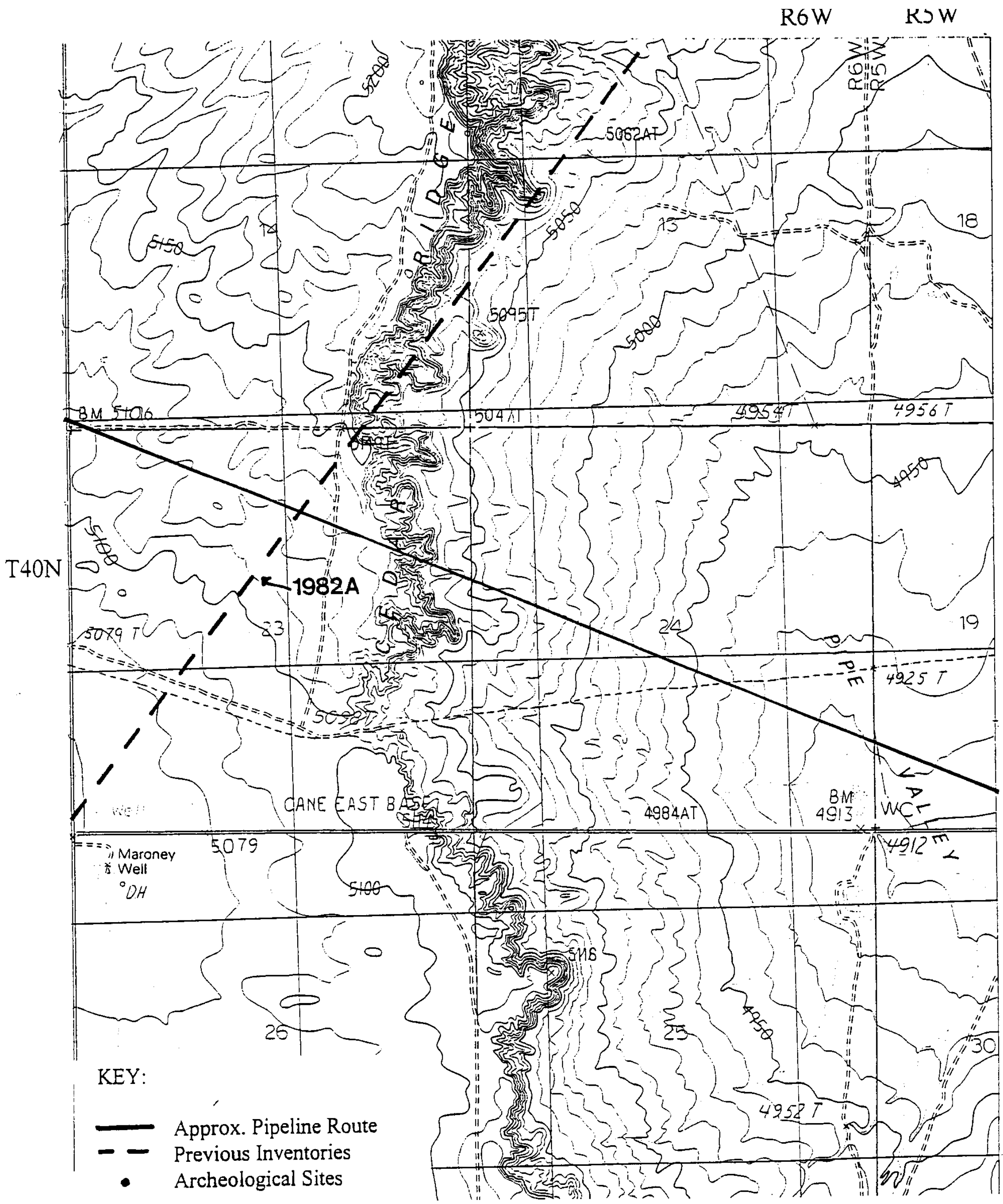


Fig. 10. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map USGS Maroney Well, 7' (PE 1988) B:1:SW

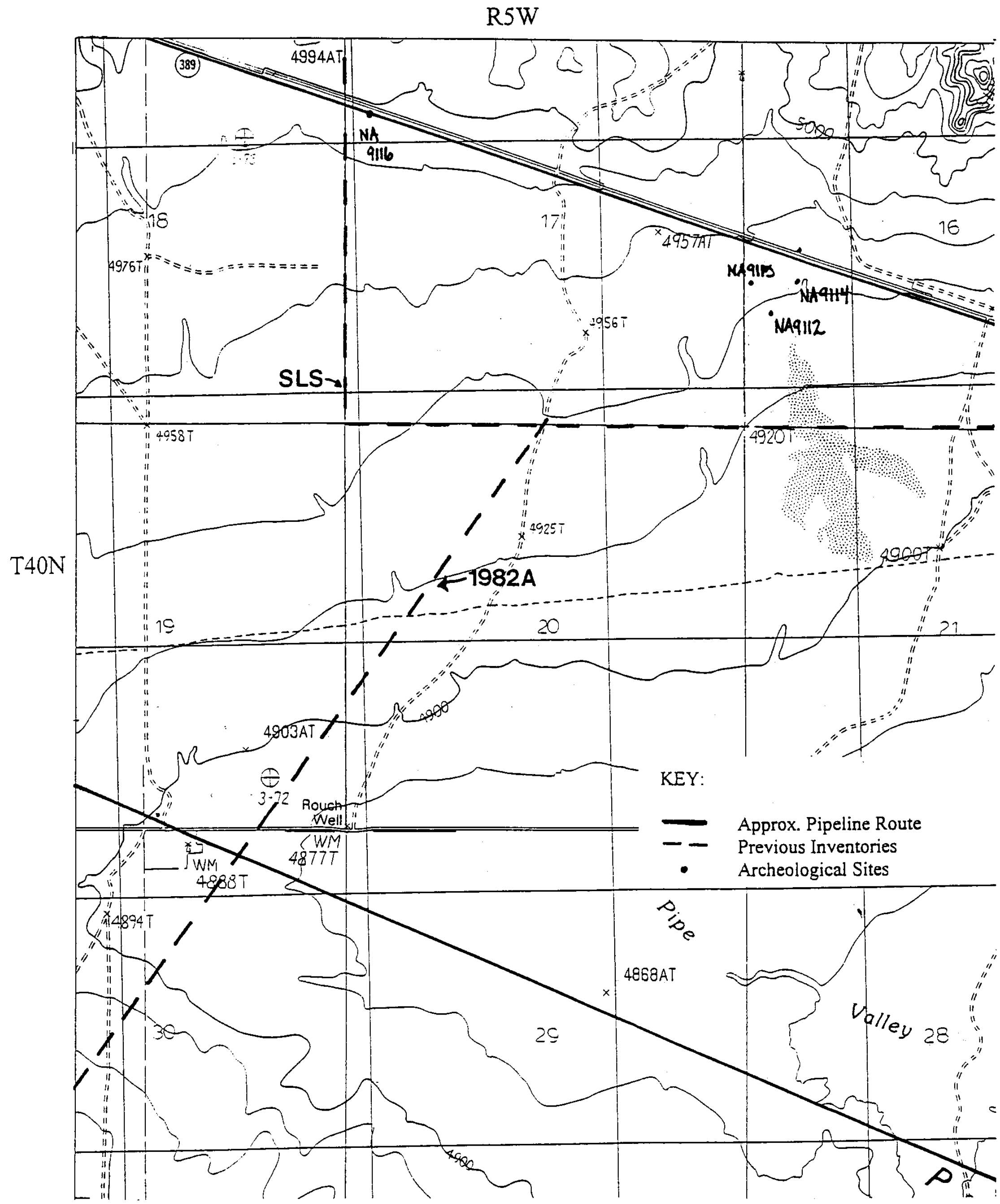


Fig. 11. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Pipe Valley 7.5' (PE 1988) B:1:SE

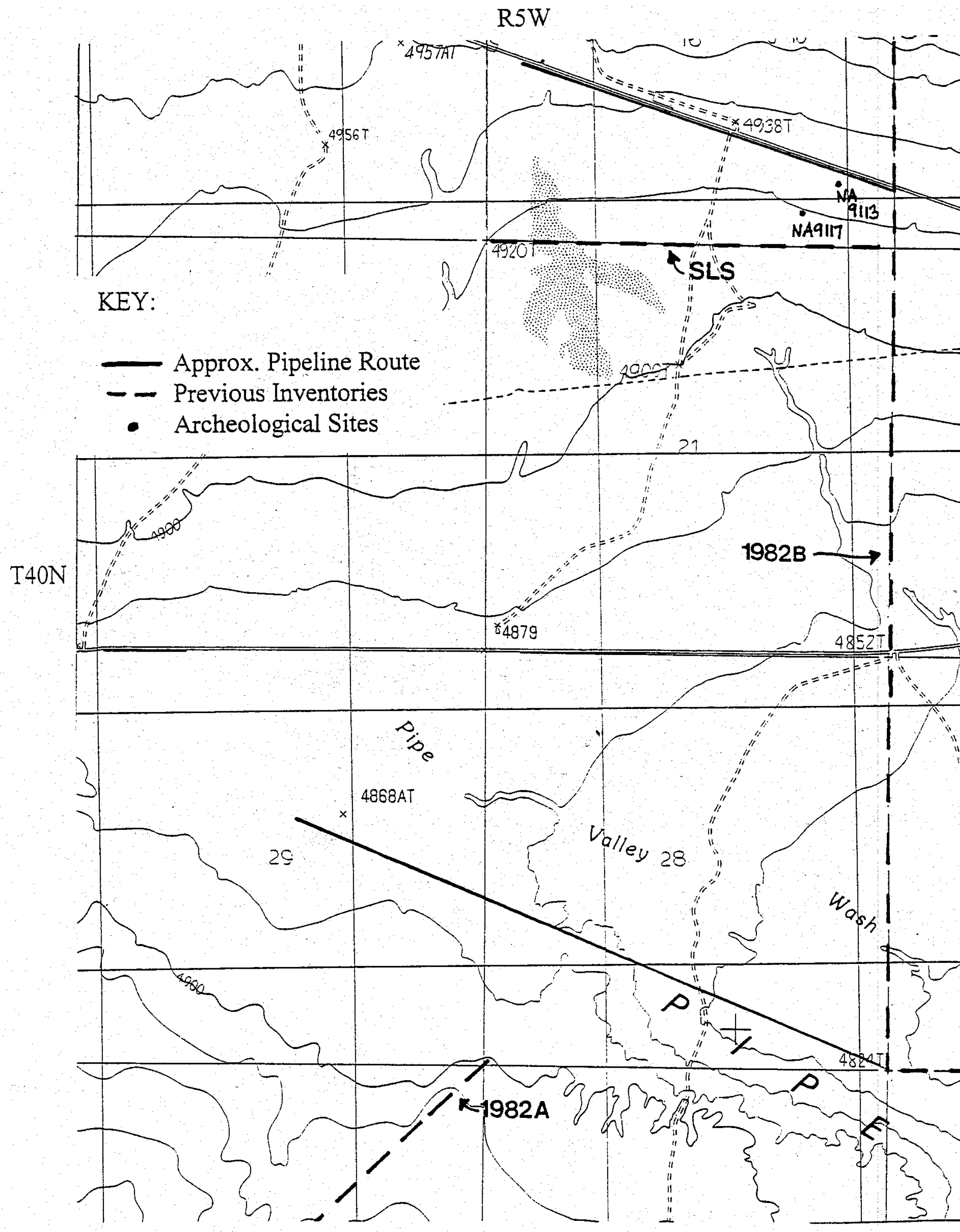


Fig. 12. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Pipe Valley 7.5' (PE 1988) B:1:SE

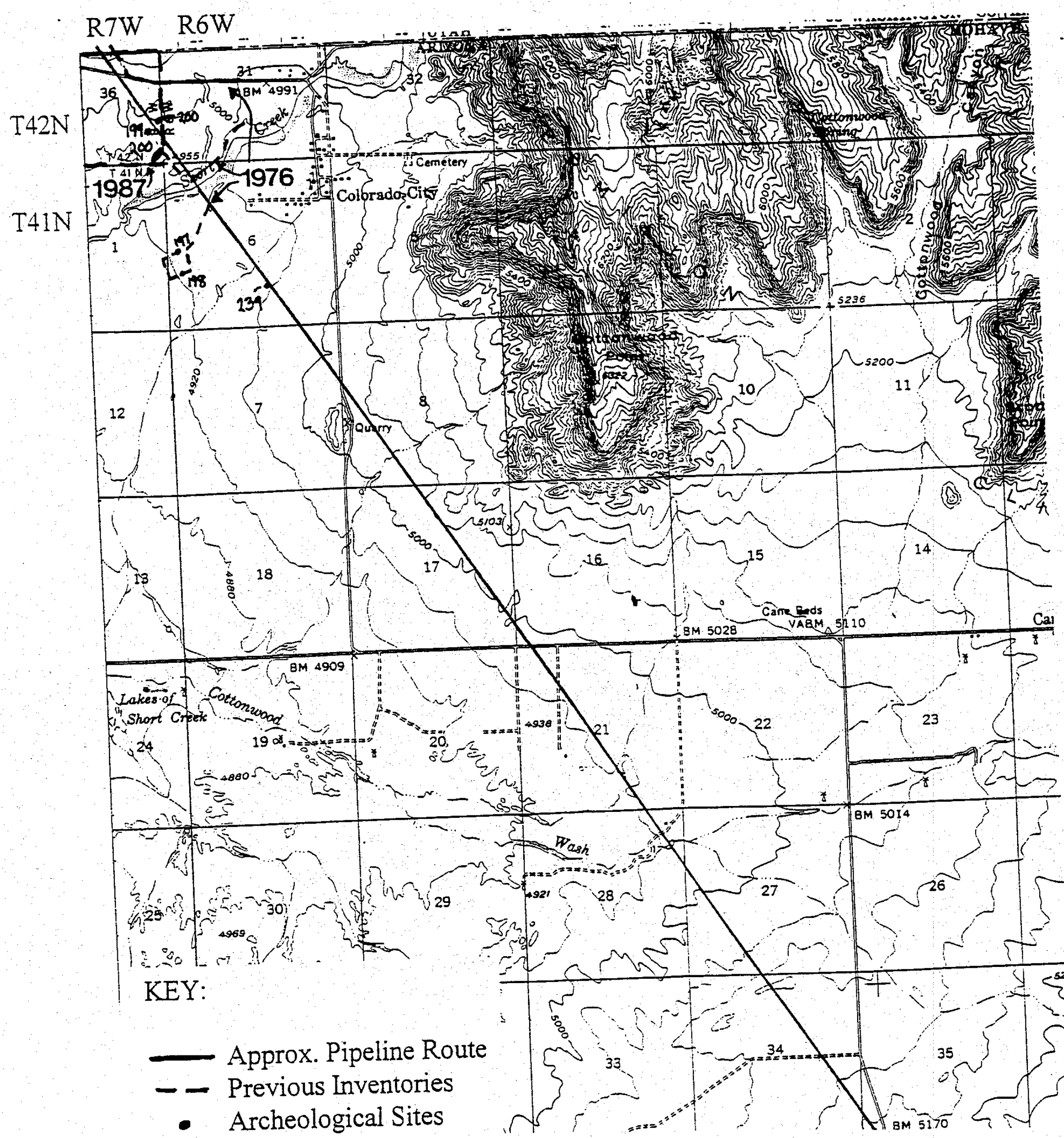


Fig. 13. Lake Powell Pipeline Project - Mojave County, Arizona Section Project, Inventory and Archeological Site Map
USGS Colorado City 15' (1954) B:1:NW

Post-it™ Fax Note 7671	Date 11 NOV 02	# of pages ▶ 3
To PAUL FESSER	From MIKE AVANT	
Co./Dept. BOYLE ENGR	Co. GARKANE ENERGY	
Phone #	Phone #	
Fax # 801-942-8600	Fax #	

Garkane energy

1802 SOUTH 175 EAST, KANAB, UT 84741
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FAX: 435-644--8120
www.garkane.com
e-mail: mavant@qwest.net

DATE: 14 Nov 01

FAX: 801-379-1159

TO: Eugene E. Hawkes

Page 1 of 3

FROM: Mike Avant, Engineering Manager

SUBJECT: Preliminary cost estimate for Feasibility Study

Gene, per you request I obtained the following information from our power supplier regarding the power for the proposed pipeline:

Mike: In response to your request, I am providing below an estimate of wholesale power prices delivered at Bonanza, based on delivery starting in January 2002. I am also providing current Western transmission rates and losses such that a delivered price at Glen Canyon can be approximated. In addition to the wholesale power, transmission and loss costs there will be other Ancillary Service costs which I have not provided pricing for. All wholesale power prices are an estimate, are intended for analysis purposes only, and are not a proposal by Deseret to furnish wholesale electricity.

1. Wholesale power price estimate: Starting in January 2001, $36.50 per MWH for all energy provided at the delivery point (Bonanza). Effective each January starting with January of 2005, the wholesale power price in effect for the prior year will be increased by 3.8%per year for the remaining term of the agreement.

2. Term of the Agreement is 10 years.

3. Quantity: 36 Mw of capacity with energy deliveries at a 95% load factor.

4. Transmission pricing: Western Area Power Administrations current Open Access Transmission Tariff wheeling rate is $2.14 per kW of reserved capacity per month. PacifiCorp's current Open Access Transmission Tariff wheeling rate is $2.025 per kW of reserved capacity per month. The availability of transmission for delivery to Glen Canyon on either suppliers system has not been reviewed.

5.Transmission Losses: Western Area Power Administrations current Open Access Transmission Tariff loss rate is 5.5% of scheduled energy. PacifiCorp's current Open Access Transmission Tariff loss rate is 4.48% of scheduled energy.

6. Ancillary Services: At a minimum Western's control area would require the following services either be purchased form them or provided by a third party:

a. Voltage and var support.
b. Regulation.
c. Energy Imbalance.
d. Reserves (spinning and ready).

The above wholesale power prices do not include any of the required Ancillary Services.

Mike, I believe the information above will allow you to provide wholesale power pricing information for the pumping project study you are working on with the Bureau. If you need assistance with developing a delivered total cost or assessing the Ancillary Service costs let me know and I would be happy to assist you with that cost development. Please call me if you have any questions or require further information.

Phil

In the work you provided to me were estimates some one has put together for proposed facilities. In reviewing these estimates there seems to be an inconsistency in that the one line station diagram shows the incoming voltage to be 345 kV with a 20 MVA 345 kV/13.8 kV transformer. The "Cost Estimate – Site 2" sheets shows a 230 kV Breaker and a 25 MVA 230 kV/4160v transformer.

Garkane's current delivery from Glen Canyon Switch Yard is at 138 kV. I have indicated the approximate location of the line on the attached map. Extension of the existing 138 kV line would require a switching station at the points of connection with the existing line and new line to be constructed from those points to the site of each pumping station substation. Each switching station will cost approximately $600,000. We are currently building 138 kV overhead line at a cost of approximately $125,000 per mile exclusive of right of way cost. I have no experience with the cost of under ground line of that cost and can give no cost estimates for that portion at this time. I would suggest you consider putting a 138 kV to 34.5kV substation at the end of the transmission line and running parallel 19.9/34.5 kV URD feeders to the pumping station site in place of the transmission underground. I believe that this would be less expensive than $1,000,000 per mile, based upon information you provided, for under ground transmission and will give just as good of service. You have included cost in your estimate for the substation at the site already. I have not made any analysis to determine what if any improvements may be needed to the existing 138 kV line and facilities required to serve these new loads. Additional data on the starting conditions of the pumps will be needed for this analysis to be made.

If delivery at 230kV or 345kV is required there will be additional cost by Western Area Power Administration to provide one or possibly two delivery points at the delivery voltage. The cost of the lines will be significantly more than our current cost of 138 kV construction. Approximately 40 miles of new line will be required, if 230 or 345 is used, from Glen Canyon Switch Yard to the Cockscomb site.

Gene in addition to the above cost there will be cost for delivery from Glen Canyon to the project sites both in terms of one time facility costs and also ongoing O&M expenses. Once we have a better handle on what facilities will be needed we can make some kind of estimates of the O&M cost.

The above numbers are for discussion purposes only and DO NOT constitute any type of an offer to serve the proposed loads at the cost indicated.

Please contact me if any additional questions come up.